Conservation status of the endangered Scaly-sided Merganser *Mergus squamatus* on the Korean Peninsula

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Abstract

The Scaly-sided Merganser *Mergus squamatus* is assessed as an Endangered migratory species globally. Effectively restricted for most of the year to rivers in eastern and northeast Asia, the global population in the wild is estimated at 3,600–4,800 individuals. This century has seen a substantial increase in research and conservation effort in the riverine forests of far eastern Russia and northeastern China, where the species is known to breed, and in eastern China where coordinated surveys have found a large proportion of the global population wintering. Data from geolocating loggers and ground observations confirms that a substantial, though still unknown, number of Scaly-sided Merganser pass through the Korean Peninsula during southward and northward migration. In the Republic of Korea (RO Korea), surveys during southward migration found 144–198 individuals along the Imjin River in 2021, and a total of 215 during one-day surveys of three rivers in November 2022. Based on national winter surveys between 2012 and 2022, probably 5% or more of the population also overwinters in the RO Korea. Status in the Democratic People's Republic of Korea (DPR Korea) remains less clear. The species is assessed in the RO Korea as Endangered nationally and in the DPR Korea as Threatened. Yet there are no sites on the Korean Peninsula being managed for the conservation of Scaly-sided Mergansers, and every river known to be important for the species is being negatively affected by infrastructural development or disturbance.

Key words: conservation, Korean Peninsula, *Mergus squamatus*, migration, overwintering.

The Scaly-sided Merganser *Mergus squamatus* is a shy and easily disturbed migratory duck species, which is confined for most of its annual cycle to rivers in the far east of the Russian Federation (hereafter Russia) and northeastern People's Republic of China (hereafter China) where it breeds, and also to eastern China and the Korean Peninsula where it occurs during migration and in winter (Zhao & Pao 1998; Moores & Kim 2014; Zeng *et al.* 2015a; Solovyeva *et al.* 2017; Xu *et al.* 2021). Modelling suggests that there is suitable breeding habitat in the northeast of the Democratic People's Republic of Korea (hereafter DPR Korea; Xu *et al.* 2021). However, there appears to be no documented record of breeding on the Korean Peninsula (this paper).

The species is classified as Endangered globally in the IUCN Red List of Threatened Species (BirdLife International 2023a), and the monotypic world population is currently estimated at 3,600–4,800 individuals (Solovyeva *et al.* 2014a) with a 1% of population threshold of 45 individuals (Wetlands International 2023). This 1% threshold, based on a 5-year geometric mean of counts where data are available, is one of the criteria used to identify wetlands of international importance (Ramsar 2023a, b) and priority sites for conservation (BirdLife International 2023b).

In recognition of the Scaly-sided Merganser's poor global conservation status, an International Single Species Action Plan (ISSAP) was developed calling for conservation actions by the four Principal Range States, namely China, Russia, the DPR Korea and the Republic of Korea (hereafter RO Korea). Actions relevant to the Korean Peninsula to be taken by 2025 include: (1) more research on breeding, wintering and stopover/staging areas in the DPR Korea, (2) refinement of knowledge of habitat use in winter and, (3) ensuring that key sites are protected, including through nomination as Flyway Network Sites (Solovyeva *et al.* 2017).

Substantial effort has been conducted in the past decade towards research and conservation of the species in China and Russia. Recent modelling predicts that 90% (38,813 km^2) of highly suitable breeding habitat is concentrated in the Sikhote-Alin and Changbai Mountain ranges of Russia and China respectively (Xu *et al.* 2021). Some of this highly suitable habitat extends into the Korean side of the Changbai Mountain range (in Korea known as Paektusan or Baekdusan), and in adjacent provinces of DPR Korea.

In eastern China, large-scale winter surveys conducted from 2014 to 2016 recorded a high count of 1,138 Scaly-sided Mergansers (Zeng *et al.* 2018). These surveys helped to identify previously unknown sites (Zeng *et al.* 2015a, 2018). At the larger scale, modelling also suggested that the most significant environmental variables in winter in China include the annual mean temperature, the mean temperature of the coldest quarter, minimum temperature in the coldest month and precipitation of the driest quarter (Zeng *et al.* 2015a). At a smaller scale, in China in winter – where the species congregates at river segments with larger and more contiguous gravel patches – merganser numbers are negatively correlated with the number of houses along the riverbank, with houses considered a

proxy for human disturbance levels (Zeng *et al.* 2015b).

Migration strategies, including the timing, route and use of staging sites during migration, exert strong effects on seaduck population dynamics (Petersen & Savard 2015), and knowledge of staging sites is also considered important for the conservation of the Scaly-sided Merganser. Most of the population migrates southwestward, up to a maximum of *c.* 3,000 km from breeding areas to wintering sites in eastern China, with an unknown number staging on the Korean Peninsula *en route* whilst others remain to overwinter there (Solovyeva *et al.* 2012; Moores & Kim 2014). In language adapted from Piersma (1987) and Warnock (2010), migration between breeding and wintering areas can be undertaken either in unbroken direct "jumps" (*i.e.* single non-stop flights), "skips" (longer flights interrupted with only one or two short or long stops), or "hops" (multiple shorter flights punctuated with multiple short stops), but the strategy used by Scaly-sided Mergansers is not yet known.

In the RO Korea, there has to date been no coordinated single-species research on the Scaly-sided Merganser led by government or academic institutions. Instead, a winter bird census covering all bird species, conducted under the auspices of the national Ministry of Environment (hereafter MOEK) is used as the basis for determining national population estimates (MOEK 1999–2022; NIBR 2014, 2019). By 2022, the winter bird census had recorded Scaly-sided Merganser at a total of 21 locations, four of which supported the species during a third or more of the surveys. There was a geometric mean of 64 individual Scaly-sided Merganser nationwide between 2013 and 2022 (MOEK 1999–2022; Kim 2023). This compares with 140–149 recorded during a single-species survey of 10 rivers by Birds Korea in February 2012 (Moores & Kim 2014). The Scaly-sided Merganser was designated as National Natural Monument #449 in 2005 (NBC 2018) and is currently assessed as Endangered nationally (NIBR 2019). Both designations potentially restrict threats to the species and its habitat; however, at present, there are no stretches of river known regularly to support mergansers in the country which are protected from development, or which is being managed for the species. Instead, large-scale river-works in the 2000s have been followed by further construction of hiking and cycle roads along rivers and camp sites and pocket parks within river bunds, resulting in a further increase in disturbance levels (Moores & Kim 2014; Moores 2022, 2023).

In the DPR Korea, the species is assessed as nationally Threatened, and formal calls have been made for research on its population and protection of its habitat (DPR Korea 2002, 2016a). The DPR Korea has pursued reforestation to reduce soil erosion and to reverse reduced flows in rivers and streams (DPRK 2016b). Moreover, since 2018, it has joined the East Asian–Australasian Flyway Partnership (EAAFP), acceded to the Ramsar Convention, published an updated national wetlands inventory, and increased research efforts in wetlands as part of the Asian Waterbird Census (DPRK 2018; Moores *et al.* 2019; International Waterbird Census 2023). To

the best of our knowledge, however, there has been little focused research on Scaly-sided Merganser following observations of at least 40 individuals along the Chongchon River in November 2003 and of flocks along the same river in March and November 2004 (Duckworth & Kim 2005). The only subsequent single-species survey that we are aware of was conducted along three rivers in western DPR Korea (including the Chongchon River) in February 2019, which found that all three rivers were affected by hydroelectric dams and material extraction (Moores 2019).

In support of national and international efforts for *in situ* conservation of the species on the Korean Peninsula, this paper provides insights on migration through and overwintering on the Korean Peninsula based on previously unpublished analysis of data from geolocating loggers (recorded from 2007–2011) and ground observations of Scaly-sided Merganser, especially between 2014 and 2023. In particular, it focuses on rivers in central Korea (on both sides of the Korean inner border) likely to be especially important for the species during southward migration.

Methods

Capturing for geolocating

As outlined by Solovyeva *et al.* (2012, 2014b), 27 breeding female Scaly-sided Mergansers, each at least two years old, were fitted with Mk9, Mk11 and Mk14 light level geolocators (weighing 2.5 g and 1.5 g; British Antarctic Survey) in 2006–2011. Devices were attached to engraved plastic tarsus rings by two cable ties, secured through drilled holes. Birds were trapped at their nests in artificial nest sites and known natural cavities in the Kievka (43.3ºN, 133.8ºE), Avvakumovka (43.8ºN, 135.0ºE) and Margaritovka (43.5ºN, 134.7ºE) catchments, all in Primorye, Russia. Some devices were re-used after completing a year of logging on other females, once the data had been downloaded and deleted from the device memory.

Data processing

Latitude and longitude coordinates were estimated for each date using BirdTracker software (British Antarctic Survey) to determine midnight and noon locations. All positions generated by sunrises delayed by ≥ 15 min and sunsets advanced by ≥ 15 min compared to the previous and following days were deleted from location analyses. Geolocator data collection, data processing and position estimate accuracy are described in Solovyeva *et al.* (2012). During spring and autumn equinox periods day-length is similar at all positions, so that latitude for 30 days before and after equinoxes could not be determined. Because there was much migration activity around the equinoxes, estimates of longitude were retained because this could be determined during both migration periods. The exposed gold terminals on the geolocators (to enable data download) also measure conductivity whilst activated, providing a trace of when birds were on brackish or saltwater at each logging interval. Water salinity ranged between 0 (fresh water and air) and 200 (marine water). A bird is attributed to being in a brackish water environment if salinity ranged between 7 and 170. This feature

was used to identify the start and end of migration flight, by combining light and salinity records. The start and end of migration flight could not be recognised in females which migrated from fresh water to fresh water or from marine waters to marine waters.

Ground-based observations

In the RO Korea, a total length of 653 km of named streams and rivers were surveyed for Scaly-sided Mergansers by Birds Korea between 2012 and 2023, with additional surveys made of un-named streams, ponds and adjacent reservoirs. The survey comprised: (1) active searches along river and stream stretches and in adjacent wetlands, (2) repeat surveys of stretches that were found to be important for the species, and (3) three single-species surveys during the mid-winter period, in 2012, 2014 and 2022 (from here on, the "national winter surveys") (Table 1).

During fieldwork, all counts of Scaly-sided Mergansers were made by observers who either had substantial previous experience of the species or who had followed basic training. Count methods varied by location and project, but included observers driving alongside stretches of rivers and actively searching for the species through high-quality optics (binoculars and tripod-mounted telescopes). During all counts, birds were assessed as being "adult male", "female-type" or "second calendar-year" and suspected pairing was noted, along with observations of whether or not birds were in flight. Times of observation and coordinates were recorded of each count point. River length was measured as the distance between the first and last count point, with some gaps in coverage due to access difficulties along most larger rivers. During the 2014 national winter survey, at each count point, irrespective of whether Scaly-sided Mergansers were recorded or not, observers filled out forms on, *e.g.*, ice cover, presence of rocks or gravel spits and estimated distance between birds and roads, bridges or other potential points of disturbance. Conscious efforts were made to reduce the possibility of double-counting. Birds were not added to day totals if double-counting seemed likely and only single-day totals for sites are used in data presentation. Scaly-sided Mergansers were also actively searched for during surveys of marine waters, coastal wetlands and islands (Choi *et al.* 2019; Choi *et al.* 1998–2023, unpubl. data).

In the DPR Korea, the survey was conducted by Birds Korea and additional members of the Scaly-sided Merganser Task Force along 56 km of three rivers in early February 2019, including *c.* 41 km of the Chongchon River. In Rason, five surveys were conducted in coastal wetlands, including a stretch of the Tumen River, between 2014 and 2019, and two additional rapid assessments of birds were made along the east coast from Hamhung (39.81°N, 127.66°E) south to Wonsan and Kosong (38.63°N, 128.35°E) in March and November 2017. Figure 1 indicates the approximate location of selected sites mentioned in the Results and Discussion.

Other data sources

A review was also made of records from: the winter census between 1999 and the end

Table 1. National survey efforts for Scaly-sided Merganser in the Republic of Korea, 1999 to present.

Year(s)	Survey type	Description	Dates	Length of river surveyed (km)
1999–2022	Ministry of Environment National Winter Bird Census (MOEK 1999–2022)	All bird species at *c.* 200 count sites annually, at a total of 231 wetland or marine sites, including 60+ freshwater river and stream stretches	Total of 35 census counts between 13 Nov and 19 Feb, with counts in Nov (1), Dec (8), Jan (21) and Feb (5)	> 810 annually
2012	Birds Korea National Survey	Five days; 10 river systems	3–7 Feb	163
2014	Birds Korea National Survey	Eight days; 16 river systems	15–22 Jan	330
2022	Birds Korea National Survey	Ten days; 16 river systems	11–21 Feb	325

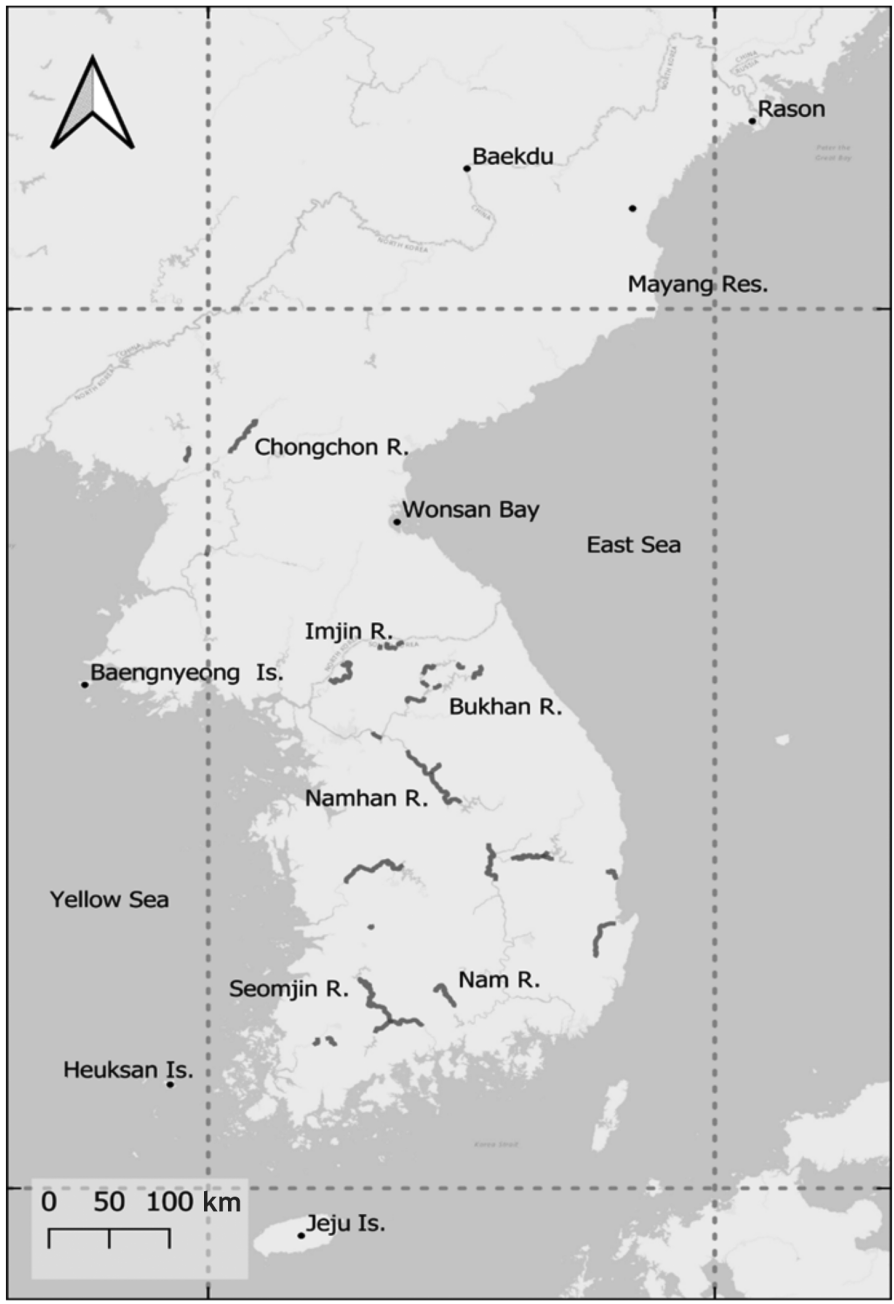

Figure 1. Map showing selected locations on the Korean Peninsula mentioned in the text. River stretches included in Birds Korea surveys (2014–2023) are indicated as dark grey striations.

of 2022 (MOEK 1999–2022); from eBird (an online database managed by Cornell University) up to April 2023; in easily accessible literature; and in online media.

Results

Southward and northward migration: geolocators

Geolocators suggest that a broadly similar route is taken during southward and northward migration. Some females spent a short time at sea before initiating migration flight and, during both migration periods, some landed at sea before entering rivers used in winter or during the breeding season. The speed of migration flight was possible to estimate in six cases: it averaged 64.5 ± 9.0 km/h. Based on this average, it should take 36–40 h to migrate directly and non-stop between the catchment of the River Kievka (where most of the geolocating loggers were fitted) and wintering areas in eastern China, as indicated by Solovyeva *et al.* (2012). Birds that overwinter in Korea likely migrate < 1,000 km (*c.* 14–18 h of sustained flight).

Eighteen migration records were used in the analysis of southward migration. The earliest departure from the breeding range (by Female 8554) was on 13 September, and the latest departure (by Female 7862) on 21 November, with a median date of departure of 4 November (n = 18; Table 2). Southward migration passed through the Korean Peninsula, with some birds stopping over there. Length of stopover was more variable than during northward migration, with some individuals also varying their migration strategy between years. The maximum length of stopover was 67 days. The first skip averaged 886 km (n = 3), and the second skip was from the Korean Peninsula to a wintering area in China (primarily within the Yangtze River floodplain), with one bird flying an estimated 553 km during this second skip. Two birds were considered to undertake non-stop or only briefly interrupted jumps, estimated at 1,350 km and 2,152 km between their breeding and wintering grounds.

In China, the earliest and latest dates on which Scaly-sided Merganser initiated northward migration were 9 March and 7 April respectively (Table 3), with a median date of 18 March. The duration of northward migration varied between 1 and 11 days (mean ± s.e. = 3.58 ± 0.68). Most females completed northward migration within 1–3 days (13 out of 19; 68.4%). Longer stopovers were reported in five females from six spring records. Female 8527, the only individual which wintered on the Korean Peninsula, had a one-day northward migration (on 29 March in 2010 and on 30 March in 2011), suggesting that migration was uninterrupted between wintering and breeding areas.

In combination, the data suggest that the main northward migration period between the breeding and wintering areas is from early March to mid-April, and that it is several weeks shorter than the main southward migration period. At least during the period for which data are available, a smaller proportion of females staged on the Korean Peninsula during northward than southward migration. It was not possible to calculate the latitude of stopover sites because the timing of northward migration

Table 2. Dates of southward migration and estimated location of stopovers in female Scaly-sided Mergansers as indicated by geolocators. *indicates "jump" migration, **indicates "skip" migration, see text for details. [1]Indicates a bird wintering in Korean marine waters. Stopover type reflects either freshwater (F) or marine (M) based on conductivity measurements made in situ by the geolocator devices.

Year	Female ID	Southward migration start date	Stopover start date	Stopover end date	Stopover duration (days)	Mean longitude	Mean latitude (°N)	Stopover type (°E)	Arrival date in wintering area
2006	7851	9 Nov	10 Nov	17 Nov	7	36.47	127.32	F	19 Nov
2007	7851	30 Oct	1 Nov	12 Nov	12	34.17	127.05	F	16 Nov
2006	7856	5 Nov	6 Nov	19 Nov	13	36.80	125.50	F	20 Nov
2007	7856	6 Nov		*				n/a	8 Nov
2008	7856	16 Nov		*				n/a	18 Nov
2009	7856	5 Nov		*				n/a	7 Nov
2006	6371	7 Nov		**				n/a	11 Nov
2007	6371	4 Nov		*				n/a	5 Nov
2008	6371	26 Oct		*				n/a	28 Oct
2007	8549	31 Oct	31 Oct	27 Nov	28	36.77	127.13	F	28 Nov
2007	7516	4 Nov			*			n/a	7 Nov
2008	8532	10 Nov			*			n/a	11 Nov
2009	8532	3 Nov	3 Nov	8 Nov	5	34.30	126.60	F & M	11 Nov
2008	8566	16 Nov			*			n/a	19 Nov
2007	7862	21 Sep	22 Sep	15 Nov	54	41.68	128.40	F	18 Nov
2009	8554	13 Sep	13 Sep	18 Nov	66	37.70	127.00	F	18 Nov
2011	8510	28 Oct	28 Oct	25 Nov	28	n.d.	124.00	F	?
2009	8527[1]	2 Nov			*			n/a	3 Nov
Mean					29.6 ± 8.1				

Table 3. Dates of northward migration and estimated longitude of stopovers in female Scaly-sided Mergansers as indicated by geolocators.

Female ID	Year	Departure from winter river	Arrival at stopover	Arrival at breeding river	Number of days of migration	Average longitude (°E) of stopover	Stopover environment
7851	2007	20 Mar	20 Mar	24 Mar	4	127.49	Fresh
7851	2008	9 Mar	10 Mar	15 Mar	5	128.13	Fresh
8549	2008	14 Mar	15 Mar	20 Mar	5	128.30	Fresh
7862	2008	7 Apr	8 Apr	11 Apr	4	127.63	n/a
8554	2010	23 Mar	26 Mar	3 Apr	8	126.25	n/a
8532	2010	16 Mar	18 Mar	23 Mar	5	125.63	Fresh

coincides with the spring equinox. Estimates of the longitude, however, ranged between 125.6°E (the approximate longitude of the Chongchon River in the DPR Korea) and 128.3°E (marginally east of all known regular sites for the species in the RO Korea), still indicated staging on the Korean Peninsula.

Ground-based observations: RO Korea

Between January 2014 and April 2023, Birds Korea observed Scaly-sided Mergansers on 16 streams or rivers, at three reservoirs, and twice during southward migration over marine waters viewed from Baengnyeong Island (37.96°N, 124.62°E). Secondary sources of records were compiled from: MOEK (1999–2022), which provided mid-winter records from eight additional sites (five reservoirs, two stretches of inshore marine water, and one estuarine bay); eBird, where a total of 303 observations were posted from 21 locations (reviewed and accepted for eBird by the lead author), including at one site not included in other surveys; and three newspaper articles and online reports which were supported by images. The vast majority of records from secondary sources overlapped in terms of period of occurrence and (based on a review of Google Earth imagery) with the main (riverine) habitat used by the mergansers as the observations made by Birds Korea. In addition to these records, a presentation on Scaly-sided Mergansers in 2022 included a 5-year geometric mean of 39 birds (annual peak count, range = 33–56) between 2017 and 2022 along upper stretches of the Seomjin River (Lee 2022 in Moores 2023), with 42 counted along the same stretch by Birds Korea in March 2023. Upper and middle stretches of the Seomjin River are not included in the winter bird census, and almost all of these

birds were recorded upstream of stretches surveyed during the three national winter surveys.

Based on these ground observations, the Scaly-sided Merganser occurs annually or near-annually on at least 12 rivers and streams nationwide. The 1% threshold of population has been reached in three or more years along four of these: the Rivers Imjin, Namhan, Nam (including part of the Umcheon River tributary) and Bukhan, and in at least one year along the Seomjin River (Table 4). The counts thus identify these five rivers as national conservation priorities for the species.

Period of occurrence

There is no evidence of Scaly-sided Mergansers breeding or over-summering in the RO Korea; the earliest and latest records are on 8 October and 12 April respectively, with one second calendar-year female on Heuksan Island (36.69°N, 125.43°E) from 1–3 June 2009 being an exceptional outlier (KNP 2009; Park Jong-Gil *in lit.* 2023). The bulk of the sight records therefore provide a good match with the dates of migration and wintering suggested by the geolocators.

Ground observations identified the northward migration period as being from

Table 4. Highest day counts of Scaly-sided Merganser between 2000 and April 2023 along regularly used rivers and streams in the Republic of Korea, by month and year.

	Degree of latitude and longitude of main survey	Peak day count	Year of peak count	Month of peak count	Source
Imjin River	38°N, 127°E	144	2021	November	Moores (2021)
Namhan River	37°N, 127°E	111	2015	January	MOEK (2015)
Nam & Umcheon Rivers	35°N, 127°E	70	2022	February	Moores (2022)
Seomjin River	35°N, 127°E	52	2021	March	Lee (2022)
Bukhan River	37°N, 127°E	46	2006	January	MOEK (2006)
Jiseok Stream	35°N, 126°E	17	2014	January	MOEK (2006)
Geum River	36°N, 127°E	15	2018	December	eBird
Han River	37°N, 127°E	14	2016	December	eBird
Boseong Stream	35°N, 127°E	13	2023	March	eBird
Nakdong River	36°N, 128°E	13	2001	March	eBird
Seom River	37°N, 127°E	7	2022	February	Moores (2022)
Mangyeung River	35°N, 127°E	2	2022	February	Moores (2022)

late February to mid-April, with a peak in mid-March, with the southward migration period occurring from mid-October to mid-December and peaking in mid-November. Four out of five records by Birds Korea of the birds seen away from rivers and streams since 2014 were made between 25 October and 17 November; *i.e.*, within the southward migration period. These were recorded close to the inner border region of Korea.

The frequency of surveys made along 46 km of the Imjin River (on 68 dates between 7 November 2021 and 13 April 2023), combined with the lack of regular overwintering there due to ice cover, allows a more detailed assessment of the timing of migration. In 2022, two to three females or second calendar-year birds were present in mid-February. Twenty counts were made between 4 March and 14 April, with a peak total count (all age and sex categories) of 56 mergansers on 11 March, whilst the highest count of adult males was on 16 March. Most birds were in pairs between 11–29 March. Subsequently, numbers fell more or less steadily, with the exception of an influx between 29 March and 2 April which largely comprised unpaired and second calendar-year birds. All birds from 4 April onwards were either adult females or in their second calendar year and were unpaired. The last observation was on 12 April. A similar pattern was repeated in 2023, with a peak count of 59 on 17 March, and the last sighting was on 10 April.

During southward migration through the same stretches of the Imjin River in 2021 and 2022, the highest day counts were of 144 birds on 11 November and 97 on 9 November respectively, with numbers falling steadily to mid-December.

During each migration season along the Imjin River, migratory turnover was suggested on most dates by the differences in numbers, sex ratios and individual plumage details of birds seen within each of 10 discrete river stretches. If it is assumed that birds did not move between stretches, as suggested by observations of behaviour in response to disturbance, and that observed differences were instead the result of immigration and emigration then – based on summing of these differences – at least 198 mergansers staged along 21 km of the River Imjin between 7 and 12 November 2021. Although no individually marked birds were seen, these differences also suggest that some birds stopped over for only one to two days (or less) while others appeared to remain for substantially longer periods, as also indicated by the birds carrying geolocators.

Research to date does not support the assumption that rivers further south are of equal importance to the Imjin during southward migration. Single one-day counts between 9 and 14 November 2022 along the same stretches as those surveyed in February 2022 along the Imjin, Namhan and Nam Rivers found 215 Scaly-sided Mergansers. While numbers were much higher in mid-November than in February of the same year along the Imjin River, numbers counted along the Namhan and Nam Rivers in February and November were remarkably similar (Fig. 2).

Winter abundance and distribution

There is no evidence of active emigration from or immigration to the RO Korea

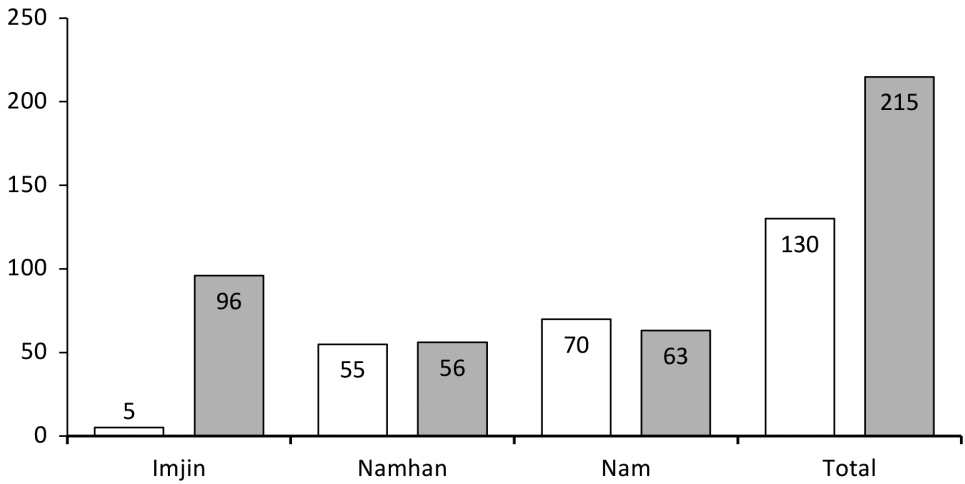

Figure 2. Single-day counts of Scaly-sided Mergansers along the Imjin, Namhan and Nam Rivers in February 2022 (white histogram columns) and in mid-November 2022 (grey columns).

between 15 December and 20 February. This period can therefore be used to define overwintering in the RO Korea. Probably *c.* 250 Scaly-sided Merganser, or > 5% of the global population, overwinter in the country each year. This estimate is based on the three national winter surveys, which recorded 140–149, 149 and 175 Scaly-sided Merganser respectively, and also awareness that these surveys did not cover all river stretches known to support the species, including, for instance, the upper stretches of the Seomjin River, and some sections of the Boseong and Geum Rivers, which likely supported an additional 50–70 individuals in total. In addition, some potentially suitable rivers have yet to be surveyed.

In the RO Korea, the Scaly-sided Merganser overwinters almost exclusively along rivers and streams (Moores & Kim 2014; Moores 2022), and 96.5% of records of Scaly-sided Merganser contained in MOEK (1999–2022) were from count sites with rivers or streams, with most remaining records from larger adjacent wetlands. As during migration, the vast majority overwinter close to riffles and narrower channels, which help to maintain ice-free stretches of water and concentrate river flow, often used by foraging birds. A very small number (< 10 annually) winter on rivers immediately below dams, where open water is maintained artificially by water discharge. None overwinter regularly on ponds or reservoirs and only a few individuals (< 10 in total since 2000) have been observed on open sea.

During the 2014 national winter survey, Scaly-sided Mergansers were recorded along nine of the 16 rivers and streams that were surveyed. The majority (90) were found along 30 km of one river. Flock size ranged from 3–16 individuals. The width of rivers, measured as the maximum width of river channels, that held birds ranged from 27–320 m, with 63% on stretches 150–250 m wide. Almost all were on or

near fast-flowing water where there were undisturbed boulders or gravel- or sand-spits. Almost all avoided stretches largely comprised slow-moving, deeper water and none were found on stretches with an urban matrix within 100 m of both sides of the river or where substrates were entirely sandy (Moores & Kim 2014).

Within-site behaviour and disturbance

Counts (in *c.* 10 winters each) along the Bukhan, Namhan and Nam Rivers since 2005 suggest that, in the absence of major changes to the local environment or high levels of disturbance, Scaly-sided Mergansers occur in the same river stretches every or almost every winter.

Between November 2021 and April 2023, Scaly-sided Mergansers were found on > 10 survey dates in a total of nine discrete stretches along 21 km of the Imjin River, in which birds both foraged and rested, with one additional discrete stretch a further 20 km downstream. Two of the stretches held birds in every count made during the main migration periods, and all 10 stretches held birds in November 2021, March and November 2022, and again in March 2023. These 10 preferred stretches all included gravel spits and riffles, rocks or faster river channels, and all had at least some trees on one or both banks or an elevated bank, hindering human access to the river. Each preferred stretch was divided from the next by deeper stretches of water, bridges or a dam. Birds were only seen flying back and forth between these preferred stretches during extreme disturbance events. During our observations the birds instead remained within core parts of the preferred stretches (when there was no disturbance), swam or flew to outer parts of the preferred stretch on avoiding disturbance events, and returned to the core areas when the source of the disturbance was no longer evident. The two smallest stretches (both less frequently used) were of 1.1 ha and 1.7 ha in area; the eight larger stretches supported larger groups and had a mean area of 11.6 ha (± 3.4 ha).

Foraging birds typically fed on small fish, including species of loach (order: Cypriniformes). These were caught either (as also by some foraging Goosander *Mergus merganser*) through a combination of prolonged periods of swimming with only the head submerged, followed by longer dives in open water, or (unlike the Goosander) by frequent, rapidly repeated dives in shallow water (often among rocks close to the riverbank or immediately below or in riffles) and by "channel fishing", in which birds dive and swim upstream through narrower river channels where the river flow is concentrated, before flying back downstream to repeat the process. Channel fishing has been observed at all five priority rivers for the species in the RO Korea, and foraging in very shallow water along the river edge or in riffles has been observed at all rivers used regularly by the species. These specialised foraging strategies are tied closely to local geomorphology. They therefore likely contribute to the species' patchy distribution along the rivers. Both of these specialised foraging strategies also potentially expose Scaly-sided Mergansers to a higher level of human disturbance from recreational fishers and hikers than experienced by the generally less wary

Goosander, which tends instead to forage in deeper, slower-moving water away from the river's edge.

Scaly-sided Mergansers have apparently become habituated to people at only two to three river stretches nationwide, where they allow approach to within 100 m. At most sites the flight initiation distance from point of disturbance is *c.* 150–250 m, up to an estimated 300 m or more from boats (Moores *et al.* 2022).

Evidence to date suggests that an increase in chronic disturbance has coincided with declines or local extirpation. For example, the winter census recorded 46 individuals along 40 km of the Bukhan River in 2006. Subsequently, cycle roads were built and the species – while still occurring in small numbers – is no longer recorded there annually during the winter censuses. Similar infrastructural development has been followed by extirpation or decline along stretches of the Nakdong and Hantan Rivers, and also the Jiseok Stream.

Surveys in DPR Korea

Observations of Scaly-sided Mergansers along the Chongchon River in November and March presented by Duckworth & Kim (2005) and nine seen during the Birds Korea survey of Lake Dongchon on the east coast (at 39.08°N, 127.77°E) on 4 November 2017, fit within the main migration periods. The survey in late January 2019 along the Chongchon River failed to find any Scaly-sided Merganser and, similarly, no Scaly-sided Merganser were found along stretches of two other near-adjacent rivers pre-selected based on Google Earth imagery: the Taedong River (in and downstream of Pyongyang, south to the West Sea Barrage at 38.69°N, 125.22°E) and the Taeryeong River, including an area of shingle banks, riffles and *c.* 50 ha of open water below a major dam (at 39.84°N, 125.60°E). In spite of extensive ice cover and only small patches of open water, Goosanders were found along all three rivers. The observations in 2019 therefore fit well with those made by Duckworth in 2000–2004, who did not see Scaly-sided Merganser in mid-winter along the Chongchon River or in urban areas at any time, but did see Goosander along the Chongchon and Taedong Rivers in mid-winter, including within urban areas of Pyongyang (Duckworth & Kim 2005; J.W. Duckworth *in lit.* 2023).

Survey work along several stretches of the east coast combined with review of Google Earth imagery suggest that most rivers in eastern and northeastern DPR Korea are short, have only seasonal flows, and are likely to be heavily disturbed. In addition, they are likely to be largely frozen during the mid-winter period.

Discussion

There has been substantial progress with research and conservation efforts for Scaly-sided Mergansers in both China and Russia in recent years, yet there is still no robust evidence to suggest that the population of the species is increasing. On the Korean Peninsula, knowledge of the species and its ecological requirements has also improved over the last decade, but major information gaps remain throughout the annual cycle and at a range of scales, with few actions yet taken to protect key stretches of the rivers used by the species.

The ISSAP estimates 116 breeding pairs in the DPR Korea, and modelling suggests that a small population likely breeds in the four northeastern provinces (Solovyeva *et al.* 2017; Xu *et al.* 2021), with breeding said to occur at Mayang Reservoir in the northeast (42.07°N, 129.51°E) by BirdLife International (2023a). However, once records in Duckworth & Kim (2005) are excluded, we can trace < 10 dated records nationwide for Scaly-sided Mergansers in the DPR Korea. Tomek (1999) provides four of these: on 29 March 1958 and 16 April 1912; and from Mayang Reservoir in May 1986 and on 20 September 1989. The latter two records are listed by DPRK (2002) as five birds present on 2 May 1987 and three on 21 September 1989. The September record corresponds well with dates of two birds carrying geolocators during southward migration, and neither Science and Technical Publishers (2005) nor DPRK (2018) indicate that the species breeds at Mayang Reservoir or nationally, with the latter source stating that the species is only "rarely" recorded at the reservoir. In addition, Google Earth imagery (2023) shows that the feeder river for Mayang Reservoir has one or more roads along it for 150 km upstream, that it largely lacks riverside forest, and that it flows through areas of human habitation and arable land apparently similar to many rivers in the DPR Korea which suffer intense levels of disturbance (Duckworth & Kim 2005; Moores 2019; N. Moores, pers. obs.). Based on the description of breeding habitat in Russia (Solovyeva & Vartanyan 2019) it therefore seems unlikely that a substantial breeding population currently exists close to Mayang Reservoir.

Elsewhere in the northeast of the DPR Korea, ornithologists, including Yankovskii in the 1890s (cited by Tomek 1999), and Bergman in the 1930s, did not observe the species (see Duckworth & Moores 2008). DPRK (2018) list presence at several shallow coastal lakes, but without dates or numbers and DPRK (2016a) provides only one additional dated record, of two birds in October 2007 on marine waters in Rason. This record falls within the period of southward migration and other survey work in Rason did not find any Scaly-sided Merganser (Edwards *et al.* 2003; P. Edwards, pers. obs.). Away from the River Tumen, most hillsides in Rason are covered in pine forest and most streams lack river flow for much of the year.

To confirm whether Scaly-sided Mergansers breed in the DPR Korea, surveys are required in the Paektu/Baekdu Mountain range and elsewhere in the northeast in May–July, prioritising areas suggested in the modelling by Xu *et al.* (2021) to be most likely to support the species. Factors limiting the size of the breeding population need to be identified and where possible mitigated, *e.g.* through strengthening protections of riverine forest and the placement of artificial nest boxes as described by Solovyeva & Vartanyan (2019). As an active partner in the EAAFP, the DPR Korea is well-positioned to benefit from technical support for such conservation actions.

Throughout the Korean Peninsula, information gaps on migration timing and distribution also need to be closed through additional fieldwork. Personal observations and inland records of several marine-

preferential species in Duckworth (2006) suggest that during southward migration several bird species migrate southwest along the DPR Korea coast before taking the shortest land crossing across the Korean Peninsula, a straight-line distance from Wonsan Bay to the Yellow Sea of 180–200 km. The pattern of records presented in this paper suggests that Scaly-sided Merganser might also choose to migrate along this relatively narrow corridor across central Korea, largely between 37° and 40°N.

Total numbers of Scaly-sided Merganser supported by key river stretches in this narrow corridor, including the Chongchon, Imjin and Bukhan Rivers, are likely to be substantially higher during whole migration periods than suggested by single-day peak counts, currently and in past years. This is due to asynchronous migration timing, as confirmed by the geolocator data and as suggested by our ground-based observations. Greater survey effort is required along rivers within this narrow band and to the north of it during the migration season, both to enable a comparison of counts along the Chongchon and Imjin Rivers with those made in earlier years (for assessing the impacts of recent changes to habitat) and to identify additional important rivers and river stretches.

Further single-species survey work is also required to refine understanding of mid-winter distribution and numbers on the Korean Peninsula. Although research effort in the RO Korea has increased substantially in recent years, data remain inadequate to identify a population trend. Winter census data show a national decline of 18% in the 5-year geometric counts, from 70 recorded between the 2012/2013 and 2016/2017 winters, to 58 between the 2017/2018 and 2021/2022 winters (MOEK 1999–2022). However, a comparison of counts made along some of the same river stretches in the same month by the winter census and by Birds Korea confirm that many birds are missed by the census (Moores & Kim 2014; Moores 2022). The Birds Korea national winter surveys instead recorded an increased number between 2014 and 2022, with this increase ascribed to better knowledge of and access to sites; the greater length of river surveyed, and the addition of sightings by observers outside of the main survey teams (Moores 2022). There are currently too few data to identify whether or not overwintering birds are able to relocate to different river systems following changes to habitat. However, both datasets show that the species has declined or been extirpated from several stretches of river which used to be important for the species. The winter census does not provide any analysis of changes in habitat. Ground observations and use of Google Earth imagery confirm, however, that all river stretches used by the species have experienced an increase in river-works and subsequent infrastructural development since 2010.

We have been unable to find evidence that the Scaly-sided Merganser overwinters regularly in the DPR Korea although it has been suggested that some have been seen from the Chinese side of the Yalu/Amnok River in mid-winter, concentrated into ice-free stretches below dams. In accordance with modelling of wintering habitats in China by Zeng *et al.* (2015a) and observations further south in the RO Korea, it seems

likely that mid-winter temperatures are too low in much of the DPR Korea to allow regular overwintering.

At sites throughout the Korean Peninsula where the species is known to occur regularly in winter and during migration, more research is required on feeding ecology; the relationship between foraging strategies and river geomorphology; the daily energy budget; and mitigation of disturbance along favoured river stretches. Evidence presented in this paper suggests that because of apparent fidelity to preferred stretches, the vast majority of which are centred on obvious landscape features < 20 ha in extent, disturbance mitigation measures are likely not required along whole rivers. Instead, they can be focused on preferred stretches and connectivity between them. Proposed measures include re-routing of walking and cycle trails along certain sections, with seasonal access restrictions, and construction of screens alongside roads and trails (Moores *et al.* 2022; Moores 2022).

Finally, the ISSAP calls for the protection of key sites and their nomination as Flyway Network Sites. The most important known river on the Korean Peninsula during the migration period is the Imjin River in the RO Korea. More than 40 km of this river is contained within the Yeoncheon Imjin River Biosphere Reserve and in 2023 Yeoncheon County expressed interest in designating the most important stretches of river as a Flyway Network Site. The county has also initiated projects aimed at reducing disturbance to Scaly-sided Mergansers, and at educating local residents about the importance of river and biodiversity conservation in fulfilling the Sustainable Development Goals (United Nations 2023).

For the Imjin and other rivers in the RO Korea, however, the most urgent need is the strengthening of domestic legislation, including the Environmental Impact Assessment process, and the enactment of legislation to protect the habitat of threatened species. Currently, there are no legal statutes to prevent infrastructural development along rivers outside of protected areas, even along stretches of river that are known to support Scaly-sided Merganser and other threatened species and habitats.

Acknowledgements

The authors would like to thank the anonymous reviewers for their comments and insights; all those who participated in Birds Korea surveys; Andreas Kim, Jang Ryang and other Birds Korea Yeoncheon members for contributing to survey work and data organisation; Yeoncheon County for supporting research; the EAAFP Secretariat for providing small grants to support the national winter surveys in 2014 and 2022; the Hanns Seidel Foundation (Korea office) for participating in and funding surveys in the inner border area of Korea and in the DPR Korea; MOLEP and members of the SSME Task Force team who supported or joined survey work in the DPR Korea; and Lee Myeong Jeong and Park Mun-Sik for contributing their data from the Seomjin R. Geolocation of Scaly-sided Merganser in 2006–2012 was supported by the Wildfowl and Wetlands Trust, UK.

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