Migration routes and population status of the Brent Goose *Branta bernicla nigricans* wintering in East Asia

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Abstract

Of the world's Brent Goose *Branta bernicla* populations, the migration routes and winter distribution of the East Asian population of Brent Geese *B. b. nigricans* are the least well known. We therefore marked Brent Geese at their primary pre-migratory staging area in Notsuke Bay, Hokkaido, Japan to describe their migration between breeding and wintering areas in East Asia. Additionally, count data were compiled from the literature to identify important wintering and staging sites for the species, following Ramsar Convention criteria, and to assess trends in numbers of Brent Geese recorded in Japan and South Korea. The tracking data provided the first direct evidence of migratory connectivity between staging sites in northern Japan and the Korean Peninsula. A total of 26 internationally important sites were identified in the Russian Far East (7), northern Japan (16), northeast China (2) and the Korean Peninsula (1). Autumn surveys made at staging sites in Japan indicate that the East Asian population is increasing, although more extensive surveys for Brent Geese in China and on the Korean Peninsula are needed to confirm overall population trends and to identify critical habitats and wintering sites. We encourage the continuation of tracking studies, to describe more precisely the main migration routes, staging areas and, importantly, the breeding grounds for this vulnerable Brent Geese population.

Key words: autumn, *Branta bernicla nigricans*, East Asia, migration, spring, staging, trends, wintering.

The Brent Goose *Branta bernicla nigricans*, known in America as the Black Brant, breeds widely across the arctic from eastern Russia to western Canada, and in the subarctic of western Alaska, USA (Kear 2005; Lewis *et al.* 2013). While the majority of this subspecies winters along the Pacific coast of North America, from southern Alaska to northern Mexico (*c.* 162,000; Sedinger *et al.* 2019), a smaller proportion of the overall population winters in East Asia from northern Japan to northeast China and the Korean Peninsula (*c.* 5,000–8,700 birds; Wetlands International 2012). The East Asian population is of conservation concern because of its low population size and threats from anthropogenic pressures (*e.g.* poaching and habitat loss or degradation; Syroechkovskiy 2006; MacKinnon *et al.* 2012). Accordingly, the Brent Goose was considered to be a priority species for protection in East Asia under Arctic Migratory Birds Initiative (CAFF 2019). It is also Red-listed in Japan (Vulnerable: Ministry of the Environment 2014), South Korea (Vulnerable: National Institute of Biological Resources 2014) and Russia (Category 3, a rare species: Bolkhin 2000), including on the Kamchatka Peninsula (Category 3, a rare species: Gerasimov 2006) and the Sakhalin Oblast (Category 3, a rare species: Tiunov & Antipin 2016).

Relatively little is known about the breeding grounds, migration routes and important staging and wintering sites for the East Asian population of Brent Geese (Lane & Miyabayashi 1997; Ohtaishi *et al.* 2018), though the population is believed to nest along the central arctic coast of Russia, in or near the Lena River delta (Uspenski 1960; Syroechkovskiy 2006). Recent marking of Brent Geese wintering in Japan which led to the recovery of one of these birds near the mouth of the Lena River delta in 2015, and also a resighting in Hokkaido, Japan (Shimada *et al.* 2017), of an adult caught and marked on the delta during the breeding season (T. Ikeuchi pers. comm.) provides initial support for this hypothesis. From sightings of marked individuals in the early 1990s, Derksen *et al.* (1996) established links between breeding areas in Alaska and wintering areas in Japan, but this connection is likely to be limited given that only one marked individual has since been recorded in Japan since the 2000s (a juvenile in 2013; Yamashina Institute for Ornithology 2014), despite continued extensive banding of Brent Geese in Alaska and observations in Japan.

In autumn, the East Asian population of Brent Geese is believed to migrate eastward along the arctic coast of Russia and then head south along the Bering Sea and Kamchatka Peninsula coasts to northern Japan (Syroechkovskiy 2006). There, they stage for 1–2 months at Notsuke Bay in eastern Hokkaido, Japan (Ministry of the Environment Japan 2015a; Fujii 2017). As winter approaches, birds move either south to winter in northern Honshu, Japan (Sawa *et al.* 2020) or possibly west to the Korean Peninsula and Yellow Sea of China (Lane & Miyabayashi 1997; Fujii 2017), but staging and wintering sites are poorly known in this part of their winter range (Lane & Miyabayashi 1997; Fujii 2017; Ohtaishi *et al.* 2018).

Two spring migration routes between the wintering areas and the breeding grounds have been proposed. Shimada *et al.* (2016, 2017) suggested that Brent Geese wintering in Japan migrate northward from Japan via the northern coast of the Sea of Okhotsk, after which they follow an interior route along the Lena and Yana Rivers to their breeding sites in the Russian arctic. Brent Geese wintering in Korea and China, on the other hand, are believed to migrate north overland through China and Russia before also following the interior route along the Lena River and Yana River valleys to their nesting areas in northern Russia (Uspenski 1960; Syroechkovskiy 2006). However, the primary migration routes and exact breeding grounds have yet to be identified.

This lack of knowledge has important management implications, given that habitat loss and/or intensive harvest levels could have a significant impact on this relatively small population. In this study, we therefore marked Brent Geese with transmitters during autumn-staging area in Notsuke Bay in order to determine their migratory routes to and from wintering areas in East Asia. We also reviewed published information on Brent Goose use of staging and wintering sites, and analysed survey data to assess trends in numbers in Japan and South Korea, with a view to providing better information on the status in of the species in East Asia.

Methods

Transmitter deployment and tracking

We captured four Brent Geese on 21–22 and 24 November 2017, and 20 between 28 October–6 November 2018 at Notsuke Bay in eastern Hokkaido, Japan (43.58°N, 145.23°E). Geese were caught using leg loop traps set inter-tidally at a sandbar where geese usually come to grit, rest and preen in the morning (Sawa *et al.* 2019). Each captured goose was fitted with a yellow-coloured plastic band with a numeric code on the left leg, a metal ring on the right leg and a transmitter which was attached using a modified Dwyer (1972) harness. In 2017, three adults (two females, one male) were marked with 44 g GPS-GSM-based transmitters (WT-300, KoEco Inc.). The transmitter recorded one GPS location per every 2 h and transmitted data via the GSM mobile networks twice a day. In 2018, nine adults were fitted with either a 34 g GPS-

GSM-based transmitter (WT-300, KoEco Inc.; one female, one male), a 17 g satellite transmitter (PinPoint GPS Argos P-350, Lotek Wireless, Inc.; three females, one male), or a 18 g Platform Transmitting Terminal satellite tracking device (PTT-100, Microwave Telemetry Inc.; three females). The WT-300 transmitters recorded one GPS location every 4 h and transmitted data once a day. Pinpoint GPS Argos transmitters recorded one GPS location every five days and transmitted data about every 15 days. The PTT-100 transmitters were programmed to transmit location data to the satellite for 10 h in every 48 h period, and these data were retrieved using the Argos Data Collection and Location System (CLS Inc., Largo, Maryland, USA). Data recorded included latitude, longitude, location accuracy, temperature, battery voltage and activity code.

Migration routes were mapped using fixed GPS location (positional accuracy of < 5 m) for the WT-300 and Pinpoint GPS Argos transmitters, and the most accurate location classes (LC 1, 2 & 3; positional accuracies of < 250 m, 500 m and 500–1,500 m, respectively) for each transmission period for the PTT-100 transmitters. To minimise transmitter effects on movements, we mapped the tracks of tagged birds with > 2 weeks of signal transmissions. We took the start of autumn migration as being the date and time at which the birds departed the combined Notsuke Bay, Lake Furen, Hokkaido and Kunashiri Island area (Fig. 1), because of the close proximity of these sites to each other and because tagged birds regularly moved between these sites.

Staging and wintering sites in East Asia

Numbers of Brent Geese at staging and wintering sites in Russia, Japan, the Korean Peninsula and China were collected from published literature sources, monitoring data and observation records. For Japan, we obtained count data from a 32-site nationwide Brent Goose survey organised by the Eastern Hokkaido Brent Goose Research Network during autumn, winter and spring in 2014/15–2016/17 inclusive (Fujii 2017). For South Korea, most of the count data were extracted from the annual nationwide "Winter Waterbird Census" of Korea reports (National Institute of Biological Resources 2004–2019), which gives the results of surveys made each year of the lakes, reservoirs, seashores and bays known to be important for waterbirds in the country. For North Korea, some data were available from the east coast (Tomek 1999; Moores 2017, 2018), but none from the west coast, despite some potentially suitable wetlands along the Yellow Sea (BirdLife International 2004). For the Russian Far East, count data were gathered from published literature for sites on the Kamchatka Peninsula, the north coast of the Sea of Okhotsk, Sakhalin Oblast and Primorsky Krai (Gerasimov & Gerasimov 2000; Nechaev 2003; Andreev 2013; Zhuravlev & Kulikova 2014.). No count data were available from Khabarovsk Krai. For China, we obtained count data from the *China Coastal Waterbird Census* (China Coastal Waterbird Census Group 2015), which covers 32 sites of the vast area from the Yellow Sea to Hainan, augmented by sightings posted on the Bird Report portal

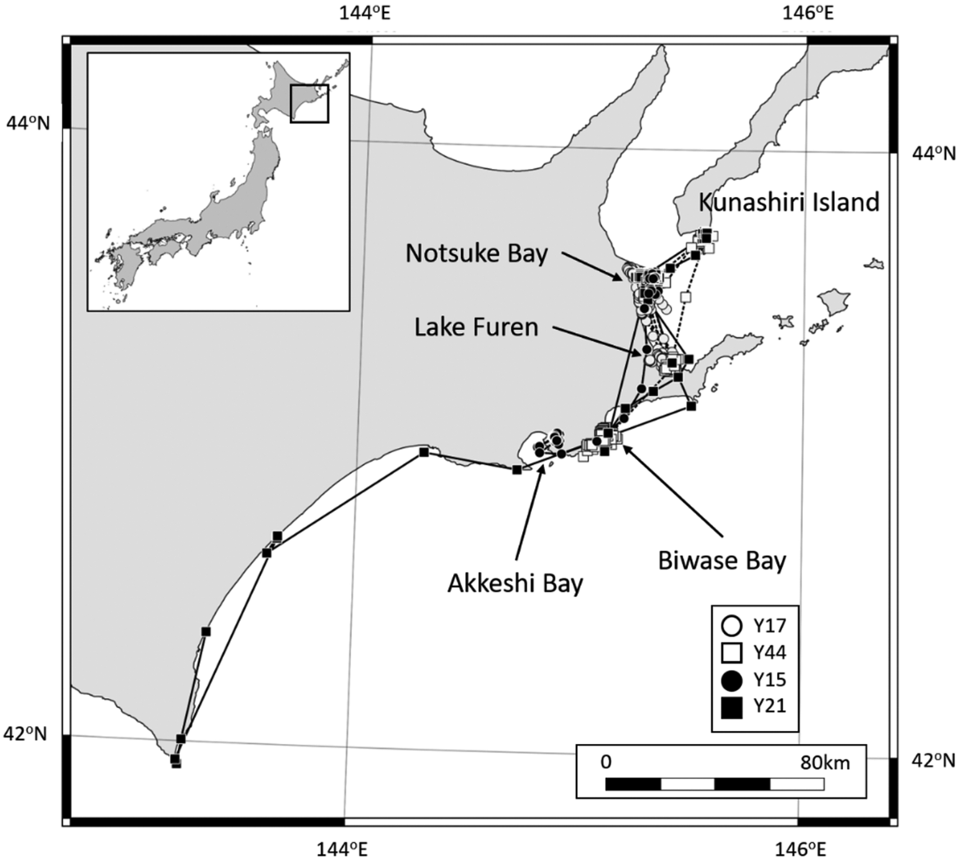

Figure 1. Autumn movements of four Brent Geese marked with transmitters from Notsuke Bay to wintering sites on Hokkaido, Japan. Dotted lines = tracks in 2017; straight line = tracks in 2018.

website for China (http://www.birdreport.cn). Finally, we also describe the habitats and main foods used by Brent Geese at staging and wintering sites from a review of the literature (Suzuki 1989; BirdLife International 2004; Notsuke Peninsula Nature Center 2009; Shimada *et al.* 2013, 2016, 2018; Kataoka 2015; Hirata *et al.* 2015).

We defined the autumn staging period as September–November, winter as December–February and spring staging period as March–May, and grouped the count data by each season. Wetlands that supported ≥ 1% of the whole of the East Asia Brent Goose population, or ≥ 65 birds, were classed as internationally important sites, on the basis of a total population estimate of 5,000–8,700 Brent Geese in the flyway, following Ramsar Convention criteria (Wetlands International 2012). The conservation status of sites identified as being important for Brent Goose was gleaned from Bird Life International (2004) and from Stishov (2014).

Population trends

Annual population trends for winter in Japan and South Korea were analysed using count data recorded during the annual mid-winter nationwide survey of waterfowl in Japan (http://www.biodic.go.jp/gankamo/gankamo_top.html), and the "Winter Waterbird Census" of South Korea (National Institute of Biological Resources 2004–2019), respectively. The survey in Japan was conducted annually in mid-January at *c*. 9,000 sites since the 1970s. The survey in South Korea was undertaken annually from December to February at 200 major migratory waterbird sites since 1998. We used these data to evaluate long-term changes in the numbers of Brent Geese recorded in winter using the rtrim package (Bogaart *et al.* 2018). This package is a reimplementation of TRIM ("Trends and Indices for Monitoring Data") software, developed to analyse monitoring data from incomplete counts using a log-linear Poisson regression (Pannekoek & van Strien 2005). We used the "time effect" basic model which corrects for over-dispersion and autocorrelation, and estimates trends based on the imputed slope. The population trends were assigned to one of six categories depending on the overall slope: 1) steep decline, 2) strong increasing trend with a significant change of > 5% per year, 3) moderate decline, 4) moderate increase with a significant change of < 5% per year, 5) stable trend, for non-significant changes of < 5%, and 6) uncertain trend, for non-significant changes of > 5% per year (Pannekoek & van Strien 2005). The estimated slopes of the population trend reflect the average percentage change per year.

Seasonal population trends in Japan were determined from the "Monitoring Sites 1000" survey which has covered *c*. 80 sites each year in autumn (September–November), winter (December–February) and spring (March–May) since the 2004/05 season (Ministry of the Environment 2015b). In this survey, the maximum number of waterbirds was extracted from the three main survey attempts (autumn, winter and spring) made at each site for each season. The timing of surveys were not coordinated synchronously across sites within a season and there was a greater likelihood of flock movement and double-counting the same birds across sites. Nevertheless, while using the maximum count may overestimate population size, it provides an index of the population for determining annual trends in seasonal abundance. In this analysis, autumn and spring data were analysed using TRIM, as mentioned above, and the imputed yearly indices were calculated. Indices of the first year of the survey (2004/05) were treated as the base year and given the value 1; all other indices were then calculated in relation to this year.

Results

Tracking during autumn migration

In 2017, we obtained movement data from two tagged adult Brent Geese (Table 1). Brent Goose Y17 remained in the Notsuke Bay, Lake Furen and Kunashiri Island combined area from 22 November until 27 December, when the signal transmission was lost. Brent Goose Y44 moved to Kunashiri Island on 25 November and stayed there until 30 November. Then it

Table 1. Date of capture, and the start of autumn and spring migration for Brent Geese fitted with tracking devices.

ID	Sex	Age	Deployment start date	Autumn migration start date	Spring migration start date	Deployment end date	No. days tracked
Y17[1]	F	A	22 Nov 2017	–	–	27 Dec 2017	35
Y44[1]	M	A	22 Nov 2017	25 Nov 2017	–	8 Jan 2018	47
Y15[2]	M	A	31 Oct 2018	4 Nov 2018	–	15 Nov 2018	15
Y21[2]	F	A	3 Nov 2018	28 Dec 2018	–	30 Dec 2018	57
Y03[2]	F	A	28 Oct 2018	10 Dec 2018	–	20 Dec 2018	53
Y13[2]	F	A	31 Oct 2018	10 Nov 2018	–	10 Dec 2018	40
Y27[2]	M	A	6 Nov 2018	10 Dec 2018	20 Mar 2019	1 May 2019	176
Y04[3]	F	A	30 Oct 2018	–	–	24 Dec 2018	25
Y07[3]	F	A	30 Oct 2018	28 Dec 2018	10 Apr 2019	7 Sep 2019	312
Y18[3]	F	A	31 Oct 2018	8 Nov 2018	–	15 Nov 2018	15

[1]WT-300, [2]Pinpoint GPS Argos p-350, [3]PTT-100

migrated to Biwase Bay via Lake Furen and remained there until the signal was lost on 8 January 2018 (Fig. 1). While the signal from Y44 had stopped, it was sighted in Biwase Bay on 10 and 20 February 2018 (Sawa *et al.* 2020), where the bird was presumed to have wintered.

In 2018, we tracked movements of eight tagged adults (Table 1). Brent Goose Y15 migrated to Akkeshi Bay, Hokkaido, on 4 November where it stayed until signal transmission was lost on 15 November (Fig. 1). Brent Goose Y21 departed on 28 December and moved along the south coast of eastern Hokkaido until its signals were lost on 30 December (Fig. 1). Two Brent Geese Y03 and Y27 started migration on 5 December and reached Kesen-numa and Shizugawa bays, Honshu, on 15 December respectively (Fig. 2). Y27 stayed in or near Shizugawa Bay until 20 March 2019, while the signals of Y03 stopped on 20 December. Brent Goose Y04 moved to Lake Furen, Hokkaido, on 22 November where signals were lost on 24 November. Brent Goose Y07 migrated on 28 December and reached Shimokita Peninsula, Honshu, on 31 December (Fig. 2). It stayed there until 10 April 2019. Brent Goose Y18 left Notsuke Bay between 6–8 November and reached Tanchon on the east coast of North Korea after crossing the Japan Sea on 10 November. The last signal from Y18 was received from Tanchon on 13 November (Fig. 2). The mean departure date of tagged Brent Geese from the combined Notsuke Bay,

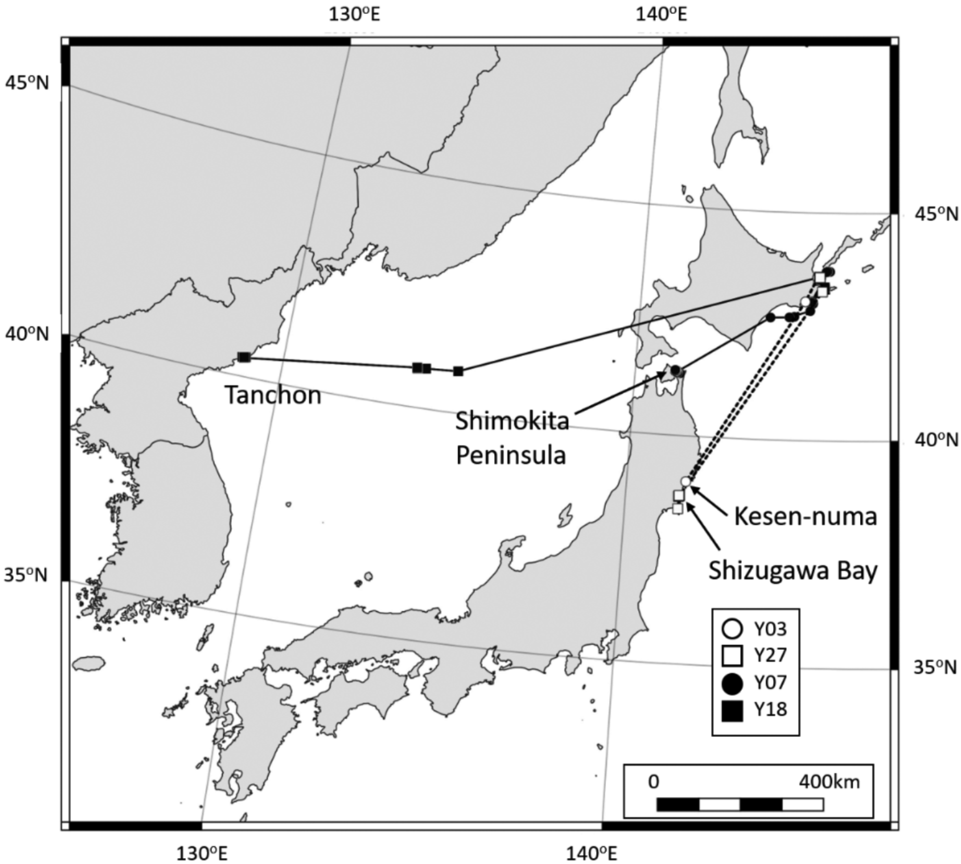

Figure 2. Autumn migration of four Brent Geese marked with transmitters from Notsuke Bay to wintering sites in northern Honshu, Japan in 2018/19 (dotted lines) and North Korea in 2018 (straight line).

Kunashiri Island, and Lake Furen area was 1 December ± 23.5 days (mean ± s.d.) in 2018.

Tracking during spring migration

Brent Geese Y07 and Y27 were tracked during spring migration in 2019 (Fig. 3). Y27 migrated from Shizugawa Bay where it wintered, on 20 March, and arrived in Notsuke Bay on 25 March. It then moved to Veslovskiy Peninsula and Izmeny Bay on Kunashiri Island on 30 March until its signal was lost on 1 May. Y07 migrated north on 10 April from Shimokita Peninsula, Honshu, on 10 April, stopped briefly on the Nemuro Peninsula, Hokkaido, and reached Kunashiri Island on 15 April. It stayed on Kunashiri Island from 15 April to 10 June and visited Notsuke Bay twice on 19 and 24 May. Y07 attempted a northward migration from Kunashiri Island along the east coast of Sakhalin Island on 12 June, but returned

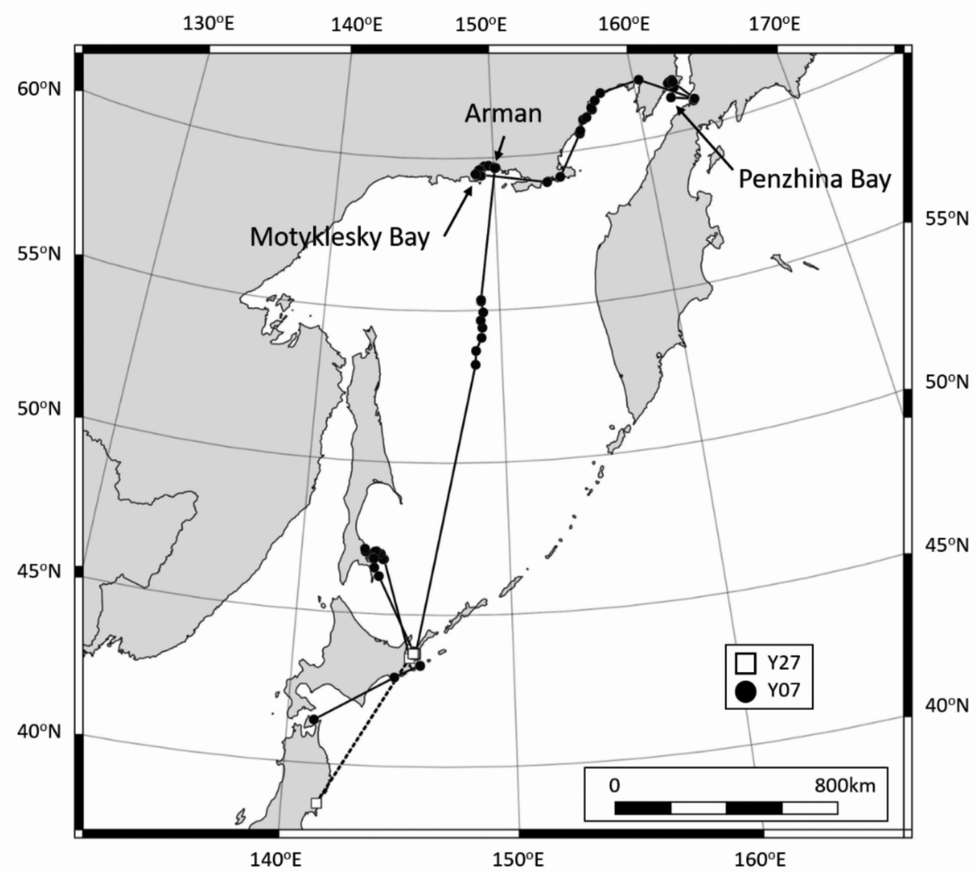

Figure 3. Spring migration of Brent Geese marked with transmitters from their wintering site in Shizugawa Bay (dotted line) or on the Shimokita Peninsula, Honshu, Japan (straight line) to staging areas in northeastern Hokkaido and the Magadan region of Russia.

to Kunashiri Island on 15 June. On 27 June, Y07 initiated another northward movement, successfully crossing the Sea of Okhotsk to mainland Russia near Arman, Russia, on 1 July, and later moved to nearby Motyklesky Bay on 19 July. Then, it moved northeast along the Magadan coast of Sea of Okhotsk on 21 July, and stopped in Penzhina Bay on 23 July where Y07 remained until 7 September when its signal was lost.

Autumn staging sites

We identified 11 important (*i.e.* supported ≥ 65 birds) autumn staging sites for Brent Geese: five sites in Russia, five sites in Japan, and one site in North Korea (Fig. 4, Appendix 1). Four of the important sites in Russia occurred on the Kamchatka Peninsula, where large numbers of autumn migrants were observed at coastal sites (Gerasimov & Gerasimov 2000). Flocks were observed primarily along the east coast

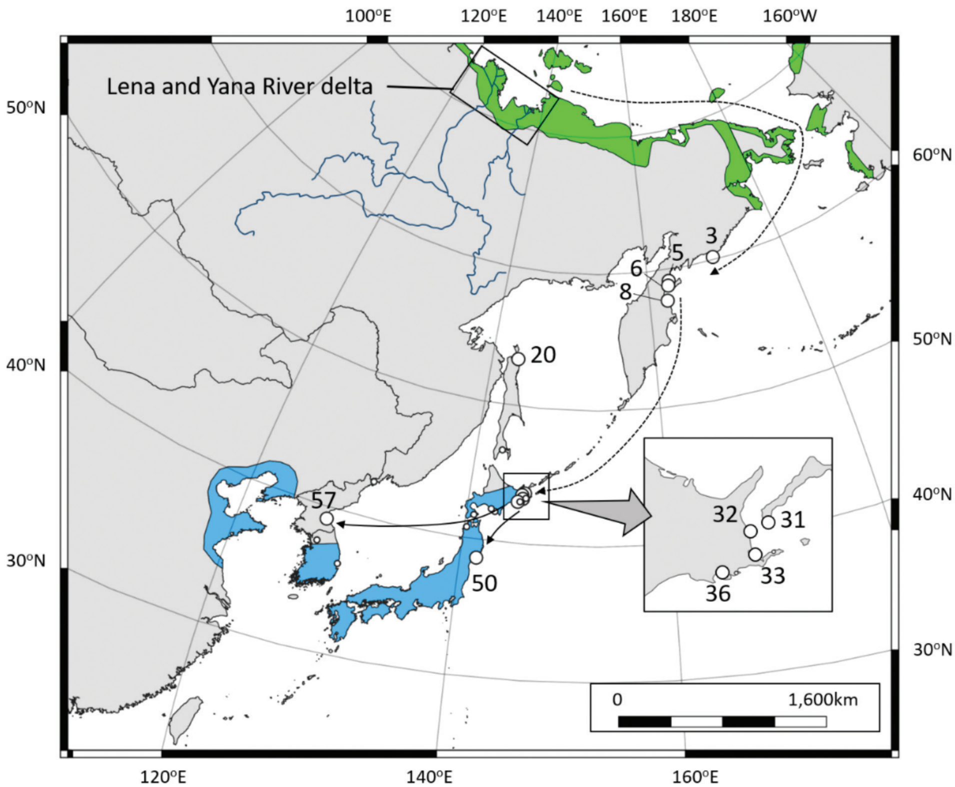

Figure 4. Autumn staging sites of Brent Geese in East Asia. Larger circles represent sites that meet the 1% Ramsar Convention criteria for the overall East Asian population (see *Methods*; numbers correspond to Appendix 1). Smaller circles represent the sites where a smaller number of Brent Goose were observed. Confirmed (solid line) and unconfirmed (dotted line) autumn migration routes are also shown. The light green and blue shaded areas indicate the breeding range and the wintering range, respectively (BirdLife International 2020).

of the peninsula with up to 4,800 birds found in Malamvayam Lagoon during early October. Gerasimov & Gerasimov (2000) estimated that 6,000–7,000 Brent Geese migrated south along the Kamchatka Peninsula to East Asia. The other important autumn site in Russia was in north Sakhalin Island, where one flock of 200 Brent Geese was recorded (Tiunov & Antipin 2016). There were also small numbers of autumn migrating Brent Geese observed adjacent to Sakhalin Island along the coast of Primorsky Krai, Russia (Zhuravlev & Kulikova 2014). Four of the important autumn sites in Japan occurred in eastern Hokkaido at Notsuke Bay, Lake Furen, Akkeshi Bay and Kunashiri Island. These combined sites were estimated to support *c.* 8,600 Brent Geese in autumn (Fujii 2017; Sawa *et al.* 2020). The one important autumn site for Brent Geese on the Korean Peninsula was at Wonsan, North Korea, where a flock of 150 birds were observed in autumn 2018 (Moores 2018).

Wintering sites

We identified 15 important wintering sites: 13 sites in Japan, and two sites in China (Fig. 5, Appendix 1). In Japan, the main winter sites were located in southern Hokkaido and northern Honshu, where the winter population of Brent Geese was estimated at *c.* 2,500 birds (Fujii 2017). The important sites in China occurred along the coast of the Yellow Sea and in Bohai Bay (Lane & Miyabayashi 1997). Highest counts of Brent Geese were recorded on Changshan Island, Yellow Sea coast in 1993 (1,200 birds; Waterbird Specialist Group of the Chinese Ornithological Association 1994), and in Rongcheng Whooper Swan Nature Reserve, Yellow Sea coast in 1998 (203 birds; Yan 1999). Although one site in South Korea, Gwangyang Bay/Galsa Bay, met the 1% criterion (supported ≥ 65 birds) once in 2001, the combined total

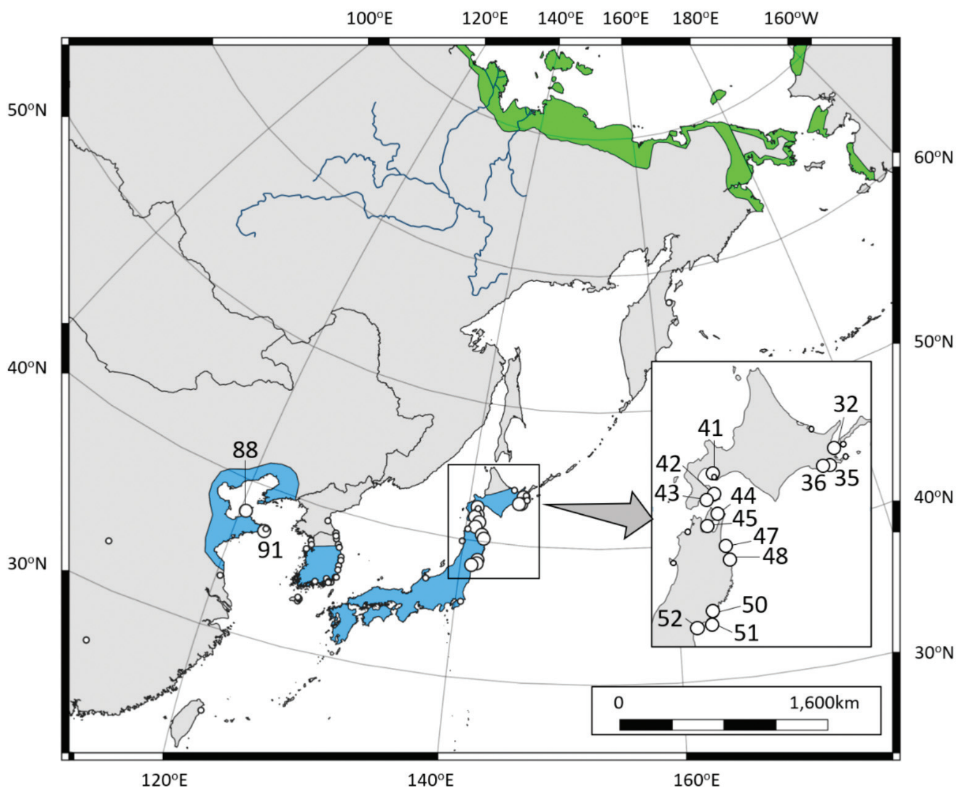

Figure 5. Wintering sites of Brent Geese in East Asia. Larger circles represent sites that meet the 1% Ramsar Convention criteria for the overall East Asian population (see *Methods*; numbers correspond to Appendix 1). Smaller circles represent the sites where a smaller number of Brent Geese were observed.

numbers of Brent Geese counted in these bays have been much smaller in recent years (Appendix 1; National Institute of Biological Resources 2004–2019). There have been few waterbird surveys along the east coast of North Korea, which is reported to have very low numbers of Brent Geese, and no surveys have been undertaken along the west of North Korea in winter. Therefore, we identified no important wintering sites for the species on the Korean Peninsula.

Spring staging sites

Eleven important spring staging sites were identified: eight in Japan, and three sites in Russia (Fig. 6, Appendix 1). In Japan, seven sites were located in Hokkaido, with one at the northern end of Honshu. The total number of Brent Geese spring-staging in Japan was estimated at *c.* 3,100 birds, with most found in these eight important sites (Fujii 2017). Only small numbers of Brent Geese were observed in spring along the east coast of North Korea and the adjacent

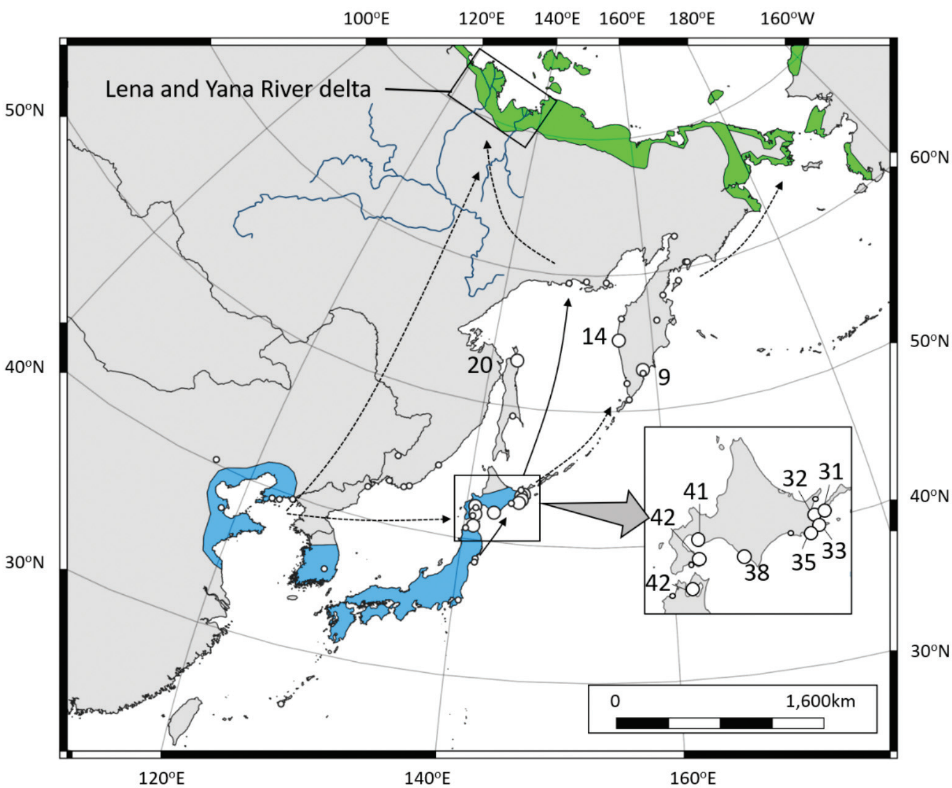

Figure 6. Spring staging sites of Brent Geese in East Asia. Larger circles represent sites that meet the 1% Ramsar Convention criteria for the overall East Asian population (see *Methods*; numbers correspond to Appendix 1). Smaller circles represent the sites where a smaller number of Brent Geese were observed. Confirmed (solid line) and unconfirmed (dotted line) autumn migration routes are also shown.

Primorsky Krai coast in Russia (Zhuravlev & Kulikova 2014; Moores 2017). In Russia, one spring staging site was located in the northern part of Sakhalin Island, but Brent Geese are thought to be rare spring migrants on this island (Tiunov & Antipin 2016). The two other spring staging sites identified in Russia were located on the Kamchatka Peninsula. Flocks of up to 200 birds have been along both coasts of the peninsula in spring (Gerasimov & Gerasimov 2000). No important spring sites were identified for Brent Geese on the Korean Peninsula.

Population trends

We detected a "moderate increase" trend (mean 2.0% per year) in the numbers of Brent Geese wintering in Japan between 1998/99 and 2018/19 (Fig. 7, multiplicative slope ± s.e. = 1.020 ± 0.006, P < 0.01). Although the trend for those wintering in South Korea over the same period was "uncertain" (multiplicative slope ± s.e. = 0.889 ± 0.121, P = 0.40, n.s.), the number of Brent Geese decreased in the early 2000s and has remained very low over the last decade (< 15 birds, Fig. 7). There was no relationship in the annual change in population size between Japan and Korea (linear regression: $R^2 = 0.002$, $t_{20} = 0.19$, $P = 0.84$, n.s.).

Analyses of seasonal trends in numbers in Japan indicated a strong increase in the autumn counts, with an average annual increase of *c.* 10.1% (Fig. 8, multiplicative slope ± s.e. = 1.107 ± 0.013, P < 0.01), and a moderate increase in spring with an average annual increase of *c.* 4.7% (Fig. 8, multiplicative slope ± s.e. = 1.047 ± 0.017, P < 0.01).

Discussion

Migratory routes of the East Asian population

This study provided direct evidence for an autumn migration route between Notsuke Bay, Japan, and the Korean Peninsula (Fig. 3), supporting the hypotheses of Lane & Miyabayashi (1997) and later Fujii (2017) that Brent Geese staging in eastern Hokkaido migrate to the Korean Peninsula and China. They speculated on a major migratory route across the Sea of Japan because Brent Geese survey numbers decrease significantly between autumn and winter in Japan and there are no other known locations for Brent Geese in East Asia. The satellite-tagged Brent Goose Y17 appeared to fly a direct, overwater migration to Tanchon in North Korea. We suspect that this tagged bird was part of a larger migration of Brent Geese to the North Korean coast because its arrival occurred within a few days of an observation of 150 Brent Geese at Wonsan, North Korea (Moores 2018), about 200 km to the south.

The spring migration route of Brent Geese north from China and the Korean Peninsula to the breeding grounds in Russia is unknown but may include a reversal of the autumn migration route across the Sea of Japan to staging sites in eastern Hokkaido and Kunashiri Island (Fig. 6). This seems plausible given regular observations of spring migrants near Hakodate on Hokkaido and Mutsu Bay on Honshu, where geese would make their first landfall after the overseas crossing. There is also speculation about another more direct northward migration corridor for

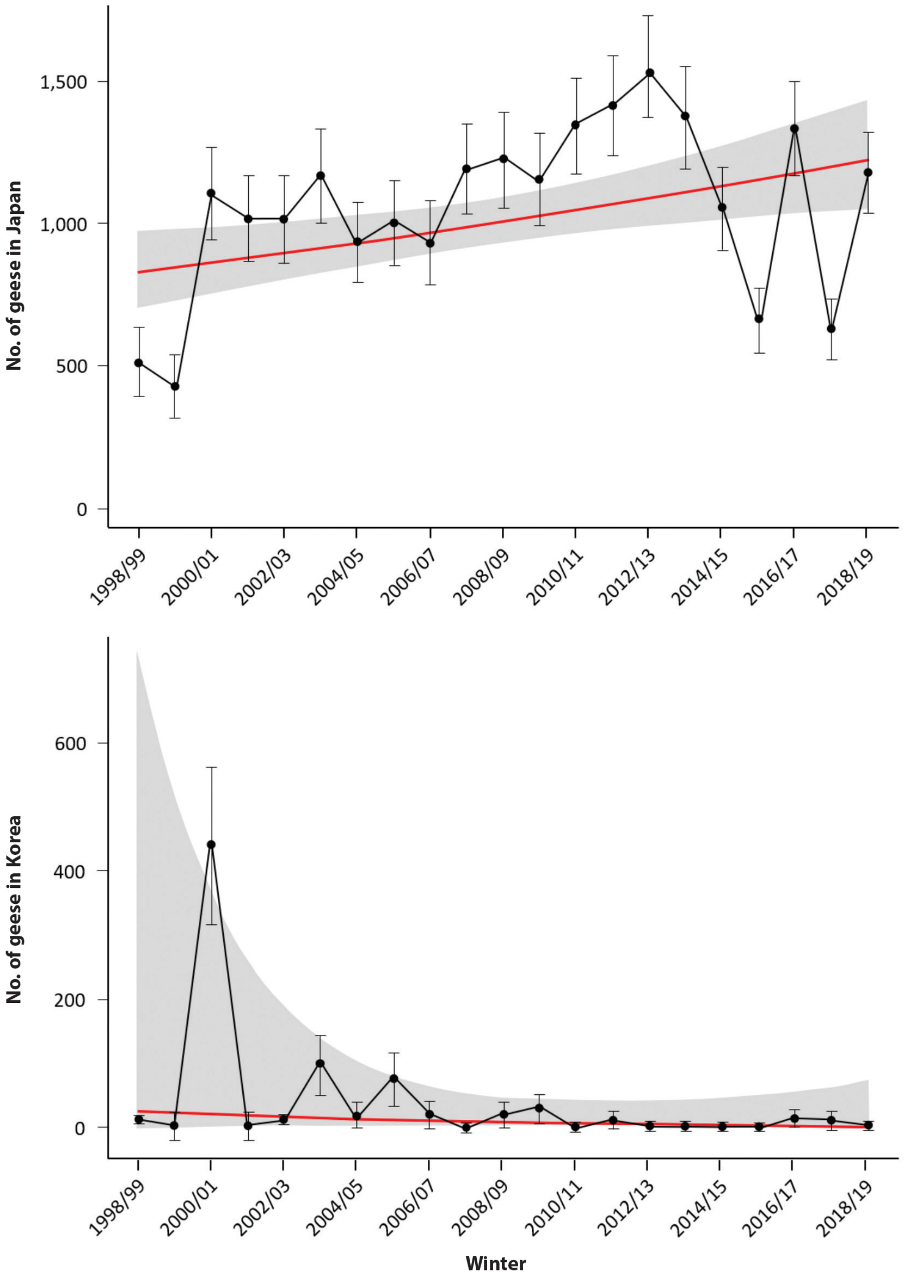

Figure 7. Trends (red line) and 95% confidence intervals (shading) in the wintering population of Brent Goose in Japan (top) and Korea (bottom), 1998/99–2018/19. Points represent annual estimates with 95% confidence intervals (vertical lines).

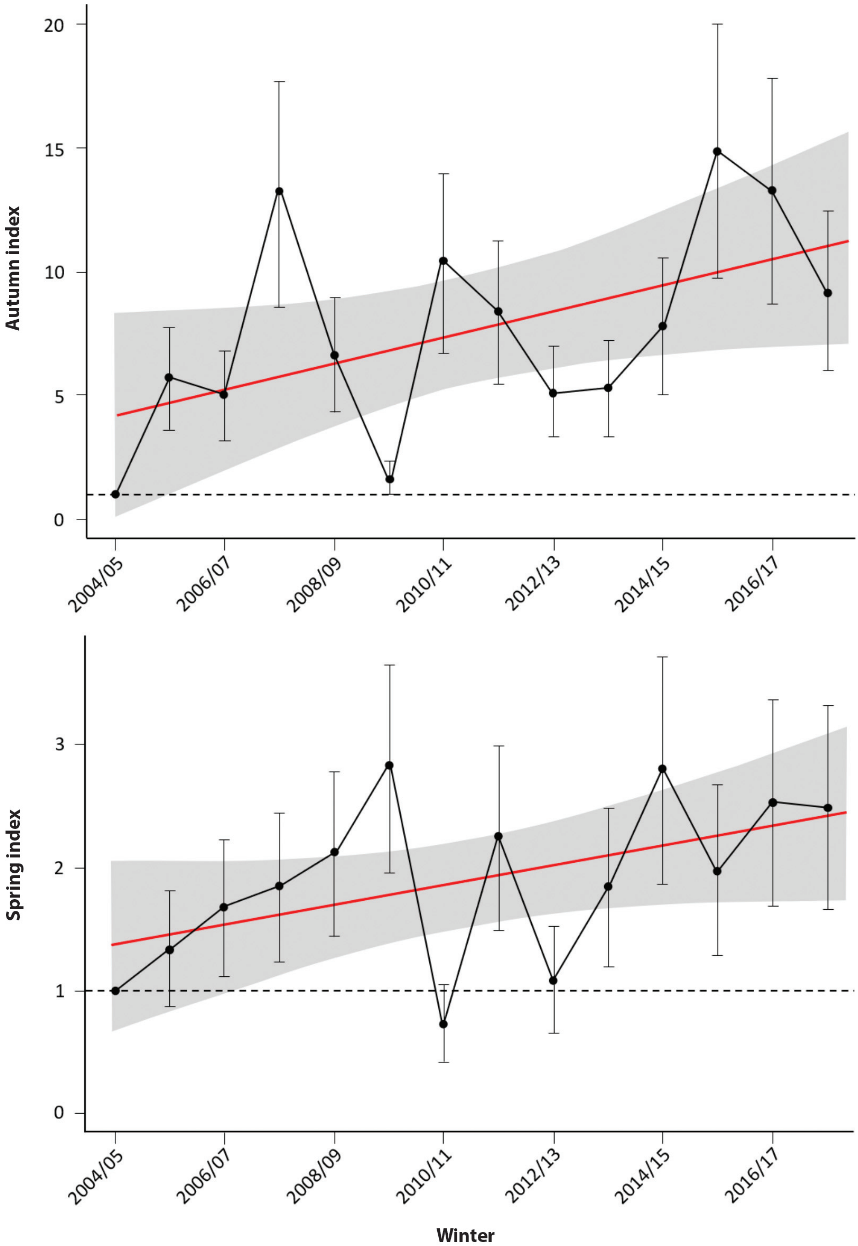

Figure 8. Trends (red lines) and 95% confidence intervals (shading) in the population of Brent Goose in Japan during autumn and spring, 2004/05–2017/18. Vertical lines represent the standard error of the trend indices. Horizontal dotted line represents the index value (1) for the base year (winter 2004/05), which is the reference point for comparing each of the annual indices.

these wintering Brent Geese, overland through China and Russia via the Lena and Yana Rivers to nesting grounds in the central Russian arctic (Uspenski 1960; Syroechkovskiy 2006), but observations to confirm this migration route remain scarce. Additional tracking studies are needed to confirm spring migration routes for Brent Geese wintering in China and on the Korean Peninsula.

Brent Geese wintering in northern Japan appear to fly non-stop to spring-staging sites in eastern Hokkaido as indicated by the routes of two of the tagged birds (Fig. 3). From there, birds likely follow a direct route across the Sea of Okhotsk to coastal staging sites near Magadan, as shown previously by the migration tracks of satellite-tagged Brent Geese in 2014 (Shimada *et al.* 2016, 2017). The migration track of the satellite-tagged Brent Goose Y07 also supports an overseas route across the Sea of Okhotsk (Fig. 3) and further suggests that this route may be the main flight corridor for Brent Geese between Japan and mainland Russia. Once on mainland Russia, these Brent Geese are also believed to migrate along the Lena and Yana Rivers to nesting grounds in or near the Lena River delta (Syroechkovski 2006; Shimada *et al.* 2017). While this interior route in East Asia still needs to be confirmed, other Brent Goose populations, such as those that breed in high arctic Canada, are known to make an overland migration to their nesting areas (Boyd *et al.* 2013), so it is conceivable that breeding birds of the East Asian Brent Goose population may also fly overland to their breeding range. Our satellite-tagged Brent Goose Y07, however, appeared to be a non-breeder because it initiated spring migration after the start of nesting season on the Lena River delta (Sawa *et al.* in press) and migrated east to the Kamchatka Peninsula rather than northwest towards the breeding grounds. As noted above, a small number of flocks have been observed in spring along both the west and east coast of Kamchatka Peninsula (Gerasimov & Gerasimov 2000). These two observations may suggest the existence of another spring migration route in the Far East used by non-breeding birds migrating to known moulting areas in Chukota, Russia (Fig. 6; Uspenski 1960).

Important sites and population in East Asia

Twenty-six sites used by Brent Geese were identified as meeting the 1% Ramsar Convention criterion (Appendix 1, Figs. 4–6): seven in the Russian Far East; 16 in northern Japan; one on the Korean Peninsula; and two sites in northeast China. Two of these sites, Malamvayam Lagoon in Russia and Notsuke Bay in Japan, supported significant numbers of Brent Geese during autumn migration and may be ideal sites for monitoring trends in the overall East Asian population, as illustrated by the results of repeated autumn surveys at Notsuke Bay (Fujii 2017). The relatively few important sites identified in China and the Korean Peninsula is perplexing, given that a majority (up to 70%) of the overall East Asian population is believed to winter in this region (Lane & Miyabayashi 1997; Syroechkovskiy 2006; Fujii 2017). However, there have been no coordinated surveys and only few observations of Brent Geese in

China and North Korea, especially in the last two decades, so it is difficult to assess how many birds winter in these countries. So where are the remaining Brent Geese wintering: in China or North Korea? This question can only be answered by a coordinated East Asia-wide (at all potential sites in Japan, China, the Korean Peninsula and on the Kamchatka Peninsula in Russia) survey of the Brent Goose population, using improved Brent Goose survey techniques (Fujii 2017).

Analyses of population trends suggest that the numbers of Brent Goose have risen in Japan during all non-breeding seasons, in autumn, winter and spring. The greatest increasing trend (10.1%) was detected in autumn (Fig. 8) and may indicate that the East Asian population has grown, given that most (if not all) of these birds stage in eastern Hokkaido in autumn (Fujii 2017). Many of these autumn migrants may also be short-stopping their migration to overwinter in Japan, which may help to explain the increasing numbers of Brent Geese wintering there (Fig. 7), especially in Hokkaido and northern Honshu (Fujii 2017). This short-stopping behaviour is common in geese and is currently being exhibited by the western Pacific population of *B. b. nigricans* in response to climate warming (Ward *et al.* 2009). Although we did not detect a correlation in annual winter numbers of Brent Geese between Japan and South Korea, goose numbers were lower in South Korea during the years of greatest increase in the wintering population in Japan (Fig. 7). The low number of wintering Brent Geese in South Korea may be attributable to increased anthropogenic pressures from the reclamation and industrialisation of coastal wetlands in known Brent Goose wintering areas, such as Gwangyang Bay and the Nakdong Estuary (Moores 2012). Finally, the increasing numbers of Brent Geese in Japan may be driven, in part, by improved survey techniques and a more organised nationwide survey of these geese since 2014 (Fujii 2017).

Habitat loss and degradation of wintering areas are likely to be the main drivers of change in the East Asian population of Brent Goose. From the review of the literature, Japanese Brent Geese feed mainly on eelgrass *Zostera* sp. during autumn migration, and on green algae during winter and spring as *Zostera* sp. becomes less available. This preference for *Zostera* sp. is similar to other subpopulations of Brent Geese, like the Light-bellied Brent Goose *B. b. hrota* whose diet of *Zostera* sp. also decreases until mid-winter, when it is supplemented by green algae and terrestrial grasses (Ganter 2000; Inger *et al.* 2006). Brent Geese are strictly coastal foragers in Japan except during extreme coastal events, such as the Great East Japan Earthquake of 2011, when access to seagrasses and algae is restricted and the birds may move inland to feed (Shimada *et al.* 2018). Because the abundance and spatial extent of *Zostera* sp. and green algae influences use of staging and wintering sites by Brent Geese (Wilson & Atkinson 1995; Ward *et al.* 2005), it is important to identify and protect these key habitats.

Conclusion

Overall, the study suggests a loop migration route between wintering and breeding areas for the East Asian population of Brent

Geese. Spring migrants leaving wintering areas move north to mainland Russia and follow the Lena and Yana River valleys to their suspected nesting grounds in or near the Lena River delta (Uspenski 1960; Syroechkovskiy 2006; Shimada *et al.* 2017) and return along the Russian Far East arctic coast via the Kamchatka Peninsula to eastern Hokkaido and wintering areas in northern Japan, northeast China and the Korean Peninsula. Prior to arrival in eastern Hokkaido, the autumn migrants may also stage along the west coast of Alaska, to feed on the extensive Common Eelgrass *Zostera marina* beds, particularly at Izembek Lagoon (Derksen *et al.* 1996). This proposed loop migration needs confirmation and further testing, with additional migration tracking studies to fill knowledge gaps.

Systematic monitoring of Brent Geese in Japan during autumn, winter and spring suggests that the East Asian population appears to be increasing; however, additional surveys of Brent Geese are urgently needed in China and the Korean Peninsula to confirm overall population trends and to identify critical habitats and wintering sites. Although 16 of 26 important sites are protected or partially protected under each country's regulation (Appendix 1), many of the sites are still threatened by coastal land reclamation and development (including the installation of offshore wind farms). There is also hunting pressure even in the protected areas such as Malamvayam Lagoon (Gerasimov & Gerasimov 2000). We urgently need better information about this population, in order to provide the conservation measures needed to protect coastal wetlands for Brent Geese and other waterbirds.

Acknowledgements

The procedures in this study were approved by the Ministry of the Environment, Japan (No. 17-154 in 2017; No. 18-162 in 2018). We are grateful to Noriyoshi Sasaki, Yoshihiro Fukuda, Kanomi Shiina, Mari Kawaguchi, Akiko Kusanagi, Yoshiaki Ariyama, Mayumi Minari and Yuka Kosono for their help with the field surveys, and to Mr. and Mrs. Sakashita for accommodation during the survey. We also thank Lee Tibbitts for assistance with satellite tracking the tagged birds, including downloading the Argos data. John Pearce, Lee Tibbitts and two anonymous referees made constructive comments on an earlier draft of the manuscript. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. This work was partly supported by Pro Natura Foundation, Japan's 28th Pro Natura Fund, the Tsukamoto Shogakukin Fund, the U.S. Fish and Wildlife Service, Izembek National Wildlife Refuge and the U.S. Geological Survey, Alaska Science Center, USA.

References

Andreev, A.V. 2013. *Okhotsk-Kolyma Country: The Standards of Nature*. Russian Academy of Sciences, Far-East Branch, Institute of Biological Problems of the North, Magadan, Russia. [In Russian.]

BirdLife International. 2004. *Important Birds Areas in Asia: Key Sites for Conservation.* BirdLife International, Cambridge, UK.

BirdLife International. 2020. Species factsheet: *Branta bernicla*. BirdLife International, Cambridge, UK. Available at http://www.birdlife.org (last accessed on 17 June 2020).

Bogaart, P., van der Loo, M. & Pannekoek, J. 2018. *Package 'rtrim'. Trends and Indices for Monitoring Data (Version 2.0.6).* Statistics Netherlands, The Hague, the Netherlands.

Bolkhin, Y.Y. 2000. American Brent Goose *Branta nigricans*. *In* V.Yu. Ilyashenko & Yu. Yu. Blokhin (eds.), *The Red Data Book of the Russian Federation. Animals: Birds*. Astrel Publishing House, St. Petersburg, Russia and A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, Russia, Available at http://biodat.ru/db/rb/ (last accessed 31 May 2020). [In Russian.]

Boyd, W.S., Ward, D.H., Kraege, D.K. & Gerick, A.A. 2013. Migration patterns of Western High Arctic (Grey-belly) *Brant Branta bernicla*. *Wildfowl* (Special Issue No. 3): 3–25.

China Coastal Waterbird Census Group. 2015. *China Coastal Waterbird Census Report (1.2010–12.2011)*. Hong Kong Bird Watching Society, Hong Kong, China. [In Chinese.]

Conservation of Arctic Flora and Fauna (CAFF). 2019. *Arctic Migratory Birds Initiative (AMBI): Workplan 2019 –2023*. CAFF Strategies Series No. 30. Conservation of Arctic Flora and Fauna, Akureyri, Iceland.

Derksen, D.V., Bollinger, K.S., Ward, D.H., Sedinger, J.S. & Miyabayashi, Y. 1996. Black brant from Alaska staging and wintering in Japan. *Condor* 98: 653–657.

Dwyer, T.J. 1972. An adjustable radio package for ducks. *Bird Banding* 43: 282–284.

Fujii, K. 2017. Population size and distribution of Brent Geese in Japan (2014 to 2017). *Bird Research* 13: 69–77. [In Japanese with English summary.]

Ganter, B. 2000. Seagrass (*Zostera* spp.) as food for brent geese (*Branta bernicla*): an overview. *Helgoland Marine Research* 54: 63–70.

Gerasimov, N.N., & Gerasimov, Y.N. 2000. Pacific Brent Goose *Branta bernicla nigricans* in Kamchatka. *The Biology and Conservation of the Birds of Kamchatka* 2: 101–104. [In Russian.]

Gerasimov, Y.N. 2006. American Brent Goose *Brant nigricans* (Lawrence, 1846). *In* A.M. Tokranov (ed.), *Red Book of Kamchatka. Vol. 1. Animals*, pp. 109–110. Kamchatka Printing Yard, Petropavlovsk-Kamchatsky, Russia. [In Russian.]

Hirata K., Senzaki, M., Horimoto, T., Osafune, Y., Sakai, J., Nakahama, S., Narita, T. & Yoshioka, T. 2015. Population and habitat of wintering Brent Geese *Branta bernicla* in eastern Oshima Peninsula, Tsugaru Strait and Mutsu Bay. *Japanese Journal of Ornithology* 64: 77–82. [In Japanese with English summary.]

Inger, R., Ruxton, G.D., Newton, J., Colhoun, K., Robinson, J.A., Jackson, A.L. & Bearhop, S. 2006. Temporal and intrapopulation variation in prey choice of wintering geese determined by stable isotope analysis. *Journal of Animal Ecology* 75: 1190–1200.

Kataoka, Y. 2015. *Report on the Wintering Population of Brent Goose in Hamanaka Town.* Etopirika Fund, Hamanaka, Japan. [In Japanese.]

Kear, J. 2005. *Ducks, Geese and Swans*. Oxford University Press, Oxford, UK.

Lane, S.J. & Miyabayashi, Y. 1997. Status and distribution of Pacific Brent Geese *Branta bernicla nigricans* wintering in Japan. *Wildfowl* 48: 108–117.

Lewis, T.L., Ward, D.H., Sedinger, J.S., Reed, A. & Derksen, D.V. 2013. Brant (*Branta bernicla*). *In* A. Poole (ed.), *The Birds of North America Online*. Cornell Laboratory of Ornithology, Ithaca, New York, USA.

MacKinnon, J., Murray, N. & Verkuil, Y.I. 2012. *IUCN Situation Analysis on East and Southeast Asian Intertidal Habitats, with Particular Reference to the Yellow Sea (including the Bohai Sea)*. IUCN, Gland, Switzerland.

Ministry of the Environment Japan. 2014. *Red Data Book 2014. Threatened Wildlife of Japan*. GYOSEI Co., Tokyo, Japan. [In Japanese.]

Ministry of the Environment Japan. 2015a. Notsuke-hanto and Notsuke-wan. *In* Ministry of the Environment Japan (ed.), *Ramsar Sites in Japan*, pp. 13. Ministry of the Environment Japan, Tokyo, Japan.

Ministry of the Environment Japan. 2015b. *Second Summary Report on Monitoring Sites 1000 Anatidae Survey*. Biodiversity Center of Japan, Ministry of the Environment, Yamanashi, Japan. Available at http://www.biodic.go.jp/moni1000/findings/reports/index.html#2460 (last accessed 19 October 2020). [In Japanese with English summary.]

Moores, N. 2012. A wild goose chase through the literature. Birds Korea Blog. Available at http://www.birdskoreablog.org/?p=4886 (last accessed 31 August 2020).

Moores, N. 2017. Birds and their conservation in Rason Special Economic Zone, Democratic People's Republic of Korea. *Forktail* 33: 124–133.

Moores, N. 2018. DPRK record count of Brant Geese *Branta bernicla*. Birds Korea Blog. Available at http://www.birdskoreablog.org/?p=4886 (last accessed 30 April 2020).

Nechaev. V.A. 2003. New information about the birds of Southern Primorye. *Russian Ornithological Journal* (Express Issue) 210: 86–89.

National Institute of Biological Resources. 2004. *'99–04 Winter Migratory Bird Census*. National Institute of Biological Resources, Incheon, South Korea. [In Korean.]

National Institute of Biological Resources. 2005–2014. *2005–2014 Winter Migratory Bird Census*. National Institute of Biological Resources, Incheon, South Korea. Annual Reports. [In Korean.]

National Institute of Biological Resources. 2014. *Korean Red List of Threatened Species*. Jisungsa, Seoul, Republic of Korea.

National Institute of Biological Resources. 2015. *2014–2015 Winter Migratory Bird Census*. National Institute of Biological Resources, Incheon, South Korea. [In Korean.]

National Institute of Biological Resources. 2016. *2015–2016 Winter Migratory Bird Census*. National Institute of Biological Resources, Incheon, South Korea. [In Korean.]

National Institute of Biological Resources. 2017. *2016–2017 Winter Migratory Bird Census*. National Institute of Biological Resources, Incheon, South Korea. [In Korean.]

National Institute of Biological Resources. 2018. *2017–2018 Winter Migratory Bird Census of Korea*. National Institute of Biological Resources, Incheon, South Korea. [In Korean.]

Notsuke Peninsula Nature Center. 2009. The report on the status of wintering Brent Goose in Notsuke Peninsula. *In* K. Fukatsu & K. Fujii (eds.), *Report on Inhabitation Status of Birds in Notsuke Peninsula*, pp. 50–64. Municipal Board of Education, Bekkai-cho, Japan. [In Japanese.]

Ohtaishi, N., Fujii, K., Sawa, Y., Taishi, Y., Ishioroshi, A. & Antipin, M.A. 2018. Recent advances of Brent Goose *Branta bernicla* study: staging and wintering status in Japan, Russia–Japan joint research and migratory route. *Bulletin of the Shiretoko Museum* 40: 47–58. [In Japanese with English summary.]

Pannekoek, J. & van Strien, A.J. 2005. *TRIM 3 Manual (Trends & Indices for Monitoring data)*. Statistics Netherlands, Voorburg, the Netherlands.

Peh, C.C. 2008. Sea bird watching in Shicheng Islands. *China Bird Watch* 63: 8. [In Chinese.]

Sawa, Y., Tamura, C., Ikeuchi, T., Fujii, K., Ishioroshi, A., Shimada, T., & Ward, D.H. 2019. A leg-hold noose capture method for Brent Goose at staging or wintering sites. *Wildfowl* 69: 230–241.

Sawa, Y., Tamura, C., Ikeuchi, T., Shimada, T., Fujii, K., Ishioroshi, A., Tatsuzawa, S. &

Ward, D. 2020. Evidence of Brent Geese *Branta bernicla* moving between an autumn staging area in east Hokkaido and wintering sites in west Hokkaido and northern Honshu. *Ornithological Science* 19: 211–216.

Sawa, Y., Sato, T., Ikeuchi, T., & Pozdnyakov, V. In press. Banding survey at colonies of Brent Goose, *Branta bernicla* in the Lena Delta, Russia and a recovery record. *The Bulletin of the Japanese Bird Banding Association* 31.

Sedinger, J.S., Riecke, T.V., Leach, A.G. & Ward, D.H. 2019. The black brant population is declining based on mark recapture. *Journal of Wildlife Management* 83: 627–637.

Shimada, T., Kurechi, M., Suzuki, Y., Miyabayashi, Y. & Higuchi, H. 2013. Effects of the Great East Japan Earthquake on the wintering distribution of Brent Geese. *Japanese Journal of Ornithology* 62: 9–15. [In Japanese with English summary.]

Shimada, T., Hijikata, N., Tokita, K., Uchida, Y., Kurechi, M., Suginome, H., Yamada, Y. & Higuchi, H. 2016. Satellite-tracking of the spring migration and habitat of the Brent Goose *Branta bernicla* in Japan. *Ornithological Science* 15: 37–45.

Shimada, T., Hijikata, N., Tokita, K., Uchida, Y., Kurechi, M., Suginome, H. & Higuchi, H. 2017. Spring migration of Brent Geese wintering in Japan extends into Russian high arctic. *Ornithological Science* 16: 159–162.

Shimada, T., Yamada, Y., Hijikata, N., Tokita, K., Uchida, K., Kurechi, M., Suginome, H., Suzuki, Y. & Higuchi, H. 2018. Utilisation of terrestrial habitat by Black Brant *Branta bernicla nigricans* after the Great East Japan Earthquake of 2011. *Wildfowl* 68: 172–182.

Stishov, M.S. 2014. *Protected Areas in the Russian Arctic: Current State and Prospects for Development*. World Wide Fund for Nature (WWF) – Russia, Moscow, Russia.

Suzuki, M. 1989. Brent Goose in the Gamou tidal flat. *Wildlife Report* 10: 98–100. [In Japanese.]

Syroechkovskiy, E.E. 2006. Long-term declines in Arctic goose populations in eastern Asia. *In* G.C. Boere, C.A. Galbraith & D.A. Stroud (eds.), *Waterbirds Around the World*, pp. 649–662. The Stationery Office, Edinburgh, UK.

Tiunov, I. . & Antipin M.A. 2016. American Brent Goose – *Branta bernicla nigricans* (Lawrence, 1846). *In* V.N. Efanov (ed.), *Red Data Book of Sakhalin Oblast. Animals*, pp. 51–52. Buki-Vedi, Moscow, Russia. [In Russian.]

Tomek, T. 1999. The birds of North Korea. Non-Passeriformes. *Acta Zoologica Cracoviensia* 42: 1–21.

Uspenski, S.M. 1960. The Brent Goose in the Soviet Union. *Wildfowl* 11: 80–93.

Ward, D.H., Dau, C.P., Tibbitts, T.L., Sedinger, J.S., Anderson, B.A. & Hines, J.E.. 2009. Change in abundance of Pacific brant wintering in Alaska: evidence of a climate warming effect? *Arctic* 62: 301–311.

Ward, D.H., Reed, A., Sedinger, J.S., Black, J.M., Derksen, D.V., & Castelli, P.M. 2005. North American brant: effects of changes in habitat and climate on population dynamics. *Global Change Biology* 11: 869–880.

Waterbird Specialist Group of the Chinese Ornithological Association. 1994. *Waterbird Research in China*. East China Normal University Press, Beijing, China. [In Chinese.]

Wetlands International. 2012. *Waterbird Population Estimates, 5th Edition*. Wetlands International, Wageningen, the Netherlands.

Wilson, U.W., & Atkinson, J.R. 1995. Black brant and spring staging use at two Washington coastal areas in relation to eelgrass abundance. *Condor* 97: 91–98.

Yamashina Institute for Ornithology. 2014. *Report on the Japanese Bird Banding Scheme for 2014*. Yamashina Institute for Ornithology, Chiba, Japan.

Yan, J. 1999. New record of birds in Shandong – Brent Goose. *Shandong Forestry Science and Technology* 2: 35. [In Chinese.]

Zhang, X. 2012. Monitoring of species and quantity of ducks and geese in Shandong Yellow River Delta National Nature Reserve. *Shandong Forestry Science and Technology* 3: 50–53. [In Chinese.]

Zhong, F. & Chen, D. 1989. Investigation report on overwintering ducks in Bird Island, Hunan. *Wild Animal* 5: 5. [In Chinese.]

Zhuravlev, Y.N. & Kulikova, I.V. 2014. New record of the Black-bellied brent goose *Banta bernicla nigricans* (Lawrence, 1846) in Primorsky Krai. *Far Eastern Journal of Ornithology* 4: 78–81.

Appendix 1. Observations of Brent Geese at staging and wintering sites in the East Asian-Australasian Flyway. The conservation status, habitat and key foods in internationally important sites. Numbers in the first column of the table correspond to site locations in Figs. 4–6.

No.	Area	Location	Cordinate	Peak Count			Year	1% Criteria	Conservation status	Habitats	Key foods	References
				Autumn	Winter	Spring						
1	East Coast of	Tilichiki	60°25'N 166°05'E	-	-	7	May 1998					*1
2	Kamchatka	Gavan' Skobeleva	60°24'N 166°20'E	-	-	4	May 1998					*1
3		Kavacha River	60°13'N 169°55'E	120	-	-	Sep 1991	○	Unprotected	Unknown	Unknown	*1, *2
4		Karaginsky Island	59°11'N 164°35'E	-	-	4	Apr 1983					*1
5		Karaga Bay	59°10'N 163°00'E	500	-	-	Sep 1984	○	Unprotected	Unknown	Unknown	*1, *2
6		Ivashka River	58°50'N 162°50'E	500	-	-	Unknown	○	Unprotected	Unknown	Unknown	*1, *2
7		Rusakova River	58°18'N 162°07'E	-	-	2	Apr 1983					*1
8		Malamvayam Lagoon	57°45'N 162°28'E	4,800	-	-	Oct 1985	○	Protected	Coastal lagoons	Unknown	*1, *2
				-	25	-	Jan 1990					
9		Avacha Bay	53°00'N 158°30'E	-	-	200	Apr 1994	○	Partially protected	Protected embayment	Unknown	*1, *3
10		Bolshaya Sarannaya Bay	52°45'N 158°30'E	-	-	5	Apr 1982					*1
11	Inland Kamchatka	Kharchinsky Lake	56°32'N 160°52'E	-	-	2	May 1999					*1
12	West Coast of	Talovka River	62°25'N 165°10'E	-	-	30	May 1977					*1
13	Kamchatka	Oblukovina River	55°15'N 155°43'E	-	-	70	May 1976	○	Unprotected	Unknown	Unknown	*1, *2
				-	-	125	May1977					
14		Opala River	52°04'N 156°30'E	-	-	11	May 1990					*1
				-	-	30	Apr 1994					
15		Cape Lopatka	50°52'N 156°40'E	3	-	-	Sep 1999					*1
16	Magadan	Olskaya Lagoon	59°34'N 151°24'E	-	-	*	*					*4
17		Perevolochny Bay	59°30'N 154°16'E	-	-	*	*					*4
18		Motyklesky Bay	59°26'N 148°53'E	-	-	*	*					*4
19	Sakhaline	North Sakhalin	53°24'N 143°07'E	200	-	110	1988–1991	○	Unprotected	Coastal lagoons	Unknown	*2, *5
							1999–2001					
20		Aniva Bay	46°41'N 142°43'E	7	-	-	Oct 1980					*5
21	Primorsky Krai	Lake Blagodatnoye	44°56'N 136°32'E	-	-	*	*					*6
22		Lake Khanka	44°55'N 132°21'E	-	-	*	*					*6
23		Tachingouza Bay	43°01'N 134°08E	-	-	*	*					*6
24		Ussuri Bay	43°03'N 132°09'E	-	-	1	Apr 1989					*7
				-	-	1	May 1991					
				-	-	1	May 1992					
				-	-	3	May 1994					
				-	-	2	Apr 1996					
25		Kiyevka River	42°52'N 133°39'E	-	-	*	*					*6
26		Lebedinoye Lake	42°35'N 130°41'E	1	-	-	Nov 2014					*6
27	North Japan	Abashiri	44°01'N 144°18'E	-	2	-	2014–2017					*8
28		Rausu	44°01'N 145°12'E	-	-	30	2014–2017					*8
29		Kunashiri	43°42'N 145°32'E	799	32	987	2014–2017	○	Protected	Protected embayment	Unknown	*8
30		Notsuke Bay	43°34'N 145°16'E	7,233	317	1,930	2014–2017	○	Protected	Protected embayment	*Zostera spp.* (e.g. *Zostera marina*)	*8, *9, *10
				8,469	-	-	Nov 2019					
31		Lake Furen	43°18'N 145°22'E	475	-	113	2014–2017	○	Protected	Coastal lagoons	Unknown	*8
32		Nemuro Peninsula	43°21'N 145°40'E	2	1	-	2014–2017			Rocky shoreline/Harbor	Unknown	*8
33		Biwase Bay	43°04'N 145°06'E	30	392	204	2014–2017	○	Protected	Protected embayment	*Zostera spp.* Green algals (e.g. *Ulva spp.*)	*8, *11
34		Akkeshi Bay	43°03'N 144°53'E	250	154	-	2014–2017	○	Protected	Protected embayment	Unknown	*8
35		Kushiro	42°59'N 144°21'E	-	-	55	2014–2017					*8
36		Urakawa	42°10'N 142°45'E	31	-	200	2014-2017	○	Unprotected	Rocky shoreline/Harbor	Unknown	*8
37		Shizunai	42°20'N 142°21'E	2	-	-	2014–2017					*8
38		Muroran	42°21'N 140°56'E	-	31	11	2014–2017					*8
39		Date	42°28'N 140°51'E	-	149	147	2014–2017	○	Unprotected	Rocky shoreline/Harbor	Unknown	*8
40		Oshima Hanto	41°54'N 140°58'E	-	467	145	2014–2017	○	Unprotected	Rocky shoreline/Harbor	*Zostera spp.* Green algals	*8, *12
41		Hakodate	41°45'N 140°45'E	28	289	26	2014–2017	○	Unprotected	Rocky shoreline/Harbor	*Zostera spp.* Green algals	*8, *12
42	Honshu Island	Shimokita	41°24'N 141°13'E	-	110	-	2014–2017	○	Partially protected	Rocky shoreline/Harbor	*Zostera spp.* Green algals	*8, *12
43		Mutsu Bay	41°02'N 140°55'E	-	559	91	2014–2017	○	Partially protected	Protected embayment Rocky shoreline/Harbor	*Zostera spp.* Green algals	*8, *12
44		West coast of Aomori	40°48'N 140°14'E	1	15	8	2014–2017					*8
45		East coast of Aomori	40°31'N 141°38'E	-	88	-	2014–2017	○	Partially protected	Rocky shoreline/Harbor	*Zostera spp.* Green algals	*8, *12
46		Iwate	40°15'N 141°51'E	-	84	-	2014–2017	○	Partially protected	Rocky shoreline/Harbor	Unknown	*8
47		Akita	39°53'N 139°53'E	-	9	-	2014–2017					*8
48		Minami Sanriku	38°40'N 141°31'E	242	433	53	2014–2017	○	Protected	Rocky shoreline/Harbor	*Zostera spp.* Green algals	*8, *13, *14
49		Ojika Hanto	38°25'N 141°29'E	-	131	62	2014–2017	○	Partially protected	Rocky shoreline/Harbor	Unknown	*8
50		Gamou tidalflat	38°15'N 141°01'E	-	68	-	2014–2017	○	Protected	Coastal lagoons	Green algals	*8, *15
51		Toyama	36°50'N 137°06'E	-	1	-	2014–2017					*8
52		Chiba	35°32'N 140°28'E	-	3	2	2014–2017					*8
53		Okinawa	26°09'N 127°39'E	-	-	1	2014–2017					*8

Appendix 1 (*continued*).

No.	Area	Location	Cordinate		Peak Count			Year	1% Criteria	Conservation status	Habitats	Key foods	References
					Autumn	Winter	Spring						
54	East Coast of North	Rason	42°14'N	130°18'E	-	-	21	Apr 2017					*16
55	Korea	Wonsan	39°11'N	127°27'E	150	-	-	Nov 2019	○	Unprotected	Protected embayment	Unknown	*17, *18
					-	14	-	Apr 1988					
56	East Coast of South Korea	Sokcho- Ganseong coast	38°19'N	128°32'E	-	19	-	Jan 2001					*19
					-	10	-	Jan 2003					
					-	2	-	Jan 2012					
					-	3	-	Jan 2014					
					-	4	-	Dec 2016					
					-	6	-	Jan 2017					
					-	7	-	Dec 2017					
57		Ganseong-Daejin coast	38°30'N	128°26'E	-	7	-	Jan 2017					*19
58		Goseong Offshore	38°32'N	128°26'E	-	1	-	Jan 2010					*19
					-	1	-	Jan 2011					
59		Yangyang-Sokcho coast	38°09'N	128°37'E	-	1	-	Jan 2007					*19
					-	3	-	Dec 2019					
60		Songji Lake	38°20'N	128°31'E	-	1	-	Jan 2005					*19
61		Gangneung-Jumunjin coast	37°48'N	128°54'E	-	4	-	Jan 2012					*19
62		Samcheok-Gangneung coast	37°37'N	129°03'E	-	1	-	Jan 2001					*19
63		Uljin-Wondeok coast	37°00'N	129°25'E	-	2	-	Jan 2005					*19
					-	2	-	Jan 2006					
64		Yeongdeok-Pyeonghae coast	36°23'N	129°24'E	-	2	-	Jan 2012					*19
					3	-	-	Nov 2014					
					-	5	-	Feb 2017					
65		Pyeonghae-Uljin coast	36°47'N	129°28'E	-	2	-	Jan 2017					*19
66		Pohang-Yeongdeok coast	36°05'N	129°26'E	-	1	-	Jan 2005					*19
					-	3	-	Feb 2015					
					-	1	-	Dec 2015					
67		Ulsan Bay	35°33'N	129°22'E	-	1	-	Jan 2006					*19
68		Ulsan-Guryongpo coast	35°34'N	129°28'E	-	2	-	Jan 2005					*19
69		Busan-Ulsan coast	35°08'N	129°08'E	-	1	-	Jan 2006					*19
70	South Coast of South Korea	Gwangyang Bay-Galsa Bay	34°55'N	127°48'E	-	328	-	Jan 2001					*19
					-	62	-	Jan 2004					
					-	11	-	Jan 2005					
					-	63	-	Jan 2006					
					-	17	-	Jan 2007					
					-	18	-	Jan 2009					
					-	4	-	Jan 2012					
71		Junam Reservoir	35°19'N	128°41'E	-	1	-	Feb 2015					*19
72		Lower Nakdong River	35°10'N	128°56'E	-	1	-	Jan 2010					*19
73		Nakdong River Estuary	35°04'N	128°55'E	-	11	-	Jan 1999					*19
					-	21	-	Jan 2004					
					-	1	-	Jan 2008					
					-	23	-	Jan 2010					
74		Seongsan-Namwon coast	33°19'N	126°50'E	-	1	-	Jan 2003					*19
75		Seongsan	33°28'N	126°55'E	-	1	-	Jan 1999					*19
					-	1	-	Jan 2003					
					-	4	-	Jan 2004					
					-	1	-	Jan 2010					
76		Hado	33°30'N	126°54'E	-	1	-	Feb 2015					*19
77		Hamdeok-Hado coast	33°34'N	126°47'E	-	2	-	Jan 2001					*19
78	West Coast of South Korea	Seongsu Bridge-Paldang Dam	37°35'N	127°10'E	1	-	-	Nov 2016					*19
79		Yeongjong Island	37°32'N	126°32'E	-	1	-	Jan 2019					*19
80		Shihwa Lake	37°18'N	126°40'E	-	43	-	Jan 2001					*19
					-	-	1	Mar 2014					
81		Garolim Bay	36°55'N	126°21'E	-	4	-	Feb 2018					*19
82		Geumho Lake	35°53'N	128°29'E	-		1	Mar 2017					*19
83	Bohai Bay / Yellow	Yalujiang Estuary	39°50'N	124°05'E	-	-	17	Mar 2011					*20
84	sea	Shicheng Islands,Zhuanghe	39°30'N	122°59'E	-	-	5	Apr 2008					*21
85		Changshan Islands	38°00'N	120°27'E	-	1200	-	Feb 1993	○	Protected	Unknown	Unknown	*23
86		Yellow River Delta National Nature Reserve	37°34'N	118°39'E	-	-	1	May 2005					*24
87		Swan Lake,Rongcheng	37°20'N	122°34'E	-	3	-	Dec 2001					*22
88		Rongcheng Whooper Swan Nature Reserve	37°10'N	122°30'E	-	203	-	Dec 1998	○	Protected	Unknown	Unknown	*25
89		Sheyang Salt Works	33°25'N	120°19'E	-	46	-	Jan 1990					*23
90	Inland China	Huairou Reservoir	40°19'N	116°37'E	-	-	2	Apr 2014					*22
91		Danjiangkou Reservoir	32°43'N	111°35'E	-	1	-	Jan 2010					*22
92		Waterbird island, Hengyang	26°40'N	112°51'E	-	1	-	Jan 1986					*26
93	Taiwan	Yilan County, Su'ao Township	24°37'N	121°52'E	-	1	-	Dec 2012					*22

References: *1 Gerasimov & Gerasimov 2000, *2 Stishov 2014, *3 BirdLife International 2004, *4 Andreev 2013, *5 Tiunov & Antipin 2016, *6 Zhuravlev & Kulikova 2014, *7 Nechaev 2003, *8 Fujii 2017, *9 Sawa *et al*. 2020, *10 Notsuke Peninsula Nature Center 2009, *11 Kataoka 2015, *12 Hirata *et al*. 2015, *13 Shimada *et al* 2013, *14 Shimada *et al*. 2018, *15 Suzuki 1989, *16 Moores 2017, *17 Moores 2018, *18 Tomek 1999, *19 Winter Waterbird Census of Korea, *20 China Coastal Waterbird Census Group 2015, *21 Peh 2008, *22 Bird Report website in China (http://www.birdreport.cn), *23 Waterbird Specialist Group of the Chinese Ornithological Association 1994, *24 Zhang 2012, *25 Yan 1999, *26 Zhong & Chen 1989.