Regional variation in long-term population trends for the Greater White-fronted Goose *Anser albifrons* in Japan

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Abstract

Japan has the largest population of Greater White-fronted Geese *Anser albifrons* wintering in eastern Asia. The effective conservation of this East Asia goose population requires an understanding of their status and distribution in Japan. Long-term (15-year) trends in numbers were analysed from four main wintering areas – northern Miyagi, Kaetsu, Hokuriku and Sanin – in relation to nationwide trends recorded for Greater White-fronted Geese in Japan. Annual trend indices over 5-year (2013/14–2017/18), 10-year (2008/09–2017/18) and 15-year (2003/04–2017/18) periods were calculated using TRIM software. These indices showed a significant increase both for Japan nationally and for northern Miyagi over the 15-year timescale, with moderate declines in Hokuriku and uncertain trends for Kaetsu and Sanin. Analysis of more recent, shorter-term trends found that numbers in Japan and in northern Miyagi have undergone a "moderate or strong increase" over the past 5 and 10 years. Conversely, goose trends showed "moderate declines" in Sanin and Hokuriku over the past 10 years. Despite a significant positive correlation between trends recorded for the whole of Japan and those for northern Miyagi, there were no significant correlations with the other regions. There was no evidence for weather conditions, notably air temperature and snow depth, having an effect on numbers of geese in Miyagi and Kaetsu. Snow depth and air temperature, however, had a negative effect on numbers in Hokuriku and Sanin, respectively. In addition to the winter trends analyses, data from satellite tracking and recovery data from marked geese suggested that difference in the trends recorded between geese in northern (northern Miyagi) and those in southwestern Japan (Hokuriku and Sanin) could be explained by differences in migration routes taken by geese wintering in northern and southwestern Japan.

Key words: Greater White-fronted Goose, long-term population trends, regional variation.

The conservation status of the world's waterbird populations is based on an assessment of their abundance and trends in the main biogeographic regions and flyways (Wetlands International 2012). In Japan, the Ministry of the Environment therefore has coordinated nationwide surveys of wintering waterfowl at thousands of sites in mid-January each year since 1970, in cooperation with prefectural and city governments (Ministry of the Environment 2018a). Furthermore, a national monitoring survey (known as "Monitoring Sites 1000"), launched in 2003, has continued long-term monitoring of important ecosystems including waterfowl and shorebirds habitats, at fixed points in > 1,000 sites nationwide (Ministry of the Environment 2018b). Some data from the Monitoring Sites 1000 initiative contribute to the nationwide survey of waterfowl wintering in Japan.

The Greater White-fronted Goose *Anser albifrons* breeds from the central Canadian Arctic south to the boreal forest marshes of the Mackenzie Basin and west across parts of Alaska to the Russian lowland tundra. It migrates along different flyways from the breeding grounds to winter in western Europe, North America and eastern Asia, with the East Asian population *A. a. frontalis* extending from eastern China to Japan through the Korean Peninsula (Kear 2005). Most *A. albifrons* populations in western Europe and North America are increasing or stable in numbers, although the Greenland White-fronted Goose *A. a. flavirostris* is in decline (Fox & Leafloor 2018a). In east Asia, the Chinese sub-population has decreased to 55,000 birds, while sub-populations wintering in Japan and Korea have increased, with recent population size estimates of 138,000 and 85,000 respectively (Fox & Leafloor 2018a).

Greater White-fronted Geese historically have wintered on agricultural areas and natural wetlands in Japan. Their numbers were dramatically reduced by habitat destruction and hunting pressure during the first half of the 20th century (Austin & Kuroda 1953). Hunting was prohibited in 1971 however, and the species was designated as a "natural treasure", after which the wintering population increased roughly 40-fold over 40 years from < 6,000 birds in 1979 to > 220,000 in 2018 (Ministry of the Environment 2018a). In addition to the protection of the geese, the birds' food supply increased as waste rice grain became more available through the modernisation of farming when reapers (which cut the rice stalks without threshing) were replaced by combine harvesters (Shimada 2002; Shimada & Mizota 2011). An increase in food resources for geese in the United States similarly advanced with expansion of rice fields since the late 1980s (Fleskes *et al.* 2005), although modernisation of harvesting machinery has more recently led to a decrease in waste grain in some areas (Fleskes *et al.* 2012). In Japan, however, the number of goose wintering areas has remained stable at about 40 sites. More than eighty percent of Greater White-fronted Geese winter in Miyagi Prefecture in the northern part of the country, in an area around Izunuma-Uchinuma (a pair of interconnected freshwater lakes) as well as around Lake Kabukurinuma. These areas have both been designated as Ramsar Sites for the geese and other waterbirds (Shimada 2009).

Japan has the largest proportion of the East Asian Greater White-fronted Goose population (Fox & Leafloor 2018a). In spring, the geese leave the country via western Hokkaido and migrate along the Kamchatka Peninsula to reach breeding sites in the Khatyrka and Pekul'ney regions of Russia (Takekawa *et al.* 2000). To maintain their current favourable conservation status, it is important that factors affecting not only the trends in numbers but also their migratory patterns are understood, including any changes in the distribution of the geese wintering in Japan. Elsewhere, long-term studies of Greylag Geese *Anser anser* in Europe, have found a shortening of the migration distances and earlier spring migration to the breeding grounds in recent decades, associated with warmer conditions across the wintering range (Ramo *et al.* 2015; Podhrázský *et al.* 2017; Nilsson & Kampe-Persson 2018; Nilsson 2018), a possible effect of climate change. As a result, the location of key sites, which should be protected for the species, may change over time. Therefore, besides the nationwide surveys by the Ministry of the Environment, monitoring of the geese has been conducted at stopover and wintering sites more than twice each month from September–April inclusive since winter 2003/04, with the counts being undertaken by a large number of volunteers. In an earlier study, Shimada (2009) described seasonal and regional fluctuations in numbers across Japan during four consecutive winters (2003/04–2006/07 inclusive). Most geese wintered in Miyagi Prefecture, but variation in the numbers using stopover sites was described following the satellite-tracking of individuals' use of staging sites during spring migration (Takekawa *et al.* 2000). In the present study, we analysed long-term (15-year) national population trends, as well as those in the four main goose wintering areas in Japan, to seek regional differences that would suggest shifts in the distribution of the species within Japan.

Methods

Data from wintering sites were grouped according to the four main winter areas for Greater White-fronted Geese in Japan (Miyabayashi 1994). In northern Miyagi, the survey sites were Lakes Izunuma-Uchinuma (38.72°N, 141.12°E), Kabukurinuma (38.67°N, 141.17°E) and Kejonuma (38.62°N, 141.95°E); in Kaetsu the surveys were made at Fukushimagata Lagoon (37.90°N, 139.25°E); in Hokuriku at Katano-Kamoike Pond (36.32°N, 136.30°E); and in Sanin at Lake Shinjiko (35.43°N, 132.87°E) and the Izumo Plain (35.42°N, 132.87°E, Fig. 1).

Greater White-fronted Geese roost at night on lakes, ponds and lagoons and fly out early in the morning ("morning flight") to forage in surrounding rice fields. The number of geese at each site were counted during the morning flights by volunteers, mainly members of the Japanese Association for Wild Geese Protection but with specialist goose researchers also involved in the counts at each site. On days when it was impractical to complete a count in the morning due to bad weather, the geese were counted as they returned to the same roost during the evening flight later the same day, based on the assumption that the geese generally return to the same roost location on consecutive nights. In addition

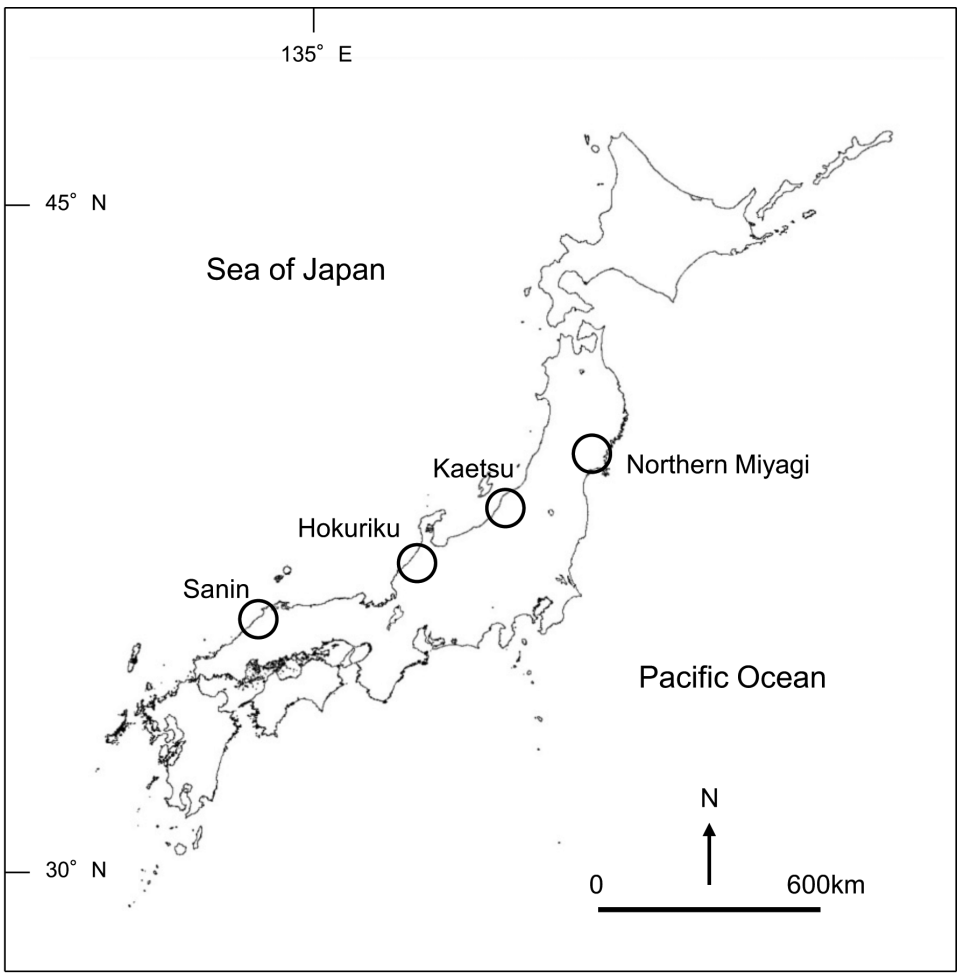

Figure 1. Location of the four Greater White-fronted Goose study areas in Japan.

to the flight counts, geese were also counted on rice fields during the day at the Fukushimagata Lagoon and Izumo Plain.

From all the goose counts made during the 15 years between winter 2003/04 and 2017/18, we selected data from early January in each year (around 10 January) in each of the four study areas for analysis. Mid-January data from the nationwide surveys conducted annually by the Ministry of the Environment (Ministry of the Environment 2018a) were used to determine the population trend for the species across the whole of Japan, again for the 15 years from 2003/04 to 2017/18 inclusive.

Trends in abundance and annual indices were calculated using the freeware programme TRIM version 3.53 (Pannekoek & van Strien 2001), developed for the analysis of wildlife count data, for three

different time-spans: over 5 years (2013/14–2017/18), over 10 years (2008/09–2017/18) and over 15 years (2003/04–2017/18). Long-term trends (*i.e.* for the whole time period) were determined from multiplicative trends, which reflect the mean percentage change per year (Pannekoek & van Strien 2001). We present the annual change indices in the results. No geese were recorded in Kaetsu during 2004, so the year 2004 was omitted from the TRIM analyses for this region. Spearman's rank correlations were used to test whether the numbers counted in each region in each year correlated with the annual totals recorded for the whole of Japan.

To assess whether annual variation in the numbers of Greater White-fronted Geese in the four wintering areas was explained by winter weather conditions, we used a generalized linear model (GLM) to analyse the dataset with modelled predictors. The numbers of White-fronted Geese included in the TRIM analysis were used as the response variables in the GLMs. Average values of daily air temperature and snow depth recorded from 1–10 January every year in each area, provided by the Japan Meteorological Agency (2019), were used as explanatory variables because movements of geese occur over relatively short time periods in response to low temperatures and to snow cover within winters (*e.g.* Shimada 2010). Negative-binomial distributions were selected as probability distributions. We constructed four models with all combinations of the two explanatory variables (from the full model containing two parameters to the null model with none). The best-fitting model among the four models was selected by AIC (Akaike's information criteria) values. Statistical software R (version 3.5.0, R Core Team 2018) and function glm.nb (included in library MASS) were used for this analysis. We confirmed the non-existence of multicollinearity among the explanatory variables using the vif function (included in library car).

Results

Annual changes, standard errors (s.e.) and long-term population trends for the Greater White-fronted Geese are summarised in Table 1 and Figs. 2 and 3. The population indices showed significant increases nationally as well as in the northern Miyagi region over the 15-year study. Annual numbers determined from the nationwide counts increased from 68,363 in 2004 to 224,149 in 2018. For northern Miyagi the numbers also increased, from 55,961 in 2003/04 to 207,075 in 2017/18. A moderate decline was indicated for Hokuriku between 2003/04 and 2017/18, with trends for Kaetsu and Sanin being "uncertain" over the long (15-year) timescale.

Analysis of more recent trends, over the past 10 and 5 years, also found that the numbers have undergone a "moderate or strong increase" in northern Miyagi and for the country as a whole. Overall, the annual rates of change indicated that the moderate or strong increases continued over each of the 15 year, 10 year and 5 year timescales for Japan nationally (ranging from +4.28% to +6.48; Table 1) and also for northern Miyagi (+4.11% to +10.73%). In Sanin and Hokuriku, conversely, the trends over the past 10 years were classed as a "moderate decline". The annual decreases were most

Table 1. Annual percentage changes (with estimated s.e. in parentheses) of population indices and trends in numbers over the past 15, 10 and 5 years, as classified by TRIM, for four areas in Japan and for the country as a whole. * $P < 0.05$, ** $P < 0.01$.

	Over 15 years (2003/04–2017/18)		**Over 10 years (2008/09–2017/18)**		**Over 5 years (2013/14–2017/18)**	
Area	Annual % change (s.e.)	Long-term trend (TRIM classification)	Annual % change (s.e.)	Long-term trend (TRIM classification)	Annual % change (s.e.)	Long-term trend (TRIM classification)
Japan	+6.48(0.008)**	moderate increase	+4.28(0.009)**	moderate increase	+5.83(0.029)*	moderate increase
Northern Miyagi	+6.45(0.011)**	moderate increase	+4.11(0.016)*	moderate increase	+10.73(0.026)*	strong increase
Kaetsu	+9.96(0.359)	uncertain	+9.63(0.652)	uncertain	+42.27(1.731)	uncertain
Hokuriku	–5.38(0.024)*	moderate decline	–8.47(0.034)*	moderate decline	+10.40(0.125)	uncertain
Sanin	–1.65(0.020)	uncertain	–5.89(0.018)**	moderate decline	–4.14(0.054)	uncertain

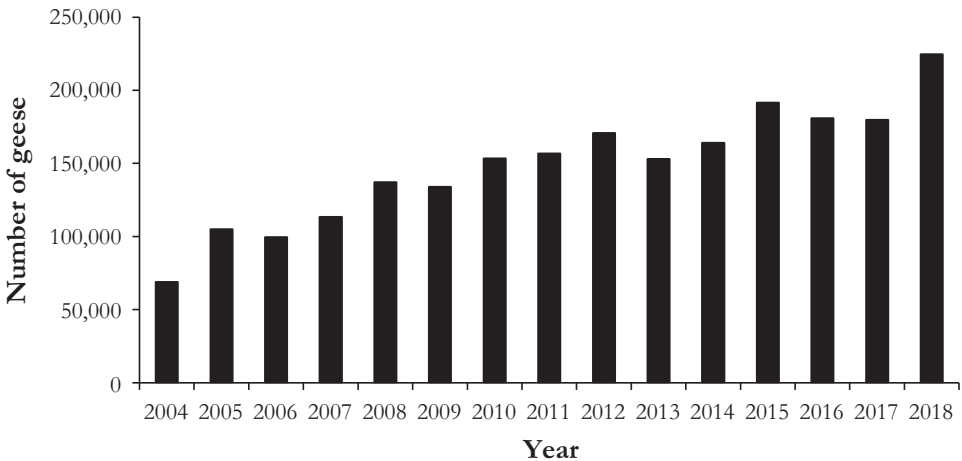

Figure 2. Long-term trends in the numbers of Greater White-fronted Geese recorded wintering in Japan, during January each year.

evident over 15 years (–5.38%) and 10 years (–8.47%) for Hokuriku and over 10 years (–5.89%) for Sanin.

There was a significant positive correlation between the population trends recorded for Japan and northern Miyagi (Spearman's rank correlation: $r = 0.907$, $n = 15$, $P < 0.001$), but not between Japan and other wintering areas used by the geese (Kaetsu: $r = 0.436$, $n = 15$, $P = 0.106$; Hokuriku: $r = –0.396$, $n = 15$, $P = 0.145$; Sanin: $r = –0.139$, $n = 15$, $P = 0.621$; n.s. in each case).

Analysis of whether weather conditions explained the variation in goose numbers found that the null models had the lowest AIC values for the Miyagi and Kaetsu, indicating that air temperature and snow depth had no effect on the number of geese counted in these regions (Table 2). Conversely, snow depth and air temperature had negative effects on numbers recorded in Hokuriku and Sanin, respectively (Table 2).

Since weather conditions were found to influence variation in the number of geese in Hokuriku and Sanin, we checked the relationship between the weather variables and year to confirm that the trends were not a pseudo-correlation between the number of geese and year. However, there was no evidence of collinearity between the year and weather variables (Spearman's rank correlations, for air temperature and snow depth, respectively, Miyagi: $r = 0.259$, $P = 0.351$ and $r = –0.274$, $P = 0.324$; Kaetsu: $r = 0.143$, $P = 0.611$ and $r = –0.032$, $P = 0.909$; Hokuriku: $r = 0.143$ and $P = 0.611$, $r = –0.194$, $P = 0.490$; Sanin: $r = 0.215$, $P = 0.442$ and $r = –0.194$, $P = 0.980$; n.s. in each case).

Discussion

The significant positive correlation found between the numbers of geese recorded in northern Miyagi in mid-winter with those recorded nationally showed that variation in

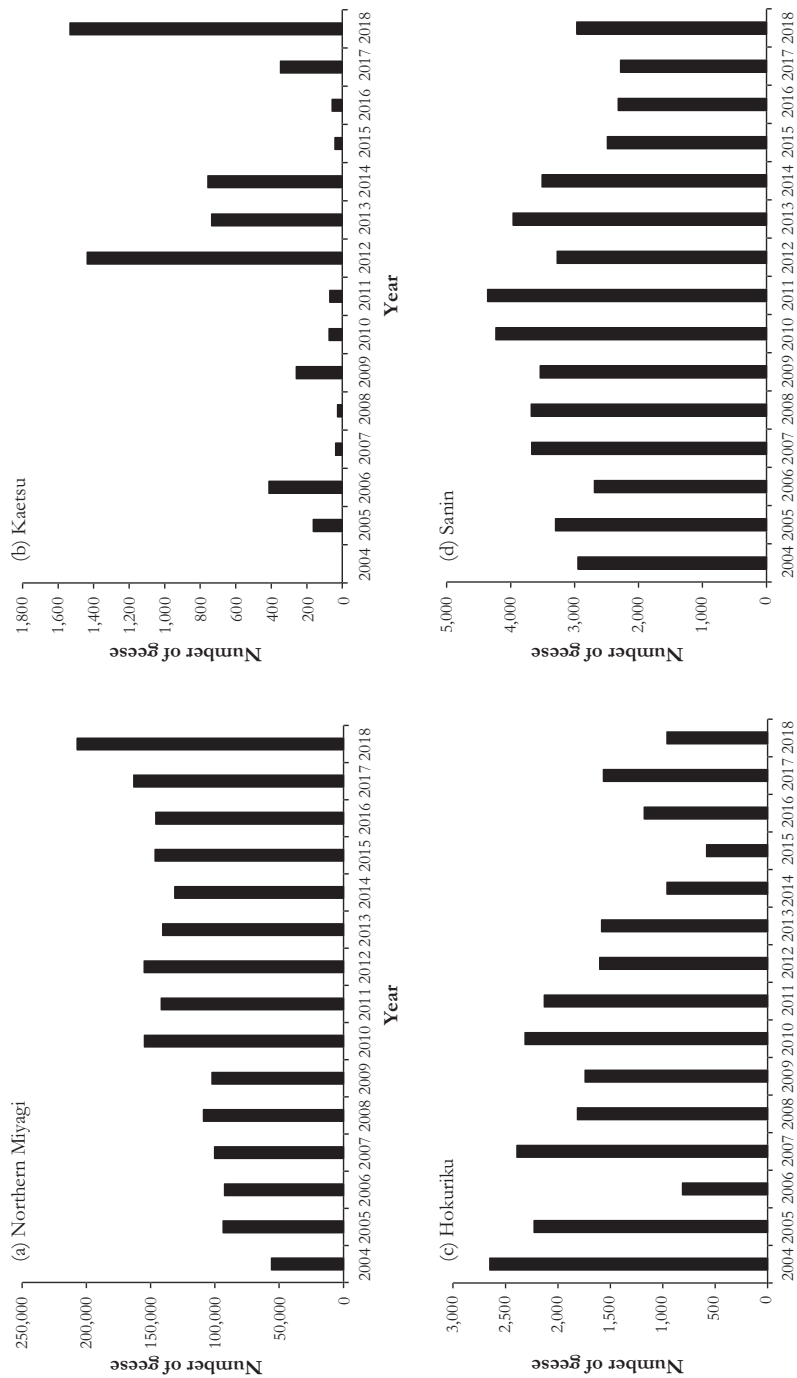

Figure 3. Long-term trends in the numbers of Greater White-fronted Geese in the four main wintering areas for the species in Japan; (a) = Northern Miyagi, (b) = Kaetsu, (c) = Hokuriku and (d) = Sanin.

Table 2. The effects of weather conditions on the number of geese, analysed using GLM. Estimates with bold character had a significant effect (Wald-test: $P < 0.05$).

Area	Explanatory variables				AIC	ΔAIC
	Air temperature		Snow depth			
	Estimate	s.e.	Estimate	s.e.		
Miyagi	–	–	–	–	362.0	–
	0.035	0.041	–	–	363.4	1.4
	–	–	–0.008	0.016	363.8	1.8
	0.036	0.057	0.0005	0.020	365.4	3.4
Kaetsu	–	–	–	–	208.8	–
	–0.346	0.215	–	–	209.0	0.2
	–	–	0.069	0.074	210.3	1.5
	–0.582	0.383	–0.101	0.128	210.5	1.7
Hokuriku	–	–	**–0.010**	0.005	238.3	–
	–0.080	0.081	**–0.015**	0.007	239.5	1.2
	–	–	–	–	239.7	1.4
	0.043	0.064	–	–	241.3	3.0
Sanin	**–0.078**	0.027	–	–	236.1	–
	–0.077	0.033	0.0005	0.009	238.1	2.0
	–	–	–	–	240.4	4.3
	–	–	0.011	0.008	240.4	4.3

the Japanese totals was determined mainly by numbers of geese wintering in this northern part of the country, where the majority of Japanese Greater White-fronted Geese overwinter. In contrast, trends were classified as showing a "moderate decline" over the past 10 and 15 years in Hokuriku and over the past 10 years in Sanin, both areas where annual numbers were affected negatively by adverse weather.

Earlier studies have shown that dense single-species crops (such as rotational grassland, early growth cereals and root crops) and spilled grain in agricultural

landscapes offer elevated energetic and nutritional intake rates of food of higher quality compared to natural or semi-natural vegetation (Fox *et al.* 2017). The growth in numbers wintering in northern Miyagi therefore may be at least partially attributable to an increase in the food resources available in the agricultural landscape, following the modernisation of rice farming (Shimada & Mizota 2011). Despite the change in harvesting techniques, declining trends were however evident in Hokuriku and Sanin. The difference in the trends between regions (*i.e.* northern Miyagi *versus* Hokuriku and Sanin) could possibly be related to their separate breeding origins and migration routes. During spring migration, Greater White-fronted Geese leave northern Miyagi by following a Pacific route along the northern Akita Prefecture to western Hokkaido and the Kamchatka Peninsula, to reach the Khatyrka and Pekul'ney regions of Russia (Takekawa *et al.* 2000). Geese wintering on the Izumo Plain in Sanin, on the other hand, fly directly over the Sea of Japan to the Korean Peninsula (Yamaguchi & Higuchi 2008) and from the Korean Peninsula they migrate through the Northeast China Plain and the Khanka Plain to the Russian Arctic (Fox & Leafloor 2018b).

During the 1980s to 2000s, several hundred Greater White-fronted Geese were marked on the Kamchatka Peninsula or the eastern Siberian region of Russia, along with more than 1,000 Bean Geese *A. fabalis serrirostris* and *A. fabalis middendorffii* (*e.g.* Kurechi 2006; JAWGP 2018). Many of the Eastern Taiga Bean Geese *A. f. middendorffii* were recovered from north and southwest Japan (including at the Katano-Kamoike Pond in Ishikawa Prefecture), indicating a Bean Goose migration route along the coastal area of the Sea of Japan from Hokuriku and Kaetsu to northern Japan (*e.g.* Kurechi 2006). There was only one record of a marked Greater White-fronted Goose (neck band H31) seen in southwest Japan, however, at Katano-Kamoike Pond in winter 2009/10 and on the Izumo Plain in Shimane Prefecture in 2010/11–2013/14 and 2015/16 (Wild Bird Society of Japan 2010; S. Mori, unpubl. data). Yet there were many recovery records of marked Greater White-fronted Geese from northern Japan (*e.g.* Ikeuchi 1996), which suggests different spring migration routes and potential breeding areas used by geese wintering in northern *versus* southwestern Japan.

Seasonal fluctuation in the numbers of the geese also differed between northern and southwestern Japan. As goose numbers in northern Miyagi declined during February, goose numbers to the north increased (in northern Akita; Shimada 2009). As spring migration progressed, peak numbers moved from northern Akita to western Hokkaido, following a migration route already demonstrated by satellite-tracking (Takekawa *et al.* 2000). Conversely, the numbers of the geese in Sanin and Hokuriku remained stable regardless of the decrease in numbers in northern Miyagi during February (T. Shimada, unpubl. data). The fact that geese remained in Hokuriku and Sanin after the start of their spring migration in northern Japan also suggests flyway differences between geese wintering northern and southwestern parts of the country.

In East Asia, major population declines have been reported for Greater White-

fronted Geese in China, in contrast to an increase in the numbers in Japan and Korea (Jia *et al.* 2016). Declines resulted from human pressure on farmland such as intensive gleaning of spilled grain by domestic ducks and geese, and heavy mortality from shooting, netting and poisoning (Yu *et al.* 2017). Although our data on migration routes are limited, geese wintering in southwestern Japan appear to pass over the Sea of Japan to stage in continental Eurasia in the spring. Thereafter, the geese possibly follow northward migration routes through eastern China (Fox & Leafloor 2018b). The decrease in the geese wintering in southwestern Japan therefore may be linked to the decline of the species in China, if these birds are following the same flyway.

To support the effective conservation of Greater White-fronted Geese, it is essential that we constantly monitor the ongoing trends and distribution of the species in relation to environmental factors, such as agricultural land use and weather conditions. Shifts in distribution may result from climate change, particularly as there was a negative association between goose numbers and weather conditions in Hokuriku and Sanin. Furthermore, the areas being used as staging or wintering sites by Greater White-fronted Geese in Japan have extended northwards from northern Miyagi during November and December (Shimada *et al.* 2005). Further information, preferably based on telemetry from marked individuals, therefore is required to describe changes in the timing of migration for Greater White-fronted Geese, and on the use of different areas by the geese along their flyway.

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Photograph: Greater White-fronted Geese on rice fields near Lake Izunuma-Uchinuma, Miyagi Prefecture, Japan, by Hiromi Kano.

