Seasonal changes of roosting and foraging areas for Lesser White-fronted Geese *Anser erythropus* wintering in Japan

YUSUKE SAWA[1,*], TOSHIO IKEUCHI[2], CHIEKO TAMURA[3] & NOBORU NAKAMURA[1]

[1]Yamashina Institute for Ornithology, 115 Konoyama Abiko, Chiba 270-1145, Japan.
[2]Head Office of the "Foster a Goose Program", 159-1 Futamata, Niinuma Aza, Sanbongi, Osaki City, Miyagi 989-6315, Japan.
[3]3-19-10 Nakano, Akiha-ku, Niigata City, Niigata 956-0805, Japan.
*Correspondence author. E-mail: sawa@yamashina.or.jp

Abstract

Despite the recent decline in the Eastern Palearctic population of the Lesser White-fronted Goose *Anser erythropus* (LWfG), numbers wintering in Japan have increased modestly since the 2000s. There have, however, been no systematic studies of the wintering ecology of the species previously conducted in Japan. In this study, count surveys were made of roosting and foraging sites, directed by tracking data from a GPS-tagged bird, to describe the movements of a wintering flock. The home range of the tagged LWfG during the 2020/21 winter was 9,120 ha (core area: 2,080 ha), and the distance between roosting and foraging sites ranged from 1.95–3.64 km. A change in the foraging and roost sites used by the geese was associated with low temperatures in mid-winter. This study provides preliminary information on the movements and habitat use by LWfGs in Japan, but further studies are required to improve our understanding of their wintering ecology, including their feeding habits and energy budgets, in relation to the quality and quantity of food resources available.

Key words: *Anser erythropus*, Eastern Palearctic population, habitat use, wintering ecology.

The Lesser White-fronted Goose *Anser erythropus* (LWfG) has a widespread breeding distribution, extending from the Scandinavian Peninsula to Chukotka, Russia (Fox & Leafloor 2018), and three populations have been described: the Fennoscandian, Western Main and Eastern Palearctic populations (Jones *et al*. 2008; Fox & Leafloor 2018). The species is classified as Vulnerable in the IUCN Red List of Threatened Species (BirdLife International 2021). As a result, internationally collaborative conservation and research programmes, including population surveys and measures to reduce mortality, have been developed along the migratory routes under the auspices of the African–Eurasian Waterbird Agreement (Jones *et al.* 2008) and the Arctic Migratory Birds Initiative (CAFF 2019). In particular, the Eastern Palearctic population wintering in East Asia, which breeds from east of the Taimyr Peninsula to Chukotka, has experienced rapid decline for decades, with an estimated 65,000 individuals in the 1980s, 16,000 in 2015 and 6,800 in 2019 (Wang *et al.* 2012; Jia *et al.* 2016; Fox & Leafloor 2018; Ao *et al.* 2020). A main cause of this decline is the loss and degradation of their habitat in the main wintering area on the Yangtze River floodplain, China, such as at Caisang Lake and East Dongting Lake, resulting from hydrological changes following the building of the Three Gorges Dam (Wang *et al.* 2013; Ao *et al.* 2020). In contrast, while Japan supports only *c.* 3% of Eastern Palearctic population (Ao *et al.* 2020), numbers staging and wintering in the country have increased in recent decades (Ikawa & Ikawa 2009; Ministry of the Environment, Japan 2019; Ao *et al.* 2020). The main Japanese wintering site of Izu-numa and the surrounding farmland, in Miyagi Prefecture, supports almost all of the LWfGs occurring in Japan, with 307 individuals recorded at the site in 2019 (Ao *et al.* 2020). However, systematic research on their wintering ecology has yet to be conducted, and the cause of the population increase has not been identified. It is important to fill these knowledge gaps for the conservation of the endangered East Palearctic population.

In this study, locations recorded for one individual tracked with a GPS–GSM transmitter, combined with counts made of the geese at their roosting and foraging sites (including sites identified by the tracking data), were used to outline the main area used by the geese during the 2020/21 winter. Movements and habitat use by individual LWfGs wintering in Japan were thus described for the first time, and the results should form a basis for future work on determining the ecological and conservation requirements of the species in this region.

Methods

The study was conducted in Tome City, Miyagi Prefecture (38°38'N, 141°09'E; Fig. 1), which is adjacent to two Ramsar sites ("Izu-numa and Uchi-numa" and "Kabukuri-numa and the surrounding rice paddies"; Ministry of the Environment Japan 2015), and is part of the most important wintering area for migratory geese in Japan. Over 200,000 Greater White-fronted Goose *Anser albifrons* also now winter in the region (Shimada *et al.* 2019). The farmland of Tome City is the only place which regularly supports significant numbers of wintering LWfGs in Japan (Ao *et al.* 2020). Two main foraging and roosting sites were identified in study area, based on the movements of a single tracked LWfG. The northern area was named the Izu-numa/Naga-numa area (38°41'N, 141°08'E, hereafter INA) and the southern area the Hasama River area (38°35'N 141°13'E, HRA). There were several habitat types in the study area: rice fields, pasture and other farmland such as vegetable (*e.g.* Soybean

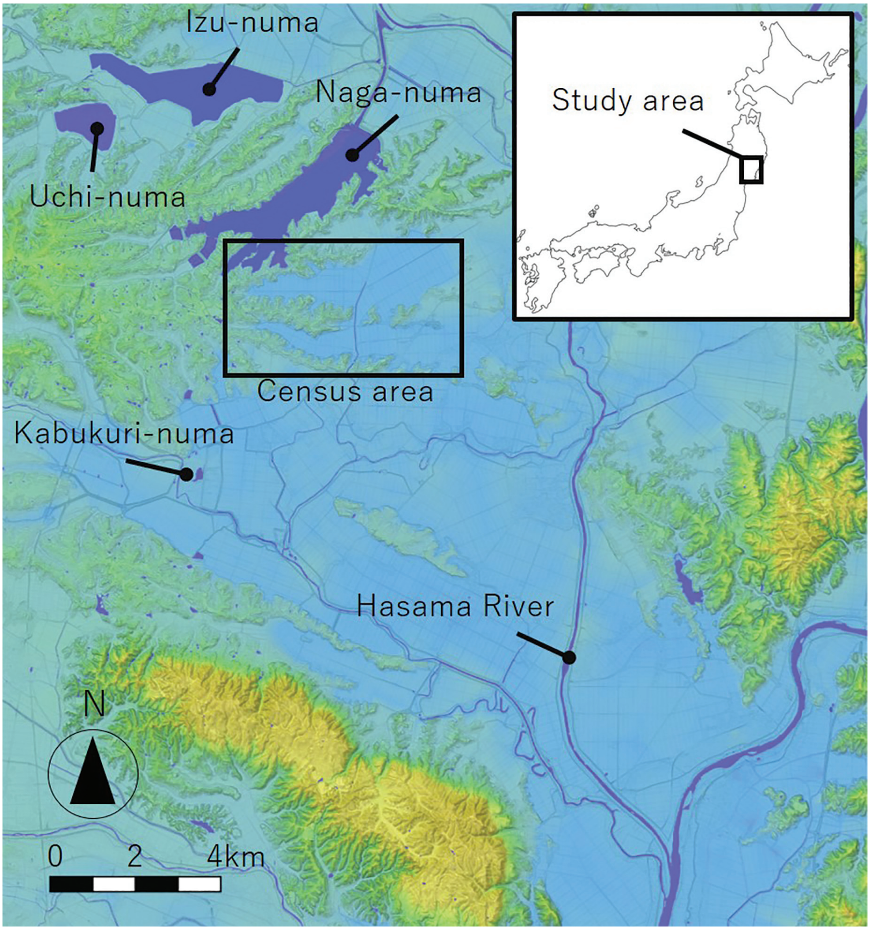

Figure 1. Study area in Tome City, Miyagi Prefecture, Japan.

Glycine max) crops. The rice fields were dry, and contained mostly split dry rice, with little to no other plant species occurring in the rice fields during winter. The main crops in pasture fields were Italian Ryegrass *Lolium multiflorum*, Timothy Grass *Phleum pratense* and White Clover *Trifolium repens*, which were harvested in late October to November 2020, with no seeding until the spring.

Tracking the LWfG

We captured one adult LWfG (sex: unknown) by cannon net at the INA on 3 December 2020. The bird was fitted with a metal ring on the right leg and a 26 g neck collar with solar-powered GPS–GSM transmitters (Lego3G, Druid Technology Inc.). The transmitter recorded one GPS location at 1 h invervals and transmitted data via the GSM mobile network at 12:00 h every day. The home range of the tracked LWfG was calculated as a 95% utilisation distribution (UD) and core range as a 50% UD using the fixed kernel density estimation (KDE) method (Seaman & Powell 1996). The KDE was calculated using the package "adehabitatHR" (Calenge 2006) in R version 4.0 (R Core Team 2020).

Logistic regression analysis was used to predict the factors resulting in a change in the foraging and roosting site used by the tagged bird during the winter, with foraging/roosting sites used in the INA coded daily as 0 and in the HRA as 1. Foraging/roosting site locations were calculated daily as the average location recorded between sunrise and sunset (for the foraging site), and between sunset and sunrise (for the roosting site). The wintering period for the tagged bird was taken as being from the day following capture to the date on which it moved out of the study area. Explanatory variables included in the analyses were the daily average temperature and snow cover. Daily average temperatures (recorded hourly over a 24 h period) were obtained from the meteorological station in Tsukidate (5 km from Izu-numa), and snow cover was represented as the snow depth at Furukawa (22 km from Izu-numa), recorded by the Japan Meteorological Agency (http://www.data.jma.go.jp/obd/stats/etrn/index.php).

To assess the extent of movement between the roosting and foraging sites, the direct-line distance between the roost and the feeding area was calculated daily for the tagged individual. Distance flown was defined as being from the roosting site to the foraging site used the following day, and was calculated for the INA and the HRA separately. The Tukey–Kramer test (R version 4.0; R Core Team 2020) was used to compare distances between the roost and feeding sites at the INA with those at the HRA.

Count survey at roosting and foraging sites

Two roosting sites were identified from the tracking data: one at the INA and the other at the HRA. The distance between the two roosting sites was 14 km. Count surveys made at the roosting site of the INA were conducted 1–3 times per month from December to February; at the HRA, the surveys were conducted twice in January and once in February. The number of flying individuals that came in to roost on the water surface was counted every minute between 15:30 h and 18:00 h, from an observation point 100–300 m from the roost. There were usually no geese present on the roost at 15:30 h and none arrived as late as 18:00 h, with sunset occurring at times ranging from 16:15–17:15 h during the study period. The LWfGs usually formed small flocks (range: 2–208 birds) at the roost, arrived slightly earlier than *A. albifrons* using the same site, and were identified by call. However, when LWfGs arrived with a large number of *A. albifrons*, we could not identify the number of LWfGs in the group. In these instances, we recorded all individuals as *A. albifrons*.

Count surveys at foraging sites were conducted across a 650 ha area of the INA which were the known sites from previous years' observations to be used by geese during the winter (Fig. 1). Individuals/flocks in the study area were searched for by car 1–4 times per month, from November 2020 to February 2021. When the tagged bird stayed at the HRA, we searched for it there and counted the LWfGs within a 500 m radius of the tagged bird. The habitat type where the LWfGs were found was also recorded as one of the following: rice field, pasture field, other farmland (*e.g.* Soyabean, vegetables), or ridge/channel. Borders between the fields were clear because they were divided by ridges, and each was planted with a monoculture crop.

Results

Tracking results for the tagged bird

The tagged LWfG remained in the study area from 4 December 2020–14 February 2021 and from 21–27 February 2021. We obtained 1,940 locations from the tag during this period. The tagged bird used foraging and roosting sites at the INA throughout the period from 4–29 December, and moved to the HRA roosting site on 30 December. From 31 December–22 January, the bird mainly used the HRA (foraging entirely at the HRA; roosting for 13% of the time at the INA and 87% of the time at the HRA), then returned to the INA on 22 January until 14 February (foraging: 79% at the INA and 21% at the HRA; roosting: 87% at the INA and 13% at the HRA). The goose left the study area on 15 February and stayed in an area 170 km north of the study area (Ogata-mura, Akita Prefecture) until 20 February. When the goose returned to the study area, from 21–27 February, it roosted at the INA and foraged outside of the study area (at Ichinoseki, 24 km north of Izu-numa; Fig. 2). We therefore defined 4 December 2020–14 February 2021 as the wintering period of the tagged LWfG and 21–27 February as its post-wintering period in the study area. The tagged goose departed further north on 28 February 2021 and, after staging in the Tsugaru Plain, Aomori Prefecture and the Ishikari Plain, Hokkaido Prefecture, it stayed in Sarobetsu, Hokkaido Prefecture until 11 May before moving out of the range of the GSM network.

The home range for the tagged individual, estimated by KDE, was 9,120 ha (core area: 2,080 ha) during winter and 149,540 ha (core area: 30,662 ha) during the post-wintering period. The average distances (mean ± s.d.) between the roosting and foraging sites during winter were 3.64 ± 2.82 km (range: 1.45–13.9 km) at the INA, 1.95 ± 1.42 km (range: 0.86–6.55 km) at the HRA, and 45.4 ± 15.7 km (range: 29.6–78.3 km) at the INA during the post-wintering period (Fig. 3). The distance flown at the INA during the post-wintering period was significantly longer than during the winter for both the INA and the HRA (Fig. 3; Tukey–Kramer test, $q = 2.390$, $P < 0.001$).

Logistic regression analysis indicated that the average daily temperatures may have had a significant influence on the tagged bird's movement to and occurrence at the HRA. This was the case both for the roosting site (estimate ± s.d. = −0.504 ± 0.154, $z = -3.273$, $P < 0.005$) and the foraging site (estimate ± s.d. = −0.509 ± 0.148, $z = -3.442$, $P < 0.001$). The propensity to use the HRA *versus* the INA did not vary with snow cover (roosting site: estimate ± s.d. = 0.025 ± 0.035, $z = 0.716$, $P = 0.474$; foraging site: estimate ± s.d. = –0.004 ±

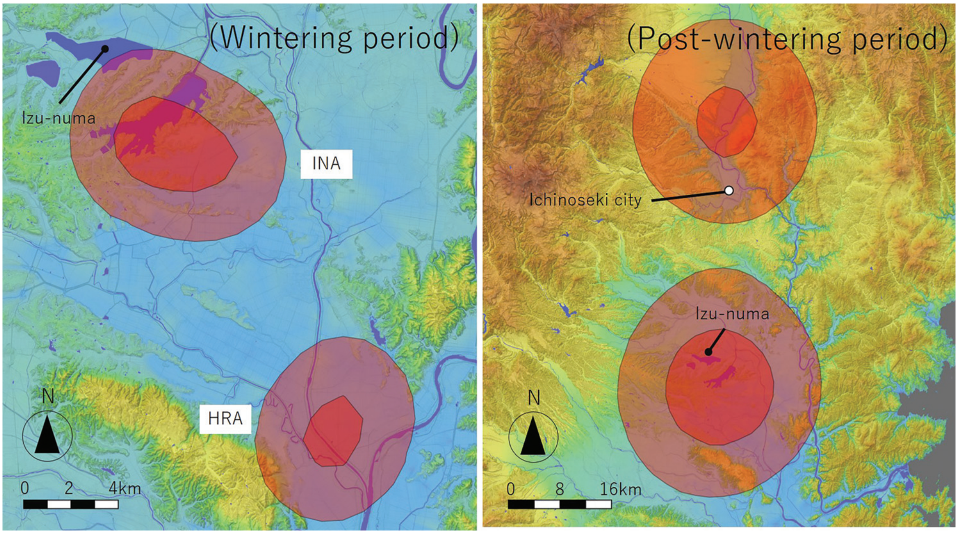

Figure 2. Home range of the tagged Lesser White-fronted Goose during the wintering period (4 December–14 February), and post-wintering period (21–27 February). The northern area used by the LWfG during winter was named the Izu-numa/Naga-numa area (INA), and the southern area used was the Hasama River area (HRA). Thin red polygon represents the home range calculated as a 95% utilisation distribution and dark one represents core range as a 50% UD using the fixed kernel density estimation.

0.035, z = –0.113, P = 0.910, n.s. in both cases). The tagged bird seemed to move to the HRA when the average temperature dropped to below –2°C (Fig. 4).

Count surveys at the roosting and foraging sites

A total of seven roost surveys were conducted at the INA and two roost surveys at the HRA (Table 1). The maximum count of 357 individuals was recorded at the INA in December. In early January, when only a small number of LWfG roosted at the INA (Table 1, Fig. 4), 80% of the surface water at the roost was frozen. During this period, the tagged bird used the HRA (Fig. 4), and 91 and 44 birds were recorded at the HRA roost, on 3 and 14 January respectively (Table 1). The Hasama River, used as the roosting site at the HRA, remained unfrozen throughout winter. From late January, when the daily temperatures rose to > 0°C, the number of roosting individuals at the INA recovered to 320 birds on 30 January (Fig. 4).

Count surveys at the foraging site of the INA were initiated in November, and 318 birds were recorded there on 24 November, but numbers then decreased from mid-December to mid-January (Fig. 4). Although the number of birds recovered in late January, it decreased again in mid-February, and no birds were found on 26 February. On searching for the tagged bird during 13 and 31 January, when it used foraging sites in the

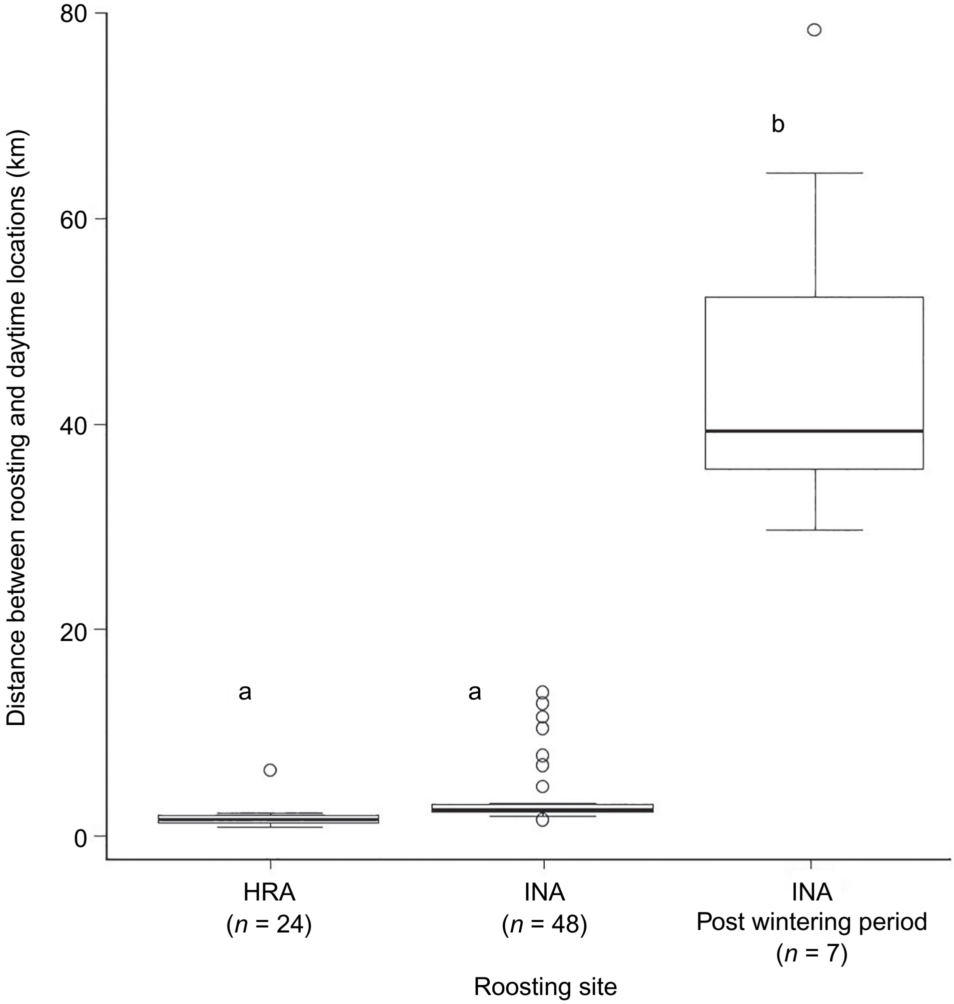

Figure 3. Average distance between the roosting and daytime locations used by the tagged Lesser White-fronted Goose during each period, with outliers above the s.d. bars. Different lower case letters represent significant differences in the distances between the daytime and roost sites (Tukey–Kramer test, $P < 0.001$).

HRA, it was found in flocks of 118 and 13 birds, respectively (Table 1).

Habitat use and food

The percentage of LWfGs recorded on different habitats during counts made at their foraging sites is illustrated in Fig. 5. The geese occurred mainly in pasture fields from November–January, but the use of pasture fields decreased gradually, whereas the birds' use of rice fields increased throughout the season. Although 115 birds

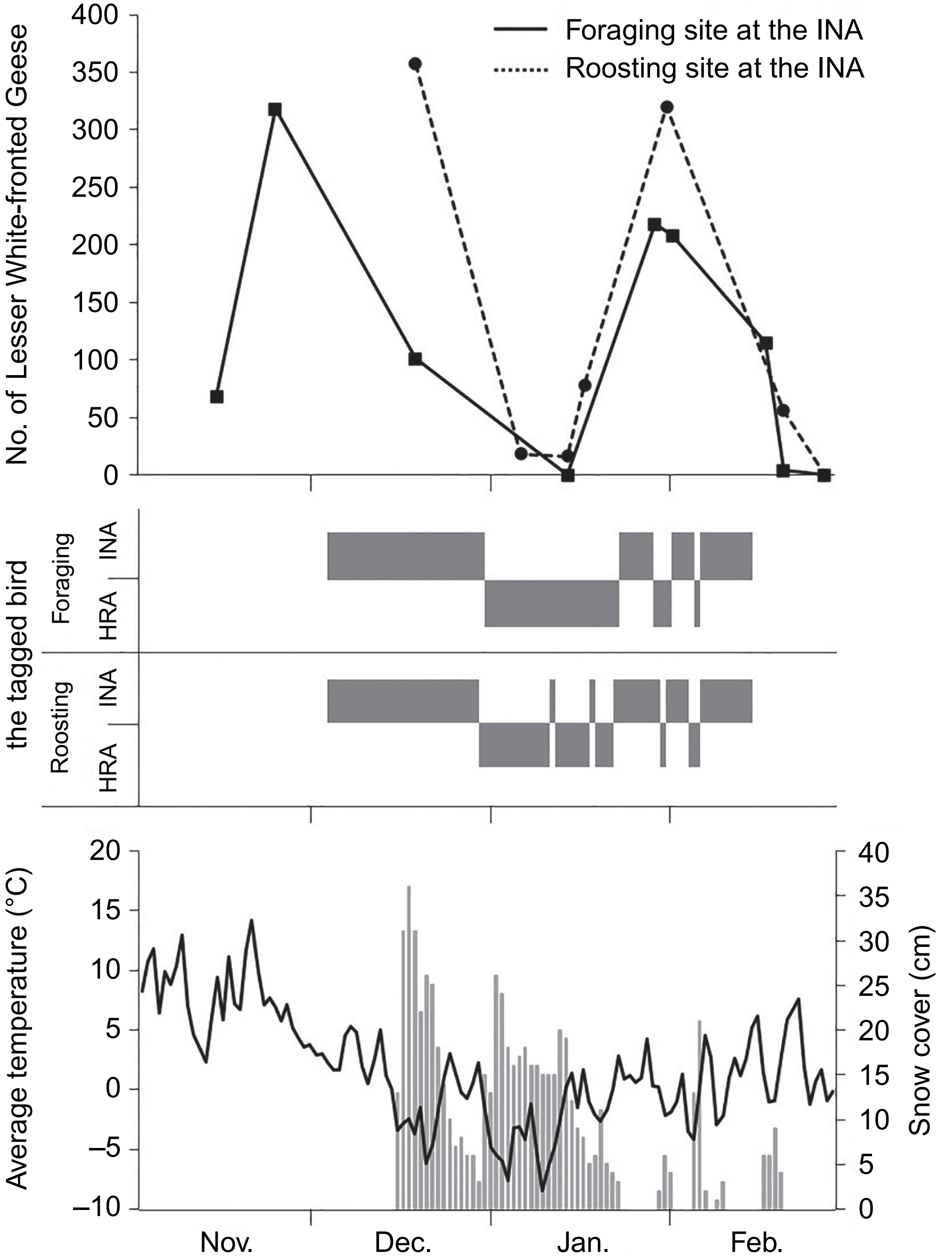

Figure 4. Number of Lesser White-fronted Geese at roosting and foraging sites in the INA (upper figure), location of the tagged bird during the day at 12:00 h and at roost at 0:00 h (middle figure), and the average temperature (line) and snow depth (bars) around the study area (lower figure).

Table 1. Number of Lesser White-fronted Geese counted during surveys at the roosting and foraging sites.

Date	Roosting site		Foraging site	
	INA	HRA	INA	HRA
14 Nov.	–	–	68	–
24 Nov.	–	–	318	–
18 Dec.	357	–	101	–
3 Jan.	–	91	–	–
5 Jan.	18	–	–	–
13 Jan.	16	–	0	118
14 Jan.	–	44	–	–
16 Jan.	78	–	–	–
28 Jan.	–	–	218	–
30 Jan.	320	–	–	–
31 Jan.	–	–	208	13
16 Feb.	–	–	115	–
18 Feb.	–	–	4	–
19 Feb.	56	–	–	–
26 Feb.	0	–	0	–

INA = Izu-numa/Naga-numa area; HRA = Hasama River area.

were observed on a field planted with Soybeans on 13 January, they foraged on short grasses around these plants and not on the Soybean crop. The foods taken by the geese throughout the wintering period were identified as Italian Ryegrass, White Clover, Common False Pimpernel *Lindernia procumbens* and Annual Bluegrass *Poa annua*.

Discussion

The tagged bird roosted and foraged within the INA in December, and its subsequent move to the HRA in early January coincided with low average temperatures and perhaps ice formation at the INA roosts. The presence/absence of the tagged bird in the INA concurred with the results of the count surveys at roosting and foraging sites in the INA (Fig. 4), which indicated that a change in site use was made by most of the LWfGs wintering around the study area. The number of individuals roosting and foraging in the HRA in mid-January was not as high as in the INA during December, however, suggesting that the LWfGs might have dispersed over a wider area during this period. Numbers at the INA recovered from the end of January following an increase in temperatures. Most of the wintering LWfGs in the study area, including the tagged individual, started migrating north from around mid-February.

The distribution and behaviour of ducks, swans and geese are affected by snow cover and temperature in Japan (Shimada & Ueda 2006; Ueta 2007), and also by food abundance (Cong *et al.* 2012; Karmiris *et al.* 2017). Snow cover affects the availability of food at foraging sites, and temperatures can affect the conditions at roosting and resting sites due to the freezing of the water surface (Ueta 2007). The daily activities and habitat use by *A. albifrons* in the same region are likewise influenced by temperature and snow depth, with the birds shifting to areas further south when snow cover increases (Shimada 2002, 2020). Food availability also affects the distribution and abundance of LWfGs

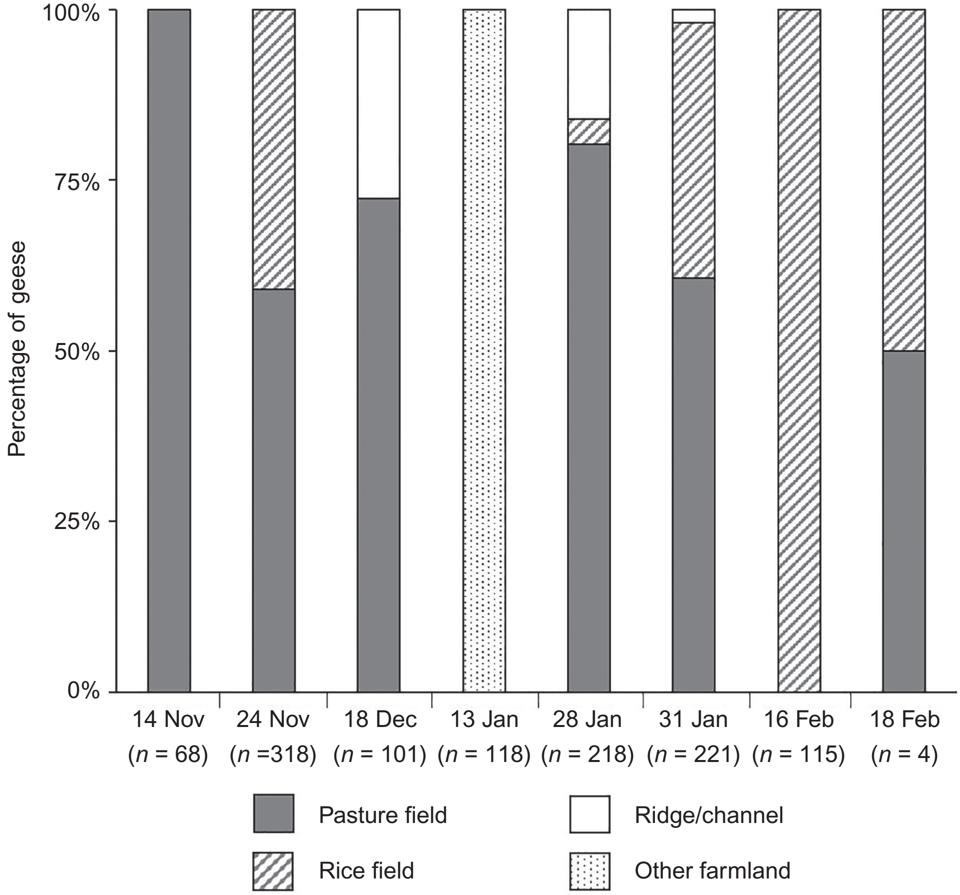

Figure 5. The percentage of Lesser White-fronted Geese found on different habitats during the count surveys, at foraging sites shown in Table 1.

wintering in China and in Europe, inducing changes in the use of foraging/roosting sites (Cong *et al.* 2012; Karmiris *et al.* 2017). The change in foraging/roosting sites and habitat use by LWfGs in this study may likewise be attributable to a combination of conditions at the roosting sites and food availability in the surrounding area, but the interaction of factors affecting their distribution could not be detected in the analyses presented here.

The average distance between the roosting and foraging sites was 1.95–3.64 km and was shorter than that of the *A. albifrons* in the same area (11 km, based on Argos PTT data with an accuracy of < 1 km; Takekawa *et al.* 2000). Wang *et al.* (2013) suggested that the highly localised distribution of LWfGs in winter could be explained by food constraints in a certain habitat. Although we did not make a comprehensive assessment of food availability, the distribution of suitable habitats such as pasture fields might account for their narrow home ranges. Habitat selection will be investigated in a future study.

This study is the first, to our knowledge, to investigate roosting and foraging site use and movements for LWfGs wintering in Japan, and it provides important implications for their conservation, such as identifying key Japanese roosting sites, the relationship between the roosting and foraging sites, and movement and habitat use by the species throughout winter. However, given that the movements of wintering LWfGs were described from a combination of count surveys and tracking data for a single bird, more tracking studies will be needed in the future. Ao *et al*. (2020) suggested that the recent population increase in Japan might be caused by the birds utilising the abundant agricultural crops, including those left after the harvest, but LWfGs were found to peck mainly at grasses in pasture fields rather than taking spilt grain in the rice fields. Further studies of the feeding habits, food availability, energy budgets and movements during winter therefore are needed to evaluate the quality of wintering areas in Japan and promote conservation activities in this country, which would benefit the endangered population of LWfGs in the Eastern Palearctic.

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