Estimated size of the Eastern population of the Lesser White-fronted Goose *Anser erythropus* revealed from aerial surveys of key moulting sites

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Abstract

The Eastern population of the Lesser White-fronted Goose *Anser erythropus* (EPLWFG) breeds and moults in Russia and the majority winter in China. Intensive surveys of lakes in the Yangtze River floodplain and in Japan estimated the EPLWFG at 6,600 individuals in 2020 compared to 14,000–19,000 in 2016. Waterfowl are easier to count when concentrated in relatively small areas at key times of the year, and the non-breeding and failed breeding elements of the EPLWFG (an estimated 87% of the population) concentrate at remote moulting sites from early July to mid-August during remigial moult. Locations of GPS-tagged EPLWFG (non-breeding birds and failed breeders), which moulted between 25 June and 17 August, recorded during an earlier study, were plotted on maps of the key moulting region, along the San-Yuryakh and Kyuanekhtyakh Rivers which flow into Omulyakhskaya Bay. An aerial survey undertaken in July 2021 aimed to cover as many locations of the tracked individuals as possible, together with Svyatoy Nos Cape and the New Siberian Islands (where the species was also thought to moult), to count the numbers of geese moulting in these areas. Moulting sites on the delta of the Lena River were also surveyed from the air during the EPLWFG moulting periods in 2019 and 2020. Goose groups were photographed and digitally tagged to GPS coordinates, generating a database which included a date/time stamp to the nearest second, coordinates to the nearest 0.000001 degree, and a picture ID. Photographs were processed using Adobe Photoshop V

21.1.3 software. From detection rates in the survey area, we were able to assess the extent of similar habitat elsewhere in the EPLWFG moulting range, to obtain an estimate of the potential total population size. Moulting EPLWFG were found on Bolshoy Lyakhovaskiy Island in the New Siberian Islands, a new site discovered during this study. A total of 9,373 EPLWFG was counted in moulting flocks at all known and newly discovered moulting sites. The extrapolated estimate for the number of non-breeding and failed breeding birds, on taking the expanded area of suitable habitat into account, was of potentially 24,060 geese. Considering that *c.* 10% of EPLWFG are successful breeders (*i.e.* remain on their breeding sites and do not join the moulting flocks), we propose that the overall population size could be as high as 26,733 individuals, excluding offspring of the year.

Key words: aerial survey, moulting period, newly-discovered site, population estimate.

The Eastern population of the Lesser White-fronted Goose *Anser erythropus* (hereafter EPLWFG) breeds and moults in Russia and winters almost exclusively in China (BirdLife International 2018; Cao *et al.* 2018), although a few (*c.* 300) winter in Japan where numbers have recently increased (Ikawa & Ikawa 2009; Ao *et al.* 2020). The summer range has been recognised as a continuous area extending from the Olenyok River (119.2°E) in the west to the lower Anadyr River (174.8°E) in the east and northward from 64°N, excluding the arctic archipelagos (Tian *et al.* 2021). This finding contrasts with previous assumptions of a fragmented summer range (Morozov 1995; Morozov & Syroechkovski Jr. 2002; Cao *et al.* 2018). The arctic archipelagos and New Siberian Islands were not considered to be part of the summer range because of the absence of records in the literature. The EPLWFG (extending to 119°E) seems to be isolated from the nearest other breeding population of the species, the Western Main population, which breeds on the northern Russian tundra westwards from the Taimyr Peninsula at 103°E (Cao *et al.* 2018).

Estimates of the abundance of the EPLWFG vary. Intensive ground-based surveys of lakes in the Yangtze River floodplain, including the most important wintering sites at Dongting, Poyang and Shengjin Lakes in China, estimated 6,600 EPLWFG individuals in 2020 (Ao *et al.* 2020), compared to 14,000–19,000 individuals estimated in 2016 (Jia *et al.* 2016). Ground-based counting of wintering EPLWFG on the large lakes of the Yangtze River floodplain might yield underestimates, because birds in the centre of very large lakes may not be easily visible. For this reason, population size and trends of the EPLWFG remain uncertain.

Waterfowl are easily counted when concentrated in relatively small areas during certain periods of the year. For many Northern Hemisphere migratory waterfowl, birds are most concentrated in winter in specific habitats, making winter surveys effective for population estimates (for goose population estimates see Fox & Leafloor

2018 and for swan populations Rees *et al.* 2019). Other waterfowl species' populations can be better estimated from breeding surveys, however, such as the Scaly-sided Merganser *Mergus squamatus*, whose breeding range is smaller than its wintering range and whose linear breeding habitats are clearly defined (Solovyeva *et al.* 2014). Species or populations which habitually congregate in specific periods outside of winter may thus offer alternative methods for reliable population size estimation outside of winter surveys.

The concentration of non- and failed breeding EPLWFG at three moulting sites from early July to mid-August, during their remigial moult, was discovered through the use of GPS-GSM tracking (Solovyeva *et al.* in press; for tracking details, see Ao *et al.* 2020 and Tian *et al.* 2021). One of these, in the lower reaches of the San-Yuryakh and Kyuanekhtyakh Rivers, which flow towards the Omulyakhskaya Bay in the East Siberian Sea, was used by 70.0% of the adult GPS-tagged EPLWFG (*i.e.* 14 of 20 tracked individuals) not involved in brood-rearing during the study (Solovyeva *et al.* in press). The other two moulting sites were on the Bolshaya Kuropatoch'ya River (a small river 150 km long which flows into the East Siberian Sea, utilised on 15.0% of 20 non- or failed breeding occasions), and the Lena River Delta (used by a non-breeding bird, which represented 5.0% of the 20 non- or failed breeders). Only two (10%) of 20 EPLWFG were considered to have nested successfully during 2017–2020 (as they remained on their breeding grounds for the entire summer and did not join the moulting concentrations), leaving 90% as non- or failed breeders (calculated from the data in Solovyeva *et al.* in press).

This paper describes the numbers and distribution of moulting EPLWFG recorded during the aerial surveys at all three known moulting sites, including brood-rearing adults recorded on territories within the same areas as those used by flocks of non- and failed breeding birds. The results are discussed in comparison to the population estimate obtained from counts made on the wintering grounds.

Methods

Selection of survey areas, dates and routes

Data from the tracked birds (non-breeding and failed breeders) indicated that the EPLWFG moulted between 25 June and 17 August (Solovyeva *et al.* in press), which dictated our survey dates (Table 1). Tracks of moulting EPLWFG were plotted on maps of the key moulting areas and aerial survey routes were planned in order to cover as many locations of tracked individuals as possible (Fig. 1). The aerial surveys made in 2021 covered the majority of the courses of the San-Yuryakh and Kyuanekhtyakh Rivers (Fig. 2). The upper reaches of both rivers remained unsurveyed, although the tracks of moulting ELWFG showed that these areas were also used. Two survey routes were flown over the lacustrine tundra between San-Yuryakh River and the coast (hereafter referred to as the vicinity of Svyatoy Nos Cape; Fig. 3), in 2020 and 2021. The New Siberian Islands were surveyed along a single route during a long two-day flight, on 12–13

Table 1. Areas covered during aerial surveys of the Eastern Lesser White-fronted Goose population's moulting sites in 2019–2023. ND = Not determined for rivers, where linear measures used.

Moulting site/area	Survey dates	Survey length (km)	Surveyed area (km^2)	Overall expanded area/river stretch
San-Yuryakh River	12 July 2021	72.7	ND	122.7 km
Kyuanekhtyakh River	12 July 2021	59.1	ND	62.1 km
Vicinity of Svyatoy Nos Cape	8 July 2020/12 July 2021	665	1,368	18,376 km^2
Bolshoy Lyakhovskiy Island*	12–13 July 2021	62.8	54	448 km^2
Bolshaya Kuropatoch'ya River	15–16 August 2023	214.8	ND	ND
Lena Delta	29 June–9 July 2019/	3,420	6,899	24,285 km^2
	11–14 July 2020	2,382	ND	ND

*Moulting area discovered during this study.

July 2021, which was severely limited by the fuel supply (Table 1, Fig. 4).

The Lena Delta was surveyed by long flights covering uniform habitats (*i.e.* the coastal strip or the inland part of the delta) in 2019 and by regular longitudinal transects in 2020. The transects followed those made during earlier surveys, in 1993–1994 (Fig. 5; see Hodges & Eldridge 2001 for further details). A single track of an EPLWFG which moulted in the Lena Delta was plotted on the map but was not used for planning of the survey route (Fig. 5). The Bolshaya Kuropatoch'ya River was surveyed on 15 and 16 August 2023, which was too late to encounter moulting geese (Table 1).

A potential bias in population estimates arising from the surveys of different moulting sites being made in different years was addressed by surveying the areas where most GPS moulting locations were recorded in a single year.

The light Sterkh C1 seaplane was used in the survey, flying at an altitude of 38 m above ground at a speed of 80–100 km/h. One observer (SR) took photos of geese flocks, and the pilot (GK) assisted by pointing out flocks on his side of the aircraft (Rozenfeld *et al.* 2019, 2023).

Treatment of the survey data

Each group of geese was photographed by a camera connected to the Global Positioning System (GPS). The database comprised encounter entries which included a date/time stamp to the nearest second, coordinates to the nearest 0.000001 degree, and a picture ID. Photographs were

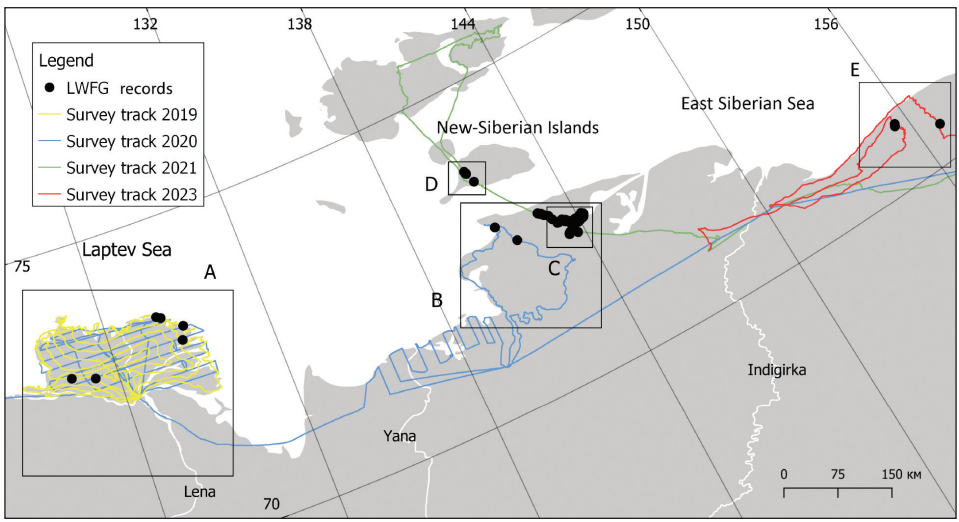

Figure 1. Map of the areas surveyed for moulting EPLWFG in 2019–2021 and 2023. Black dots indicate positions of EPLWFG flocks reported during this study. Survey tracks from different years are shown in different colours. Known and newly discovered moulting areas are indicated as follows: A = the Lena Delta; B = vicinity of Svyatoy Nos Cape; C = San-Yuryakh and Kyuanekhtyakh Rivers; D = Bolshoy Lyakhovskiy Island; E = Bolshaya Kuropatoch'ya River. The key moulting site of the San-Yuryakh and Kyuanekhtyakh Rivers is shown as a separate polygon (C) within polygon B (in the vicinity of Svyatoy Nos Cape).

processed by one of the authors (VD) using Adobe Photoshop V 21.1.3 software. Each individual in the flock or family group was identified to species level, and an individual number was assigned to each by clicking on it (Fig. 6). The Adobe Photoshop Count Tool was used to count individual birds. Species identification was verified by two other authors (DS and DB) and only LWFG agreed upon by all three authors were considered confirmed observations. In mixed flocks, we distinguished between Tundra Bean Goose *Anser fabalis serrirostris*, Greater White-fronted Goose *A. albifrons*, Lesser White-fronted Goose and unidentified goose species *Anser* sp. The latter category was ignored in abundance estimates.

To estimate goose density along the route, we calculated the width of the survey strip as the distance from the transect line at which geese could be effectively detected. Sixteen images were selected from the entire set of photographs of moulting goose flocks (regardless of species) along the route covering the vicinity of Svyatoy Nos Cape and Bolshoy Lyakhovskiy Island. We then measured the distance from the camera (the coordinate being recorded by the camera) to the farthest flock, and the position of the flock was determined from the configuration of lakes or channels in a Google Earth or ESRI satellite image. From this, we determined that the survey strip width for detecting geese in flocks, and thus for

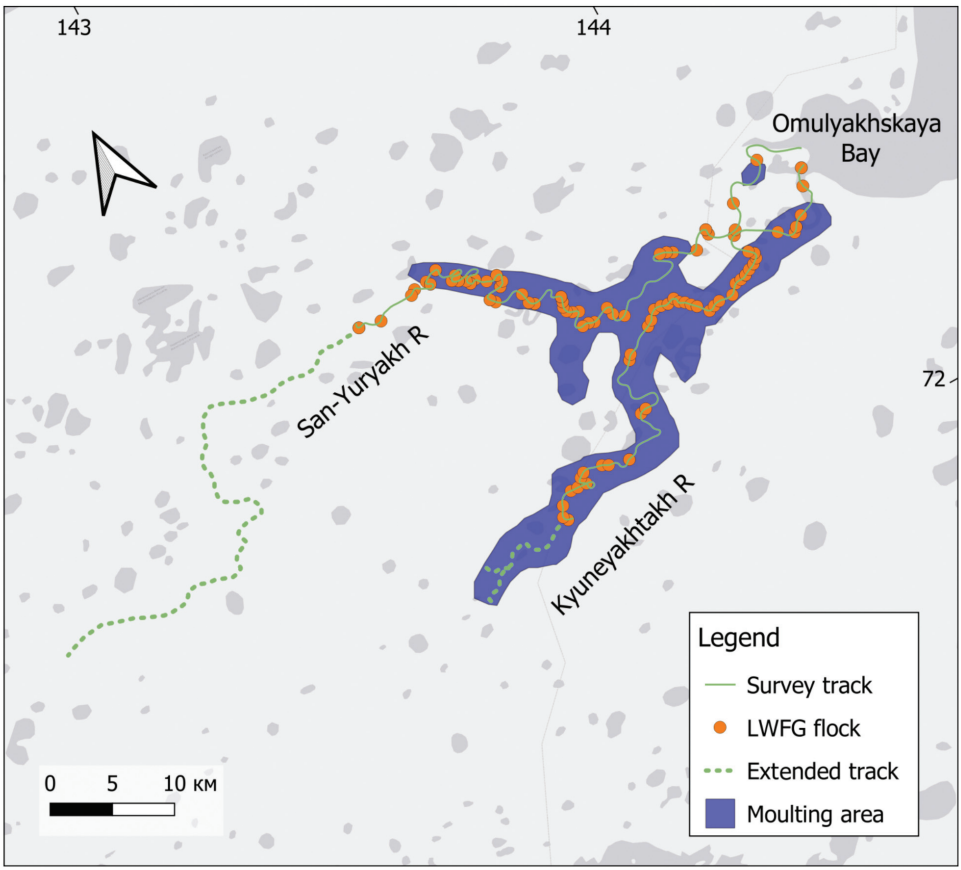

Figure 2. Survey tracks, overall expanded river stretches, and sightings of EPLWFG moulting flocks (orange) along the San-Yuryakh and Kyuneyakhtakh Rivers. Survey tracks are represented by green solid lines. Local abundance was estimated for the river stretches not covered by the aerial survey (shown by dashed green lines), based on equivalent densities encountered along each river. The combined overlapping moulting ranges of 13 tagged EPLWFG are indicated by the blue polygon. Note the high correspondence between the moulting ranges of individual tagged geese and the location of moulting flocks detected during the aerial survey.

calculating goose density, was on average 1,023 m (s.d. ± 105 m, range = 511–1,900 m). To calculate geese density along the flown transects, we therefore set the effective strip width to 1,023 m out from the aircraft track for all years except for 2020, when the count strip was specifically defined for those flights at 200 m wide (further details of the 2020 survey of the Lena River Delta are provided in Solovyeva *et al.* 2023).

We created layers in the Quantum GIS v. 3.16.5 software for: (i) aerial survey tracks with buffers, (ii) locations of EPLWFG

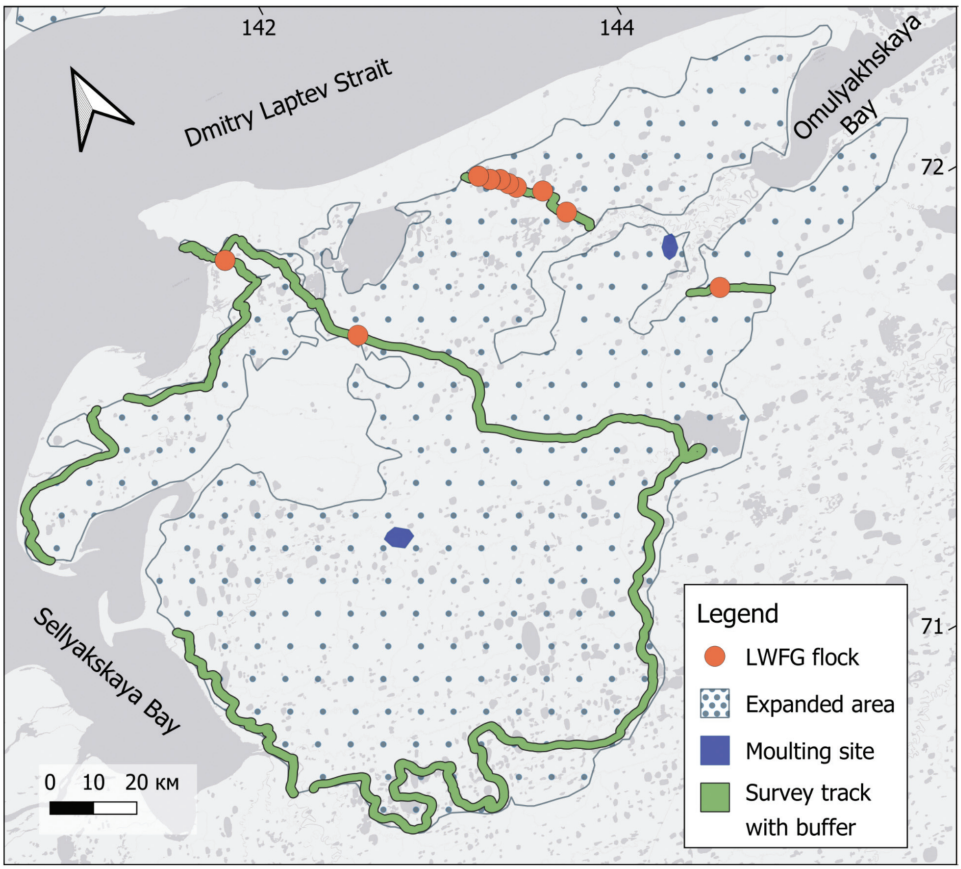

Figure 3. Survey tracks, overall expanded area (used to extrapolate densities from transect data), and individual sightings of moulting EPLWFG in the vicinity of Svyatoy Nos Cape. Conventions are as described for Fig. 2.

flocks, (iii) moulting ranges of individual geese obtained from GPS-GSM tracks and (iv) the areas within each survey area with uniform habitat over which we extrapolated goose densities from transect data ("overall expanded areas", shown as polygons in Figs 2–5). The overall expanded areas were manually delineated for the vicinity of Svyatoy Nos Cape and for Bolshoy Lyakhovskiy Island, considering the habitat uniformity of inland lacustrine tundra, based on Google satellite images and layers in ESA WorldCover 10m v100. In the Lena Delta, the overall expanded area extended to 24,285 km^2, representing the entire Lena Delta, of which 28.4% was covered during the aerial survey (Fig. 5).

For the key moulting site along the San-Yuryakh and Kyuanekhtyakh Rivers, we calculated the linear density as individuals per kilometre of river, and estimated total abundance as the sum of the geese counted

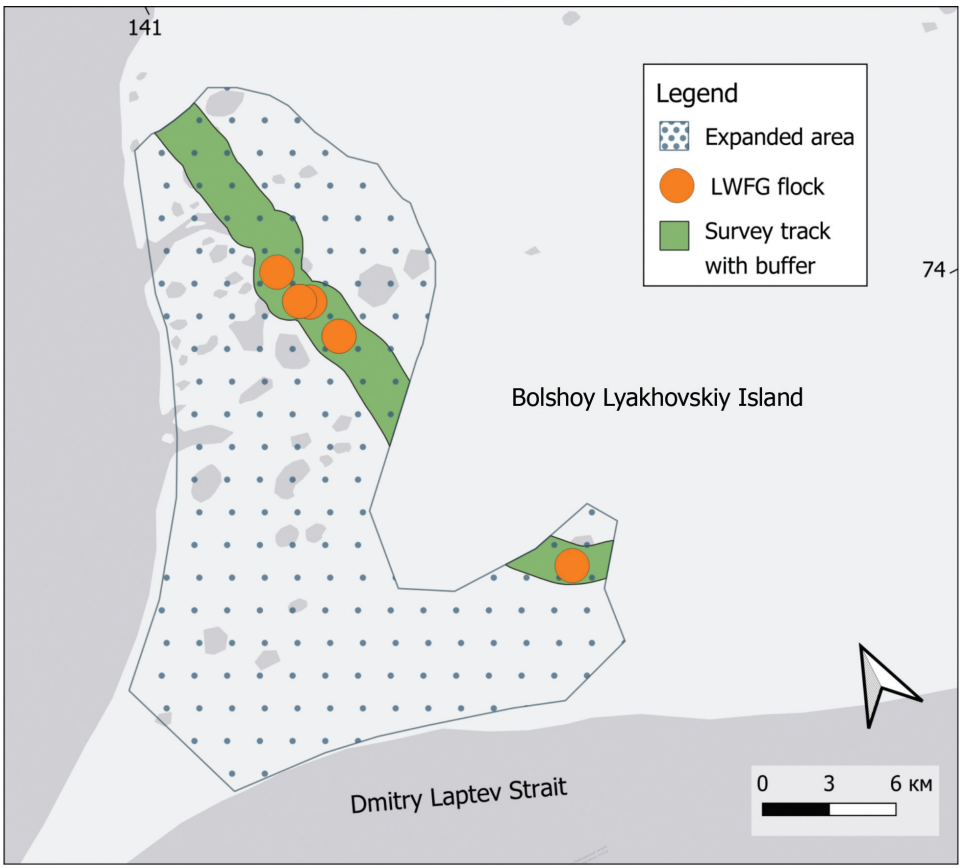

Figure 4. Survey tracks, overall expanded area (used to extrapolate densities from transect data), and sightings of EPLWFG on Bolshoy Lyakhovskiy Island. Conventions are as described for Fig. 2.

plus an estimated number of geese for the unsurveyed sections of the rivers, assuming equal linear density along each of the two rivers. The uppermost parts of the San-Yuryakh and Kyuanekhtyakh Rivers (with a river width of < 25 m) were excluded from the estimate.

Overall expanded areas and expanded river stretches were determined carefully to avoid overestimation of goose density. All calculations were conducted in the Asia_North_Albers_Equal_Area_Conic coordinate system, using the field calculator integrated into GIS for survey length and area computations. All maps were built and designed using the built-in GIS function.

Results

A total of 24,791 geese of three species was counted in mixed flocks along the San-Yuryakh and Kyuanekhtyakh Rivers, in the vicinity of Svyatoy Nos Cape and on Bolshoy Lyakhovskiy Island. Only 5.4% of mixed flocks containing unidentified geese;

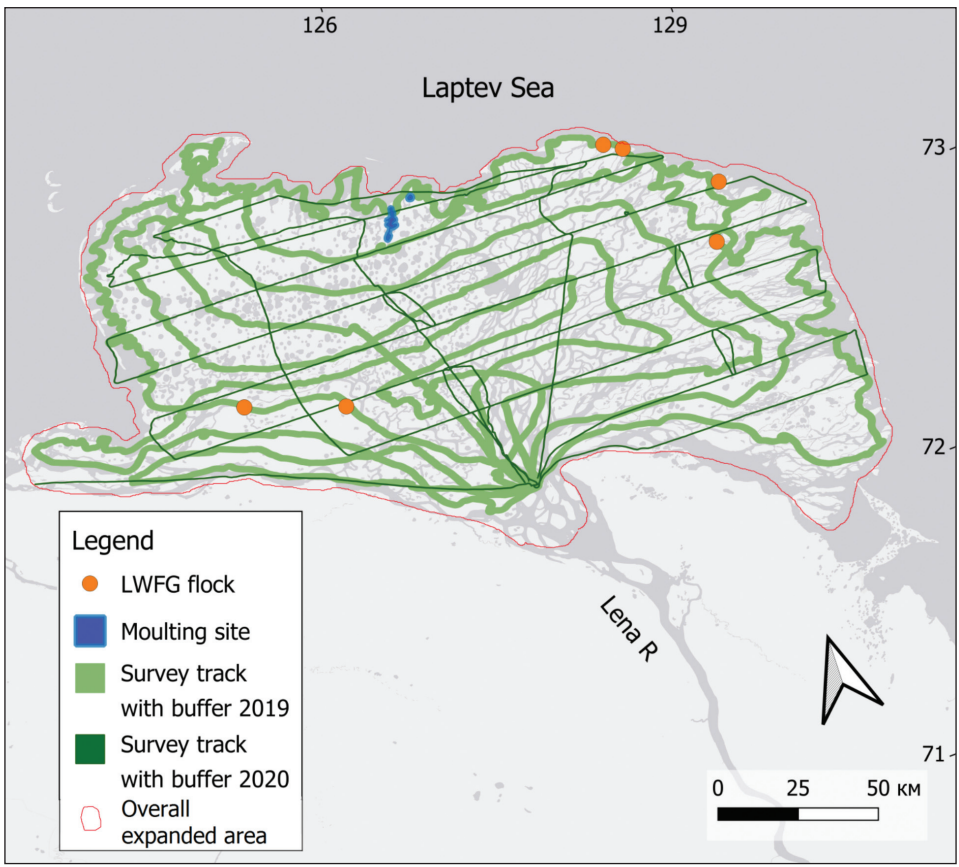

Figure 5. Survey tracks, overall expanded area and sightings of EPLWFG in the Lena Delta. Survey transects with buffers are represented by green lines. Broad green lines represent transects with a 1,023 m buffer from each side (total 2,046 m), and thin dark green lines represent transects with a 200 m buffer from one side of the plane (observer side, see Methods for explanation). Sightings of EPLWFG are indicated by orange circles, regardless of the flock size. The blue polygon shows the moulting range of the tracked EPLWFG (individual BFUL057 in 2017; see Solovyeva *et al.* in press).

therefore, we are confident that the majority of flocks were fully identified.

The vast majority of adult EPLWFG not engaged in brood care seemed to have gathered on two relatively small rivers, the San-Yuryakh and Kyuanekhtyakh, near the northeast coast of Yakutia (Fig. 2, Table 2). We counted 4,727 EPLWFG along the San-Yuryakh River and 3,553 EPLWFG along the Kyuanekhtyakh River with densities of 65 and 60 individuals/km of the river, respectively.

Fewer geese used the lake tundra in the vicinity of Svyatoy Nos Cape, with 589 EPLWFG counted during surveys on 8 July 2020 and 12 July 2021 (Fig. 3, Table

Figure 6. An example of a moulting flock of EPLWFG with 145 individuals (each goose is numbered for counting using the Count Tool) on the Kyuneyakhtyakh River, northeast Russia (72.078°N 143.484°E), on 12 July 2021.

2), constituting a mean density of 0.4 individuals/km^2 over the entire expanded area (Fig. 3).

Moulting of EPLWFG on Bolshoy Lyakhovskiy Island was discovered during an aerial survey on 12 and 13 July 2021, as part of this study (Fig. 4). We counted 504 EPLWFG on this island with a density of 9.3 individuals/km^2 in the lake tundra, covering a small portion of the island.

The delta of the Lena River was surveyed more extensively than other known and newly discovered moulting sites, but only 72 EPLWFG were counted in the delta in 2019 (Fig. 5). Moreover, no EPLWFG were encountered during 2020, when the survey followed precisely the transects previously established for counting waterbirds (particularly King Eiders *Somateria spectabilis*) at the site (Hodges & Eldridge 2001).

Only nine EPLWFG were counted along the Bolshaya Kuropatoch'ya River on 15–16 August 2023, but the survey was probably conducted too late to monitor moulting geese there effectively (see Fig. 1 and Table 1).

Monospecific moulting flocks of EPLWFG were recorded only along the San-Yuryakh and Kyuanekhtyakh Rivers. At other sites, EPLWFG were moulting in mixed flocks with Tundra Bean Geese

Table 2. Population size estimate for the Eastern Lesser White-fronted Geese, determined from counts of moulting birds. Note: only adult geese are considered.

Moulting site/area	No. of LWFG counted (individuals)	Density	Estimated number (individuals)	Proportion of juveniles (%)
San-Yuryakh River	4,727	65.0 ind./km	7,978	0
Kyuanekhtyakh River	3,553	60.1 ind./km	3,733	1
Vicinity of Svyatoy Nos Cape	589	0.43 ind./km^2	7,914	0
Bolshoy Lyakhovskiy Island	504	9.33 ind./km^2	4,181	0
Lena Delta	72	0.01 ind./km^2	253	0
TOTAL	9,373		24,060	

and Greater White-fronted Geese, or both species. Monospecific flocks averaged 77.7 ± 20.0 individuals (n = 10; range = 12–188). The composition of mixed flocks is shown in Fig. 7. EPLWFG families were detected during the aerial surveys only on the Kyuanekhtyakh River; at other sites, all geese were adults (Table 2, Fig. 7). All EPLWFG and other goose sightings obtained during aerial surveys are accessible on the Goose, Swan and Duck Study Group of Northern Eurasia website at http://rggsurveys.ru/.

Discussion

We excluded all unidentified geese (5.4% geese in mixed flocks) from the estimate of EPLWFG abundance. At the key moulting site – on the San-Yuryakh and Kyuanekhtyakh Rivers – 89.5% of the tracked geese detected were moulting on the rivers (Solovyeva *et al.* in press). Given the GPS locations of the tracked geese, the survey was planned to follow the line of the rivers, which was an easy task because they did not exceed 530 m in width. A total of 8,280 EPLWFG were counted on both rivers combined during the survey (Table 2).

We estimated the number of EPLWFG in the vicinity of Svaytoy Nos Cape at 7,914 (Table 2); however, we recommend that more intensive surveys are undertaken in future covering this area.

An early version of the EPLWFG summer range model suggested, from environmental predictors, that there are suitable habitats for the species on both Bolshoy and Maly Lyakhovskiy Islands. However, one of the authors (DS) insisted on excluding the arctic archipelagos from the analyses because of a lack of evidence in the literature for EPLWFG occurring there (Tian *et al.* 2021). A recent study has helped

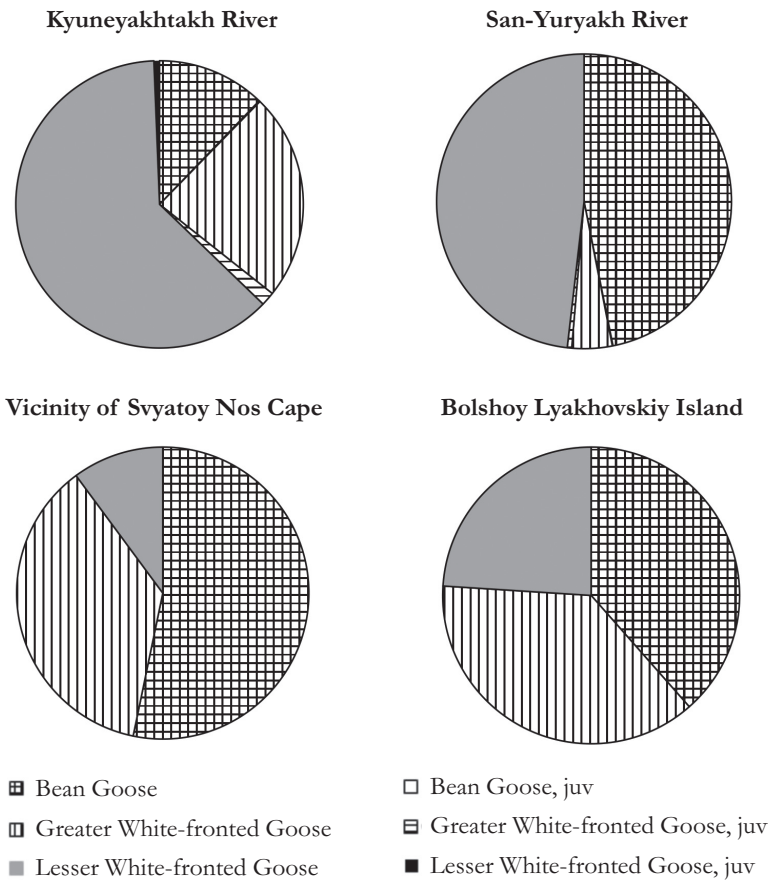

Figure 7. Proportions (and age classes) of different goose species seen in mixed flocks during the annual moult at the main EPLWFG moulting areas.

to correct this misinterpretation. Climate change in recent years means that conditions on Bolshoy Lyakhovskiy Island are now suitable for moulting EPLWFG (Yu *et al.* 2017). Detailed avian studies on the Bolshoy Lyakhovskiy Island were undertaken in the early 1950s, when no EPLWFG were listed on the island (Rutilevskiy, 1958). Subsequent reviews of LWFG distribution also did not report EPLWFG from anywhere in the arctic archipelagos (Morozov & Syroechkovski Jr 2002; Cao *et al.* 2018; Morozov 2021). In our study, a total of 4,181 EPLWFG was estimated (based on 504 individuals counted during surveys on Bolshoy Lyakhovskiy Island (Table 2).

The Lena River Delta appears to be a moulting site for the westernmost EPLWFG (geese from the East Asian Continental Flyway, whose northern limit follows the Lena River; see details of this flyway in Deng *et al.* 2020). The total number of

EPLWFG moulting in the Lena Delta is estimated at 253 individuals (Table 2).

The moulting site on the Bolshaya Kuropatoch'ya River was discovered through the tracks from two adult EPLWFG, known to breed on the Rauchua River 600 km away (Solovyeva *et al.* in press; see Solovyeva & Vartanyan 2011 for details of the Rauchua River birds). It remains unclear if the Bolshaya Kuropatoch'ya River has a moulting site of local importance, but we suggest that the Bolshaya Kuropatoch'ya River is at least an important moulting river for the EPLWFG breeding in Chukotka, although we lack data to confirm its numerical importance.

On extrapolating counts recorded along the aerial survey transects to the carefully selected total expanded area, we estimate a potential total of 24,060 non-breeding and failed breeding adult EPLWFG. Considering that 10% of successful breeders had remained on their breeding grounds (Solovyeva *et al.* in press), the total EPLWFG adult population would be estimated at 26,733 individuals, excluding offspring of the year. This estimate is 1.5–4 times higher than previous EPLWFG population estimates derived from counts made on the wintering grounds (Jia *et al.* 2016; Ao *et al.* 2020). It therefore seems reasonable to estimate the EPLWFG population size at concentrated moulting sites, despite of the extreme remoteness of these sites and the expense of aerial surveys. Ground-based surveys on the wintering grounds, particularly at Dongting, Poyang, Caizi and Shengjin Lakes, currently seem to underestimate the population, potentially due to EPLWFG being missed in the middle of very large water bodies. There also remains the possibility of undiscovered wintering sites yet to be found.

It is evident that the Kyuanekhtyakh River, followed by the San-Yuryakh River, are the core areas where EPLWFG predominated in flocks of mixed goose species. The Bean Goose predominated these mixed flocks in the vicinity of Svyatoy Nos Cape, and equal proportions of Bean and Greater White-fronted Geese were present in such mixed flocks encountered on Bolshoy Lyakhovskiy Island (Fig. 7). Juvenile EPLWFG were reported only on the Kyuanekhtyakh River in this survey. The proportion of juveniles was small on the Kyuanekhtyakh River (1%; see Table 2), compared to 46.9% on medium-sized rivers in West Chukotka, which are brood-rearing habitats (Solovyeva *et al.* in press). Aerial surveys of the major moulting sites confirmed the separation of these elements of the population during the post-nesting period: non-breeding and failed breeding adult geese gathered in larger concentrations at moulting sites (important for the entire EP), while successful breeders with offspring dispersed at relative low densities on the breeding rivers by themselves.

Recommendations for future research

We propose that detailed aerial surveys of the lake tundra in the vicinity of Svyatoy Nos Cape (Fig. 3) and along the Bolshaya Kuropatoch'ya River are required in the near future. Reiterating a previous conclusion, we strongly advise against conducting ground-based field work on the San-Yuryakh and

Kyuanekhtyakh Rivers (Solovyeva *et al.* in press), because any visits to this area during the EPLWFG moulting period (and even earlier in the season) may result in the geese being displaced from these safe sites which are isolated from human access. We suggest that aerial surveys conducted over key moulting sites on a 5-year cycle would best provide estimates of population size for the EPLWFG, and also track their overall trends in abundance over time.

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References

Ao, P., Wang, X., Solovyeva, D., Meng, F., Ikeuchi, T., Shimada, T., Park, J., Gao, D., Liu, G., Hu, B., Natsagdorj, T., Zheng, B., Vartanyan, S., Davaasuren, B., Zhang, J., Cao, L. & Fox, A.D. 2020. Rapid decline of the geographically restricted and globally threatened Eastern Palearctic Lesser White-fronted Goose *Anser erythropus*. *Wildfowl* (Special Issue No. 6): 206–243.

BirdLife International. 2018. *Anser erythropus*. The IUCN Red List of Threatened Species 2018: e.T22679886A132300164. BirdLife International, Cambridge, UK. Available at https://www.iucnredlist.org/species/22679886/132300164 (last accessed on 15 November 2019).

Cao, L., Fox, A. D., Morozov, V., Syroechkovskiy, E. & Solovieva, D. 2018. D1 Eastern Palearctic Lesser White-fronted Goose *Anser erythropus*. *In* A.D. Fox & J.O. Leafloor (eds.), *A Global Audit of the Status and Trends of Arctic and Northern Hemisphere Goose Populations*, pp. 38–39. Conservation of Arctic Flora and Fauna International Secretariat: Akureyri, Iceland.

Deng, X., Zhao, Q., Solovyeva, D., Lee, H., Bysykatova-Harmey, I., Xu, Z., Ushiyama, K., Shimada, T., Koyama, K., Park, J., Kim, H., Liu, G., Xu, W., Hu, B., Gao, D., He, B., Zhang, Y., Natsagdorj, T., Davaasuren, B., Moriguchi, S., Barykina, D., Antonov, A., Stepanov, A., Zhang, J., Cao, L. & Fox, A.D. 2020. Contrasting trends in two East Asian populations of the Greater White-fronted Goose *Anser albifrons*. *Wildfowl* (Special Issue No. 6): 181–205.

Fox, A.D. & Leafloor, J.O. 2018. *A Global Audit of the Status and Trends of Arctic and Northern Hemisphere Goose Populations*. Conservation of Arctic Flora and Fauna International Secretariat: Akureyri, Iceland.

Hodges, J.I. & Eldridge, W.D. 2001. Aerial surveys of eiders and other waterbirds on the eastern Arctic coast of Russia. *Wildfowl* 52: 127–142.

Ikawa, M.-J. & Ikawa, H. 2009. Lesser White-fronted Goose *Anser erythropus* at Sarobetsu in northern Hokkaido, Japan: a preliminary report on numbers in autumn. *Ornithological Science* 8: 131–138.

Jia, Q., Koyama, K., Choi, C.-Y., Kim, H.-J., Cao, L., Gao, D., Liu, G. & Fox, A. D. 2016. Population estimates and geographical

distributions of swans and geese in East Asia based on counts during the non-breeding season. *Bird Conservation International* 26: 397–417.

Morozov, V.V. 1995. Status, distribution and trends of the Lesser White-fronted Goose (*Anser erythropus*) population in Russia. *Bulletin of Geese Study Group of Eastern Europe and Northern Asia* 1: 132–144. [In Russian with English summary.]

Morozov, V.V. 2021. Piskulka *Anser erythropus* (Linnaeus, 1758). *In* D.S. Pavlov, A.M. Amirkhanov & V.V. Rozhnov (eds.), *Red Data Book of Russian Federation*, pp. 561–563. FGBU VNII Ecologia Publishing House, Moscow, Russia. [In Russian.]

Morozov, V. & Syroechkovski Jr., E. 2002. Lesser White-fronted Goose on the verge of the Millenium. *Casarca* 8: 233–276. [In Russian with English summary.]

Rees, E.C., Cao, L., Clausen, P., Coleman, J., Cornely, J., Einarsson, O., Ely, C.R., Kingsford, R., Ming, M., Mitchell, C.D., Nagy, S., Shimada, T., Snyder, J., Solovyeva, D.V., Tijsen, W., Vilina, Y.A., Włodarczyk, R. & Brides, K. 2019. Conservation status of the world's swan populations, *Cygnus* sp. and *Coscoroba* sp.: a review of current trends and gaps in knowledge. *Wildfowl* (Special Issue No. 5): 35–72.

Rozenfeld, S.B., Kirtaev, G.V., Rogova, N.V. & Soloviev, M.Y. 2019. Results of an aerial survey of the western population of *Anser erythropus* (Anserini) in autumn migration in Russia 2017. *Nature Conservation Research* 4: 29–36.

Rozenfeld, S.B., Popovkina, A.B., Soloviev, M.Y., Kirtaev, G.V. & Rogova, N.V. 2023. Experience in assessing the abundance and spatial distribution of geese on the Taimyr Peninsula using the aerial survey method. *Trudy Zoologicheskogo Instituta RAN* 327: 643–658. [In Russian with English summary.]

Rutilevskiy, G.L. 1958. Birds of the Bolshoy Lyakhovskiy Island. *Problemy Arctiki* 4: 79–90. [In Russian.]

Solovieva, D. & Vartanyan, S. 2011. Lesser White-Fronted Goose *Anser erythropus*: good news about the breeding population in west Chukotka, Russia. *Wildfowl* 61: 108–118.

Solovyeva, D.V., Liu, P., Antonov, A.I., Averin, A.A., Pronkevich, V.V., Shokhrin, V.P., Vartanyan, S.L. & Cranswick, P.A. 2014. The population size and breeding range of the Scaly-sided Merganser *Mergus squamatus*. *Bird Conservation International* 24: 393–405.

Solovyeva, D.V., Barykina, D.A., Kirtaev, G.V., Danilova, V.V. & Rozenfeld, S.B. 2023. The Tundra Swan, *Cygnus columbianus* (Anatidae), in the East Asian Arctic: Trends and Ranges of Various Flyway Populations. *Biology Bulletin* 50: 1908–1919.

Solovyeva, D., Lei, J., Tian, H., Fan, R., Vartanyan, S., Danilov, G., Barykina, D., Meng, F., Lu C., Lei, G. & Zeng Q. In press. Breeding and molting ecology of the Eastern population of Lesser White-fronted Goose *Anser erythropus* from GPS-GSM tracking. *Bird Conservation International* 00: 000–000.

Tian, H., Solovyeva, D., Danilov, G., Vartanyan, S., Wen, L., Lei, J., Lu, C., Bridgewater, P., Lei, G. & Zeng, Q. 2021. Combining modern tracking data and historical records improves understanding of the summer habitats of the Eastern Lesser White-fronted Goose *Anser erythropus*. *Ecology and Evolution* 11: 4126–4139.

Yu, Q., Epstein, H., Engstrom, R. & Walker, D. 2017. Circumpolar arctic tundra biomass and productivity dynamics in response to projected climate change and herbivory. *Global Change Biology* 23: 3895–3907.

Photograph: Lesser White-fronted Goose fitted with a GPS tag on release in Chukotka, by CEAAF BFU, China.

Photograph: Brood-rearing flock of Lesser White-fronted Geese in West Chukotka, by Diana Solovyeva.

