Estimating the autumn staging abundance of migratory goose species in northern Kazakhstan

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Abstract

Northern Kazakhstan and adjoining areas of Russia have vitally important autumn staging sites for arctic breeding geese, especially for the globally threatened Lesser White-fronted Goose *Anser erythropus* (LWfG) and Red-breasted Goose *Branta ruficollis* (RbG). Part of the Fennoscandian and the entire Western Main subpopulations of LWfG and the global population of RbGs are believed to stage there, which facilitates obtaining up-to-date population estimates for these species. A total of 80 lakes were surveyed across four survey areas in autumn 2016, recording more than 1.2 million geese in the region. Greater White-fronted Geese *Anser albifrons* (GWfG) were the most abundant with an estimated *c.* 890,000 birds, with counts of *c.* 250,000 Greylag Geese *Anser anser, c.* 53,000 Ruddy Shelduck *Tadorna ferruginea*, *c.* 39,100 RbG and *c.* 32,000 LWfG also recorded during the surveys. Based on *a priori* lake classification for both LWfG and RbG, to stratify survey lakes in order to generate total population estimates, survey teams visited a sample of different lake types. After removing lakes smaller than the observed minimum lake size used by each species, the total number of potential lakes available within the core staging

areas of each species (335 lakes of > 320 ha for LWfG; 361 lakes of > 100 ha for RbG) was calculated. Bootstrapping procedures, with replacement, were then used to estimate the total numbers likely to be present in the region. These calculations produced total estimates of 34,250 birds (95% confidence intervals = 28,500–40,100 birds) for the Western Main population of LWfG (well in excess of current population estimates of 8,000–13,000 individuals) and an estimated population of 50,100 RbG (95% CI = 28,100–72,600 birds), broadly similar to recent population estimates of 55,000–57,000. We recommend that future surveys continue to monitor as large a region and as many lakes as possible in order to capture inter-annual variation in the distribution of birds and to provide more reliable assessments of population size and trends of these migratory species.

Key words: *Anser erythropus, Branta ruficollis,* flyway population estimates, sampling methodology.

The wetlands and lakes of northern Kazakhstan and adjacent parts of Russia rank among Central Asia's most extensive and important areas for Anatidae (ducks, geese and swans) and other waterbirds (Cresswell *et al.* 1999; Yerokhov 2006). These wetlands support significant numbers of Anatidae species, including species listed by the International Union for Conservation of Nature (IUCN) as being of global conservation concern such, as the White-headed Duck *Oxyura leucocephala* (classed as Endangered) and Ferruginous Duck *Aythya nyroca* (Near Threatened in IUCN 2016). The region is also vital for large numbers of arctic-breeding geese staging *en route* to/from wintering grounds further south, and which use the many lakes in spring and autumn for safe roosting by night while feeding by day on the extensive wheat stubble fields and steppe habitats characteristic of this region (Kamp *et al.* 2015). These include the globally threatened Lesser White-fronted Goose *Anser erythropus* (hereafter referred to as LWfG; classed as Vulnerable; IUCN 2016) and Red-breasted Goose *Branta ruficollis* (RbG; Vulnerable), as well as large numbers of the Greater White-fronted Goose *Anser albifrons* (GWfG; Least Concern).

While these areas of Kazakhstan and Russia are important for many species of wildfowl, they are of particular significance for the LWfG and RbG. This is because it is believed that the entire Russian Western Main subpopulation of LWfG (~10,000–21,000 birds; Fox *et al.* 2010) and part (annual average of 50%; T. Aarvak & I.J. Øien unpubl. data) of the Critically Endangered Fennoscandian subpopulation (~100–150 birds; Lorentsen *et al.* 1998; Fox *et al.* 2010) use the area during migration. For RbG the entire global population (~56,000 birds; Wetlands International 2016) is also thought to pass through this area in a 3–5 week period each year (Jones *et al.* 2008; Cranswick *et al.* 2012). Very large numbers of GWfG migrate through the region at the same time, including birds from all four geographically distinct populations of this species (Mooji

1996) which breeds across the arctic Russian tundra from the Kanin Peninsula to the Taimyr Peninsula.

The presence within a short time window of so many geese in a relatively restricted area of Kazakhstan and Russia has previously been identified as an opportunity to determine population sizes, to monitor population trends and assess the breeding success of these species (*e.g.* Gurtovaya *et al.* 1999; Markkola *et al.*1997). Obtaining an up-to-date population estimate for the Western Main LWfG subpopulation is one of the key priorities of the AEWA Lesser White-fronted Goose International Working Group. Surveys of migratory geese in the region have been undertaken by international teams in spring and autumn in previous years (*e.g.* Aarvak *et al.* 2004; Gurtovaya *et al.* 1999; Markkola *et al.*1997; Tolvanen *et al.* 1999a, 2000, 2001; Tolvanen & Pynnönen 1997), and more recently counts have been made by staff from the Association for the Conservation of Biodiversity of Kazakhstan (ACBK) and other Kazakh and Russian ornithologists (*e.g.* Rozenfeld 2011; Rozenfeld *et al.* 2009; Yerokhov *et al.* 2000, 2004). Such studies have produced estimates of migrating numbers, knowledge of key lakes and an assessment of threats to the geese (Yerokhov 2013). These studies also found high levels of inter-annual variability in numbers recorded both within and between sites. This poses the question as to whether such variability results from genuine changes in goose abundance from year to year, or from sampling variation and error caused by varying patterns of distribution and/or migration phenology and the inherent difficulty in obtaining accurate counts of migratory geese. These estimates are based upon counts made at a relatively small number of lakes within a very large overall staging area (~920,000 km^2; see Methods), containing thousands of lakes potentially used by the geese, and where the birds move between lakes and feeding grounds throughout the day. Moreover, estimates at a site are based upon counting geese as they depart from lakes at dawn or arrive at dusk in flocks numbering tens to hundreds of thousands of birds, while species and age distribution is recorded when the geese return to the lakes during daytime to drink and rest. Numbers obtained from such counts also depend upon the timing of the surveys in relation to the peak migration period. Counts and population estimates of LWfG are further complicated by the very similar appearance of this species to GWfG (Øien *et al.* 1999) and their presence within large mixed species flocks where LWfG typically occur as a small proportion (~5–10%) of the total.

Such challenging situations in the field require resolution, not only for interpreting previous counts from northern Kazakhstan and Russia, but also to determine the best methods for assessing overall population sizes and longer-term trends into the future. Here, we report on the results from counts carried out by Kazakh and international goose experts between 24 September and 16 October 2016 from a stratified sample of sites based on an *a priori* categorisation of the maximum number of LWfG and RbG recorded at lakes across the study region. Bootstrapping the counts recorded in relation to these lake categories was

undertaken in order to produce the first total population estimates for LWfG and RbG passing through the region.

Methods

Study area

A database of records of LWfG in the region, covering 12 surveys between 1997 to 2015, was used to define the overall study area based on the outermost coordinates of sites where this species had been recorded (48.83°–55.78°N and 59.60°–74.15°E, encompassing an area of 923,350 km^2; Fig. 1). While some migrating geese may occur outside this range, we consider it likely – based on satellite tracking and observations (Lorentsen *et al.* 1998; Aarvak & Øien 2003) – that the vast majority of the staging populations of LWfG and other migratory goose species would occur within this area.

Categorising sites and sampling strategy

The database of sites (as above) was combined with lakes listed in Yerokhov (2013) and by the AEWA LWfG International Working Group (AEWA LWfG IWG, unpubl. data), as well as searches of Important Bird Areas (IBAs) on the BirdLife website (http://datazone.birdlife.org/home) for Kazakhstan, Central Asian and European regions of Russia using the search terms: "*Anser erythropus*", "*Anser albifrons*", "*Branta ruficollis*", "*Anser*" species and "A4iii" (*i.e.* sites known or thought to

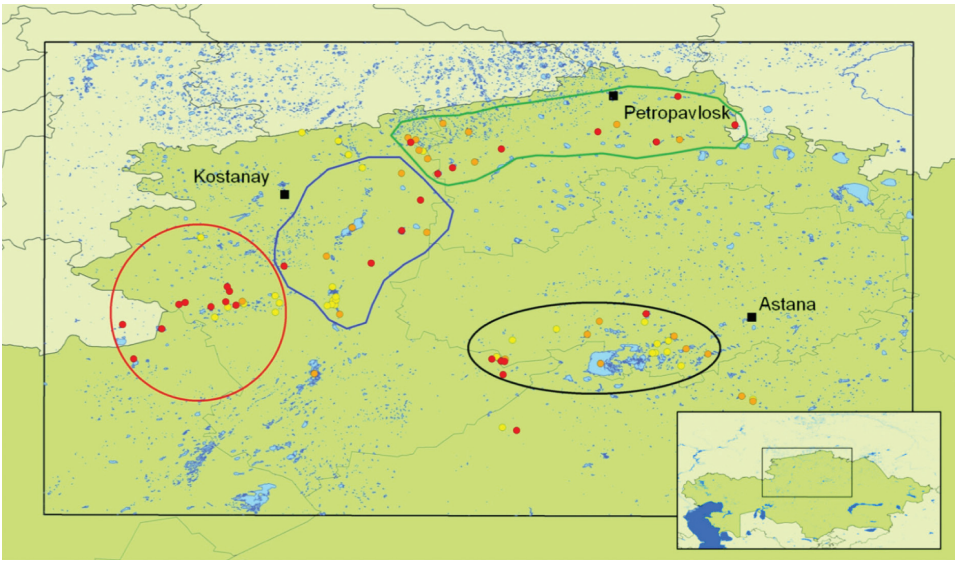

Figure 1. Map of the four survey areas indicating the West Kostanay (red line), North Kostanay (blue), North Kazakhstan (green) and Akmola (black) survey areas and Category 1 (red filled circles), Category 2 (orange) and Category 3 (yellow) sites (see Methods). The insert map (lower right) shows the study area within northern Kazakhstan and in relation to neighbouring countries.

hold, on a regular basis, > 20,000 waterbirds). After removing duplications, this provided a final list of 85 lakes within the study area where migratory geese and waterbirds were known or likely to occur. Previous surveys and satellite tracking of LWfG (Morozov & Aarvak 2004) have identified the Kulykol Lake (51.37°N, 61.86°E) and Taldykol Lake (51.40°N, 61.96°E) system in West Kostanay, and also Zhetykol Lake (51.03°N, 60.97°E) in the neighbouring Orenburg oblast of Russia, as likely to be of critical importance because of the large numbers of LWfG and other geese recorded here. These three lakes therefore were prioritised for surveys. The remaining 82 lakes were then split into three categories, based on the lower limit of the estimated global population of LWfG (a range of 8,000–13,000 individuals; Jones *et al.* 2008) and the estimated global population of RbG (56,000 birds; Wetlands International 2016). LWfG sites with previous maximum counts of > 10% of the global population (*i.e.* > 800 birds) were classified as "Category 1" sites, those with maximum counts of between 1–10% of the population (80–800 birds) were "Category 2", and those with counts of < 1% of the population (< 80 birds) were "Category 3" sites. The same rationale was applied to RbG, sorting Category 1, 2 and 3 lakes by a 10% and 1% threshold (5,600 and 560 birds, respectively). Finally, and for both species, we defined all remaining lakes (where we had no prior information on goose numbers or knowledge of their suitability as a staging site) as "Category 4" sites.

Four teams, each consisting of Kazakh and international experts, simultaneously covered different regions in northern Kazakhstan (West Kostanay, North Kostanay, North Kazakhstan and Akmola; see Fig. 1) in autumn 2016. The West and North Kostanay teams undertook circular routes that started and finished at the city of Kostanay, with the West Kostanay team also surveying Zhetykol Lake in Russia. The North Kazakhstan and Akmola teams started from Kostanay and travelled eastwards finishing at Petropavlovsk and Astana, respectively. Each survey team visited Category 1–3 lakes across each region, with the sequence of lakes visited determined by the route and constraints of road and weather conditions. Very isolated or distant lakes were excluded due to time constraints, as were sites in border regions where visits were not permitted. Category 4 sites were visited opportunistically during travel time between other lakes. A full list of lakes in all four survey areas, with latitude and longitude of count locations, is reported in Cuthbert & Aarvak (2016). To reduce the potential for duplicate counts of migrating geese, teams counted the most important sites within each survey area within an eight day period (28 September to 4 October 2016). These priority sites were: Kulykol and Taldykol in West Kostanay; Koybagar in North Kostanay; Balikty in North Kazakhstan; and Kazkhsky Zharkol and Taldykol in Akmola. Lakes Kulykol, Taldykol and Koybagar were subject to repeat visits to increase the likelihood that peak number of birds would be observed during the survey.

Field survey methods

Geese were surveyed following methods adapted from Tolvanen *et al.* (1999b), with

estimates based on total counts of all geese departing from or arriving at roosting lakes in the 2–3 h period after dawn and before dusk, respectively, and the subsequent identification of species composition through observing birds in flocks during the middle hours of the day when they returned from the feeding fields to the lakes to drink and rest. Ruddy Shelduck *Tadorna ferruginea* were also included in these counts, as this species was frequently found within mixed species flocks and often could not be separated from geese during crepuscular counts. For smaller flocks (*i.e.* of hundreds or thousands of birds) all returning geese were identified to species or species group (see below) and this occurred at 59 of 66 lakes where geese were present. When very large numbers (*i.e.* tens of thousands) returned, species composition was estimated from identifying every fifth bird in the flock (*c.f.* Tolvanen *et al.* 1999b when samples of 20–30 birds were identified). This sampling method was adopted to increase the precision of the resulting estimates due to the tendency for geese species to group in flocks of their own kind (especially in family units), which invalidates the assumption of random mixing and causes less precise estimates when samples of 20–30 birds are counted in blocks as undertaken previously (see Cuthbert & Aarvak 2016). At some lakes photography of flocks was also used to supplement species identification, with species composition evaluated afterwards from images. This was undertaken primarily at four lakes in the Akmola survey area, where very large numbers of birds were present.

Geese were identified to species based on established field guides and with LWfG separated from GWfG on the basis of their eye ring, colour of head and neck, and colour and shape of bill (as detailed in Øien *et al.* 1999). For LWfG and GWfG the number of adult and juvenile birds in flocks were also recorded, as well as brood size based on juvenile birds accompanying adult pairs or single adults. Adult and juvenile birds were differentiated based on the absence of white blaze and black patches on the belly in juveniles, as well as other features detailed in Øien *et al.* (1999). Where light or other conditions prevented identification to species level geese were identified to the nearest species group. These groupings included GWfG/LWfG where it was certain the birds were "White-fronted Geese" but where identification of these very similar species could not be definite. *Anser* species included birds that were clearly "grey geese" but where identification to GWfG/LWfG or Greylag Geese *Anser anser* was not possible. *Anser/Branta* species related to counts which included unidentified grey geese and RbGs and *Anser/Branta/Tadorna* species where mixed flocks of geese may have included grey geese, RbGs, and Ruddy Shelduck. Observations of migrating geese were also made during the surveys, recording species or species group, total numbers and flight direction.

Calculating total numbers recorded during the survey

Most lakes (59 of 66 lakes with geese) were surveyed completely and without sampling, with all birds present counted and species identified during commuting flights to the roost in late afternoon/evening, and also during counts made of commuting birds

departing from the roost next morning. The highest count recorded during a morning or evening flight was used as the total number present at the site. At Kubikol, Tengiz, Kumdykol and Shandykol Lakes in the Akmola region, at Taldykol and Kulikol Lakes in West Kostanay and at Zhetykol Lake in Russia, total numbers were estimated using the methods described below.

Taldykol and Kulikol Lakes. Because of its known importance for migratory geese, 17 counts were made at the Taldykol/Kulikol Lake system between 26 September and 11 October 2016. Geese regularly moved between these two neighbouring lakes and, given their close proximity (2.5 km apart at their nearest point), a single count of 348,150 mixed geese and shelduck (*Anser/Branta/Tadorna* species) observed at the lakes between 19:00–19:45 h on 6 October was taken as the maximum count for both sites. The total number of each species was then estimated from counts undertaken between 15:15–19:00 h on the same day as the maximum count, when ~5,000 birds were observed flying from Lake Taldykol to stubble fields to the west/northwest of the lake. During this period species identification was undertaken for each bird in multiple small flocks that totalled 1,552 individuals. Species composition of birds in four larger flocks (comprising 3,880 unidentified geese in total) was undertaken by identifying every fifth bird in these four flocks; a total of 676 birds was identified to species level in this manner. As with previous surveys in the region (Tolvanen *et al.* 1999b), this approach assumes that the species composition of birds feeding in stubble fields is the same as the species composition of birds roosting on the lakes. A weighted average (equivalent to a "single group summary" in a meta analysis, which incorporates information on the total number of birds and the proportion of birds in each sample) of the overall prevalence of each goose species within these five samples was then calculated following the methods detailed in Neyeloff *et al.* (2012). To calculate a weighted average in this manner we first evaluated the heterogeneity of species composition among flocks based on an I^2 statistic which describes the percentage of variation across the counts likely due to heterogeneity rather than chance. In all of the flocks counted there was high variation in species composition in the sampled flocks and consequently we used a "random effects model" (in the context of a meta-analysis; Neyeloff *et al.* 2012) to calculate the weighted average with 95% confidence intervals. A continuity correction of 0.5 (Cox 1970) was used for all instances where there was a zero count for a species, in order to calculate I^2.

We calculated total number of each species (± 95% CI) at the Taldykol/Kulikol Lake system based on the following expression:

$$\text{Total } N_{\text{species A}} = \text{Total } N_{\text{mixed geese}} * \text{weighted average}_{\text{species A}}$$

Zhetykol Lake. As it was difficult for survey personnel to cross the Kazakhstan/Russian border, counts at Zhetykol Lake could be undertaken only by a single observer, and the relatively high numbers of birds present meant that counts of species composition were approximate. We therefore used a maximum count of 73,500 mixed geese seen on 9 October 2016 and the

weighted average on the prevalence of each species (as above) from observations on 8, 9, 10 and 11 October in the analyses. We considered the weighted average and 95% confidence intervals of these four proportions to be a better approximation of each species present at the lake than using any single sample. Species totals were calculated in the same manner as for the Taldykol/Kulikol Lake system.

Kubikol, Tengiz, Kumdykol and Shandykol Lakes. At Kubikol, Tengiz, Kumdykol and Shandykol in Akmola, a total count of all geese present on the lakes was first obtained by the team during either the dawn or dusk count; this was an estimate for all *Anser/Branta/Tadorna* species combined, with no attempt at species identification. Species composition was then calculated by counting and identifying as many birds to species level as possible during the day, together with photographs taken of "unidentified flocks" during poor light conditions near dusk when direct identification of species was not possible. Composition for the flocks of "Unidentified Species" was calculated based on photography of flying birds and the proportion of species present in these flocks. Because species identification from photographs was a sample of the total number, we calculated 95% binomial confidence intervals for these proportions based on the inverse Fisher F probability function within Excel. Totals estimated for each species at the site were then based on the sum of the number identified through direct counts and the estimated number within the remaining Unidentified Species group, as follows:

$$\text{Total } N_{\text{species A}} = N_{\text{direct count species A}} + [N_{\text{Unidentified Species}} * \text{proportion}_{\text{species A}}]$$

This approach assumes that there was no systematic bias in the species composition of birds returning after dusk.

Species totals for remaining unidentified species groups

Direct observations or classification from sampling meant that most observations across all four survey regions (93%) could be determined to the level of individual species; however, 91,455 birds remained unidentified at species level. Such records were recorded from all four survey areas, although large numbers of migrating birds in the North Kostanay and North Kazakhstan regions resulted in a high number of observations of GWfG/LWfG in these two areas (8,085 and 11,156 birds, respectively), and restricted access at Lake Kozhakol (Akmola) meant that 45,000 geese could only be identified as "*Anser* species".

Estimates of the likely overall species composition of these groups (and by extension calculation of total numbers) were undertaken for all areas combined, calculated by taking the weighted average proportion of identified species across all sites where geese were recorded following Neyeloff *et al.* (2012) and the methods outlined previously, and weighted by the number of birds present at each site. These calculations were undertaken separately for each species within the species grouping as set out below for estimating the predicted total numbers of LWfG within mixed flocks of GWfG/LWfG:

$$\text{Total } N_{\text{LWfG}} = N_{\text{direct counts LWfG}} + [N_{\text{GWfG/LWfG}} * \text{weighted average}_{\text{LWfG}}]$$

The estimated number of each species was summed across all species groups where it could have occurred and with species composition matching the observed proportions in other flocks where they were conclusively identified to species level. For example LWfG were observed to comprise 3.5%, 2.7%, 2.6% and 2.5% of the species composition of mixed flocks of "GWfG/LWfG", "*Anser*", "A*nser/Branta*" and "*Anser/Branta/Tadorna*", respectively, and these proportions were then applied to these species groups where further identification was impossible in order to provide an estimate of LWfG numbers. While this approach is an assumption it was applied to only a small proportion (7%) of the total number of observations.

Estimating global populations of Lesser White-fronted and Red-breasted Geese from the core staging areas

The lakes monitored during the survey represent a sample of all available potential lakes within the study area, and geese will undoubtedly occur at sites that were not visited. These sites included some Category 1–3 lakes where the constraints of time and distance precluded visits, as well as an unknown number of Category 4 lakes where we have no prior knowledge of their potential for supporting staging LWfG or RbG and where it was only possible to visit a sample of such lakes. The total population estimate was derived from the sum of the average number (μ) of geese recorded within a lake category multiplied by the number of sites (N) in each of the four categories. Thus for LWfG this would be:

$$\text{Total population}_{\text{LWfG}} = (\mu_{\text{LWfG Cat 1}} * N_{\text{Cat 1}}) + (\mu_{\text{LWfG Cat 2}} * N_{\text{Cat 2}}) + \ldots$$

Because LWfG and RbG counts were not normally distributed and highly overdispersed we utilised bootstrapping procedures (which make no assumptions regarding the underlying distribution of data) with samples taken with replacement from all observed counts (including zero counts) within each lake category in order to extrapolate numbers to include unvisited Category 1–3 sites. A final population estimate and confidence intervals calculated in this manner also depends upon extrapolating the number of geese potentially present at unvisited Category 4 lakes and including them in the total. We decided to define the number of Category 4 lakes potentially used by migratory geese based on: (a) the minimum lake size where LWfG or RbG were observed to occur in 2016 (around 320 ha and 100 ha, respectively), and (b) the plausible geographic distribution of these two species within the entire study area. Records from 2016 and earlier years indicated that these two species were mainly staging in two core areas that consisted of lakes distributed across North Kazakhstan and the northern areas of Kostanay Province, along with a further core area in the southern regions of Akmola Province (see Results). These core areas corresponded closely with areas of northern Kazakhstan where croplands formed 10–25% and 25–50% of the land area and with forest cover of < 10% (Figs. 2 & 3). We applied a buffer of 20 km

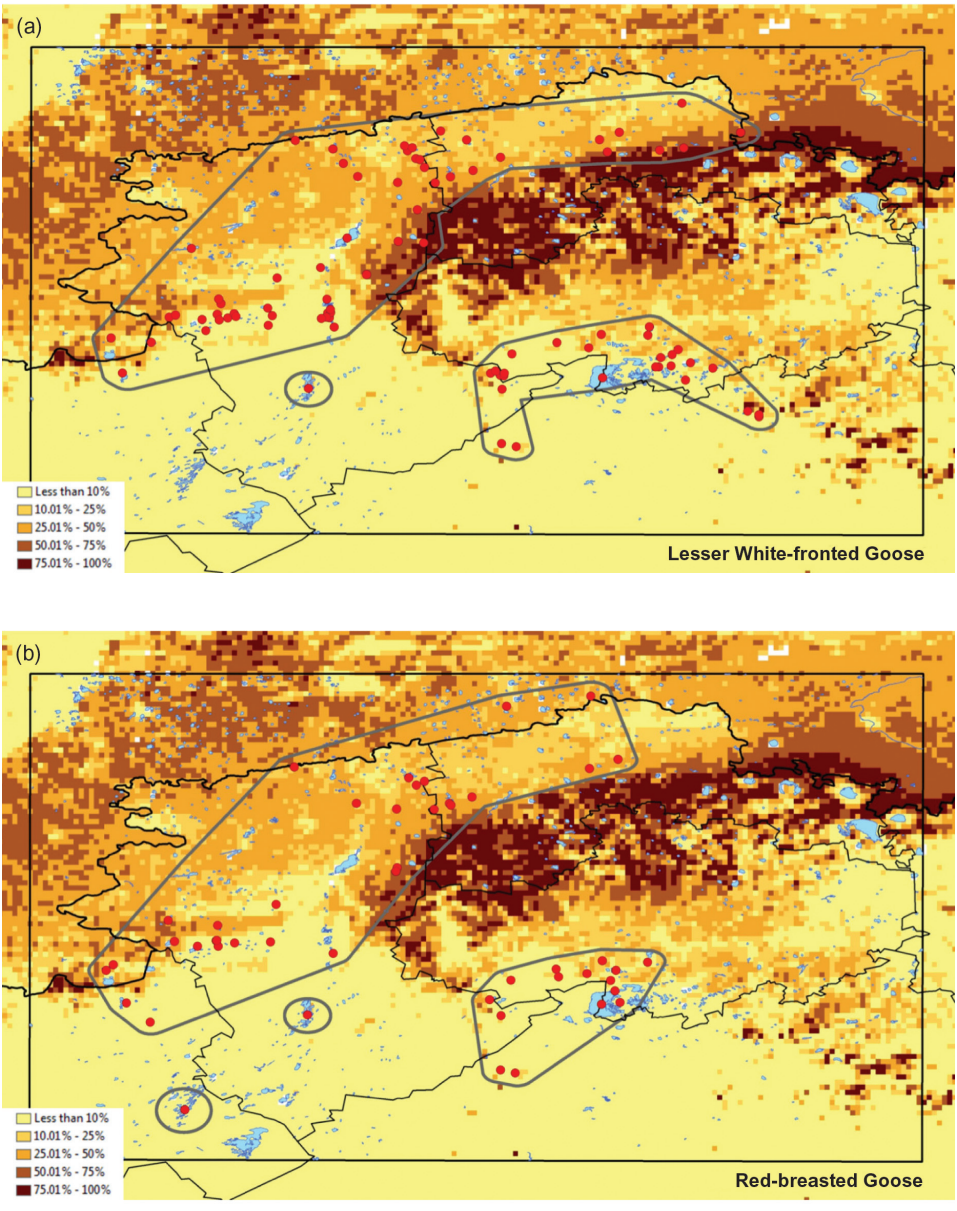

Figure 2. Known locations (red circles) of (a) Lesser White-fronted Geese, and (b) Red-breasted Geese and their core areas (polygons with grey lines) plotted on the extent of occurrence of croplands (given as %) in the region. The overall study area is indicated (rectangle), along with regional and national boundaries.

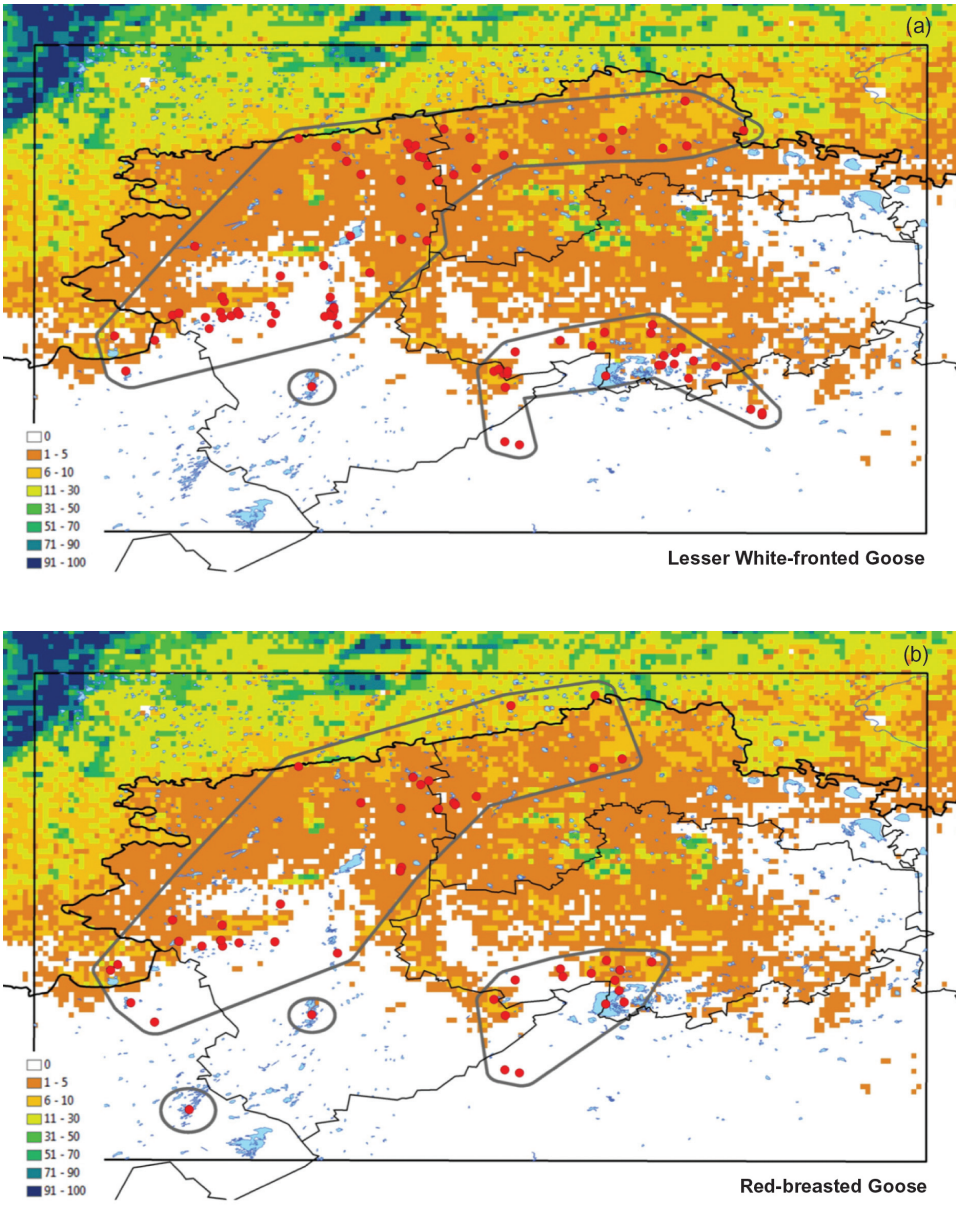

Figure 3. Known locations (red circles) of (a) Lesser White-fronted Geese, and (b) Red-breasted Geese and their core areas (polygons with grey lines) plotted on the extent of forest cover (given as %) in the region. The overall study area is indicated (rectangle), along with regional and national boundaries.

to the resulting polygons of core areas (in Arc Map 10.2 software), based on the reported foraging range of GWfG (Kear 2005), in order to ensure that the areas captured lakes and wetland areas that were likely to be within the range of foraging geese. The resulting buffered polygons were then used to determine the total number of lakes of > 320 ha and > 100 ha within the core area of LWfG and RbG, respectively, in order to provide a more plausible estimate of the number of available Category 4 lakes.

A total of 10,000 bootstrap samples were derived in this manner in order to calculate a mean population estimate, and the 95% confidence intervals were calculated by selecting the lower 2.5% and upper 97.5% quantiles from the set of 10,000 estimates. Given the number of assumptions associated with the number of unknown Category 4 sites, we undertook these bootstrapping procedures for LWfG and RbG including all categories of lake (1–4 sites) in the study area, as well as just for Category 1–3 sites where previous surveys had recorded these species.

Table 1. Number of lakes identified prior to 2016 as being used by Lesser White-fronted Geese and Red-breasted Geese, and also the number surveyed during the 2016 expedition. Categories 1, 2 and 3 lakes were sites where respectively > 10%, 1–10% and < 1% of the global population of each species had previously been recorded. Category 4 lakes were sites with no prior information on goose occurrence or abundance. Category 1 sites below include lakes Kulykol, Taldykol and Zhetykol, although these were analysed separately in the final analysis (see Methods). *Total = Category 1–3 sites only.

Species	Lake classification	Identified *a priori*	Surveyed in 2016	% coverage
Lesser White-fronted Goose	Category 1	28	26	93%
	Category 2	26	15	58%
	Category 3	31	9	29%
	Category 4	Unknown	30	
	Total	85*	80	
Red-breasted Goose	Category 1	10	4	40%
	Category 2	11	10	91%
	Category 3	6	3	50%
	Category 4	Unknown	63	
	Total	27*	80	

Results

Lakes covered and goose numbers recorded during the survey

More than 1.2 million geese were counted at lakes, spread across all four count regions. These lakes included sites previously identified as important for both LWfG and RbG (Categories 1, 2 and 3, as described in Methods), and an additional number of "unknown" (Category 4) sites where no previous information was available (Table 1). Geese in highly varying numbers (1–348,150 birds) were present at 66 of the 80 lakes surveyed, with the remaining sites containing no geese. Sites with zero counts included dry lakes as well as apparently suitable lakes holding water but where no geese were present.

Totals for each species and the four count areas are presented in Table 2, which indicates the very high numbers of birds in the Akmola and Kostanay West survey regions (Figs. 4–7). As for previous surveys, very high numbers of geese were recorded at the Taldykol/Kulikol Lake system, with estimated numbers for the site derived from a maximum count of 348,150 geese seen on the evening of 6 October 2016 and the proportions of each of the species present recorded on the same day. Based on these methods, these two lakes accounted for 72.5% of the total number of LWfG recorded (an estimated 23,205 geese, 95% CI = 18,750–27,650) and 44.9% of all RbG (17,550 geese, 95% CI = 1,550–33,550). Large numbers of GWfG and Greylag Geese (around 220,200 and 79,250 birds,

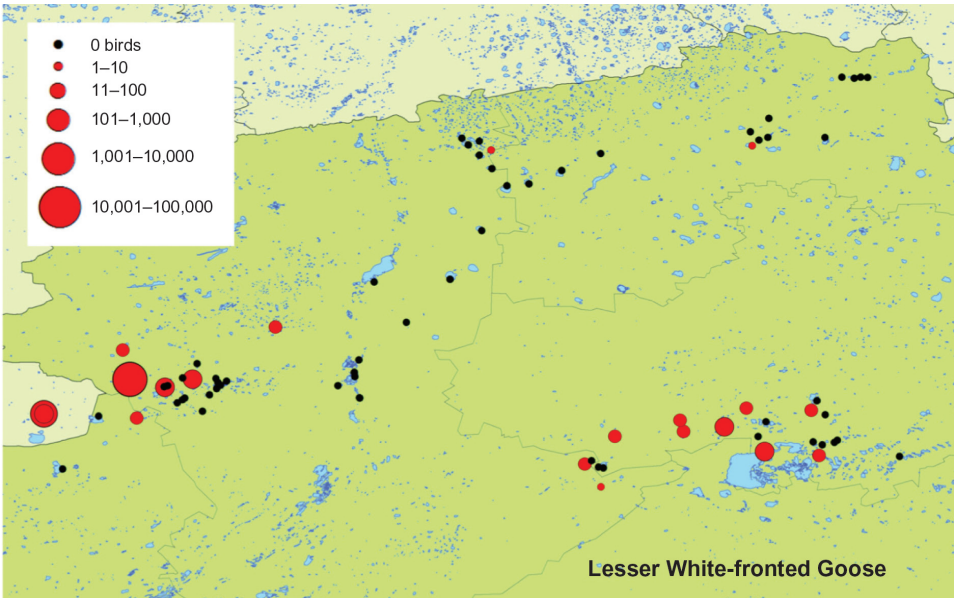

Figure 4. Location and numbers of Lesser White-fronted Goose staging at lakes in northern regions of Kazakhstan and at Zhetykol and Balakol Lakes in Russia during the autumn 2016 survey.

Table 2. Estimated total numbers of geese and Ruddy Shelduck counted across the four survey regions and the whole study area, ± 95% CI in parentheses. Lower and upper CI values are rounded to the nearest 100 birds (excepting Bean Geese which are rounded to the nearest 10), based upon the estimated number of each species within unidentified species groups. Staging geese = birds counted on the ground or water; migrating geese = birds counted flying overhead.* All species include Ruddy Shelduck.

Species/group	Akmola	Kostanay West	Kostanay North	North Kazakhstan	All areas
GWfG	586,907 (585,200–588,400)	241,599 (150,500–332,600)	229	2,533	891,300 (789,900–992,600)
LWfG	1,673 (1,200–2,400)	29,299 (23,300–35,200)	12	10	32,000 (25,400–38,700)
Greylag	104,466 (103,100–106,000)	100,163 (31,800–168,600)	1,576	12,331	248,800 (177,700–320,000)
RbG	466	32,994 (10,900–55,100)	3,269	194	37,100 (15,000–59,100)
Ruddy Shelduck	14,950	38,260 (24,000–52,500)	0	2	53,200 (39,000–67,500)
Bean Goose	0	52 (50–55)	0	4	55 (50–60)
GWfG/LWfG	0	1,699	8,095	11,156	
Anser sp.	46,200	8,946	0	5,580	
Anser/Branta	0	3,320	4,519	200	
Ans/Bra/Tad	0	1,740	0	0	
All species*	754,662	458,072	17,700	32,010	1,262,455
Goose species	739,712	419,812	17,700	32,008	1,209,255
Staging geese	739,712	415,965	13,175	16,121	
Migrating geese	0	3,847	4,525	15,887	

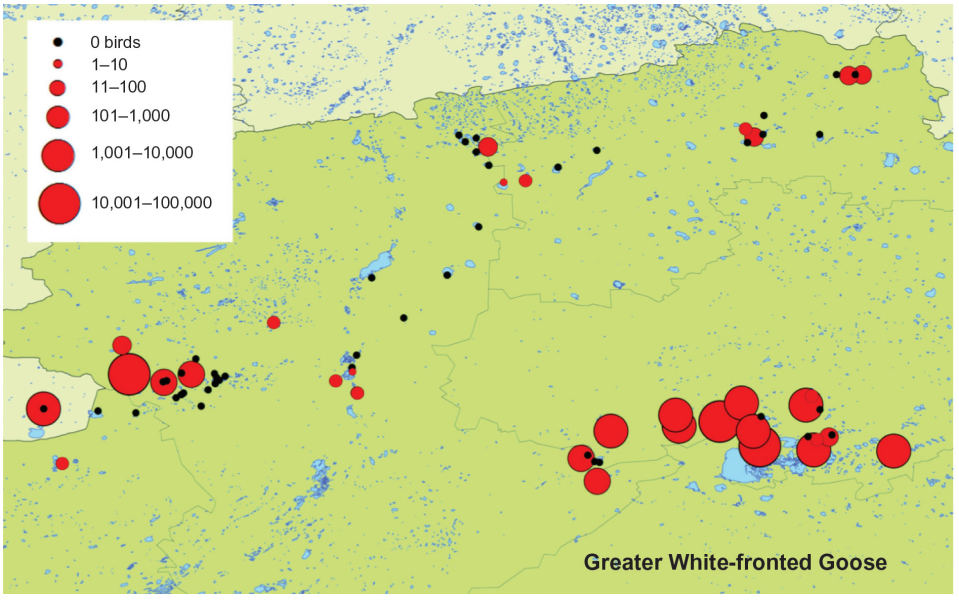

Figure 5. Location and numbers of Greater White-fronted Geese staging at lakes in northern regions of Kazakhstan and at Zhetykol and Balakol Lakes in Russia during the autumn 2016 survey.

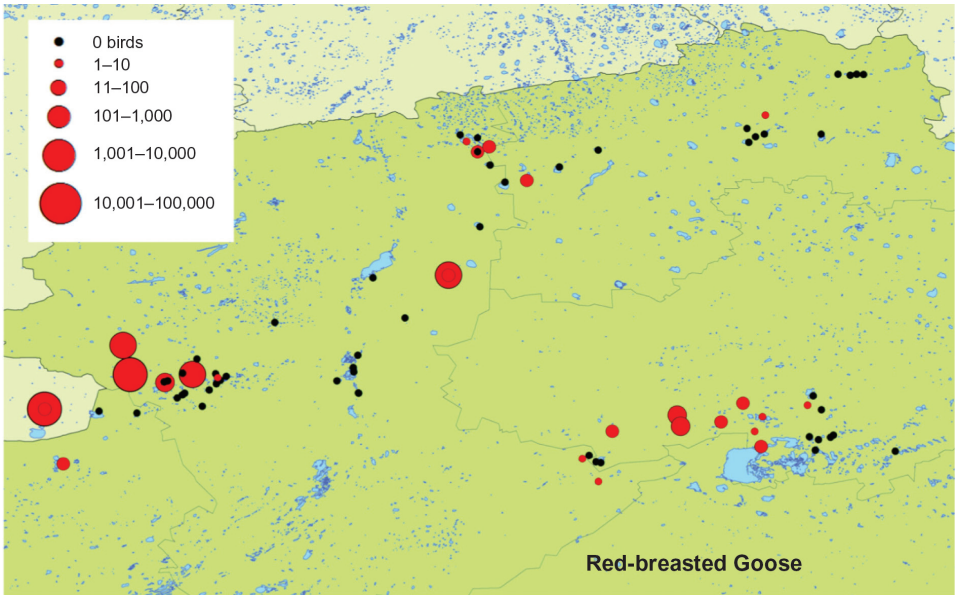

Figure 6. Location and numbers of Red-breasted Geese staging at lakes in northern regions of Kazakhstan and at Zhetykol and Balakol Lakes in Russia during the autumn 2016 survey.

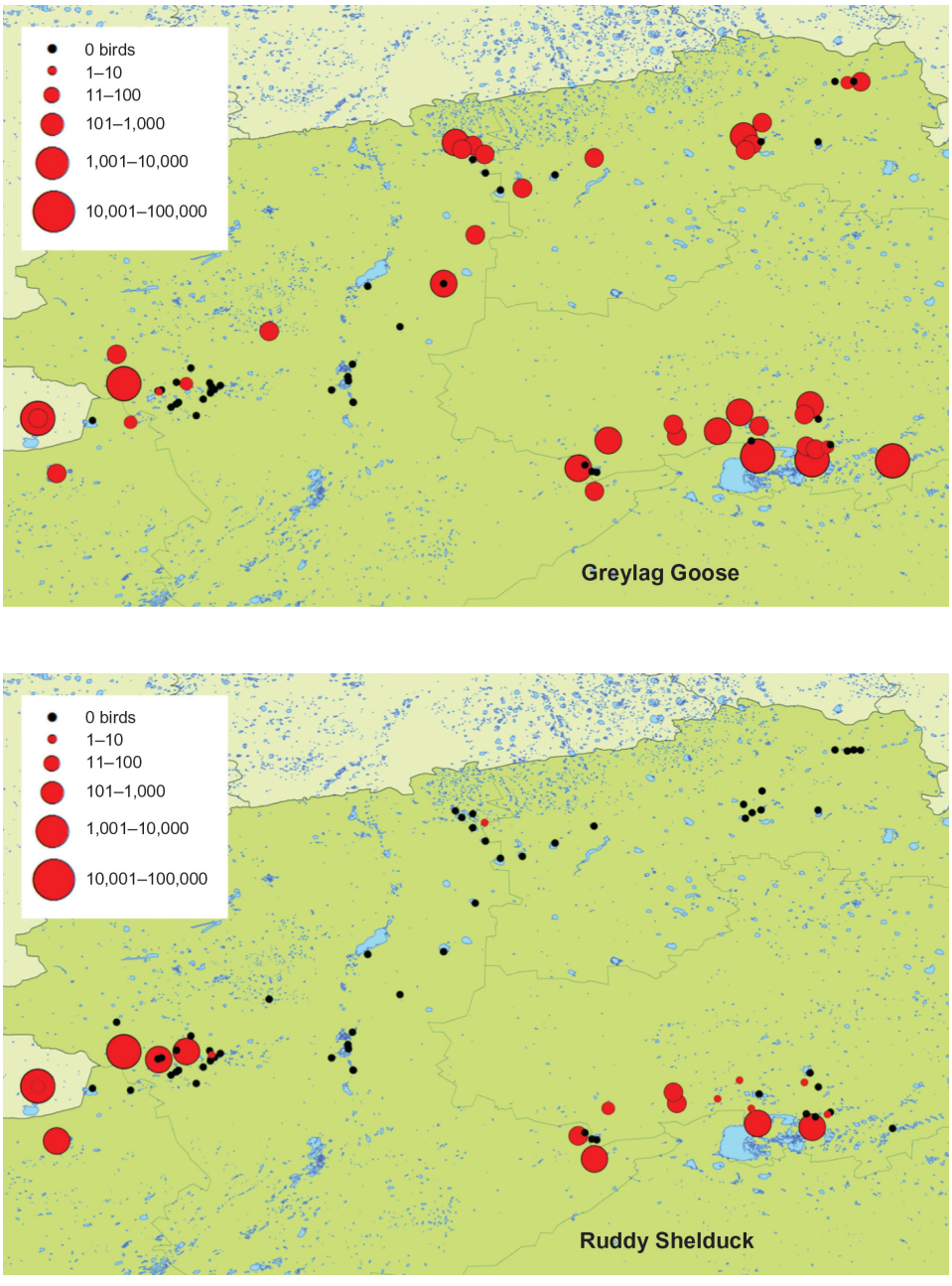

Figure 7. Location and numbers of Greylag Geese and Ruddy Shelduck at lakes in northern regions of Kazakhstan and at Zhetykol and Balakol Lakes in Russia during the autumn 2016 survey.

respectively) were also recorded at Taldykol/Kulikol; however, these species as well as Ruddy Shelduck were more widely distributed at lakes across the southern West Kostanay and Akmola count regions (Fig. 5 & Fig. 7). Comparatively few birds were seen staging at lakes or in stubble fields in the Kostanay North or North Kazakhstan areas, but large numbers of migrating geese (primarily mixed species flocks of GWfG/LWfG) were instead observed moving overhead (Table 2). Peak numbers of migrating GWfG/LWfG in these two areas were recorded between 28 September and 2 October (total of 19,824 birds counted) and with 10,321 and 2,399 birds recorded on the 29 September in North Kazakhstan and Kostanay North, respectively. A second small pulse of migration was seen in North Kazakhstan from 6–9 October with 2,293 birds seen during this period. Large numbers of Common Cranes *Grus grus* were observed migrating during these same time periods. Observations on flight direction indicated that geese in eastern areas of North Kazakhstan were predominantly flying southwards and may have been moving directly to Akmola. In contrast, GWfG/LWfG in western areas of North Kazakhstan and adjoining areas of northern Kostanay were heading southwest and may have been heading towards key lakes in western Kostanay.

Observations of 106 family groups indicated a mean brood size for LWfG of 2.5 ± 1.4 juveniles per pair (range = 1–7 juveniles, 95% CI = 2.2–2.8) and ageing of 2,403 birds estimated that 31.1% of the LWfG population were juveniles (95% CI = 33.0–39.3%). Similar observations for GWfG indicated a mean brood size of 2.86 ± 1.57 juveniles per pair (range = 1–7 juveniles, 95% CI = 2.5–3.2) based on 87 family groups, with 29.3% (95% CI = 27.0–29.5%) juveniles amongst a sample of 5,208 birds aged.

Population estimates for the Lesser White-fronted Goose and Red-breasted Goose

Sites from all four categories were visited during the expedition, although coverage for LWfG was more comprehensive than for the RbG (Table 1). Due to the low coverage of some site categories, the original site categories were combined (Table 3) in order to provide more robust samples for bootstrapping. Due to their high numbers of geese and influence on the results, data from Taldykol/Kulikol and Zhetykol were sampled separately, with bootstrapping between the calculated 95% confidence interval for each site.

Based on a minimum lake size of 320 ha, there were 335 suitable lakes within the four buffered core areas of the LWfG, which included 85 of the previously identified Category 1–3 lakes (including Taldykol, Kulikol and Zhetykol) and another 250 Category 4 lakes of unknown importance. For the RbG and a minimum lake area of 100 ha there were a total of 361 lakes within the species buffered core areas, which included 27 Category 1–3 lakes (including Taldykol, Kulikol and Zhetykol) and a further 331 Category 4 lakes. Utilising these lake categories and bootstrapping from observed count data provided an estimated total population for the Western Main

Table 3. Total number of lakes within each category identified within the study area for Lesser White-fronted Geese and Red-breasted Geese, and the reclassification and grouping of lakes and sample sizes used for the bootstrapping and percentage coverage of lakes. Category 1* sites = Taldykol Lake, Kulikol Lake and Zhetykol Lake.

Lake classification	No. of lakes	Classification for bootstrap	Sampled for bootstrap	% coverage
Lesser White-fronted Goose				
Category 1	28	Category 1*	3	100%
		Category 1	23	92%
Category 2	26	Category 2–3	24	42%
Category 3	31			
Category 4	250	Category 4	30	12%
Red-breasted Goose				
		Category 1*	3	100%
Category 1	10			
Category 2	26	Category 1–3	14	52%
Category 3	31			
Category 4	384	Category 4	63	19%

population of LWfG of around 34,250 birds (95% CI = 28,500–40,100) (Table 4). Excluding Category 4 sites from the bootstrapping produced a total estimate of 32,600 birds (95% CI = 27,000–38,200), a 5% reduction on the estimate derived from all sites. Based on the observed age ratio of birds in the 2016 expedition, this population is likely to consist of around 23,600 adults and 10,650 juvenile birds. With a non-breeding component of around 50% of the population (T. Aarvak & I.J. Øien, unpubl. data), the number of actual breeding pairs staging in Kazakhstan during the autumn migration would be approximately 5,900 pairs.

For RbG we counted 37,100 birds during the expedition, and following bootstrapping to extrapolate numbers to unvisited lakes we estimated the global population of birds passing through the region to be around 50,100 birds (95% CI = 28,100–72,600). Excluding Category 4 sites and only including the previously identified Category 1–3 sites produced an estimate of 39,100 birds (95% CI = 18,300–60,600), a reduction of 22% on the estimate from across all potential lakes.

Table 4. Estimates and 95% confidence intervals for the Western Main population of Lesser White-fronted Goose and the global population of Red-breasted Goose based on bootstrapping totals across all previously identified Category 1–3 lakes and at unknown Category 4 lakes within the core staging areas for each species.

Species	Estimate	Lower 95% CI	Upper 95% CI
Lesser White-fronted Goose			
Total population	34,250	28,500	40,100
Adults	23,600	19,100	28,350
Juveniles	10,650	8,350	13,250
Red-breasted Goose			
Total population	50,100	28,100	72,600

Discussion

The total numbers of geese recorded and sites surveyed during the study helped to provide one of the most comprehensive and robust assessments to date on the numbers of geese staging in this region of Kazakhstan, along with an understanding of some of the factors that are associated with their presence. We provide the first global estimates of RbG and of the Western Main subpopulation of LWfG derived from stratified sampling and extrapolation to unvisited sites in this important region. While these surveys rely on a number of assumptions, we believe that this approach offers a number of key advantages over more geographically-restricted surveys, and that the results provide a good baseline for future long-term monitoring of these populations.

Previous staging goose surveys in Kazakhstan tended to focus on well-known key sites such as the Taldykol/Kulikol Lake system. A principal aim of the 2016 expedition was to survey as wide an area visiting as many lakes as possible, including sampling those for which we had no prior knowledge. Simultaneous coverage avoided repeat counts of the same birds, by using four separate survey teams surveyed a total of 80 lakes across Kostanay, North Kazakhstan, Akmola and a bordering area of Russia, recording more than 1.2 million geese over the three-week autumn migration period.

Results confirmed the importance of Akmola Province and western regions of Kostanay Province for migratory geese, where the majority of the geese were found staging, including 350,000 alone at the Taldykol/Kulikol Lake system. These areas, and particularly the Taldykol/Kulikol Lake system, are of critical importance for staging LWfG, RbG and GWfG, and conservation

efforts should be prioritised here to ensure that lake developments, land use changes and hunting are undertaken in ways that do not adversely affect geese. Analyses reported elsewhere found that all goose species tended to use larger, more vegetated lakes that were more distant from settlements, suggesting that all species selected the same features and/or were stopping at lakes already holding geese (Cuthbert & Aarvak 2016). Maintenance of lake water levels and emergent vegetation at key lakes and planning constraint on new settlements are needed to safeguard the value of these to migratory geese. Lake salinity, as well as the factors above, may also influence the use of lakes by migrating geese and warrants further investigation.

Compared to very high goose numbers in the southern survey regions, relatively few geese were recorded north of Kostanay and in North Kazakhstan in 2016. Observations of migrating birds suggest that most GWfG and LWfG moved straight through directly to more southerly staging areas. Satellite tracking of LWfG, caught and equipped with transmitters during summer 2016 in the northern reaches of the Ural Mountains, confirm this migration pattern and four birds moved through Kazakhstan in the same time period as the present survey was undertaken (Morozov *et al.* 2017). All staged in border areas between Orenburg oblast in Russia and Kostanay in Kazakhstan, with two birds using Zhetykol Lake and two others using Lake Taldykol (BirdLife Norway and the Russian Research Institute for Nature Conservation, unpubl. data). The peak period of goose migration over the Kostanay North and North Kazakhstan regions during 2016 coincided with a weather front, which brought northerly winds, and it seems likely that geese were using these favourable wind conditions to migrate southwards. While the migration pattern and distribution of large numbers of birds in Akmola and Kostanay West regions appear typical (Lorentsen *et al.* 1998; Jones *et al.* 2008), it is also plausible that birds will alter their route and site use (distribution) depending on hydrological conditions of individual lakes. Many lakes in northern Kazakhstan follow a 3–4 year severe drought and dry storm cycle (Kraemer *et al.* 2015), affected by snow melt in spring (Klein *et al.* 2013). Recent studies in the Tengiz-Korgalzhyn Lake system show reduced water levels during the last two decades, which were dryer, with less precipitation and less inflow and probably increased evaporation due to significant increases in summer air temperatures (Klein *et al.* 2013). Such varying patterns of lake water levels and also salinity may heavily affect birds' use of different staging areas and the observed inter-annual variability in numbers recorded from previous surveys, highlighting the importance of surveying across the whole geographical range to assess total numbers reliably.

The estimate of around 34,250 LWFG (range = 28,500–40,100) in 2016, was more than double the previous estimate (10,000–21,000; Fox *et al.* 2010). This estimate depends critically on the interpretation of Taldykol/Kulikol Lakes counts, where we estimated 23,205 LWfG (range = 18,750–27,650 birds). This estimate was derived from a count of 350,000 mixed geese (*Anser/Branta/Tadorna* species) on 6 October and the proportion of LWfG

sampled from goose flocks moving between lakes and feeding areas on the same afternoon. Support for the reliability of this estimate comes from the fact that the proportion of LWfG in mixed goose flocks was relatively constant at these two lakes over the period 26 September to 11 October 2016. LWfG comprised 6.7% (95% CI = 5.3–7.9%) of the 6 October total compared to an overall mean proportion of 7.4% (95% CI = 6.0–8.7%) based on 17 separate surveys of these lakes (see Appendix 5 of Cuthbert & Aarvak 2016 for further details).

The population estimate for LWfG (and for RbG) was also dependent on other assumptions relating to survey design. We make the assumptions that all birds passed through the survey area were present in the survey period, that birds were not double-counted at sites, that the sample of lakes visited in Categories 1–4 were representative of all lakes in these categories, and that the core area over which we extrapolated our data was an accurate reflection of where the geese actually staged in the region. Some of these assumptions may not always have been met. For instance, selection of Category 4 sites was not truly random, because these lakes were visited within the logistics of the overall survey, although sites were "random" insofar that we had no prior knowledge about their suitability for geese. Such site selection could be refined in future to ensure a representative sample of Category 4 lakes, although here they contributed only *c.* 5% to the total population estimate. Satellite-tracking of LWfG and GWfG (BirdLife Norway and the Russian Research Institute for Nature Conservation, unpubl. data) suggested that the vast majority of geese were likely surveyed during the time and geographical area of the surveys. Four simultaneously active survey teams covered key sites within a narrow time-scale that reduced the likelihood of double-counting. Moreover, core area selection for extrapolating total LWfG and RbG numbers, and their association with GIS data on cropland and forest distribution, fits with the staging behaviour of the geese, which fed by day within the extensive wheat stubble fields and lightly wooded steppe habitats characteristic of this region. As a consequence, we consider the approach applied here to be robust given current knowledge, but which can be further refined in future surveys.

Other recent counts of LWfG lend support to there being a larger population of this species than previously estimated, with a maximum count of 19,566 LWfG recorded at Taldykol/Kulykol Lakes in 2014 (AEWA LWfG International Working Group, unpubl. data). Based on these counts alone it is likely that the total Western Main LWfG population is considerably higher than the 8,000–13,000 birds previously reported (Jones *et al.* 2008; Fox *et al.* 2010). The new and larger population estimate of 34,250 birds has important implications for understanding the extent of occurrence of the Western Main LWfG population on the breeding grounds and also for understanding their distribution during the winter months. Winter counts of the population are currently known only from the border areas of the Nakhchivan Autonomous Republic (Azerbaijan) and Iran, and possibly also other areas of Azerbaijan, Iraq and Uzbekistan, and

consist of a few thousand birds. Based on the numbers recorded in Kazakhstan in 2016, a larger proportion of the population is likely to be wintering in as yet unknown or unsurveyed locations.

The 2016 surveys also provided an estimated 50,100 RbG present (range = 28,100–72,600 birds). This estimate is also influenced by the counts at Taldykol/Kulykol Lakes and we have less confidence in these than for LWfG due to the highly variable proportions of RbG observed at these lakes (Cuthbert & Aarvak 2016). Records from Taldykol/Kulikol Lakes contributed less than half (47%) of the RbG total, with more than 19,000 birds observed at other sites. The total population estimate of around 50,100 RbG recorded in 2016, broadly accords with previous counts of 40,800 birds and 44,300 birds in the spring and winter periods of 2008 (Cranswick *et al.* 2012) and 56,860 in autumn 2010 (Rozenfeld 2011) and is close to the population estimate of 55,000–56,900 for 2009–2013 (Wetlands International 2016). Rozenfeld *et al.* (2012) reported *c.* 150,000 RbG in 2012 based on surveys of migrating geese in the same region of Northern Kazakhstan. Estimates of RbG proportions in goose flocks in our study region were complicated by the species' behaviour. They depart and return to lakes at different times compared to other species, so the proportions of RbG is very dependent upon survey timing. We recommend investigating further the best methods to survey this species, either through differentiating it from *Anser* sp. during dawn counts (based on silhouettes) and/or sampling of flock species composition be undertaken over 4–5 h periods of time in order to provide reliable estimates. Further refinement and targeting more counts at Category 1–3 sites would also help to provide better RbG estimates, as nearly a quarter (22%) of the overall total was estimated to occur in previously unsurveyed Category 4 lakes.

Previous counts of LWfG and other geese species in Kazakhstan have varied greatly in size from year to year, making estimates of population size and trends difficult to interpret. Whether such variability results from genuine changes in goose abundance, habitat variability or from sampling variation and error and the inherent difficulty in obtaining accurate counts of aggregated migratory geese is difficult to judge. Numbers of LWfG reported from Taldykol/Kulykol Lakes include 1,552 birds in 2008, 207 in 2009 and 5,400 in 2010, 19,566 in 2014, 2,239 in 2015 and 23,205 from the present study (AEWA LWfG International Working Group, unpubl. data). Such variation cannot reflect true changes in overall population size, as it is demographically impossible for geese to increase their numbers by an order of magnitude from one year to the next, as was apparent between 2009–2010 and 2015–2016. We consider high inter-annual variability is most likely to represent variation in bird distributions across the staging landscape, perhaps in response to differing lake or weather conditions, and the absence of a stratified sampling design that permits extrapolation. We recommend that future surveys continue to cover a wide region using an effective sampling protocol, for best monitoring of year-to-year variation

in the distribution and numbers of geese, and to help provide reliable estimates of the population size and trends for migratory geese in the region.

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Photograph: Lesser White-fronted Goose and Red-breasted Goose in a mixed goose flock at Lake Tayyncha in North Kazakhstan, by Ivan Zuban.