Home range and migration of the Red-breasted Goose *Branta ruficollis* mapped by satellite telemetry: implications for conservation

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Abstract

The Red-breasted Goose *Branta ruficollis*, classified as Vulnerable by the IUCN Red List of threatened species, is a long-distance migrant which breeds on the Yamal, Gydan and Taymyr Peninsulas of the Russian arctic. Understanding the birds' breeding ecology and behaviour during migration can contribute to their efficient conservation. In this study, we fitted two male geese with 18 g Argos Solar PTTs and one female with a 9.5 g Solar PTT to provide information about their breeding home range, time spent in key stopover and staging sites, and the duration of migration. One male and one female goose completed one full cycle of migration, breeding in Taymyr Peninsula and returning to their wintering grounds in southeast Romania. The pre-nuptial migration of the male goose was longer in duration and distance than the post-nuptial migration, which was much shorter. The female goose had shorter pre- and post-nuptial migration than the male. Both geese made more stops during spring than autumn which may be explained by a combination of capital breeding (so stopping more frequently to gain energy reserves in preparation for breeding) and arriving in areas yet to thaw during northbound migration. The summer season in the Taymyr Peninsula lasted roughly 85 days. The male goose bred on a small tributary of the Pyasina River, with a core home range of 20 km^2. The female goose had a smaller home range, of 6 km^2 in the vicinity of the Rarikha River, near the Gulf of

Yenisey. Results of this study provide important knowledge about the birds' home range, days spent at stopover and staging areas and the distance between those sites. These findings can support conservation communities throughout the species' range in enabling them to carry out essential conservation activities more effectively.

Key words: arctic peninsulas, *Branta ruficollis*, migration, satellite tracking, stopover sites.

The Red-breasted Goose *Branta ruficollis* (hereafter, RBG) is a long-distance migrant, which breeds on the peninsulas of the Russian arctic – the Yamal, Gydan and Taymyr Peninsulas – and winters in the northwest Black Sea region (Cramp *et al.* 1977; Hunter & Black 1996; Reeber 2015). According to the IUCN Red List, the species is classified as Vulnerable with a global population estimated at about 56,000 individuals (Birdlife International 2024).

In recent years, extensive monitoring has been conducted at key stopover sites in Kazakhstan (Cuthbert & Petkov, 2022; Cuthbert *et al.* 2018) and along the western bank of Black Sea, where almost half of species' population is wintering (Iliev *et al.* 2023). The stopover and staging areas are usually wetland complexes, used by the geese for refuelling and resting during their migration (Hübner *et al.* 2010). In these areas, the geese accumulate fat and nutrient reserves, which are thought to have a crucial role in determining the success of the breeding season (Ryder 1970; Ankney & McInnes 1978; Ebbinge & Spaans 1995; Kostin & Mooij 1995). Post-nuptial migration begins in mid-September (Dementyev *et al.* 1952), with the geese heading southwards along the River Ob, Russia (Reeber 2015). The Ob floodplains in the Yamal-Nenets region provide the first important stopover site for the geese. The second key stopover area is on the middle Ob, between Surgut and the Vakh River, in the Khanty-Mansi region. Next the geese stage at a large complex of wetlands in Northern Kazakhstan, particularly in Kostanay region, but also in the adjacent Tyumen, Kurgan and Orenburg regions of Russia. The last main stopover area before the geese reach their wintering grounds is the Manych-Gudilo depression in the Stavropol region and the wetlands of the Kalmykia region in southern Russia. The main wintering range lies along the western bank of the Black Sea coast in Ukraine, Romania and Bulgaria, particularly in the coastal Dobrogea region. This area of the Black Sea hosts three wintering goose species, in significant numbers: the Greater White-fronted Goose *Anser albifrons* (the most numerous), the Greylag Goose *Anser anser* and the RBG (Dereliev *et al.* 2000; Fox & Leafloor 2018; Snow *et al.* 1998).

The winter distribution of the RBG and other goose species varies between and within the winters depending on the severity of the weather in January. The RBG has been reported to reach Hungary, Greece and Turkey, in small numbers. In some winters, up to 20,000 individuals can remain in Manych-Gudilo, Russia and Syvash, Ukraine (Andryushchenko *et al.* 2019; Cranswick

et al. 2012; Iliev *et al.* 2023; Oláh *et al.* 2017). Since 2014, more than 30% of the species' global population has been wintering in Romania, with up to 23,783 individuals found in the southeastern part of the country (Todorov *et al.* 2023).

In spring, the birds' pre-nuptial migration retraces their autumn migration route in the opposite direction. Most of the geese depart from their wintering grounds in Romania at the end of February, or in some years at the beginning of March (Todorov *et al.* 2023). Arrival at the breeding grounds occurs at the end of May and breeding starts in the first days of June, with the first birds departing from the breeding areas in mid-September (Dementyev *et al.* 1952; del Hoyo *et al.* 1992). The breeding distribution of the species across its vast breeding range on the peninsulas of the Russian arctic is not well known. New areas, indicated as potential key habitat within the breeding range, were detected in the Taymyr and sections of the Yamal Peninsula in 2017 by modelling data from tracking studies, but these have not as yet been confirmed by ground-based fieldwork (Hilarides *et al.* 2017).

The first attempt to GPS-tag RBG within the species' wintering range dates from December 2007, when a single RBG caught by the Romanian Ornithological Society was fitted with 18 g Solar Argos platform terminal transmitters (PTT) and released near Techirghiol Lake (Romanian Ornithological Society, 2007). Unfortunately, the team lost the signal within a week. To better understand the movements of the species within its wintering grounds and migratory routes, between 2011 and 2015, a team from the Bulgarian Society for the Protection of Birds (BSPB) and the Wildfowl & Wetlands Trust (WWT) organised the first comprehensive tagging of Red-breasted Geese within the frame of the LIFE09 NAT/BG/000230 project. Three geese were fitted with satellite tags and another 22 with GPS loggers (Harrison *et al.* 2015). In 2012, another 10 geese were tagged with GPS-GSM tags in their breeding range by a team of Belgian and Russian scientists (Vangeluwe *et al.* 2012). In the period 2012–2014, a further six RBG were fitted with satellite tags in their wintering grounds in Bulgarian coastal Dobrogea (Simeonov *et al.* 2012, 2014). The most recent tagging efforts took place between 2017 and 2022 when a team of the LIFE16NAT/BG/000847 project caught and tagged 40 geese, some with pilot GPS neck collars (Petkov 2023). A study reported that 25% of the RBG population in southeast Romania was found foraging outside of the protected areas during winter, exposing the species to various threats such as hunting, poaching and significant disturbance by farmers (Todorov *et al.* 2023). As the RBG is a gregarious and highly mobile species, sensitive to anthropogenic activities, the ground-based monitoring might not provide sufficient data to understand how the birds react to different threats. For this reason, the tracking studies are crucial for understanding the species' movements over its wide range.

In this initial study, pending analysis of data from the larger project, we monitored the movements of Red-breasted Geese captured in Bulgaria and Romania tracked to their breeding grounds, with the aim of collecting detailed data on their breeding

home range, time spent in key stopover and staging sites, and duration of the pre-nuptial and post-nuptial migration.

Methods

Satellite tracking

Three adult RBG were captured and equipped with satellite tags. Two male geese were caught (catching permit no. 548/28.11.2013, issued by the Bulgarian Ministry of Environment and Waters) using cannon nets (Bub 1995) at their foraging ground near Durankulak Lake (43°41.38'N 28°32.76'E) in the Coastal Dobrogea of Bulgaria on 12 February 2014 (Harrison *et al.* 2015). The average weight of both geese was 1,450 g. The geese were fitted with 18 g Solar Argos platform terminal transmitters (PTT), manufactured by Microwave Telemetry Inc. Columbia, MD, USA, and released at the same date. Another female goose was found on 18 January 2020, injured in the yard of a house in Mihail Kogalniceanu village (44°40.74'N 27°42.71'E), Ialomita County, Romania. The goose had minor injuries in the carpo-metacarpal areas of both wings and was admitted to the Wildlife Rescue and Rehabilitation Centre – "Visul Luanei" Foundation. After a rehabilitation period of one month, the goose (which weighed 1,100 g), was equipped with 9.5 g Solar Argos PTT and released on 20 February 2020, in the vicinity of Strachina Lake, Romania. Each goose was equipped with an aluminium ring from either the Bulgarian Ornithological Centre or the Romanian Ornithological Centre on its right tarsus, and a white plastic ring with black inscriptions provided by the International Red-breasted Goose Working Group of the African-Eurasian Migratory Waterbird Agreement (AEWA) on its left tarsus. The satellite transmitters were attached as a backpack to the geese using 5 mm tubular Teflon tape harnesses (5 g). The total weight of the 18 g PTTs and harnesses was 23 g and 14.5 g for the 9.5 g PTTs, which represented an average of 1.56% of the birds' body mass when the devices were fitted. The PTTs were programmed to record regular positions of the individual goose every 2 days, within a duty cycle of 10 h ON/24 h OFF. PTTs are equipped with temperature, battery voltage, activity sensors, a solar rechargeable battery, and a microprocessor-controlled duty cycle timer that regulates battery charge control and commands the PTT to transmit during the ON time of its duty cycle, depending on the state of the charge of the battery. Data on the positions of the birds were obtained via the ARGOS system. References to the accuracy of the location classes (LC) are those provided by ARGOS: class 3, < 250 m (± 1 s.d.); class 2, 250–500 m (± 1 s.d.); class 1, 500–1,500 m; class 0, > 1,500 m (no estimate of accuracy); and class A and B, no estimate of location accuracy provided, but has to be judged by the user (https://www.cls-telemetry.com). We received a total of 5,549 fixes from all three transmitters. For this study, we selected the most precise data (2,403 fixes), which included only LCs 3, 2 and 1, representing 42.5% of the total fixes received. The rejected LCs (0, A, B) constituted the remaining 57.5% (see Supporting Materials Table S1 for details).

Data obtained from the satellite tags were also uploaded to www.movebank.org and can be accessed by the following Movebank IDs: ID 1892604708 for the female goose with tag no. #134855, and ID 133087460 for both male geese with tag nos. #134138 and #134139.

Data analyses

The onset of pre-nuptial migration was defined as the first day on which the tracked goose moved > 100 km in a north-northeast direction and the end of the pre-nuptial migration was defined as the first day when it remained stationary for > 5 days in its breeding range. The species is considered to breed between 67°N and 76°N, and between 67°E and 116°E (Cranswick *et al.* 2012; del Hoyo *et al.* 1992). The post-nuptial migration was defined as the first day when the tracked goose left the breeding area and moved > 100 km in a south-southwest direction, and the end was defined as the first day on which the bird arrived in its wintering range of the western shore of Black Sea and remained stationary for > 5 days, usually at the end of October (Todorov *et al.* 2023).

To delineate stopover sites used by each of the geese, groups of continuous locations were identified where the individual's movements were clustered and positions were no greater than 30 km apart, which is the maximum distance between resting and foraging grounds at wintering and stopover sites (Van Wijk *et al.* 2012). Stopover sites were defined as places where the birds remained for at least 48 h (Drent *et al.* 2007). The staging areas were described, following the recommendation of Warnock (2010), as places where the geese spent more than a week or two for rebuilding their energy reserves and the distance to the next area is generally > 1,000 km.

The breeding home range area was identified from the most precise LCs 3 and 2 received, between the first date after the geese reached their breeding grounds and the date when they left their breeding area. Home range was calculated using 100% Minimum Convex Polygon (MCP), while the utilisation distribution (95% of the range) and core areas (50% of the range) were calculated using the fixed kernel density estimation (KDE) method (Seaman & Powell 1996). The KDE was calculated in the R "rhr" package (Signer & Bankenhol 2015; R Core Team 2018).

In order to assess whether the stopover and the staging areas in Kazakhstan and Russia are effectively secured as protected areas, we overlapped all LCs 3, 2 and 1 coordinates recorded for both geese with the boundaries of the Important Bird Areas (IBAs) identified by Birdlife International (https://datazone.birdlife.org) and protected areas currently listed in the World Database on Protected Areas (WDPA, https://www.protectedplanet.net).

All spatial calculations and presented figures were made in ArcMap 10.8.2 (ESRI Redland, CA, USA, 2013).

Results

Pre-nuptial and post-nuptial migration

Two RBG, male (#134138) and female (#134855), completed one full cycle of migration, to arctic breeding grounds on the Taymyr Peninsula and returning to wintering sites in southeast Romania. The other

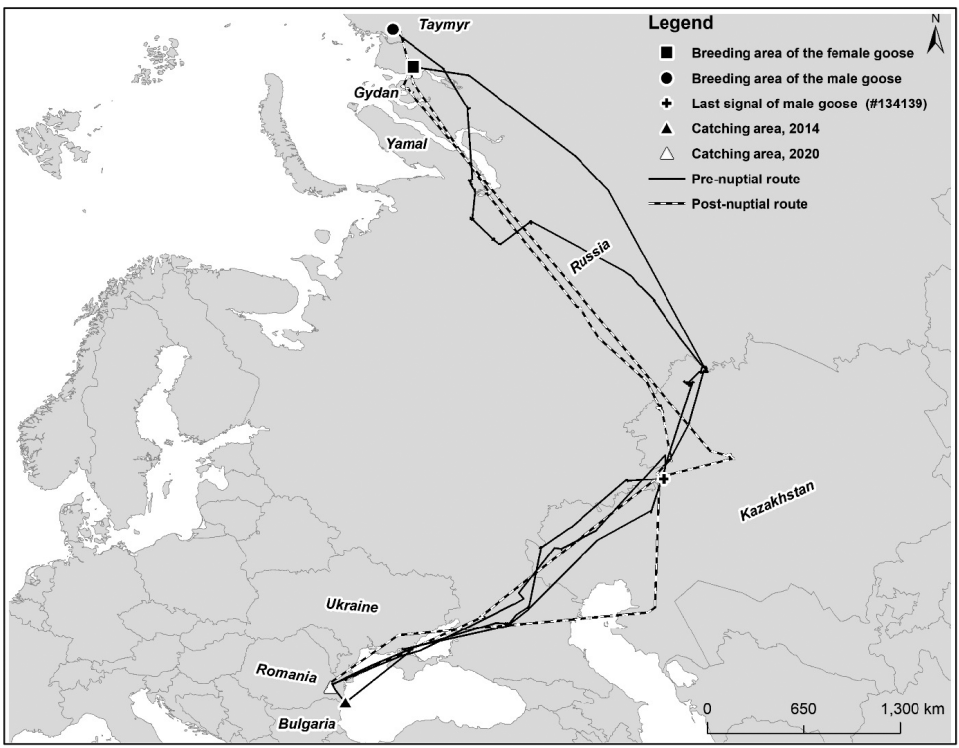

Figure 1. Migratory flyway routes (Azimuthal Equidistant Projection) between breeding and wintering areas of two male Red-breasted Geese, equipped with 18 g Solar Argos Platform Transmitter Terminals (PTTs) in 2014 and one female equipped with 9.5 g Solar Argos PTT in 2020.

male goose (#134139) did not complete its pre-nuptial migration, as the transmission was lost in Russia at the border with Kazakhstan (Fig. 1).

The pre-nuptial migration for all three geese started almost simultaneously. One of the male geese left its winter quarters on 11 March and the other on 12 March, with the female also leaving on 12 March (Supporting Materials Table S2). The pre-nuptial migration of the male RBG lasted 97 days, spent in 11 stopovers, and flying 6,359 km. The post-nuptial migration was shorter, at 61 days spent in just four stopovers, and flying 5,847 km. The pre-nuptial migration of the female goose was shorter than for the male, at 80 days spent in 9 stopovers, with a flight of 5,505 km. On returning to the wintering areas, she flew 5,420 km in 80 days, and used 6 stopovers (details in Supporting Materials Table S2). The mean time spent in the stopover and staging areas during pre-nuptial migration was 8 days for both geese (male goose: n = 11, s.d. = 4.39, 95% CI = 3.07, 7.7; female goose: n = 9, s.d. = 10.96, 95% CI = 7.41, 21) while the mean time for the post-nuptial migration was 12 days (male goose: n = 4, s.d. = 13.08,

95% CI = 7.41, 48.76; female goose: *n* = 6, s.d. = 4.47, 95% CI = 2.79, 10.97; Fig. 1).

The male bird's transmitter ceased transmission on 15 November 2014 in the vicinity of Insula Mare a Brăilei, Romania. The last transmitted fix of the female goose was on 4 December 2020, 14 days after its arrival in Romania within the fish farm complex situated near Câşliţa village in the northern part of the Danube Delta and Razim-Sinoe Complex (ROSPA0031). The lifetime of other male goose (no. #134139) was much shorter. The transmission was lost in the vicinity of Shalkar-Ega-Kara Lake in Russia on 16 June 2014, 96 days after the start of its pre-nuptial migration. However, the tag continued to transmit only LCs (A and B) from the vicinity of the Shalkar-Ega-Kara Lake until mid-December 2014, when the transmission was completely lost. The precision of the LCs were insufficiently accurate to pinpoint the positions of the PTT's reliably, for subsequent recovery.

The mean (± s.d.) distance between the stopovers during the pre-nuptial migration was 580 ± 390.2 km (*n* = 11, 95% CI = 272.6, 684.7) for the male goose and 551 ± 598.7 km (*n* = 10, 95% CI 411.8, 1093.1) for the female goose, while during post-nuptial migration it was 1,169 ± 641.76 km (*n* = 5, 95% CI = 384.5, 1844.1) for the male and 774 ± 865.13 km (*n* = 7, 95% CI = 557.48, 1905.07) for the female.

In total, we registered 18 stopover sites and 12 staging areas used by the two RBG during their spring and autumn migration cycle. There was only one site in Ukraine, 13 in Kazakhstan and 16 in Russia. All staging areas were located in Kazakhstan and Russia. Both geese began their migration from wintering sites in Romania, located within Special Protected Areas (SPAs) that form part of the of European ecological network of protected areas, Natura 2000. They returned to these same areas in Romania after their migration to and from the breeding grounds. Seven stopover areas and seven staging areas used by the geese during their migration were found to be overlapping with Important Bird Areas (IBAs) or nationally protected areas. The remaining stopovers were located outside of designated protected areas (Supporting Materials, Table S2 provides further details).

Breeding home range

The two tracked geese monitored throughout the breeding season chose areas with herbaceous vegetation around small tributaries of two rivers on the Taymyr Peninsula (Fig. 2). The duration of the summer season was 77 days for the male goose (from 16 June–30 August 2014) and 96 days for the female (from 30 May–2 September 2020). The male had a range of 119 km^2, based on 95% KDE, while the female had 29 km^2. The core breeding area of 50% KDE was 20 km^2 in the vicinity of Pyasina River for the male and 6 km^2 in the vicinity of Sarikha River for the female (Fig. 3). The elevation of both breeding areas was 8–25 m above sea level. At the end of the summer, the male goose moved *c.* 100 km to the north of its core breeding area, while the female goose remained relatively close to its breeding site, moving just 25 km to the south. Post-nuptial migration started in the first two days of September for both geese, already heading in a southerly direction.

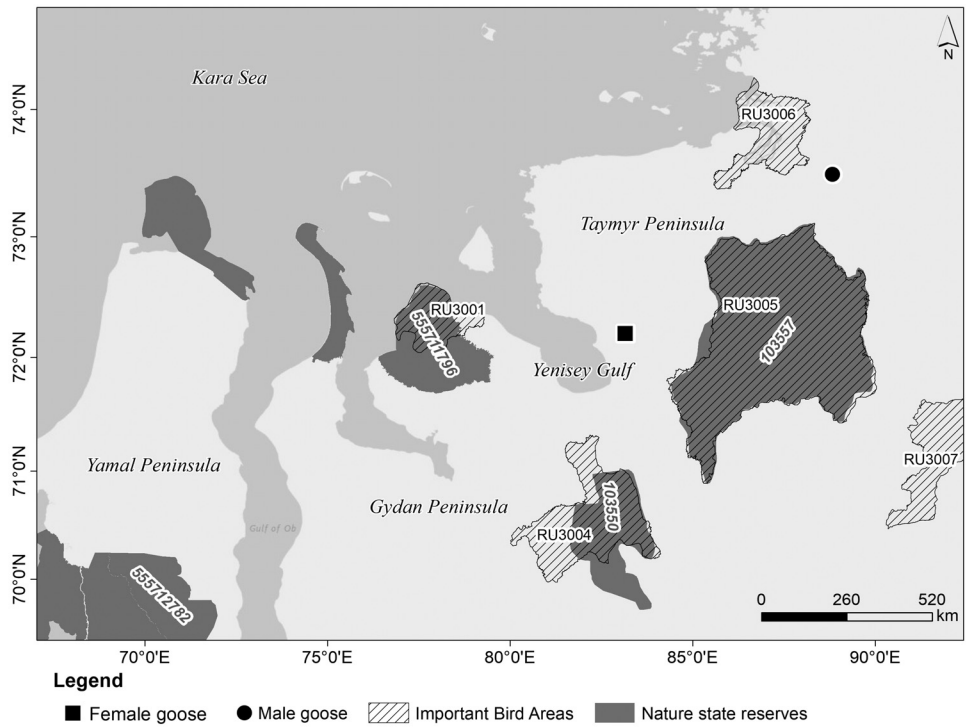

Figure 2. Breeding locations of the tracked Red-breasted Geese on the Taymyr Peninsula, Russia in relation with the IBAs and national protected areas. Codes of the nationally protected areas (in italics) are oriented vertically.

Discussion

The data obtained from the Solar Argos PTTs used in this study provides useful information not only on time spent by the RBG at their stopover and staging sites but also on their breeding home range in the Russian arctic. Despite the small sample sizes provided by data from just two geese, and the limited accuracy of locations received from ARGOS (*i.e.* classes 3, 2 and 1, ranging from < 250 m to 1,000–1,500 m), we believe that the data presented here is sufficient to inform the conservation community about the birds' migratory patterns and gives a basis for further more detailed and extensive research (*e.g.* from more recent tracking studies; Petkov 2023), which should contribute to the conservation of this vulnerable species.

In this study, the fate of the studied geese remains unknown. The sudden cessation of transmission of both PTTs could suggest either technical failure or anthropogenic causes, such as the birds being killed during hunting. RBG often gather in mixed flocks with the Greater White-fronted Goose, which is a quarry species, and the more recent satellite tracking study involving 40 tagged RBG found evidence of foul play

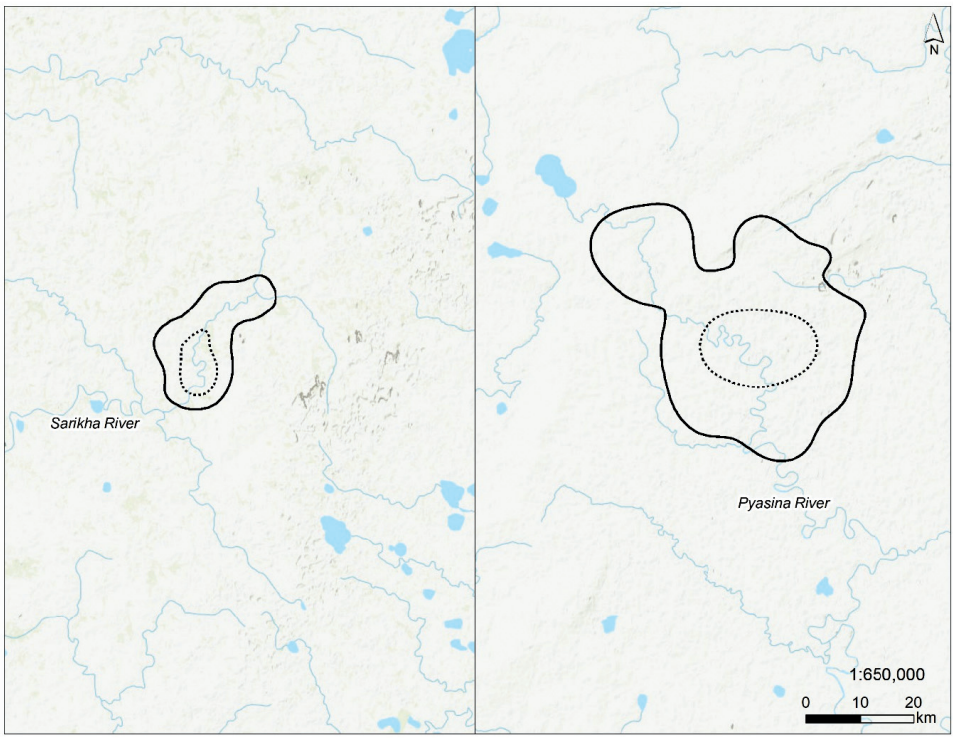

Figure 3. Breeding home range of the female Red-breasted Goose (left) in the vicinity of Sarikha River and the male Red-breasted Goose (right) in the vicinity of Pyasina River, described by their Argos satellite tag (PTT) data. Dash line = 50% of the core area; bold line = 95% utilisation distribution.

in several cases (Petkov 2023). A tracking study of Lesser White-fronted Goose *Anser erythropus* (also a protected species) similarly reported 6 out of 13 tagged geese being shot during their post-nuptial migration across Russia and former Soviet Republics (Aarvak & Øien 2003; Lorentsen *et al.* 1998).

The two tracked geese displayed some variation in the number of stopovers made during their migrations. The male goose had 11 stopovers and the female had 10 during their pre-nuptial migration, with the number of post-nuptial stopovers being 5 and 7, respectively. The higher number of stopovers observed during pre-nuptial migration may be attributed to the energetic demands of capital breeding, as RBGs need extensive time for refuelling and recovering their reserves prior to the breeding season (Drent *et al.* 2006), and also to the geese encountering harsh weather conditions as they reach higher latitudes. The tracking revealed that both geese spent considerable time in the Kostanay region of northwest Kazakhstan during their migration cycle. This region is considered to be a bottleneck for the migration of RBG, Lesser White-

fronted Geese and Greater White-fronted Geese, and counts to update global population estimates have recently been carried out in the area (Cuthbert & Petkov 2022; Cuthbert *et al.* 2018). The results show that the geese need *c.* 12 days between mid-April and mid-May to recover their energy reserves and almost one month between end of September and the end of October during the autumn migration. This reinforces the view that the Kostanay region is one of the most important goose staging areas along their flyway. In Russia, the geese had more stopovers, but of shorter duration, spending on average 7–8 days at these sites (Supporting Materials Table S2).

The location data showed that the geese spent a total of 110 days in 17 sites (including stopovers, staging and the breeding areas) which are not protected by national legislation in Kazakhstan and Russia. This highlights the need for conservation assessments and management plans for these unprotected areas where the geese are spending significant periods during their annual migratory cycles. Stopovers not yet under protection were identified in the vicinity of Aksu and Aleksandrovka villages, Balykty Lake, the Shoshkaly Lake system and Ordabay in Kazakhstan, and also at Chonta in Russia, where an enlargement of existing important bird areas or declaring new protected areas must be considered of high priority.

The geese utilised breeding sites in the vicinity of small river systems within the tundra of Taymyr Peninsula. This peninsula is considered to hold *c.* 70% of the global population (Cranswick *et al.* 2012). An ecological and behavioural study found that RBG show a preference for breeding sites on mainland tundra, in association with raptors eyries such as Peregrine Falcon *Falco peregrinus*, Snowy Owl *Nyctea scandiaca* and Rough-legged Buzzard *Buteo lagopus* nests, or on small islands in the arctic rivers which is likely an adaptation to reduce predation risk from the Arctic Fox *Alopex lagopus* (Quinn *et al.* 2003). Home range analysis showed that neither of the geese used breeding sites within in an IBA or nationally protected area on the Taymyr Peninsula. Two relatively close IBAs – the Pura River Basin (RU3005) and Pyasina Delta (RU3006) – were 150 km and 80 km respectively from the breeding area of the male goose. The nearest IBA to the breeding area of the female goose was 300 km away, and the existing state reserve (zapovednik) – the Taymyr Nature Reserve – was also far from the breeding locations.

The smaller home range of the female goose could be explained by the fact that the females spend more time close to the nest than the males. Quinn *et al.* (2003) found that female RBG tended to be much more closely associated with their nesting areas than the males, which were seen by the shoreline guarding the breeding area of the pair. Studies on the home range of the Greenland Barnacle Goose *Branta leucopsis* revealed a breeding home range of 7 km^2 (Doyle *et al.* 2023), which is similar to the range of the female goose (6 km^2) presented here. We were not able to detect clearly where the moulting areas are located, but the two tracked geese did not move far from their breeding areas. Some withdrawal from the core breeding areas was observed at the end of August, however, prior the start of the post-nuptial migration.

A minimum requirement for the conservation of the species' breeding habitats should be the creation of sensitivity maps, based on the birds' habitat preferences, in order to provide an appropriate spatial framework for land-use planning, to be distributed among developers and relevant authorities. Another important management requirement, which needs to be addressed among national authorities throughout the flyway, is hunting regulation. A temporary ban on hunting during pre-nuptial and post-nuptial migration should be implemented in all countries, wherever possible, but special attention should be paid to the IBAs of: Syvash Bay (UA069) in Ukraine; the Shalkaro-Zhetykol'ski Lake System (RU1217) in Russia; and the Koybagar-Tyuntyugur Lake System (KZ032), Kulykol-Taldykol Lake System (KZ036), Naurzum State Nature Reserve (KZ040) and Sarykopa Lake System (KZ041) in Kazakhstan. In Russia, following a two-year temporary ban on spring hunting at Lake Manych-Gudilo (RU1165) and its surrounding areas, a permanent ban was enacted in January 2021. This measure represents a significant conservation achievement for numerous waterfowl species, including the RBG (Petkov 2023). Similar approaches should be implemented in the other important areas utilised by the geese, to ensure the availability of safe roosting and foraging grounds. These habitats are critical for the geese for accumulating sufficient reserves for their long and demanding migration.

Expanding tagging efforts to more individuals would significantly improve our understanding of the RBG's movements across their vast and often inaccessible range across its flyway. This approach would complement land monitoring, which can be challenging and is often logistically complex in remote areas. Detailed studies on the distribution of the species in its wintering range are also essential, especially for providing insight into movements between sites and habitat selection. Integrating our results with other similar research projects on tracking RBG would further contribute to a comprehensive understanding of the impact of hunting and other anthropogenic activities on this species and may serve to provide information on how the species responds to environmental factors such as weather conditions, habitat alterations and changes in land use.

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