Distinguishing Tundra Bean Goose *Anser fabalis* subspecies: blind testing goose experts, using photographs taken in the field

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Abstract

Two Tundra Bean Goose *Anser fabalis* subspecies – the western *A. f. rossicus* (Buturlin, 1935) and eastern *A. f. serrirostris* (Swinhoe, 1871) – have been described based on morphological and distributional criteria, although identifying these subspecies outside their breeding and wintering ranges can be challenging. In recent years, studies of other goose populations have increasingly used photographs to identify species in the field. An assessment of whether experts can differentiate the two Tundra Bean Goose subspecies from photographs therefore was undertaken, to verify the accuracy of this potentially useful method for this particular species. Here, we analysed the consistency with which experienced goose researchers attributed pictures of Tundra Bean Geese to either subspecies, using 48 photographs of the heads of individual Tundra Bean Geese, taken at five sites where the birds were caught or observed within different parts of the breeding range. Each individual was assigned to subspecies on the basis of its catch location. Photographs were numbered, mixed using a random number generator, and then submitted to four internationally renowned Bean Goose experts (selected on the basis of their publications) as a blind test. Each expert was asked to identify each picture as either *rossicus* or *serrirostris*.

Three birds were omitted because they were not assigned as *rossicus* or *serrirostris* by all four experts. Overall, 17 (37.8%) of the 45 geese were classed as the same subspecies by the four experts, and a further 18 (40.0%) by three experts, indicating that although some individuals could be identified to the subspecies level in this way, they are not well recognised by the photographs taken during our study. The probability of each expert misassigning subspecies ranged from 0.16 to 0.49 (mean ± s.d. = 0.28 ± 0.07), and the mean probability of the experts classing subspecies correctly (*i.e.* in accordance with the catch site) was 0.72 ± 0.15 across the study area, increasing to 0.79 ± 0.06 on omitting the least "accurate" expert. There was no difference between catch locations in the proportion of photographs assigned correctly. This study reinforces the view that photographs cannot be used for reliable *post hoc* identification of Tundra Bean Goose subspecies. Thus, photographs taken during aerial surveys in the arctic, during ground surveys in China, and those posted on eBird and other birding platforms should be treated with caution as a means of describing their distribution. Taking detailed morphological measurements is strongly recommended when handling Bean Geese. Genetic analysis of feathers or blood samples would also help to clarify Tundra Bean Goose systematics and distribution, by identifying the markers that permit differentiation of the two forms.

Key words: *Anser fabalis rossicus*, *Anser fabalis serrirostris*, blind test, identification by photograph, Tundra Bean Goose.

Taiga and Tundra forms of the Bean Goose *Anser fabalis* have been recognised since the early 20th century, based on the different habitats frequented during the breeding season (the former occurs mainly in dense taiga forest; the latter on open tundra landscapes) and morphological adaptations to exploit different food sources. The two Taiga Bean Goose subspecies – *Anser f. fabalis* and *A. f. middendorffii* – consequently are larger with a relatively long, more robust bill, whereas the smaller Tundra Bean Geese have shorter, deeper, more wedge-shaped bills (Alpheraky 1904; Sushkin 1914, 1938; Buturlin 1935; Tugarinov 1941; Delacour 1951; Cramp & Simmons 1977; Huyskens 1986; Fox 2005). Further splitting of the Tundra Bean Geese into western *A. f. rossicus* (Buturlin, 1935) and eastern *A. f. serrirostris* (Swinhoe, 1871) subspecies was also based on morphological criteria (Buturlin 1935; Tugarinov 1941; Cramp & Simmons 1977) and on their differing migration routes and separate wintering grounds. *Rossicus*, which is described as being smaller and having a thinner bill than *serrirostris*, winters in Europe, whereas the eastern tundra birds have relatively short but massive bills and winter in Asia (mainly in China and Korea but to a lesser degree in Japan; Fox 2005; Carboneras & Kirwan 2020; Li *et al.* 2020). Additionally, it is thought that the orange or flesh-colour band on the beak generally does not extend under the nostrils (or goes just slightly under them) in *rossicus*, whereas in *serrirostris* the bill band is yellow-orange (in some cases reddish), and sometimes extends beneath the nostrils (Emelianov 2000).

The two Tundra Bean Goose subspecies overlap on their breeding grounds between the River Khatanga and River Lena in central Siberia (Portenko 1939; Ptushenko 1952; Stepanyan 1990; Emelianov 2000). Those breeding on the Taimyr Peninsula were traditionally considered to be western tundra birds, which winter in western Europe (a view supported by leg-ring and neckband recoveries; Fox & Leafloor 2018), but ring recoveries and recent tracking of individual birds fitted with GPS transmitters have demonstrated that geese from Chinese wintering grounds also migrate to tundra areas to the south of the Taimyr Peninsula, west of the River Khatanga (Borzhonov 1975 cited by Emelianov 2000; Li *et al.* 2020). These data enlarged the overlap zone to the 1,500 km distance between the Rivers Yenisei and Lena, which potentially makes subspecies identification much more challenging in this region (Fig. 1). At the same time, further assessment of individuals in the field is required, to support delineation of the two subspecies' distribution across the breeding range.

In recent years, the distribution and abundance of geese (including Tundra Bean Geese) across the Russian arctic have been studied by aerial surveys, using photographs taken from a plane to identify species and subspecies (Rosenfeld *et al.* 2017, 2018). Photographs of wintering flocks have also been taken during the winter goose surveys in China, to permit further identification

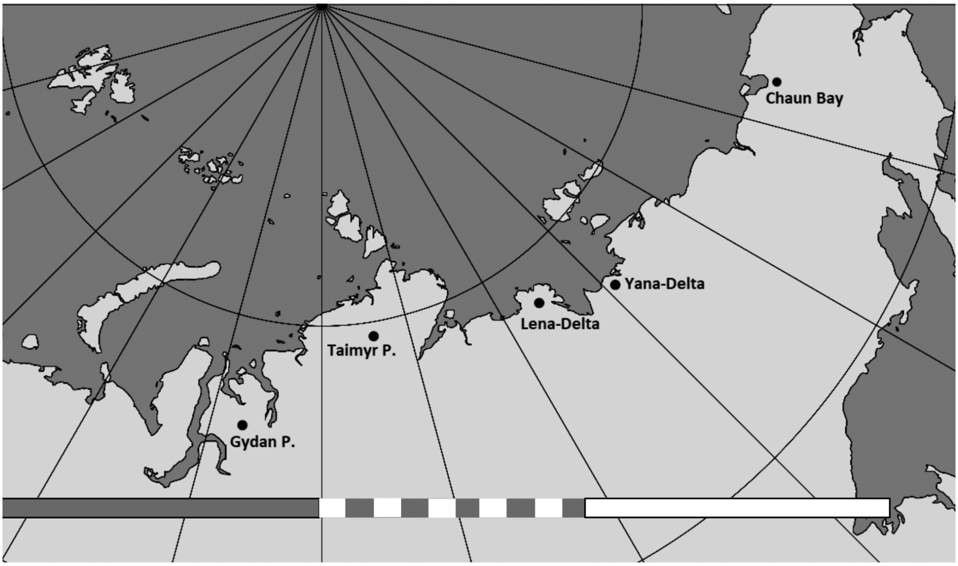

Figure 1. Map showing the location of sites in the Russian arctic where the Bean Geese were photographed. Grey bar = geographical range of *A. f. rossicus*; white bar = the range of *A. f. serrirostris*; dashed bar = overlap of the subspecies (from Emelianov 2000).

by experienced experts. Public services, *e.g.* eBird, supply photographs that could be used for subspecies identification. These photographs have been taken from different angles, under different weather and light conditions, and include variable numbers of birds, sometimes of mixed subspecies. Some tracking studies have involved taking pictures during the catching and tagging of birds, because collection of the detailed biometrics data required for reliable identification of Tundra Bean Goose subspecies were not recorded due to a lack of time and/or experience of the fieldwork teams. We are therefore becoming more reliant upon photographs to assign captured individual Bean Geese to a given subspecies, yet our ability to do so has never been tested. An understanding of experts' ability to identify subspecies of Tundra Bean Goose from photographs taken during catches (as well as during surveys) consequently is required, to determine whether it provides a valuable means of assigning or confirming subspecies following release of the birds.

The overarching objectives of this study therefore were to use the photographs taken of Tundra Bean Geese at sites across the Russian arctic to determine: (a) whether the images support the current assessment of the distribution of the two subspecies, and (b) the ability of researchers familiar with Bean Geese to attribute pictures of individual birds accurately to subspecies level. For the first objective, we consider whether the experts assign photographs of the geese to subspecies in accordance with their distribution (*e.g.* catch location), with birds in the west thought to be *rossicus* and those in the east *serrirostris*. For the second, we determine the level of agreement among experts on classing the photograph of each bird. The study investigated and tested four underlying hypotheses, with a view to providing insight into these objectives, as follows:

(1) That the subspecies are easy to recognise from photographs, and do not overlap in distribution. For this hypothesis, experts are expected to assign geese photographed at western catch sites to the western race and geese from eastern catch sites to the eastern race (with a probability of correct assignment of > 0.95 for each location). The percentage of "correct" assignments should not differ among locations.

(2) That the subspecies are not readily recognisable from photographs (*e.g.* may require measurements to confirm identification), and do not overlap in distribution. In this case, experts are expected to make misidentifications (probability of correct assignment being < 0.95 for each location). The percentage of correct assignments should not differ among locations.

(3) That the subspecies are easy to recognise, and overlap in some areas, but not across the whole range. Experts are expected to assign birds from the easternmost and westernmost locations in line with the subspecies that mostly occur in these areas, but to make more misidentifications for birds from catch sites where the subspecies are thought to overlap.

(4) That the subspecies are not readily recognisable from photographs and do

overlap in some areas. In this case, experts are expected to misidentify subspecies in a systematic or non-systematic way.

Methods

We gathered a sample of 48 photographs taken of heads of individual Tundra Bean Geese from five discrete areas within the breeding distribution of the species, from the Gydan Peninsula (*n* = 7), the Taimyr Peninsula (*n* = 11), the Lena River delta (*n* = 10), the River Yana delta (*n* = 10) and at Chaun Bay in Chukotka (*n* = 10) (Fig. 1, Fig. 2, Supporting Materials Table S1). The photographs were taken by the authors and other researchers from known locations, either during tracking studies (in the hand or on release) or from the air during aerial surveys on approaching geese in the wild. Additional photographs taken during the study were omitted because they were considered of insufficient quality (*e.g.* the head profile was at an angle) to determine the subspecies. Providers confirmed that none of the experts were familiar with their pictures. Subspecies was assigned in the field on the basis of the catch/observation site, with western birds (on the Gydan and Taimyr Peninsulas) classed as *rossicus* and eastern birds (on the Lena Delta, Yana Delta and Chaun Bay), as *serrirostris*. Although both *rossicus* and *serrirostris* occur on the Taimyr Peninsula, the birds in this study were treated as *rossicus* because they were caught in the western part of the region.

The photographs were numbered, mixed using a random number generator, then submitted to four internationally-renowned Bean Goose experts as a single-blind test. Selection of the experts was based on their publications. Experts, unaware of where each image was taken, were asked to classify each picture as being of *rossicus* or of *serrirostris* from the photograph only. Two photographs where one or two experts did not provide their opinion on the subspecies (Nos. 18 and 26 in Supporting Materials Table S1), both from the Taimyr Peninsula, were omitted from the analysis. Additionally, two experts attributed one bird moulting on the Yana Delta to *A. f. middendorffii*, which reflects the difficulty sometimes involved in separating Taiga from Tundra Bean Geese, and this was also omitted. It is possible that the bird was misidentified because the photograph was not strictly in profile and was taken using a wide-angle lens, but it is not uncommon for Taiga Bean Geese to moult in the tundra zone, where they may appear in Tundra Bean Goose flocks (Gerasimov 2018; Piironen *et al.* 2021). Expert identifications for the remaining 45 individuals were summed for each geographical region and the proportion of each subspecies identified correctly was calculated for each region. In addition we calculated an overall rate for which each bird was attributed to *rossicus* or *serrirostris*. Expert identification was classed as "incorrect" (although in actuality it "did not match") cases when a bird was attributed to the subspecies not expected for a given geographical region. A one-way ANOVA was used to compare the probability of misidentification among regions.

Results

Of the 45 Tundra Bean Goose photographs fully assessed, only 17 (37.7%) were identified to the same subspecies by all four experts

Gydan Peninsula: *rossicus*

Taimyr Peninsula: *rossicus*

Lena Delta: *serrirostris*

Yana Delta: *serrirostris*

Figure 2. Examples of photographs of Tundra Bean Goose heads, submitted to experts for identification, showing their location of capture. Note: all photographs used in the study are available in the Supporting Materials online (Table S1).

(Table 1). Three experts agreed on the subspecies for a further 12 (26.6%) of the photographs, with one expert (not always the same individual) giving a different opinion. For ten pictures (22.2%), experts' opinions were split, with two assigning the photograph to one subspecies and two to the other. The mean (± s.d.) probability of an expert differing from colleagues in subspecies identification was 0.34 ± 0.07 (range = 0.24–0.42) on including birds for which expert opinion was equally split,

Table 1. Consistency in the experts' identification of Tundra Bean Goose subspecies for each catch/observation site. Responses ranged from all four experts assigning the subspecies in accordance with whether *A. f. rossicus* or *A. f. serrirostris* were expected to be prevalent in the area ("correct"; left column), to all four experts concurring that an individual was "out of range" (right column; no cases). The number of photographs inspected be each expert for each location is given in parentheses. Subspecies on the Gydan and Taimyr Peninsulas were considered likely to be *rossicus*; those on the Lena Delta, Yana Delta and Chaun Bay were treated as *serrirostris*.

Assignment	**Correct**				**Incorrect**
No. of experts	**4 to 0**	**3 to 1**	**2 by 2**	**1 to 3**	**0 to 4**
Gydan P. (7)	2	3	2	0	0
Taimyr P. (9)	5	1	2	1	0
Lena Delta (10)	5	3	2	0	0
Yana Delta (9)	2	3	1	3	0
Chaun Bay (10)	3	2	3	2	0
Overall (45)	17	12	10	6	0

reducing to 0.31 ± 0.06 (range = 0.24–0.42) on omitting the least consistent expert. Although there were six cases (13.3% of images) where the majority of experts assigned a bird photographed in the western part of the range to an eastern subspecies or *vice versa*, there were no cases of all four experts doing so (Table 1).

On considering subspecies identification in relation to the birds' geographical location in greater detail, the probability of assigning subspecies "correctly" on the basis of where it was photographed was 0.72 ± 0.17 (range = 0.61–0.83 between regions), increasing to 0.79 ± 0.06 (range = 0.74–0.87) on omitting the least consistent expert (Table 2). Over 75% of the photographs of geese from the Gydan Peninsula (a traditional breeding area for the western *rossicus* subspecies) were attributed to *rossicus* by the experts (Table 2). For the next study area eastwards, on the Taimyr Peninsula, 78% of the photographs were classed as *rossicus* and 22% *serrirostris*, in what is considered to be an area where both subspecies occur. There was little evidence for a cline in the occurrence of Tundra Bean Goose subspecies, however, as birds from the Lena Delta (also potentially a *rossicus/serrirostris* overlap area; Fig. 1) were classed primarily *serrirostris* (83–87%, depending on whether three or all four experts' opinions were included; Table 2).

Table 2. Proportion of the photographs taken of 45 Tundra Bean Goose, assessed by all four goose experts, that were classed in accordance with the subspecies expected to be prevalent in the area, and also on excluding one (the least "accurate") expert. Number of photographs for each location is given in parentheses.

Location	**All experts**			**Excluding one expert**		
	Mean	**No. of expert assignments (*n*)**	**s.d.**	**Mean**	**No. of expert assignments (*n*)**	**s.d.**
Gydan P. (7)	0.75	28	0.14	0.81	21	0.08
Taimyr P. (9)	0.78	36	0.09	0.74	27	0.06
Lena Delta (10)	0.83	40	0.10	0.87	30	0.06
Yana Delta (9)	0.61	36	0.28	0.74	27	0.13
Chaun Bay (10)	0.65	40	0.31	0.80	30	0.10
Overall (45)	0.72	180	0.15	0.79	135	0.06

This high percentage of birds classed as *serrirostris* on the Lena Delta exceeded estimates for more eastern locations, such as the Yana Delta (61–74%) and Chaun Bay (65–80%). At the two western- and eastern-most locations (the Gydan Peninsula and Chaun Bay, respectively), however, minimally 19% and 20% of subspecies identified by experts from the photographs differed from those expected for these areas.

Assuming that all Tundra Bean Geese seen on the Gydan and Taimyr Peninsulas were *rossicus*, and that the geese on the Lena Delta, Yana Delta and Chaun Bay were *serrirostris*, the probability of experts classing subspecies "correctly" did not differ significantly among locations (ANOVA: $F_{4,182} = 1.409$, $P = 0.23$, n.s.). Whilst exclusion of the least consistent expert ("mistake" probability = 0.49) improved the results to 81% and 74% for *rossicus* in the Gydan and Taimyr Peninsulas, respectively, in the western study areas, and to 87%, 74% and 80% for *serrirostris* in the Lena Delta, Yana Delta and Chaun Bay further east (Table 2), the percentage of "correct" attributions again did not differ significantly among locations ($F_{4,135} = 0.76$; $P = 0.55$, n.s.).

Discussion

Our results found that, although all four experts concurred on the subspecies for 38% of Tundra Goose photographs presented to them, there was a lack of consistency in their ability to identify individuals as *Anser f. rossicus* or as *A. f.*

serrirostris, which illustrates the need to avoid using photographs for this purpose, but to use other methods (morphological or genetic) to class the birds quickly and accurately in the field. Moreover, the extent to which experts identified Tundra Bean Geese in accordance with the subspecies expected at the observation site was relatively low (averaging 79% and 72% for 3 and 4 experts, respectively; *i.e.* below a 95% accuracy level), suggesting (albeit in the absence of genetic verification) that classification of subspecies by study site is also subject to error. In either event, however, it should be emphasised that it is tricky to identify species and subspecies solely from photographs, especially when these are of low quality and the characteristics used for identification are non-exclusive but follow a gradient. This cline, proposed for Bean Goose subspecies by several authors including Alphéraky (1904), Delacour (1951), Dementiev & Gladkov (1952), Cramp & Simmons (1977), Roselaar (1977) and Mooij & Zöckler (1999), was confirmed by Ruokonen *et al.* (2008) who showed that bill length (a proxy for body size) increased from west to east across the breeding range, with *rossicus* and *serrirostris* also differing in the height of the bill.

Recording a range of biometrics data, including the shape and colour of the stripe on the beak, is invaluable for determining Tundra Bean Goose subspecies, but can be time-consuming when handling large numbers of captured geese. This is particularly the case when the processing time available is limited, for instance during tracking studies when more time is required to fit the transmitters, and taking other samples from individuals may be critical for their welfare. Other, more immediate, methods for subspecies identification therefore would be greatly beneficial, bearing in mind that there are also logistical issues in getting a sufficiently large and experienced team to remote catch sites to assist in recording morphological measurements. Guidelines on the optimal set of measures required to differentiate between the various forms therefore would be immensely helpful, with the results of this study showing that profile head photographs do not in themselves allow reliable identification to the subspecies level when considered in isolation. The difficulty in recognising Tundra Bean Goose subspecies accurately from photographs is further supported by researchers being able to distinguish between Taiga and Tundra Bean Geese, but not between the two Tundra forms, in photographs taken during aerial surveys over the Russian tundra (Rozenfeld *et al.* 2017, 2018). Differences in the appearance of the Taiga and Tundra forms of Bean Geese is thought to be attributable to their divergence over a longer period, and to their occupancy of different habitats particularly during the breeding season (Ottenburghs *et al.* 2020).

Of the four hypotheses tested, we found that the results obtained in our blind tests correspond best to the predictions of Hypothesis #2. Subspecies seemingly exist but the extent of the overlap zone was not clearly revealed, with experts reporting *serrirostris* occurring on the Gydan and western part of the Taimyr Peninsula and *rossicus* as far east as Chaun Bay. The lack of consistency between experts however show that the subspecies are not well recognised from photographs only. The probability of correct assignment in relation to the observation site averaged 0.72 ± 0.15 among locations (below the 0.95 threshold taken as indicative of correct assignment and no overlap in distribution), rising to an average of 0.79 ± 0.06 after exclusion of the least consistent expert, and the percentage of correct assignments did not differ significantly among locations. Earlier studies suggest that there is quite an extensive area where both Tundra Bean Goose subspecies occur in the Russian arctic (Alphéraky 1904; Delacour 1951; Cramp & Simmons 1977; Roselaar 1977; Mooij & Zöckler 1999), which means that Hypothesis #4 could also be favoured. The relatively high proportion of *serrirostris* geese recorded on the Lena Delta suggests that the area of overlap does not extend that far east, and that it occurs on the eastern part of the Taimyr Peninsula. Further studies using more accurate methods to confirm subspecies are required, however, to assess whether some Tundra Bean Geese roam more widely, with *rossicus* individuals potentially extending further east and *serrirostris* further west than has been envisaged to date.

Whilst this study found that *post hoc* identification of Tundra Bean Goose subspecies by photographs is not particularly reliable (Tables 1 & 2), the sample sizes were small, and further assessment may find that accuracy improves with an increasing number of experts, with more photographs taken of the individual birds, or with additional confirmation (using other methods) of the subspecies being photographed. Taking detailed morphological measurements is strongly recommended when handling Bean Geese during ringing and tracking studies (Mooij & Zöckler 1999), even if the time available for fitting individuals with leg-rings, neckbands and tracking devices is limited. Collecting feathers and blood samples for genetic analysis would also help towards unravelling the taxonomy and distribution history of the Tundra Bean Goose, by conducting further investigation into the markers that differentiate the two forms.

Overall, the results of our study are consistent with the medium site tenancy (even in adult birds) and high frequency of population interchange suggested for Tundra Bean Geese in Asia (Li *et al.* 2020). Regular movement of individuals between populations provides a consistent gene flow and may prevent Tundra Bean Geese from making a definitive split into two distinct subspecies. In an earlier genetic study, Ruokonen *et al.* (2008) were unable to differentiate between western and eastern birds within the tundra-breeding Bean Geese on the basis of mtDNA haplotypes only, so it is to be expected that identifying these forms with confidence, based on their morphology, would be similarly difficult.

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Photograph: Release of Bean Geese fitted with GPS trackers on the Lena Delta, Russia (July 2017), by Denis Kochetkov.