Geolocator tagging of east Siberian Bluethroats

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Abstract
The Bluethroat subspecies Cyanecula svecica svecia occurs throughout the northern Palearctic. European C. s. svecia has been shown to follow a route west of the Himalaya to winter quarters in southern Asia. Out of 30 Bluethroats tagged with geolocators in eastern Siberia, we obtained one track suggesting that it migrated east of the Himalaya to a wintering area located in Myanmar. The different routes of western and eastern C. s. svecia implicate the presence of a migratory divide in Siberia, either formed in situ during the post-glacial colonization process or resulting from a secondary contact between different refuge populations.

Keywords East Asian Flyway · Cyanecula svecica · Migration · Songbirds · Bluethroat

Introduction
It has repeatedly been observed that the migration routes and use of wintering areas of long distance migratory birds often resemble recolonization routes since last ice age (Sutherland 1998). Direct evidence of postglacial colonization routes are of course lacking, however history seems often to be a better explanation to migration routes and wintering areas than is the species ecology or the distance to presumed suitable wintering areas (Ruegg and Smith 2002).

The Bluethroat has ten described subspecies (Cramp 1988) within its range that encompasses most of the Palearctic. The subspecies Cyanecula svecica svecia occurs in the northern areas of the Palearctic from the Atlantic to Alaska and belongs to the group of “red-spotted” subspecies. The specific winter quarters of the different subspecies are poorly known because there are few ringing recoveries and the characters delimiting the subspecies are not expressed when the birds are wearing the winter plumage (Cramp 1998).

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Phylogeographic analyses of mitochondrial DNA from a broad sampling of Bluethroats across Eurasia, with representatives of most subspecies, demonstrated poor congruence between mtDNA haplotypes and subspecies (Zink...
et al. 2003). Low genetic structure among northern Blue-throats (Zink et al. 2003) and the fact that the birds breeding between Norway and Alaska are so similar to plumage and size that they have been described as the same subspecies (C. s. svecica), are suggesting that they have colonized the present range from a common refuge population following the retreat of the last glaciation. There are four migration tracks from European C. s. svecica (Lislevand et al. 2015); two from Norway and two from a mountainous population in Czech Republic, the latter shown to be genetically inseparable from north European C. s. svecica (Johnsen et al. 2006). The tracks demonstrated that they winter in the Indian subcontinent and follow a route that probably goes north of the Black Sea and the Caspian Sea (Lislevand et al. 2015). These routes agree with ringing recoveries from Swedish and Finnish C. s. svecica (Ellegren and Staav 1990). Before the present study, there was no information on the migration of east Siberian Bluethroats. The most obvious migration route and wintering area would be east of the Himalaya to southeast Asia. This is indeed the dominating migration pattern of other migratory species in eastern Siberia, which is expected, because the majority of these have colonized the present breeding range from glacial refugia located further south in the eastern Palearctic.

However, if all C. s. svecica spread from a common glacial refuge population, it is possible that the birds breeding in eastern Siberia (and Alaska) will back-track the postglacial colonization route to an ancestral wintering area, i.e., start the autumn migration westwards and slide south along the western side of the Himalaya towards a common winter ground in the Indian subcontinent (Fig. 1). Although definitely a detour, the first half of such a route would be similar to several species of Afrotropical migrants that have their breeding ranges extending into eastern Siberia (e.g. Bairlein et al. 2012; Sokolovskis et al. 2018).

To test between these two alternative hypotheses, we equipped east Siberian Bluethroats with light-level geolocators to find out whether they reach their south Asian wintering grounds by migrating west or east of the barrier consisting of the Himalaya and Tibetan Plateau.

**Methods**

**Field work**

In June 2018, we attached light level geolocators (Intigeo-W30Z11-DIP 12 x 5x4mm, 0.32 g) to 30 adult male Bluethroats at Ayopechan island in the Chaun delta in northeast Russia (68.81° N, 170.62° E). The habitat consisted of typical Sub-Arctic tundra with thick Duschekia and Salix shrubs along the shores of rivers and small lakes. We used playback of song to capture territorial males in mistnets. The geolocators were mounted with a nylon string using

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**Fig. 1** Approximate distribution range of the Bluethroat Cyanecula svecica. The breeding range is marked in red for C. s. svecica and in yellow for all other subspecies combined. The wintering range (all subspecies combined) is marked in blue. Solid arrows show the inferred routes to winter grounds of four birds tracked with geolocators from Europe (Lislevand et al. 2015). The stippled arrows indicate two alternative migratory routes of Bluethroats from the Chaun delta. The summer and winter breeding ranges are from BirdLife International and Handbook of the Birds of the World, available at [http://datazone.birdlife.org/species/requestsdis](http://datazone.birdlife.org/species/requestsdis). The breeding range of C. s. svecica is reproduced from (Zink et al 2003)
a leg loop harness. Each bird was ringed with a metal ring and one-color ring. In the breeding season of 2019, the whole area, including a radius of 500 m outside the tagging area, was searched for banded birds. Only one of the birds was relocated and retrieved. The bird had moved 0.3 km from the initial tagging site.

Geolocation data analysis

The data from the geolocator was extracted by Migrate Technology LTD. We used the R version 4.1.1 (R Core Team 2021) and the package GeoLight 2.0.0 (Lisovski and Hahn 2012) to process the light data to obtain coordinates. Great circle distances were calculated with R package geosphere 1.5–10 (Hijmans 2019). We set the threshold of light intensity to > 1 lx. With GeoLight, we used a “Loess filter” and a K value 1 to remove extreme outliers. Further, we omitted all longitudes west of 0° and latitudes south of 0°. The logger was set to start data collection on the 15th of July 2018 and continued to record until 13th of March 2019. Due to the bush-dwelling lifestyle of Bluethroats, the majority of the collected data, even after heavy filtering, was of poor quality except for the month of February. When using the data restricted to February, which should reflect a stationary period of the winter quarter, a Hill-Ekström calibration provided a sun elevation angle of −1.9 and corresponded to latitudes matching northern Mongolia, which for climatic reasons is an unlikely winter site. We then increased the sun elevation angle to +3 for latitude estimates, to include the closest suitable winter sites in southern Asia (Supplementary Table 1). Because the longitudes are not as sensitive to data quality or choice of sun elevation angle, we estimated the longitudinal positions also for the autumn migration period.

Results

The tracked Bluethroat spent the winter east of the mountain ranges in Central Asia (Fig. 2). The unfiltered positions were extremely scattered, probably due to the bird residing in dense vegetation (Suppl Fig. 1), preventing us from determining locations during its migration. However, during the main wintering period (February), longitudes centered narrowly at 98.5° E (s.d. 2.8). With a sun elevation angle set to +3, latitudes varied substantially (s.d. 10) but included northern Myanmar. By inspecting the longitudes during the supposed period of the autumn migration (end of August–end of November), there is no support for the bird being west of 90°E (Fig. 2). The great circle distance from the breeding site in Chaun to the inferred wintering site (98.5°E, 30.3°N) is 6200 km.

Discussion

The data from the single bird retrieved demonstrated that it reached its Asian winter quarter, tentatively located in Myanmar, by flying east of the Central Asian mountain ranges. By assuming that the migration of this bird is representative of eastern C. s. svecica, we can reject the presence of a common migration path of all C. s. svecica funnelling in along a corridor west of the Himalaya.

Because Bluethroats spend most of their time in dense vegetation, shading makes it challenging to obtain migration tracks using light-level geolocators, as previously has been seen in other species with similar life styles (Heim et al. 2018). It was therefore not possible to obtain more precise information of the route. However, from the longitudes (that are less sensitive to errors than latitudes) we can safely exclude that this bird was west of the Himalaya Mountain range.

This finding implies that somewhere north of the barrier in Central Asia, there should be a migratory divide. A question is whether this presumed migratory divide, that remains to be located, has been formed in situ during the postglacial range expansion (from the west or the east) or if it is a result of secondary contact of populations that were allopatrically distributed, e.g. during the last ice age. The absence of differences in mtDNA across the range of C. s. svecica (Zink et al. 2003) may favor the former. However, it is well-known from many species that mtDNA may not follow the evolution of the populations, including the Bluethroat (Zink et al. 2003). In contrast to the NW Palearctic, eastern Siberia was not fully glaciated during Pleistocene, when a complicated relief supported a wide range of local climates (Binney et al. 2017) in which boreal shrubs and even trees may have survived the cold and dry conditions of the last glaciation maximum (LGM). Hence, it is possible that migratory Bluethroats might have existed in NE Palearctic during the last glaciation and later formed a secondary contact zone (migratory divide) in Siberia with C. s. svecica populations that spread east from a glacial refugium somewhere in the western Palearctic. Support for such a scenario comes from analyses using species distribution models that inferred that Bluethroats had allopatric migratory populations both in the NW and NE Palearctic during the LGM (Ponti et al. 2020). To resolve the question whether C. s. svecica survived the last glaciation in one or two refugia will require genome resequencing of multiple samples across the subspecies range.
**Fig. 2** A time-series plot of longitudes after strict filtering. The red line shows 5-day rolling means. The grey shaded period shows the time period with stable longitudes which was used to infer the winter site, illustrated in the map by a black circle with whiskers representing standard deviations of latitude and longitude.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s10336-022-01988-z.

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**Author contributions** The study was conceived by SB, KS, MW and DS. The fieldwork was done by SI, SV and DS. The statistical analyses were carried out by KS. A first draft was written by SB and KS, and commented and approved by all authors.

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Data availability  The unfiltered light data of the tracked Bluethroat is available in Dryad Data Repository https://doi.org/10.5061/dryad.qjq2bvhq.

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