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Authors: Heim, Wieland, Antonov, Aleksey, Beermann, Ilka, Lisovski, Simeon, Sander, Martha Maria, et al.

Source: Ornithological Science, 21(1) : 121-126

Published By: The Ornithological Society of Japan

URL: https://doi.org/10.2326/osj.21.121

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Ornithol Sci 21: 121–126 (2022)

SHORT COMMUNICATION

Light-level geolocation reveals unexpected migration route from Russia to the Philippines of a Blue-and-white-Flycatcher *Cyanoptila cyanomelana*

Wieland HEIM[1,#,*], Aleksey ANTONOV[2], Ilka BEERMANN[1,**], Simeon LISOVSKI[3], Martha Maria SANDER[4] and Steffen HAHN[5]

[1] *Institute of Landscape Ecology, University of Münster, Münster, Germany*
[2] *Khinganskiy Federal Nature Reserve, Ministry of Nature Resources and Ecology, Arkhara, Russia*
[3] *Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Polar Terrestrial Environmental Systems, Potsdam, Germany*
[4] *Department of Life Sciences and Systems Biology, University of Turin, Torino, Italy*
[5] *Department Bird Migration, Swiss Ornithological Institute, Sempach, Switzerland*

ORNITHOLOGICAL SCIENCE

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Abstract East Asian songbirds are known to migrate along two major corridors: from mainland Eurasia via China to South-East Asia, and from Japan and easternmost Russia through chains of islands in the Pacific to Indonesia and the Philippines. We successfully tracked the hitherto unknown migration of a Blue-and-white Flycatcher *Cyanoptila cyanomelana* breeding in the Russian Far East. The bird spent five months on Mindoro Island in the Philippines during the non-breeding season and migrated through Taiwan, the Chinese east coast, and the Korean peninsula. Thus, we provide the first direct evidence for songbird migration from mainland Russia to the Philippines.

Key words East Asian flyway, Landbird, Songbird, Stopover, Timing

The East Asian–Australasian flyway connects northern Eurasia with tropical South-East Asia and Australia (Yong et al. 2015). Two main migration corridors have recently been described for East Asian songbirds: a mainland flight corridor connecting the Russian Far East with mainland South-East Asia (Heim et al. 2018, 2020), and an island flight corridor connecting Sakhalin, Kamchatka and Japan with the Philippines and Indonesia (Koike et al. 2016; Uemura et al. 2019). Some landbird species breeding on the Japanese archipelago cross the sea to migrate along the mainland corridor (Yamaura et al. 2017; Aoki et al. 2021). However, the migration routes of most East Asian landbirds, especially passerines, are still unknown, despite a recent increase in tracking efforts (Yong et al. 2021).

The Blue-and-white Flycatcher *Cyanoptila cyanomelana* is one of the little-studied songbirds of the East Asian–Australasian flyway. Its breeding distribution includes North-East China, southern Russian Far East, and the Korean Peninsula (subspecies *intermedia*), as well as the Kuril Islands and Japan (subspecies *cyanomelana*) (Clement & Marks 2020). Both subspecies are known to spend the non-breeding season on the Asian mainland (South-East Asia, South China) and on islands (Hainan, Taiwan, Philippines and Greater Sundas) (Clement & Marks 2020). More than 10,000 individuals of this species had been ringed since the 1960's, especially in Japan, but not a single ring recovery connecting breeding with non-breeding sites had been reported (McClure 1974; Biodiversity Center of Japan 2012; Konstantin Litvin in litt. 2021).

The population of the Blue-and-white Flycatcher is thought to be stable (Higuchi & Morishita 1999; BirdLife International 2021). However, as a forest specialist, this species might be vulnerable to ongoing habitat loss both in its breeding range in the Russian Far East (Potapov et al. 2017) and in its tropical

(Received 16 April 2021; Accepted 7 July 2021)
Corresponding author, E-mail: wieland.heim@posteo.de
* Present address: *Department of Biology, University of Turku, Turku, Finland*
** Present address: *EuroNatur Foundation, Radolfzell, Germany*

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non-breeding range (Zeng et al. 2018; Namkhan et al. 2020). Forest cover loss has been identified as a key driver of bird declines in East Asia (Higuchi & Morishita 1999; Wilcove et al. 2013), and has been linked to local declines in the Blue-and-white Flycatcher in Korea (Lee & Park 1995). Knowledge of the distribution and habitat use of the Blue-and-white Flycatcher throughout its annual cycle is likely to be crucial to identify potential threats for this species.

Here we have used light-level tracking data to determine the timing of annual cycle events as well as the stopover and non-breeding sites of Blue-and-white Flycatchers breeding in the Russian Far East. Given that all Passerine long-distance migrants previously tracked from mainland Eastern Russia migrated through China to South-East Asia (Heim et al. 2020), we expected a similar route for the Blue-and-white Flycatcher.

MATERIALS AND METHODS

1) Fieldwork

Field work took place in mixed, so called Manchurian, forests near Kundur village within Khinganskiy State Nature Reserve (49°5′24″N 130°42′36″E,) in the Russian Far East, close to the north-western border of the known breeding range of the Blue-and-white Flycatcher (Clement & Marks 2020). Six males (two second-year birds, four adults) were caught with mist-nets (Ecotone, Poland) and playback of their song from 15–18 May 2018. The recordings can be found on www.xeno-canto.org (catalogue numbers XC371903 and XC371907). All birds were marked with a metal ring on one leg and one individual colour ring on the other leg and equipped with light-level geolocators (GDL2.0, Swiss Ornithological Institute) using flexible leg-loop harnesses. The mass of the geolocator with harness (0.7 g) corresponded to less than 4 % of the individual body mass (19.7–21.5 g). We searched for returning individuals from 16–23 May 2019. Two birds were relocated and recaptured using playback and a decoy of a male Blue-and-white Flycatcher. One male was found in its former territory, while the second was found 1.4 km away from the place of tagging. We retrieved one geolocator, while the second individual had lost its device. Both returning individuals were marked as adults (after their second calendar year). The return rate was similar to birds marked only with rings (2 out of 6 geolocator-tagged vs. 2 out of 4 ringed individuals).

2) Data analysis

Light-intensity data were recorded at 5 min intervals and analysed using a threshold method and the *GeoLocTools* toolbox (Lisovski et al. 2019) in R version 3.5.3 (R Development Core Team 2019). Twilights (sunrise and sunset events) were identified on log transformed light data with a threshold of 1. We used a breeding site calibration (11 July to 19 August 2018) to determine the sun elevation angle using the *thresholdCalibration* function (Lisovski et al. 2019).

For further analysis we included data only for those periods when both latitude and longitude could be estimated. Twilight timings were grouped using a probability of movement >0.7 and periods of residency shorter than two days were discarded (Lisovski et al. 2019). The defined twilight times, the error distribution (gamma density distribution) and the grouping results were then used within the R package SGAT (Wotherspoon et al. 2013) to refine the estimated tracks using the group model (Lisovski et al. 2019). We combined prior information on twilight error distribution and the flight speed distribution (defined using a relaxed gamma distribution of shape$=$2.2 and rate$=$0.08) with the location estimates to pinpoint locations based on Markov chain Monte Carlo (MCMC) simulations. The last location was fixed to the deployment site, but the first location was fixed to the non-breeding site (see above). We included a simple land-sea mask in the model, as we could be confident that Blue-and-white Flycatchers would only stop on land. We first ran a modified Gamma model (relaxed assumptions) for 4,000 iterations to initiate the model, before tuning the model with final assumptions/priors (three runs with 300 iterations). The final run included 2000 iterations to ensure convergence. We then used the last 2,000 MCMC chains to estimate the most likely track (median location estimates) and the 95 % credible intervals.

RESULTS

We retrieved one geolocator containing light data for one year. On 19 August 2018 the Blue-and-white Flycatcher was still present in its breeding area (Table 1). However, we were unable to determine either its departure date from the breeding ground or its autumn flight track due to consistently very low ambient light intensities recorded during late summer and autumn. The bird spent the non-breeding season on Mindoro Island, Philippines, where it stayed

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Table 1. Details on the migration of a Blue-and-white Flycatcher obtained by geolocator tracking. Location estimates are given with standard deviation (SD). Breeding site coordinates refer to the place of tagging.

Site	Arrival	Departure	Longitude	Latitude
Breeding	07 May 2019	>19 August 2018	130.71	49.09
Non-breeding	<29 October 2018	26 March 2019	120.97±0.16	12.74±0.45
Spring stopover 1	31 March 2019	25 April 2019	116.47±0.54	33.66±1.45
Spring stopover 2	30 April 2019	4 May 2019	128.79±1.28	41.44±1.91

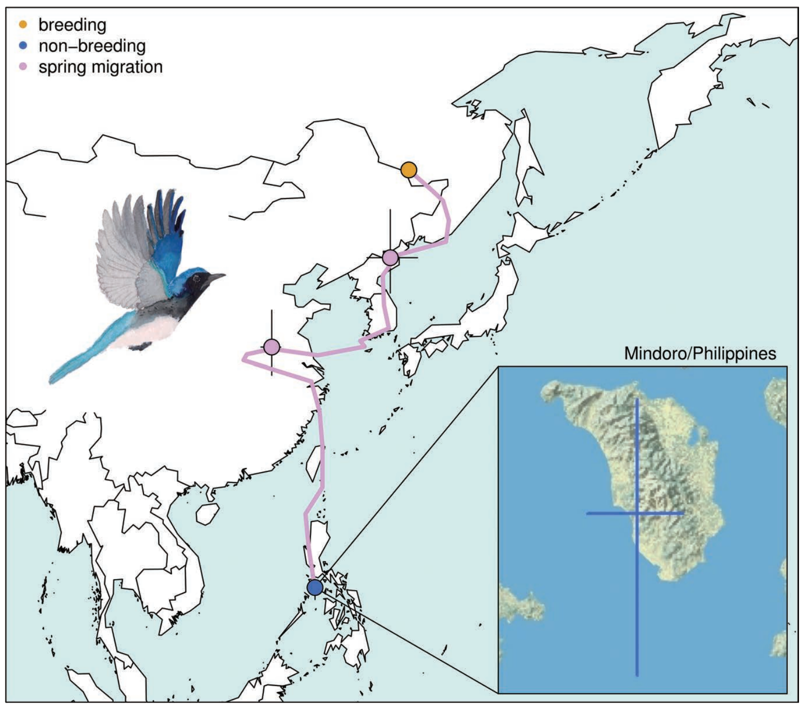

Fig. 1. Spring migration route of a Blue-and-white Flycatcher from its non-breeding site on Mindoro Island, Philippines (see inset), through China and the Korean Peninsula to its breeding site in the Russian Far East. Crosses indicate the standard deviation of the positions. Positions and routes were estimated using light-level geolocation data and the SGAT package in R (Wotherspoon et al. 2013).

for at least 148 days (29 October 2018 to 26 March 2019; Fig. 1, Table 1). During spring migration (total duration: 42 days), we found two stopovers, one most likely in Anhui Province, China (25 days) and one in North Korea (four days). Our tracking models suggested a spring migration route through Taiwan, along the Chinese east coast, and the Korean Peninsula, thereby crossing the Yellow Sea (Fig. 1, Appendix S1). By 7 May 2019, the bird had arrived on the breeding grounds in the Russian Far East (Table 1), having covered around 5,700 km during spring migration (Appendix S1), at an average travel speed of 438 km/day (excluding stopover periods).

DISCUSSION

This record of the migration route of a single Blue-and-white Flycatcher is the first direct evidence of songbird migration from mainland Russia to the Philippines, and differs from all recently tracked songbirds in this migration system which spend the non-breeding season in tropical South-East Asia (Heim et al. 2020; Yong et al. 2021).

Reverse movements, such as from islands in the Pacific to the South-East Asian mainland, have been documented for other landbird species, such as Stejneger's Stonechat *Saxicola (maurus) stejnegeri*

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(Yamaura et al. 2017) and Brown Shrike *Lanius cristatus superciliosus* (Aoki et al. 2021). Movements from northern Asia to the Japanese archipelago during the non-breeding season have been confirmed for waterbirds (Higuchi et al. 2004; Yamaguchi et al. 2008; Shimada et al. 2014) and raptors (Yamaguchi et al. 2017), and also for short-distance landbird migrants (Takagi et al. 2014). However, these species do not migrate farther south to spend the boreal winter in the tropics. The only taxonomic group that has been confirmed to link the Philippines and northern Eurasia are waders (Johnson et al. 2017; Mu et al. 2018). However, unlike the Blue-and-white Flycatcher in our study, these species use coastal habitats and wetlands along the chains of islands as stopovers.

We can only speculate about explanations for the migration route of the Blue-and-white Flycatcher. Different habitat availability in the Philippines and the South-East Asian mainland are unlikely to explain this pattern, as both regions are mainly covered by tropical and subtropical moist broadleaf forests (The Nature Conservancy 2020). The current migration route of the Blue-and-white Flycatcher might mirror the path of past colonization towards its northern breeding grounds in mainland Russia (Newton 2008; Aoki et al. 2021). A similar migration route from mainland Asia to the Philippines or even farther might have evolved in further landbird species, such as Oriental Dollarbird *Euristomus orientalis*, Pechora Pipit *Anthus gustavi*, Streaked Reed Warbler *Acrocephalus sorghophilus* and Gray's Grasshopper Warbler *Locustella fasciolata* (Dickinson et al. 1991).

Given the species' strong habitat specialisation the most likely non-breeding site of the tracked Blue-and-white Flycatcher on Mindoro Island might be situated in the lowland forests of the Sablayan penal colony or in the last primary forest of the Mounts Iglit-Baco National Park on the otherwise largely deforested island (UNESCO 2006). This highlights the importance of tropical forest protected areas not only for local biodiversity (Laurance et al. 2012), but also for migratory species.

Spring migration of our tracked individual took place largely across continental China (Fig. 1). The importance of China as a migration corridor for this species has been formerly confirmed by field studies in coastal forests of Jiangsu province, eastern China (Liu et al. 2021).

A remarkable feature of this individual's migration is the long-lasting spring stopover of almost one month in China. Blue-and-white Flycatchers may be forced to leave their non-breeding sites well before the conditions are favourable at their temperate breeding grounds, as feeding conditions might deteriorate towards the end of the dry season in the Philippines, if insect abundance decreases (Wolda 1978). Conversely, they might also choose to leave before the monsoon season starts in April or May. Other songbird species moving along the East Asian flyway make only brief spring stopovers (Heim et al. 2018, 2020), but a similar migration with long spring stopovers in East Asia was recently discovered in Pacific Swifts *Apus pacificus* and might also be explained by the avoidance of monsoon rainfalls as well (Ktitorov et al. in 2021).

After the long spring stopover in China, our location estimates suggested that the Blue-and-white Flycatcher might have crossed the Yellow Sea from Jiangsu Province, China, to Jeju Island, Republic of Korea (Fig. 1). Other migratory songbirds are also known to cross this ecological barrier at this point (Yamaura et al. 2017; Choi et al. 2020).

The timing of the arrival of the tracked Blue-and-white Flycatcher at the breeding grounds in the Russian Far East likely correlates with the flush of spring growth in the region, as has been shown for Siberian Rubythroats *Calliope calliope* breeding in the same region and showing a similar migration schedule (Heim et al. 2018, 2020).

Since our study was limited to only one individual, inferences on the general migration pattern of the Blue-and-white Flycatcher must be interpreted with caution. Individuals breeding in the same location might take different routes, as shown for other landbird migrants (Delmore et al. 2020). Further studies including more individuals and populations of both subspecies of the Blue-and-white Flycatcher are necessary to prove whether the route of the tracked individual is typical for this species.

Our study highlights the importance of tracking little-known and secretive species such as the Blue-and-white Flycatcher to uncover unknown migration routes. Understanding the spatio-temporal distribution of migratory species is key for their conservation (Kirby et al. 2008). The very long spring stopover found in the tracked Blue-and-white Flycatcher further stresses the importance of including stopover sites in conservation plans for migratory species (Sheehy et al. 2011). Unsustainable hunting at stopover sites in China has recently been linked to the decline of other migratory landbird species (Kamp et al. 2015; Heim et al. 2021). Blue-and-white Flycatch-

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ers are known to be trapped for food and the songbird trade (Chng et al. 2015, 2016; Yong et al. 2021), and a range-wide monitoring of the species' population is therefore urgently required (Yong et al. 2021). Tracking studies can fill important knowledge gaps, help to link potential threats to population trends, and guide conservation measures (Fraser et al. 2018). We hereby hope to encourage further tracking studies, especially on understudied small landbirds moving along the East Asian flyway (Yong et al. 2021).

ACKNOWLEDGMENTS

Geolocator tracking was possible under permission # 326 of FSTEC (Federal Service for Technical and Export Control) of the Russian Federation.

The authors thank Marc Bastardot, Leo Damrow, Friederike Kunz and Vera Volkova for their fieldwork support. We give special thanks to Alexander Thomas for providing recordings of the species and to Dora Schilling for making a decoy, both of which facilitated catching the birds efficiently. We further acknowledge the provision of rings and information on ring recoveries by the Bird Ringing Centre of Russia.

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