Autumn Migration of the Rare Yellow-Eyed Pigeon Columba eversmanni from Western Tian Shan (Tanyrtau), Kazakhstan

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Autumn migration of the rare Yellow-eyed Pigeon *Columba eversmanni* from western Tian Shan (Tanyrtau), Kazakhstan

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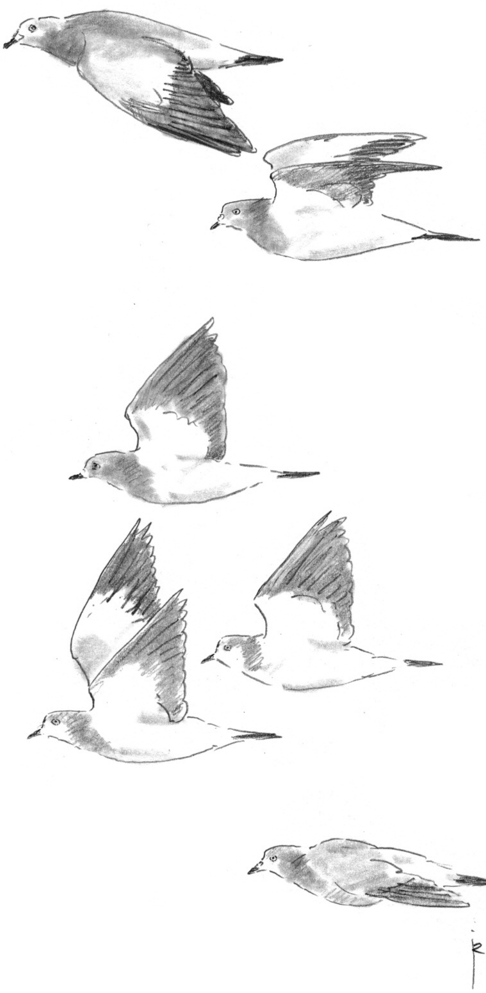

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The Yellow-eyed Pigeon *Columba eversmanni* is globally endangered and one of the rarest pigeons with a predominantly Central Asian distribution, nesting in the valleys of the Syr Darya and Ili Rivers in Kazakhstan. The causes of the sharp population decline of the species are unknown, partially due to fragmentary migration data and a lack of information on their migration routes. In this study we aimed to gather novel information on the migration patterns of Yellow-eyed Pigeons by deploying GPS/GSM transmitters. Long-term ringing data showed a clear decline in the number of captured Yellow-eyed Pigeons. Two individuals were tagged in mid-September, during autumn passage at the Shakpak Pass in Kazakhstan. Both could be tracked over a migration distance of more than 1000 km, yielding precise data about the flight direction, speed, distance and stopover behaviour of these birds during their autumn migration. During migration, the two birds achieved maximum travel rates of 257 km/day and 243 km/day, respectively, with an average of 102 km/day. The flyway during autumn migration includes several stopover sites located in south Kazakhstan, east Uzbekistan and north Afghanistan. The birds primarily utilized forest belts, crop fields and trees in rural areas as stopover sites during autumn migration, while preferred night-time roosting in trees in crop fields and on buildings. These findings are significant as they underscore the importance of using GPS/GSM trackers to study Yellow-eyed Pigeon migration on a larger scale, which could provide more comprehensive data on their habitats and movements and facilitate the identification of potential threats.

Key words: Yellow-eyed Pigeon, Shakpak Pass, migration, stopovers, GSM transmitter, GPS tracking

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The Yellow-eyed Pigeon is experiencing more severe population declines than many other Columbia species (Gavrilov & Gistsov 1985). Causes of declines are unclear, but could be varied and complex including habitat fragmentation and unsustainable hunting (Baptista *et al.* 2020). The species is classified as ‘vulnerable’ on the IUCN Red List (BirdLife International 2022) and is listed as a ‘narrow-range endemic species in decline’ in the Red Book of Kazakhstan (1996).

The distribution of the Yellow-eyed Pigeon is primarily limited to the deserts and foothills of Central Asia, particularly in southern Kazakhstan. It extends westward to the Caspian Sea and eastward to the lower reaches of the Tarim and Dzungaria. In the south, it occurs in northeastern Iran, Afghanistan and Kashmir (Dolgushin 1962). Its northern distribution is the Balkhash Basin, the Black Irtysh River (Gavrilov *et al.* 2005) and the extreme northwestern part of China. However, the migration of the Yellow-eyed Pigeon has been little studied. The fragmentary data available does not make it possible to determine the timing of its migration in various geographical areas across its distribution range. For wintering, most Yellow-eyed Pigeons appear to migrate to northwest India, Pakistan and north Afghanistan, while part of their population migrates to northwest China (Baptista *et al.* 2020). They breed mainly in the valleys of the rivers Syr Darya and Ili, partly in the Zaysan depression (Dolgushin 1962). Early spring migration of the pigeons in the foothills of western Tian Shan starts in the beginning of March and peak migration occurs from the middle–end of April to the beginning or middle of May. Autumn migration is observed from mid-August to mid-September with a notable peak in September and ending in early November (Gryaznov 1990).

Trapping and ringing of Yellow-eyed Pigeons has been conducted in Kazakhstan since 1969 at Shakpak Pass, located in the western Tian Shan, to monitor its temporal population dynamics. Historically, the species was abundant in south and southeast Kazakhstan, but its population was inferior in numbers to other species such as the Rock Pigeon *Columba livia* and Stock Dove *Columba oenas* (Sklyarenko & Karpov 2006). The number of Yellow-eyed Pigeons trapped and ringed at Shakpak Pass declined from roughly 50–100 per year in the 1970's to 10–30 per year in the 1980's (Gryaznov 1990).

The study aimed to investigate the migration patterns of the Yellow-eyed Pigeon using GPS telemetry data, but due to limited data availability, only the autumn migration was analysed. We had five specific goals: (1) estimate the population trend using ringing data, (2) assess the suitability of GPS/GSM loggers to study the movements of Yellow-eyed Pigeon, (3) to identify the migration routes and non-breeding areas, (4) to analyse the movement characteristics of the migration such as direction, speed and flight distance and (5) to describe the stopover behaviour and roosting sites.

METHODS

Study area

We conducted our study at the Shakpak Pass (42.517°N, 70.633°E); a site located between the Talas Alatau and Karatau ranges of the west Tian Shan Mountains (Tanyrtau) in Kazakhstan. The Shakpak Pass is situated in the narrowest point between the two ranges and a well-known geographical bottleneck for migrating birds, as the western side of Tian Shan creates a significant physical barrier for birds migrating from North and East Kazakhstan and Central Siberia. The site lies at the crossroads of the Central Asian and East Asian-East African Flyways (Boere *et al.* 2006). Additionally, the Himalayas and Tibetan plateau present a major obstacle for migratory birds to the south of Asia, causing some bird populations to migrate to East Africa instead (BirdLife International 2010).

Ringing and recapture

The autumn trapping and ringing season at Shakpak Pass begins on 15 August and runs until mid-November each year. The Committee for Forestry and Wildlife in the Republic of Kazakhstan approved the trapping, ringing and tracking of birds at Shakpak Pass. Long-term bird ringing data allows for monitoring avian survival rates and changes in bird numbers, while recapture data provides insight into individual movements and predicts bird migration paths (Peach 1999). Long-term ringing and recapture data of trapped birds were analysed from 1969 to 2022 at the Shakpak Pass. The Bird Ringing Center of the Institute of Zoology developed a comprehensive database compiling species composition and numbers of birds ringed at various locations of Kazakhstan since 1961. The databases have a wealth of information including species name, sex, age class, date of capture, type of trap used, body mass and other morphometric data, and information on recaptures dating back to 1966.

Tracking data

During the annual migration monitoring in September 2020, three 2nd-year or older Yellow-eyed Pigeons were caught using a stationary Heligoland type trap. We used two types of traps to capture Yellow-eyed Pigeons: three stationary traps and mist nets. We used GPS trackers with GSM technology for data recovery. The transmitters were attached to two of the ringed individuals. We applied 6-g backpack GSM transmitters (YH-GTG0306, Hangzhou Yuehai Technology Co., Ltd.). The transmitter mass did not exceed 3% of a pigeon's mass (185 and 253 g), consistent with internationally accepted best practices for tracking birds. The device has sensors for temperature, speed, altitude, activity and battery voltage. The transmitters provided measures of location accuracy using Position Accuracy Intensity (PDOP) and Horizontal Dilution of Precision (HDOP) values. Lower values indicate higher accuracy, with PDOP (range 0.5 to 99.9) and HDOP below 4 being considered ideal for precise tracking. The GSM signal frequency emitted by the transmitter can range from once every hour to once every six hours. Transmitter data is automatically sent to a central server from where it can be downloaded (Hangzhou Yuehai Technology 2022).

Data analysis

To assess the population dynamics of Yellow-eyed Pigeons at Shakpak Pass, we calculated annual and seasonal capture rates. To identify a population trend, we used linear regression with capture rate as the response variable and year as the predictor. We included season as a categorical variable. The capture rate was weighted by the inverse of the variance of ringed individuals per season. Ringing data was analysed using R v. 4.3.0 (R Core Team 2023).

To describe the land cover the tracking points, we used Google Earth Pro. Migration routes were visualized by processing and mapping the data using QGIS v. 3.26.2. In our analysis, ground level (GL) was determined using a Digital Elevation Model from the GPS Visualizer platform. To ensure accurate data, we used the PDOP and HDOP values to filter out potential incorrect locations. Only locations with PDOP and HDOP values below 4 were included in our dataset.

By analysing the time-stamped GPS locations, we were able to calculate the flight distance. This was done using the Haversine formula (Sinnott 1984) to accurately determine the great-circle distance between two points on Earth.

To classify stopover events, we applied the OUF Ornstein-Uhlenbeck motion model (Fleming *et al.* 2014) through the ctmmweb v. 0.2.10 (Dong *et al.* 2018) online application, which is built on the 'ctmm' R package (Calabrese *et al.* 2016).

RESULTS

Population trend

Long-term ringing data from the Shakpak Pass reveal negative population trends of Yellow-eyed Pigeons (Figure 1). A total of 1269 Yellow-eyed Pigeons were ringed during this period, with 260 individuals captured during spring and 1009 individuals captured during autumn. There is a clear declining trend in numbers over time, particularly evident in the autumn season. The peak count of 155 ringed individuals was observed in 1974, while the lowest count of one bird occurred in 2007. When accounting for variation in trapping effort (an average of 78 trapping days with all stationary traps per season), a significant negative population trend was observed at Shakpak Pass (spring: $F_{2.33}$ = 5.218, P = 0.0012, autumn: $F_{2.183}$ = 8.87, P < 0.001). Notably, there were no recorded sightings of Yellow-eyed Pigeons between 2008 and 2019, as well as in 2021 and 2022.

Tracking data quality assessment

The GPS/GSM trackers provided us with high-quality data that allowed us to observe the flight paths, migration speed and stopover locations of the birds. The first transmitter attached to a Yellow-eyed Pigeon (from hereon called Orange) provided 201 data points over a period of 36 days, while the second (from hereon called Blue) provided 406 data points over a period of 68 days. Data were received at average intervals of 4.38 h for the first transmitter and 4.62 h for the second transmitter, resulting in a daily frequency of 5–6 signals. 97.5% of signals from the first transmitter and 96.4% from the second transmitter had PDOP and HDOP values below 4, indicating a high degree of location accuracy. However, 12 data points (6%) from the first transmitter and 57 (14%) from the second were excluded due to a lack of coordinates or velocity information, mostly occurring at the beginning and end of the tracking period for both transmitters. The battery voltage remained above 3.7 V throughout the tracking

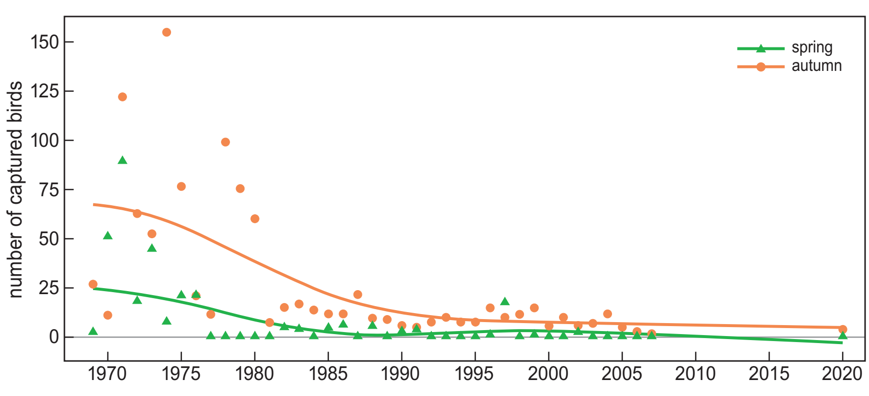

Figure 1. Population trends of Yellow-eyed Pigeons captured in spring and autumn from 1969 to 2022 in the Shakpak Pass in Kazakhstan. The points represent the number of birds captured in each season and year. The lines represent linear regression models fitted to the data.

period for both transmitters, indicating good health and functionality. Additionally, it is worth noting that the trackers were programmed to provide regular location updates at a frequency that allowed for accurate tracking of migration. Overall, the trackers' high spatial resolution and long battery life enable continuous monitoring of bird movements over long distances.

Migration routes

The first individual ('orange' in Figure 2) provided valuable information about its migration from the Shakpak Pass to the eastern part of Uzbekistan. We installed the transmitter on 12 September 2020 at the Shakpak Pass. During the initial four days, the pigeon remained within a 20-km radius of the Shakpak Pass. Afterward, it stayed for nine days in the northern forest belt of the Talas region in Kyrgyzstan, which was approximately 18 km northeast of the ringing place. On 26 September 2020, it travelled southwest to the Gorge Mashat of the Turkestan region in Kazakhstan, covering a distance of 107 km. This bird deviated from the expected migration pattern: after spending more than nine days at the Kazygurt location, the bird flew back towards the northeast on 6 October 2020. It is noticeable on the map, that during its stopover migration, the bird crossed the Shakpak Pass five times. Its flight path took

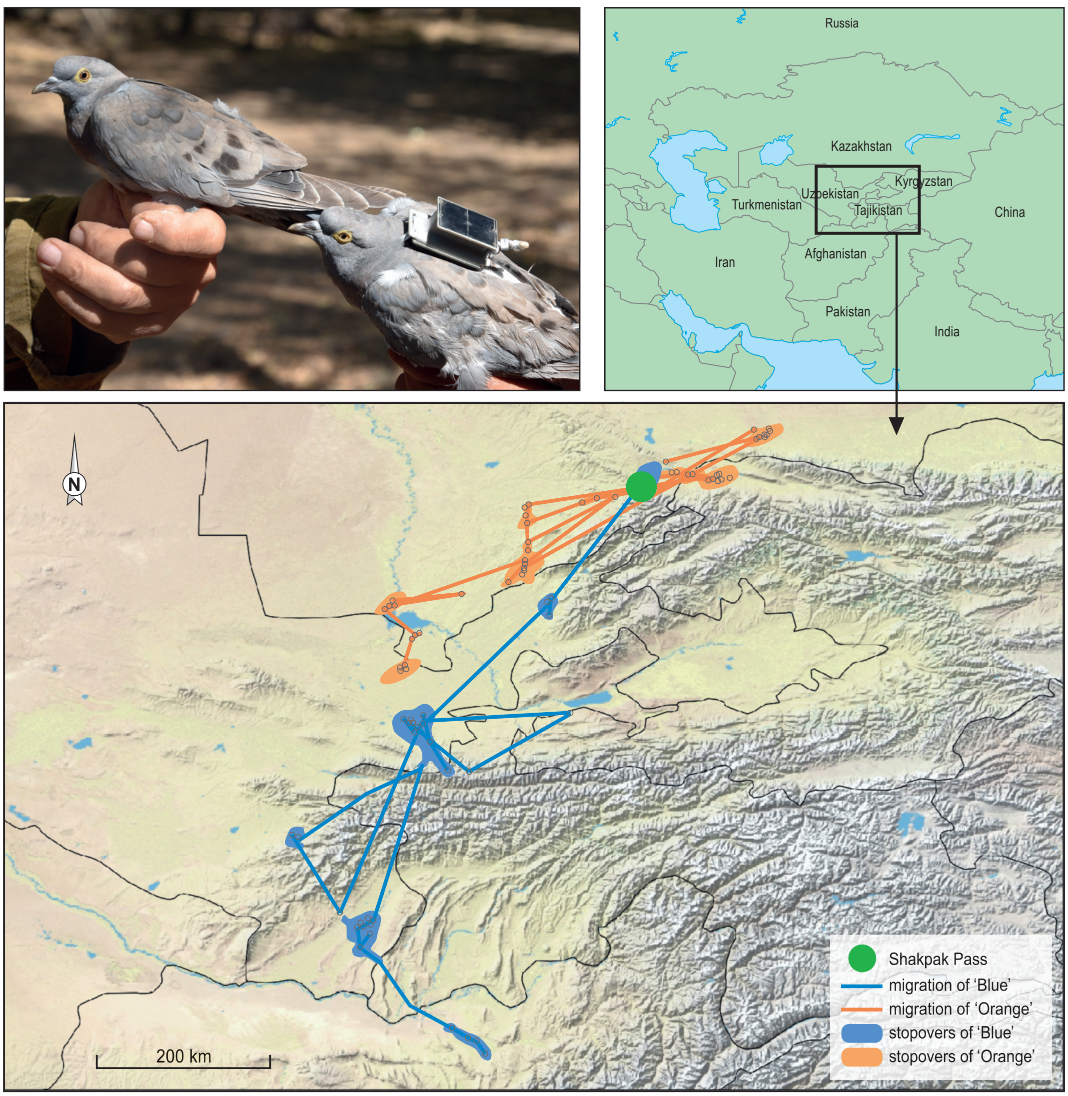

Figure 2. Autumn migration paths and stopover locations of two Yellow-eyed Pigeons (Orange and Blue) based on GSM/GPS tracking data in 2020. The lines show the routes of Orange and Blue as they flew southward. The green circle marks the capture location of Shakpak Pass. The dots show the estimated sizes of stopover sites, based on an OUF motion model.

it over the Ugam Range in the Karatau Mountains, which includes both the Sairam-Ugam State National Natural Park and the Aksu-Zhabagly Natural Park. Eventually, the bird reached a forest belt near the city of Taraz and flew further south, stopping for almost four days near the Shardara reservoir in the Turkistan region. The bird finally stopped and stayed in the Jizzakh region, Uzbekistan, from 28 October 2020 to 30 June 2021. The last signal indicating normal bird behaviour was received on 29 November 2020. One possible explanation for this pattern is that the bird had died between 29 November 2020 and 30 June 2021, with the tracker continuing to send signals until it ran out of power or was damaged. However, this hypothesis is based on limited evidence and alternative scenarios, such as migration or tracker failure, cannot be ruled out.

The second individual ('blue' in Figure 2) crossed Uzbekistan and the western parts of Kyrgyzstan and Tajikistan, finally stopping in northern Afghanistan along the Kunduz River. This bird was equipped with a transmitter in the morning of 16 September 2020 at Shakpak Pass. The bird did not fly far in the first six days of tracking, remaining mainly within a radius of 6 km, and flew mainly in the forest belt around the village of Karasaz close to Shakpak Pass. On 22 September 2020 it flew south and stopped in the Parkent region of Uzbekistan, traveling 167 km in 4 h 56 min. The next day it flew 127 km to the Bahri Tojik reservoir in the Leilek region of Uzbekistan, then headed southwest in the evening and took off on 23 September to the Devashtich region of Tajikistan, in the Ferghana Valley (39°32'56.72''N, 68°48'44.14''E). At night, this bird flew back to the forest belt of the Zaaminsky district of Uzbekistan and stayed there for 10 days. On 11 October it initiated flight from the mountains of western Tajikistan, soaring at an altitude of 2918 m, and subsequently reached the Kumkurgan district in the Surkhandarya region of Uzbekistan. The journey continued, and on 21 October 2020, it crossed the border into Tajikistan, eventually arriving in the Kunduz province of Afghanistan. The last signal from the transmitter was received after a flight duration of 10 h on 22 October 2020. Following this, the transmitter ceased functioning.

Recapture data

From 1969 to 1987, 1086 birds were captured and 10 recaptures were recorded (Sema 1994). Between 1987 and 2013, an additional 180 individuals were captured, with only one recapture documented (Zaripova 2014). In total, only 13 recaptures have been documented, which amounts to 1.02% of the total number of ringed birds (Figure 3). The largest number of return data was received from Uzbekistan (46.2%), followed by Kyrgyzstan (23%) and 7.7% each from Kazakhstan, Pakistan, Tajikistan and Afghanistan.

The one young pigeon, ringed on 25 September 1971 at the Shakpak Pass, was observed a day later in the Syrdarya region of Uzbekistan. This suggests that young birds could cover up to 245 km per day, comparable to the maximum daily migration distance we recorded by GPS tracking adult birds. The longest migration route was determined to be 1482 km, covered in 30 days, based on the GPS tracking data. The longest recovery was recorded in 1983: 1324 days after ringing an adult individual at the Shakpak Pass.

Migration features

During the autumn migration, the maximum speeds were recorded at 257 km/day for Orange and 243 km/day for Blue, with an average speed of 102 km/day (Table 1). The non-stop flight duration was approximately 13 hours. Orange's longest flights occurred through the Mashat Gorge (107 km on 26 September) and across the Ugam range in Kazakhstan (174 km on

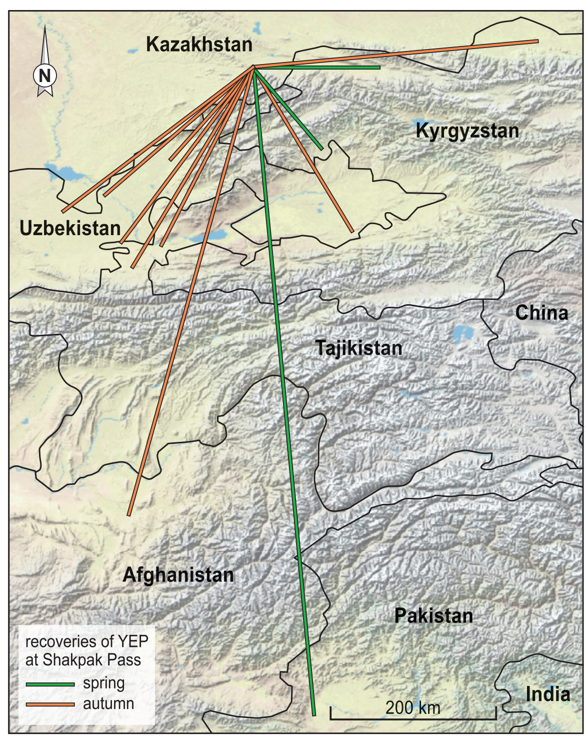

Figure 3. Recapture map of Yellow-eyed Pigeons in 1969–2022. Green lines: spring recaptures, orange lines: autumn recaptures. The two GPS-tracked birds of this study are included.

6 October and 257 km on 15 October). On the other hand, Blue's longest flights took place from the Parkent region to the Fergana Valley near the Zaamin National Park, covering a distance of 243 km per day on 23 September 2020. Additionally, Blue reached an altitude of 3508 meters above sea level during its migration. During the time interval between 10 June 2020 16:30 and 21:35, Orange's flight distance reached the maximum value of 173.6 km in a four-hour period. Blue's maximum flight distance of 166.7 km in any 4-h period was recorded between 22 September 2020 20:27 and 23 September 2020 0:21. It should be noted that the four-hour intervals on average may not provide an accurate representation of daily flight activity. The highest recorded ground speeds were 60.56 km/h for Orange (October 26 2020), and 62.04 km/h for Blue (11 October 2020), while on average the pigeons flew at ground speeds of 45.64 km/h. The velocity at the stopovers averaged 0.29 km/h, reaching up to 4.82 km/h.

Our data indicate that when birds fly over a distance and through mountain passes, they fly at their maximum speed (Figure 4). It is important to note that the observed altitudes above sea level were primarily

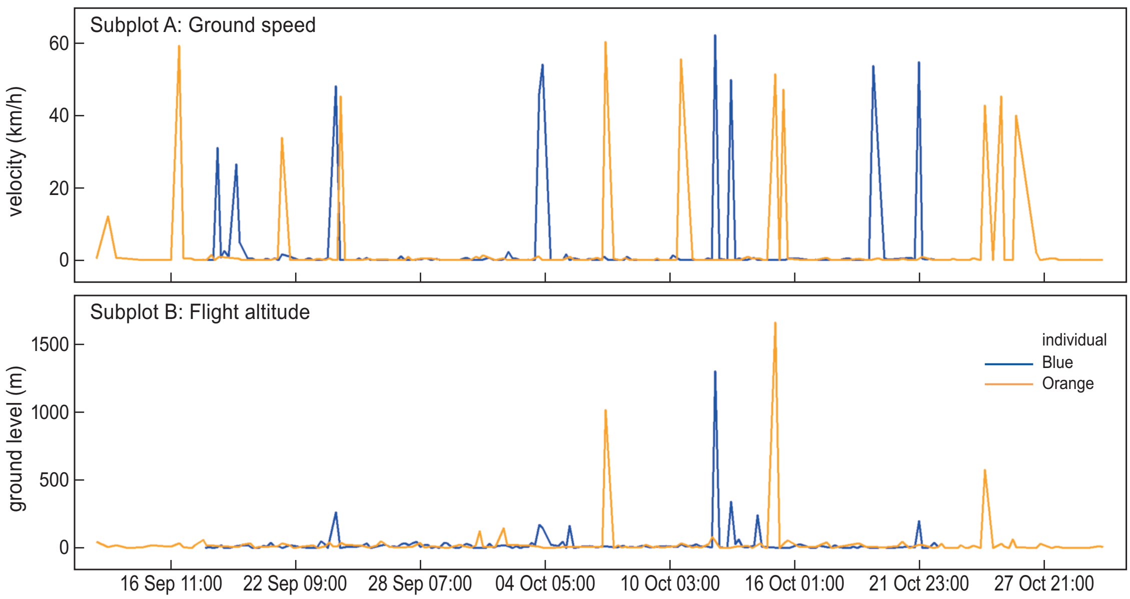

Figure 4. Ground speed (km/h) and flight altitude (m above ground level) of two GPS-tracked Yellow-eyed Pigeons.

Table 1. Data summary of two GPS-tracked Yellow-eyed Pigeons caught in the Shakpak Pass in Kazakhstan.

Individual	Orange	Blue
Tracking period	12/09/2020–19/11/2020	16/09/2020–22/10/2020
Tracking period length	68 d	36 d
Total distance	1482 km	1334 km
Maximum daily migration distance	256 km/d	243 km/d
Average daily migration distance	101 km/d	104 km/d
Maximum velocity	60.56 km/h	62.04 km/h
Average velocity during migration	44.7 km/h	47.22 km/h
Average velocity during stopovers	0.29 km/h	0.29 km/h
Maximum stopover length	9 d 8 h	8 d
Maximum flight altitude (above sea level)	2948 m	3508 m
Average flight altitude (above ground level)	513 m	576 m
Number of recorded signals from transmitter	309	191

influenced by the underlying terrain, as the birds were migrating through mountainous regions. Additionally, both birds demonstrated instances of 'fast' flights where they did not reach significant altitudes. This suggests that factors other than altitude, such as wind patterns or specific flight strategies, might also influence their ground speed during certain segments of their migration.

We indeed found a significant positive relationship between velocity (km/h) and height above ground level ($\beta = 7.33$, $P < 0.001$; Figure 5). This suggests that as their altitude above the ground increases, the velocity of the pigeons increases. However, it is important to note that the model's predictive power is relatively low, as indicated by the R^2-value of 0.30.

Our analysis of the merged data from two individuals revealed a moderate positive linear relationship between flight speed and altitude ($r = 0.59$). Flight speed ranged between 0 and 62.56 km/h, with a mean of 2.81 km/h, while the ground altitude was between 0 and 1653.8 m, with a mean of 33.43 m.

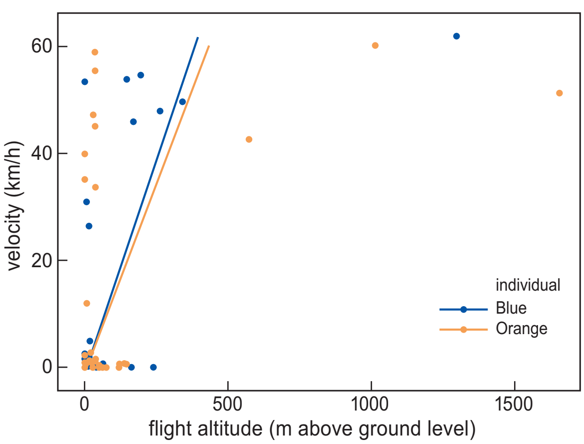

Figure 5. Flight altitude above ground level and velocity of two GPS-tracked Yellow-eyed Pigeons. The colours orange and blue correspond to the data and the linear model for both individual.

Stopover behaviour

GPS tracking data has revealed that Yellow-eyed Pigeons use forest belts, crop fields and remote mountain habitats as stopover sites during migration, counting every night as a single roosting site. The autumn migration night-time roosting sites ($n = 68$) of Orange were primarily trees in crop fields (44%), followed by forest along roads and in backyard of farms (18% each), natural forest groves (8%), forest belts near water (6%) and shrubs (6%). Meanwhile, Blue ($n = 36$) mainly used village building roofs (38%), followed by trees in crop fields and near buildings (25% each), natural forest groves (11%) and remote mountain areas (1%). Our data show that both tracked birds use the same habitats for daily roosting during migration stopovers. Both individuals mainly fed in agricultural fields and occasionally in wheat warehouses in the Kazygurt forest belt.

During autumn migration, the longest stopover duration of Orange was 9 days and 8 hours in the eastern forest belt of the Kazygurt district in the Turkistan region of Kazakhstan. Meanwhile, Blue had a maximum stopover duration of 9 days and 4 hours in the forest belt of Zardbor city in the Jizzak district, as well as in Tashkeskan village in the Zaamin district of Uzbekistan. It is worth noting that Orange's 25-day stopover in the southwest of Gagarin City of Jizzakh region of Uzbekistan, could potentially mark the start of the wintering period.

We identified key stopover sites for the Yellow-eyed Pigeon based on the duration of stays at stopover sites during autumn migration. These sites include forest belts in the west part of the Zhambyl region, the eastern outskirts of Kazygurt city and the northern part of Shardara reservoir in the Turkistan region of Kazakhstan (Table 2). Other important stopover sites were found in the northern part of the Talas region in Kyrgyzstan, the southwest of Gagarin city and Zaamin district in Jizzakh region of Uzbekistan, Shurchi city in Surkhandarya, as well as the Balkh region and Kunduz province in Afghanistan.

The OUF model analysed GPS tracking data to determine the distribution area of the Yellow-eyed Pigeon. The largest stopover sites were observed in the Jizzakh region (Uzbekistan), Tashkeskan (1494 km^2), Shurchi city in the Surkhandarya region (1463 km^2) and Kazygurt district in the Turkistan region (1105 km^2) of Kazakhstan. However, the analysis was based on a limited number of transmitter signals from just two individuals, which will impact the accuracy of the distribution areas. Furthermore, these areas should not be considered as representative of the species' overall stopover distribution.

DISCUSSION

Using GPS/GSM transmitters, we successfully tracked the migratory movements of Yellow-Eyed Pigeons for the first time along the Central Asian Flyway. Trackers yielded data for a period of up to 68 days after tagging. Mortality or tag failure was assessed based on factors such as abrupt data transmission cessation. One bird experienced tag failure, while the other showed continued transmitter activity even after death.

The ringing data results, as depicted in Figure 1, are consistent with previous studies that have reported a rapid decline in the Yellow-eyed Pigeon population due to hunting and habitat loss. The decreasing number of captures suggests a potential decline in the local population or changes in their migratory patterns.

Considering the information available from GBIF and eBird.org regarding the main wintering areas of Yellow-eyed Pigeons in Northwest India, particularly Rajasthan and Central Pakistan, it is reasonable to hypothesize that the individual labelled as Blue, whose signal was lost during tracking, may have been en route to the primary wintering region in Northwest India. Additionally, the presence of our bird Orange in Uzbekistan until November suggests that Central Asia, including Uzbekistan, could serve as a wintering area for at least a portion of the Yellow-eyed Pigeon population. These findings highlight the potential for Yellow-eyed Pigeons to spend the northern winter in Central Asia before continuing their migration. While the tracking efforts focused on the autumn migration, the information from GBIF and eBird.org provides valuable insights into the known wintering areas of Yellow-eyed Pigeon. It allows us to make informed predictions about the destinations and behaviour of the tracked individuals. However, it is important to note that the tracking data does not provide comprehensive information about their complete migratory cycle or the specific locations they inhabit during the winter period.

In our observations of bird behaviour, we have noticed instances of reverse migration patterns in one individual. Possible explanations for this behaviour could include a scarcity of food at the initial stopover site, a bird's need to find more suitable wintering habitat or an attempt to avoid unfavourable weather conditions and other potential hazards (Gilroy & Lees 2003, Kasper 2004).

Studies on barrier crossings, specifically ecological barriers such as mountain ranges, have illuminated their influence on migratory behaviour. In our study, we observed that the longest non-stop flights of the tracked pigeons occurred during the crossing of mountainous regions. This suggests that the limited availability of suitable resting or feeding sites along these challenging routes may compel the birds to undertake prolonged flights.

Our data revealed that Yellow-eyed Pigeons utilized a diverse range of habitats during migration, including forest belts, crop fields and remote mountain areas. They also used varied types of roosting sites, such as large trees (particularly Turanga groves in Kazakhstan), dense understory vegetation, trees in crop fields or along roads, forest belts near water bodies, and buildings. By scaling up tracking efforts it may become

Table 2. Important stopovers of two GPS-tracked Yellow-eyed Pigeons.

Bird 'Orange'	**Duration**	**Period**	**Area*** (km^2)	**Habitat type****
Zhanatalap and Zhanaturmys vill., Shakpak Pass, Zhualy district, Zhambyl region, KZ	5 d 8 d	12–16 Sep 07–14 Oct	709	Forest belt of Teris River
Kok-Dobo village, Talas region, KG	9 d	17–25 Sep	876	Forest belt of Talas River
Kazygurt district, Turkistan region, KZ	9 d 5 h 9 d 8 h	27 Sep – 06 Oct 15–23 Oct	1105	Forest belt of Keles River
Shardara reservoir, Turkestan region, KZ	1 d	24–25 Oct	482	Forest belt of Syrdarya River
South-west of Gagarin city, Mirzachul district, Jizzakh region, UZ	25 d (probably wintering)	26 Oct – 19 Nov	688	Forest belt near to city
Bird 'Blue'				
Shakpak Pass, Karasaz village, Zhualy district, Zhambyl region, KZ	6 d	16–21 Sep	838	Forest belt of Teris River
Parkent village, Toshkent district, UZ	1 d	22–23 Sept	384	Forest belt of Parkentsoy River
Zardbor city, Jizzak region, Tashkeskan, Zaamin district, UZ	9 d 4 h 8 d	24 Sep – 2 Oct 4–10 Oct	1494	Forest belt Near to city
Shurchi city and Surkhandarya region, UZ	8 d 12 h	12 Oct – 20 Oct	1463	Forest belt of Surkhandarya River
Kunduz Province, Afghanistan	1 d	21–22 Oct	535	Forest belt of Kunduz River

*Predicted size of the stopover location calculated using the OPF model. **Based on satellite imagery from Google Earth.

possible to study how Yellow-eyed Pigeon select between different foraging and roosting habitats depending on the availability of food, shelter and water in a particular area. The use of trees in crop fields or near farms as roost sites likely reflects the use of grains for food.

Our findings contradict early reports that this species avoids humans, as they have been observed to roost on the roofs of buildings or warehouses in urban areas. According to our data, pigeons spend more nights roosting in trees in cultivated fields than in dense forests. This could be due to the availability of food in the fields or a decrease in the number of natural forests that cannot provide adequate food.

The tracking efforts focused on the autumn migration of Yellow-Eyed Pigeons, providing insights into their initial migratory movements. However, future studies or tracking efforts during different seasons, including winter, are needed to gain a more comprehensive understanding of Yellow-eyed Pigeons' complete migration and wintering habits. Combining tracking and recapture data enhances our understanding of Yellow-eyed Pigeon migration, including routes, stopover sites and wintering areas.

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SAMENVATTING

De Oosterse Holenduif *Columba eversmanni* is een van de zeldzaamste duivensoorten en wereldwijd bedreigd. De soort heeft een overwegend Centraal-Aziatische verspreiding en broedt onder andere in de valleien van de rivieren Syr Darya en Ili in Kazachstan. De oorzaken van de sterke populatieafname van de soort zijn onbekend, deels als gevolg van fragmentarische kennis over hun trek en een gebrek aan informatie over de trekroutes. In dit artikel presenteren we informatie over de trekpatronen van Oosterse Holenduiven uitgerust met GPS/GSM-zenders. Langetermijnringgegevens laten een duidelijke daling zien in het aantal gevangen duiven. Twee individuen kregen medio september 2020 een zender tijdens de herfsttrek op de Shakpakpas in Kazachstan. Beide konden worden gevolgd over een afstand van meer dan 1000 km, wat nauwkeurige gegevens opleverde over de vliegrichting, snelheid, afstand en tussenstops van deze vogels tijdens de trek. Tijdens die trek bereikten de twee vogels een maximale treksnelheid van respectievelijk 257 km/dag en 243 km/dag, met een gemiddelde van 102 km/dag. De vliegroute tijdens hun herfsttrek omvatte verschillende tussenstops in Zuid-Kazachstan, Oost-Oezbekistan en Noord-Afghanistan. De vogels gebruikten voornamelijk bosgebieden, akkers en bomen bij gebouwen in landelijke gebied als tussenstop om te foerageren, terwijl ze de voorkeur gaven aan nachtelijke roestplaatsen in bomen in akkers en op gebouwen in het landelijke gebied. Uitbreiding van het gebruik van GPS/GSM-trackers maakt het mogelijk om de trek van Oosterse Holenduiven op grotere schaal te bestuderen, wat het opsporen van potentiële bedreigingen zou kunnen vergemakkelijken.

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