IRSTI 34.33.27 https://doi.org/10.26577/bb202510328

B.T. Berdikulov[1,2*], Y.V. Akentyeva[1,2], A.E. Tashimova[1], A.E. Gavrilov[1]

[1]Republican state enterprise with the right of economic management "Institute of Zoology" of the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan, Almaty, Kazakhstan
[2]Al-Farabi Kazakh National University, Almaty, Kazakhstan
*e-mail: bekzhan.berdikulov@zool.kz

POST-FLEDGING BEHAVIOUR OF A JUVENILE EASTERN IMPERIAL EAGLE *(AQUILA HELIACA)* TRACKED BY GPS IN THE TAUKUM DESERT, SOUTHERN BALKHASH REGION IN KAZAKHSTAN

The post-fledging period is a critical stage in raptor development, influencing survival, dispersal, and recruitment into the breeding population. However, knowledge of juvenile Eastern Imperial Eagle *(Aquila heliaca)* movement ecology remains limited, particularly in Central Asia. This study presents the first GPS tracking-based analysis of a juvenile Eastern Imperial Eagle from the Taukum Desert, Balkhash-Alakol Basin, Kazakhstan, providing insights into post-fledging dispersal, movement behavior, and habitat selection. The study aimed to document the timing of dispersal, territorial expansion of the range and habitat use of post-fledging Eastern Imperial Eagles during the first months *(Aquila heliaca)*. A 65-day-old nestling was fitted with a GPS- transmitter and monitored from mid-July to late September 2024. Movement patterns were analyzed using GPS telemetry and Kernel Density Estimation (KDE) to assess habitat preferences.

The eagle was tracked for 77 days, producing 1,859 GPS locations and covering 713 km. It remained within 2 km of the nest for six weeks before gradually expanding its range. True dispersal began at 112 days old, marked by a 6-8 km westward flight. The maximum recorded distance was 18.6 km (September 11, 2024), while the longest single-day movement reached 49.6 km. Flight altitude averaged 453.5 m, peaking at 1,498 m, with a maximum flight speed of 85.9 km/h. Habitat analysis showed a strong preference for semi-desert steppe and riparian habitats, with over 95% of locations in natural landscapes. The eagle avoided human settlements. KDE identified core home ranges within 10 km of the nest, extending up to 290 km².

The study highlights the importance of preserving natal habitats and implementing powerline hazard mitigation measures to prevent mortality of young raptors. Future studies should track multiple individuals to assess dispersal and survival trends in Central Asia. Future research should track multiple individuals to assess dispersal trends and survival in Central Asia.

Keywords: Eastern Imperial Eagle, GPS telemetry, Taukum, post-fledging dispersal, habitat selection, juvenile raptor behavior, conservation.

Б.Т. Бердіқұлов[1,2*], Е.В. Акентьева[1,2], А.Е. Ташимова[1], А.Э. Гаврилов[1]

[1]Қазақстан Республикасы Ғылым және жоғары білім министрлігі Ғылым комитетінің "Зоология институты" шаруашылық жүргізу құқығындағы республикалық мемлекеттік кәсіпорны, Алматы, Қазақстан
[2]Әл-Фараби атындағы қазақ ұлттық университеті, Алматы, Қазақстан
*e-mail: bekzhan.berdikulov@zool.kz

Балқаштың оң жағындағы Тауқұмда GPS орнатылған жас қарақұстың *(Aquila heliaca)* ұядан ұшқаннан кейінгі мінез-құлқы

Ұядан ұшқаннан кейінгі кезең жыртқыш құстардың дамуы үшін аса маңызды, өйткені бұл олардың тіршілік ету қабілетіне, таралуына және ұрпақ өрбітуіне тікелей әсер етеді. Алайда, Орта Азиядағы жас қарақұстың *(Aquila heliaca)* таралу экологиясы туралы мәліметтер жеткілікті емес. Бұл жұмыста қарақұс балапанының Балқаш-Алакөл ойпатындағы Тауқұмда, ұядан ұшқаннан кейінгі қозғалысын алғаш рет GPS-трекер арқылы бақыланғаны талданады. Атап айтқанда, ұядан ұшқаннан кейінгі таралуы, ұшу ерекшеліктері мен мекендеу ортасын таңдауы зерттеледі. Зерттеудің мақсаты – қарақұстың ұядан ұшқандағы алғашқы айларындағы таралу кезеңін, аумақтық кеңеюін және тіршілік ету ортасын пайдалануын анықтау. 65 күндік балапанға

GPS-трекер 2024 жылғы шілденің ортасынан қыркүйектің соңына дейін сигнал беріп тұрды. Ұшу ерекшеліктері GPS-телеметрия арқылы, ал мекендеу ортасына деген бейімділігі Тығыздықты ядролық бағалау (KDE) әдісі арқылы есептелді. Қарақұсқа орнатылған GPS трекиңнен 77 күн ішінде 1859 сигнал түсті. Осы уақыт ішінде ол 713 км қашықтықты ұшып өткен. Ол алғашында 6 апта бойы ұядан 2 км дейінгі радиуста ұшса, кейін біртіндеп қозғалыс ауқымын кеңейтті. Қарақұстың балапаны 112 күнге толғанда алғаш рет 6-8 км қашықтыққа батысқа қарай ұшқан сәті – ұя маңынан нақты түрде қоныс аудару кезеңінің басталғанын көрсетті. Ең алыс қашықтық 2024 ж. 11 қыркүйегінде тіркеліп, 18,6 км көрсетсе, ең ұзақ бір күндік ұшу 49,6 км құрады. Орташа ұшу биіктігі теңіз деңгейінен 453,5 м, ең жоғарғы ұшу биіктігі 1498 м, ал ең жоғары жылдамдық 85,9 км/сағ жетті. Мекендеу ортасын зерттеу қарақұстың жартылай шөлейтті дала және өзен аңғары экожүйелеріне айқын бейімделгенін көрсетті: тіркелген сигналдың 95%-дан астамы табиғи ландшафттарда орналасқан. Қарақұс адам қоныстарынан аулақ болған. KDE талдауы бойынша негізгі тіршілік аймағы ұядан 10 км радиуста, ал аумақты пайдалануы ауқымы 290 км² құрады.

Бұл зерттеу жас жыртқыш құстардың өлімінің алдын алу үшін ұялау ортасын сақтаудың және электр желілерінің қаупін азайту шараларын енгізудің маңыздылығын көрсетеді. Болашақ зерттеулерде GPS-бақылау жүргізуді кеңейтіп, бірнеше құсқа орнату арқылы Орта Азиядағы қырандардың таралуы мен тіршілік ету мүмкіндіктерін толық зерттеу ұсынылады.

Түйін сөздер: қарақұс, GPS телеметрия, Тауқұм, ұядан ұшқаннан кейінгі таралу, тіршілік ортасын таңдау, жас жыртқыш құстардың мінез-құлқы, түрлерді қорғау.

Б.Т. Бердикулов[1,2*], Е.В. Акентьева[1,2],
А.Е. Ташимова[1], А.Э. Гаврилов[1]

[1]Республиканское государственное предприятие на праве хозяйственного ведения Институт зоологии Комитета науки Министерства науки и высшего образования Республики Казахстан, Алматы, Казахстан
[2]Казахский национальный университет им. аль-Фараби, Алматы, Казахстан
*e-mail: bekzhan.berdikulov@zool.kz

Послегнездовое поведение молодого могильника *(Aquila heliaca)* по данным GPS-трекера в пустыне Таукумы, южное прибалхашье

Период после вылета из гнезда является критическим этапом в развитии хищных птиц, влияющим на их выживание, расселение и дальнейшее вступление в гнездовую популяцию. Однако знания об экологии перемещений молодых особей восточного могильника *(Aquila heliaca)* остаются ограниченными, особенно в Центральной Азии. В этом исследовании впервые представлены данные GPS-трекинга и анализ перемещения ювенильного восточного могильника из пустыни Таукум, Балхаш-Алакольский бассейн, Казахстан. Эти сведения дают понимание о расселении после вылета из гнезда, поведении при передвижении и выборе местообитаний. Цель исследования – документирование сроков расселения, территориального расширения ареала и использования местообитаний восточного могильника *(Aquila heliaca)* в течение первых месяцев после вылета из гнезда. 65-дневный птенец был снабжен GPS-передатчиком и наблюдался с середины июля по конец сентября 2024 года. Модели перемещения анализировались с использованием GPS-телеметрии и оценки плотности ядра (KDE) для оценки предпочтений в отношении местообитаний.

Орла отслеживали в течение 77 дней, что дало 1859 сигналов GPS и охватило 713 км. Он оставался в пределах 2 км от гнезда в течение шести недель, прежде чем постепенно расширить свой ареал. Расселение началось в возрасте 112 дней, отмеченное полетом на 6-8 км на запад. Максимальное зарегистрированное расстояние составило 18,6 км (11 сентября 2024 г.), в то время как самое длинное однодневное перемещение достигло 49,6 км. Высота полета в среднем составила 453,5 м, достигнув пика в 1498 м, с максимальной скоростью полета 85,9 км/ч. Анализ среды обитания показал предпочтение полупустынным степям и прибрежным местообитаниям, причем более 95% местоположений находились в естественных ландшафтах. Орел избегал человеческих поселений. KDE определил основные участки обитания в пределах 10 км от гнезда, простирающиеся до 290 км².

Исследование подчеркивает важность сохранения натальных местообитаний и внедрению мер по снижению опасности линий электропередач для предотвращения смертности молодняка хищных птиц. Будущие исследования должны отслеживать несколько особей для оценки тенденций расселения и выживания в Центральной Азии.

Ключевые слова: могильник, GPS-телеметрия, Таукум, послегнездовое расселение, выбор местообитаний, поведение ювенильных хищных птиц, сохранение биоразнообразия.

1. Introduction

The Eastern Imperial Eagle is a large raptor inhabiting steppe and forest-steppe ecosystems across Eurasia. Due to habitat loss, mortality from electrocution on power lines, collisions with vehicles, hunting, and declining prey availability, the species is classified as Vulnerable on the IUCN Red List [1]. In Kazakhstan, the species is listed as Category I ("disappearing") in the national Red Data Book [2], emphasizing its threatened status and the necessity for strict conservation measures. Despite its imperiled status, Kazakhstan harbors one of the most significant breeding populations of Eastern Imperial Eagles, estimated at 3,400-4,200 pairs [3]. The species nests widely across the country, from the Edil-Zhaiyq (Volga-Ural) interfluve in the northwest to the Ustyurt Plateau and Mangystau in the southwest, spanning diverse habitats including steppe, semi-desert, and desert regions such as Betpak-Dala, the Karakum and Kyzylkum deserts, and the Shu Valley. In the foothills of the Altai, Tarbagatai, and Zhetysu Alatau, the species is present but avoids high mountainous regions [4-7]. During migration, Eastern Imperial Eagles are encountered across Kazakhstan, while wintering birds are recorded mainly in the south and southeast of the country [8].

Despite this broad distribution, relatively little research has been conducted on the dispersal of juvenile Eastern Imperial Eagles from Kazakhstan. Most ecological studies on the species have been conducted in Europe (e.g., Central and Eastern Europe) [9-14], where populations are smaller but more intensively monitored. Consequently, a significant knowledge gap remains regarding the post-fledging dispersal behavior of juveniles from Central Asian populations, which may differ due to the region's vast semi-desert landscapes and continental climate.

The post-fledging period, defined as the phase between fledging and independence, is critical for juvenile raptor survival and recruitment into the breeding population [13]. During this time, juveniles gradually develop flight and hunting skills, disperse from their natal areas, and navigate environments fraught with threats such as food scarcity, predation, and human-related hazards [9]. Research on Eastern Imperial Eagles in Bulgaria found that juvenile mortality rates were highest during the first year, with electrocution and poisoning being major causes of death [11]. These findings emphasize the need for region-specific research to assess survival rates and threats in Central Asia, where land-use patterns and environmental pressures differ significantly.

Dispersal strategies among large eagle species exhibit substantial geographic and ecological variation. For instance, studies on Golden Eagles (*Aquila chrysaetos*) have revealed that juvenile dispersal distances differ by population. In resident populations, juveniles often remain near their natal areas [12], whereas migratory populations undertake longer dispersal movements, influenced by habitat availability and climate [10]. Similarly, Bonelli's Eagles (*Aquila fasciata*) are known for their long-distance dispersal, with juveniles moving 1 to 1,020 km from natal sites, though most (57%) remain within 100 km [9]. In contrast, Steppe Eagles (*Aquila nipalensis*), known for long-range transcontinental migration, have been tracked traveling ~4,200 km during their first autumn migration [15, 16], often wintering as far as India and southern Africa [17]. Meanwhile, White-tailed Eagles (*Haliaeetus albicilla*), which are less migratory, exhibit moderate dispersal distances, with females dispersing farther than males [18]. These studies highlight that juvenile dispersal varies widely across raptor species, reinforcing the necessity of species- and region-specific research on Eastern Imperial Eagles in Kazakhstan.

Historically, banding and wing-tagging provided limited insights into juvenile eagle movements due to low resighting rates and difficulty in tracking non-territorial juveniles [13, 19]. In Kazakhstan, 206 Eastern Imperial Eagles have been ringed, primarily juveniles, with 146 individuals marked in the Naurzum Nature Reserve and others across western, northern, southern, southeastern, and eastern regions. However, these methods provide only sporadic data points. The advent of GPS satellite and GSM telemetry has revolutionized tracking capabilities, allowing continuous, high-resolution monitoring of individual movements. Katzner et al. (2006) noted that the historical challenge of monitoring non-territorial eagles during the dispersal period is now being addressed through these modern technologies [20].

By integrating GPS data with GIS analysis, including Kernel Density Estimation (KDE) and remote sensing, researchers can delineate home range expansion, identify important stopover sites, and assess habitat preferences with unprecedented detail [21]. Such methods have been successfully applied in raptor studies worldwide, including Golden Eagles in Scotland [22] and Eastern Imperial Eagles in the Czech Republic [14]. However, few studies have focused on juvenile Eastern Imperial Eagles in Central Asia [23], where the species' dispersal patterns and survival strategies remain poorly understood.

To address this knowledge gap, we conducted a GPS-tracking study of a juvenile Eastern Imperial Eagle from a nest in the Taukum Desert, southeastern Kazakhstan. The objectives of our study were: (1) to document the timing and extent of the juvenile's post-fledging movements, (2) to identify stopover sites and temporary settlement areas used during dispersal, (3) to characterize the habitats selected by the juvenile, (4) to discuss the implications of these findings for eagle conservation in the region.

We formulated the following research question: how does a juvenile Eastern Imperial Eagle behave post-fledging in terms of movement patterns and habitat selection during its first months of life? Based on dispersal patterns observed in other large eagles and the partially migratory nature of Eastern Imperial Eagles, we hypothesized that the juvenile would exhibit a prolonged period of localized movement near the natal site (the post-fledging dependency period) before engaging in more extensive exploratory movements later in the season. We expected that initial forays would remain close to the nest, gradually increasing in distance as the bird's flight capabilities and independence developed. Additionally, we anticipated that open steppe and semi-desert habitats would be preferentially used, while areas with intensive human activity would be avoided.

2. Materials and methods

Study Area

This study was conducted in the Taukum Desert (~1 million ha) in southeastern Kazakhstan, a semi-arid region with hot, dry summers and cold winters [24]. The Taukum Desert extends 200 km along the left bank of the Ili River, from the Kurtu River to Alakol Bay near Lake Balkhash. Together with the Zhusandala clay plain and Topar inter-dune lakes, it forms a distinct desert-steppe ecosystem [25]. This ancient alluvial-eolian plain is composed of fine-grained sands, with semi-fixed dunes and sparse vegetation, dominated by sagebrush (*Artemisia spp.*), astragalus, sand acacia, tamarisk, ephedra, and black saxaul (*Haloxylon ammodendron*) [24]. The Sarytaukum region, the highest part, features large sand ridges, while Moyynkum in the north consists of stabilized dunes (10-30 m high), resembling mountainous terrain [26].

Water resources are limited to artesian wells and seasonal streams, with groundwater at 10-25 m depths, supporting livestock farming in the 1970s-80s. However, overgrazing led to land degradation, shifting dunes, and vegetation loss [26].

The climate is extremely continental, with an annual mean temperature of +9°C, ranging from -8.7°C in January to +25.5°C in July. Maximum summer temperatures exceed +42°C, and winter lows drop to -44.8°C. The growing season lasts ~210 days (March-October), with low annual precipitation (<150 mm) and high evaporation [27, 28].

The flora of the area includes about 200 species of flowering plants, 5% of which are considered endemic to Kazakhstan. The region features unique landscapes of inter-marsh lakes with plant associations including turanga (desert poplar), saxaul, Russian olive trees, and others [29].

The ornithofauna of the Taukum Desert includes up to 120 species of birds, among which are several listed in the Red Data Book. In addition to the Eastern Imperial Eagle, these include the Golden Eagle, Steppe Eagle, Booted Eagle, Short-toed Snake Eagle, as well as MacQueen's Bustard, and the Black-bellied and Pin-tailed Sandgrouse [26]. Eastern Imperial Eagles in this region prey on small mammals (such as Spermophilus, gerbils, and hares) and reptiles [25]. They nest in tugai woodlands, on isolated trees, or in open areas – on the ground or low bushes.

Research Question and Hypothesis

We aimed to answer: how does a juvenile Eastern Imperial Eagle behave post-fledging in terms of movement and habitat selection? Specifically, we examined departure timing, movement distances and directions, stopover sites, and habitat preferences. We hypothesized that the juvenile would remain near the natal site for an extended post-fledging dependence period, relying on parental support before gradually expanding its range. In terms of habitat selection, we anticipated a preference for open steppe and semi-desert habitats while avoiding human-altered areas like agricultural fields and settlements. GPS tracking and spatial analysis were used to test these expectations.

Data Collection

On 12 July 2024, we equipped a 65-day-old Eastern Imperial Eagle nestling with a 23 g solar-powered GPS-transmitter (model HQ G3621L, Hunan Global Messenger Technology Co., Ltd.) using a safe backpack harness. The device weighed less than 3% of the bird's body mass, minimizing behavioral impact [30]. We set the device to log the eagle's location, altitude, speed, temperature, activity, and heading every hour [31, 32]. Each GPS fix included coordinates (latitude/longitude in WGS84 decimal degrees) with estimated horizontal accuracy (HDOP) values, as well as ancillary data like flight speed (in km/h) and altitude (in meters above sea level) as measured by the GPS. The raw tracking data were stored on Global Messenger's online server (GM-Tracking) [33], accessible through the manufacturer's platform. We periodically downloaded the data as CSV files for analysis. During the tracking period (July 12 to September 28, 2024), the juvenile fledged from the nest. We monitored its movements remotely via the GPS data. No interventions were made after tagging; the bird was left to behave naturally. By the end of September, the transmitter had recorded over 1,850 GPS fixes, providing a detailed trajectory of the juvenile's movements through its first 2.5 months out of the nest.

GIS Analysis and Kernel Density Estimation

We analyzed GPS data using QGIS 3.22 and R 4.2.2, mapping the eagle's movement from the natal site. To quantify movement patterns, we calculated daily travel distance, straight-line distances (haversine formula), and displacement from the nest over time. Key metrics included dispersal onset (first movement >5 km from the nest without return), maximum distance reached, daily displacement, and flight speed statistics (mean and max speeds).

To identify core habitat selection, we applied Kernel Density Estimation (KDE), using a bivariate normal kernel to estimate the eagle's utilization distribution. We derived 50% and 95% KDE contours, representing core use areas and home range, respectively. A Minimum Convex Polygon (MCP) was also computed for comparison.

We analyzed daily activity patterns by summing distances moved per hour and tracking altitude changes over time to assess flight development. All statistical analyses were carried out using standard packages in R. Summary statistics are reported as mean ± standard deviation. Given that our study tracks a single individual (n=1), we emphasize descriptive and comparative interpretations rather than formal inferential statistics. We compare our findings with similar studies, acknowledging that one bird's data may not capture all behaviors but still offers valuable insights.

3. Results and discussion

On July 12, 2024, a nest of the Eastern Imperial Eagle was located in the floodplain of the Kurty River, 8,5 km from Aktogay village, Ili District. The nest, situated at N44°13′ E76°37′, was positioned 3,5 – 4 meters above the ground on a large branch of a Russian olive tree *(Elaeagnus angustifolia)* (Figure 1).

Figure 1 – The nest of Eastern Imperial Eagle on the tree

It was substantial in size and appeared well-established, constructed from branches and lined with dry grass, leaves, and bark, suggesting repeated use by the same breeding pair over multiple seasons. At the time of discovery, the nest contained two fledglings. Upon approach, both juveniles attempted to fly; one managed a significant flight distance, while the second, likely on its first flight, landed 15 meters from the nest, where it was safely captured for examination. This individual was fitted with a GPS tracker for monitoring. Tracking began when the eagle was approximately 65 days old, after which it was carefully returned to the nest to resume normal development. The juvenile Eastern Imperial Eagle was tracked for a total of 77 days, from mid-July to late September 2024, resulting in 1,859 recorded GPS locations. Over this period, the eagle traveled a cumulative distance of 713 km, with an average daily movement of 9.02 km/day. The longest recorded distance traveled in a single day was 49.6 km, while the longest continuous flight spanned 40.43 km. The bird's maximum flight speed was 85.9 km/h. The altitude data revealed an average flight altitude of 453.5 meters, with the highest recorded altitude reaching 1,498 meters.

Table 1 – GPS tracking summary of Eastern Imperial Eagle

GPS data	Value
Total tracking duration	77 days
Total GPS signal records	1859 signals
Total distance traveled	713 km
Longest distance in one day	49.6 km
Average speed	1.35 km/h
Maximum speed	85.9 km/h
Mean daily distance traveled	9.02 km
Average altitude	453.5 m
Maximum altitude	1498.0 m
Number of stopovers resting events	44.0
Longest continuous flight	40.43 km

Movement Patterns

The GPS tracking map (Figure 2) shows a dense cluster of points around the natal nest site, indicating a period of continued dependency on parental care. In the early days of tracking, the bird primarily stayed within a 3-5 km radius of the nest, returning regularly to roost in familiar locations.

During the early tracking period, the juvenile eagle stayed close to its nest, gradually expanding its movements. The first significant flight beyond 1 km occurred when the bird was 81 days old. Over the following weeks, the eagle continued exploring its surroundings, reaching 2 km from the nest by the time it was 104 days old. This phase was marked by short-distance flights, with the juvenile testing its flight abilities while still relying on the nest area for rest and food. As the eagle grew more confident, its range increased. By 112 days of age, it had ventured 5 km from the nest, signaling the beginning of broader dispersal behaviors. The juvenile started exploring new habitats, perching in different locations, and likely developing independent foraging skills. Returning to the nest became less frequent, indicating a gradual transition toward independence.

A clear behavioral shift occurred when the eagle was approximately 83 days old, marking the start of dispersal. On this date (August 28, 2024), the eagle flew 6-8 km west for the first time, departing from the immediate natal area. This movement can be considered the initial emigration event, indicating the transition from post-fledging dependence to independent dispersal.

After this initial departure, the juvenile's movements became more extensive. Over the next two weeks (late August – mid-September 2024), the eagle took increasingly longer flights and sometimes remained away from the natal area for more than a day. It primarily explored regions to the north and west of the nest.

The maximum recorded distance from the nest was 18.6 km, reached on September 11, 2024, at 11:00 local time. At this point, the eagle flew west-northwest, marking its farthest excursion during the tracking period. However, rather than continuing in a linear dispersal pattern, the bird returned to the general natal area later in September, suggesting a pattern of exploratory looping movements rather than immediate long-distance migration. By late September 2024, the eagle had settled within ~3 km of the natal nest, suggesting a temporary settlement phase before further dispersal. This behavior aligns with a local disperser strategy, where some juveniles remain in their natal regions rather than immediately migrating. Similar patterns have been observed in Eastern Imperial Eagles in Europe, where many juveniles stay near their natal sites for winter, while only a few migrate long distances. The eagle's daily movement distances increased as it gained independence and flight proficiency. In July, it remained largely sedentary, traveling an average of 1.6 km per day. By August, as exploratory movements began, the mean daily distance increased to 7.3 km/day. During September, at the peak of dispersal, the juvenile covered an average of 16.3 km/day. The most active day occurred on September 11, 2024, when the eagle traveled 49.5 km, the longest single-day movement recorded.

This pattern supports the hypothesis that juveniles initially remain near the nest before expanding their range. The increasing distances reflect the development of sustained flight ability and growing exploratory tendencies. Similar patterns have been documented in Bonelli's Eagles, where juveniles initially make short-range movements (cover up to 20 km/day in their early dispersal phase) before transitioning to long-distance dispersal [34].

Movement Direction. In terms of directionality, our eagle did not show a consistent directional migration during the study period. Instead, its movements were exploratory, with no clear long-distance dispersal. While it traveled in various directions around the natal area, there was a noticeable tendency to move westward and northwestward rather than eastward. This directional bias may be influenced by habitat differences – Lake Balkhash and open desert areas lie to the east, whereas the west and north offer more diverse landscapes, slightly higher elevations, and potentially richer foraging opportunities in steppe habitats. The farthest recorded point, located west-northwest (WNW) of the nest, had an elevation of approximately 1100 m, compared to ~430 m at the nest. This suggests that the bird had reached the foothills of a low mountain or plateau. However, its return from this excursion indicates that the area was not immediately suitable for settlement, and the juvenile was likely assessing different habitats for foraging potential in its first independent months.

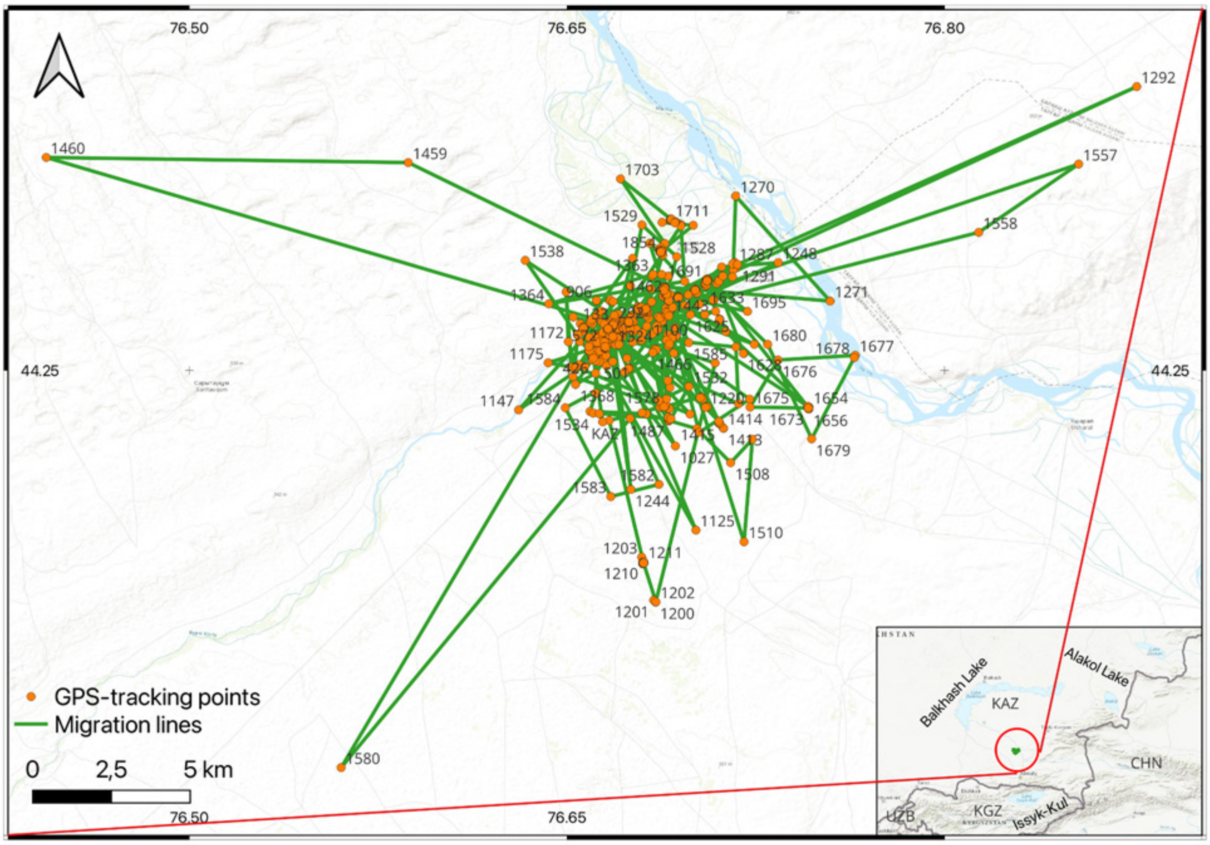

Figure 2 – Post-fledging movement patterns of a juvenile Eastern Imperial Eagle in the Taukum Desert, Southern Kazakhstan

Analysis of movement frequency further supports this dispersal trend *(Figure 3)*. The most common movement direction was north-northwest (330°), with 671 recorded movements in the 0°-45° and 315°-360° sectors. In contrast, movement to the east (398 movements), south (349 movements), and west (441 movements) was less frequent. This pattern suggests that the juvenile favored northwestward dispersal, potentially avoiding less favorable environments in the east and south.

Flight Altitude. Another dimension of movement is the altitude of the eagle's flights. The GPS altitude readings (relative to sea level) ranged from approximately 330 m to over 1100 m during the tracking period (Figure 4). Given that the ground elevation around the nest is ~430 m, early flights likely remained close to the surface. Indeed, some negative deviations in altitude readings in the first week suggest that the juvenile was on the ground or perched below nest height, consistent with short test flights or resting phases. As flight capacity improved, it regularly reached 500-600 m asl (70-170 m above ground level) by late August. On September 2-3 and September 11, the eagle hit its highest recorded altitudes (~1050-1100 m asl), coinciding with its longest exploratory trips. The altitude jumps to ~1094 m on September 11 suggests it was soaring over higher terrain (~700-800 m), maintaining 300-400 m above ground level. Higher flights correlated with longer travel distances, aiding navigation and gliding efficiency. After returning to the natal area, altitudes dropped back to 450-500 m, consistent with more localized movements.

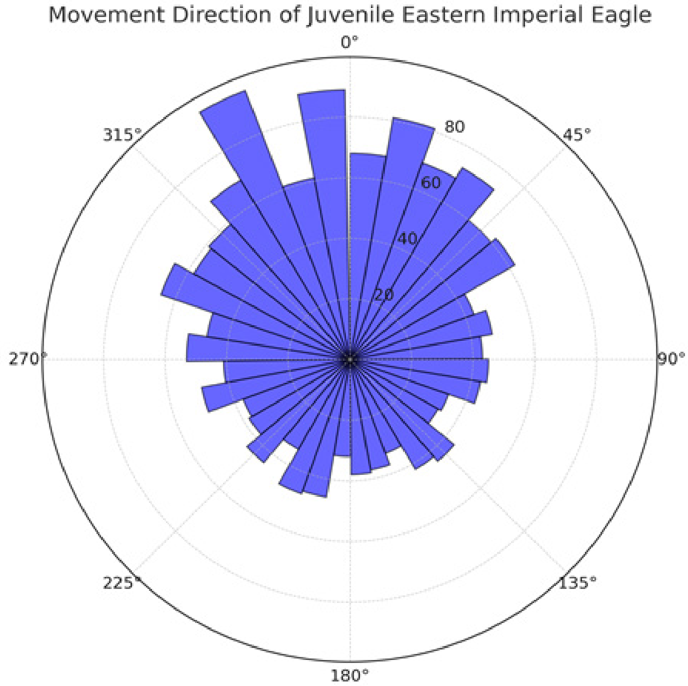

Figure 3 – Movement direction of the Eastern Imperial Eagle.
(The circular histogram represents movement frequency in different compass directions, 0° (North).
Radial grid values indicate the number of movements in each direction.
Taller bars reflect more frequent movements, revealing dominant dispersal patterns

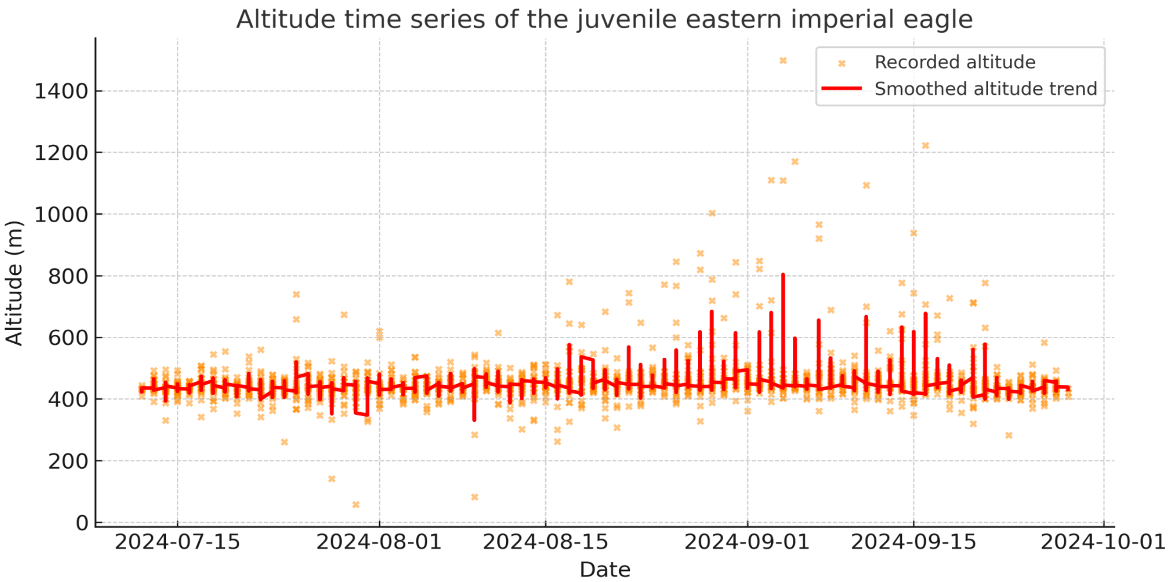

Figure 4 – Altitude time series of the juvenile Eastern Imperial Eagle

Flight Speed. The eagle's flight speed data reflect its changing movement behavior (Figure 5). In July, speeds were mostly near 0 km/h, indicating it was largely stationary, with occasional short flights (10-30 km/h) likely linked to flight practice or food-chasing behavior. By mid-August, sustained flights became more common, with speeds of 30-50 km/h, suggesting purposeful movement. Notably, peak speeds reached 85.9 km/h during long-distance flights on 30 August. This peak coincided with the period of greatest geographic range expansion, aligning with increased dispersal activity. After early September, high-speed movements tapered off, and by late September, the eagle was spending more time near the natal area, possibly due to sufficient foraging opportunities or awaiting migratory cues.

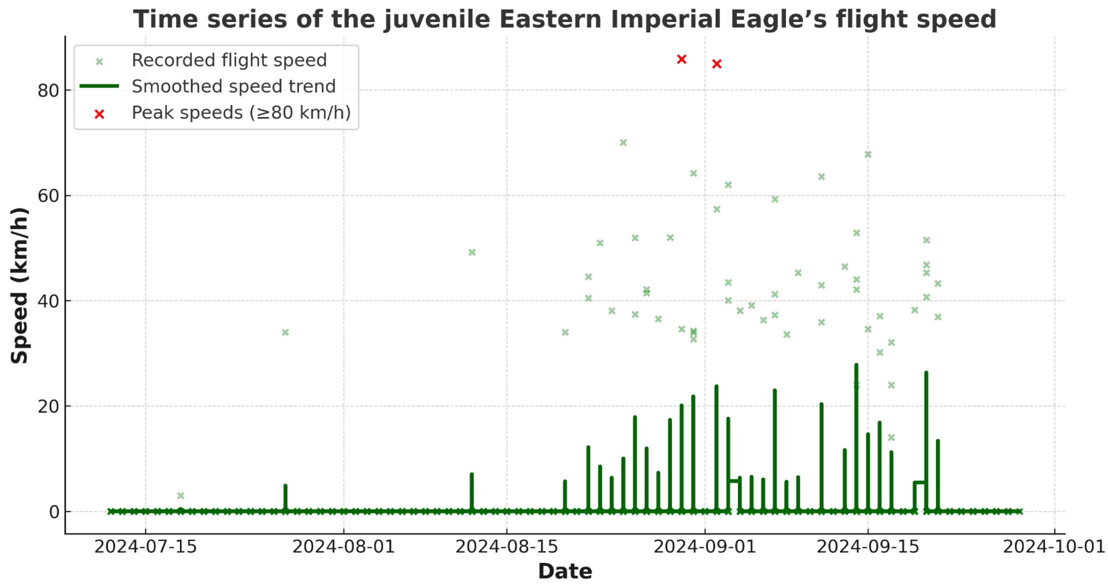

Figure 5 – Flight speed over the post-fledging period. Each green point represents the eagle's recorded GPS flight speed at a given time; The graph illustrates the near-zero speeds (perching/roosting) dominating early weeks, followed by increasingly frequent high-speed flight bouts in late August and early September as the eagle's dispersal activity intensified

Daily Activity and Stopover Behavior

Daily Activity. Analysis of the timing of movements revealed that the juvenile eagle was strictly diurnal in its activity, as expected for an eagle of this species *(Figure 6).* The bird roosted each night, either at the nest tree or later at other tall perches, and did not travel during nighttime hours. GPS fixes from roughly 21:00 to 05:00 local time showed essentially no movement (speeds ~0, positions static). The eagle's day typically started at dawn (around 05:00) with short flights near the roost, increasing in the morning (05:00-10:00) as temperatures rose and thermal currents formed. The eagle was most active between 11:00 and 17:00, when it undertook longest flights and exploratory movements.

During early morning (06:00-10:00) and late afternoon (16:00-19:00), both distance traveled and flight speed were highest, suggesting periods of active dispersal or foraging-related movements. In contrast, a significant reduction in activity occurred between 11:00 and 15:00, coinciding with the warmest hours of the day. This decline in movement and speed indicates perching or resting behavior, likely to minimize energy expenditure during intense solar radiation. Such midday inactivity is consistent with thermoregulatory behavior observed in other large raptors. The strong correlation between movement distance and flight speed supports the hypothesis that the eagle engages in longer, faster flights during peak activity periods, while shorter, slower movements dominate the midday resting phase.

Figure 7 illustrates the eagle's daily movement patterns as a heatmap of distance traveled by hour. Nighttime hours (midnight-04:00) show little to no movement, confirming the bird was roosting. Activity began around 05:00, with movement gradually increasing. The most intense activity (red blocks) occurred between 10:00 and 14:00, aligning with peak thermal uplift, which eagles use for efficient soaring. On days with long excursions (e.g., August 28, September 11), the heatmap shows sustained movement from late morning through late afternoon, indicating extended flight periods. In contrast, July's heatmap shows only faint activity, reflecting short flights and perch-bound behavior. By late September, movement intensity declined, suggesting the eagle had settled into a smaller area, consistent with location data showing it near the natal zone.

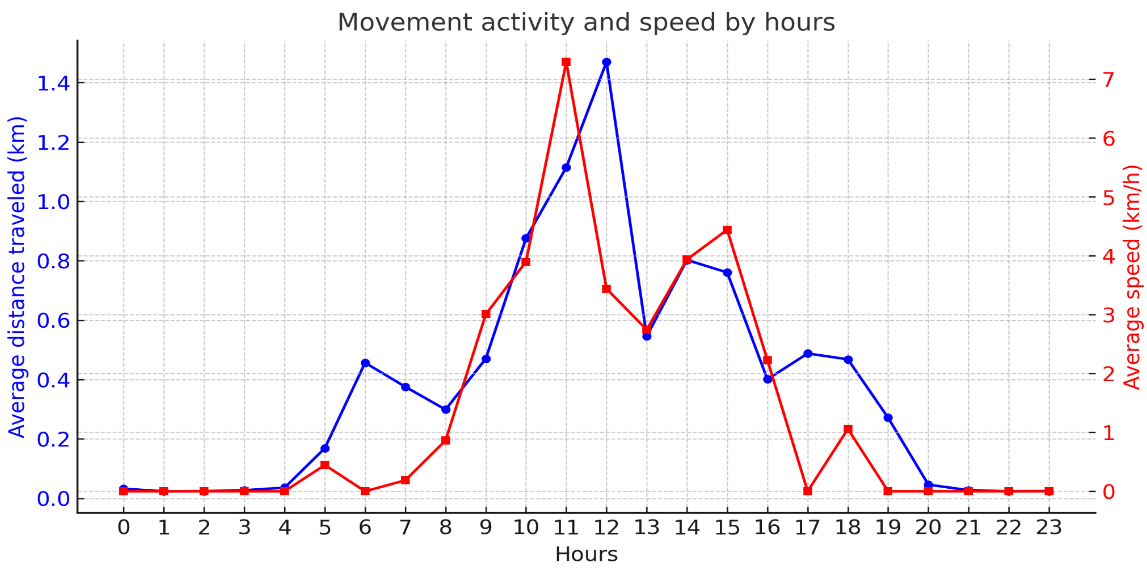

Figure 6 – Post-fledging daily movement activity of the Juvenile Imperial Eagle during the day

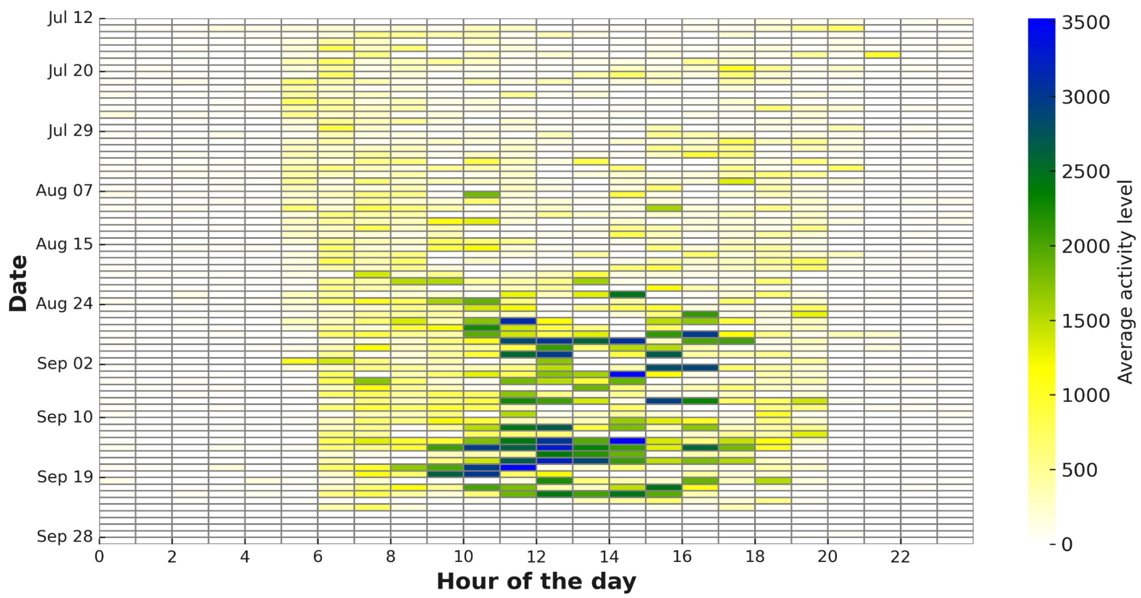

Figure 7 – Heatmap of the juvenile eagle's hourly movement. Warmer colors indicate greater distances traveled per hour. The eagle was inactive at night (21:00-04:00), became active at dawn (~05:00), and peaked in movement midday (12:00-15:00). Activity intensified in late August-early September, reflecting increased dispersal

Stopover Sites. The concept of "stopover sites" in the context of juvenile dispersal often refers to temporary focal areas where a bird may linger and forage for days or weeks before moving on. Since our eagle did not migrate directionally during the study, a more accurate term is "temporary settlement areas" or core use areas rather than distinct stopovers.

The primary settlement area was the natal site, heavily used throughout July and early August, and revisited later. A secondary area was near the farthest recorded point (~18 km WNW), but the eagle did not stay long – there is no evidence it roosted overnight. Instead, its movements resembled ranging behavior within an expanding home range rather than point-to-point migration.

By late September, the eagle was still within ~3 km of its natal site, suggesting it had not yet relocated to a distant range. While it may move farther in the following months, our findings highlight the importance of natal areas for juvenile survival. This aligns with studies in the Czech Republic, where most tracked juveniles wintered near their birthplaces [14], reinforcing the need to protect natural habitats for both breeding and early dispersal phases.

Habitat Preferences

Throughout the study, the juvenile strongly favored natural habitats, with >95% of GPS locations in steppe and semi-desert areas. It primarily used arid grasslands and shrublands, particularly near a dry riverbed close to the nest, which provided taller vegetation, potential prey, and scattered perches. As its range expanded, the eagle explored foothills ~18 km WNW, likely assessing foraging potential, but ultimately returned to flatter plains, suggesting it did not find the new terrain significantly better.

Notably, the eagle avoided human-modified landscapes. It did not enter agricultural lands or settlements, with its closest approach to a village being ~10 km away. Similar avoidance has been documented in other large raptors, such as White-tailed Eagles and Eastern Imperial Eagles in Hungary [34].

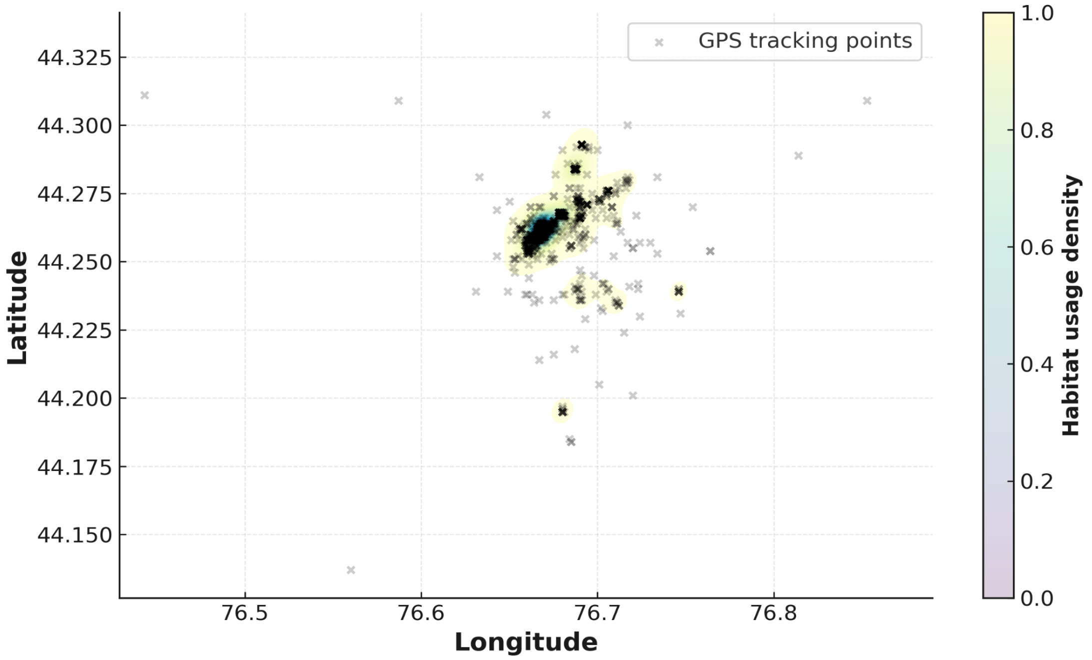

Figure 8 – Kernel Density Estimation (KDE) of habitat use by the juvenile Eastern Imperial Eagle. The heatmap represents the spatial distribution of GPS locations, with higher density areas (dark blue) indicating core habitats where the eagle spent the most time. The total 95% KDE home range is ~290 km². GPS tracking points (gray) are overlaid to illustrate individual recorded locations

Kernel Density Estimation (KDE) identified a primary core area (~10 km²) around the natal nest and a secondary high-use zone 5-8 km west, indicating early exploratory movements. The total 95% KDE home range spanned ~290 km² but was strongly influenced by a single long-distance excursion. Unlike fully nomadic juveniles that disperse over vast areas, this individual remained within a restricted range.

The eagle's movements were selective, preferring steppe with some structural diversity (bushes, low hills) and riparian zones, while avoiding open sand deserts, highways (>15 km away), and densely forested areas. Its occasional use of elevated perches, including electric poles, highlights its opportunism in open landscapes. This behavior proved fatal, as the juvenile probably died from electrocution. Thus, on November 11, 2024, the remains of a bird, feathers were found under a bird-hazardous power line pole (Figure 9).

Figure 9 – Location of the last received GPS signal. Feathers of the bird are visible under the power line pole

However, most of the carcass, and along with it the transmitter, were not found, presumably carried off by predators. This case underscores the conservation risks posed by unsafe power infrastructure and highlights the urgent need for mitigation measures to prevent raptor electrocution in steppe ecosystems.

Conclusion

This study provides novel insights into the post-fledging dispersal behavior of a juvenile Eastern Imperial Eagle in southeastern Kazakhstan, a region where movement ecology remains poorly understood. By utilizing GPS telemetry, we monitored the eagle for 77 days, tracking its gradual expansion from localized movements near the nest to broader dispersal at 112 days old. The findings confirm that juvenile Eastern Imperial Eagles initially exhibit strong natal site fidelity, with movements increasing progressively as flight capabilities develop. The maximum recorded distance of 18.6 km, coupled with a return to the natal area, suggests a local dispersal strategy rather than immediate long-distance migration.

Key findings include dispersal onset, a ten-fold increase in daily movement distances from July to September, and a peak single-day flight of ~50 km. The study highlights the strong preference for semi-desert and steppe habitats and avoidance of human-modified landscapes, reinforcing the need to preserve undisturbed foraging and roosting areas for juvenile survival. However, the electrocution-related mortality of this individual underscores a major conservation threat – unsafe power lines. This finding emphasizes the urgent need for mitigation measures, including insulating power infrastructure and identifying high-risk areas for future interventions. Given the limitations of a single-bird study, future research should track multiple juveniles across different regions to examine variations in dispersal patterns, migratory tendencies, and survival rates. Long-term monitoring would also provide valuable insights into settlement patterns, breeding recruitment, and potential climate-driven shifts in dispersal ecology.

This study demonstrates the power of GPS telemetry in understanding raptor dispersal, offering actionable data to inform conservation strategies. By safeguarding both nesting areas and dispersal landscapes, we can improve juvenile survival and contribute to the stability of Eastern Imperial Eagle populations in Kazakhstan and beyond.

Acknowledgments

This research has been funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR21882199 – *Cadastre of wild animals of arid territories of the Balkhash-Alakol Basin with an assessment of threats to their conservation and sustainable use*). We also express our gratitude to the staff of the Sunkar Falconry Reserve for their assistance.

Literature

1. BirdLife International. 2019. *Aquila heliaca* (amended version of 2017 assessment). *The IUCN Red List of Threatened Species* 2019: e.T22696048A155464885. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T22696048A155464885.en. Accessed on 20 March 2025.
2. Red Data Book of the Republic of Kazakhstan. Volume 1. Animals. / Ed. by Dr. R.V. Yashenko. 5th edition, revised and updated. – Almaty: Institute of Zoology, Committee of Science, Ministry of Science and Higher Education of the Republic of Kazakhstan, 2024. – 532 p.

3. Карякин, И.В. (2020). *Популяционная структура гнездового ареала орла-могильника.* Пернатые хищники и их охрана, (41), 64-332.

4. Березовиков Н.Н., Губин Б.М., Гуль И.Р., Ерохов С.Н., Карпов Ф.Ф., Коваленко А.В. Птицы пустыни Таукумы (юго-восточный Казахстан). Киев-Львов, 1999. – 117 стр.

5. Gavrilov, E. I., & Gavrilov, A. E. (2005). *The birds of Kazakhstan* (Vol. 2). Tethys.

6. Карякин, И.В. (2016). Орлы России и Казахстана: места обитания и зоны электросетевой опасности. Новосибирск: Сибэкоцентр.

7. Каптёнкина А.Г., Пуликова Г.И., Сагалиев Н.А., Карякин И.В. (2023). Орёл-могильник на юго-востоке Казахстана в 2022-2023 годах: распространение, численность, угрозы. *Пернатые хищники и их охрана*, (2), 329-334.

8. Коваленко, А. В. (2018). О зимовках могильника *Aquila heliaca* в Юго-Восточном и Южном Казахстане. Русский орнитологический журнал, 27(1623), 2785-2786.

9. Real, J., & Manosa, S. (2001). Dispersal of juvenile and immature Bonelli's Eagles in northeastern Spain. *Journal of Raptor Research,* 35(1), 2.

10. Weston, E. D., Whitfield, D. P., Travis, J. M., & Lambin, X. (2013). When do young birds disperse? Tests from studies of golden eagles in Scotland. *BMC ecology*, *13*, 1-13.

11. Stoychev, S., Demerdzhiev, D., Spasov, S., Dobrev, D., & Meyburg, B. U. (2014). Survival rate and mortality of juvenile and immature eastern imperial eagles *(Aquila heliaca)* from Bulgaria studied by satellite telemetry. *Slovak Raptor Journal,* 8(2014), 53-60.

12. Nygård, T., Jacobsen, K. O., Johnsen, T. V., & Systad, G. H. (2016). Dispersal and survival of juvenile golden eagles *(Aquila chrysaetos)* from Finnmark, Northern Norway. Journal of Raptor Research, 50(2), 144-160.

13. McIntyre, C. L., & Lewis, S. B. (2018). Statewide movements of non-territorial Golden Eagles in Alaska during the breeding season: Information for developing effective conservation plans. *Alaska Park Science,* 17, 65-73.

14. Rymešová, D., Horal, D., Matušík, H., Raab, R., Spakovszky, P., & Literák, I. (2023). Dispersal of eastern imperial eagles from the Czech Republic. *Journal of Vertebrate Biology*, *72*(23009), 23009-1

15. Weiss, N., Haviv, E., Alon, D., Perlman, Y., & Schäckermann, J. (2019). How Fast Does the Steppe Eagle Population Decline? Survey Results from Eilat, Israel. *Raptors Conservation, 38.*

16. Keijmel, M., Babbington, J., Roberts, P., McGrady, M. & Meyburg, B. U. (2020). *The world's largest gathering of Steppe Eagles Aquila nipalensis discovered in central Saudi Arabia*. Sandgrouse, 42: 59-68.

17. Karyakin, I. V., Nikolenko, E. G., Shnayder, E. P., Zinevich, L. S., Pulikova, G. I., Bartoszuk, K., Horváth, M., Juhász, T., Aghababyan, K. & Andreyenkova, N. G. (2019). *Results of the GPS/GSM-Tracking of Juvenile Steppe Eagles from Russia and Kazakhstan*. Raptors Conservation, (39).

18. Nemesházi, E., Szabó, K., Horváth, Z., & Kövér, S. (2018). Genetic structure confirms female-biased natal dispersal in the White-tailed Eagle population of the Carpathian Basin. *Acta Zoologica Academiae Scientiarum Hungaricae*, *64*(3), 243-257.

19. Al-Sheikhly, O. F., Al-Barazangi, A. N., Haba, M. K., Fazaa, N. A., Abdulzahra, H. K., Turab, M. K. A., & Al-Azawi, A. J. (2017). Ring Recoveries from Steppe Eagles and Eastern Imperial Eagles from the Russian and Kazakhstan Breeding Populations and a Review of Major Threats to Eagles in Iraq. *Raptors Conservation,* 35.

20. Katzner, T. E., Bragin, E. A., & Milner-Gulland, E. J. (2006). Modelling populations of long-lived birds of prey for conservation: a study of imperial eagles *(Aquila heliaca)* in Kazakhstan. *Biological Conservation*, *132*(3), 322-335.

21. Murgatroyd, M., Underhill, L. G., Rodrigues, L., & Amar, A. (2016). The influence of agricultural transformation on the breeding performance of a top predator: Verreaux's Eagles in contrasting land use areas. *The Condor: Ornithological Applications*, *118*(2), 238-252.

22. Hixson, K. M., Slater, S. J., Knight, R. N., & Lonsinger, R. C. (2022). Seasonal variation in resource selection by subadult golden eagles in the Great Basin Desert. *Wildlife Biology*, *2022*(1), e01002.

23. Katzner, T. E., Jackson, D. S., Ivy, J., Bragin, E. A., & DeWoody, A. (2014). Variation in offspring sex ratio of a long-lived sexually dimorphic raptor, the Eastern Imperial Eagle *Aquila heliaca. Ibis*, *156*(2), 395-403.

24. Issanova, G., Kaldybayev, A., Ge, Y., Abuduwaili, J., & Ma, L. (2023). Spatial and temporal characteristics of dust storms and aeolian processes in the Southern Balkash deserts in Kazakhstan, central asia. *Land*, *12*(3), 668.

25. Курочкина Л.Я. Пустыни Казахстана и степень их освоенности // Редкие животные пустынь Алма-Ата, 1990. С. 7-23.

26. Романова СМ., Казангапова Н.Б. Озеро Балхаш – уникальная гидроэкологическая система. – Алматы, 2003. – 175 с

27. Ivanovich, B. A. & Nikolaevich, B. N. (2013). *On the Nesting of the Steppe Eagle Aquila nipalensis on the northeast coast of Lake Balkhash*. Russian Ornithological Journal, 862: 813-817.

28. Османова Л.Т., Байгозова Г.А., Карибаева К.Б. 1988. Таукумский стационар Института ботаники АН КазССР// Пустынные стационары Казахстана и Средней Азии. Алма-Ата: 11-23.

29. Ilina, V. O., Berdikulov, B. T., Lei, F., Filimonov, A. N., Akentyeva, Y. E., Song, G., Tashimova, A. & Gavrilov, A. E. (2025). Migration patterns and spatial connectivity of Pallas's Gulls *(Ichthyaetus ichthyaetus)* from Alakol Lake, Kazakhstan using ring recovery and tracking data. *Avian Research,* 100253.

30. Berdikulov, B. T., Gavrilov, A. E., Ilina, V. O., Song, G., & Lei, F. M. (2024). Autumn Migration of the Rare Yellow-Eyed Pigeon *Columba eversmanni* from Western Tian Shan (Tanyrtau), Kazakhstan. *Ardea*, *112*(1), 21-30.

31. Berdikulov, B. T., Gavrilov, A. E., Gang, S., & Akentyeva, E. V. (2024). Analysis of environment use and behavior of *Bubo Bubo* in the Western Tien Shan, Shakpak Pass using GPS/GSM telemetry. *Eurasian Journal of Ecology*, *78*(1).

32. Global Messenger. (n.d.). *GM-Tracking: GPS tracking platform*. Retrieved March 21, 2025, from https://www.gm-tracking.com/

33. Cadahía, L., Urios, V., & Negro, J. J. (2007). Bonelli's Eagle *Hieraaetus fasciatus* juvenile dispersal: hourly and daily movements tracked by GPS. *Bird Study,* 54(2), 271-274.

34. Carver, S., Mayhew, M., Blatchford, K., Carver, B., & Carver, E. (2022). Pre-feasibility Study: White-Tailed Eagle (WTE) Reintroduction in Cumbria Funded by Natural England.

References

1. Al-Sheikhly, O. F., Al-Barazangi, A. N., Haba, M. K., Fazaa, N. A., Abdulzahra, H. K., Turab, M. K. A., & Al-Azawi, A. J. (2017). Ring Recoveries from Steppe Eagles and Eastern Imperial Eagles from the Russian and Kazakhstan Breeding Populations and a Review of Major Threats to Eagles in Iraq. *Raptors Conservation, 35.*

2. BirdLife International. (2019). *Aquila heliaca* (amended version of 2017 assessment). *The IUCN Red List of Threatened Species 2019: e.T22696048A155464885.* https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T22696048A155464885.en. Accessed on 20 March 2025.

3. Berdikulov, B. T., Gavrilov, A. E., Ilina, V. O., Song, G., & Lei, F. M. (2024). Autumn Migration of the Rare Yellow-Eyed Pigeon *Columba eversmanni* from Western Tian Shan (Tanyrtau), Kazakhstan. *Ardea, 112(1), 21-30.*

4. Berdikulov, B. T., Gavrilov, A. E., Gang, S., & Akentyeva, E. V. (2024). Analysis of environment use and behavior of *Bubo Bubo* in the Western Tien Shan, Shakpak Pass using GPS/GSM telemetry. *Eurasian Journal of Ecology, 78(1).*

5. Berezovikov N.N., Gubin B.M., Gul I.R., Erokhov S.N., Karpov F.F., Kovalenko A.V. Ptitsy pustyni Taukumy (yugo-vostochnyy Kazakhstan) [Birds of the Taukum Desert (Southeastern Kazakhstan)]. Kyiv–Lviv, 1999. – 117 p.

6. Cadahía, L., Urios, V., & Negro, J. J. (2007). Bonelli's Eagle *Hieraaetus fasciatus* juvenile dispersal: hourly and daily movements tracked by GPS. *Bird Study, 54(2), 271-274.*

7. Carver, S., Mayhew, M., Blatchford, K., Carver, B., & Carver, E. (2022). Pre-feasibility Study: White-Tailed Eagle (WTE) Reintroduction in Cumbria Funded by Natural England.

8. Gavrilov, E. I., & Gavrilov, A. E. (2005). *The birds of Kazakhstan* (Vol. 2). *Tethys.*

9. Global Messenger. (n.d.). *GM-Tracking: GPS tracking platform.* Retrieved March 21, 2025, from https://www.gm-tracking.com/

10. Hixson, K. M., Slater, S. J., Knight, R. N., & Lonsinger, R. C. (2022). Seasonal variation in resource selection by subadult golden eagles in the Great Basin Desert. *Wildlife Biology, 2022(1), e01002.*

11. Ilina, V. O., Berdikulov, B. T., Lei, F., Filimonov, A. N., Akentyeva, Y. E., Song, G., Tashimova, A. & Gavrilov, A. E. (2025). Migration patterns and spatial connectivity of Pallas's Gulls *(Ichthyaetus ichthyaetus)* from Alakol Lake, Kazakhstan using ring recovery and tracking data. *Avian Research,* 100253.

12. Issanova, G., Kaldybayev, A., Ge, Y., Abuduwaili, J., & Ma, L. (2023). Spatial and temporal characteristics of dust storms and aeolian processes in the southern Balkhash deserts in Kazakhstan, Central Asia. *Land, 12(3), 668.*

13. Ivanovich, B. A. & Nikolaevich, B. N. (2013). On the Nesting of the Steppe Eagle *Aquila nipalensis* on the northeast coast of Lake Balkhash. *Russian Ornithological Journal, 862: 813-817.*

14. Karyakin, I. V. (2016). Orly Rossii i Kazakhstana: mesta obitaniya i zony elektrosetevoy opasnosti [Eagles of Russia and Kazakhstan: Habitats and Power Line Hazard Zones]. Novosibirsk: *SibekoCenter*

15. Karyakin, I. V., Nikolenko, E. G., Shnayder, E. P., Zinevich, L. S., Pulikova, G. I., Bartoszuk, K., Horváth, M., Juhász, T., Aghababyan, K. & Andreyenkova, N. G. (2019). Results of the GPS/GSM-Tracking of Juvenile Steppe Eagles from Russia and Kazakhstan. *Raptors Conservation, (39).*

16. Karyakin, I. V. (2020). Populyatsionnaya struktura gnezdovogo areala orla-mogil'nika [Population structure of the breeding range of the Eastern Imperial Eagle]. Birds of *Prey and Their Conservation,* (41), 64-332

17. Kaptyonkina, A. G., Pulikova, G. I., Sagaliyev, N. A., & Karyakin, I. V. (2023). Orel-mogil'nik na yugo-vostoke Kazakhstana v 2022-2023 godakh: rasprostranenie, chislennost', ugrozy [The Eastern Imperial Eagle in southeastern Kazakhstan in 2022-2023: Distribution, abundance, and threats]. *Birds of Prey and Their Conservation,* (2), 329-334.

18. Katzner, T. E., Bragin, E. A., & Milner-Gulland, E. J. (2006). Modelling populations of long-lived birds of prey for conservation: a study of imperial eagles (*Aquila heliaca*) in Kazakhstan. *Biological Conservation, 132(3), 322-335.*

19. Katzner, T. E., Jackson, D. S., Ivy, J., Bragin, E. A., & DeWoody, A. (2014). Variation in offspring sex ratio of a long□lived sexually dimorphic raptor, the Eastern Imperial Eagle *Aquila heliaca*. *Ibis, 156(2), 395-403.*

20. Kovalenko, A. V. (2018). O zimovkakh mogil'nika *(Aquila heliaca)* v Yugo-Vostochnom i Yuzhnom Kazakhstane [On the wintering of the Eastern Imperial Eagle *(Aquila heliaca)* in Southeastern and Southern Kazakhstan]. *Russian Ornithological Journal,* 27(1623), 2785-2786.

21. Keijmel, M., Babbington, J., Roberts, P., McGrady, M. & Meyburg, B. U. (2020). The world's largest gathering of Steppe Eagles *Aquila nipalensis* discovered in central Saudi Arabia. *Sandgrouse, 42: 59-68.*

22. Kurochkina, L. Ya. (1990**).** Pustyni Kazakhstana i stepen' ikh osvoennosti. In Redkie zhivotnye pustyn' [Deserts of Kazakhstan and Their Level of Development. In Rare Animals of the Deserts] Almaty, 7-23.

23. McIntyre, C. L., & Lewis, S. B. (2018). Statewide movements of non-territorial Golden Eagles in Alaska during the breeding season: Information for developing effective conservation plans. *Alaska Park Science, 17, 65-73.*

24. Murgatroyd, M., Underhill, L. G., Rodrigues, L., & Amar, A. (2016). The influence of agricultural transformation on the breeding performance of a top predator: Verreaux's Eagles in contrasting land use areas. *The Condor: Ornithological Applications, 118(2), 238-252.*

25. Nemesházi, E., Szabó, K., Horváth, Z., & Kövér, S. (2018). Genetic structure confirms female-biased natal dispersal in the White-tailed Eagle population of the Carpathian Basin. *Acta Zoologica Academiae Scientiarum Hungaricae, 64(3), 243-257.*

26. Nygård, T., Jacobsen, K. O., Johnsen, T. V., & Systad, G. H. (2016). Dispersal and survival of juvenile golden eagles (*Aquila chrysaetos*) from Finnmark, Northern Norway. *Journal of Raptor Research, 50(2), 144-160.*

27. Osmanova, L. T., Baigozova, G. A., & Karibaeva, K. B. (1988). Taukumskiy stantsionar Instituta botaniki AN KazSSR. Pustynnye stantsionary Kazakhstana i Sredney Azii [Taukum Station of the Institute of Botany, Academy of Sciences of the Kazakh SSR. Desert Stations of Kazakhstan and Central Asia*]*. Almaty. 11-23.

28. Real, J., & Manosa, S. (2001). Dispersal of juvenile and immature Bonelli's Eagles in northeastern Spain. *Journal of Raptor Research, 35(1), 2.*

29. Red Data Book of the Republic of Kazakhstan. Volume 1. Animals. / Ed. by Dr. R.V. Yashenko. 5th edition, revised and updated. – Almaty: Institute of Zoology, Committee of Science, Ministry of Science and Higher Education of the Republic of Kazakhstan, 2024. – 532 p.

30. Romanova, S. M., & Kazangapova, N. B. (2003). Ozero Balkhash – unikal'naya gidroekologicheskaya sistema [Lake Balkhash – A Unique Hydroecological System]. Almaty. – 175 p.

31. Rymešová, D., Horal, D., Matušík, H., Raab, R., Spakovszky, P., & Literák, I. (2023). Dispersal of Eastern Imperial Eagles from the Czech Republic. *Journal of Vertebrate Biology, 72(23009),-1.*

32. Stoychev, S., Demerdzhiev, D., Spasov, S., Dobrev, D., & Meyburg, B. U. (2014). Survival rate and mortality of juvenile and immature Eastern Imperial Eagles (*Aquila heliaca*) from Bulgaria studied by satellite telemetry. *Slovak Raptor Journal, 8(2014), 53-60.*

33. Weiss, N., Haviv, E., Alon, D., Perlman, Y., & Schäckermann, J. (2019). How Fast Does the Steppe Eagle Population Decline? Survey Results from Eilat, Israel. *Raptors Conservation, 38.*

34. Weston, E. D., Whitfield, D. P., Travis, J. M., & Lambin, X. (2013). When do young birds disperse? Tests from studies of golden eagles in Scotland. *BMC Ecology, 13, 1-13.*

Information about authors:

Bekzhan Berdikulov (corresponding author) – Acting Head of the Department of Ornithology and Herpetology at the Institute of Zoology; Graduated from the PhD program at Al-Farabi Kazakh National University (Almaty, Kazakhstan; email: bekzhan.berdikulov@zool.kz).

Yekaterina Akentyeva – Junior Researcher at the Institute of Zoology; PhD student at Al-Farabi Kazakh National University (Almaty, Kazakhstan; email: yekaterina.akentyeva@zool.kz).

Aizhan Tashimova – Junior Researcher at the Institute of Zoology; Master of Environmental Science (Almaty, Kazakhstan; email: aizhan.tashimova@zool.kz.

Andrey Gavrilov – Candidate of Biological Sciences; Director of the Bird Ringing Center at the Institute of Zoology (Almaty, Kazakhstan; email: andrei.gavrilov@zool.kz).

Авторлар туралы мәлімет:

Бекжан Бердіқұлов (корреспондент-автор) – Зоология институтының орнитология және герпетология лабораториясының меңгерушісінің міндетін атқарушы; әл-Фараби атындағы Қазақ Ұлттық университетінің PhD оқу-бағдарламасын аяқтаған (Алматы, Қазақстан; электрондық пошта: bekzhan.berdikulov@zool.kz

Екатерина Акентьева – Зоология институтының кіші ғылыми қызметкері; әл-Фараби атындағы Қазақ Ұлттық университетінің PhD-докторанты (Алматы, Қазақстан; электрондық пошта: yekaterina.akentyeva@zool.kz).

Айжан Ташимова – Зоология институтының кіші ғылыми қызметкері; жаратылыстану ғылымдарының магистрі (Алматы, Қазақстан; электрондық пошта: aizhan.tashimova@zool.kz.

Андрей Гаврилов – Биология ғылымдарының кандидаты; Зоология институтының құстарды сақиналау зерттеу орталығының меңгерушісі (Алматы, Қазақстан; электрондық пошта: andrei.gavrilov@zool.kz).