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ANALYSIS OF ENVIRONMENT USE AND BEHAVIOR OF *BUBO BUBO* IN THE WESTERN TIEN SHAN, SHAKPAK PASS USING GPS/GSM TELEMETRY

The study focuses on the habitat use and behavioral characteristics of the Eurasian eagle-owl (Bubo bubo) at Shakpak Pass, located in the Western Tien Shan. This work is the first detailed research on the spatial behavior and habitat use of this species in this vital migratory corridor. The goal was to map the tagged Eurasian eagle-owl's range, identify habitat preferences, and analyze behavioral adaptations using a mixed-methods approach that combines quantitative GPS tracking with qualitative behavioral observations.

The findings show the eagle owl's significant localization of movements, demonstrating its attachment to specific nesting and hunting territories. The analysis reveals the eagle owl's capacity to adapt to various hunting and roosting habitats, indicating a high degree of ecological plasticity. Distinct diurnal and nocturnal activity patterns were identified, highlighting the owl's specific hunting times and preferred habitats, ranging from open areas to rugged terrains.

The temperature analysis and daily activity tracking over nine days show that the eagle owl is more active at lower temperatures, particularly at sunset and dawn, with peak activity periods from 7 pm to 11 pm and during dawn hours from 4 am to 7 am. This research provides valuable insights into the behavioral ecology of the Eurasian eagle-owl. The findings hold practical significance for avian ecology and conservation science and can be useful for future research in the Tien Shan and analogous ecosystems.

Key words: Bubo bubo, bird behavior, nocturnal birds, GPS telemetry, GSM transmitter, habitat use, bird conservation.

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Батыс Тянь-Шань, Шақпақ асуында кездесетін үкінің *Bubo Bubo* қоршаған ортасын пайдалану ерекшеліктерін GPS/GSM телеметрия арқылы талдау

Бұл зерттеу жұмысы Батыс Тянь-Шаньда (Тәңіртауда) орналасқан Шақпақ асуындағы үкінің *(Bubo bubo)* тіршілік ету ортасы мен мінез-құлық ерекшеліктерін түсінуге арналған. Бұл жұмыста алғаш рет GPS/GSM трекиң қолданылып, үкінің маңызды көші-қон дәлізі саналатын Шақпақ асуында тіршілік етуі туралы егжей-тегжейлі ақпарат берілді. Жұмыстың мақсаты – үкінің таралу аймағын картаға түсіру, тіршілік ету ортасына талаптарын анықтау, сандық және сапалық әдістерді біріктіретін аралас әдістерді қолдану арқылы мінез-құлық бейімделуін талдау болды.

Алынған нәтижелер үкі қозғалысының маңызды маршруттарын, оның ұя салатын және аң аулайтын аумақтарға бағыныштылығын көрсетеді. Үкінің аңшылық және түрлі мекендеу ортасына бейімделу қабілетіне қарап, олардың экологиялық икемді түр екенін білуге болады. Үкінің аң аулау уақыты мен ашық жерлерден ойлы-қырлы ландшафтарға дейін мекендейтін жерлері анықталды. Күнделікті белсенділігін және температураға тәуелділігін талдау барысында, үкінің төменгі температурада көбірек аңға шығатыны, ымырт пен таң атқанда белсенді болатыны нақтыланды.

Үкіні GPS трекер арқылы бақылау 9 күн бойы жүргізілді, және тәуліктегі ең белсенді кезеңі 19.00-ден 23.00-ге дейін және таңғы сағат 4-тен таңғы 7-ге дейін болды. Бұл зерттеу үкінің мінез-құлық ерекшеліктері туралы құнды ақпарат береді. Нәтижелер құстардың биологиясы мен табиғатты қорғау ғылымын зерттеуге практикалық маңызы бар, бұл Тянь-Шань мен ұқсас экожүйелерде болашақ зерттеулерге негіз болады.

Түйін сөздер: үкі, құс экологиясы, түнгі құстар, GPS телеметрия, GSM таратқышы, тіршілік ету ортасын пайдалану, құстарды қорғау.

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Анализ использования среды и поведения филина *Bubo Bubo* в Западном Тянь-Шане, на перевале Шакпак с помощью GPS/GSM телеметрии

Исследование посвящено использованию среды обитания и поведенческим особенностям филина (Bubo bubo) на перевале Шакпак, расположенном в Западном Тянь-Шане. Это первое детальное исследование пространственного поведения вида и использования среды обитания в этом важном миграционном коридоре. Целью было составить карту ареала помеченного филина, определить предпочтительные места обитания и проанализировать поведенческую адаптацию, используя смешанный подход, который сочетает в себе количественное GPS-отслеживание с качественными наблюдениями за поведением.

Результаты подчеркивают значительную локализованность перемещения филина, показывая его привязанность к гнездовой и охотничьей территории. Анализ показывает способность филина адаптироваться к разнообразным средам обитания для охоты и ночевки, что указывает на экологическую пластичность. Были выявлены отчетливые модели дневной и ночной активности, демонстрирующие конкретное время охоты этого вида и предпочтительные места обитания: от открытых территорий до пересеченной местности.

Анализ суточной активности и зависимости от температурного режима показывает, что филин активен при более низких температурах, на закате и на рассвете. Отслеживание суточной активности проводилось в течение 9 дней, в результате был выявлены наиболее активные часы – с 7 вечера до 11 ночи, а в рассветные часы – с 4 до 7. Это исследование дает ценную информацию о поведенческих особенностях филина. Результаты имеют практическое значение для изучения биологии данного вида птиц и природоохранной науки, предлагая основу для будущих исследований на Тянь-Шане и подобных экосистемах.

Ключевые слова: филин, поведение птиц, ночные птицы, GPS телеметрия, GSM передатчик, использование среды обитания, охрана птиц.

Introduction

The Eurasian Eagle-Owl (Bubo bubo), is a species of notable conservation interest, yet its behavioral patterns and habitat utilization in the Western Tien Shan region remain insufficiently understood. The choice of topic is driven by both a theoretical interest in the ecological adaptations of Bubo Bubo and a practical concern for its conservation status, especially given its classification as rare and red-listed in Kazakhstan.

The object of this study is the ecology, particularly habitat utilization and behavioral dynamics of Bubo bubo within the Shakpak Pass where located in Western Tien Shan. This area, known for its unique topographical and ecological characteristics, serves as a crucial corridor for migrating birds, offering a rare opportunity to study the species in a migratory bottleneck.

Our research aims to fill the existing knowledge gap by providing detailed insights into the spatial movements, habitat preferences, and behavioral patterns of Bubo Bubo, utilizing first time cutting-edge GPS/GSM telemetry technology. The objectives include mapping the home range, identifying key habitat components, and analyzing behavioral adaptations to the environment and human disturbances.

This study employs a mixed-methods approach, integrating quantitative GPS tracking data with qualitative observations of behavioral patterns.

The significance of this study is to enhance our understanding of the Eurasian eagle owl's ecology and behavior. By exploring these areas, we aim to gain insights into the species' survival strategies and habitat requirements. This knowledge is for developing effective conservation measures to protect the owl and its environment.

The Eurasian Eagle-Owl *(Bubo bubo)* is a large owl species found in various habitats across Europe and Asia. It is a rare and red listed bird [1] nests and is found in wintering grounds throughout almost all of Kazakhstan [2, 3]. They are found in a wide variety of areas, including flat and hilly areas with rocks and cliffs, in river valleys, in dense deciduous, coniferous or mixed forests, in the Tien Shan at an altitude of up to 3000 meters above sea level. It nests in separate pairs, very far from each other. Nesting territories are stable and, in the absence of external disturbance, are used by birds year after year [4]. Within the administrative borders of Kazakhstan in the Aral-Caspian region, at least 1200-1500 pairs of eagle owls are known to nest [5]. In southern Kazakhstan in 1985-1988, 6 cases of nesting of the eagle owl Bubo Bubo were recorded [6]. In Eastern Kazakhstan, the population of the eagle owl has been declining; once common two decades ago, it is now one of the rarest species in the region [7].

Research by Heggoy et al. (2021) utilized GPS satellite telemetry to investigate space use and movements of Eurasian Eagle-owls in Norway. The study found that adult breeding eagle owls had a mean home range size of 42.9 km² and exhibited long excursive movements away from their breeding territories during the post-breeding season, highlighting the species' wide-ranging behavior [8]. Van Nieuland et al. (2019) also conducted a habitat suitability assessment for Eurasian Eagle-Owls in Limburg, the Netherlands, using GPS tracking data to validate the model. The assessment identified quarries and vegetation structures as primary attractors for the species, emphasizing the importance of these features for conservation efforts [9].

A study explored the behavior of Eagle Owls in an operating quarry in Hungary, discovering that the tracked female owl was not disturbed by regular human activities, but unexpected and non-regular disturbances proved to be more disruptive. This finding highlights the adaptability of Eagle Owls to human-modified environments while also pointing out potential stressors [10]. Another investigation delved into the potential of bioacoustic methods for monitoring individual Eagle Owls, demonstrating that individuals could be identified by their calls. This has significant implications for understanding population dynamics and informing conservation strategies [11].

The adaptability of the Eurasian Eagle-Owl to human-altered landscapes has been studied, showing that breeding pairs prefer territories at lower elevations and closer to human activities, despite the associated risks such as electrocution, indicating a complex balance between benefits and costs in these environments [12].

Materials and methods

Study Area

The study was conducted at Shakpak Pass, located at longitude E70.60549° and latitude N42.53038°, at an altitude of 1161 meters. This location is a well-known geographical bottleneck for migrating birds between Karatau and Talas Alatau in the Western Tian Shan region (Fig 1). The area is significant as a habitat for both migrating and non-migrating birds, offering a diverse landscape that encompasses open areas, agricultural lands, and rocky terrains.

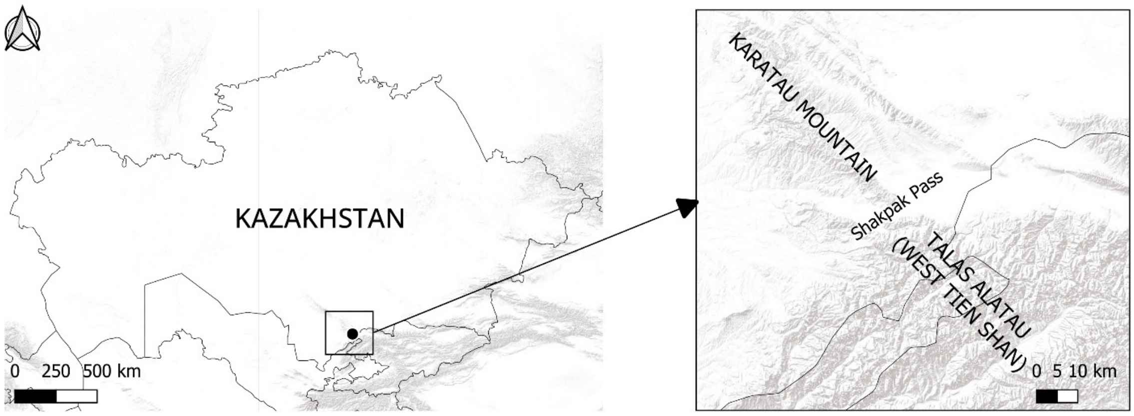

Figure 1 – Map of study area

Trapping and Tracking

During the annual migration monitoring on September 7, 2022, an adult Eurasian Eagle-Owl, weighing 2300 g, was captured at the Shakpak ornithology station using a stationary Heligoland-type trap [13]. This marked the sixth capture of this species at the station in 58 years, with the last capture occurring in 1995 [14].

The Eurasian Eagle-Owl was equipped with the GPS satellite transmitter model Global Tracking HQBG1815S to monitor its movements, habitat use, and activity patterns. This transmitter is designed as a backpack unit, weighing between 15-18 grams, and measures 63 by 23 by 18 millimeters in length, width, and height, respectively. It boasts a substantial storage capacity of 2,600,000 fixes and utilizes multiple positioning modes including GPS, BDS, and GLONASS, ensuring a positioning accuracy of 5 meters. The transmitter is solar-powered, and is designed to have a lifespan of more than 5 years. Additionally, it is waterproof up to 10 ATM, making it resilient in various environmental conditions. The transmitters were designed to record geographical location, altitude, flight speed, exercise, validity, and temperature at 1-hour intervals [15].

Data Collection

The tracking device was attached to an adult Eurasian Eagle-Owl at Shakpak Pass, initiating data collection on September 7, 2022. Over 8.3 days, until September 15, 2022, 193 GPS data points were recorded. Key quality indicators assessed for each data point included the number of satellites connected, Horizontal Dilution of Precision (HDOP), Vertical Dilution of Precision (VDOP), and the validity status of the data.

Data Analyses

For the movement analysis, the total distance traveled, average speed, and home range area were calculated using the GPS tracking data. The collected data were then imported into QGIS v.3.26.2. for detailed spatial analysis and mapping [16]. To understand the home range and occurrence patterns, motion models from the ctmmweb v. 0.2.10 online application were employed [17, 18]. The selection of the best model was based on several factors including the delta Akaike Information Criterion corrected (dAICc) value, degrees of freedom (DOF) metrics, and the performance characteristics of each model, such as area, speed, and diffusion. The dAICc value is important for comparing models to minimize information loss and identify the model that most closely represents the true mechanism.

Further analysis of the data was conducted to identify diurnal behavior patterns, hunting times, and preferred habitats. This step involved noting periods of high speed and rapid altitude changes, which served as indicators of hunting activity. Altitude data were meticulously analyzed to deduce vertical habitat use, differentiating between flying, perching, and ground-level activities.

Temperature Correlation: The relationship between the owl's activity levels and environmental temperature was examined to assess how temperature influences behavior, especially in terms of mobility and hunting strategies.

Results and discussion

Tracking Data Quality

The starting point of GPS tracking for Bubo bubo at Shakpak Pass was recorded on September 7, 2022, at 10:17 AM. Key quality indicators assessed included the number of satellites connected at each data point, Horizontal Dilution of Precision (HDOP), Vertical Dilution of Precision (VDOP), and the data validity status. The majority of the data points (approximately 85%) were collected with a satellite count of 6 or more, ensuring a high level of positional accuracy. The distribution of GPS data quality grades, ranging from 'A' for excellent to 'D' for satisfactory. The HDOP values, predominantly ranging between 1.1 and 2.2, and VDOP values, generally around 0.8 to 0.9, further corroborated the precision of the location data. The validity status of the data was also examined, with all of the points marked as 'Valid'. This 100% validity rate indicates a robust and reliable dataset.

Migration Patterns

The Eurasian Eagle-Owl traveled a total distance of 106.786 km at an average speed of 12.8 km/day during 8.3 days (Fig 1). The OUF anisotropic model, with a perfect dAICc score of 0, accurately captures the movement of Bubo bubo. According to the model, the bird covered an area of 20.26 km². Tau metrics reveal that the owl's location remained consistent for approximately 28.47 hours, with speed changes occurring roughly every 12.77 minutes. There was no evidence of long-distance migration; instead, the owl's movements were localized, staying within approximately 0.05 degrees from the tagging point, indicating a stable utilization of the area during the study.

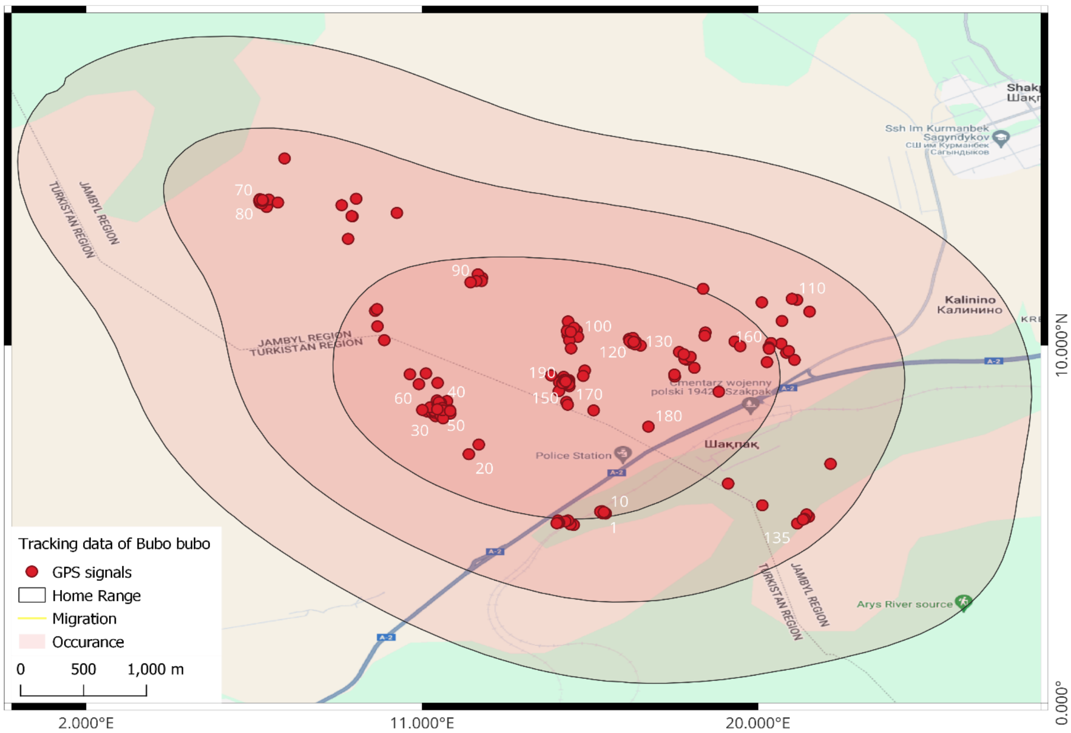

Figure 2 – GPS tracking map of Bubo bubo at Shakpak Pass. The numbers indicate sequential tracking signals. Point 1 marks the starting location of the tracking. 70.61° E, 42.53° N

During the tracking period, the Eurasian Eagle-Owl prefers Shakpak Pass, exhibiting localized, non-migratory movement patterns within a 1100-1300 m sea level altitudinal range, which corresponds to the topographic characteristics of the area (Fig 2).

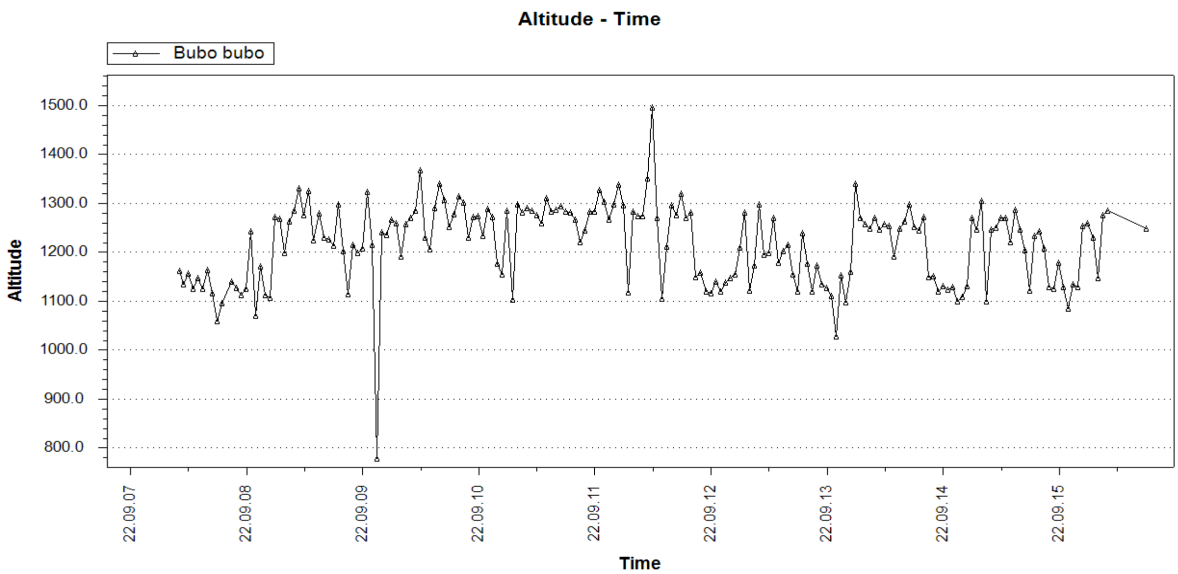

Figure 3 – Flight altitude of Bubo bubo at Shakpak Pass recorded by GPS transmitter (Sea level)

Habitat Use and Activity Patterns

The data on the Eurasian Eagle-Owl at Shakpak Pass revealed distinct diurnal behavior patterns, highlighting its ecological and physiological adaptations. Active primarily from early evening until morning, the owl engaged in hunting across diverse habitats such as open areas near railways, agricultural lands, rocky terrains, and areas close to water utilities (Table 1). Hunting times, identified by the owl's peak nocturnal speeds, reflect its adaptability to different environments.

Table 1 – Daily Activity Patterns of a Eurasian Eagle-Owl at Shakpak Pass.

Day	Activity time	Inactivity time	Hunting time and habitat*	Roosting site
September 7	9 pm – 7 am	10 am – 8 pm	11pm, open area near railway	Forest belt near highway
September 8	7 pm – 3 am	8 am – 6 pm	9 pm, open area near tree	Trees in the ravine
September 9	7 pm – 7 am	4 am – 6 pm	11 pm, agricultural land	Trees in the ravine
September 10	8 pm – 7 am	8 am – 7 pm	7 am, rocky open space	Shrubs near the forest belt
September 11	9 pm – 7 am	8 am – 8 pm	9 pm, open space near water utility	Shrubs near the forest belt
September 12	8 pm – 7 am	8 am – 7 pm		Forest belt near highway
September 13	9 pm – 7 am	8 am – 8 pm	10 pm, agricultural land near highway	Forest belt near highway
September 14	9 pm – 7 am	8 am – 8 pm	6 pm, rocky open space	Forest belt in the ravine
September 15	7 pm – 7 am	8 am – 6 pm		Forest belt in the ravine

*Hunting times were identified based on periods of the owl's highest recorded speeds during nighttime

Hunting Behavior

Speed bursts, coupled with rapid altitude changes, were key indicators of hunting activity. The data showed these bursts were most frequent in the hours just after sunset and before sunrise, suggesting crepuscular hunting habits.

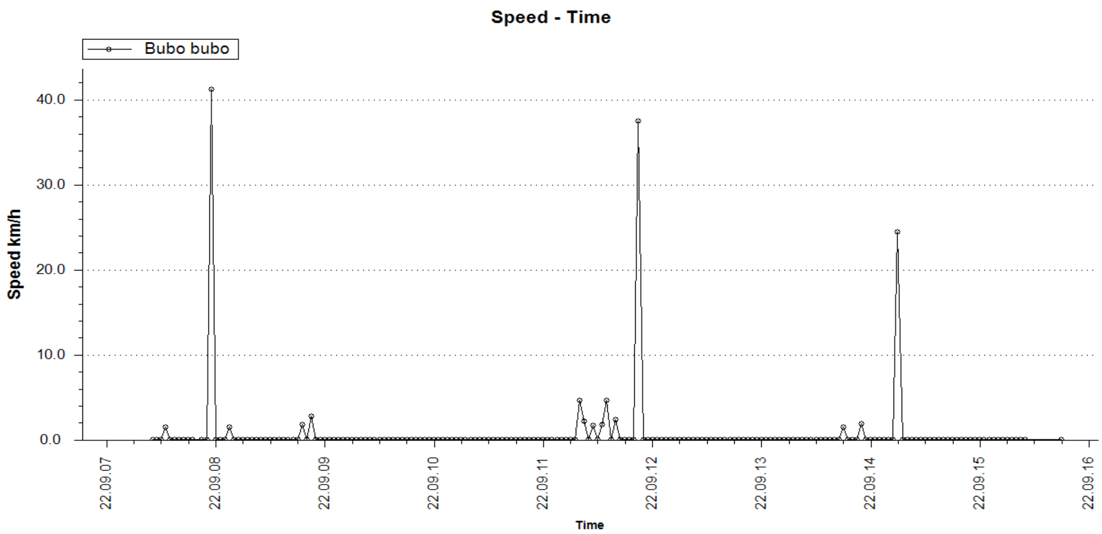

Figure 4 – The flight speed of Bubo bubo recorded by GPS transmitter

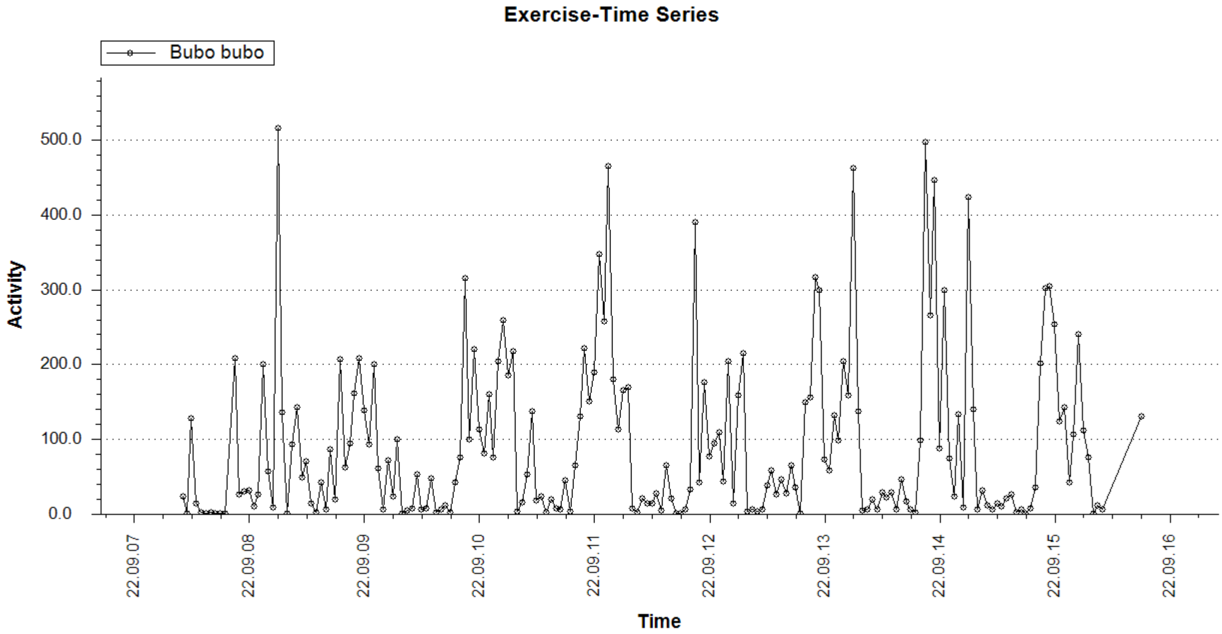

Figure 5 – The daily activity of Bubo bubo recorded by GPS transmitter

Roasting sites

Locations where the owl remained stationary for prolonged periods, during daylight, were pinpointed as likely roosting sites. Observations indicated a preference for natural shelters such as forest belts near highways, trees in ravines, and shrubs close to forested regions for these rest periods. These chosen sites imply a deliberate selection for areas that provide safety from predators and disturbances, while being close to hunting territories.

Temperature Effects on the Behavior

The temperature's impact on the activity of Bubo bubo was analyzed by correlating the owl's movements with temperature readings from the GPS tracker. The owl was more active at cooler temperatures, showing increased movement at dawn and dusk. Higher temperatures were associated with reduced movement, suggesting the owl was resting or avoiding heat. Hunting was more dynamic at comfortable temperatures, with the owl utilizing a variety of altitudes. Extreme temperatures, however, seemed to restrict hunting to specific altitudes where conditions were likely more tolerable. Temperature fluctuations had a limited effect on roosting.

Discussion

To calculate ground level information, we compared a digital elevation model (DEM) with GPS data. The middle ground level altitude was 22 m.

The altitudinal data from the GPS tracking of *Bubo bubo* at Shakpak Pass offer insights into the owl's vertical use of its environment. The recorded altitudes range from 0 to 468.6 meters above ground level, with numerous readings indicating ground level (0 meters), which can be associated with roosting or hunting behaviors.

Significant altitudinal changes were noted, with the owl reaching a maximum of 468.6 meters, which likely corresponds to flight behavior. Periods of sustained high altitudes, notably readings such as 169.3, 193.9, 204, and 150.6 meters, suggest active flying, potentially for hunting or territory exploration. Conversely, numerous instances of low altitude readings, especially the consistent 0 meters, suggest ground-level activities. These could be indicative of the owl's interaction with the terrain, such as hunting or roosting at ground level or near it. Intermediate altitude readings, such as 11.3, 17.8, 43, 52.4, and similar, may represent perching behavior, where the owl is likely resting or observing the area, possibly in preparation for hunting. Fluctuations between these intermediate altitudes and higher values may indicate the owl's take-off and landing patterns, which are essential for understanding its hunting strategies and energy expenditure. Furthermore, the frequency of 0-meter readings at night could suggest preferred roosting sites. In contrast, the daytime readings with greater altitude variation could reflect the owl's active period, engaging in hunting and territorial defense. The sporadic high values, such as the singular peak at 468.6 meters, might signify exceptional events, perhaps disturbances that prompted an unusually high flight, or could be anomalies in the data requiring further verification.

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