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**Ornis Hungarica 2023. 31(2): 1–12.**
DOI: 10.2478/orhu-2023-0015

# Raptors and linear infrastructure in Chhattisgarh, India: species composition and conservation concern

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*Received: June 02, 2023 – Revised: September 30, 2023 – Accepted: October 02, 2023*

Ashwin, C. P., Alby, M. J., Arjun, M. S., Arun, P. R. & Nandu, V. S. 2023. Raptors and linear infrastructure in Chhattisgarh, India: species composition and conservation concern. – Ornis Hungarica 31(2): 1–12. DOI: 10.2478/orhu-2023-0015

**Abstract** We investigated the species diversity of diurnal raptors along the selected linear infrastructure projects in northern Chhattisgarh, India, between December 2020 and September 2022. The study identified a total of 14 raptor species, consisting of 11 species in Accipitridae, two in Falconidae, and one in Pandionidae families. Two species were under threatened category of the IUCN red list, the Vulnerable Indian Spotted Eagle *(Clanga hastata)* and the Near Threatened Pallid Harrier *(Circus macrourus)*. Linear infrastructure development, such as roads, railways, pipelines, canals, and power lines, is expanding rapidly, causing the degradation and fragmentation of habitats, and leading to the loss of biodiversity. Unfortunately, the impacts of linear infrastructure on bird populations in India have not been adequately studied, resulting in limited understanding and few measures to mitigate these impacts. This study specifically focuses on the status of raptors along selected linear infrastructure intrusions and provides baseline information that can help in understanding their conservation needs. The findings of this study underline the necessity of implementing appropriate measures to mitigate the negative effects of linear infrastructure development in India.

Keywords: raptors, linear infrastructure, Chhattisgarh, Accipitridae, Falconidae, Pandionidae

**Összefoglalás** 2020 decembere és 2022 szeptembere között vizsgáltuk a nappali ragadozómadarak fajdiverzitását kiválasztott vonalas infrastruktúra projektek mentén Chhattisgarh északi részén Indiában. A kutatás során összesen 14 ragadozómadár-fajt azonosítottunk, amelyek közül 11 az Accipitridae, kettő a Falconidae és egy a Pandionidae családba tartozott. A feljegyzett 14 faj közül két faj szerepelt az IUCN vörös listájának veszélyeztetett kategóriájában: a sebezhető indiai békászó sas *(Clanga hastata)* és a mérsékelten veszélyeztetett fakó rétihéja *(Circus macrourus)*. A vonalas infrastruktúra-fejlesztés, mint az utak, vasutak, csővezetékek, csatornák és elektromos vezetékek, gyors ütemben épülnek, amelyek az élőhelyek degradációját és feldarabolódását okozzák, és a biológiai sokféleség csökkenéséhez vezetnek. Sajnos a vonalas infrastruktúra indiai madárpopulációkra gyakorolt hatásait eddig nem vizsgálták megfelelően, így az információk hiányában limitált a hatások enyhítésére tehető beavatkozások lehetősége is. Ez a kutatás a vonalas infrastruktúra-beruházások mentén élő ragadozómadarak helyzetére összpontosít, és olyan alap információkkal szolgál, amelyek segíthetnek kialakítani a szükséges védelmi intézkedéseket. A tanulmány megállapításai kiemelik a megfelelő intézkedések végrehajtásának szükségességét az indiai vonalas infrastruktúra-fejlesztés negatív hatásainak mérséklése érdekében.

Kulcsszavak: ragadozómadár, vonalas infrastruktúra, Chhattisgarh, Accipitridae, Falconidae, Pandionidae

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## Introduction

The decline in biodiversity is occurring at an unprecedented rate, globally, primarily caused by human activities that have affected approximately 50–70% of the Earth's land surface. Consequently, ecosystem functioning has been altered, significantly changing global biodiversity patterns. Several factors drive this loss of biodiversity, including land use and land cover modifications, pollution, climate change, and infrastructure development (Sala *et al.* 2000, Mace & Baillie 2007, Butchart *et al*. 2010, Ceballos *et al*. 2015, McCallum 2015).

The significant expansion of linear infrastructure (LI) always had a negative role resulting in the massive degradation and decline of natural habitats and an irrevocable scar on the Earth's surface (Ramachandran *et al*. 2018, Nayak *et al*. 2020). Linear infrastructure, which includes roads, railways, pipelines, canals, power lines, etc., is essential for human progress and covers a significant part of the Earth's surface (Dulac 2013, Meijer *et al*. 2018). They are critical for contributing to the economic growth of any country by facilitating the transportation of people, energy, fuel, and goods from one place to another (WII 2016). The effect of linear infrastructure developments on wildlife is significant and includes not only direct harm caused by collisions or electrocution but also the deterioration and fragmentation of habitats resulting in barriers that hinder connectivity between habitat patches and populations. The fragmentation of large, continuous habitats into smaller, isolated patches may eventually result in the loss of viable populations and genetic diversity in the long term (Fahrig 2003, Loss *et al*. 2014, Santos *et al*. 2016).

Linear infrastructures are expanding globally and can pose a severe threat to wildlife, including avifauna (van der Ree *et al*. 2015, Demeter *et al.* 2018). Birds that are flying in flocks, immature individuals lacking experience, and species with larger biometrics, such as weight and wing load (e.g. raptors, cranes, and bustards), which are associated with faster flight but lower manoeuvrability, are at a higher risk of colliding with lines (Bevanger 1998, Drewitt & Langston 2008, Wiącek *et al*. 2020). Due to the larger body size and preference for elevated perches, raptors are more susceptible to colliding with the lines and this source of non-natural mortality is contributing to declines in raptor populations (Slater *et al*. 2020, Dwyer *et al*. 2023). Among other linear infrastructure intrusions; power lines are one of the primary causes of avian mortality and it is estimated to cause the deaths of over 60 million birds annually in the United States and Canada (Loss *et al*. 2014). Most of the research on avian electrocution is concentrated in North America and Europe, as evidenced by the references cited in recent reviews by Bernardino *et al.* 2018 and Slater *et al*. 2020.

There is an increasing amount of research on avian electrocution coming out of Asia, as evidenced by recent studies such as Harness *et al.* 2013, Dixon *et al.* 2020, Kolnegari *et al.* 2020, Guil and Pérez-García 2022. These studies are helping to broaden our understanding of avian electrocution patterns and impacts in different geographic regions. India is recognized as one of the 17 mega-diverse countries globally, known for its high number of endemism (Mittermeier *et al.* 2011). In recent years, India's economy has witnessed rapid growth, and as a result, Indian infrastructure networks, such as roads, railways, and power lines, have been extensively expanded and modernized. India has the world's second-largest road system, covering 5.2 million km, and the third largest railway network, spanning over

64,000 route km. Furthermore, India ranks fifth globally in terms of its installed power generation capacity, which is 271 GW (WII 2016). Among that, Chhattisgarh is a state in India that is undergoing significant development in its power sector, to provide reliable and affordable electricity to all citizens.

Additionally, the railway network in the state is being rapidly expanded to enhance connectivity and facilitate economic growth. However, the expansion of linear infrastructure, including power lines and railway networks, can have a detrimental impact on avifauna. Despite the rapid progress in developing these infrastructure projects, there has been a lack of attention given to researching and understanding the impacts of these projects on bird populations in India. This lack of attention has resulted in a limited understanding of the impacts, and consequently, very few measures are in place to mitigate these impacts. Avifauna is an essential part of India's biodiversity, and the country is home to many endemic bird species. The degradation and loss of habitat due to linear infrastructure projects can lead to a significant decline in bird populations and a loss of biodiversity. Furthermore, birds that collide with power lines and other linear infrastructure can suffer fatal injuries, leading to a decline in their populations. Therefore, it is crucial to conduct thorough research on the impact of linear infrastructure projects on avifauna in India to develop effective management strategies that can mitigate the negative effects of these projects.

Without appropriate measures in place, the development of linear infrastructure in Chhattisgarh and other parts of India could lead to irreversible damage to bird populations and their habitats. The current research concentrates on the status of the raptor population along selected linear infrastructure intrusions located in the northern region of Chhattisgarh. The study aims to generate crucial baseline information regarding the raptor population in the area, which can help in understanding their conservation needs and devising effective conservation measures.

## Methods

### Study area

Chhattisgarh state covers an area of 135,191 km$^2$, which is 4.1% of the total area of the country. The forest area of the state is approximately 59,772 km$^2$, accounting for 44.21% of the state's total area. Chhattisgarh is located in the East Deccan physiographic zone, and its southern part is part of the Deccan Plateau. The Deccan physiographic zone is divided into three agro-climatic zones: the Chhattisgarh Plains, the Northern Hills of Chhattisgarh, and the Bastar Plateau. Chhattisgarh experiences very warm weather, with an average daily high temperature of 33 °C. The climate is hot and humid throughout the year, with an annual average temperature of 33 °C, as it is located near the Tropic of Cancer and receives rainfall from the monsoon season.

The current study area for raptor surveys was initiated by September 2020 and continued till September 2022 covering five linear infrastructures projects: the Ranchi – Dharamjaigarh Transmission Line (RDTL), Korba – Jabalpur Transmission Line (KJTL), Champa – Kurukshetra Transmission Line (CKTL), East Rail Line (ERL) and East-West Rail Line (EWRL). Surveys were carried out along the five Linear Infrastructure corridors in respective districts i.e., Korba, Bilaspur, Janjgeer-Champa, Raigarh and Jashpur in the state of Chhattisgarh *(Figure 1, Table 1)*.

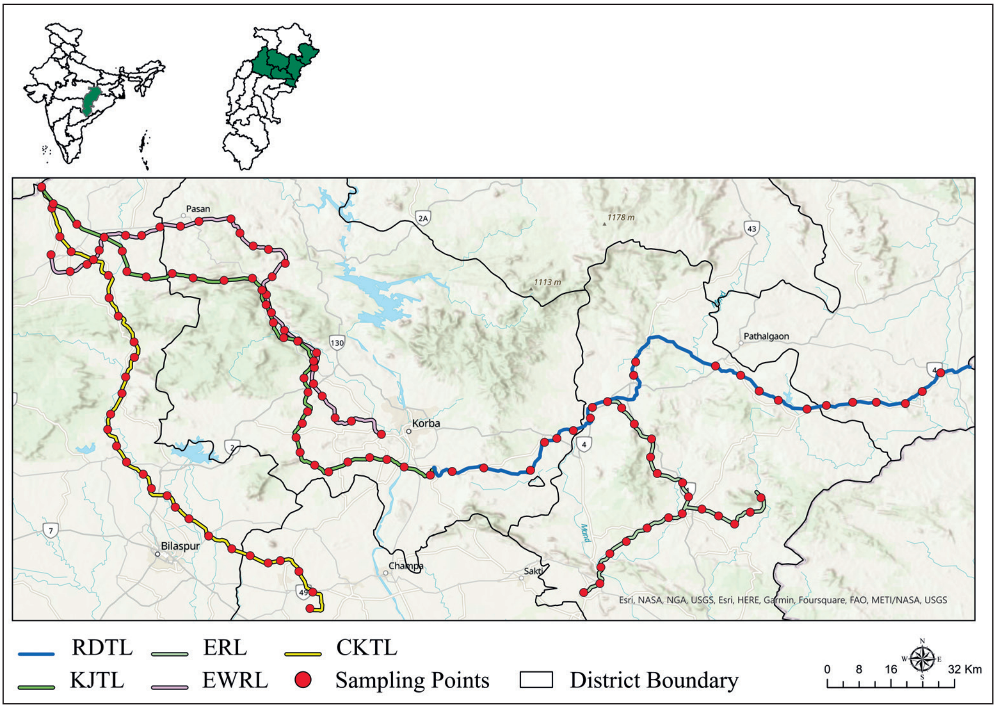


*Figure 1.* Study area in Chhattisgarh state, India (see *Table 1* and text for abbreviations)
*1. ábra* Kutatási terület Chhattisgarh államban, Indiában (rövidítéseket ld. az 1. táblázatban és a szövegben)

*Table 1.* Details of the Linear Infrastructures surveyed
*1. táblázat* A felmért vonalas infrastruktúra létesítmények adatai

| Linear infrastructures studied | Abbreviation | Districts | Length (km) | Operational Status |
|---|---|---|---|---|
| Korba – Jabalpur Transmission Line (765 kV) | KJTL | Korba Bilaspur | 153.28 | Operational |
| Champa – Kurukshetra Transmission Line (800 kV) | CKTL | Bilaspur Janjgeer-Champa | 154.77 | Operational |
| Ranchi – Dharamjaigrah Transmission Line (765 kV) | RDTL | Korba, Raigarh& Jashpur | 168.27 | Operational |
| East Rail Line | ERL | Raigarh | 100.55 | Operational |
| East-west Rail Line | EWRL | Korba Bilaspur | 134.66 | Under Construction |

**Survey design and data collection**

A systematic survey was carried out to determine the composition and abundance of raptors in the vicinity of selected linear infrastructure project sites from December 2020 to September 2022. Raptors were sampled at intervals of four kilometres along the selected linear infrastructures to obtain the necessary data (Kajzer-Bonk *et al.* 2019). The sampling points were located adjacent to the lines with maximum visibility to detect the soaring raptors. The sampling locations were defined as the area within a 500-meter radius of the observer (Planillo *et al.* 2015). The raptor survey was conducted by the observer in a 360-degree circle around a fixed point for 15 minutes, identifying birds through direct sightings and calls. The surveys were carried out between 11:00 and 15:00.

A special search was made to identify the raptor nests on the pylons along the lines. Fieldwork was carried out on days without wind or rain to prevent weather-related biases in sampling (Bibby *et al.* 2000). The "Avian Sensitivity Tool for Energy Planning" (AVISTEP) was employed to determine areas in the study region that are sensitive to bird species with the existing transmission line infrastructure (BirdLife International 2022). AVISTEP was also utilized to map out the study area, providing valuable insight into its level of sensitivity. All the maps were made with the help of ArcGIS. Pearson's correlation coefficient between the predicted sensitivity score (by AVISTEP) and the recorded raptor abundance was computed using IBM SPSS Statistics V23.0.

The raptors were scrutinized through Nikon Monarch (10×42) binoculars, while Nikon COOLPIX P900 was used to capture photographs that facilitated the identification of the challenging species. Additionally, standard field guides were consulted to aid in the identification of the raptors (Grimmett *et al.* 2011) and the nomenclature of birds was followed by Praveen and Jayapal 2023.

## Result and Discussion

We recorded a total of 14 diurnal raptor species, consisting of nine residents, four winter migrants, and one partial migrant. Two of these species were under threatened category of the IUCN red list, the Vulnerable Indian Spotted Eagle *(Clanga hastata)* and the Near Threatened Pallid Harrier *(Circus macrourus)*. The most recorded species was the Black Kite *Milvus migrans* (81 individuals), followed by the Shikra *Accipiter badius* (22), Oriental Honey Buzzard *Pernis ptilorhynchus* (9), Black-winged Kite *Elanus caeruleus* (8), and Eurasian Sparrowhawk *Accipiter nisus* (5). The Accipitridae family had the highest number of individuals observed (134), followed by Falconidae (4) and Pandionidae (1). The overall species diversity of the five Linear infrastructures we studied was measured at 1.51 (Shannon's H index).

Among the lines *(Figure 2)* surveyed, the Champa – Kurukshetra transmission line had the highest number of individuals recorded (36 individuals of 6 species). The Korba – Jabalpur transmission line had the second-highest number of individuals recorded (33 individuals of 9 species), followed by the East-west rail (28 individuals of 5 species), the East Rail

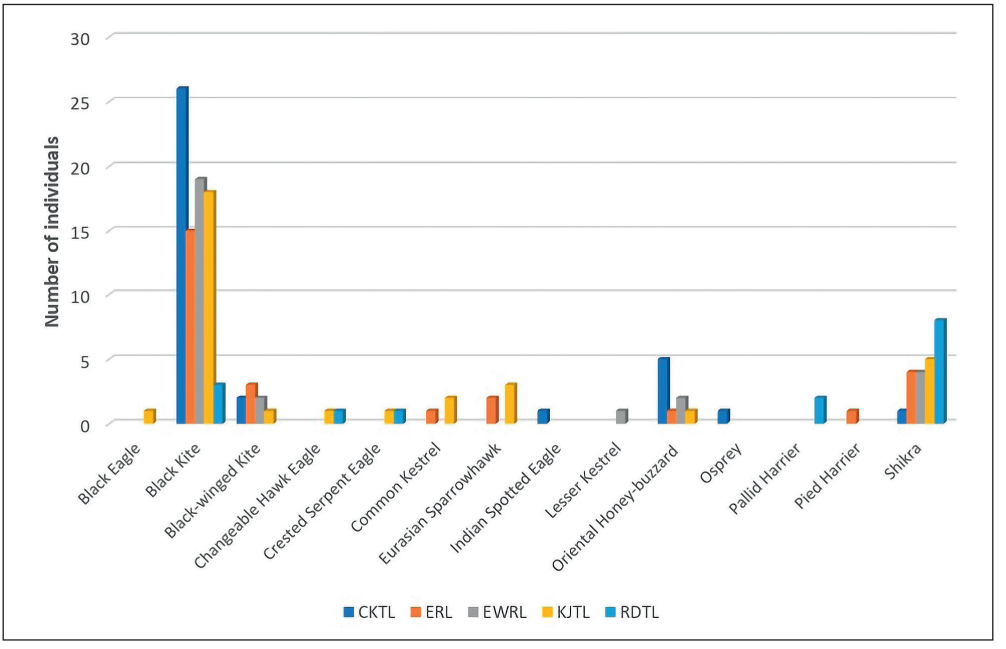


*Figure 2.* The abundance of raptor species along the five linear infrastructures surveyed. Black Eagle (BLEA), Black Kite (BLK), Black-winged Kite (BWKI), Changeable Hawk Eagle (CHEA), Crested Serpent Eagle (CSEA), Common Kestrel (COKE), Eurasian Sparrowhawk (EUSP), Indian Spotted Eagle (ISEA), Lesser Kestrel (LEKE), Oriental Honey-buzzard (OHBU), Osprey (OSPR), Pallid Harrier (PAHA), Pied Harrier (PIHA), Shikra (SHIK)

*2. ábra* A ragadozómadár fajok egyedsűrűsége az 5 vonalas infrastruktúra létesítménye mentén. Maláj sas (BLEA), barna kánya (BLK), feketeszárnyú kuhi (BWKI), főkötős vitézsas (CHEA), bóbitás kígyászsas (CSEA), vörös vércse (COKE), karvaly (EUSP), indiai békászósas (ISEA), fehérkarmú vércse (LEKE), bóbitás darázsölyv (OHBU), halászsas (OSPR), fakó rétihéja (PAHA), tarka rétihéja (PIHA), sikra (SHIK)

Corridor (27 individuals of 7 species), and the Ranchi – Dharamjaigarh transmission line (15 individuals of 5 species).

The Korba-Jabalpur transmission line has the highest raptor diversity, with Shannon's H value of 1.53, followed by the East Rail Corridor (H = 1.41), Ranchi-Dharamjaigarh transmission line (H = 1.29), East-west rail (H = 1.04), and Champa-Kurukshetra transmission line (H = 0.97).

The results of this study are significant because they highlight raptor status along the lines and also the importance of considering the possible impact of linear infrastructure on raptor populations. The presence of good diversity along with the threatened species emphasizes the need for effective planning and management of linear infrastructures to minimize its impact on bird communities. The variation in raptor diversity across the different linear infrastructures emphasizes the need for site-specific management strategies and future studies must be carried out by emphasising bird mortality along the lines.

Furthermore, certain species are attracted to infrastructure. For instance, power line poles are often utilized by raptors as perches for hunting and roosting, and also serve as support structures for nesting sites of multiple species (Benítez-López *et al.* 2010, Mainwaring 2015). The group of birds most frequently subjected to electrocution are raptors, and such non-natural deaths are playing a major role in the reduction of Asian raptor populations. The significant decline of Steppe Eagle *(Aquila nipalensis)* populations in the Caspian steppes of Kazakhstan and southern Russia, from 20,000 pairs to 1,100 pairs is attributed to electrocution by transmission lines (Karyakin 2013, Dwyer *et al.* 2022). The attraction of raptors to power line poles may lead to non-natural deaths, leading to their population decline (Walters *et al.* 2014).

During the present study period, we documented seven active nests of Black Kites on the pylons located adjacent to the cross arms of the Champa-Kurukshetra Transmission line. Various species of birds were found to be utilizing the powerline poles for activities such as roosting, hunting, and feeding as well. This creates both challenges and opportunities. However, it is important to note that the birds' utilization of powerline poles also increases the risk of electrocution by contacting the lines (Lehman *et al*. 2007, Kemper *et al.* 2013). The interactions between these birds and power line structures can also lead to economic costs such as power outages (Jenkins *et al.* 2013). Information on the effect of power lines on nesting birds and their breeding performance is often overlooked. Breeding on power poles also makes birds more vulnerable to heavy rains, intense solar radiation, and strong winds, which may have adverse effects on the hatching success and survival of nestlings compared to breeding on trees (Gilmer & Wiehe 1977, Janiszewski *et al.* 2015).

During our rapid surveys along the LI routes, we did not find any instance of bird mortality related to lines. However, with the exponential growth of linear infrastructure, the likelihood of such collisions occurring is high. Birdlife International has developed a tool called „The Avian Sensitivity Tool for Energy Planning" (AVISTEP) that identifies bird-sensitive areas in relation to transmission line networks *(Figure 3)*. Essentially, the tool helps to identify locations where bird species are likely to be impacted by the transmission lines, allowing policymakers and researchers to better understand the potential ecological impacts of the infrastructure on the local avian population. The AVISTEP has identified sensitive areas for birds throughout India, based on a sensitivity index that considers the presence of sensitive bird species, habitats, and overlaps with protected areas and Important Bird and Biodiversity Areas. According to AVISTEP, most of the areas in Chhattisgarh fall under moderate to very high sensitivity for bird collisions. We analysed five LI corridors with AVISTEP's bird-sensitive areas and found that the Champa-Kurukshetra Transmission Line (TL) and Korba – Jabalpur TL routes are most likely to have high chances of bird collisions, followed by the Ranchi – Dharamjaigarh TL route.

The Champa – Kurukshetra transmission line spans various areas with distinct sensitivities. It covers 26 km of very highly sensitive areas, where bird abundance was recorded as 2. Additionally, the line passes through 11 km of highly sensitive area. Moreover, the transmission line crosses 115 km of moderately sensitive areas with a recorded bird abundance of 36. In a 2 km stretch of low sensitive area, no birds were recorded. The Korba – Jabalpur TL traverses a route that encompasses 34 km of very highly sensitive areas, where the bird abundance is recorded as 5, and an additional 100 km of moderately sensitive areas, where the bird abundance is observed to be 28. No birds were recorded from the 19 km low sensitive area. The Ranchi-Dharamjaigarh TL passes through 153 km of moderately sensitive areas and 15 km of low sensitive areas whereas the moderately sensitive area was recorded bird abundance as 15 and no birds were recorded from the low sensitive areas. Out of the total East rail length, 93 km traverses moderately sensitive areas, and the bird abundance in this region is recorded at 27. Conversely, the remaining 7 km of the rail line passes through low sensitive areas, where no bird presence has been recorded. The East-West rail area spans a total of 134 km, of which 67 km passes through highly sensitive areas with a recorded bird abundance of 15. Additionally, 56 km of the rail line traverses moderately sensitive areas, where the bird abundance is recorded as 13. Lastly, an 11 km segment of the line passes through low sensitive areas, with no bird sightings recorded.

The Pearson's correlation coefficient between sensitivity score and abundance is -0.08, which indicates a weak negative correlation between sensitivity score and abundance. The two-tailed significance value associated with the correlation coefficient is 0.518 (p>0.05), indicating that the correlation between sensitivity score and abundance is not statistically significant at the 0.05 level. Altogether the routes of linear infrastructures and the abundance of raptors along these sensitive areas especially in moderate, high and very high regions predict the higher vulnerability or chance of bird mortality related to linear infrastructures.

Our field data on the raptor abundance, combined with AVISTEP, highlights the conservation concern of linear infrastructure routes of Chhattisgarh from the avian conservation point of

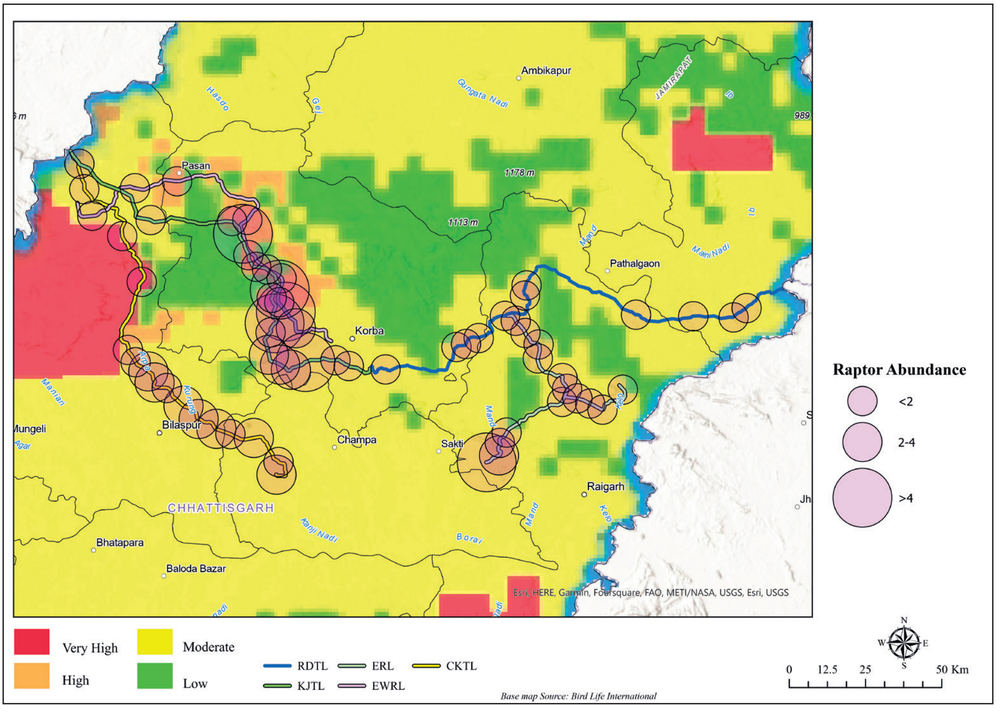


*Figure 3.* Bird sensitive area map according to AVISTEP tool (©AviStep – BirdLife International 2022) and the abundance of raptors recorded at sampling locations along the five linear infrastructures surveyed

*3. ábra* A területek érzékenységének térképe az AVISTEP (©AviStep – BirdLife International 2022) eredményei alapján, feltüntetve a ragadozómadarak egyesűrűségét az egyes vizsgálati pontokon view. The AVISTEP model proves to be a valuable and versatile asset, encompassing a wide array of species and habitats. Nevertheless, its strength lies in generating predictions rather than fine-tuned projections for individual taxa. In instances where precise insights are required for a particular taxon, it becomes imperative to complement the model's output with targeted field surveys. This synergy between the model's overarching trends and on-ground observations can yield a more comprehensive and accurate understanding of the ecological dynamics. Nevertheless, it serves as a valuable baseline dataset that can be strategically leveraged for the meticulous formulation of developmental projects within the specific region. The visual aid *(Figure 3)* holds the potential to play a pivotal role in steering and ranking forthcoming research endeavours, especially in scenarios demanding a judicious allocation of resources and a focused approach to conservation initiatives.

## Conservation implication

Linear infrastructure, such as roads, power lines, and railways, can pose risks to raptors and their habitats. These birds of prey, including kites, eagles, hawks, and owls, are particularly susceptible to the disturbances caused by linear infrastructure, which can impact their survival, reproductive success, movement patterns, and habitats. Effective planning and management of linear infrastructure are crucial in minimizing its impact on raptor populations. Best management practices, such as reducing light pollution and managing vegetation growth near infrastructure, can help reduce the risks of collisions and electrocutions, while innovative technology like bird diverters and underground power lines can also help to minimize the impact of linear infrastructure on raptors. Monitoring and research are essential to assess the impact of linear infrastructure on raptor populations and to frame management strategies. Remote sensing technologies, such as satellite tracking and drones, can provide valuable insights into raptor movements and behaviour, identifying key habitat areas that need protection. Modelling tools can also predict the potential impact of linear infrastructure on raptor populations and help in management decisions. Effective conservation of raptors in the context of linear infrastructure requires collaborative efforts among stakeholders from the transportation, energy, and wildlife management sectors. This proactive and comprehensive approach considers the needs of both raptors and human communities to ensure that linear infrastructure is planned, designed, and managed with minimal impact on raptor populations. By adopting such an approach, we can protect these magnificent birds of prey and enable them to thrive in their natural habitats.

## Acknowledgements

We would like to thank Salim Ali Centre for Ornithology and Natural History, South India Centre of Wildlife Institute of India, and the Chhattisgarh Forest Department for their continuous support and guidance. The authors are also thankful to anonymous reviewers for their valuable input in this manuscript.

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*Appendix 1.* A checklist of raptors recorded along the five Linear Infrastructures
*1. melléklet* Az öt lineáris infrastruktúra mentén rögzített ragadozómadarak fajlistája

| Sl. No. | English Name | Scientific Name | Order | Family | IUCN Status | WPA Schedule | Resident/ Migrant |
|---|---|---|---|---|---|---|---|
| 1 | Black Eagle | *Ictinaetus malaiensis* | Accipitriformes | Accipitridae | LC | Schedule-I | R |
| 2 | Black Kite | *Milvus migrans* | Accipitriformes | Accipitridae | LC | Schedule-II | R |
| 3 | Black-winged Kite | *Elanus caeruleus* | Accipitriformes | Accipitridae | LC | Schedule-II | R |
| 4 | Changeable Hawk Eagle | *Nisaetus cirrhatus* | Accipitriformes | Accipitridae | LC | Schedule-I | R |
| 5 | Common Kestrel | *Falco tinnunculus* | Falconiformes | Falconidae | LC | Schedule-II | R |
| 6 | Crested Serpent Eagle | *Spilornis cheela* | Accipitriformes | Accipitridae | LC | Schedule-I | R |
| 7 | Eurasian Sparrowhawk | *Accipiter nisus* | Accipitriformes | Accipitridae | LC | Schedule-I | WM |
| 8 | Indian Spotted Eagle | *Clanga hastata* | Accipitriformes | Accipitridae | VU | Schedule-I | R |
| 9 | Lesser Kestrel | *Falco naumanni* | Falconiformes | Falconidae | LC | Schedule-II | PM |
| 10 | Oriental Honey Buzzard | *Pernis ptilorhynchus* | Accipitriformes | Accipitridae | LC | Schedule-II | R |
| 11 | Osprey | *Pandion haliaetus* | Accipitriformes | Pandionidae | LC | Schedule-I | WM |
| 12 | Pallid Harrier | *Circus macrourus* | Accipitriformes | Accipitridae | NT | Schedule-I | WM |
| 13 | Pied Harrier | *Circus melanoleucos* | Accipitriformes | Accipitridae | LC | Schedule-I | WM |
| 14 | Shikra | *Accipiter badius* | Accipitriformes | Accipitridae | LC | Schedule-I | R |