Research Article

# Threats and conservation status of threatened birds in Chitwan Annapurna Landscape, Nepal

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## Abstract

Chitwan-Annapurna Landscape (ChAL), a biologically diverse region in Nepal, is progressively being influenced by human activities. This has impacted population and habitat of nationally and internationally threatened bird species. To identify ongoing threats for these birds, we conducted field surveys and expert opinions. Field surveys were performed using a grid-based point-count method (within a 50-meter radius), throughout 472 accessible 1 km² grids during the winter (November–February) and summer (April–July) seasons of 2020 and 2021. Species were classified using the IUCN Red List and the National Red List of Nepal, and threats were documented using the IUCN threat categorization scheme. Scope, severity and urgency were ranked qualitatively. Among the identified birds, globally, nine species were categorized as Near Threatened (NT), four as Vulnerable (VU), three as Endangered (EN), and three as Critically Endangered (CR). Pollution was the most prominent threat, followed by alterations to natural systems, residential and commercial building, and transportation infrastructure. Several threats were found to significantly affect species such as the Grey-crowned Prinia (*Prinia cinereocapilla*), Common Pochard (*Aythya ferina*), and Red-breasted Parakeet (*Psittacula alexandri*). These results highlight the significance of ChAL for bird conservation and the need of adopting immediate measures to reduce pollution, manage regional risks, and regulate habitat modification. For bird diversity to survive in this ecologically critical area over the long run, species-specific conservation techniques are advised in addition to routine monitoring and updated threat assessments. Safeguarding the ChAL from pollution, habitat degradation and human pressure is essential to conserve its threatened bird species and maintain long term ecological balance.

*Keywords*: Landscape conservation, pollution, severity, threats, urgency

## Introduction

Nepal holds 902 bird species, accounting for 8.5% of all bird species worldwide (DNPWC & BCN, 2022, DNPWC & BCN, 2025). Of these, 40 are globally threatened, near threatened (NT-31), and one is endemic (Spiny Babbler *Turdoides nipalensis*) (DNPWC & BCN, 2025). According to Nepal's National Red List Series, 172 species, or approximately 19% of the country's bird population, are classified as nationally threatened. Of these, 22% are endangered, 38% are vulnerable, and 40% are critically endangered. Additionally, according to Inskipp et al. (2017), 62 species are classified as Near Threatened nationally. National Parks and Wildlife Conservation (NPWC) Act 1973 (DNPWC, 1973) has listed nine species of birds as nationally protected and 121 bird species in the CITES category (DNPWC & BCN, 2025). Out of the total species assessed, 22 species (2.5%) are data deficient. Additionally, eight species (1%) of the total threatened list, have been listed as regionally extinct in Nepal, with no record since the 19th century (Inskipp et al., 2016).

Avian faunas are played significant roles on the natural pollinators, seed distributors, and pest controllers, and establish the overall stability and function of their ecological environment. (Mariyappan et al., 2023). They serve as bioindicators of ecosystem health and are necessary for nutrient cycling and energy transfer across trophic levels (Whelan et al., 2015). The high diversity of birds across Nepal's ecosystems reflects the overall health and functionality of different habitats from low land to high land (from lowland wetlands and grasslands to mid-hill forests and alpine meadows) (Mariyappan et al., 2023; Gaston, 2022). Besides their ecological functions, birds contribute significantly to local livelihoods and cultural values (Téllez-Hernández et al., 2023). Many communities rely on bird-related tourism such as birdwatching, which promotes conservation-based income generation (Gyawali, et al., 2017). Similarly, birds also inspire local traditions, art, and culture, and their role as natural pest controllers supports sustainable agriculture (Díaz-Siefer et al., 2022; Dinesh et al., 2022; Inskipp & Baral, 2010). Thus, the conservation of birds directly benefits both biodiversity and local communities which coexist with these ecosystems.

Despite their ecological and socio-economic importance, birds in Nepal faces increasing threats from anthropogenic pressure. Habitat loss and degradation

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represent the highest risks, affecting nearly 86% of threatened species (Inskipp et al., 2016). As many as 55% of lowland grassland specialists birds are at risk particularly vulnerable followed by wetland birds (25%) and tropical and subtropical forest birds (24%) (Inskipp et al., 2017). In many protected areas, human and livestock pressures cause frequent disturbances to wildlife including birds (Bhattarai et al., 2017). Major drivers include agricultural intensification and practice, pesticide use, infrastructure and industrial development, eutrophication of wetlands, forest encroachment, and biological invasions (Chhetri & Shakya, 2016, Johnson et al., 2020; Pyšek et al., 2017; Symes et al., 2018). Moreover, deforestation, overgrazing, and climate change alter land cover and food availability by affecting bird abundance and distribution (Lee et al., 2012; Mengesha et al., 2011). ChAL is biologically significant and diverse regions which are highly fragmented and have high anthropogenic pressure that seriously threatens both globally and nationally threatened species of birds.

Although avifauna of Nepal has been well documented, there is a lack of spatially detailed assessments of threats across major landscapes such as ChAL. Information on species-specific threats and the relative importance of different threats remains limited. It hypothesizes that pollution, habitat degradation, and infrastructure development are the major factors influencing bird populations in this region. Therefore, this study was formulated to evaluate the existing threats prevalent for globally and nationally threatened birds of ChAL.

## Materials and Methods
### Study Area
The Chitwan-Annapurna Landscape (ChAL) was conceptualized to uphold and preserve ecological connectivity throughout the diverse eco-physiographic zones of Nepal's Himalayan region, ranging from Chitwan National Park (CNP) in the southern part to the northern extents of Manaslu Conservation Area, Langtang National Park, and Annapurna Conservation Area (MoFSC, 2015). It is geographically positioned in central Nepal, encompassing latitudinal coordinates from 27°35' to 29°33' N and longitudinal coordinates from 82°88' to 85°80' E. The ChAL region includes either whole or partial territories of 19 districts of central Nepal from Terai to high Himalayas (MoFSC, 2015). The landscape of ChAL can be systematically classified according to elevation, geological composition, and climatic conditions into five distinct zones: Terai (59–200 meters above sea level), Siwaliks (200–1500 meters above sea level), mid-hills or mountains (1000–2500 meters above sea level), and high mountains. The main natural ecosystems in ChAL are the cryosphere, wetlands/rivers, forests, grasslands, and rangelands (MoFSC, 2015). The mid-hills of the ChAL are mostly populated by humans and make up a large human-made matrix of land use with a high fragmentation of forest areas (Adhikari et al., 2022) (Fig. 1).

Forest management in the ChAL is divided into four main categories: protected areas, designated protection forests, government-managed forests, and community-based forest management systems (including community forests, leasehold forests and Collaborative Forest Management account for 29% of the forests in the area) (MoFSC, 2015). The community forests located in the ChAL are essential for biodiversity conservation and mitigating climate change risks.

### Flora and fauna
The Chitwan-Annapurna Landscape (ChAL) covers a high diversity of forest types distributing in different elevations and moisture levels. The core woodlands are dominated by Sal trees, often mixed with species like Saaj (*Terminalia alata*) and Tatari (*Dillenia pentagyna*). Along the banks, riverine forests along with Sisso (*Dalbergia sissoo*), Khayer (*Acacia catechu*), Simal (*Bombax ceiba*). Ascending into the hilly region is covered with trees like Chilaune (*Schima wallichii*) and Katus (*Castanopsis indica*). The high mountain areas are home to major forest types, including Lower Temperate Oak, Chir Pine, and Rhododendron-Quercus forests, while the moist river areas are dominated by Alder Forest (http://efloras.org).

The ChAL is an important biodiversity hotspot and is the home of large mammals like the tiger, leopard, sloth bear, and the Greater One-Horned Rhino. Beyond the large fauna, the landscape is also important for avian life, supporting numerous endangered birds, including four species of critically endangered vultures (Indian, Red-headed, Slender-billed, and White-rumped) (Adhikari et al., 2022).

### Methods
Prior to data collection, a general study was done in October 2019 to collect baseline data on the habitat types, topographic features, general threats to birds and bird species. It also aids in determining possible problems, improving data collecting, and ensuring the validity and reliability of the study.

### Data Collection
The entire ChAL we applied the grid-based point count technique during bird survey (Bastola et al., 2025). In heterogenous landscapes like CHAL characterized by uneven terrain, patchy vegetation, and fragmented habitats, point count method offer reliability than transect methods (Buckland et al., 2001). We used the point count method to ensure a systematic and accurate sampling approach. This technique is an effective method in human-dominated areas, to identify the diverse microhabitats, maximize the detection of various bird species, and achieve higher identification accuracy (Ralph et al., 1995). At first, the study area was divided into 9440 grids (1 × 1 km²) and, 514 survey grids were determined by the help of a sample size calculator (https://www.calculator.net/sample-size-calculator.html) at a 98% confidence level, and a 5% margin of error. Among them, 42 grids were eliminated due to inaccessibility, with the remaining 472 grids selected for the survey (Bastola et al., 2025).

At each point, a 1-5 minute period was allocated for adjustment within the site and duration of 20 minutes for counting birds, recording habitats, and other environmental parameters (Bastola et al., 2025). The observation/survey was done at early morning (7:00–10:00 AM) and late afternoon (3:00–6:00 PM) timeframe, when birds are mostly active in foraging (Bastola et al., 2025). Each survey points were surveyed by two observers, placed in the opposite direction to reduce the detection bias and minimize the chance of missing bird species. Birds were observed by using binoculars (Olympus, 20 × 50 magnification) and photographed by a Nikon camera (80× zoom) for identification (Bastola et al., 2025). To avoid the duplicate counts, the survey points were spaced at least 1 km apart and the standard data sheet was used to record the species, number of individuals, time period, weather and habitat conditions (Bastola et al., 2025). GPS coordinates were recorded at each survey point and bird calls were recorded using a recording device to support identification (Bastola et al., 2025). The identification of the bird was supported by the field guide (Grimmett et al., 2016), confirmation by bird experts displaying the photographs (Bastola et al., 2025), and the Merlin Bird ID application.
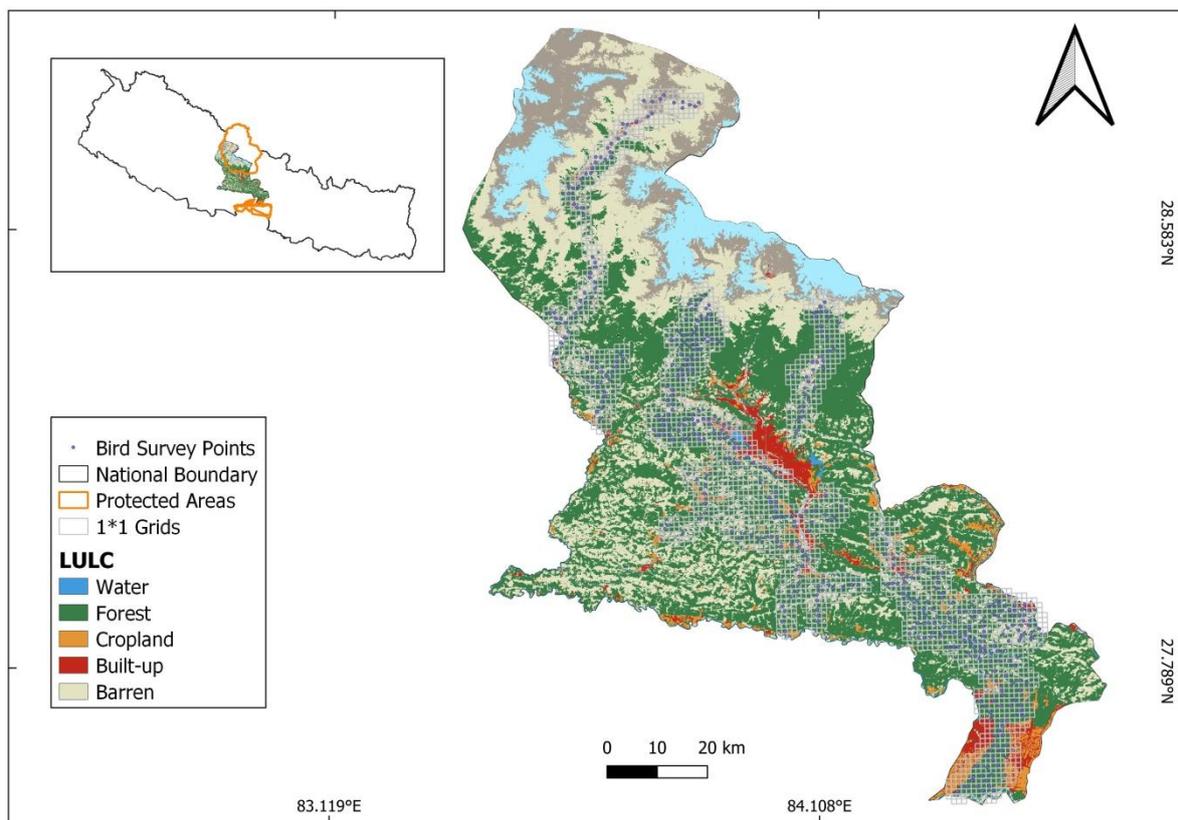


**Figure 1.** A GIS-based land use and land cover (LULC) map of ChAL showing bird survey locations

### Data Analysis

Bird species recorded during the study were categorized according to their conservation status using the IUCN Red List and the National Red List of Nepal. A descriptive analysis was used to summarize the number of species in each threat category. The results were visualized using bar graphs to illustrate the distribution of species across conservation status categories. To assess the threats to birds within the Chitwan–Annapurna Landscape, the IUCN Red List classification scheme for threats was adopted, which categorizes threats into 11 major classes (Salafsky et al., 2008).

During field surveys, we systematically observed and recorded the presence/absence of classified potential threats in the point count site of the study area. Each threat encountered was identified and classified into its respective categories according to the IUCN classification scheme. The observed threats were then qualitatively scaled based on their scope, severity, and urgency from 1- 4, as perceived during the field visits following Margoluis and Salafsky (1998) and adopted by Neupane et al. (2020). This scaling was informed by direct observations, incidental encounters, and contextual information gathered from bird experts, nature guides, and local stakeholders during informal discussions. The scaled threat data were compiled and analyzed to identify the most prominent threat across the landscape. The data was arranged in MS-Excel and threat

assessment was conducted in R studio and visualized using ggplot2 package (Wickham, 2016).

## Results and Discussion

The conservation status according to IUCN Red data assessment revealed that nine bird species in the study area were categorized as Near Threatened (NT), followed by Vulnerable (VU) species (n = 4). Only three species were classified as Endangered (EN), while three species fell into the Critically Endangered (CR) category

(Fig. 2). This pattern reflects a global and national trend where a considerable fraction of avifauna faces increasing extinction risk due to different anthropogenic pressures. Although most species are not yet critically endangered, the presence of multiple species in the NT and higher-risk categories signals that local habitats are under growing ecological stress (Adhikari et al., 2019; Bastola et al., 2025).
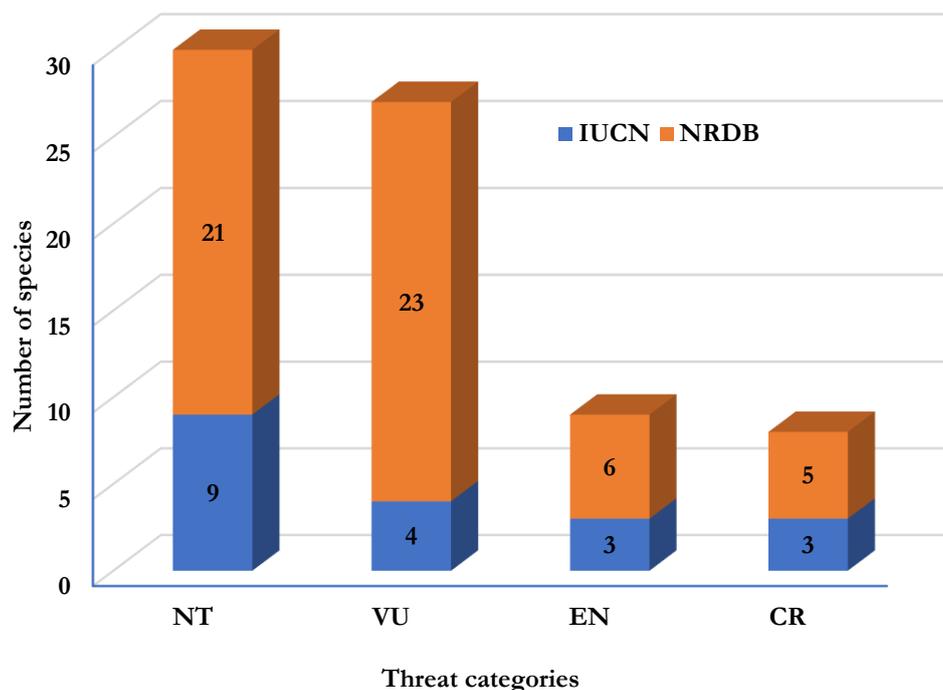


**Figure 2.** Distribution of recorded bird species conservation status across International Union for Conservation of Nature and National Red List Categories (CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened) in the study area.

Based on the National Red List of Birds of Nepal, the majority of recorded species in the study area were categorized as Vulnerable (VU) (n = 23) and Near Threatened (NT) (n = 21). A smaller proportion of species were listed as Endangered (EN) (n = 6) and Critically Endangered (CR) (n = 5). This distribution highlights that a large fraction of the avifauna is already under significant conservation concern nationally, with several species facing high to very high risk of extinction (Fig. 2). The presence of several NT and VU species suggests that preventive conservation measures including habitat conservation and management, ecological restoration, and regular monitoring could prevent further status decline. As emphasized by DNPWC and BCN (2022) and BirdLife International (2023), early intervention for such species is essential to prevent them from reaching higher threat categories.

The primary conservation issues that the region's avifauna faces on a national and worldwide scale are

highlighted by the conservation status assessment of bird species in the Chitwan–Annapurna Landscape (ChAL). Three species are categorized as Critically Endangered (CR), and three are listed as Endangered (EN), indicating that most species currently known are of lower conservation priority than the most critical categories, according to the IUCN Red List. However, the very high percentage of species that are categorized as Near Threatened and Vulnerable is concerning because these categories highlight species that could become extinct if current risks continue or intensify (Butchart et al. 2004, 2007). The situation is more severe at the national level, as demonstrated by the National Red List of Birds of Nepal, which ranks the majority of documented species as Vulnerable or Near Threatened. As has been noted in other biodiversity hotspots, this disparity between national and global evaluations raises the possibility that some species are more susceptible to local or regional stresses than are represented internationally (Inskipp et al., 2016). ChAL is a major conservation priority area, as

seen by the high percentage of species in vulnerable categories nationwide. The existence of species in the CR and EN categories indicates that immediate and focused conservation actions are needed.

Out of the identified threats, pollution was ranked to be the most prominent threat category in the landscape followed by natural system category, residential and commercial development, transportation and service corridors, and agriculture and aquaculture. On the contrary, biological resources use, invasive and problematic species, genes and diseases, and geological events were least prominent threat categories for analyzed bird species in ChAL (Fig. 3). Threat analysis revealed that pollution was the main factor contributing to the decline of the avifaunal species in the area. This data is in line with mounting evidence that pollution, specifically, runoff from agrochemicals, solid waste buildup, and water contamination has become a persistent and widespread danger to South Asian bird (Sugumaran et al., 2024). Significant pressures are being exerted by rapid land-use change, habitat degradation, and infrastructure growth, as evidenced by the ranking of residential and commercial development and natural system modification as the next most serious risks. In regions like ChAL, where ecological connectedness is deteriorating, these concerns are especially noticeable (Thapa et al., 2015).

Of the analyzed birds, Common Pochard, Grey-crowned Prinia, and Red-breasted Parakeet were the most impacted species by the identified threat categories. Asian wollyneck, and Lesser adjutant were other species that were impacted by the categories but to a lesser extent. River lapwing and Oriental darter were found to be relatively safe from the identified threats within the landscape (Fig. 3).

Some species are surprisingly vulnerable to multiple stressors, according to species-specific threat mapping. These species include the Red-breasted Parakeet (*Psittacula alexandri*), Common Pochard (*Aythya ferina*), and Grey-crowned Prinia (*Prinia cinereocapilla*). These species are prime candidates for focused conservation efforts since they are probably affected by a mix of habitat loss, pollution, and direct human disturbance. However, species like the Oriental Darter (*Anhinga melanogaster*) and River Lapwing (*Vanellus duvaucelii*) were shown to be comparatively less affected, either because they live in locations that are less exposed to human pressures or because they have a higher tolerance for their habitat. However, this relative safety shouldn't be taken as a guarantee against future changes, since emerging dangers like climate change could rapidly alter this dynamic (Both et al., 2006; Møller et al., 2008).
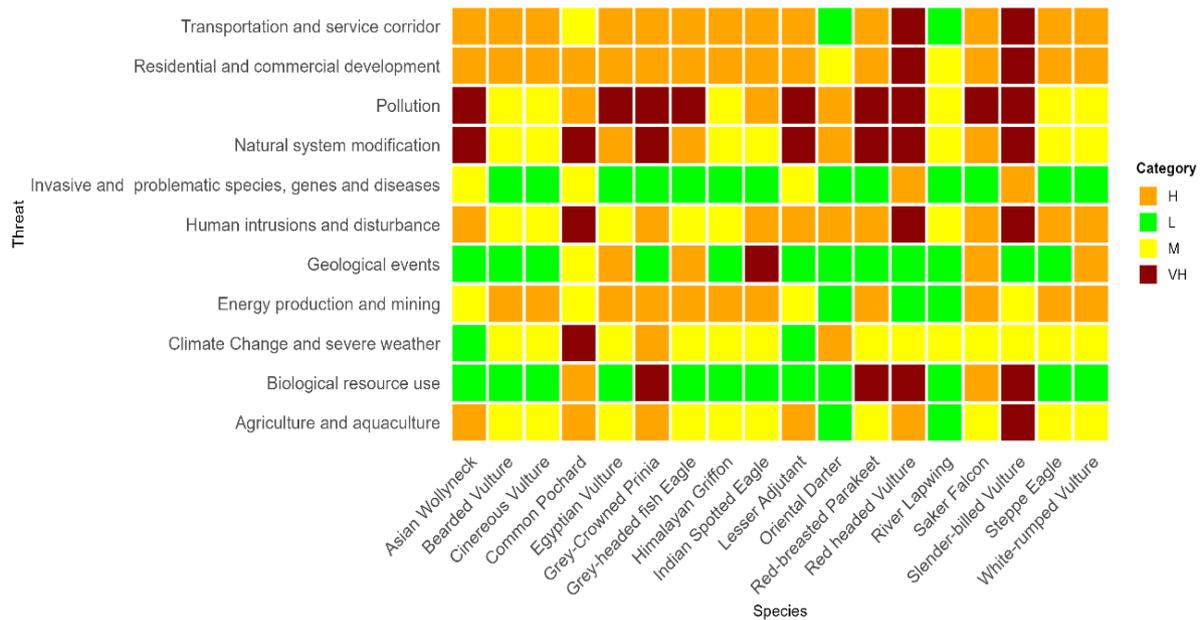


**Figure 3.** Classification of threats to the observed globally threatened birds in Chitwan-Annapurna Landscape.

Threat analysis and conservation status assessments' findings underscore the necessity of a variety of conservation approaches in the ChAL. The most endangered taxa should have species-specific action plans in place, along with measures like pollution control, habitat restoration, and sustainable land-use planning. It is also essential to regularly monitor and update national and international threat assessments to identify changing risk trends and make sure that

conservation objectives continue to be in line with new threats.

## Conclusions
In accordance with the Chitwan-Annapurna Landscape's conservation status assessment, a substantial portion of the avifauna is seriously threatened on a national and international scale. National evaluations show a significantly higher number of species in threatened

categories, reflecting more localized pressures, even if three species are listed as Critically Endangered or Endangered internationally. Several species, including Common Pochard, Grey-crowned Prinia, and Red-breasted Parakeet, are extremely vulnerable to various stressors, with pollution emerging as the most significant danger, followed by habitat change, development, and infrastructure growth. According to these findings, certain conservation measures are necessary to protect the region's avian variety, namely pollution prevention, habitat restoration, and sustainable land-use planning. It is essential to implement species-specific solutions, conduct continuous monitoring, and update assessments to prevent further decreases and ensure the long-term survival of threatened and near-threatened species in the landscape.

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**Data Availability Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

## References

Adhikari, J.N., Bhattarai, B.P., Rokaya, M.B., & Thapa, T.B. (2022). Land use / land cover changes in the central part of the Chitwan Annapurna Landscape, Nepal. *Peer J*, e13435. https://doi.org/10.7717/peerj.13435.

Adhikari, J.N., Bhattarai, B.P., & Thapa, T.B. (2019). Factors affecting diversity and distribution of threatened birds in Chitwan National Park, Nepal. *Journal of Threatened Taxa,* 11(5), 13511–13522. https://doi.org/10.11609/jott.4137.11.5.13511-13522.

Adhikari, S., Sharma, H.P., Gautam, R., & Basaula, R. (2020). Effects of weather on breeding success of ashy prinia (*Prinia socialis*) in Manigram of Tilottama Municipality, Nepal. *Nepal Journal of Environmental Sciences*, 8, 11–16. https://doi.org/10.3126/njes.v8i1.35404.

Areaya, H., Yonas, M., & Haileselasie, T.H. (2013). Community composition and abundance of residential birds in selected church forests, Tigray Region, Northern Ethiopia. *Scientific Research and Essays*, 8(22), 1038–1047. https://doi.org/10.5897/SRE2013.5367.

Basaula, R., Sharma, H.P., Belant, J.L., & Sapkota, K. (2021). Invasive water hyacinth limits globally threatened waterbird abundance and diversity at Lake Cluster of Pokhara Valley, Nepal. *Sustainability*, 13(24), 13700. https://doi.org/10.3390/su132413700.

Bastola, S.C., Kandel, P., Mahato, H.R., Adhikari, J.N., & Bhattarai, B.P. (2025). Diversity, abundance and community composition of birds in Chitwan Annapurna Landscape, Central Nepal. *Ecology and Evolution*, 15(7). https://doi.org/10.1002/ece3.71781.

BirdLife International. (2023). *The IUCN Red List of Threatened Birds*. BirdLife International, Cambridge, UK.

Both, C., Bouwhuis, S., Lessells, C.M., & Visser, M.E. (2006). Climate change and population declines in a long-distance migratory bird. *Nature*, 441(7089), 81–83.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., & Thomas, L. (2001). Introduction to distance sampling: Estimating abundance of biological populations. *Oxford University Press*. https://doi.org/10.1093/OSO/9780198506492.001.0001.

Butchart, S.H., Stattersfield, A.J., Bennun, L.A., Shutes, S.M., Akçakaya, H.R., Baillie, J.E., Stuart, S.N., & Hilton-Taylor, C., Mace, G.M. (2004). Measuring global trends in the status of biodiversity: Red list indices for birds. *PLoS Biology*, 2(12), e383. https://doi.org/10.1371/journal.pbio.0020383.

Butchart, S.H., Stattersfield, A.J., & Brooks, T.M. (2006). Going or gone: Defining "possibly extinct" species to give a truer picture of recent extinctions. *Bulletin of the British Ornithologists' Club*, 126, 7–24.

Chhetri, M.B.P., & Shakya, A. (2016). *Environmental degradation in Nepal*. Ministry of Physical Planning and Works, Government of Nepal.

Dhakal, H., Sharma, H.P., McClure, C.J., Virani, M., Rolek, B.W., Pradhan, N.M., & Bhusal, K.P. (2022). Vulture distribution and people perception of vultures in Pokhara Valley, Nepal. *Ecology and Evolution*, 12(1), e8528. https://doi.org/10.1002/ece3.8528.

Díaz-Siefer, P., Olmos-Moya, N., Fontúrbel, F.E., Lavandero, B., Pozo, R.A., & Celis-Diez, J.L. (2022). Bird-mediated effects of pest control services on crop productivity: a global synthesis. *Journal of Pest Science*, 95(2), 567–576. https://doi.org/10.1007/s10340-021-01438-4.

Dinesh, G.K., Priyanka, B., Anokhe, A., Ramesh, P.T., Venkitachalam, R., Sri, K.K., ... & Soni, R. (2022). Ecosystem services and ecological role of birds in insect and pest control. *Plant Protection: From Chemicals to Biologicals. First Edit. De Gruyter, Berlin, Boston, Germany*, 463-504.

DNPWC. (1973). *National Parks and Wildlife Conservation Act, 1973*. Department of National Parks and Wildlife Conservation, Ministry of Forestry and Soil Conservation, Kathmandu, Nepal.

DNPWC & BCN. (2022). *Birds of Nepal: An official checklist*. Department of National Parks and Wildlife

Conservation and Bird Conservation Nepal, Kathmandu, Nepal.

DNPWC & BCN. (2025). *Birds of Nepal: An official checklist.* Department of National Park and Wildlife Conservation and Bird Conservation Nepal, Kathmandu, Nepal.

Gaston, K.J. (2022). Birds and ecosystem services. *Current Biology*, 32(20), R1163-R1166.

Grimmett, R., Inskipp, C., Inskipp, T., & Baral, H.S. (2016). *Birds of Nepal: Helm field guide.* Bloomsbury Publishing India Pvt. Ltd., New Delhi, India.

Gyawali, K., Karki, B., & Ghimire, M. (2017). To study the avian diversity and possibilities of bird watching tourism in Annapurna Sanctuary trekking route. Pokhara Bird Society.

Inskipp, C., & Baral, H.S. (2010). Potential impacts of agriculture on Nepal birds. *Our Nature*, 8(1), 270–312. https://doi.org/10.3126/on.v8i1.4339.

Inskipp, C., Baral, H.S., Inskipp, T., Khatiwada, A.P., Khatiwada, M.P., Poudyal, L.P., & Amin, R. (2017). Nepal's National Red List of Birds. *Journal of Threatened Taxa, 9*(1), 9700–9722. https://doi.org/10.11609/jott.2855.9.1.9700-9722.

Inskipp, C., Baral, H.S., Phuyal, S., Bhatt, T.R., Khatiwada, M., Inskipp, T., ... & Amin, R. (2016). *The status of Nepal's birds: The national red list series.* Zoological Society of London, UK, 628 pp.

Lee, J.H., Park, D., & Sung, H.C. (2012). Large-scale habitat association modeling of the endangered Korean rat snake (*Elaphe schrenckii*). *Zoological Sciences*, 29(5), 281–285. https://doi.org/10.2108/zsj.29.281.

Margoluis, R., & Salafsky, N. (1998). *Measures of success: Designing, managing and monitoring conservation and development projects.* Island Press, Washington, DC.

Mariyappan, M., Rajendran, M., Velu, S., Johnson, A.D., Dinesh, G.K., Solaimuthu, K., ... & Sankar, M. (2023). Ecological role and ecosystem services of birds: A review. *International Journal of Environment and Climate Change, 13*(6), 76-87. https://doi.org/10.9734/IJECC/2023/v13i61800.

Mengesha, G., Bekele, A., & Carl, S. (2011). Abundance and distribution of bird species in the Nech Sar National Park, Ethiopia. *African Journal of Ecology*, 49(3), 292–300. https://doi.org/10.1111/j.1365-2028.2011.01266.x.

MoEFC. (2016). *Conservation Landscapes of Nepal.* Ministry of Forests and Soil Conservation, Singha Durbar, Kathmandu, Nepal.

Møller, A.P., Rubolini, D., & Lehikoinen, E. (2008). Populations of migratory bird species that did not show a phenological response to climate change are declining. *Proceedings of the National Academy of Sciences*, 105(42), 16195–16200.

Neupane, B., Singh, B.K., Poudel, P., Panthi, S., & Khatri, N.D. (2020). Habitat occupancy and threat assessment of gharial (*Gavialis gangeticus*) in the Rapti River, Nepal. *Global Ecology and Conservation*, 24, e01270.

Pyšek, P., Blackburn, T.M., García-Berthou, E., Perglová, I., & Rabitsch, W. (2017). Displacement and local extinction of native and endemic species: Impact of biological invasions on ecosystem services. In Vilà, M., & Hulme, P.E. (Eds.), *Impact of biological invasions on ecosystem services* (pp. 157–175). Springer. https://doi.org/10.1007/978-3-319-45121-3_10.

Ralph, C.J., Sauer, J.R., & Droege, S. (1995). *Monitoring bird populations by point counts.* Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture.

Salafsky, N., Salzer, D., Stattersfield, A.J., Hilton-Taylor, C., Neugarten, R., Butchart, S.H. M., Collen, B., Cox, N., Master, L.L., O'Connor, S., & Wilkie, D. (2008). A standard lexicon for biodiversity conservation: Unified classifications of threats and actions. *Conservation Biology*, 22(4), 897–911. https://doi.org/10.1111/j.1523-1739.2008.00937.x.

Sugumaran, M.P., Goveanthan, A.S., Natarajan, K., Kalaichelvi, K., Jayakumar, J., Gayathry, G., ... & Sinduja, M. (2024). Impacts of various insecticide forms on avian health and mortality: A comprehensive review. *Journal of Experimental Agriculture International*, 46(10), 524–537.

Symes, W.S., Edwards, D.P., Miettinen, J., Rheindt, F.E., & Carrasco, L.R. (2018). The combined impacts of deforestation and wildlife trade on tropical biodiversity are severely underestimated. *Nature Communications*, 9(1), 1–9. https://doi.org/10.1038/s41467-018-06579-2.

Téllez-Hernández, E., Domínguez-Vega, H., Zuria, I., Marín-Togo, M.C., & Gómez-Ortiz, Y. (2023). Functional and ecological diversity of urban birds: Conservation and redesign of biocultural landscapes. *Journal for Nature Conservation*, *73*, 126395. https://doi.org/10.1016/j.jnc.2023.126395.

Thapa, G.J., Wikramanayake, E., & Forrest, J. (2015). *Climate-change impacts on the biodiversity of the Terai Arc Landscape and the Chitwan-Annapurna Landscape.* WWF Nepal, Hariyo Ban Program, Kathmandu, Nepal.

Whelan, C.J., Wenny, D.G., & Marquis, R.J. (2008). Ecosystem services provided by birds. *Annals of the New York Academy of Sciences*, 1134(1), 25–60. https://doi.org/10.1196/annals.1439.003.

Wickham, H. (2016). Getting started with ggplot2. In *ggplot2: Elegant graphics for data analysis* (pp. 11–31). Springer International Publishing.

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