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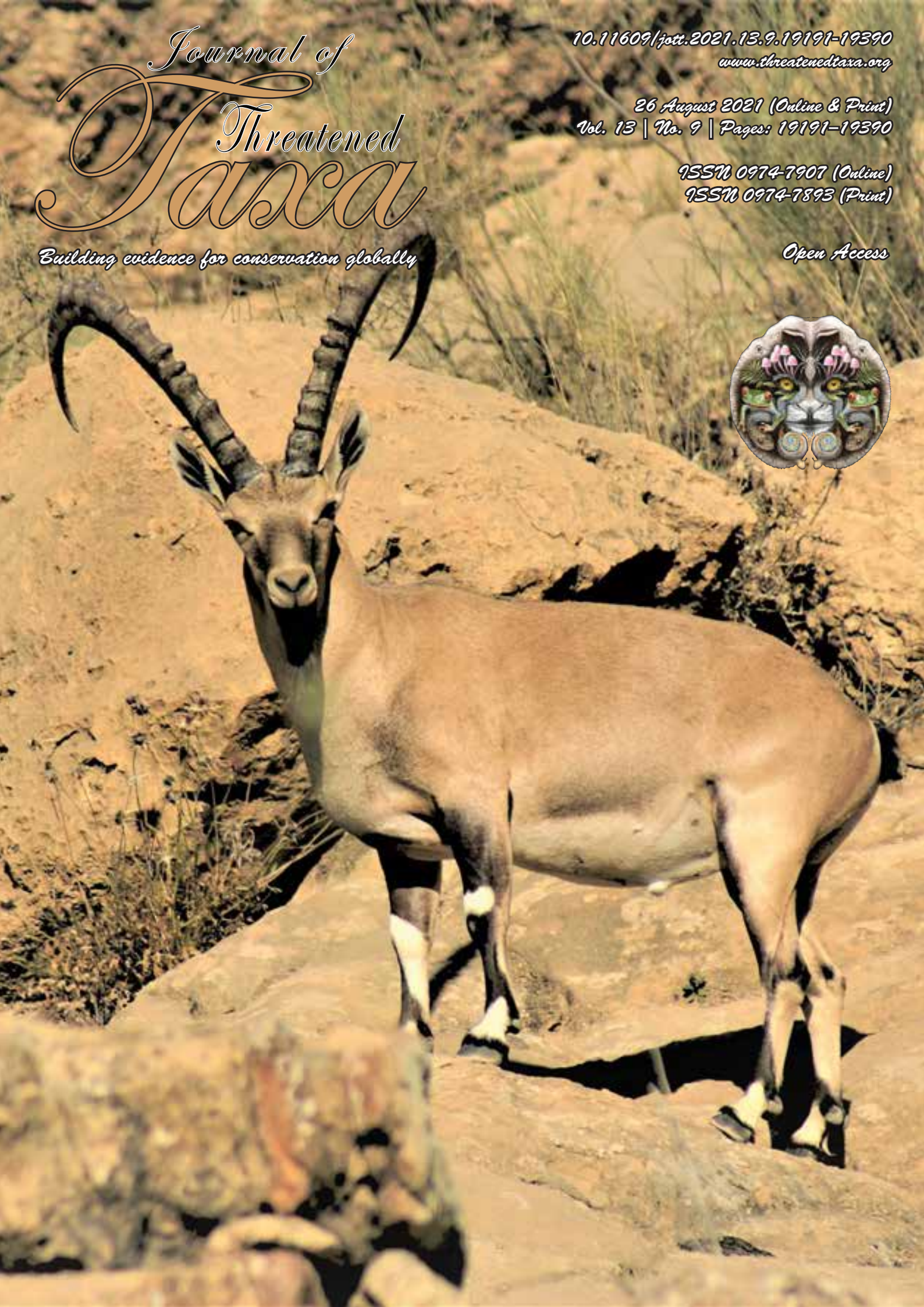

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**Caption: Nubian Ibex *Capra nubiana* at Dana Biosphere Reserve. © Ehab Eid.**

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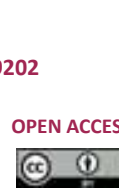

**ARTICLE**

# On the impact of earthquake-induced landslides on Red Panda *Ailurus fulgens* (Mammalia: Carnivora: Ailuridae) habitat in Langtang National Park, Nepal

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**Abstract:** In addition to the threats of human encroachment, infrastructure development, tourism activities, habitat fragmentation, and human-wildlife interactions, natural disasters also pose a threat to the habitat of endangered species such as the Red Panda. This study aims to assess the impact of the 2015 Gorkha earthquake-induced landslides on the Red Panda's habitat in Langtang National Park (LNP), central Nepal Himalaya. Remote sensing and geographical information system were applied to estimate the potential and core habitats of the Red Panda, and collect information on earthquake-induced landslides. Field sampling and verification of remotely collected data were done within a year of the earthquake. Considering preferred vegetation types, elevation range, aspects, distance from water sources, and Red Panda presence points, an area of 214.34 km$^2$ was estimated as the potential habitat of Red Panda in the Park. Thirty-nine landslides were identified in LNP triggered by the Gorkha earthquake, 14 of which occurred in the core Red Panda habitat. As a result of the earthquake-induced landslides, a significant decrease in tree density was observed in the areas affected by the landslides. Similarly, the bamboo cover was observed to be significantly lower in the areas affected by landslides compared to the unaffected adjacent areas. The average size of the landslide, causing damage to the Red Panda habitat was 0.8 ha. The potential habitat damaged by the earthquake-induced landslide was estimated to be 11.20 ha which is equivalent to the habitat required by one Red Panda. The findings could be useful in initiating restoration of the damaged Red Panda habitat in LNP.

**Keywords:** Disaster, endangered species, geographical information system, habitat loss, habre, natural hazards, threat, wildlife.

**Nepali:** वन्यजन्तुहरुको वासस्थान अतिक्रमण, पूर्वाधार विकास, पर्यटनका गतिविधिहरु, वासस्थान विखन्डन, र मानव वन्यजन्तु द्वन्दका अतिरिक्त, प्राकृतिक प्रकोपले पनि अस्तित्वको खतराको सूचीमा रहेका रेड पाण्डा (हाब्रे) जस्ता प्रजातिहरुको वासस्थानमा जोखिम पैदा गर्दछ । यो अध्ययनको मुख्य उदेश्य गोरखा भूकम्पबाट सृजित भूस्खलनहरुले नेपालको लाङटाङ राष्ट्रिय निकुञ्ज भित्र रेड पाण्डाको वासस्थानमा पारेको प्रभावको पहिचान तथा आँकलन गर्नु हो । यसका लागि रिमोट सेन्सीन्ङ र भौगोलिक सूचना प्रणाली, स्थलगत अध्ययन तथा अवलोकन, नमुना भूस्खलन (पहिरो) हरुको विस्तृत तथ्याङ्क संकलन जस्ता विधीहरु अपनाईएको थियो । यस अध्ययन अनुसार लाङटाङ राष्ट्रिय निकुञ्जमा रेड पाण्डाको सम्भावित वासस्थान २१४.३४ वर्ग कि.मि. क्षेत्रफलमा फैलिएको छ । निकुञ्ज भित्र पहिचान गरिएका ३९ पहिरो मध्ये १४ वटा पहिरो रेड पाण्डाको वासस्थानमा परेको देखिन्छ । भूस्खलन तथा पहिरोबाट रेड पाण्डाको लागि उपयुक्त भूगोल, खाद्य वनस्पति, वासस्थानका लागि रेड पाण्डाले रुचाउने रुख प्रजातिहरु र पानीको स्रोतमा प्रभाव परेको देखिन्छ । भूकम्पबाट सृजित भूस्खलनले लाङटाङ राष्ट्रिय निकुञ्ज भित्र करिब ११.२० हेक्टर रेड पाण्डाको सम्भावित वासस्थानलाई क्षति पुर्याएको अनुमान गरिएको छ । यस अध्ययनले भूकम्प जस्ता प्राकृतिक प्रकोपबाट मानवजाति मात्र हैन, वन्यजन्तु तथा तिनका वासस्थान समेत उत्तिकै जोखिममा रहने देखाउँछ ।

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## INTRODUCTION

Natural disasters such as earthquakes can severely affect the earth's biodiversity. Some disasters may severely threaten plant and animal species due to the destruction of resources than the other ones (Lai et al. 2007; Ding & Miao 2015). The Gorkha earthquake (Mw 7.8), that hit Nepal on 25 April 2015, had triggered 4,312 co-seismic and post-seismic landslides (Kargel et al. 2016). The Gorkha earthquake had severely impacted forests and biodiversity, mainly by the earthquake-induced landslides (MOSTE 2015). Furthermore, the debris avalanche and the air blasts that were triggered by the earthquake flattened the forests up to 1 km (Collins & Jibson 2015). A loss of around USD 303 million was estimated in the environment and forestry sector due to the Gorkha earthquake (NPC 2015a,b).

Habitat loss due to fragmentation and degradation affects over 2,000 mammal species, which is considered as the greatest threat to biodiversity globally (Wang et al. 2014). Some 13,800 km$^2$ of suitable habitats are available for Red Pandas in Nepal (Panthi et al. 2019), which is significantly lower than the previous estimates by Kandel et al. (2015) and Thapa et al. (2018), who had estimated 17,400 km$^2$ and 20,150 km$^2$ of suitable habitat for Red Pandas, respectively. According to Yonzon et al. (1991) and Yonzon & Hunter (1991a) an area ranging 68–108 km$^2$ habitat within the Langtang National Park is suitable for Red Pandas; they are sensitive to even the slightest alteration in land use patterns; and 24–68 individuals were estimated in LNP residing in three to four population patches.

Increasing human population and interference to nature such as road construction and tourism activities are causing habitat destruction of Red Panda (Dorji et al. 2012). Furthermore, habitat fragmentation (Mahato & Karki 2005; Preece 2010; Wei & Zhang 2010), habitat loss (Wei et al. 1999a; Preece 2010), poaching (Choudhury 2001; Zhang et al. 2008; Sharma & Belant 2009; Zhou et al. 2013) and livestock grazing (Yonzon & Hunter 1991b; Mahato & Karki 2005; Sharma & Belant 2009; Dorji et al. 2012; Zhou et al. 2013) are also threatening Red Pandas seriously. Large-scale habitat loss and fragmentation are hampering gene flow among the Red Panda population (Hu et al. 2011). On the other hand, the majority of the subpopulations currently existing are of a smaller size, increasing the probability of their extinction, even in the absence of threats from humans (Jnawali et al. 2010). Studies have shown that Red Panda being bamboo specialists, more than 80% of their diets consist of bamboo grass and is a major habitat component (Reid et al. 1991; Wei et al. 1999b; Panthi et al. 2015; Bista et al. 2019). The survival of Red Pandas is also being threatened by deforestation and degradation caused by the collection of forest products (Mahato & Karki 2005; Bearer et al. 2007; Dorji et al. 2012; Zhou et al. 2013), killing by the locals (Mahato & Karki 2005), cattle herders, and domestic dogs (Yonzon & Hunter 1991a; Dorji et al. 2012).

In addition to the human-induced threat, natural disasters also pose significant threats to the survival of Red Panda (Deng et al. 2010; Zhang et al. 2011, 2012; Meng et al. 2016; Wang et al. 2018). Gorkha earthquake-induced landslides in the LNP have affected the habitat of the Red Panda. However, a systematic and scientific study on the extent of the impact has been lacking. Ecological considerations are crucial in disaster preparedness and post-disaster management (Chang et al. 2006). An earthquake-induced landslide would be one of the indicators to estimate impacts of the earthquake on important ecological parameters like habitat area, tree density and food preferred by Red Panda. This study aims to assess the impact of the Gorkha earthquake-induced landslide on the habitat of Red Panda in the LNP. Specifically, this study explores the effect of earthquake-induced landslides on vegetation preferred by Red Pandas as shelter and food (mainly bamboo) and estimate the loss of habitat.

## MATERIALS AND METHODS

### Study area

This study was carried out in the LNP (between 28.3856–27.9628 latitude and 85.2154–85.8849 longitude, IUCN category II, National Park). Established in 1976, LNP is one of the prime habitats of Red Panda in Nepal. It has an area of 1,710km$^2$ and extends over Nuwakot, Rasuwa, and Sindhupalchok districts of Nepal and is linked with the Qomolangma National Nature Preserve in Tibet to the North (DNPWC 2017) (Figure 1). Main Central Thrust (MCT) is one of the most tectonically significant structures in the Himalayan orogeny that extend across the LNP in the middle (Reddy et al. 1993). Another major Himalayan fault called Main Boundary Thrust (MBT) extends further south of the Langtang making the region seismically more vulnerable (Macfarlane et al. 1992). The region lies about 74.3 km away from the epicentre of the Gorkha earthquake. Multhala area, one of the core habitats of Red Panda in the park was considered for field sampling and survey. The sampled habitat has an area of 4.26 km$^2$. The field

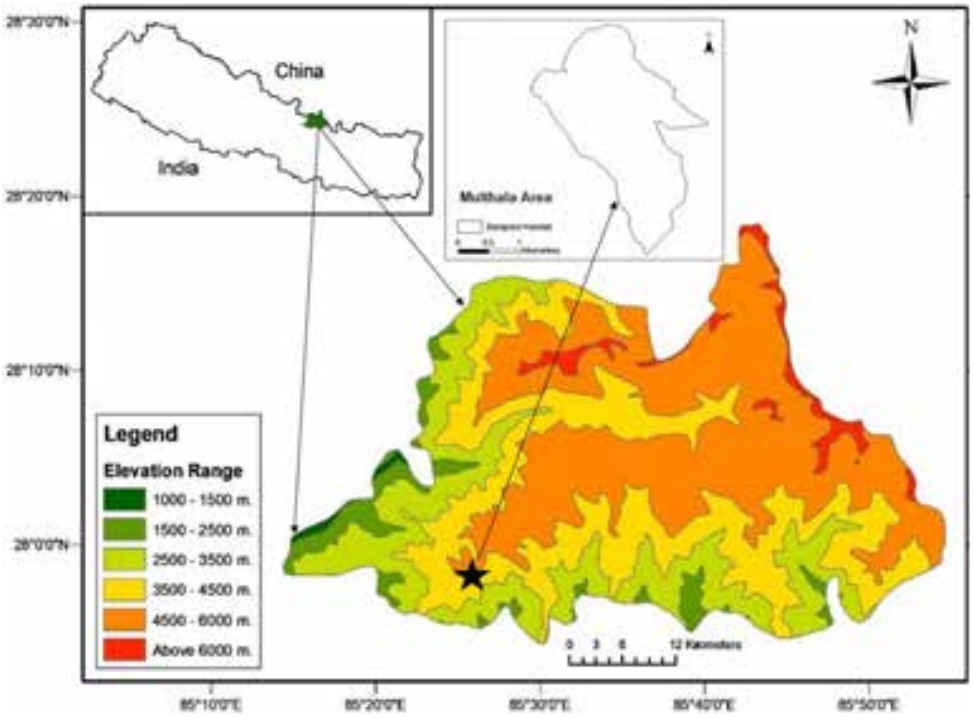


**Figure 1. Location of Langtang National Park.**

survey was conducted within one year of the Gorkha earthquake (22–29 March 2016).

## Data and methods

Primary data were collected from the field sampling, whereas other necessary data were collected from several secondary sources and open-access database (Table 1). Data on (i) Red Panda presence point (Kandel et al. 2015), (ii) rapid damage maps (Yun et al. 2015), (iii) earthquake-induced landslides points (Kargel et al. 2016), (iv) epicentres of Gorkha earthquake and aftershocks (Adhikari et al. 2015), (v) land cover map of Nepal, 2010 (Uddin et al. 2015), (vi) administrative boundary maps, and (vii) 30m Resolution Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) (Jha 2018) were collected.

Based on the literature on the niche and core habitat of Red Panda in LNP (e.g., Yonzon & Hunter 1991a; Yonzon et al. 1991; Kandel et al. 2015), we developed a potential habitat map of Red Panda in LNP for which we selected a maximum range for each niche factors. Broadleaved open/closed forests, needle-leaved open/closed forests were extracted from the land cover map of Nepal (Uddin et al. 2015). Although, sightings from lower elevations have also been recorded (e.g., at 2,210 m in Ilam, eastern Nepal; Bista et al. 2013), we used the elevation range of 2,800–3,900 m considering the sighting ranges of Red Panda in LNP. Preferred aspects (West, north, north-east, north-west) were extracted from the aspect map prepared out of the DEM using a surface analysis tool in GIS. The buffer map of less than or equal to 200 m from the water sources and geographical location of Red Panda signs in LNP were generated and used to develop the potential habitat map using QGIS version 3.0.3. The methodological flow chart is given in Figure 2.

Earthquake-induced landslides were masked for LNP from Kargel et al. (2016) and superimposed on the potential habitat map of Red Panda. Later, the validation of the landslides was done during the field visit. Based on the occurrence of landslides over the potential habitat, Multhala—one of the core habitats with high densities of signs and evidence of Red Panda—was selected for the field survey and sampling (Image 1a,b). The area was surveyed for the earthquake impact on the Red Panda habitat. Horizontal transect walk (n= 5) of length each 1,000 m was done along the five altitudinal belts at 2,900 m, 3,100 m, 3,300 m, 3500 m, and 3,700 m. Transect survey was carried out along small forest trails as opportunistic sightings of species is the most common data collection technique for the elusive Red Panda (Pradhan et al. 2001; Jnawali et al. 2010). Earthquake damage evidence along five horizontal transects were visually observed and recorded. Droppings of Red

**Table 1. Description of data and sources.**

| Data | Source | Description |
|---|---|---|
| Red Panda presence point | Kandel et al. 2015 | Freely available Red Panda presence points were extracted and overlaid in LNP on the map. |
| Rapid damage maps | Yun et al. 2015 | Information of earthquake-induced landslides taken from this part of the literature helped to identify the areas of occurence of landslides in core habitat. |
| Earthquake-induced landslides points | Kargel et al. 2016 | Earthquake-induced landslides points were overlaid in LNP in the map which helped for accuracy and validation of rapid damage images. |
| Epicentres of Gorkha earthquake and aftershocks | Adhikari et al. 2015 | Epicentres of the Gorkha earthquake and aftershocks overlaid in the map of LNP. |
| Land cover map of Nepal, 2010 | Uddin et al. 2015 | The land cover map was overlaid in the map of LNP to select the range of preferred vegetation to map out a potential habitat range within LNP. |
| Digital Elevation Model (SRTM 30 m) | USGS 2017 | 30m Resolution Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) was extracted from United States Geological Society (https://earthexplorer.usgs.gov) |
| Landslides points and dimensions | Transect Walk | Landslides were observed along transects in the sampling area and the dimensions were measured. |
| Tree density, vegetation cover and canopy cover of bamboo | Quadrat sampling | Quadrats of 10 x 10 m were laid inside landslides and adjacent to the landslide to compare tree density, vegetation cover and canopy cover of bamboo. |

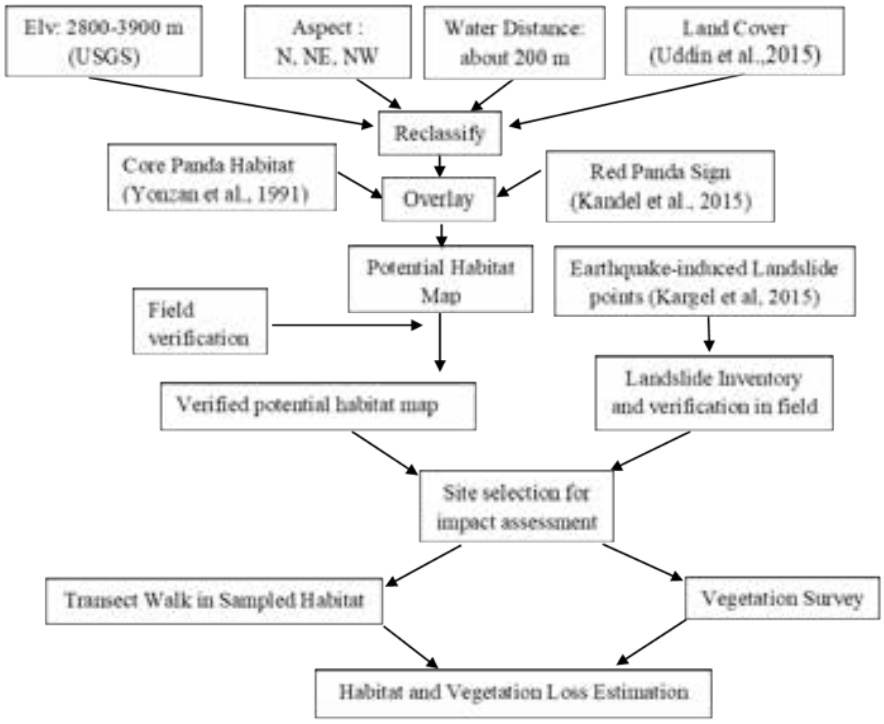


**Figure 2. The methodological framework of the study.**

Panda—the most reliable indirect evidence—was used for sign survey as the animals usually defecate at the feeding site and it is difficult to observe elusive Red Panda directly in the field (Wei et al. 1999c; Pradhan et al. 2001; Zhang et al. 2004; MoFSC 2016). Droppings of Red Panda and other mammals within 10 m of each transect were recorded. Only those damages such as landslides and habitats that occurred after the Gorkha earthquake were considered after confirming the locations with the help of the local guide and informants from the nearest settlements.

The vegetation (tree density and bamboo cover) within and adjacent to landslides were compared (Linderman et al. 2005). Shannon-Wiener index of diversity and Simpson Diversity index within each plot was also calculated. Shannon-Wiener index 'H' is commonly used to characterize species diversity in a community. It accounts for both the abundance and


**Image 1. a—earthquake-induced landslide in the habitat of Red Panda: b—droppings observed around the landslide (within 10m).**

evenness of the species present. It was calculated using the following formula (Shannon 1948).

$$H = -\sum_{i=1}^{S} \left(\frac{ni}{N}\right) ln\left(\frac{ni}{N}\right)$$

Where *S* is the number of different tree species, $n_i$ is the number of individual species, *N* is the total number of species.

Simpson Diversity index *D* is also a measure of diversity. It accounts for the number of species present, as well as the abundance of each species. It was calculated by the following formula (Simpson 1949).

$$D = \sum_{i=1}^{S} \left(\frac{n(n-1)}{N(N-1)}\right)$$

Where *S* is the number of different tree species, $n_i$ is the number of individual species, *N* is the total number of species.

The vegetation loss percentage within each landslide was also estimated. Data collected was analyzed using MS Excel 2013 and R (R Core Team 2020) to test significant differences in vegetation (i.e., tree density and bamboo cover) within and adjacent to earthquake-induced landslides. We used paired t-test to test the significant differences between the density and coverage of trees and bamboo in the sample sites within and adjacent to earthquake-induced landslides.

## RESULTS

### Potential habitat of Red Panda in LNP

This study estimated an area of 214.34 km$^2$ as the potential habitat of Red Panda in LNP. It is estimated that potential habitat including core habitat covers 12.53% of the total area of LNP. The presence points of Red Panda taken before the earthquake (red colour dots) falls within the estimated potential habitat (Figure 3). The recording of pellet groups (n= 27) and direct sightings of Red Panda (n= 3) in the potential habitat during the field visit indicate the validity of produced potential habitat map of Red Panda in LNP.

### Earthquake-induced landslides distribution

Earthquake-induced landslides in LNP were masked out from the earthquake-induced landslide distribution map produced by Kargel et al. (2015). Thirty-nine landslides were observed to occur in LNP as a result of the Gorkha earthquake (Figure 4). The earthquake-induced landslide distribution map produced shows that 14 landslides occurred only in the Multhala region (landslides detail in Table S1). These landslides were verified during the field visit. The minimum and maximum area of the landslides were measured to be 123 m$^2$ and 14,567 m$^2$, respectively. Most landslides occurred in the slopes of 45–55 on the north and north-east aspects which were distributed close to the water sources like rivers and streams. Most of the landslides (85.7%) were of dry and rockfall types.

The total area of the landslides within the potential habitat of Red Panda was estimated to be 111,975 m$^2$. This accounts for 2.6% of the sampled habitat. During the field study, it was observed that many landslides

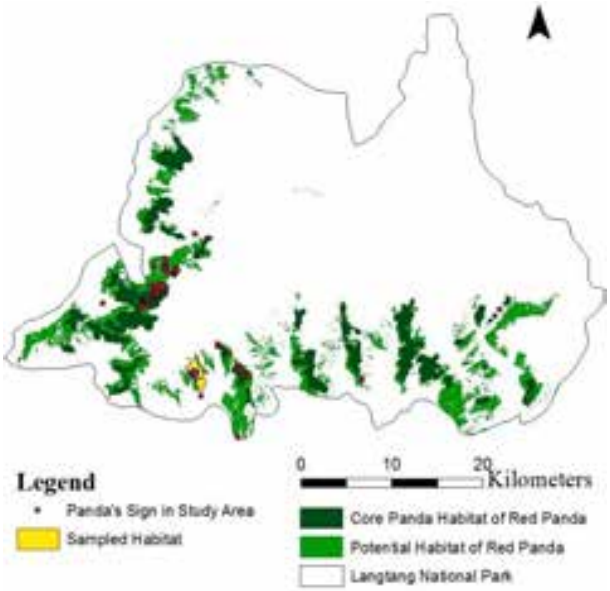


Figure 3. Potential and core habitats of Red Panda in LNP.

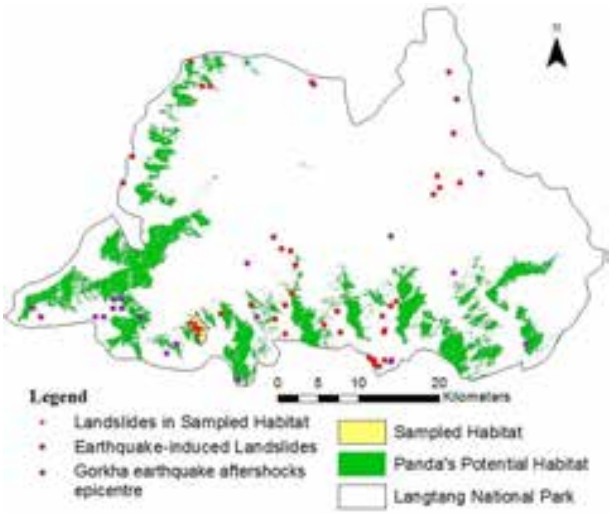


Figure 4. Earthquake-induced landslide distribution in LNP.

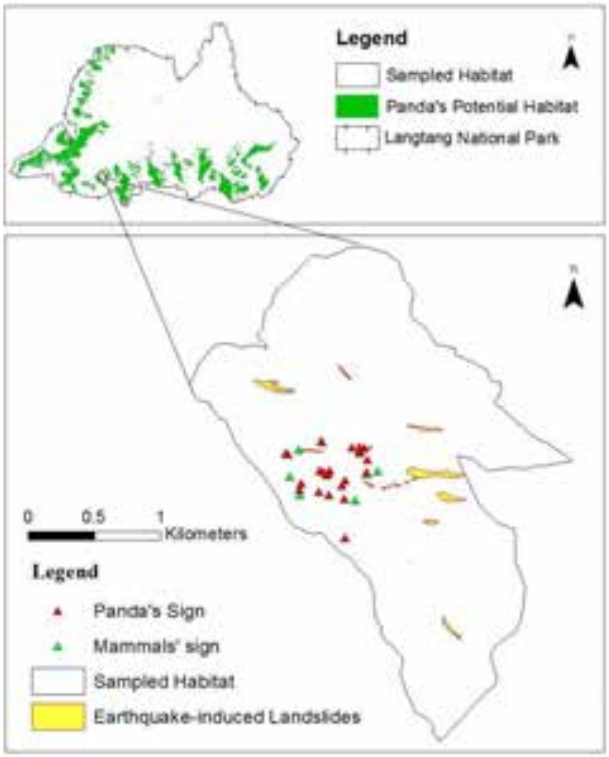


Figure 5. Landslides distribution in sampled habitat.

Table 2. Vegetation characteristics in the habitat affected by the landslide and adjacent habitat.

| Parameters | Habitat impacted by landslides | Habitat adjacent to the landslides |
|---|---|---|
| Shannon Diversity Index (H) | 0.99 | 1.017 |
| Simpson Diversity index (D) | 0.614 | 0.621 |
| Bamboo cover (%) | 0.147 | 0.521 |
| Tree density (no./m$^2$) | 2.714 | 2.828 |
| *Pinus wallichiana* (no./m$^2$) | 0.428 | 0.50 |
| *Rhododendron* sp. (no./m$^2$) | 0.87 | 0.90 |
| *Betula utilis* (no./m$^2$) | 1.30 | 1.414 |

were not included in the landslide distribution map produced by Kargel et al. (2015) as the work was solely based on remote sensing applications. It was also observed that some streams and springs had gone dry after the earthquake. The direct and indirect signs of Red Panda were recorded within sampled habitat (Figure 5). Indirect signs of other mammals were also observed within the sampled habitat (see Table S2).

**Impact on vegetation**

Three species (*Pinus wallichiana, Rhododendron*, and *Betula utilis*) and bamboo cover were considered for vegetation analysis (Table S3 and S4). A significant decrease in trees density (80% less) was observed in the areas affected by the landslides. Similarly, the bamboo cover was observed to be significantly lower (71% less) in the areas affected by landslides compared to the adjacent area within the sampled habitat ($p < 0.05$). The mean value of both, bamboo cover and tree density, and diversity indices (Shannon & Simson) were found to be lower in the habitat affected by earthquake-induced landslides compared to the habitat without the impact (Table 2). However, diversity indices do not differ significantly between the two habitats.

**An estimated loss of Red Panda habitat**

The presence of Red Panda in and around landslides was confirmed by fresh (n= 5) and old groups of pellets (n= 22) recorded during the transect walk (Image 2). The pallet groups were found in landslides (2 spots), within *Betula utilis* trees (9 spots), *Juniperous indica* tree/bush (4 spots), *Pinus wallichiana* tree (3 spots), Bamboo bush (3 spots), *Rhododendron* species (1 spot), on stone (3 spots), and bare land (2 spots). The average size of a landslide that caused damage to the Red Panda habitat in the sample site was calculated to be 7,998.21 $m^2$ (0.8 ha). The area of the potential habitat damaged by the earthquake-induced landslide was estimated to be 111,975 $m^2$ (11.2 ha). Based on the ecological density of Red Panda (one adult /2.9 $km^2$) (Yonzon & Hunter 1991b), the habitat loss was equivalent to the habitat of one adult Red Panda in LNP.

**Image 2. Red Panda *Ailurus fulgens* observed during the field expedition. © Saroj Shrestha, Red Panda Network**

## DISCUSSIONS

The potential distribution and quantified ecological niche of any species describe suitability and occurrence for supporting the survival of the species (Cushman & Huettmann 2010). The main factors that influence on habitat selection of Red Pandas are vegetation, source of water and human disturbance (Wei et al. 1998). Our study estimated the potential habitat to be 214.34 $km^2$ in LNP. The parameters used were: elevation range between 2,800 m and 3,900 m, distance from water sources up to 200 m, the land cover of broadleaf forest, evergreen forest, coniferous forest, shrubland, aspect of north, east, west, north-east, and north-west. The potential habitat map was in agreement with the distributions of Red Panda predicted by Kandel et al. (2015).

In the Hindu Kush Himalayan region, Thapa et al. (2018) estimated an area of 134,975 $km^2$ as potential habitat while Kandel et al. (2015) estimated potential Red Panda habitat at approximately 47,100 $km^2$ including 47.6% of potential habitat within Nepal and 27.8% within China. Compared to this, other studies have made 5.5–22.7% lesser estimates (Wei et al. 1999a,b, 2014; Choudhury 2001). Thapa et al. (2018), Kandel et al. (2015), and Mahato (2010) predicted an area of 20,150 $km^2$, 22,400 $km^2$, and 20,397 $km^2$, respectively, as the habitat of Red Panda in Nepal. A lower estimate of 8,200 $km^2$ has been made by Choudhury (2001). Two estimates have been made for LNP. Yonzon et al. (1991) considering suitable forest type, altitude, and aspect estimated an area of 68 $km^2$ as the suitable habitat, whereas Yonzon & Hunter (1991a) estimated an area of 108 $km^2$ as the suitable habitat of Red Panda. The distance from the water sources, one of the important parameters for habitat selection (Pradhan et al. 2001), was not incorporated in both studies. Furthermore, Pradhan et al. (2001) also recorded the occurrence of Red Panda in other forest types such as *Rhododendron, Betula utilis, Pinus wallichiana* forest besides *A. spectabilis* forest.

The number of earthquakes induced landslides in LNP was observed to be higher than estimated by Kargel et al. (2015). This could be due to the use of large sets of high-resolution satellite imageries for landslides mapping without intensive field visit as in the cases of other similar studies (e.g., Gorum et al. 2011). The sliding patterns were observed to be consistent in a diverse geological substrate and clustered near ridge crests, which are often the characteristics of earthquake-induced landslides (Meunier et al. 2008). The Red Panda habitat was damaged by the earthquake-induced landslides in LNP as the density of preferred vegetation varied significantly in the areas affected by the landslide. The earthquake-induced landslides also damaged the panda's preferred species for food. The tree density and bamboo cover were observed to be significantly lower in the areas affected by the landslides in comparison with the adjacent area within the sampled habitat. The preferred habitat of the Red

Panda is a forested area dominated by *Abies spectabilis, Rhododenron campanulatum, Betula utilis, Juniperus indica,* and *Arundinaria* sp., which provide ample food value and habitat for it (Pradhan et al. 2001; Sharma & Belant 2009). The spatial distribution of bamboo has a substantial effect on panda habitat (Linderman et al. 2005) as they are highly specialized to feed on bamboo (Kong et al. 2014). The loss in diversity and richness could be concerning as it may contribute to declines in forest productivity. Yet, disasters such as earthquakes may also contribute to new growth and higher forest diversity in the long term and large scale (Tilman 1996). The presence of remnant vegetation (20% on average) can be a driving factor for forest recovery. It is not only because it allows for seed dispersal, but also improves soil nutrient levels and raises soil humidity (Holl et al. 2000).

Although several studies have been conducted regarding the impact of the earthquake on wildlife habitats in other parts of the world, this is the first one in Nepal. This study estimated about 11.2 ha of the potential habitat of Red Panda in the LNP was affected by the earthquake-induced landslides that caused habitat degradation, fragmentation, and food loss. Furthermore, signs of other mammals observed in the damaged site indicate that the habitat of other wildlife were also affected by the landslides. The finding shows that the habitat required for only one panda has been affected in LNP. It is significant damage and threat to the elusive species considering its low population (24–68 individuals) in LNP and the practice of illegal hunting of this species in the area. Similarly, the fragmentation of habitat by the landslides could have severe consequences like damaging the food and associated trees favoured by Red Pandas. Mapping potential habitat for the Red Panda has broader implications in population estimates, forecasting, reintroduction, and science-based adaptive management in the LNP. Remote sensing and GIS application could be an essential tool to study the impact of the disaster on the wildlife habitat.

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**Table S1. Landslides in sampled habitat.**

| Landslide No | Lat. | Long. | Elevation (in m) | Slope | Aspect | Landslide type | Water status | Dead vegetation in landslide (in %) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 28.028 | 85.432 | 3,189 | 46–50 | N | rock fall | dry | 75 | |
| 2 | 28.028 | 85.432 | 3,236 | 45–55 | NE | rock fall | dry | 75 | old droppings |
| 3 | 28.0288 | 85.432 | 3,130 | 50–55 | NE | rock fall | dry | 75 | |
| 4 | 28.028 | 85.416 | 3,168 | 45–50 | N | rock fall | dry | 75 | |
| 5 | 28.026 | 85.417 | 3,201 | 45–55 | NE | rock fall | dry | 75 | |
| 6 | 28.028 | 85.429 | 3,343 | 45 | N | rock fall | dry | 75 | |
| 7 | 28.025 | 85.434 | 3,138 | 45–60 | NE | rock fall | dry | 90 | |
| 8 | 28.025 | 85.434 | 3,082 | 50 | NE | rock fall | dry | 90 | |
| 9 | 28.025 | 85.434 | 3,063 | 50 | SE | rock fall | dry | 90 | |
| 10 | 28.026 | 85.435 | 3,082 | 50 | SE | rock fall | dry | 75 | |
| 11 | 28.026 | 85.436 | 3,086 | 45 | NE | rock fall | dry | 95 | |
| 12 | 28.027 | 85.437 | 2,968 | 45 | NE | rock fall | Spring | 75 | mammal scat |
| 13 | 28.025 | 85.433 | 3,199 | 70–80 | SW | rock fall | Spring | 80 | |
| 14 | 28.020 | 85.436 | 3,190 | 45–50 | N | rock fall | dry | 75 | |

**Table S2. Sign of mammals (other than Red Panda) in the sampled habitat observed during field survey.**

| | Lat | Long | Elevation (m) | Animal sign (probably) |
|---|---|---|---|---|
| 1 | 28.026 | 85.434 | 3212 | Scat of unknown mammals |
| 2 | 28.028 | 85.430 | 3301 | Scat of deer (*Cervidae* sp.) |
| 3 | 28.028 | 85.428 | 3332 | Scat of deer (*Cervidae* sp.) |
| 4 | 28.026 | 85.428 | 3490 | Scat of goral (*Naemorhedus* sp.) |
| 5 | 28.025 | 85.428 | 3500 | Scat of yellow-throated martin (*Martes flavigula*) |
| 6 | 28.026 | 85.433 | 3232 | Fresh pellets of other mammals |
| 7 | 28.024 | 85.432 | 3390 | Scat of deer (probably *Cervidae* sp.) |

**Table S3. Vegetation data from quadrate sampling in the Red Panda habitat without landslide impact.**

| Quadrate | *Betula* sp. | *Rhododendron* sp. | *Pinus wallichiana* | Total number of trees | Bamboo cover % |
|---|---|---|---|---|---|
| Q1 | 5 | 4 | 0 | 9 | 80 |
| Q2 | 1 | 2 | 0 | 3 | 85 |
| Q3 | 1 | 0 | 0 | 1 | 25 |
| Q4 | 1 | 1 | 1 | 3 | 90 |
| Q5 | 0 | 1 | 4 | 5 | 80 |
| Q6 | 1 | 5 | 0 | 6 | 80 |
| Q7 | 3 | 1 | 0 | 4 | 75 |
| Q8 | 5 | 0 | 0 | 5 | 45 |
| Q9 | 0 | 1 | 0 | 1 | 25 |
| Q10 | 0 | 1 | 1 | 2 | 50 |
| Q11 | 0 | 1 | 1 | 2 | 40 |
| Q12 | 1 | 5 | 0 | 6 | 35 |
| Q13 | 5 | 0 | 0 | 5 | 20 |
| Q14 | 0 | 0 | 0 | 0 | 25 |
| Q15 | 0 | 0 | 1 | 1 | 5 |
| Q16 | 1 | 1 | 0 | 2 | 75 |
| Q17 | 0 | 1 | 1 | 2 | 80 |
| Q18 | 3 | 0 | 1 | 4 | 25 |
| Q19 | 2 | 0 | 1 | 3 | 20 |
| Q20 | 0 | 0 | 1 | 1 | 33 |
| Q21 | 0 | 2 | 0 | 2 | 35 |
| Q22 | 1 | 3 | 0 | 4 | 75 |
| Q23 | 3 | 0 | 0 | 3 | 20 |
| Q24 | 0 | 1 | 0 | 1 | 90 |
| Q25 | 0 | 1 | 0 | 1 | 80 |
| Q26 | 0 | 1 | 1 | 2 | 0 |
| Q27 | 0 | 1 | 0 | 1 | 5 |
| Q28 | 0 | 1 | 0 | 1 | 20 |
| Q29 | 2 | 1 | 0 | 3 | 10 |
| Q30 | 0 | 0 | 0 | 0 | 99 |
| Q31 | 1 | 1 | 0 | 2 | 75 |
| Q32 | 1 | 0 | 0 | 1 | 30 |
| Q33 | 0 | 1 | 0 | 1 | 75 |
| Q34 | 3 | 1 | 0 | 4 | 20 |
| Q35 | 0 | 0 | 0 | 0 | 45 |
| Q36 | 0 | 1 | 0 | 1 | 55 |
| Q37 | 0 | 0 | 0 | 0 | 55 |
| Q38 | 1 | 1 | 0 | 2 | 75 |
| Q39 | 2 | 0 | 0 | 2 | 60 |
| Q40 | 1 | 0 | 0 | 1 | 80 |
| Q41 | 0 | 2 | 1 | 3 | 10 |
| Q42 | 0 | 1 | 0 | 1 | 85 |
| Q43 | 0 | 1 | 0 | 1 | 35 |
| Q44 | 1 | 0 | 0 | 1 | 95 |
| Q45 | 1 | 1 | 1 | 3 | 75 |
| Q46 | 0 | 1 | 4 | 5 | 70 |
| Q47 | 0 | 1 | 0 | 1 | 85 |
| Q48 | 0 | 0 | 5 | 5 | 65 |
| Q49 | 0 | 0 | 2 | 2 | 35 |
| Q50 | 0 | 1 | 3 | 4 | 75 |
| Q51 | 3 | 0 | 1 | 4 | 75 |
| Q52 | 7 | 0 | 0 | 7 | 20 |
| Q53 | 1 | 1 | 0 | 2 | 50 |
| Q54 | 0 | 1 | 0 | 1 | 95 |
| Q55 | 0 | 1 | 3 | 4 | 5 |
| Q56 | 3 | 3 | 0 | 6 | 25 |
| Q57 | 9 | 0 | 1 | 10 | 95 |
| Q58 | 3 | 3 | 0 | 6 | 5 |
| Q59 | 5 | 0 | 1 | 6 | 10 |
| Q60 | 3 | 1 | 0 | 5 | 0 |
| Q61 | 0 | 2 | 0 | 2 | 35 |
| Q62 | 0 | 3 | 0 | 3 | 61 |
| Q63 | 4 | 0 | 0 | 4 | 80 |
| Q64 | 4 | 0 | 0 | 4 | 95 |
| Q65 | 3 | 0 | 0 | 3 | 95 |
| Q66 | 3 | 0 | 0 | 3 | 25 |
| Q67 | 1 | 0 | 0 | 1 | 25 |
| Q68 | 1 | 0 | 0 | 1 | 75 |
| Q69 | 2 | 0 | 0 | 2 | 65 |
| Q70 | 1 | 0 | 0 | 1 | 85 |

**Table S4. Vegetation data from quadrat sampling in the Red Panda habitat with landslide impact.**

| Quadrate | *Betula utilis* | *Rhododendron* sp. | *Pinus wallichiana* | Total number of trees | Bamboo cover % |
|---|---|---|---|---|---|
| Q1 | 1 | 4 | 1 | 6 | 75 |
| Q2 | 1 | 4 | 1 | 6 | 25 |
| Q3 | 1 | 2 | 1 | 4 | 45 |
| Q4 | 4 | 1 | 2 | 7 | 55 |
| Q5 | 7 | 11 | 5 | 23 | 0 |
| Q6 | 0 | 0 | 5 | 5 | 90 |
| Q7 | 0 | 1 | 1 | 2 | 45 |
| Q8 | 0 | 1 | 1 | 2 | 80 |
| Q9 | 1 | 2 | 0 | 3 | 75 |
| Q10 | 0 | 1 | 0 | 1 | 66 |
| Q11 | 3 | 0 | 0 | 3 | 75 |
| Q12 | 0 | 4 | 2 | 6 | 25 |
| Q13 | 0 | 1 | 0 | 1 | 45 |
| Q14 | 1 | 1 | 0 | 2 | 10 |
| Q15 | 1 | 0 | 0 | 1 | 5 |
| Q16 | 2 | 0 | 0 | 2 | 5 |
| Q17 | 3 | 0 | 0 | 3 | 5 |
| Q18 | 0 | 1 | 0 | 1 | 1 |
| Q19 | 0 | 0 | 1 | 1 | 10 |
| Q20 | 0 | 0 | 0 | 0 | 10 |
| Q21 | 1 | 2 | 0 | 3 | 25 |
| Q22 | 1 | 3 | 0 | 4 | 10 |
| Q23 | 1 | 1 | 0 | 2 | 0 |
| Q24 | 2 | 0 | 0 | 2 | 10 |
| Q25 | 0 | 0 | 1 | 1 | 0 |
| Q26 | 0 | 0 | 0 | 0 | 10 |
| Q27 | 3 | 0 | 0 | 3 | 5 |
| Q28 | 0 | 1 | 1 | 2 | 30 |
| Q29 | 1 | 0 | 0 | 1 | 5 |
| Q30 | 0 | 1 | 0 | 1 | 2 |
| Q31 | 0 | 0 | 0 | 0 | 5 |
| Q32 | 1 | 1 | 0 | 2 | 5 |
| Q33 | 1 | 0 | 0 | 1 | 0 |
| Q34 | 2 | 0 | 0 | 2 | 0 |
| Q35 | 1 | 0 | 0 | 1 | 5 |
| Q36 | 1 | 0 | 0 | 1 | 2 |
| Q37 | 0 | 1 | 0 | 1 | 2 |
| Q38 | 1 | 1 | 0 | 2 | 0 |
| Q39 | 2 | 0 | 0 | 2 | 0 |
| Q40 | 1 | 0 | 0 | 1 | 2 |
| Q41 | 0 | 0 | 0 | 0 | 10 |
| Q42 | 1 | 1 | 0 | 2 | 20 |
| Q43 | 1 | 0 | 0 | 1 | 45 |
| Q44 | 0 | 1 | 0 | 1 | 10 |
| Q45 | 0 | 0 | 0 | 0 | 5 |
| Q46 | 0 | 1 | 0 | 1 | 5 |
| Q47 | 0 | 0 | 3 | 3 | 0 |
| Q48 | 0 | 1 | 1 | 2 | 5 |
| Q49 | 0 | 0 | 1 | 1 | 5 |
| Q50 | 0 | 0 | 1 | 1 | 5 |
| Q51 | 1 | 1 | 0 | 2 | 0 |
| Q52 | 1 | 0 | 1 | 2 | 0 |
| Q53 | 1 | 0 | 0 | 1 | 0 |
| Q54 | 1 | 0 | 0 | 1 | 0 |
| Q55 | 1 | 0 | 0 | 1 | 0 |
| Q56 | 11 | 3 | 0 | 14 | 0 |
| Q57 | 3 | 1 | 0 | 5 | 0 |
| Q58 | 7 | 1 | 0 | 8 | 5 |
| Q59 | 1 | 0 | 0 | 2 | 0 |
| Q60 | 3 | 0 | 0 | 3 | 0 |
| Q61 | 2 | 1 | 0 | 3 | 5 |
| Q62 | 3 | 0 | 0 | 3 | 15 |
| Q63 | 2 | 0 | 0 | 2 | 0 |
| Q64 | 1 | 0 | 1 | 2 | 2 |
| Q65 | 3 | 1 | 0 | 4 | 10 |
| Q66 | 3 | 1 | 0 | 4 | 5 |
| Q67 | 2 | 1 | 0 | 3 | 5 |
| Q68 | 3 | 0 | 0 | 3 | 0 |
| Q69 | 0 | 1 | 0 | 1 | 5 |
| Q70 | 2 | 1 | 0 | 3 | 5 |

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ARTICLE

# Rhesus Macaque *Macaca mulatta* (Mammalia: Primates: Cercopithecidae) in a human-modified landscape: population, activity budget, and societal perceptions in Bangladesh

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**Abstract:** Rhesus Macaques are widely distributed and ecologically diverse primate species that attract special focus from the research and conservation approaches. We studied population, activity budget, and societal perceptions of Rhesus Macaque at Old Dhaka City, Bangladesh from March 2015 to February 2016. Total count was used to determine the group size and composition. Daily activity budgets of Rhesus Macaques were studied using scan sampling method. Questionnaire survey was conducted to know the attitudes of local people towards monkey conservation in the area. Seven groups with a total of 169 individuals were recorded. The population density was 15.5 individuals/ km² and group size ranged from 8 to 63 individuals. Rhesus Macaque spent most of their time in resting (38.5%) followed by feeding (25.7%), moving (18.4%), grooming (12.8%), and playing or object manipulation (4.6%). There was a significant variation in each behavioral activity among the age-sex classes. Questionnaire survey revealed that property damage was the main problem created by the monkeys. A significant majority of people (83.4%) held a positive outlook toward conservation of this species. Variables such as religion, education, and occupation of the respondents significantly influenced their opinion about conservation. These findings have implications for not only conservation and management interventions of Rhesus Macaque but also helpful for minimizing human-monkey interactions in urban areas.

**Keywords:** Behavioral activity, conservation, human-primate interactions, management interventions, questionnaire survey, urban landscape.

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**Author contributions:** SAN: conceptualization, investigation, methodology, resources, writing-original draft, formal analysis, validation, writing-review and editing, visualization. MAUH: conceptualization, investigation, methodology, resources, data curation, formal analysis, validation, writing-review and editing, visualization. MAB: writing-review and editing, supervision. SS: supervision

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## INTRODUCTION

Rhesus Macaques *Macaca mulatta* are one of the world's most widespread, abundant, and ecologically adaptive primate species. *M. mulatta* is distributed in Bangladesh, India, Pakistan, Nepal, Myanmar, Thailand, Afghanistan, southern China, and some neighboring areas (Green 1978). In Bangladesh, they are found in substantial numbers in a wide variety of habitats including semi-evergreen and evergreen forests in the northeastern and southeastern regions, moist deciduous forests in the central region, and Sundarbans mangrove forest in the south-west (Hasan et al. 2013; Hasan et al. 2016). Populations of macaques also inhabit human dominated landscapes in urban settings, roads, canal banks, villages, temples, and shrines (Southwick & Siddiqi 1994; Maestripieri & Hoffman 2012; Hasan et al. 2013; Jaman & Huffman 2013). They depend mainly on anthropogenic food sources and play a vital role in the culture and religion of some communities (Southwick & Siddiqi 1994). Old Dhaka city is one of the historical sites of Rhesus Macaque distribution in Bangladesh. Rhesus Macaques are considered as non-seasonal breeders and are often termed as 'weed species' in response to their capability of living in densely populated urban habitats (Teas et al. 1980; Richard et al. 1989; Southwick et al. 2005). This species is categorized as Vulnerable (IUCN Bangladesh 2015) and a total of 251 individuals in seven groups were reported in urban areas of Dhaka city (Hasan et al. 2013). Assessing the population status in urban landscape is necessary to understand the ecological needs of Rhesus Macaque and developing effective conservation strategies (Malaivijitnond et al. 2005; Lwanga et al. 2011).

An important feature in studies of the behavioral ecology of a species is to evaluate the percentage of time spent in different activities throughout a day or year (Kabir 2002). Activity budgets is a method of quantifying behavior of how animals allocate their time in various activities that are crucial for survival, reproduction, and might help in the understanding of life history traits and environmental adaptations of animals (Bernstein 1968; Rodway 1998). Time is a limited resource that eventually impacts the behavior of various species (Pollard & Blumstein 2008). Primates usually change their daily behavior in response to ecological and social factors to ensure their survival (Jaman & Huffman 2008; Okekedunu et al. 2014). Numerous studies have investigated that activity budgets and feeding behavior vary in response to diet, habitat structure, distribution, and availability of food sources and individual requirements (Peres 1993; Passamani 1998; Neha et al. 2020). Activity budgets for primates thriving in the human altered habitats are different from those in their natural habitat (Krebs & Davies 1993). Rhesus Macaques are one of the primates that are greatly influenced by human activities in manipulating their habitat (Hambali et al. 2012). We selected a group of Rhesus Macaques living commensally with humans where these macaques are opportunistically omnivorous, obtaining provisioned food along with a few garden plants from nearby public parks, to know how a species adapts under human-modified environmental pressures.

Primate populations are declining rapidly because of the devastation from habitat change and shrinkage of primary habitats, competition for food and space, hunting, pet trade, and body parts for traditional medicines (Wolfheim 1983; Mittermeier 1986; da Silva et al. 2016; Amano et al. 2021). However, expansion of human settlements, destruction of natural habitats and scarcity of food are the major challenges for the urban Rhesus Macaques. The severe ecological alterations as well as close interaction of macaques with humans have led to negative interactions. For example, provisioning food for the macaques in temples and the tendency of co-inhabiting with humans in urban settlements causes negative interactions between humans and primates (Beisner et al. 2015). Macaques often destroy home gardens and fruit trees in urban areas, seek shelter on the rooftops, and inside factory buildings causing damage to human properties. Also, they frighten people with a furious snarl, snatch away food items, and sometimes bite people. In contrast, they are occasionally electrocuted while crossing the utility lines, injured, and even sometimes killed by the residents. In many countries, monkeys have gained protection under traditional beliefs and religious context and are provisioned, protected and worshipped by the local people and temple authorities (Strum 1994). For instance, in Thailand and Japan, though monkeys are fed in a temple or in a village (Knight 1999), they are killed in some adjacent fields (Eudey 1994). Therefore, it is essential to evaluate the attitude of local people towards Rhesus Macaques which aid our understanding of human-monkey co-existence and be helpful to reduce the negative interactions.

Studies on Rhesus Macaque in Bangladesh have focused on population, distribution, competition among sympatric primates and genetic variation (Green 1978; Gittins 1980; Oppenheimer et al. 1983; Feeroz et al. 1995; Sultana 2012; Hasan et al. 2013, 2016; Naher et al. 2016; Neha et al. 2021). However, no studies have been

published relating to activity budget and opinions of local people about the conservation of Rhesus Macaques. The present study therefore focused on the group size and composition, activity budget, and societal perceptions of Rhesus Macaques. The aims of this study were to: (i) assess the population of urban Rhesus Macaque in Old Dhaka City, (ii) evaluate how they budget their time in different activities, and (iii) explore the attitudes of local people toward the conservation of macaques. This study is important to increase our knowledge on the ecology and behavior of Rhesus Macaque that occupy the human altered environment which leads to effective management strategies for their conservation in the area.

## MATERIALS AND METHODS

### Study area

Dhaka City is the capital of Bangladesh and is primarily divided into two parts- the historic Old Dhaka and New Dhaka. The study was carried out in the Old Dhaka City (23.722$^0$N & 90.387$^0$E, Figure 1) from March 2015 to February 2016, where Rhesus Macaques co-exist with humans in proximity. It is situated on the banks of the Buriganga River and covers an area of approximately 5 km$^2$ (Sultana 2012). The buildings and other constructions are ancient and are at high risk of cumbling down. The buildings are very close to one another that makes the roads narrow and congested to support large population of monkeys. The main planted trees in the parks and gardens include neem *Azadirachta indica*, white plumeria *Plumeria* sp., guava *Psidium guajava*, mango *Mangifera indica*, coconut *Cocos nucifera*, blackberry *Syzygium cumini*, jackfruit *Artocarpus heterophyllus*, and jujube *Ziziphus mauritiana*. The highest temperature at the study site was 39 °C in May, and lowest was 12 °C in January. The highest rainfall was recorded in August 2015 (337 mm) and lowest in March 2016 (54 mm).

### Population survey

Total counts were used to survey monkey population (Southwick et al. 1961; Bibby et al. 1992) from dawn to dusk as the study area was small that could be fully covered. Since Rhesus Macaque is the only primate living in the area, the species is easy to identify. Survey was done from all the accessible roads and lanes. Roadways and pathways were walked on foot at a pace of 1 km per hour. Observers paced along roads stopping every 200 m to explore the area by observing visual and auditory cues. When a monkey group was sighted, we recorded the information including their coordinates, group size and composition, age-sex classes, and individual characteristics like physical markings. Double counting was performed to minimize the bias in identifying age-sex of the groups. We offered provisioned food (bananas, breads, and nuts) to attract the monkeys in order to ease the counting. We also counted while respective authority offered provisioned foods in temples and factories. Individuals were classified based on their morphology (Stanford 1991).

### Behavioral sampling

Four age-sex classes of monkeys—an adult male, an adult female, a juvenile, and an infant—were studied from 0600 h to 1800 h for 5–6 days in each month, using instantaneous scan sampling method. These focal individuals were observed for 5 min followed by a 5 min break (Altman 1974). Two observers (Sufia Akter Neha and Mohammad Ashraf Ul Hasan) recorded the behavioral data. The first observer recorded the behavior of an individual of a group, and at the same time, the second observer observed another individual of different age-sex class of the same group. We made a total of 4,235 scans to record the five behavioral activities- resting, feeding, moving, grooming, and playing or object manipulation. Resting is defined when an individual desists all sorts of movements including sleeping or looking about. Feeding includes handling of food, manipulating, chewing, and swallowing food items. Moving is when a monkey travels from one place to other and changes its position. Grooming means removing or scratching dirt and other objects from hair or skin for the hygienic benefits in the form of grooming itself or being groomed. Playing behavior includes picking up stones, sticks, and other objects to manipulate them with hands, for example, hanging on tree branches, jumping, and mounting on the back of the mother as a means of non-threatening context which enables the social development within a group.

### Questionnaire survey

A structured questionnaire survey was conducted to collect data on attitudes of local people toward the conservation of Rhesus Macaque (Khatun et al. 2013; Ahsan & Uddin 2014). The interviewers visited the local residences, shops, nearby temples who have regularly encountered Rhesus Macaques and questions were administered individually to all the participants. In total, 210 respondents were interviewed representing various groups like shopkeepers, devotees, students, and housewives. Demographic (age, sex, religion,

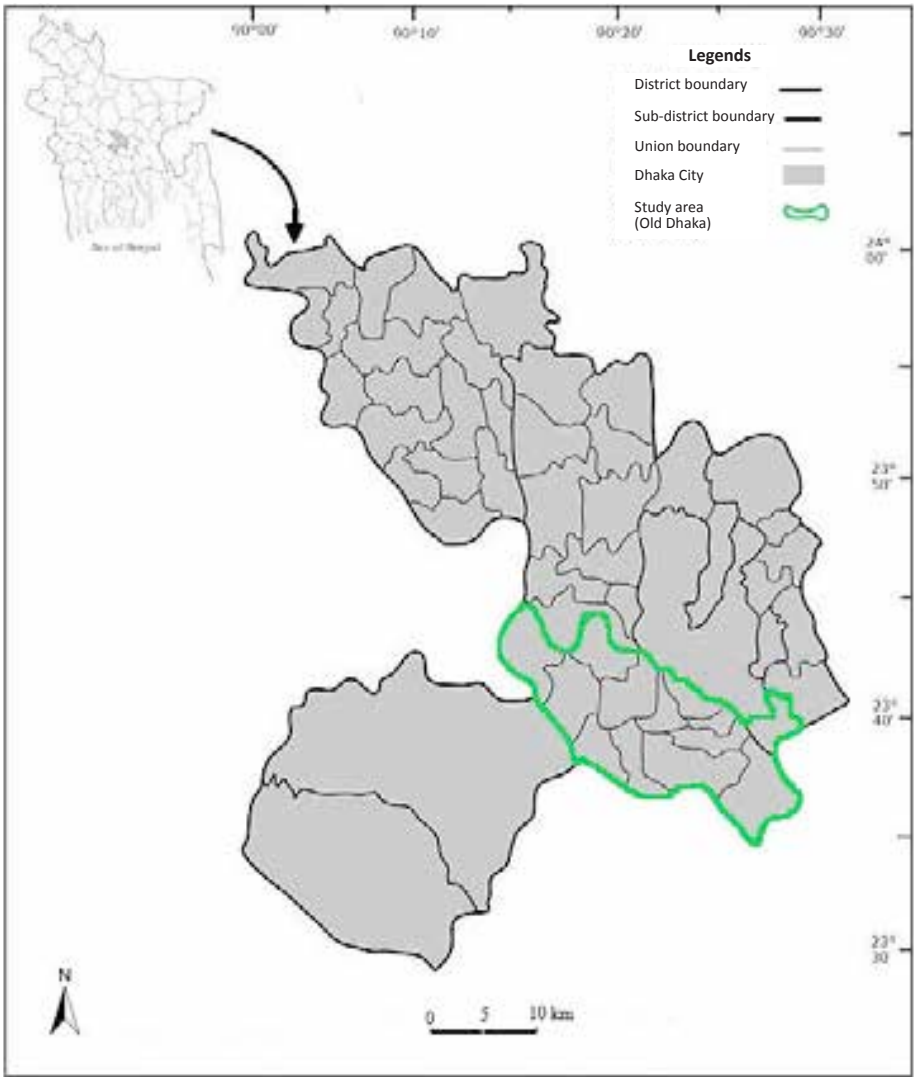


**Figure 1. Bangladesh (on the upper left) and its capital Dhaka (on the right) in which green polygon indicates the boundary of the study area (Old Dhaka) inhabited by seven groups of Rhesus Macaques. Source: modified from Sultana et al. (2018).**

education) and socio-economic (occupation) profile of the respondents were incorporated while asking the questions. We considered the respondents who had attended school up to the 10th grade or more as educated and those who had attended school below the 10th grade as less-educated.

### Data analysis

Chi square tests were performed to find out differences of age-sex classes in the groups as well as to assess the variations in the response of the interviewees. Kruskal-Wallis one-way ANOVA was employed to compare time spent for age-sex classes in each of the behavioral activities. To substantiate the Kruskal-Wallis tests, post hoc pair-wise comparisons were used to see the variation of time spent for each behavioral activity between age-sex classes in the group. Statistical Package for Social Sciences (SPSS, v. 20) was used to analyze data, considering a p value ≤0.05 to be statistically significant.

## RESULTS

### Group structure

A total of 169 individuals were encountered in seven groups. The largest group (63 individuals) was recorded in Sadhana Awshadhalay and the smallest group (8 individuals) in Banagram (Table 1). Group size ranged 8–63 individuals (mean 24.14±18.49, n= 7). Adults comprised 21.6% male and 48.15% female while non-adults comprised 25.93% juvenile and 4.32% infant of the population. The population density of Rhesus

Table 1. Group composition and age-sex ratio of Rhesus Macaque in Old Dhaka City.

| Monkey groups | Adult male | Adult female | Juvenile | Infant | population size | AM:AF | AM:JU | AM:IN | AF:JU | AF:IN | JU:IN |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sadhana Awshadhalay | 17 | 28 | 14 | 4 | 63 | 1:1.65 | 1:0.82 | 1:0.24 | 1:0.5 | 1:0.14 | 1:0.29 |
| Rabidaspara Lane | 6 | 14 | 4 | 2 | 26 | 1:2.33 | 1:0.67 | 1:0.33 | 1:0.29 | 1:0.14 | 1:0.5 |
| Uttar Musondi | 3 | 9 | 11 | 2 | 25 | 1:3 | 1:3.67 | 1:0.67 | 1:1.22 | 1:0.22 | 1:0.18 |
| Radhika Mohan Bosak Lane | 4 | 10 | 5 | 3 | 22 | 1:2.5 | 1:1.25 | 1:0.75 | 1:0.5 | 1:0.3 | 1:0.6 |
| Suritola | 2 | 7 | 3 | 1 | 13 | 1:3.5 | 1:1.5 | 1:0.5 | 1:0.43 | 1:0.14 | 1:0.33 |
| Tanti Bazar-Shakhari Bazar | 2 | 6 | 3 | 1 | 12 | 1:3 | 1:1.5 | 1:0.5 | 1:0.5 | 1:0.17 | 1:0.33 |
| Banagram | 1 | 4 | 2 | 1 | 8 | 1:4 | 1:2 | 1:1 | 1:0.5 | 1:0.25 | 1:0.5 |
| Overall | 35 | 78 | 42 | 14 | 169 | 1:2.23 | 1:1.2 | 1:0.4 | 1:0.54 | 1:0.18 | 1:0.33 |
| $\chi^2$ value | | | | | | 1.96 | 5.52 | 2.52 | 5.01 | 1.11 | 1.72 |
| p value | | | | | | 0.92 | 0.48 | 0.87 | 0.54 | 0.98 | 0.94 |

AM—Adult male | AF—Adult female | J—Juvenile | IN—Infant | *—Significant at $p \leq 0.05$

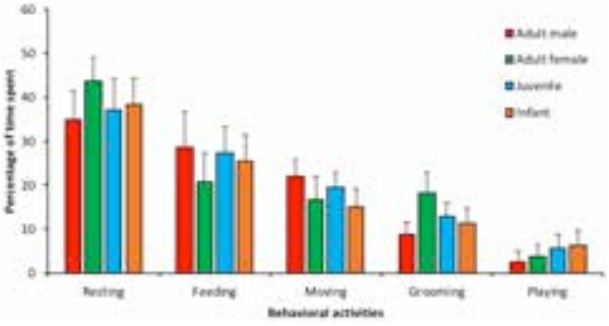


Figure 2. Variation of behavioral activities among age-sex classes of Rhesus Macaques.

Macaque was 15.5 individuals/ km². The average ratio between adult males and adult females was 1:2.23, adults and non-adults was 1:0.5, and adult females and infants was 1:0.18. There was no significant variation in the proportion of adult males and adult females ($\chi^2$= 1.96, df= 6, p= 0.92), adult females and infants ($\chi^2$= 1.11, df= 6, p= 0.98), adult females and juveniles ($\chi^2$= 5.01, df= 6, p= 0.54), and juveniles and infants ($\chi^2$= 1.72, df= 6, p= 0.94) among the groups.

### Daily time budget

Rhesus Macaque spent most of their activity in resting (38.5% of the total scans, sd= +2.59, n= 1,631), followed by feeding (25.7%, sd= +2.48, n= 1,088), moving (18.4%, sd= +1.86, n= 779), grooming (12.8%, sd= +3.06, n= 542) and playing (4.6%, sd= +1.22, n= 195). Behavioral activities among the age-sex classes of Rhesus Macaque varied during the study period (Table 2). A post hoc pair-wise comparison showed that adult females spent more time resting and grooming than adult males (p< 0.001, same value), juveniles and infants (p< 0.001, same value for all comparisons, respectively; Figure 2). But adult males spent more time feeding than adult females, juveniles, and infants (p <0.001, p= 0.036, p= 0.014, respectively). Adult males also spent more time moving than adult females, juveniles and infants (p <0.001, p= 0.026, p <0.001, respectively). Infants spent more time playing or being engaged in object manipulation than juveniles, adult females, and adult males (p= 0.042, p= 0.0011, p <0.001, respectively).

### Demographic and socioeconomic profile of the respondents

A total of 210 respondents were interviewed during the questionnaire survey, of which 111 (53%) were men and 99 (47%) were women. The age of the respondents varied between 18 and 75 years. Hindus represented 56% of the respondents and Muslims represented 44%. Furthermore, 39.5% were educated, while 60.5% were less-educated. With respect to occupation, 31% were shopkeepers, 27% housewives, 23% students, and 19% devotees. The demographic and socioeconomic status did not vary significantly among the respondents in study areas concerning gender ($\chi^2$= 8.71, df= 6, p= 0.074), age class ($\chi^2$= 2.52, df= 6, p= 0.421), and education ($\chi^2$= 5.37, df= 6, p= 0.274) however, differed significantly in relation to religion ($\chi^2$= 13.59, df= 6, p= 0.005), and occupation ($\chi^2$= 18.92, df= 6, p= 0.001).

### Societal perceptions toward Rhesus Macaques

Based on the questionnaire survey, on an average 55% people in the city area claimed property damage (e.g., entering residential buildings, damaging rooftop

**Table 2. Kruskal-Wallis one-way analysis of variance output for age-sex classes in each behavioral activities of Rhesus Macaque.**

| | Activities | H | df | p |
|---|---|---|---|---|
| Age-sex class | Resting | 43.16 | 3 | < 0.001 |
| | Feeding | 16.32 | 3 | < 0.01 |
| | Moving | 21.71 | 3 | < 0.01 |
| | Grooming | 39.58 | 3 | < 0.001 |
| | Playing | 24. 05 | 3 | < 0.001 |

**Table 3. Perception of respondents towards Rhesus Macaque at Old Dhaka City.**

| | Variables | Categories | Response % |
|---|---|---|---|
| 1 | What problems do you face by monkeys? | a) Damage to property<br>b) Food/cloth stealing<br>c) Monkey bites | 54.6<br>38.9<br>6.5 |
| 2 | How do you mitigate conflict with monkey? | a) Strike with stick<br>b) Throw stone<br>c) Use of fence/grills | 12.4<br>61.4<br>26.2 |
| 3 | Do you observe any changes in monkey population? | a) Increase<br>b) Decrease | 43.8<br>56.2 |
| 4 | What is the threat to Rhesus Macaque? | a) Loss of habitat<br>b) Food scarcity<br>c) Electrocution | 52.7<br>32.9<br>14.4 |
| 5 | Do the local people show religious sympathy? | a) Yes<br>b) No | 62.5<br>37.5 |
| 6 | How do we need to initiate conservation activities? | a) Keep them as it is now<br>b) Restrict some places for them | 24.2<br>75.8 |
| 7 | What is your opinion towards monkey conservation in your area? | a) Positive<br>b) Negative | 83.4<br>16.6 |

gardening, and disconnecting electricity, satellite, & telephone cable) was the main problem created by monkeys, whereas nearly 40% people believe food and cloth stealing were the serious problems. In contrast, a few people (6.5%) agreed that monkey bite was another problem faced by the local people (Table 3). To minimize monkey menace, many people (61.4%) threw stones, while roughly one quarter of the respondents (26.2%) used fence and iron grills and more than one in 10 people (12.4%) struck them with a stick. Just over half of the people (56.2%) stated that the monkey population has decreased in Old Dhaka City, however, more than two-fifths of the respondents (43.8%) did not agree with this. Around half of the local people (52.7%) believed that habitat loss was the main threat to monkey, whereas just under a third of the respondents (32.9%) considered food scarcity was one of the major threats. Electrocution was also reported by less than a fifth of the respondents (14.4%). A large amount of people (62.5%) from local

**Table 4. Respondents viewpoint to conservation of Rhesus Macaque in the study area.**

| Variables | Attitude towards conservation | | Chi-square test | | |
|---|---|---|---|---|---|
| | Positive % (n) | Negative % (n) | $\chi^2$ | Df | p |
| **Gender** | | | | | |
| Male | 88.4 (98) | 11.6 (13) | 0.52 | 1 | 0.71 |
| Female | 91.2 (90) | 8.8 (9) | | | |
| **Age class** | | | | | |
| Adult | 90.6 (99) | 9.4 (10) | 0.26 | 1 | 0.58 |
| Young | 86.1 (87) | 13.9 (14) | | | |
| **Religion** | | | | | |
| Muslim | 72.3 (67) | 27.7 (25) | 14.67 | 1 | 0.0001 |
| Hindu | 85.5 (101) | 14.5 (17) | | | |
| **Education** | | | | | |
| Educated | 92.3 (77) | 7.7 (6) | 11.35 | 1 | 0.002 |
| Less-educated | 74.6 (95) | 25.4 (32) | | | |
| **Occupation** | | | | | |
| Shopkeepers | 67.7 (44) | 32.3 (21) | 8.78 | 3 | 0.014 |
| Housewives | 73.7 (42) | 26.3 (15) | | | |
| Students | 81.2 (39) | 18.8 (9) | | | |
| Devotees | 90.0 (36) | 10.0 (4) | | | |

area have had religious attachments with monkeys, especially the Hindu communities, but less than two-fifths of the people (37.5%) did not feel this way. Three quarters of people (75.8%) in the city area asserted that the government should take necessary steps by shifting the monkeys to other places and restrict some places for them, while rest of the respondents (24.2%) argued to keep them where they are now.

Despite several problems created by monkeys, a significant majority of people (83.4%) had a positive attitude toward the conservation of monkeys. The variation in respondent attitude towards conservation of Rhesus Macaque were significantly explained by three of the five independent variables: (1) religion (p= 0.0001), (2) education (p= 0.002), and (3) occupation (p= 0.014) (Table 4). Hindus and educated people supported conservation and considered monkeys to be a part of the local culture and heritage and believed that the species should be safeguarded for future generations. Additionally, students and devotees had a higher opinion of monkey conservation than their corresponding counterparts (Table 4). They felt that monkeys resembled human beings and had recreational and aesthetic values.

## DISCUSSION

Rhesus Macaque at Dhaka City has shown significant variation in terms of population size and composition over the last 40 years. Akonda (1976) found 11 groups of Rhesus Macaque comprised of 196 individuals which increased to 229 individuals in 11 troops by Oppenheimer et al. (1983). Further a decrease in population was observed to 196 individuals in 11 groups by Feeroz et al. (1995). After a long gap of 17 years, Sultana (2012) reported 178 individuals in 10 groups and Hasan et al. (2013) recorded 251 individuals in seven groups. The present study identified seven groups with a total of 169 individuals. The reason for such fluctuations might be due to the different study methods or the area considered for the study. Moreover, demographic trends of the population are interconnected with habitat structure which influence the response of that population (Green 2003). Still, the possible reasons for the decline of the Rhesus Macaque population in this study area could be the consequences of habitat loss, felling of food trees, electrocution, and human disturbances. The largest group was found in Sadhana Awshadhalay area (17 adult males, 28 adult females, 14 juveniles, and 4 infants) as the Rhesus Macaques in this area mostly depend on the provisioning of food supplied by the local people. Visitors and factory people also provide shelter to these macaques. In contrast, the smallest group we recorded was in Banagram (1 adult male, 4 adult females, 2 juveniles, and 1 infant) which was due to the fact that the people of that area were unfriendly toward macaques and there was a lack of provisional food resources. Group size ranged from 8 to 63 individuals that differed from other studies: 4 to 59 individuals (Sultana 2012); 24 to 59 individuals (Hasan et al. 2013). This is because of intra-specific variation in group size relying on history of the group and occasional dispersal into the other groups (Menard 2004; Md-Zain et al. 2010). However, the number of females is higher than their male counterpart in each group. This could be because female monkeys are philopatric, remaining in the group throughout their life, while males may depart their natal families upon reaching maturity (Hasan et al. 2013).

The proportion of time spent on behavioral activities varied between populations of macaques due to habitat differences and age-sex specific physiological factors (Brent & Veira 2002; Jaman & Huffman 2008). We found the most observed daily activity from the study group was resting and feeding (38.5% and 25.7%, respectively). This study was supported by Jaman & Huffman (2013), that showed Rhesus Macaque spent 46.1% and 22.4% of their active time on resting and feeding compared to other activities. Jaman & Huffman (2008) also found that resting time was longer in captive Japanese Macaques. Time spent resting and feeding in urban Rhesus Macaque was longer due to regular supply of higher quality provisioned food, for example, fruits, vegetables, nuts, breads, biscuits, and chick-peas offered by the local people and visitors. Additionally, they ate from plant sources such as young leaves, flowers, fruits, seeds, shoots, and insects. Due to limited access to natural foraging sites, the urban macaques frequently rested after taking provisioned food by adopting lower energy search strategy to meet their metabolic requirements of a smaller amount of food in a limited amount of time (El Alami et al. 2012; Jaman & Huffman 2013). Rhesus Macaques commonly rested on the branches of trees, the roof of the buildings, graveyards and parks. Moving was the behavior recorded to have the third highest proportion in this study which is inconsistent with other macaque studies observed elsewhere (Hambali et al. 2012; Md-Zain et al. 2010; Okekedunu et al. 2014). This may be because monkeys in forest settings were mainly frugivorous, occupied more space and thus, spent most of their time searching for fruits in comparison with monkeys living commensally with humans. When the energetic demands were met, provisioned Rhesus Macaque were engaged in grooming to strengthen their social bonds-similar to other groups conducted in India and Nepal (Teas et al. 1975; Malik & Southwick 1988). Playing is a part of learning the ways of social relations and performing actions more successfully (Kipper & Todt 2002; Naples & Rothschild 2015). Playing with objects and water, pulling each other's tail and swinging on the tree branches have been observed in the study groups.

Our result showed differences in activity pattern of Rhesus Macaque among age-sex classes. Adult males spent more time feeding and moving in comparison with the rest of the group. The plausible reason for this might be that adult males undertook raids on houses, gardens and garbage bins and took over the provisioned food, continued to feed voraciously while leaving the leftover food for others. Juveniles and infants also fed more because they require more nutrients for their development and maturation (Watanuki & Nakayama 1993). The adult males are physically dominant over others and were observed moving frequently to protect their territory from neighboring groups. Adult females spent more time resting and grooming. Similar results have been reported by Jaman & Huffman (2013). As feeding is inversely related to resting, thus spending less time feeding which allowed them to rest for a longer period of time. Moreover, adult females were seen to groom other females and infants after feeding and

while resting. Mothers often groom their infants which strengthen the kinship among them. Besides, subordinate females usually groom higher ranking adult females in order to maintain hierarchy. This finding is related to those conducted by Md-Zain et al. (2010) and Hambali et al. (2012). It is also found that females groom males after mating, which has been observed in other primates such as marmosets where male marmosets were groomed by females in favor of sharing food and to gain protection (Lazaro-Perea et al. 2004). Playing behavior is commonly performed by juveniles and infants. In addition, mothers of Rhesus Macaques were also observed to play with their babies. Females often play with their young as a means of practicing survival related activities as well as keeping them safe from the predators (Hambali et al. 2012; Naples & Rothschild 2015).

Our study from the questionnaire survey revealed that the majority of the people had positive attitudes towards conservation of the Rhesus Macaque. Similar results have also been reported for other primate studies (Khatun et al. 2012; Hasan et al. 2018). The attitude towards Rhesus Macaque conservation varied significantly among the respondents of different religion, education and occupation. Religious attachment of the Hindu community with Rhesus Macaques influenced their inclination to conservation. This is because they consider monkeys as sacred animals to be conserved. Therefore, cultural and religious sympathy can increase tolerance and conservation of primates in rural and urban areas (Pirta et al. 1997; Hill 1998). Educated people were more compliant with supporting conservation of monkeys. This is due to the fact that the educated people who belonged to a higher land-holding status were less concerned about the monkey menace as their economic status was secure compared to the lesser-educated or low land-holding people. Khatun et al. (2012) also noticed that the positive attitude of local people in Keshabpur, Bangladesh towards conservation of common langurs were associated with land-holding status of the respondents. It was observed that temple authorities especially devotees and people who have visited the temple provided food to macaques and offer shelter in the temple premises. Moreover, young people and students were also seen to feed macaques from their window and balcony, which may be regarded as a popular pastime. These findings suggest that the factors influencing the local people's attitudes are crucial for the conservation of Rhesus Macaques in this area.

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ARTICLE

# Factors affecting the species richness and composition of bird species in a community managed forest of Nepal

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**Abstract:** There exists limited information on biodiversity including avifaunal diversity and habitat condition in community forests (CF) of Nepal; thus we aimed to fulfill such gaps in Tibrekot CF of Kaski district. We used the point count method for assessing bird diversity and laid out a circular plot size of radius 5-m within 15-m distance from each point count station for recording the biophysical habitat characteristics. Bird species' diversity, richness and evenness were calculated using popular indexes and General Linear Model (GLM) was used to test the respective effect of various biophysical factors associated with the richness of bird species. In total, 166 (summer 122, winter 125) bird species were recorded in 46 sample plots. The Shannon-Wiener diversity index was calculated as 3.99 and 4.09, Margalef's richness index as 16.84 and 17.53 and Pielou's evenness index as 0.83 and 0.84 for summer and winter, respectively. The influencing factors for richness of bird species were season ($\chi 2_{1, 90}$= 112.21; P= 0.016) with higher richness in the summer season and low vegetation cover ($\chi 2_{1, 89}$= 113.88; P= 0.0064) with higher richness in lower percentage cover. Thus, community managed forest should be protected as it has a significant role in increasing bird diversity, which has potential for attracting avifaunal tourism for the benefit of the local communities.

**Keywords:** Biodiversity, evenness index, Margalef's richness index, Pielou's vegetation cover, Shannon-wiener index.

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## INTRODUCTION

Nepal is a biodiversity-rich country that represents a significant share of global biodiversity (Paudel et al. 2012). The country occupies about 0.1% of the global area, but harbors 3.2% and 1.1% of the world's known flora and fauna, respectively (MoFSC 2014). This includes 5.2% of the world's known mammals, 9.5% birds, 5.1% gymnosperms, and 8.2% bryophytes. The Middle Mountains, also known as Middle Hills or Mid-hills is physiologically the most diverse region of Nepal (MoFSC 2014). The zone has the greatest diversity of ecosystems (52) and species in Nepal due to climatic variations ranging from subtropical to temperate monsoonal climate and a great variety of terrain and soil types.

Birds are an important part of forest ecosystems and a key part of food chains that are crucial for maintaining ecosystem function and resilience (Lundberg & Moberg 2003; Mahiga et al. 2019). In addition, birds play vital ecological roles in both agricultural land and forest ecosystems especially pest control, pollination, and seed dispersal (Whelan et al. 2008; Mulwa et al. 2012; Basnet et al. 2016). Bird communities are also indicators of the quality of forest habitats and thus can help to guide management and conservation at regional and landscape levels (Canterbury et al. 2000; Moning & Müller 2008). Many new research studies have focused on the distribution of bird species richness and diversity (Wu et al. 2013) and their changes over time. Studies have found variation in species diversity among different regions of Nepal. For example, Jha (2019) observed 78 bird species belonging to seven orders and 24 families in the foothills of Phulchoki Hill. Pandey et al. (2020) recorded 112 species belonging to 13 orders and 35 families in the Mardi Himal trekking region. In contrast, the diversity of bird species was found to be higher in Reshunga Forest in the west with 201 recorded bird species (Thakuri 2011).

Bird species diversity and richness are associated with distribution and presence of field margins, forest edges, habitat fragmentation, habitat quality, landscape changes, landscape structure, farming systems, type of vegetation, and climate (Basnet et al. 2016). A recent study has found that temperature, precipitation, habitat resources, and the level of disturbances influenced bird species' diversity and richness in the mid-hills (Pandey et al. 2020). Heterogeneity of bird habitats and the level of human disturbance have significantly influenced the distribution, diversity, and abundance of threatened bird species in central Nepal (Adhikari et al. 2019). However, there is limited information about the seasonal diversity and composition of bird species and the associated vegetation characteristics and other habitat factors influencing the species richness in Nepal.

Seasonal change in climate is an additional prominent characteristic of mountain ecosystems that can influence the temporal dynamics of bird species richness and composition. Birds in mountain environments are sensitive to seasonal variation in climate, due to resource bottlenecks for food and water availability and to temperature regulation requirements (Katuwal et al. 2016). In Nepal, seasonal migration of birds is closely linked to changes between the dry and monsoon seasons. Summer migration usually starts between March and May (premonsoon season) and sometimes migration is extended to the monsoon season in June and July, while the winter migration starts during the post-monsoon season in September (Katuwal et al. 2016). In contrast, although the diversity index was found to be higher in the summer season, species richness remained uniform in both summer and winter seasons in the Mardi Himal region of the mid-hills (Pandey et al. 2020).

The livelihood of people of developing countries, as well as biodiversity, is enhanced through the maintenance of forest cover (Persha et al. 2010). When forest habitats are protected, avifaunal tourism can be promoted that can contribute to the rural economy of poor people (Girma et al. 2017; Gupta et al. 2019). However, the role of community-managed forests in conservation of avifaunal diversity is often neglected. In this study, we explore the contribution of community forest to the avifaunal composition and species richness, followed by determining the associated habitat characteristics. To the best of our knowledge, such information is lacking in Nepal, therefore we believe that this study helps to fill such gaps, which can ultimately contribute to conservation of bird species and their habitats.

## STUDY AREA

Tibrekot Community Forest (CF) is located at Hemja in the northern part of Pokhara Metropolitan City ward number 25, Kaski district in Nepal at 28.29° N latitude and 83.93° E longitude (Figure 1). The CF covers an area of 120 ha with elevation of 1,000–1,400 m from mean sea level that was handed over as community forestry to the local users in the year 2000. The average annual temperature is 14–25 °C and the average annual rainfall is 1,000 mm. *Schima-Castanopsis* is the dominant species of the forest composition; other species recorded are *Alnus nepalensis, Engelhardia spicata*, and

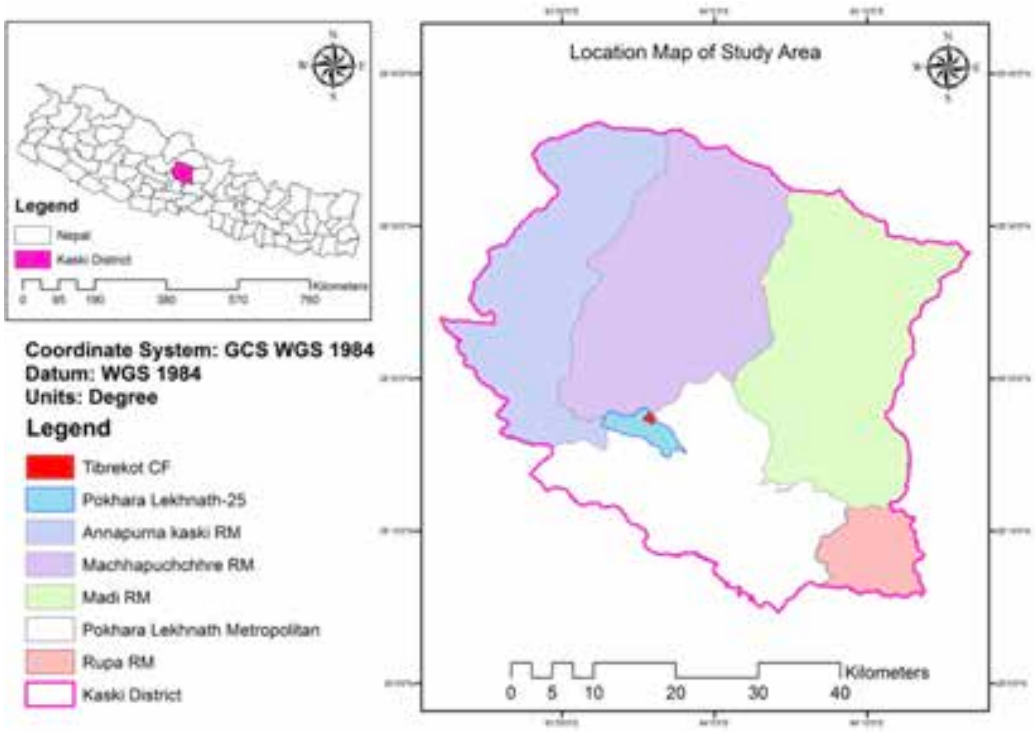


**Figure 1. Study area.**

*Myrica esculanta*. Mammal species recorded include *Rhesus macaque, Panthera pardus, Canis aureus*, *and Hystrix brachyura.*

Altogether, 260 households manage the Tibrekot CF. The forest was one of the long-term research sites of Tribhuvan University, Institute of Forestry/ ComForM Project-funded by Denmark from 2004 to 2014 (https://www.iofpc.edu.np/project/community-based-natural-forest-management-in-the-himalaya-comform). As the study site lies near the Pokhara valley and on the way to the popular Mardi Himal trekking route, protecting such community-managed forest can attract avifaunal tourists who should consequently benefit local communities. Besides, protection and maintenance of green forest nearby the city not only attracts tourists, but also provides important ecosystem services and beauty to the city's surroundings.

## FIELD METHODS

### Bird Survey

Bird species in the study area were surveyed using the point count method (Ralph et al. 1995). Points were laid at a distance of 200 m apart (as far as possible except on some sites with steep slopes, ridges, and dense bushes) along the existing trails as well as new trails in order to represent the entire forest area (Ralph et at. 1995). In addition, a few point count stations were placed on the private lands that were connected to the CF (on the southwestern side) in order to include the bird species from that region (Figure 3). The distance between two consecutive stations was maintained at 200 m to avoid double counting. The bird species seen and heard within a 20 m radius were counted for a period of 10 minutes (Ralph et al. 1995; Hostetler & Main 2001). To minimize disturbances during the survey, a waiting period of 3 to 5 min prior to counting was applied. The data collection was carried out for five hours per day from 06:30 to 10:00 h in the morning and from 16:30 to 18:00 h in the evening, as during those time intervals the activities of the birds were considered to be prominent (Hostetler & Main 2001). The winter field data was collected during January 2019 while the summer data was collected during August 2019 by assuming that most of the seasonal migratory bird species visit the study area by that time. In total, we spent 15 days for the fieldwork during each season. We avoided performing point counts in days with rain and stronger wind. We belonged to a team of 10 people including a bird expert, Bachelor in Forestry graduates, and experienced local people, for the entire field survey of each season. In addition, we hired the bird expert to identify the birds and record their associated habitat

characteristics during the field survey. The bird expert, prior to the collection of field data, trained all the field team members for a few days. Furthermore, the bird species were identified at species level with a popular guide, Helm Field Guide 'Birds of Nepal' (Nepali version) and details like number of individuals of particular bird species were also noted. Photographs and calls were used to identify the conspicuous birds whereas others were identified with the aid of binoculars and a spotting scope.

**Recording habitat characteristics**

A circular plot of 5 m radius was laid near each point count station (within 15 m) for recording the habitat characteristics of bird species (Bernard et al. 2014). The habitat characteristics include vegetation canopy layer (≥20 m above ground), understory vegetation (5 to 20 m above ground), low vegetation (2 to 5m above ground) and ground vegetation (≤2 m above ground) according to the designed quadrat size for different categories of species. Different parameters of the trees were recorded including DBH, height, crown cover, ground cover, number of trees, frequency of shrubs and herbs. Additionally, habitat parameters such as elevation, aspect, slope, geographic coordinates were also recorded from the same plots.

## Data Analysis

**Abundance and diversity analysis**

We followed Bird Life International for the nomenclature and classification of birds (Burfield et al. 2017), IUCN (2017) for the global status and population trend and National Red List Series of Nepal's Birds for the national and migratory status (Inskipp et al. 2016). The relative abundance was determined using the equation:

Relative abundance (%)= $^{n}/_{N}$ ×100

Where,

n= numbers of individuals of particular recorded species

N= total number of individuals of recorded species

In addition, the abundance status was assessed as per the criteria of Khan & Ali (2014).

Very common if seen on >75% of visits

Common if seen on 50–74% of visits

Uncommon if seen on 25–49% of visits

Rare if seen on <25% of visits

Complete checklists of bird species were compiled in Microsoft office excel showing orders, family, species, and bird type.

Similarly, species diversity was determined using Shannon-Wiener's index (Odum 1971) (H´), Margalef's richness index (Margalef 1958), and Pielou's evenness index (Pielou 1996).

**Shannon-Wiener's index**

$H' = -\sum {}^{ni}/_{N} \ln {}^{ni}/_{n}$

where,

ni= number of individuals of $i^{th}$ species

N= total number of all individuals

ln= natural logarithm

The value of the index ranges from 1.5 (low species richness and evenness) to 5.0 (high species evenness and richness).

**Margalef's richness index**

$R = {}^{S-1}/_{\ln N}$

where,

S= total number of species

N= total number of individuals encountered

ln= natural logarithm

Higher the value of 'R", higher will be the species richness.

**Pielou's evenness index**

e= H'/ ln S

where,

S= total number of species

H= Shannon-Weaver diversity index

The value of 'e' ranges from 0 to 1 with 1 being complete evenness i.e. species are equally distributed throughout the habitat.

**Modeling analysis**

Generalized linear model (GLM) was used to test the respective effect of various biophysical factors associated with occupied habitats on the richness of bird species. The independent pre-determined predictor variables were season, aspect, elevation, slope, percentage cover of different vegetation categories including canopy layer (≥20 m above ground), understory layer (5–20 m above ground), lower vegetation layer (2–5 m above ground), and ground vegetation layer (≤2 m above ground) whereas the dependent response variable was bird species richness. After checking the normality and linearity using histogram and Q-Q plot diagram, we found that most of the assumptions were fulfilled by our data and the analysis was followed by a backwards selection method (stepwise removal of non-significant variables or factors). The final model was developed with significant predictor variables for which the likelihood ratio of $\chi 2$ was significant (i.e., $P \leq 0.05$). All the modeling

analysis was performed using R×64 3.3.3 (http://cran.r-project.org/) with R Studio and the significance was set at 5%.

## RESULTS

A total of 166 bird species was recorded in 46 sample plots. Among the recorded species, 122 species of birds were recorded in summer while 125 species of birds were recorded in winter. A total of 44 bird species was recorded only in winter and 41 bird species were recorded only in summer, whereas 81 bird species were recorded in both summer and winter. Among the total number of bird species 65% species were found to be carnivores, 9% species were insectivores, 17% species were omnivores, 6% species were frugivores, and 3% species were nectivores (Figure 2). The richness of bird species was found to differ among the measured plots (Figure 3).

### Relative abundance and diversity of bird species

As per the criteria of Khan & Ali (2014), most of the species were rare (recorded on less than 25% of visits). The most abundant bird species found in the study area was Black Bulbul *Hypsipetes leucocephalus* (RA= 8.28) followed by White-crested Laughingthrush *Garrulax leucolophus* (RA= 6.99), and Great Barbet *Psilopogon virens* (RA= 6.3) in summer, whereas in winter the most abundant bird species was Grey-hooded Warbler *Phylloscopus xanthoschistos* (RA= 7.54) followed by Barn Swallow *Hirundo rustica* (RA= 6.61) and White-crested Laughingthrush *Garrulax leucolophus* (RA= 5.68) in winter. The relative abundance of 10 most dominant species is given below (Table 1).

### Species Diversity

The value of Shannon-wieners index ranges from 1.5 to 5 in which 1.5 was the low species richness and evenness and 5 was the high species richness and evenness. The values of index of bird in summer and winter were 3.99 and 4.09**,** respectively, which mean the species richness and evenness of birds was high in the study area. It was high because there were more species with single individual and two individuals recorded. The higher the value of Margalef's richness index, the higher will be the species richness. The values of the index in summer and winter were 16.84 and 17.53, respectively, which means the species richness was high. The value of Pielou's evenness index ranges from 0 to 1 in which 1 means complete evenness that indicates the species

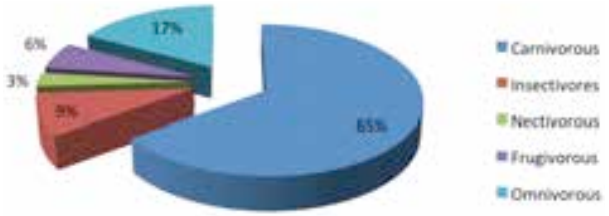


Figure 2. Feeding character of bird species recorded in the study area.

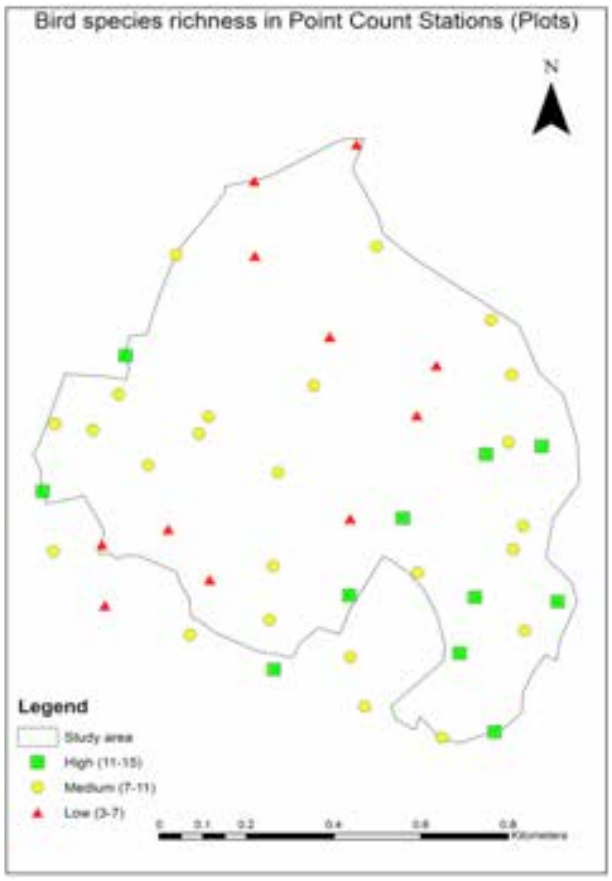


Figure 3. Richness of bird species in point count stations.

are equally distributed throughout the habitat. The values of the index in summer and winter were 0.83 and 0.84, respectively, which means the species were evenly distributed in the study area (Table 2).

### Habitat factors influencing the richness of bird species

Among different pre-determined biophysical variables, GLM analysis found significant effect of two variables only, i.e., season and low vegetation percentage cover on the richness of bird species in the occupied plots. There was a seasonal effect on richness of bird species in the study area ($\chi 2_{1, 90}$= 112.21; P= 0.016), with higher richness of bird species in the summer

**Table 1. Relative abundance and diversity of bird species.**

| | Common name | Scientific name | Relative abundance | |
|---|---|---|---|---|
| | | | Summer | Winter |
| 1 | Barn Swallow | *Hirundo rustica* | 2.27 | 6.61 |
| 2 | Black Bulbul | *Hypsipetes leucocephalus* | 8.28 | 0 |
| 3 | Black-lored Tit | *Machlolophus xanthogenys* | 1.97 | 3.05 |
| 4 | Great Barbet | *Psilopogon virens* | 6.3 | 1.52 |
| 5 | Grey-headed Canary-flycatcher | *Culicicapa ceylonensis* | 2.35 | 2.79 |
| 6 | Grey-hooded Warbler | *Phylloscopus xanthoschistos* | 4.78 | 7.54 |
| 7 | Grey Treepie | *Dendrocitta formosae* | 4.93 | 5.17 |
| 8 | Long-tailed Minivet | *Pericrocotus ethologus* | 3.03 | 4.32 |
| 9 | Red-vented Bulbul | *Pycnonotus cafer* | 2.43 | 2.88 |
| 10 | White-crested Laughingthrush | *Garrulax leucolophus* | 6.99 | 5.68 |

**Table 2. Species diversity index of the bird species.**

| | Species diversity index | Summer bird species | Winter bird species |
|---|---|---|---|
| 1 | Shannon-wieners index | 3.99 | 4.09 |
| 2 | Margalef's richness index | 16.84 | 17.53 |
| 3 | Pielou's evenness index | 0.83 | 0.84 |

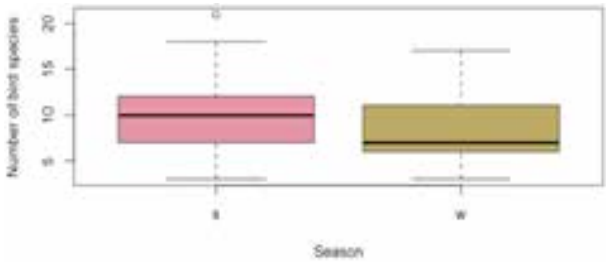


**Figure 4. Bird species richness in two different seasons.**

season than in the winter season (Figure 4). There was a significant effect of low vegetation percentage cover on the richness of bird species ($\chi 2_{1, 89}$= 113.88; P= 0.0064), with a higher richness of bird species in lower percentage cover (Figure 5). However, results of the GLM showed no significant differences in the richness of bird species with regard to other independent habitat variables.

## DISCUSSION

This study aimed to assess the species composition and the habitat factors influencing the bird species richness in Tibrekot community forests (CF) that helped to fulfill such research gap, particularly in the context of community forests in Nepal. A total of 166 bird species was recorded in 46 sample plots in the CF during summer and winter surveys. In Tibrekot CF, we recorded two globally near threatened vulture species, the Himalayan Griffon *Gyps himalayensis* and Cinereous Vulture *Aegypius monachus* and these two species were nationally Vulnerable and Endangered species, respectively.

Thus, the large number of bird species recorded including two globally near threatened species justifies the importance to birds of Tibrekot CF. The value of Shannon-wieners index (3.99 and 4.09) showed that richness and evenness of birds was high in both seasons in the study area. The value of Margalef's richness index (16.84 and 17.53) also showed that richness of birds was high. In addition, the value of Pielou's evenness index (0.83 and 0.84) showed that the bird species were equally distributed throughout the habitat in the study area. In contrast, some past studies have reported lower richness and evenness of birds in more disturbed regions (Peh et al. 2006; Shahabuddin & Kumar 2007).

The general positive effect on biodiversity is likely to

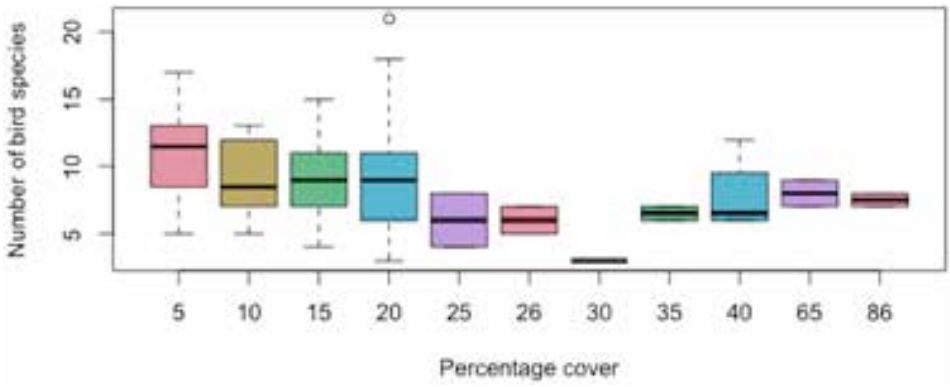


**Figure 5. Bird species richness along different percentage cover of low vegetation.**

reveal the contribution of CF not only in revitalizing the degraded forestlands, but also the communities' efforts in maintaining the richness of faunal species (Luintel et al. 2018; Joshi & Singh 2020; Joshi et al. 2020). The higher richness and diversity of forest specialists birds in sites within CF areas may be related to the fact that anthropogenic disturbance is limited in such areas (Baral & Inskipp 2005). Various studies have shown that extraction and over consumption of fodder, fuel wood, and non-timber forest product can negatively influence avifaunal communities (Shahabuddin & Kumar 2007; Dahal et al. 2009; Kumar et al. 2011; Inskipp et al. 2013). The different disturbance intolerant species of CF may therefore benefit from sustainable forest management that restricts the illegal removal of standing dead trees, fallen timber for firewood and pruning of canopies (Dahal et al. 2014; Joshi et al. 2019, 2020). However, the relationship between the richness of bird species and the level of disturbances were not investigated in this study.

Seasonality was one of the influencing factors for bird species richness in the study area. In Nepal, seasonal migration of birds is closely linked to changes between the dry and monsoon seasons. It was found to be the determining factor for the abundance and distribution of both migratory and non-migratory bird species (Girma et al. 2017). In addition, Manu & Cresswell (2007) reported that other environmental factors influence the distribution and richness of bird species including floristic composition, habitat structure, food availability, temperature, and climate. Pandey et al. (2020) reported that multiple variables have profound influences on bird diversity and richness in Nepal comprising habitat area, gradients of climate (temperature and precipitation), resource availability and disturbance. Adhikari et al. (2019) have mentioned that human disturbance negatively influences the distribution and diversity of bird species. Nevertheless, we did not take into account the climatic variables as well as habitat disturbance activities that can influence bird species composition and diversity. Heterogeneous and natural habitat conditions can help to protect the bird diversity in the mid-hills of Nepal (Basnet et al. 2016). Therefore, it is essential to conduct further studies on how birds respond to habitat modifications and the influence of different climatic and habitat biophysical variables at the local level. Such crucial information will help the concerned authorities to prepare the site-specific strategies and plans focused on protecting the bird species at the local level.

## CONCLUSION

Out of 166 bird species, 81 species were recorded in both seasons within the study area. Although richness of bird species was similar in the different seasons, relative abundance and species evenness was higher in summer. The most abundant bird species found in the study area was Black Bulbul *Hypsipetes leucocephalus*. There was a significant seasonal effect on richness of bird species with higher richness in summer season and at low vegetation percentage cover. Such vital information about the avifaunal species and the associated habitat factors in the community managed forest will help to develop strategies and plans to protect the avifaunal species and their habitats, which has also potential to initiate avifaunal tourism in Nepal for the benefit of local communities.

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**Appendix 1. Protection status of bird species.**

| | Species | Category | Number of observation |
|---|---|---|---|
| 1 | Total | | 166 |
| 2 | CITES | I | 1 |
| | | II | 19 |
| | | III | 1 |
| 3 | IUCN Global | Critically endangered | 3 |
| | | Endangered | 2 |
| | | Vulnerable | 0 |
| | | Near Threatened | 2 |
| 4 | IUCN National | Critically endangered | 2 |
| | | Endangered | 2 |
| | | Vulnerable | 5 |
| | | Near Threatened | 5 |
| 5 | B05 | | 5 |
| 6 | B07 | | 12 |
| 7 | B08 | | 22 |
| 8 | B11 | | 3 |

**Appendix 2. List of the most abundant bird species.**

| | Common name | Scientific name | Order | Family | Feeding character | No. of observations | |
|---|---|---|---|---|---|---|---|
| | | | | | | Summer | Winter |
| 1 | Barn Swallow | *Hirundo rustica* | Passeriformes | Hirundinidae | Insectivores | 30 | 78 |
| 2 | Black Bulbul | *Hypsipetes leucocephalus* | Passeriformes | Pycnonotidae | Omnivorous | 109 | 0 |
| 3 | Black-lored Tit | *Machlolophus xanthogenys* | Passeriformes | Paridae | Insectivores | 26 | 36 |
| 4 | Great Barbet | *Psilopogon virens* | Piciformes | Megalaimidae | Frugivorous | 83 | 18 |
| 5 | Grey-headed Canary-flycatcher | *Culicicapa ceylonensis* | Passeriformes | Stenostiridae | Insectivores | 31 | 33 |
| 6 | Grey-hooded Warbler | *Phylloscopus xanthoschistos* | Passeriformes | Phylloscopidae | Insectivores | 63 | 89 |
| 7 | Grey Treepie | *Dendrocitta formosae* | Passeriformes | Corvidae | Omnivorous | 65 | 61 |
| 8 | Long-tailed Minivet | *Pericrocotus ethologus* | Passeriformes | Campephagidae | Insectivores | 40 | 51 |
| 9 | Red-vented Bulbul | *Pycnonotus cafer* | Passeriformes | Pycnonotidae | Omnivorous | 32 | 34 |
| 10 | White-crested Laughingthrushh | *Garrulax leucolophus* | Passeriformes | Leiotrichidae | Insectivores | 92 | 67 |

**Appendix 3. List of total bird species (166) recorded in the study area.**

| | Common name | Scientific name |
|---|---|---|
| 1 | Ashy Drongo | *Dicrurus leucophaeus* |
| 2 | Ashy-throated Warbler | *Phylloscopus maculipennis* |
| 3 | Asian Barred Owlet | *Glaucidium cuculoides* |
| 4 | Asian Plain Martin | *Riparia chinensis* |
| 5 | Barn Swallow | *Hirundo rustica* |
| 6 | Bar-winged Flycatcher-shrike | *Hemipus picatus* |
| 7 | Black Bulbul | *Hypsipetes leucocephalus* |
| 8 | Black-chinned Babbler | *Cyanoderma pyrrhops* |
| 9 | Black Drongo | *Dicrurus macrocercus* |
| 10 | Black Eagle | *Ictinaetus malaiensis* |
| 11 | Black Francolin | *Francolinus francolinus* |
| 12 | Black-headed Jay | *Garrulus lanceolatus* |
| 13 | Black Kite | *Milvus migrans* |
| 14 | Black-lored Tit | *Machlolophus xanthogenys* |
| 15 | Black-throated Sunbird | *Aethopyga saturata* |
| 16 | Black-throated Thrush | *Turdus atrogularis* |
| 17 | Black-winged Cuckooshrike | *Lalage melaschistos* |
| 18 | Blue-bearded Bee-eater | *Nyctyornis athertoni* |
| 19 | Blue-capped Rock-thrush | *Monticola cinclorhyncha* |
| 20 | Blue-throated Barbet | *Psilopogon asiaticus* |
| 21 | Blue-throated Blue-flycatcher | *Cyornis rubeculoides* |
| 22 | Blue Whistling-thrush | *Myophonus caeruleus* |
| 23 | Blue-winged Minla | *Siva cyanouroptera* |
| 24 | Brahminy Starling | *Sturnia pagodarum* |
| 25 | Bronzed Drongo | *Dicrurus aeneus* |
| 26 | Buff-barred warbler | *Phylloscopus pulcher* |
| 27 | Cattle Egret | *Bubulcus ibis* |
| 28 | Chestnut-bellied Nuthatch | *Sitta cinnamoventris* |
| 29 | Chestnut-bellied Rock-thrush | *Monticola rufiventris* |
| 30 | Chestnut-headed Tesia | *Cettia castaneocoronata* |
| 31 | Cinereous Tit | *Parus cinereous* |
| 32 | Cinereous Vulture | *Aegypius monachus* |
| 33 | Collared Owlet | *Glaucidium brodiei* |
| 34 | Collared Scops-owl | *Otus lettia* |
| 35 | Common Barn-owl | *Tyto alba* |
| 36 | Common Green Magpie | *Cissa chinensis* |
| 37 | Common Hawk-cuckoo | *Hierococcyx varius* |
| 38 | Common Hoopoe | *Upupa epops* |
| 39 | Common Kestrel | *Falco tinnunculus* |
| 40 | Common Myna | *Acridotheres tristis* |
| 41 | Common Tailorbird | *Orthotomus sutorius* |
| 42 | Coppersmith Barbet | *Psilopogon haemacephalus* |
| 43 | Crested Serpent-eagle | *Spilornis cheela* |
| 44 | Crimson Sunbird | *Aethopyga siparaja* |

| | Common name | Scientific name |
|---|---|---|
| 45 | Egyptian Vulture | *Neophron percnopterus* |
| 46 | Eurasian Tree Sparrow | *Passer montanus* |
| 47 | Eurasian Wryneck | *Jynx torquilla* |
| 48 | Fire-breasted Flowerpecker | *Dicaeum ignipectus* |
| 49 | Fulvous-breasted Woodpecker | *Dendrocopos macei* |
| 50 | Golden-throated Barbet | *Psilopogon franklinii* |
| 51 | Goosander | *Mergus merganser* |
| 52 | Great Barbet | *Psilopogon virens* |
| 53 | Greater Coucal | *Centropus sinensis* |
| 54 | Greater Flameback | *Chrysocolaptes guttacristatus* |
| 55 | Greater Yellownape | *Chrysophlegma flavinucha* |
| 56 | Green-backed Tit | *Parus monticolus* |
| 57 | Green-billed Malkoha | *Phaenicophaeus tristis* |
| 58 | Greenish Warbler | *Phylloscopus trochiloides* |
| 59 | Green Shrike-babbler | *Pteruthius xanthochlorus* |
| 60 | Green-tailed Sunbird | *Aethopyga nipalensis* |
| 61 | Grey-backed Shrike | *Lanius tephronotus* |
| 62 | Grey-bellied Cuckoo | *Cuculus passerinus* |
| 63 | Grey-bellied Tesia | *Tesia cyaniventer* |
| 64 | Grey Bushchat | *Saxicola ferreus* |
| 65 | Grey-headed Canary-flycatcher | *Culicicapa ceylonensis* |
| 66 | Grey-hooded Warbler | *Phylloscopus xanthoschistos* |
| 67 | Grey-naped Woodpecker | *Picus canicapillus* |
| 68 | Grey Nightjar | *Caprimulgus jotaka* |
| 69 | Grey-throated Babbler | *Stachyris nigriceps* |
| 70 | Grey Treepie | *Dendrocitta formosae* |
| 71 | Grey Wagtail | *Motacilla cinerea* |
| 72 | Hair-crested Drongo | *Dicrurus hottentottus* |
| 73 | Hill Partridge | *Arborophila torqueola* |
| 74 | Himalayan Bulbul | *Pycnonotus leucogenys* |
| 75 | Himalayan Griffon | *Gyps himalayensis* |
| 76 | Himalayan Swiftlet | *Aerodramus brevirostris* |
| 77 | Hodgson's Treecreeper | *Certhia hodgsoni* |
| 78 | House Crow | *Corvus splendens* |
| 79 | House Sparrow | *Passer domesticus* |
| 80 | House Swift | *Apus nipalensis* |
| 81 | Hume's Leaf-warbler | *Phylloscopus humei* |
| 82 | Indian Cuckoo | *Cuculus micropterus* |
| 83 | Indian Cuckooshrike | *Coracina macei* |
| 84 | Indian Golden Oriole | *Oriolus kundoo* |
| 85 | Indian Pond-heron | *Ardeola grayii* |
| 86 | Jungle Myna | *Acridotheres fuscus* |
| 87 | Kalij Pheasant | *Lophura leucomelanos* |
| 88 | Large-billed Crow | *Corvus macrorhynchos* |

| | Common name | Scientific name |
|---|---|---|
| 89 | Lemon-rumped warbler | *Phylloscopus chloronotus* |
| 90 | Lesser Racquet-tailed Drongo | *Dicrurus remifer* |
| 91 | Lesser Yellownape | *Picus chlorolophus* |
| 92 | Little Egret | *Egretta garzetta* |
| 93 | Long-tailed Broadbill | *Psarisomus dalhousiae* |
| 94 | Long-tailed Minivet | *Pericrocotus ethologus* |
| 95 | Long-tailed Shrike | *Lanius schach* |
| 96 | Maroon Oriole | *Oriolus traillii* |
| 97 | Mountain Bulbul | *Ixos mcclellandii* |
| 98 | Mountain Hawk-eagle | *Nisaetus nipalensis* |
| 99 | Mountain Scops-owl | *Otus spilocephalus* |
| 100 | Northern Wren | *Troglodytes troglodytes* |
| 101 | Olive-backed Pipit | *Anthus hodgsoni* |
| 102 | Orange-bellied Leafbird | *Chloropsis hardwickii* |
| 103 | Orange-headed Thrush | *Geokichla citrina* |
| 104 | Oriental Magpie-robin | *Copsychus saularis* |
| 105 | Oriental Turtle-dove | *Streptopelia orientalis* |
| 106 | Oriental White-eye | *Zosterops palpebrosus* |
| 107 | Paddyfield Pipit | *Anthus rufulus* |
| 108 | Peregrine Falcon | *Falco peregrinus* |
| 109 | Plumbeous Water-redstart | *Phoenicurus fuliginosus* |
| 110 | Puff-throated Babbler | *Pellorneum ruficeps* |
| 111 | Red-billed Blue Magpie | *Urocissa erythroryncha* |
| 112 | Red-billed Leiothrix | *Leiothrix lutea* |
| 113 | Red-headed Tit | *Aegithalos iredalei* |
| 114 | Red-headed Vulture | *Sarcogyps calvus* |
| 115 | Red-rumped Swallow | *Cecropis daurica* |
| 116 | Red-throated Flycatcher | *Ficedula albicilla* |
| 117 | Red-vented Bulbul | *Pycnonotus cafer* |
| 118 | Rock Dove | *Columba livia* |
| 119 | Rose-ringed Parakeet | *Psittacula krameri* |
| 120 | Rosy Pipit | *Anthus roseatus* |
| 121 | Rufous-bellied Niltava | *Niltava sundara* |
| 122 | Rufous-chinned Laughingthrush | *Garrulax rufogularis* |
| 123 | Rufous-gorgeted Flycatcher | *Ficedula strophiata* |
| 124 | Rufous-throated Partridge | *Arborophila rufogularis* |
| 125 | Rufous Woodpecker | *Micropternus brachyurus* |
| 126 | Rusty-cheeked Scimitar-babbler | *Erythrogenys erythrogenys* |
| 127 | Scaly-breasted Cupwing | *Pnoepyga albiventer* |

| | Common name | Scientific name |
|---|---|---|
| 128 | Scaly-breasted Munia | *Lonchura punctulata* |
| 129 | Scaly Thrush | *Zoothera dauma* |
| 130 | Scarlet Minivet | *Pericrocotus flammeus* |
| 131 | Shikra | *Accipiter badius* |
| 132 | Slaty-backed Flycatcher | *Ficedula erithacus* |
| 133 | Slaty-headed Parakeet | *Psittacula himalayana* |
| 134 | Slender-billed Vulture | *Gyps tenuirostris* |
| 135 | Small Niltava | *Niltava macgrigoriae* |
| 136 | Snowy-browed Flycatcher | *Ficedula hyperythra* |
| 137 | Speckled Piculet | *Picumnus innominatus* |
| 138 | Spiny Babbler | *Acanthoptila nipalensis* |
| 139 | Spotted froktal | *Enicurus maculatus* |
| 140 | Spotted Owlet | *Athene brama* |
| 141 | Steppe Eagle | *Aquila nipalensis* |
| 142 | Striated Prinia | *Prinia crinigera* |
| 143 | Thick-billed Warbler | *Arundinax aedon* |
| 144 | Tickell's Leaf-warbler | *Phylloscopus affinis* |
| 145 | Ultramarine Flycatcher | *Ficedula superciliaris* |
| 146 | Velvet-fronted Nuthatch | *Sitta frontalis* |
| 147 | Verditer Flycatcher | *Eumyias thalassinus* |
| 148 | Wallcreeper | *Tichodroma muraria* |
| 149 | Wedge-tailed Green-pigeon | *Treron sphenurus* |
| 150 | Western Koel | *Eudynamys scolopaceus* |
| 151 | Western Spotted Dove | *Spilopelia suratensis* |
| 152 | Western Yellow Wagtail | *Motacilla flava* |
| 153 | Whistler's Warbler | *Phylloscopus whistleri* |
| 154 | White-bellied Erpornis | *Erpornis zantholeuca* |
| 155 | White-breasted Kingfisher | *Halcyon smyrnensis* |
| 156 | White-browed Shrike-babbler | *Pteruthius aeralatus* |
| 157 | White-browed Wagtail | *Motacilla maderaspatensis* |
| 158 | White-capped Water-redstart | *Phoenicurus leucocephalus* |
| 159 | White-crested Laughingthrush | *Garrulax leucolophus* |
| 160 | White-rumped Munia | *Lonchura striata* |
| 161 | White-rumped Vulture | *Gyps bengalensis* |
| 162 | White-tailed Nuthatch | *Sitta himalayensis* |
| 163 | White-throated Fantail | *Rhipidura albicollis* |
| 164 | White-throated Laughingthrush | *Garrulax albogularis* |
| 165 | White Wagtail | *Motacilla alba* |
| 166 | Yellow-bellied Fairy-fantail | *Chelidorhynx hypoxanthus* |

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**COMMUNICATION**

# A large mammal survey in Koyli Alpha Community Wildlife Reserve and its surroundings in the Great Green Wall extension area in Senegal

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**Abstract:** Wildlife in the Great Green Wall (GGW) area, northern Senegal, is threatened by the cumulative effects of anthropogenic activities, drought, and climatic changes. To support conservation planning in line with the GGW management objectives, we studied large mammal diversity in the Koyli Alpha Community Wildlife Reserve in the GGW extension area. We interviewed local communities, made reconnaissance & transect walks, placed camera traps, and carried out fixed point surveys to map the distribution of mammals & to estimate their relative abundance. The surveys were conducted between May 2017 and December 2019. We identified the presence of nine mammal species belonging to six families: one lagomorph, Cape Hare *Lepus capensis*; seven carnivores, Common Jackal *Canis aureus,* Pale/Sand Fox *Vulpes pallida,* Wild Cat *Felis silvestris,* Marsh Mongoose *Atilax paludinosus,* Honey Badger *Mellivora capensis,* Zorilla *Ictonyx striatus,* Common Genet *Genetta genetta*, and one primate, Patas Monkey *Erythrocebus patas*. Our results indicate that the most of the observed species range broadly across the Koyli Alpha Reserve. The Wild Cat and the Sand Fox were also found outside the reserve around the village of Koyli Alpha. Camera trapping events of humans and domestic animals were high throughout the survey area, and the majority of the large mammals observed were mainly nocturnal. The diversity of large wild mammals identified during this study points to the urgent need for the implementation of a management plan of the biodiversity in this area of the Ferlo.

**Keywords:** Biodiversity, camera trapping, Ferlo, Koyli Alpha Reserve, management plan, nocturnal.

**French:** La faune sauvage de la zone d'extension du projet de reboisement de la grande muraille verte (GMV) au Nord du Sénégal est menacée de disparition suite aux effets cumulatifs d'activités anthropogéniques, de la sécheresse et du changement climatique. Afin de contribuer à la conservation de cette biodiversité, en rapport avec les objectifs du projet de la GMV, nous avons étudié la biodiversité de grands mammifères sauvages dans la réserve naturelle communautaire de Koyli Alpha et ses environs, dans la zone d'extension du projet de la GMV. Nous avons effectué des enquêtes auprès des populations locales, des prospections de transects de reconnaissance à pied, des piégeages photographiques et des suivis au point fixe pour pouvoir cartographier la distribution géographique des mammifères et estimer leurs abondances relatives. Les travaux ont été effectués entre mai 2017 et décembre 2019. Nous avons identifié pour cette période la présence de neuf espèces de mammifères appartenant à six familles : une lagomorpha, Lièvre du cap (Lepus capensis); sept carnivores, Chacal doré (Canis aureus), Renard pâle/roux des sables (Vulpes pallida), Chat sauvage (Felis silvestris), Mangouste des marais (Atilax paludinosus), Ratel (Mellivora capensis), Zorille (Ictonyx striatus), Genette commune (Genetta genetta), et un primate, Singe patas (Erythrocebus patas). Nos résultats indiquent que la plupart des espèces observées vivent dans et aux environs de la réserve naturelle communautaire de Koyli Alpha. Le chat sauvage et le renard ont aussi été observés aux environs du village de Koyli Alpha. Le nombre d'événements du piégeage photographique sur lesquels des images d'humains et d'animaux apparaissent est élevé pour cette zone d'étude, et la majeure partie des grands mammifères sauvages observés sont de mœurs nocturnes. La diversité de grands mammifères identifiée par cette étude met en exergue le besoin urgent de mettre en place un plan d'aménagement de la biodiversité dans cette partie du Ferlo.

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**Author contributions:** AN has participated in all the stages of field works, data analysis and the writing of the manuscript. PIN has contributed in all the stages of this work to the design of the study project up the manuscript submission and revisions.

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## INTRODUCTION

Throughout history, humans have profoundly changed their environment through degradation and overexploitation of natural resources. These environmental modifications are usually related to natural resource extraction, use of unsustainable agricultural practices, infrastructure development, and human population growth, and these actions have negative impacts on biodiversity. Habitat loss is of particularly high prevalence in Africa and South America, and it is greatly affecting the vertebrates living in these regions (Visconti et al. 2020). Suitable habitat for mammals has declined globally by 5–16 %, and Africa with declines of up to 25% today and South America were the most affected regions (Baisero et al. 2020). According to these authors, loss of habitats of mammals is expected to affect a higher proportion in 2050 if adequate conservation management plans are not implemented. The Great Green Wall (GGW) of the Sahara and Sahel is an African reforestation initiative to combat desertification, reduce poverty, and to address the effects of climate change.

The GGW initiative has been envisioned by African leaders, and is led by the African Union. It is being implemented in targeted countries between Senegal and Djibouti. The GGW involves many actors and comprises a vast mosaic of healthy and productive landscapes from western to eastern Africa supporting resilient livelihoods with the aim of contributing to multiple environmental and development targets (Davies 2017). The initiative started in 2005 and extends over 7,000 km in length and 15 km in width, from Dakar (Senegal) in western Africa to Djibouti (Djibouti) in eastern Africa. In Senegal, the project is under the responsibility of the "Agence sénégalaise de la reforestation et de la grande muraille verte (ASERGMV)", a reforestation agency created in response to climate change and increasing poverty of local populations.

In Senegal, the GGW crosses Ferlo – the most hostile climatic zone of the country in the northern parts, which underwent two long drought periods in 1973–1974 and 1985–1986. These droughts led to ecological, economic, and social imbalances. The implementation of the GGW has made a notable contribution to the restoration of the original ecosystems, and to revive the economic and social activities of local populations in this region. The Food and Agricultural Organization of the United Nations (FAO) also supported local populations and the Senegalese's administration through the Agence Nationale de la Grande Muraille Verte (ANGMV) for instating a community wildlife reserve, 'Réserve Naturelle Communautaire (RNC) de Koyli Alpha' also called 'FAO wildlife reserve', as a response to the long drought. The main objective of the creation of this protected area was to restore degraded ecosystems, promote resilience and productivity of the agro-sylvo-pastoral systems through the involvement of local communities in the management of biodiversity and wildlife habitats (http://www.fao.org/senegal/actualites/detail-events/fr/c/1203521/, consulted 08/23/2020).

Many studies have been undertaken in the Ferlo area as part of the GGW project (Guisse et al. 2013; Boëtsch et al. 2019), but only a few of them have focused on wildlife (Niang 2017; Niang et al. 2019a,b). Generally, there is a scarcity of data on wildlife of this region of Senegal (Poulet 1972; Bourlière et al. 1976). Therefore, the aim of this study was to describe the diversity of large mammals present in the GGW portion in Senegal, to document their distribution and their interactions with domestic animals, as well as the local human population. We focused on Koyli Alpha for a more detailed study. Our main goal was to determine the status of large mammalian diversity of this area in the context of climate change, and generate scientific data to support decision-making in order to restore the wildlife habitat of this region. We believe that the impacts of the drought of 1973–1974 and 1985–1986, combined with the effects of climate change and anthropogenic activities, highlight the need to better understand the dynamics of the large wild mammals present in the GGW.

## MATERIALS AND METHODS

### Study area

The study was carried out in a 45 km$^2$ area in Koyli Alpha (latitude 15.730; longitude -15.511), department of Linguere, region of Louga (Image 1). Local populations belonging to the Peulh ethnic group adhere perfectly to the orientation of the GGW project. The main economic activities of these local communities are cattle farming and cattle trade. Therefore, livestock grazing is highly prevalent in this area. The FAO helped to implement a community wildlife reserve of about 700 ha, Réserve Naturelle Communautaire à Koyli Alpha (RNC). The main objective of this reserve is to contribute to the conservation of the biodiversity of the region by protecting the remaining wildlife and reintroducing other species that have been extirpated. People are allowed access to the reserve at certain times, and the RNC is open for livestock grazing during the dry season.

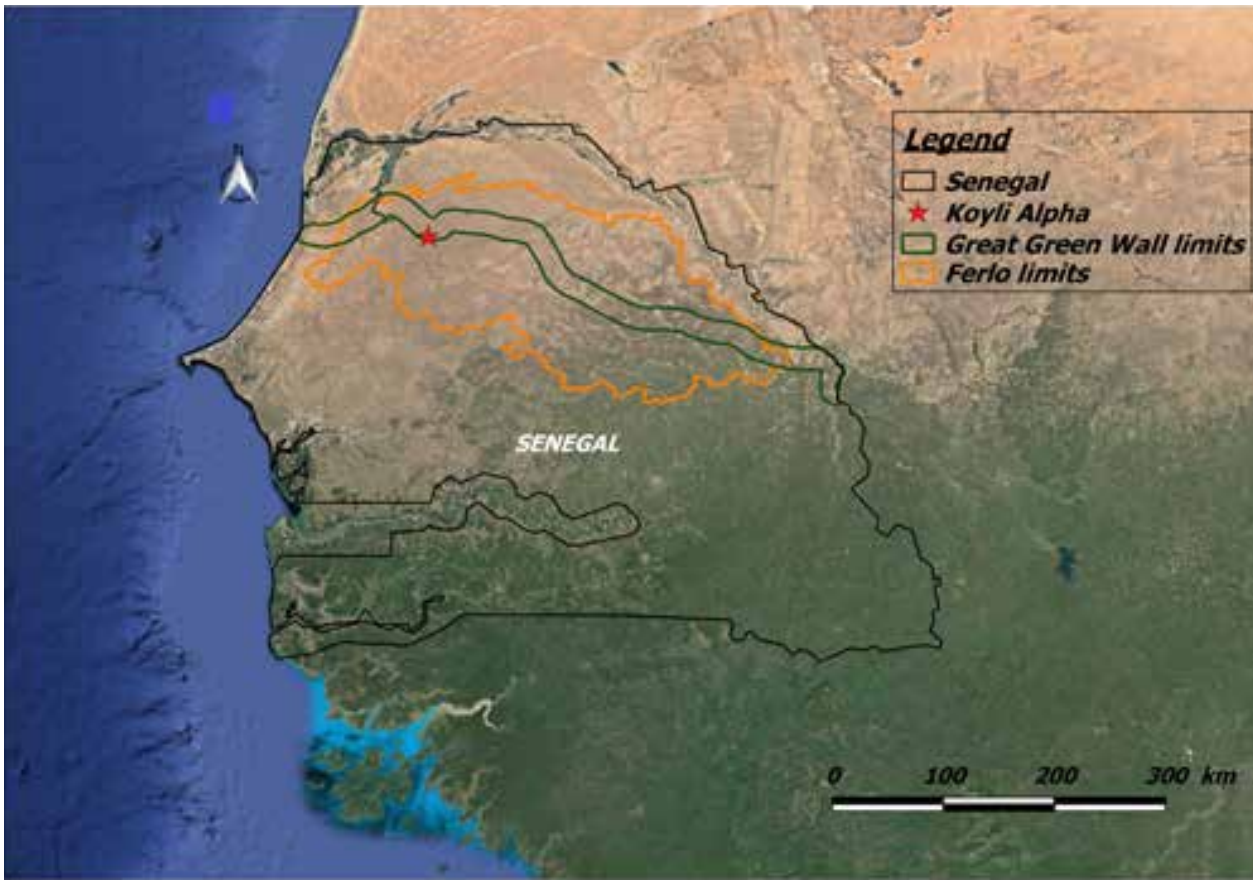


**Image 1. Location of the survey area in northern Senegal, showing the village of Koyli Alpha the extension of the Great Green Wall in Senegal and the limits of the ecogeographic zone of the Ferlo (preparedby P.I.Ndiaye, Projection: UTM Zone 28N datum WGS 84; data source: Google Earth, Global Administrative Areas and GMV)**

The climate is hot and dry tropical, characteristic of the continental Sahelian domain which lies between the isohyets 100 and 500 mm (CSE 2018). Annual rainfall ranges from 200 to 400 mm and the mean annual temperature is about 28 ºC ($t_{max}$ 43 ºC, $t_{min}$ 16 ºC). The dry season occurs from October to June and the rainy season from July to September (Agence Nationale de l'Aviation Civile et de la Météorologie du Sénégal 2018; CSE 2018; Niang 2017). Vegetation is characterized by a dominance of the tree species *Balanites aegyptiaca, Acacia senegal* and *A. radiana.*

**Data collection**

Data was collected between May 2017 and December 2019. At the beginning of the study, we conducted semi-structured interviews with the local community. We interviewed 30 people randomly selected from both genders with age ranging between 25 and 80 years in Koyli Alpha to get an idea of the state of the wildlife in this area. All interviewees were Peulh, who are known to possess a good understanding of their environment because they are mainly cattle herders. Results from the interviews allowed us to refine subsequent field surveys using four methods: 1) reconnaissance walks (recces), 2) line transects, 3) camera-trapping, and 4) fixed-point surveys.

These field surveys aimed at confirming the diversity of terrestrial mammals in the area around Koyli Alpha. Reconnaissance walks consist of walking in a predetermined direction along the path of least resistance throughout the survey area, but where one is allowed to deviate from the main direction (Kühl et al. 2008; Ross & Reeve 2011; Ndiaye et al. 2018). Reconnaissance walks were used during the prospection outside of the study areas – in two reforestation plots of the GGW (2012A and 2012B), in RNC, and along the watercourse of Lac de guier. Within the protected areas, we used line transects sampling to assess the presence or absence of large mammals (Plumptre 2000; Marshall et al. 2008). With the line transect methodology, one walks in a straight line and cannot deviate from the transect bearing (Image 2). Transects were prospected

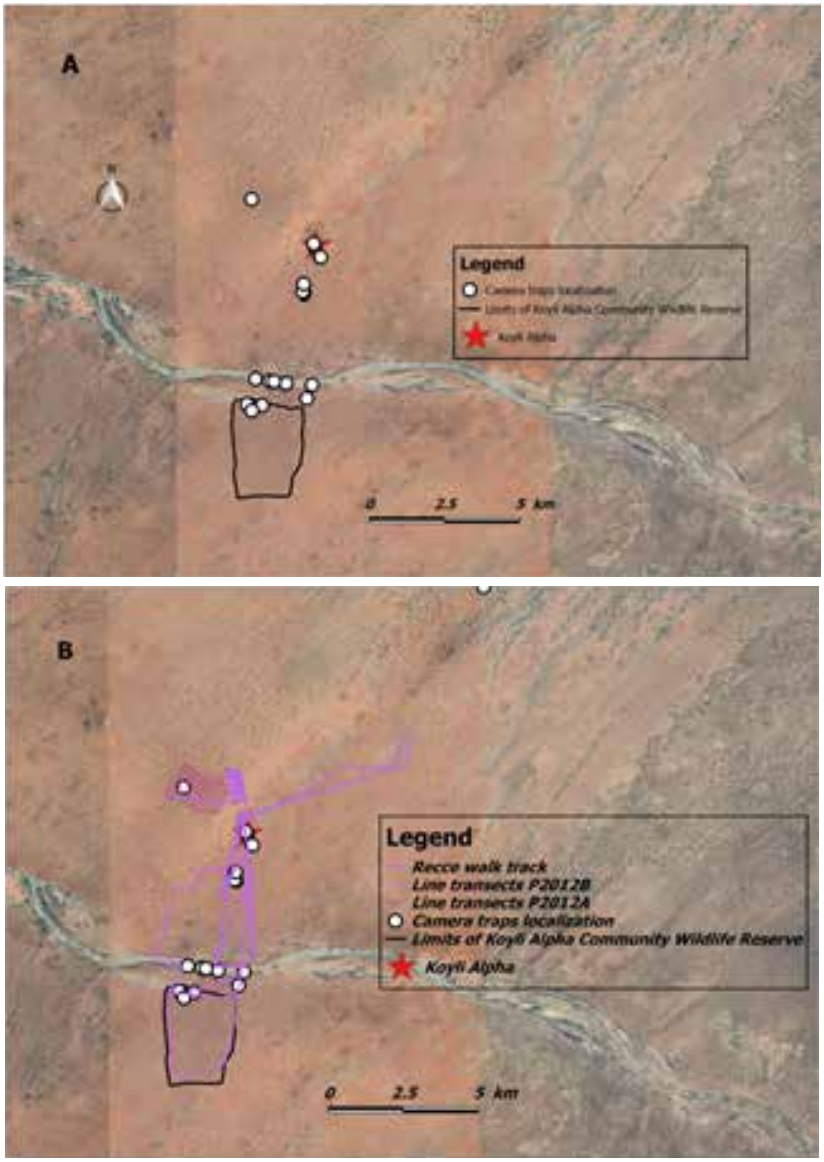


**Image 2. A—Location of the camera traps | B—prospected transects inside and outside of the reforestation plots (Parcelles 2012A and 2012B), around the lac de guier course of water and the FAO wildlife reserve (created by P.I.Ndiaye, Projection: UTM Zone 28N datum WGS 84; data source: Google Earth, Global Administrative Areas and GMV).**

in the morning between 0600 and 1200 h and in the afternoon between 1600 and 1900 h with a speed of up to 1.5 km per hour for a total of 43 days between May 2017 and December 2019.

Fixed point surveys were used as an additional method to increase our chances of detecting wildlife, and to collect additional information on the species we observed. For example, after detecting a group of Patas Monkey we stayed at a fixed point near the Koyli Alpha wildlife reserve between 0700 and 1900 h to determine its group size.

In addition, 33 camera traps were placed in strategic sites, such as water points and ground holes, to maximize the probability of detection of large mammals (Image 2). Camera traps (Bushnell Trophy Cam HD Essential) and Scout Gaurd were operational for 24 hours a day during 24/24. The camera traps are triggered by a highly sensitive passive infra-red (PIR) motion sensor with a delay of 0.3 seconds. We use a recommended minimal exploratory logistical set-up (Orban et al. 2018; Rovero et al. 2013) of 1,000 camera trap days. Camera traps were set to record only photos.

**Data processing and analysis**

Observations from the fixed point survey near the RNC (15.68329; -15.52626) between 0700 and 1900

h have allowed us to determine the group size of one group of Patas Monkeys.

Data captured with camera traps were stored on memory cards labelled with the site, location and camera trap number, downloaded and saved on a hard drive. Large terrestrial mammals were identified based on the author's knowledge and using relevant field guides (Kingdon 1997; Kingdon & Hoffmann 2013), and were then assigned relevant IUCN Red List status according to Red List of Threatened Species (www.iucnredlist.org 29.ii.2020). Large terrestrial mammals that could not be individually distinguished (species without individually identifiable morphological characteristics) and captured within 15 minutes of each other at the same station were considered the same individual and recorded as a single detection event. After 15 minutes, they were considered a new detection. Photographs with two individuals of the same or different species were considered as two events in the dataset. To calculate the photo-capture rate index (PCRI) of each species, we first identified independent captures (i.e., captures that were 15 minutes apart for each station), then we divided the number of independent captures obtained at each trap by trapping specific effort (i.e., number of trapping days that a particular trap was active) and expressed the estimate as observations per 100 trapping days (Carbone et al. 2001; Lahkar et al. 2018). We calculated the 95% confidence interval of the PCRI for each species using the variations between individual camera stations.

All observations from transect and fixed-point surveys as well as the trap specific PCRI were mapped to display the geographic distribution of species. All spatial tasks were conducted using the open source software QGIS 2.6.1.

## RESULTS

### Interviews with the local communities

During the interviews, local communities indicated the presence of seven terrestrial large mammals' species: Common Genet *Genetta genetta,* Honey Badger *Mellivora capensis,* Jackal *Canis* sp., Wild Cat *Felis silvestris,* Patas Monkey *Erythrocebus patas,* Cape Hare *Lepus capensis*, and Crested Porcupine *Hystrix cristata*; and the suspected disappearance of five large species: Roan Antelope *Hippotragus equinus,* Spotted Hyaena *Crocuta crocuta,* Striped Hyaena *Hyaena hyaena,* Common Warthog *Phacochoerus africanus*, and Leopard *Panthera pardus*. Poaching was not reported to occur in this area, however, derived animal products were reported to be used by traditional healers.

### Abundance and distribution of mammals

The combination of various methods during this study has permitted us to identify nine species of large wildlife mammals (Table 1). Local communities have reported the presence of these species during the interviews. However, they pointed to the increasing difficulties of seeing them actually. Cape Hare, Wild Cat and Sand Fox were observed widely throughout the study area (Figure 1), whereas Patas Monkeys, Common Genet, and Common (Golden) Jackal were observed only in the RNC. Most of the observations or trapping events were recorded on the edges of the Lac de guier. We also discovered that some species, namely the Wild Cat and Sand Fox, were using the same habitats at the same time.

Fixed-point surveys near the RNC of Koyli Alpha have permitted us to count 47 individuals in the single group of Patas Monkeys that we observed in the study area.

During the camera trapping surveys, we obtained a total of 7,076 photographs of wild animals, domestic animals, and humans. Most of the observations were of domestic animals (6,094) or humans (543), with only 439 observations being of large wild mammals. These observations were on nine species belonging to seven families and three orders (Table 1, Appendix 1). Simultaneous presence of large wild mammals and domestic animals in the same picture was rarely observed during this study (only 12 pictures), and only from three cameras placed near a village (Appendix 1). These observations occurred at night or early in the morning.

## DISCUSSION AND CONCLUSION

### Diversity of terrestrial large mammals in Koyli Alpha

Interviews with members of the local communities were of great help in guiding our research. They gave us an overview of the animal diversity and their distribution in Koyli Alpha. Our results however revealed that the number of large mammalian species in Koyli Alpha is greater than what is assumed by the local communities. Except for the Patas Monkey, the species of large mammals present in Koyli Alpha are mainly nocturnal carnivores. For this reason, it is more difficult to detect their presence with recces and line transect surveys, which may explain the scarcity of results with reconnaissance walks and line transects. In addition, local communities mentioned the disappearance of Dorcas

**Table 1. Repertory of the large wild mammals encountered in the Great Green Wall area and some indications to evaluate their relative abundance.**

| Orders | Families | Species | Direct observations during recces and transect surveys | | Index | | Camera trapping | | | | IUCN Red List category |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nb. Obs | % | Nb. Index | % | Nb. Capture | % | Capture rate from total event | PCRI (95%) | |
| Carnivora | Canidae | *Canis aureus* | 10 | 2.74 | 50 | 10.2 | 13 | 0.18 | 0.0088 | 0.075 (0.020; 0.182) | LC |
| | | *Vulpes pallida* | 30 | 8.22 | 11 | 2.25 | 300 | 4.24 | 0.0132 | 0.105 (0.039; 0.215) | LC |
| | Felidae | *Felis silvestris* | 51 | 13.97 | 41 | 8.40 | 43 | 0.61 | 0.0220 | 0.125 (0.061; 0.217) | LC |
| | Herpestidae | *Atilax paludinosis* | 1 | 0.27 | | | 51 | 0.72 | 0.0154 | 0.098 (0.040; 0.192) | LC |
| | Mustelidae | *Ictonyx striatus* | 0 | 0 | | | 1 | 0.01 | 0.0022 | 0.166 (0.004; 0.641) | LC |
| | | *Mellivora capensis* | 2 | 0.55 | 60 | 12.30 | 5 | 0.07 | 0.0066 | 0.272 (0.060; 0.609) | LC |
| | Viverridae | *Genetta genetta* | 2 | 0.55 | 40 | 8.20 | 7 | 0.10 | 0.0088 | 0.075 (0.020; 0.182) | LC |
| Lagomorpha | Leporidae | *Lepus capensis* | 41 | 11.23 | 276 | 56.56 | 0 | | | | LC |
| Primates | Cercopithecidae | *Erythrocebus patas* | 228 | 62.47 | 10 | 2.05 | 19 | 0.27 | 0.0066 | 0,063 (0.013; 0.175) | NT |
| NA | NA | Domestic animals | - | - | - | - | 6094 | 86.12 | 0.2499 | 10.71 | |
| NA | NA | Humans | - | - | - | - | 543 | 7.67 | 0.0403 | 4.24 | |
| | | **Total** | **365** | **100** | **488** | **100** | **7076** | **100** | | | |

**Nb. Obs**—indicates the total number of direct observations of the species of large wild mammals | **Nb. Index**—indicates the number of observations of the signs of presence of the large wild mammals (for example footprints and droppings) | **Nb. Capture—**indicates the number of camera trap photos of the large wild mammal species; capture rate from total event is the ratio of independent photograph to the number of trap day (number of 24h periods during which cameras were operating) | **PCRI**—photo-capture rate index (see Materials and Methods for details).

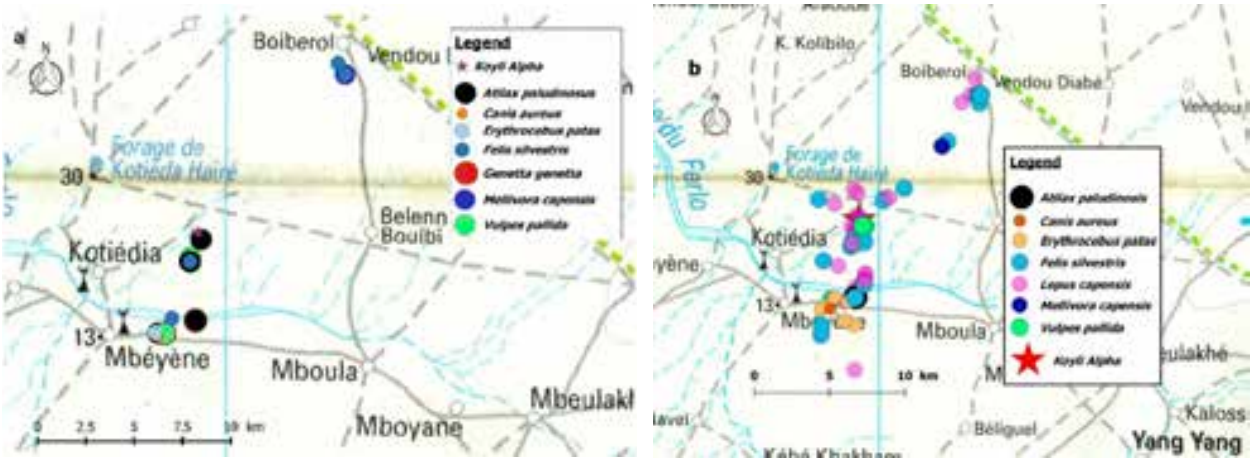


**Figure 1. Map of the occurrences of terrestrial large mammals in the study area, using results from: a—trapping cameras; and b—Reconnaissance walks and linear transect surveys. (preapared by P.I. Ndiaye, Projection: UTM Zone 28N datum WGS 84)**

Gazelle, Red-fronted Gazelle, Mhorr Gazelle, Common Warthog, and Striped Hyaena. The disappearance of these species in Koyli Alpha was supported by our surveys. The local communities of Koyli Alpha showed great interest to learn more and to be involved in the GGW program. Several initiatives to reintroduce extinct or endangered species such as the Scimitar-horned Oryx *Oryx dammah*, the African Spurred Tortoise *Centrochelys sulcata*, and the Dorcas Gazelle *Gazella dorcas* are currently underway in Ferlo to restore animal

diversity, in parallel with reforestation activities of the GGW program. Large wild mammals living in Ferlo are exposed to many types of anthropogenic and natural pressures related to the hot and dry climate and the local population with low economic power (Davies 2017; Baisero et al. 2020). Hence the establishment of the Ferlo Biosphere Natural Reserve and the RNC of Koyli Alpha (Abáigar et al. 2013, 2017) may be a necessary initiative to improve the protection of large mammals in this hot and dry sahelian ecosystem.

**Impacts of anthropic factors and global climate change on the diversity of large wild mammals**

The scarcity of observations of large wild mammals during the transect surveys in Koyli Alpha can be indicative of the risk of species extinction as presented by Baisero et al. (2020). Our data support the hypothesis of Davies (2017), that reported that human population growth combined with increasing wealth are the major factors behind biodiversity declines in the Sahel. Already large areas of Senegal are classified as 'Near Threatened' in accordance to the UICN Red List of Ecosystems. Biodiversity loss in these Sahelian ecosystems will be a great concern because they support an impressively large number of endemic species that are not found elsewhere on the planet. Specific to our study, both the Sand Fox and Patas Monkeys are endemic to this area. These species are distributed only in the Sahel – from Senegal to Ethiopia for Sand Fox and from Senegal to Sudan for Patas Monkey, respectively (www.iucnredlist.org, consulted 05.iii.2020; De Jong et al. 2020).

**Distribution of large mammals in relation to the presence of domestic animals and human population**

The high percentage of domestic animals and humans on camera trapping pictures and as recorded on transects indicate that some species of large wild mammals can continue to cohabit with domestic animals and humans despite the difficult ecological and social conditions of this site. However, it should be noted that the presence of human populations in large numbers in the study area is linked to the presence of livestock. In addition, the large wild mammal species found in the area are mostly nocturnal carnivores. This may justify an absence of interspecific competition between the species. Thus, the implementation of a good management plan of habitat and their natural resources can provide the conservation of large wild mammals in this area.

**Methodological considerations**

The camera trapping method has been used widely across the globe as a scientific tool to study medium to large terrestrial mammals and birds in often remote and difficult habitats. The number of publications per year that used camera trapping increased from less than 50 during 1993–2003 to more than 200 during 2004–2014 (Bahaa-el-din et al. 2018; Bruce et al. 2018; Rovero & Zimmermann 2016; Orban et al. 2018; Lahkar et al. 2018). Here, combining interviews and direct observations with camera trapping surveys allowed us to gain a comprehensive understanding of mammal diversity in the study area. Camera traps further provided detailed information on the high spatial and temporal overlap between wild mammals, humans and domestic animals.

**Conclusions**

This study reveals the presence of nine species of terrestrial large wild mammals that survive in the arid conditions of Koyli Alpha area. Most of the species recorded are nocturnal carnivores, and only a few direct observations were made during day time surveys. Our results contribute to a deeper knowledge of the mammal diversity in this extension area of the Great Green Wall, which can be used for developing management and conservations plans of the large wild mammals in this area.

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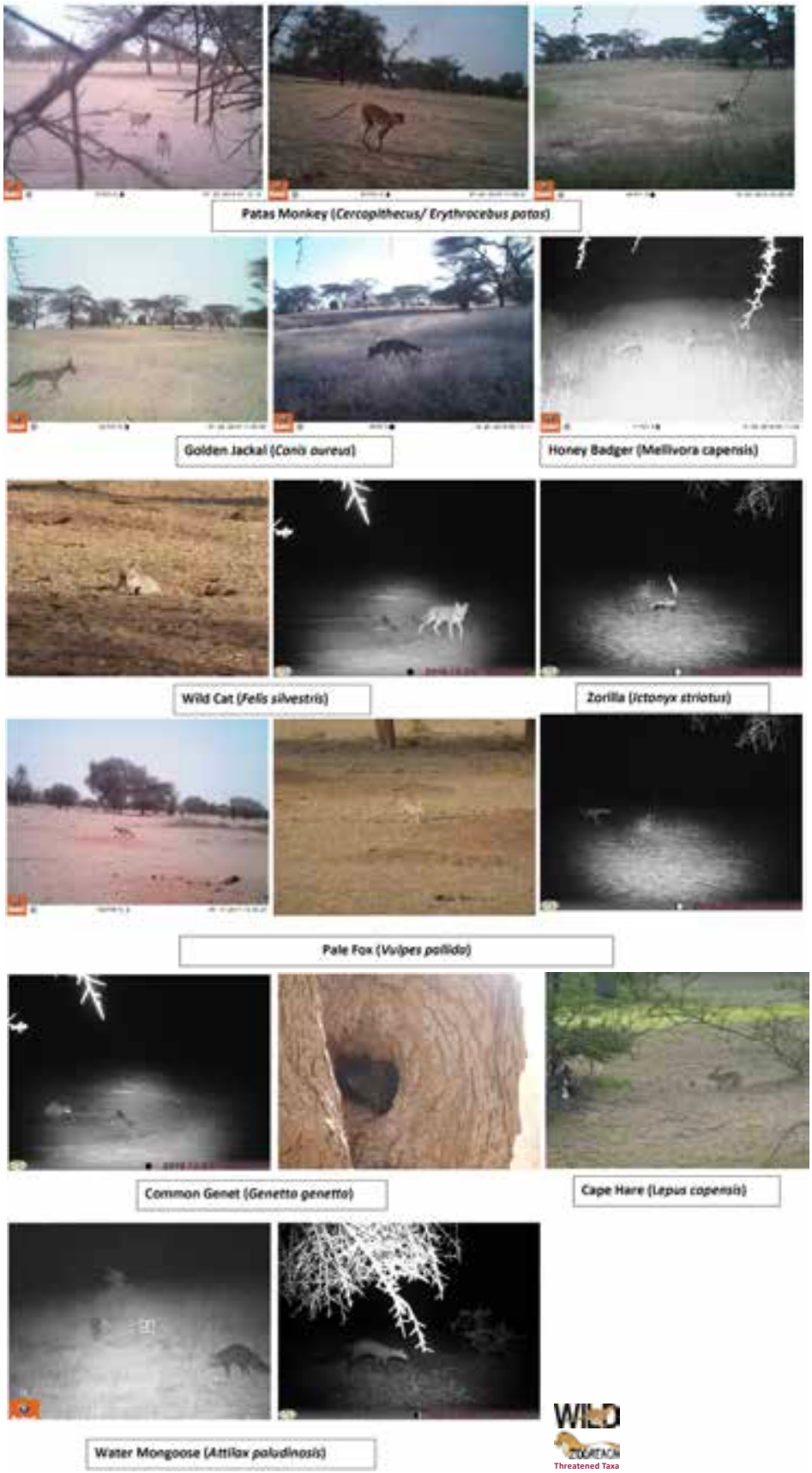
**Appendix 1. Images of large wild mammals identified in Koyli Alpha (Ferlo, Senegal).**



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**COMMUNICATION**

# Blackbuck *Antilope cervicapra* (Mammalia: Cetartiodactyla: Bovidae) estimates in human-dominated landscape in Aligarh, Uttar Pradesh, India

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**Abstract:** Information on the status of the Indian Blackbuck *Antilope cervicapra* is mostly available from protected areas (PA), although 80% of its population occurs outside PAs. We conducted surveys to assess the status, age structure, sex ratio, and conservation issues of Blackbuck in and around Aligarh between February and June 2014. A median of 672 individuals at 18 separate locations were recorded with a group size ranging 4–216 except for solitary individuals. The abundance of Blackbuck was maximum in Sikandra Rao (range: 154–216) followed by Andla (range: 47–65), and Pala-Sallu (range: 53–62). Sex ratio was skewed towards females (1:4.5) with yearling to female and fawn to female ratio of 7.8:100 and 6.7:100, respectively. The percentage of adult males of Blackbuck (12.8% adult males, 8.4% sub-adult males) as well as adult females (56.4% adult females, 11.9% sub-adult females) was higher than other age classes or groups in the population. The preliminary observations indicate that the increasing population of free-ranging feral dogs, degradation of forest patches, social forestry plantations, competition with livestock, and poaching pressure are the major conservation issues of Blackbuck in the area. The current information is expected to serve as baseline in assessing the population of Blackbuck in the future.

**Keywords:** Age structure, agricultural fields, conservation issues, grasslands, Indian Blackbuck, plantations, population status, scrublands, sex-ratio, surveys.

**सार:** भारतीय काला हिरण की आबादी की स्थिति के बारे में जानकारी अधिकतर संरक्षित क्षेत्र (पी. ए. ) से उपलब्ध है, यद्यपि इसकी 80 % आबादी पी. ए. क्षेत्र के बाहर पायी जाती है। हमने फरवरी से जून 2014 के बीच अलीगढ़ और उसके आस-पास काला हिरण की स्थिति, आयु संरचना, लिंग अनुपात और संरक्षण के मुद्दों का आकलन करने के लिए सर्वेक्षण किया। 18 अलग-अलग स्थानों पर 672 काला हिरण पाए गए । एक समूह 4 - 216 के आकार के साथ दर्ज किया गया। सिकंदरा राव (श्रेणी: 154 -216 ) में काला हिरण की बहुतायत सबसे अधिक थी, उसके बाद अंडला (श्रेणी: 47-65 ), और पाला सल्लू (श्रेणी: 53-62) का स्थान था। लिंगानुपात काला हिरण मादा की ओर झुकाव था (1:4.5), इरलिंगज़ (Yearlings) और मादाओं व बच्चों (Fawns) और मादाओं के लिए अनुपात क्रमशः 7.8:100 और 6.7:100 था। काला हिरण के वयस्क नर (12.8% वयस्क नर, 8.4% उप -वयस्क नर ) के साथ-साथ वयस्क मादा (56.4% वयस्क मादा, 11.9% उप -वयस्क मादा ) का प्रतिशत आबादी में अन्य आयु वर्गों या समूहों की तुलना में अधिक था। प्रारंभिक टिप्पणी से संकेत मिलता है की मुक्त जंगली कुत्तों की बढ़ती आबादी, वन पैच का निम्नीकरण, सामाजिक वानिकी वृक्षारोपण, पशुधन के साथ प्रतिस्पर्धा और अवैध शिकार क्षेत्र में काला हिरण के प्रमुख संरक्षण मुद्दे हैं। भविष्य में काला हिरण की जनसँख्या का आकलन करने में वर्तमान जानकारी एक अहम् भूमिका प्रदान कर सकती है।

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## INTRODUCTION

The Indian Blackbuck *Antilope cervicapra* Linnaeus, 1758, Schedule-I species in Indian Wildlife (Protection) Act, 1972, is native to the Indian sub-continent. It was listed as 'Near Threatened' in 2014 by IUCN, which has been downgraded to 'Least Concern' category in 2017 (IUCN SSC Antilope Specialist Group 2017). There are two sub-species of blackbuck; *A. c. cervicapra* and *A. c. rajputanae* (Prater 2005; Menon 2014). *A. c. cervicapra* is found roughly west and south of Delhi to Point Calimere, Tamil Nadu whereas *Antilope c. rajputanae* occurs in Gujarat and Rajasthan (Menon 2014). Blackbuck occur in a wide range of habitats ranging from semi-arid grasslands, scrublands to open forest with preference to open grassland (Isvaran 2005; Meena & Saran 2018). Rahmani (1991) has conducted country-wide survey of Blackbuck population and has mentioned the species to occur in 80–100 fragmented populations in India. However, the current distribution range of Blackbuck is shrinking due to conversion of grassland into agricultural fields and direct competition for food and space with livestock (Dabadghao & Shankarnarayan 1973; Singh & Joshi 1979; Jhala & Isvaran 2016).

In Uttar Pradesh, Blackbuck occur in some protected areas such as Kaimoor Wildlife Sanctuary, Ranipur Wildlife Sanctuary, Hastinapur Wildlife Sanctuary, Meja Forest Division (a proposed Blackbuck Conservation Reserve, 46 km southeast of Parayagraj in Uttar Pradesh) and also outside protected areas in Varanasi, Kanpur, Pilibhit, Lakhimpur Kheri, Shahjahanpur, Banda, Sitapur, Hardoi, Bijnor, Bahraich, Muzaffarnagar, Meerut, Aligarh, Bulandshahr, Ghaziabad, Etah, and Mathura districts (Ranjitsinh 1982, 1989; Rahmani 1991). But it has disappeared from some areas such as Katarniaghat Wildlife Sanctuary and Kishanpur Wildlife Sanctuary. Most of these areas outside protected areas where Blackbuck is distributed in Uttar Pradesh are densely populated with humans unlike its distribution range in peninsular India. Since then, no systematic survey was carried out and recent information on the status of Blackbuck is lacking hitherto.

Aligarh, an agricultural district in the western part of Uttar Pradesh lies between rivers Ganga and Yamuna (Khan 2017). *Prosopis juliflora* was planted in 'usar' land areas about 30–35 years ago to provide fuel-wood to the local villagers, which support a population of Blackbuck (Gautam 1991; Dubey 1993). Some recent information on Blackbuck from a few sites of Aligarh district is presented in this paper by conducting a survey on its status, age structure, group size, and sex ratio. The study also focuses on identifying various threats that are currently prevailing in the densely populated agricultural landscape in the district.

### Study area

Aligarh district (latitude 27° 54' 1.3788" N, longitude $78^0$ 4' 20.2116" E) in western part of Uttar Pradesh falls in the Gangetic plain biogeographic zone of India (Image 1). Administratively, the district is divided into 12 blocks, namely: Atrauli, Bijauli, Gangheeri, Lodha, Javan, Dhanipur, Akrabad, Iglas, Gonda, Khair, Chandaus, and Tappal. It encompasses an area of about 3,747 $km^2$ between the rivers Ganga and Yamuna. The district is bounded by the river Ganga on the north-east and Yamuna on the north-west parts and thus has a highly fertile 'doab' commonly known as the Ganga-Yamuna doab. Topographically, the district harbours vast open alluvial plains. The district is covered with loamy, sandy, clay, and silty soil. The region experiences humid subtropical climate, where average temperature ranges 35–38 $^0$C during the summer (March to May) but average temperature rises beyond $45^0$C during May–June. The average temperature is about $10^0$C during winter months (November–February), and it may even be lower than $10^0$C during January. Aligarh receives an average annual rainfall of ~800mm during the monsoon months (mid-June to September). Pulses, wheat, rice, barley, millet, and maize are mainly cultivated in Aligarh. A major portion of the district is rural with patches of forest (1%), scrublands, and wetlands interspersed among cultivated areas (Khan 2017).

Since the natural forest is less than 1% in the district, most common trees occuring in plantations, tree groves and human settlements include *Prosopis juliflora*, *Acacia nilotica*, *Azadirachta indica*, and *Adina cordifolia* besides agricultural fields. There are a few 'usar' land pockets affected by salt and remnant grassland patches interspersed within the agricultural landscape, which are used by blackbuck besides the above-mentioned categories.

## METHODS

A literature review on the earlier studies on blackbuck in this region was carried out (Gautam 1991; Rahmani 1991; Dubey 1993). In addition, forest department (FD) guards, watchers appointed by the FD and also the residents in 56 villages of Atrauli, Iglas, Khair, Aligarh, and Sikandra Rao blocks were interviewed in February 2014 regarding the occurrence of this species.

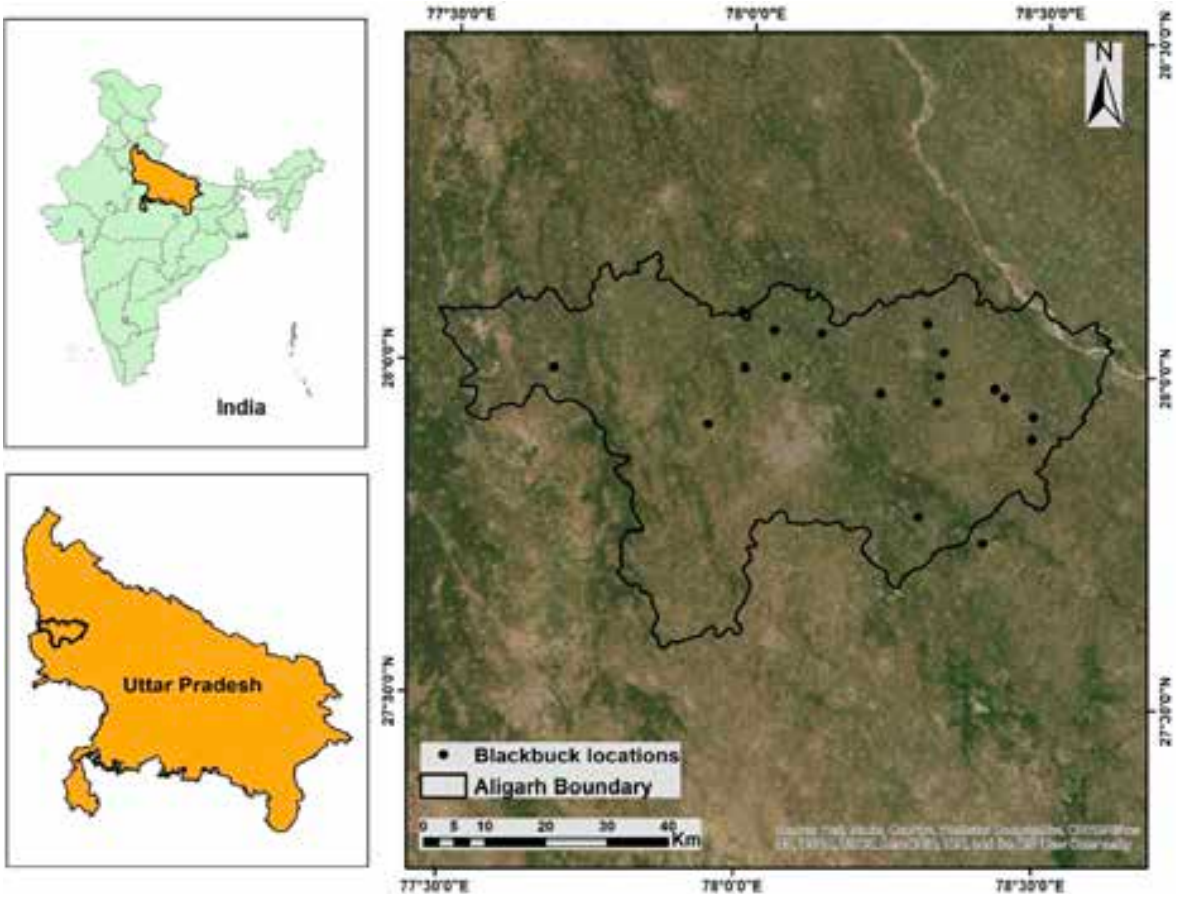


Image 1. Map of Study area in Aligarh, Uttar Pradesh.

The sites where the species was present were visited three times during March–June 2014. The observations were made from 0600 to 1000 h and 1600 to 1900 h when the Blackbucks are most active. Total or direct count method was employed to take a census of this species as it aggregates and inhabits relatively open areas (Sutherland 1996; Jethva & Jhala 2004). Data were collected block-wise in the selected 18 non-contiguous sites, among which six sites represented *Prosopis juliflora* plantations, seven agricultural fields, and five sites were located around human settlements. When sighted group size, sex, and age structure were recorded. The groups were considered as separate if (a) the herds were separated 2–3 km from each other and (b) the population was separated by some physical barrier such as water canal, which clearly classified them as separate groups (Image 2). The maximum home range of male Blackbucks recorded till date is 5.14 km$^2$ (Mahato & Raziuddin 2010). The maximum number of individuals of Blackbuck sighted at each site was considered as the maximum numbers in that area. The number of Blackbucks in a group or herd were categorized into: adult males and females (>2 years), sub-adult males and females (1–2 years), yearlings (<1 year), and fawn (>2 weeks) following Jhala (1991). Moreover, conservation threats such as the presence of dogs, degradation of resting sites, presence of livestock, and evidence of any poaching incidence were also recorded at each site.

## RESULTS

We estimated a maximum of 764 and median of 672 and minimum of 476 individuals in 18 separate areas, with group size ranging from 4 to 216 individuals except for solitary ones (Table 1, Image 1, 2). We did not document any mixing of herds during three visits to the study sites. This may primarily be due to an extensive network of metalled and unmetalled roads and canals in the area interspersed with agricultural fields and human settlement (Image 2). Their presence was higher in sites with plantations than in sites with few or no plantations. Considering the median values of the estimates, Blackbuck were recorded in the highest numbers in

**Table 1. Estimates of Blackbuck population at different sites in Aligarh District, Uttar Pradesh.**

| | Monitoring sites | Maximum | Minimum | Median |
|---|---|---|---|---|
| 1 | Sikandra Rao (Sahadatpur) | 216 | 154 | 207 |
| 2 | Andla | 65 | 47 | 54 |
| 3 | Pala-Sallu (Gabhana) | 62 | 53 | 59 |
| 4 | Neem Nadi-Bijauli Khas | 61 | 13 | 52 |
| 5 | Jarthari-Bhoolgadhi | 49 | 0 | 30 |
| 6 | Ghazipur | 41 | 32 | 38 |
| 7 | Rampur-Ladhwa | 41 | 35 | 39 |
| 8 | Tal Ka Nagla | 41 | 33 | 39 |
| 9 | Kakethal | 35 | 22 | 29 |
| 10 | Chandula- Sujanpur | 33 | 23 | 32 |
| 11 | Bajna-Nagra | 31 | 11 | 22 |
| 12 | Tewthoo-Gulapur | 30 | 27 | 28 |
| 13 | Tejpur-Rathana | 17 | 4 | 12 |
| 14 | Sindauli-Sheikpura | 10 | 7 | 7 |
| 15 | Junglegadi-Malikpura | 11 | 5 | 7 |
| 16 | Hursaina (Husaina) | 9 | 7 | 7 |
| 17 | Palla-Kashthali | 8 | 3 | 8 |
| 18 | Bijrauli-Palimuqeempur | 4 | 0 | 2 |
| | **Total** | **764** | **476** | **672** |

plantations at Sahadatpur (n= 207) followed by Pala-Sallu (n= 59) and Andla (n= 54). The median age structure was 85 males, 424 females, 62 sub-adult males, 53 sub-adult females, 18 yearlings, and 30 fawns. A higher number were adults of both sexes (12.6% AM, 7.8% SAM) as well as females (63.09% AF, 9.22% SAF). Sex ratio was skewed towards females (1:4.5) and yearling to female and fawn to female ratios were 1:17 and 1:14 respectively in the population.

Presence of the Blue Bull *Boselaphus tragocamelus* and livestock in the same sites could lead to competition for food and space, the increasing population of free ranging feral dogs, degradation of forest patches, poaching pressure, crop damage by Blackbuck (Image 5) and equally so by Blue Bull are some of the challenges for the survival of Blackbuck in Aligarh (Table 2).

## DISCUSSION

Studies on the status of Indian Blackbuck in Uttar Pradesh were first documented by Ranjitsinh (1982, 1989) who estimated 941 to 1,000 individuals. After almost a decade, Rahmani (1991) roughly estimated Blackbuck population to be about 1,100 individuals in

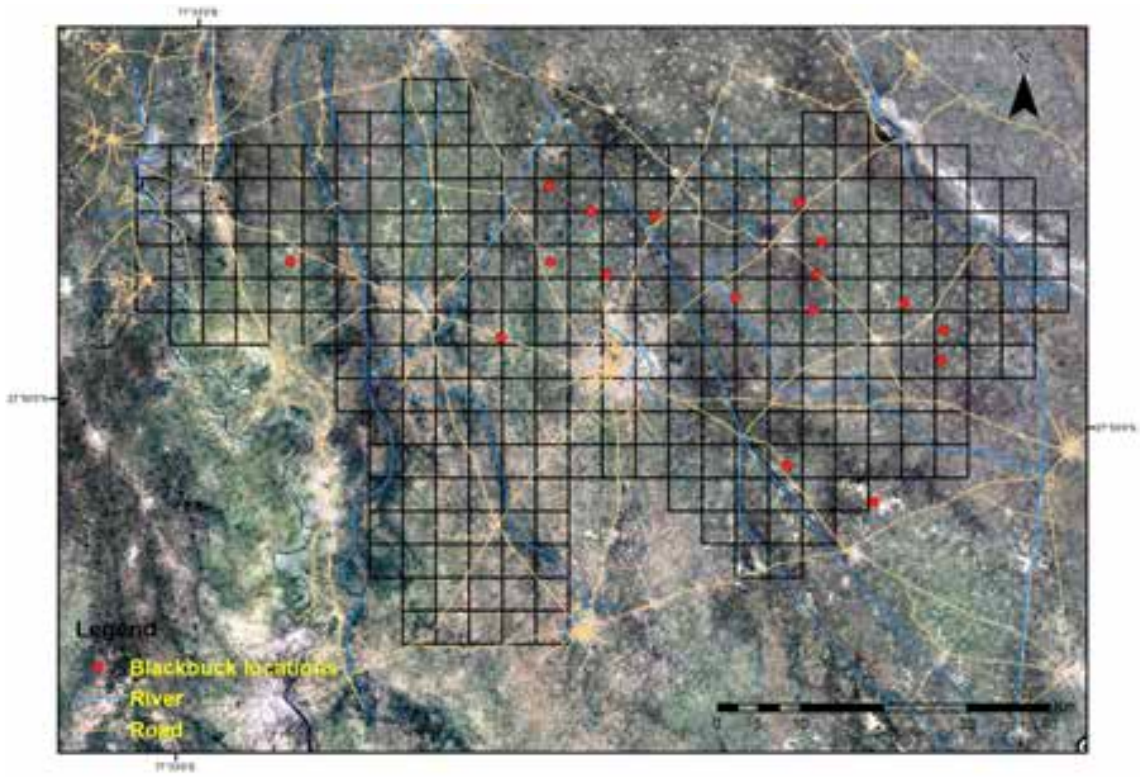


**Image 2. Individual groups of Blackbuck (4 × 4 km²) in Aligarh, Uttar Pradesh.**

**Table 2. Threats to Blackbuck recorded at various sites of Aligarh, Uttar Pradesh**

| | Monitoring sites | Competition with | | Free ranging feral dogs | Poaching | Wood extraction |
|---|---|---|---|---|---|---|
| | | Blue Bull | Livestock | | | |
| 1 | Sikandrarao (Sahadatpur) | + | + | + | - | + |
| 2 | Andla | + | + | - | - | + |
| 3 | Palla-Sallu (Gabhana) | + | + | + | - | + |
| 4 | Neem Nadi-Bijauli Khas | + | - | - | - | - |
| 5 | Jarthari Bhoolgadhi | + | - | + | - | - |
| 6 | Ghazipur | + | + | + | - | + |
| 7 | Rampur-Ladhwa | - | - | - | - | - |
| 8 | Tal Ka Nagla | + | - | - | - | - |
| 9 | Kakethal | + | - | - | + | - |
| 10 | Chandaula- Sujanpur | + | - | - | - | - |
| 11 | Bajna-Nagra | - | - | - | - | - |
| 12 | Tewthoo-Gulapur | + | - | - | - | - |
| 13 | Tejpur-Rathana | - | - | - | - | - |
| 14 | Sindauli-Sheikhpura | - | - | - | - | - |
| 15 | Junglegadhi-Malikpura | + | + | + | + | + |
| 16 | Hursaina (Husaina) | + | + | + | - | + |
| 17 | Palla-Kashthali | + | + | - | + | + |
| 18 | Bijrauli-Palimuqeempur | - | - | - | - | - |

Uttar Pradesh, including 420 individuals from Aligarh. Earlier an estimate of about 59 individuals of Blackbuck had been reported from Atrauli block of Aligarh (Dubey 1993). There were about 11 Blackbuck reported in 178 ha 'community forest' in Gursikaran village (Gautam 1991), which is now extirpated completely from the area. The increase in Blackbuck numbers in Aligarh district in comparison to the earlier estimate by Rahmani (1991) may be due to an increase in survey efforts and larger spatial coverage in this study.

The group size of Blackbuck ranged 2–207 individuals (Median value, Table 1) within the study area. Variation in abundance of Blackbuck within population has also been observed by previous studies including Isvaran (2007), Sagar & Antoney (2017), and Prashnath et al. (2016).

The variation in group size among sites could be attributed to habitat structure. Blackbuck is known to occur in large groups in open habitats and small groups in patchy environment (Isvaran 2007; Jhala & Isvaran 2016). Larger groups are usually formed in response to predation pressure. In open habitats, predation risk is reduced by forming large groups as compared to higher probability of large groups being detected in closed habitat. However, Aligarh is dominated by cultivated areas, thus providing open habitat all around


**Image 3. Female herd of Blackbuck on cultivated land of Aligarh, Uttar Pradesh.**

(Khan 2017). Natural predators are the Golden Jackal *Canis aureus* present in all the sites covered under this survey whereas the Indian Wolf *Canis lupus pallipes* was recorded from only one location, i.e., Ghazipur in Atrauli forest range. Local residents often mention Golden Jackal preying on fawns. However, there was no indication of predation by the Indian Wolf. Poaching of Blackbuck by local people is common in Malikpura, Kakethal, and Pala-Kashthali localities as reported by the ground staff of the FD.


Image 4. Fuel-wood (*Prosopis juliflora*) collection by villagers in Aligarh, Uttar Pradesh.


Image 5. Sorghum (*Sorghum bicolor*) crop damaged by Blackbuck in Aligarh, Uttar Pradesh.

Sikandra Rao with the largest *Prosopis* plantation (~100 ha) supports the largest number of Blackbuck. The sex ratio of Blackbuck was female biased in our study sites. Sex ratio of adult males to adult females was comparatively lower than in Point Calimere Wildlife Sanctuary, Tamil Nadu (Nair 1976), Andhra Pradesh (Prasad & Ramana 1990), Pipli Deer Park, Kurukshetra (Gupta & Bhardwaj 1990), M.C. Zoological Park, Chhatbir, Punjab (Vats & Bhardwaj 2009), Ganjam district and Balipadar-Bhetnoi Blackbuck Conservation Area, Odisha (Mahato et al. 2010; Murmu et al. 2013; Debata 2017), Sorsan grassland in Baran District and Tal Chappar Blackbuck Sanctuary, Rajasthan (Meena et al. 2017) and Lalpur Jheel, Haryana (Rai & Jyoti 2019). The female skewed sex ratio indicates that male mortality is higher.

The local people co-exist with Blackbuck and accept them as part of the agrarian system although they damage crops such as wheat, mustard, berseem, and chickpea (Image 3) . At present, people are tolerating and bearing the crop damages in these areas. However, the situation can worsen with the increase in abundance of Blackbuck (Chauhan & Singh 1990). There is no compensation given to locals against crop damage by Blackbuck and Blue Bull.

Competition with feral livestock and the Blue Bull is an important source of competition for limited forage. Cattle are discarded by the local people after they stop yielding milk and compete with Blackbuck for resources, mainly food and shelter. Free ranging feral dogs were often seen hunting Blackbuck frequently during the surveys. Control of free ranging feral dogs is needed to increase wild ungulate populations. Harvesting of fodder and fuelwood from plantations and other semi-natural habitat is an added cause of land degradation (Image 4) .

Forest cover as well as grassland areas are scanty in the study area and thus the only option for their survival is around such plantations and 'usar' land (patches of alkaline land) dispersed over the agricultural landscape. If there are no further changes and disturbances in the landscape, Blackbuck may continue to survive in viable numbers. Some of these sites may be protected as community reserves for protecting Blackbuck population of the area.

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COMMUNICATION

# Diet of Leopards *Panthera pardus fusca* inhabiting protected areas and human-dominated landscapes in Goa, India

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**Abstract:** The diet of leopards occupying human-dominated and protected areas (PAs) in Goa, India was analyzed through scat analysis. A total of 117 scats, 55 from wildlife sanctuaries/ national parks and 62 from human-dominated areas were collected and analyzed. Analysis of 55 scats from protected forests revealed the presence of only wild prey in the leopard diet, whereas 61% of scats collected from human-dominated areas consisted of only wild prey, 29% of domesticated animals, and 10% a mixture of both wild prey & domesticated animals. Of the prey biomass consumed in human-dominated areas, domestic animals constituted only 33% of the leopard diet. Among all leopard scats, 71% contained only one prey species, 28% contained two species, and 1% contained three.

**Keywords:** Diet composition, hair medullary pattern analysis, human-leopard interactions, scat analysis.

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**Author contributions:** BSPD collected the samples, analyzed them and wrote the manuscript. AD'C assisted with the analysis of the samples and revision of the manuscript. MKPK assisted with the analysis of the specimens. SKS supervised the study and helped in the revision of the manuscript.

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## INTRODUCTION

Big cats play an important role in maintaining the equilibrium of forest ecosystems, for which they serve as indicators of health and integrity. Tigers *Panthera tigris* and Leopards *Panthera pardus* are integral parts of forest ecosystems (Karanth & Sunquist 1995) and hence their conservation is of prime importance. Leopards are widely distributed in India and they often come into conflict with humans, indeed they are more frequently involved in human conflict than other large cats (Holland et al. 2018). Many examples have been reported from Sanjay Gandhi National Park (Mumbai), Baria Forest Division (Gujarat), Junnar (Maharashtra), and Garhwal (Himalaya), and conflicts are becoming increasingly prominent with an increasing human population and expanding developments leading to competition for shrinking resources. This presents major obstacles to the conservation of leopards, and a comprehensive region-specific study of their ecology and biology is essential for long-term conservation.

Several studies have documented the widespread distribution of leopards across India (Daniel 1996; Vijayan & Pati 2002; Athreya et al. 2013), but few studies have focused on prey availability and diet composition in human-dominated areas (Athreya et al. 2013, 2014). Hence in this study, an effort has been made to compare the diet of leopards in human habitations with those living in PAs in Goa, India using scat analysis. Scat analysis is an indirect, non-destructive and cost-effective method (Sunquist 1981; Johnsingh 1983) for recording the frequency of occurrence of prey items in the diet of a carnivore. The hair of prey is relatively undamaged in scat of leopards and tigers, hence it can be used as a tool to identify prey species (Mukherjee et al. 1994a; Ramakrishnan et al. 1999). However, there is a chance of error if molecular methods are not used to confirm species identity (Laguardia et al. 2015; Akrim et al. 2018).

In Goa, the Western Ghats run along the eastern border of the state which contains protected forest areas. In addition to this, there are various small hill ranges and plateaus stretching from Pernem in the north to Canacona in the south that connect the Western Ghats with the coastal landscape. Most of the old human settlements are situated at the base of these hills and plateaus. In the last decade or so, these areas have become prone to encroachment due to expansion of cities, towns, villages and roads. These hills and plateaus primarily consist of stunted cashew trees, thorn scrub jungle and coarse grass with dense semi-evergreen forest patches in between (Jadhav & Pati 2012), which support a variety of wildlife, such as the Indian Leopard *Panthera pardus fusca,* Golden Jackal *Canis aurius,* Dhole *Cuon alpinus,* Gaur *Bos gaurus,* Sambar *Rusa unicolor,* Chital *Axis axis,* Northern Red Muntjac *Muntiacus vaginalis,* Wild Boar *Sus scrofa,* Indian Chevrotain *Moschiola indica,* Bonnet Macaque *Macaca radiata,* Gray Langur *Semnopithecus hypoleucos*, and Indian Crested Porcupine *Hystrix indica*.

In this work we have studied the diet composition of leopards in PAs as well as human-dominated areas in Goa over a period of three years by collection and analysis of scats, to identify potential human conflicts due to livestock depredation, and to formulate management interventions and mitigating measures.

### Study area

Goa is spread over the hilly region of Western Ghats towards the east, coastal plains towards the west, a midland region with laterite plateaus and low-lying river basins. The study area consisted of the entire state of Goa lying in between latitudes 15.480–14.435N and 74.201–73.403E which included human-dominated areas, with reported presence of leopards and wildlife sanctuaries and national parks covering a total area of ~1,748.05 km$^2$ (Figure 1). The average altitude of Goa is approximately 511 m. The total geographical area is 3,702 km$^2$ of which 2,219 km$^2$ is covered with forests and 1,224 km$^2$ represents state-owned forests, of which 649 km$^2$ have been declared protected areas in the form of a national parks and wildlife sanctuaries. The overall human population density in Goa is 394 persons per km$^2$. Goa receives an average annual rainfall of 3,300 mm, and the major forest types are tropical wet evergreen, tropical semi-evergreen, tropical moist deciduous, and littoral & swamp forests.

## MATERIALS AND METHODS

### Field collection of leopard scats

Leopards and tigers prefer use of forest road and footpaths/trails to move around and also as a mechanism of inter and intra species social communication, hence they are likely to defecate along such paths (Smith et al. 1989; Karanth et al. 2004). Scat samples measuring larger than 20 mm in diameter (measured using a custom-made 20 mm diameter metal ring) were collected to avoid non-leopard predator scats (Norton et al. 1986; Rabinowitz 1989). The presence of tigers was only reported from Mhadei Wildlife Sanctuary (WS), where leopard scats were differentiated from tiger scats based on size, shape, diameter, coiling and constriction patterns, along with

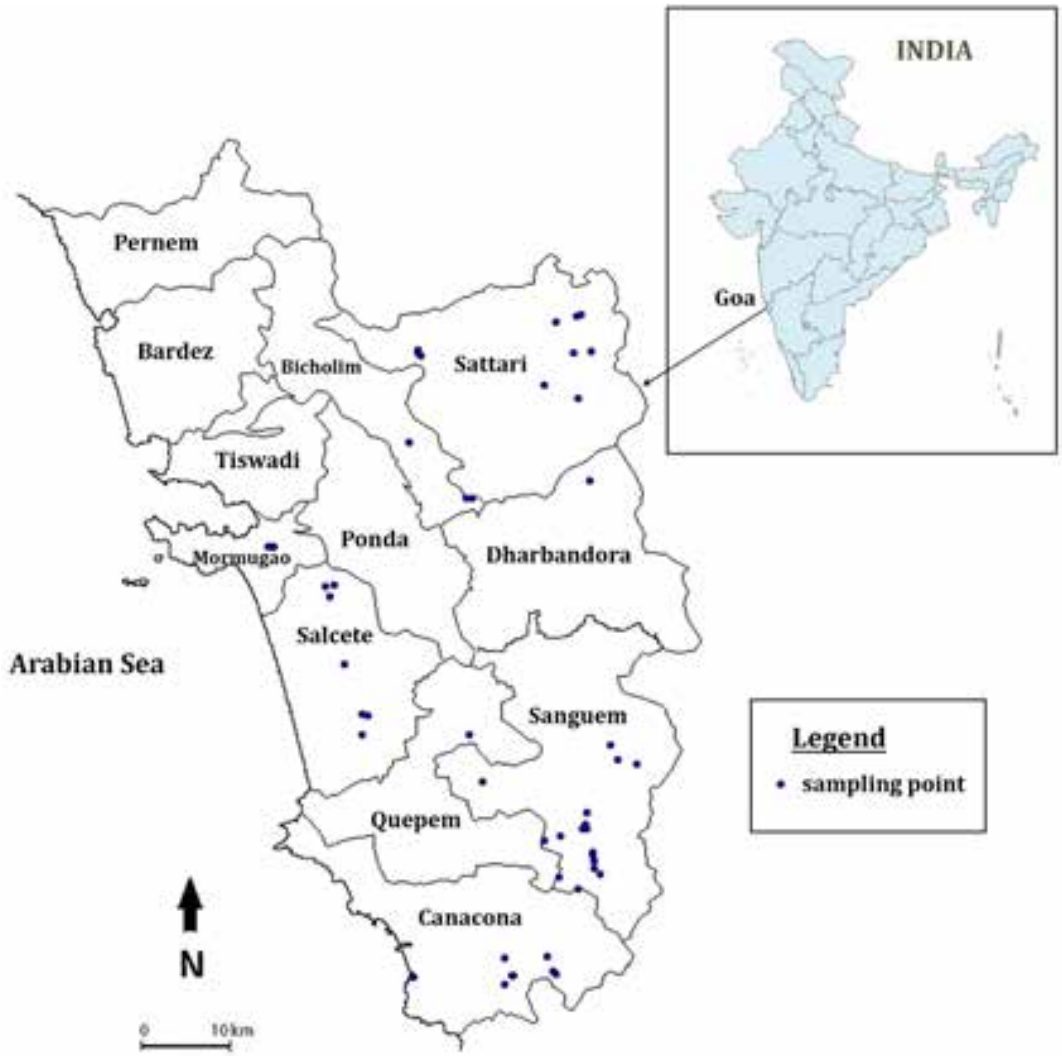


**Figure 1. Map of Goa showing scat sampling points.**

ancillary evidence such as pugmarks, scrapes, and claw marks (Lovari et al. 2014; Laguardia et al. 2015; Rostro-Garcia et al. 2018). It is important to note that there is a chance of identification error since molecular techniques were not used.

**Scat collection from protected forest areas**

A preliminary scat survey was conducted to identify carnivore trails such as foot paths and forest roads passing through the protected forest areas (wildlife sanctuaries and a national park). A total of 25.5 km of forest roads were sampled once every month with trained personnel.

**Scat collection from human-dominated areas**

To identify areas with potential human-leopard conflicts, complaint and rescue data was collected from the Forest department of Goa for the years 2013–2016. Using this data, areas prone to human-leopard interactions were identified. These areas were later visited to study the geography, crop patterns and proximity with dense forest areas of protected areas.

Preliminary scat survey was conducted to identify carnivore trails such as foot paths and unmetalled roads passing through areas having forested areas close to human habitation (hamlets with small houses and fields) with maximum complaints on leopards. These areas have medium to dense green cover and provide shelter to leopards and wild prey species. Sampling at each site was carried out once a month. A total of 34 km from such areas were sampled over a period of three years from January 2016 to December 2018.

Scats were measured and collected in polythene bags labeled with the date of collection along with the GPS location of the site. Scat samples were transported

to the lab, sun dried and the dry weight recorded. A portion of dried scats were soaked in water and passed through a metal sieve (1.5mm mesh size), leaving only undigested prey remains which predominantly consisted of hair and bone fragments. Hairs from the undigested remains were then separated and 25 hair strands were randomly picked from each sample and analyzed. For hair medullary pattern analysis, hairs were immersed in xylene for 24 hours and then mounted on permanent slides with a cover slip using DPX mount (Mukherjee et al. 1994b). For observing cuticle scale patterns of hair, an impression technique using gelatin solution with eosin stain was used following Mukherjee et al. (1994b). Slides were examined under 200x and 400x magnification based on the size of the hair using a trinocular research microscope (Olympus BX53). A set of reference slides were made from domesticated livestock and pet animals from the study area and wild prey species in captivity, rescued animals and road kills.

Prey species (identified from hair found in scat) were reported as the proportion of scats that showed their presence. A species accumulation curve was also plotted (Kshettry et al. 2018) to ascertain the number of scats required to be analyzed for a reliable diet estimate. To avoid bias due to variable prey body size, relative composition of prey species varying in body size was calculated using Ackerman's equation (Ackerman et al. 1984), assuming leopards have similar digestive physiology to Mountain Lions *Puma concolor* (Karanth & Sunquist 1995), as follows:

$Y= 1.980+0.035x$

Where Y is the kg of prey consumed per field collectible scat, and X is the average weight of the particular prey species in kg (Ackerman et al. 1984). This method has been used previously for leopards (Karanth & Sunquist 1995; Andheria et al. 2007; Khorozyan et al. 2008; Odden & Wegge 2009; Mondal et al. 2012; Athreya et al. 2014). The body weights of probable predated prey species were taken from literature (Mondal et al. 2012; Athreya et al. 2014).

The relative biomass (D) and relative numbers (E) of each prey species consumed was obtained using the equations:

$D= (A \times Y)/ \sum(A \times Y) \times 100$

$E= (D/X)/ \sum(D/X) \times 100$

Where A is the frequency of occurrence of the prey items in the scats, Y is the mass of prey consumed per scat (kg) and X is the mean mass of the prey (kg) (Athreya et al. 2014).

## RESULTS

### Protected areas

Analysis of scats collected from PAs revealed the presence of only wild prey (Indian Crested Porcupine, Wild Boar, Northern Red Muntjac, Chital, Indian Hare *Lepus nigricollis*, Bonnet Macaque, and Gray Langur) in the diet of leopards. No records of domesticated animals (such as ox, dog, pig, goat, and cat) were found in the scats from protected forest areas. Scat analysis of 55 scats collected from these areas (Table 1) revealed that Wild Boar constituted a major proportion of the prey biomass (29%), followed by Chital (25%), Indian Crested Porcupine (15%), Barking Deer (13%), Gray Langur (5.6%), Bonnet Macaque (5.4%), Sambar (4.1%), and Indian Hare (3.1%). Indian Hare was the most preyed-upon species in relative numbers (21%) followed by the Indian Crested Porcupine (18%), Bonnet Macaque (15%), Wild Boar (13%), Gray Langur (12%), Northern Red Muntjac (11%), Chital (8.9%), and Sambar (1.1%). The diet profile analysis also suggests that leopards preferred small-sized prey (77%), over medium (33%), and large-sized prey (1.1%) (Table 1).

### Human-dominated areas

The results of analysis of 62 scats collected from human-dominated areas revealed that major proportion of leopard prey biomass comprised of wild prey (67%), predominantly Wild Boar (26%), Indian Crested Porcupine (17%), Indian Hare (14%), Bonnet Macaque (5.1%), Gray Langur (3.2%), and Northern Red Muntjac (1.3%). Domestic animals (dog, pig, cat, and goat) constituted only a minor portion (33%) of the leopard diet. The dog was the most preyed-upon domestic animal (17%) followed by pig (11%), goat (2.7%), and cat (2%) (Table 2). Of the nine wild prey species observed from scat analysis, six were identified in scats collected from human-dominated areas.

### Comparative analysis of leopard habitats

A total of 117 leopard scats were collected during the period of the study, of which 55 were from PAs and 62 from human-dominated areas; 62% of scats collected from human-dominated areas contained only wild prey, 29% only domestic prey, and 9.7% had a mixture of both. A majority of scats (71%) contained only one prey species, 28% contained two species and 0.85% contained three (Figure 2). A total of 151 prey items were identified, comprising of 12 prey species.

In both habitats, Indian Hare remains were observed in the most scats (42%), followed by Indian Crested Porcupine (13%) and Wild Boar (8.7%). Of the total prey

**Table 1. Diet composition of Leopards inhabiting protected forest areas in Goa through analysis of scat samples (55) during January 2016 to December 2018.**

| | Prey species | N (Percent occurrence) | Average body weight (X) | A (%) (Percent frequency) | Y (Kg/scat) | D (%) (Relative biomass) | E (%) (Relative number of individuals consumed ) |
|---|---|---|---|---|---|---|---|
| 1 | Indian Crested Porcupine | 12 | 14 | 17.39 | 2.47 | 14.57 | 17.69 |
| 2 | Wild Boar | 18 | 37 | 26.08 | 3.27 | 28.98 | 13.31 |
| 3 | Northern Red Muntjac | 10 | 20 | 14.49 | 2.68 | 13.18 | 11.19 |
| 4 | Gray Langur | 5 | 8 | 7.25 | 2.26 | 5.56 | 11.80 |
| 5 | Indian Hare | 3 | 2.5 | 4.35 | 2.07 | 3.05 | 20.73 |
| 6 | Bonnet Macaque | 5 | 6 | 7.25 | 2.19 | 5.38 | 15.25 |
| 7 | Dog | 0 | 18 | 0 | 2.61 | 0 | 0 |
| 8 | Chital | 14 | 48 | 20.29 | 3.66 | 25.19 | 8.92 |
| 9 | Pig | 0 | 30 | 0 | 3.03 | 0 | 0 |
| 10 | Sambar | 2 | 62 | 2.90 | 4.15 | 4.08 | 1.12 |
| 11 | Cat | 0 | 3.5 | 0 | 2.10 | 0 | 0 |
| 12 | Goat | 0 | 25 | 0 | 2.85 | 0 | 0 |
| | Total | 69 | | | | | |

**Y**—estimated weight of the prey consumed per collectable scat produced.

**Table 2. Diet composition of Leopards inhabiting human-dominated areas in Goa through analysis of scat samples (62) during January 2016 to December 2018**

| | Prey species | Percent occurrence (N) | Average body weight (X) | A (%) (Percent frequency) | Y (Kg/scat) | D (%) (Relative biomass) | E (%) (Relative number of individuals consumed ) |
|---|---|---|---|---|---|---|---|
| 1 | Indian Crested Porcupine | 15 | 14 | 18.29 | 2.47 | 17.24 | 11.20 |
| 2 | Wild Boar | 17 | 37 | 20.73 | 3.27 | 25.91 | 6.37 |
| 3 | Northern Red Muntjac | 1 | 20 | 1.22 | 2.68 | 1.25 | 0.57 |
| 4 | Gray Langur | 3 | 8 | 3.66 | 2.26 | 3.15 | 3.59 |
| 5 | Indian Hare | 15 | 2.5 | 18.29 | 2.07 | 14.43 | 52.49 |
| 6 | Bonnet Macaque | 5 | 6 | 6.10 | 2.19 | 5.10 | 7.72 |
| 7 | Dog | 14 | 18 | 17.07 | 2.61 | 17.01 | 8.59 |
| 8 | Chital | 0 | 48 | 0 | 3.66 | 0 | 0 |
| 9 | Pig | 8 | 30 | 9.76 | 3.03 | 11.28 | 3.42 |
| 10 | Sambar | 0 | 62 | 0 | 4.15 | 0 | 0 |
| 11 | Cat | 2 | 3.5 | 2.44 | 2.10 | 1.96 | 5.08 |
| 11 | Goat | 2 | 25 | 2.44 | 2.85 | 2.66 | 0.97 |
| | Total | 82 | | | | | |

**Y**—estimated weight of the prey consumed per collectable scat produced.

biomass consumed, domesticated animals constituted a minor fraction (17%) of the leopard diet, the remainder consisted of Wild Boar (27%), Indian Crested Porcupine (16%), Chital (12%), Indian Hare (8.9%), Northern Red Muntjac (7.1 %), Bonnet Macaque (5.2%), Gray Langur (4.3%), and Sambar (2%).

The cumulative curve (Figure 3) suggested that the proportion of scats with remains of various prey species stabilized after 24 scats, with only one species being added after 71 scats. From this analysis it can be also interpreted that 92% of prey species were identified in the first 24 scats analyzed, with an addition of just one species

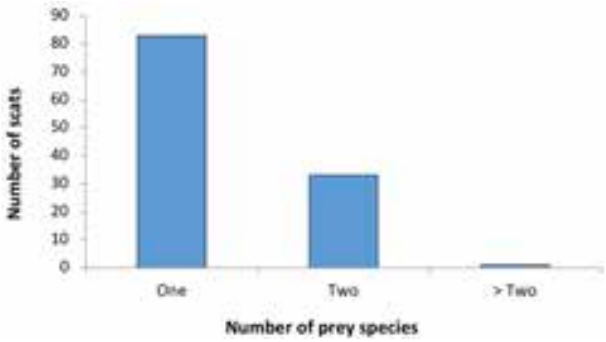


Figure 2. Number of prey species observed in each Leopard scat.

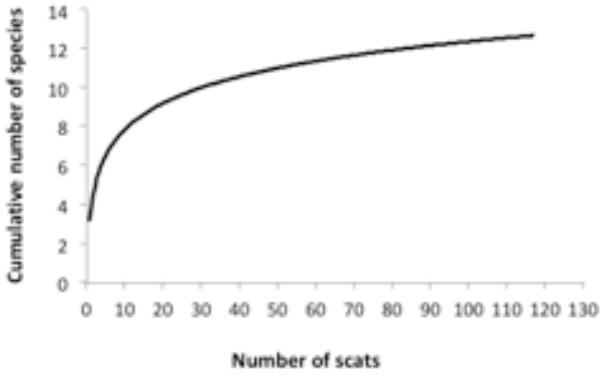


Figure 3. Cumulative number of prey species in Leopard scats.

(cat) after analysis of the 71st scat. Thus we consider the sample size adequate to interpret the overall diet profile of leopards from the study area.

## DISCUSSION

The presence of eight wild prey species in the study area may be attributed to the availability of diverse vegetation from dry thorn forests to semi-evergreen forests. The presence of leopards in human habitations is evident from the data collected from the forest department regarding complaints received from a majority of the human-dominated areas of North Goa and South Goa districts. Hence it is likely that Leopards may be distributed throughout the state of Goa.

Data analysis from protected forest areas suggests that leopards consumed medium- (Wild Boar, Northern Red Muntjac, Chital) and small-sized prey (Indian Hare, Indian Crested Porcupine, Bonnet Macaque, Gray Langur). The Indian Hare was found in the most scats, followed by Indian Crested Porcupine, Wild Boar, Gray Langur, Bonnet Macaque, Northern Red Muntjac, Chital, and Sambar. The preference of smaller to medium-sized prey was also reported in the studies of Sunquist & Sunquist (1989), Sankar & Johnsingh (2002), Henschel et al. (2005), and Ahmed & Khan (2008). Additionally, this preference may also be due to the nocturnal feeding behaviour of Leopards as well as these small mammals, thus making them more vulnerable to predation than the other species (Ahmed & Khan 2008). Another point to be considered is that in the study area, wild prey were also found to be present in human-dominated areas for the purpose of grazing or foraging which could also be a reason for the leopards entering these areas.

With regard to the domestic animals, the predation of dogs and pigs was mostly due to an increase in stray dog and pig population in human habitation probably due to improper disposal of garbage in these areas. Very few households had a safe night shelter for their domesticated pigs and dogs. During the study although few complaints of leopard attacks on cattle calves were reported, no such killings were found. Further no traces of cattle hair were found in any of the scat samples.

From informal observations and discussions with locals we realized that though leopards came into conflict with humans almost throughout the year, this conflict is significantly higher during the months of August, September, and October and again intensifies in the months of January and February. This pattern correlates with the breeding pattern of leopards (pre-breeding phase during the monsoon months of August, September, and October) when wandering males and sub-adult cubs (which have just left their mothers to fend for themselves) come in conflict with humans. The conflict during the January and February months could be mainly due to the movement of females in the post-birth phase. These leopards, which continuously change their location for the safety of the young cubs, come in contact with humans employed in cashew plantations and other agricultural activities.

## CONCLUSION

It can be interpreted from our data that although leopards were reported close to human habitations throughout the year, their dependence on domestic animals was low. This study also indicates that the wild species that the leopards preyed upon in PAs were also present in forested areas close to human habitations. This could be the reason for the presence of leopards in human-dominated areas with a low dependence on domestic animals. Hence it is of utmost importance to create awareness about the role of these large cats in

ecosystems and their feeding and behavioral patterns, and to adopt mitigating and precautionary methods in case of human-leopard conflicts.

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# First record of interspecies grooming between Raffles' Banded Langur and Long-tailed Macaque

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**Abstract:** In primates, observations of interspecies grooming are not uncommon, especially between species of the same genus. However, little is reported about grooming between different genera and less is discussed about its ecological significance. Here, we report the first sighting of Long-tailed Macaques grooming the Critically Endangered and rare Raffles' Banded Langur during two independent events at Gunung Lambak Recreational Forest in Kluang, Malaysia.

**Keywords:** Interspecies interactions, *Macaca fascicularis,* Malaysia, *Presbytis femoralis*, primate, Singapore.

**Bahasa Malaysia:** Pemerhatian terhadap proses hias diri ('grooming') antara spesies dalam kalangan primat bukanlah sesuatu yang jarang berlaku, terutama antara spesies yang memiliki genus yang sama. Walau bagaimanapun, sangat sedikit laporan ditemui berhubung proses hias diri antara genera yang berbeza dan kepentingan ekologi perilaku ini amatlah kurang dibincangkan. Di sini kami melaporkan pemerhatian awal Kera melakukan proses hias diri ke atas Lotong Cenekah yang merupakan spesies yang amat jarang ditemui dan terancam kepupusan dalam dua insiden berasingan di Hutan Rekreasi Gunung Lambak, Kluang, Malaysia.

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## INTRODUCTION

Most primate species are highly social, and behaviour like allogrooming, alloparenting, and playing between members of the same species are regularly observed in langurs and macaques (Lehman et al. 2007; Matsuda et al. 2015). Social grooming is a key behaviour in primates to facilitate kinship reciprocity (Schino & Aureli 2010), affiliation (Dunbar 1991; Lehman et al. 2007), and hygiene (Goosen 1981), involving at least two actors (groomer and recipient) physically touching each other. As an affiliative interaction, grooming plays a significant role in primate societies to reinforce social bonds and networks (Dunbar 2011). Grooming also facilitates communication, contributing to the development of social cohesion (Dunbar 2011; Dunbar & Lehman 2013; Grueter et al. 2013). Within social groups of macaques, post-conflict reconciliation and consolation often involve grooming (Long-tailed Macaques *Macaca fascicularis*: Cords 1992; Stump-tailed Macaques *M. arctoides*: Call et al. 2002; Barbary Macaques *M. sylvanus*: McFarland & Majolo 2011). Social grooming has a direct effect on the physiological health of individuals, and other positive effects are associated with release of pleasure hormone (i.e., oxytocin and endorphin; Dunbar 2010) or suppression of stress hormones (i.e., cortisol: Wooddell et al. 2016). Seyfarth (1977) proposed that social grooming in female Cercopithecidae is principally directed toward high-ranking individuals (reviewed in Schino 2001). This rank-related reciprocity in allogrooming has been demonstrated for 16 species and nine genera (*Alouatta, Cercopithecus, Cebus, Erythrocebus, Lemur, Macaca, Miopithecus*, *Sapajus* and *Semnopithecus*) (Schino & Aureli 2008a; Tiddi et al. 2012). Evidence of trading allogrooming for alloparenting is also found in female Long-tailed Macaques (Gumert 2007).

Asymmetries in allogrooming resemble the context of ecological economy as a trade for other commodities including food (reviewed in Barrett & Henzi 2001; see Russell & Phelps 2013) and services (Lazaro-Perea et al. 2004). Several studies have identified asymmetrical cost and benefits between groomer and recipient, considering that altruistic behaviour benefits the recipient but imposes some cost to the donor (Schino & Aureli 2008b; Russell & Phelps 2013). Grooming time is considered as cost to the groomer in their daily activity budgets as metabolic cost and loss of foraging opportunities (Russell & Phelps 2013). Cost and benefits can also be categorised into immediate and delayed effects. For example, ectoparasite removal is an immediate hygiene benefit to the recipient and constitutes a food source for the groomer but has a delayed risk of disease transmission from the close contact and ectoparasite consumption (reviewed in Veá et al. 1999; Russell & Phelps 2013). Furthermore, there is an immediate cost of time spent on grooming in return of immediate tension reduction with delayed agonistic support through social bonding (reviewed in Veá et al. 1999; Russell & Phelps 2013).

Grooming is not restricted to members of the same species but has been documented in members of different species in the wild such as between Rhesus Macaque *M. mulatta* and Sambar Deer *Rusa unicolor* (Vasava & Mahato 2013), Rhesus Macaque and Hanuman Langur *Semnopithecus entellus* (Nerlekar 2012), and Red-tailed Monkey *Cercopithecus ascanius* and Blue Monkey *C. mitis* (Gathua 2000). Interspecies allogrooming has also been seen in captivity between Long-tailed Macaque and Patas Monkey *Erythrocebus patas* (Baker & Preston 1973), capuchin monkeys *Cebus albifrons* & *Sapajus apella* and spider monkeys *Ateles geoffroyi* and *A. paniscus* (Maple & Westlund 1975). However, most available studies were only reviewed within the context of intraspecies allogrooming. Anecdotal records of interspecies allogrooming have been reported from the field, usually for species of the same genus and/or within mixed species groups with hybrids (e.g., *M. nemestrina* x *M. fascicularis* at Sepilok, Sabah; Gilhooly & Colquhoun 2018) but, to the authors' knowledge, published observations of intergeneric grooming in wild sympatric primates are not available. Interspecies grooming between primates of different genera is rarely reported from the wild, and has, to our knowledge, not been documented for the Critically Endangered (Ang et al. 2020; status currently being revised, A. Ang, pers. comm. 01.vi.2021) and rare Raffles' Banded Langur *Presbytis femoralis*.

Here, we report the first sighting of Long-tailed Macaques grooming Raffles' Banded Langurs in Gunung Lambak Recreational Forest in Johor, Malaysia, and discuss the potential meaning of this interspecies interaction.

## METHODS

The state of Johor in Peninsular Malaysia is home to six species of non-human primates, namely: Sunda Slow Loris *Nycticebus coucang*, Long-tailed Macaque *Macaca f. fascicularis*, Southern Pig-tailed Macaque *M. nemestrina*, Reid's Dusky Langur *Trachypithecus o. obscurus*, Raffles' Banded Langur *Presbytis femoralis*,

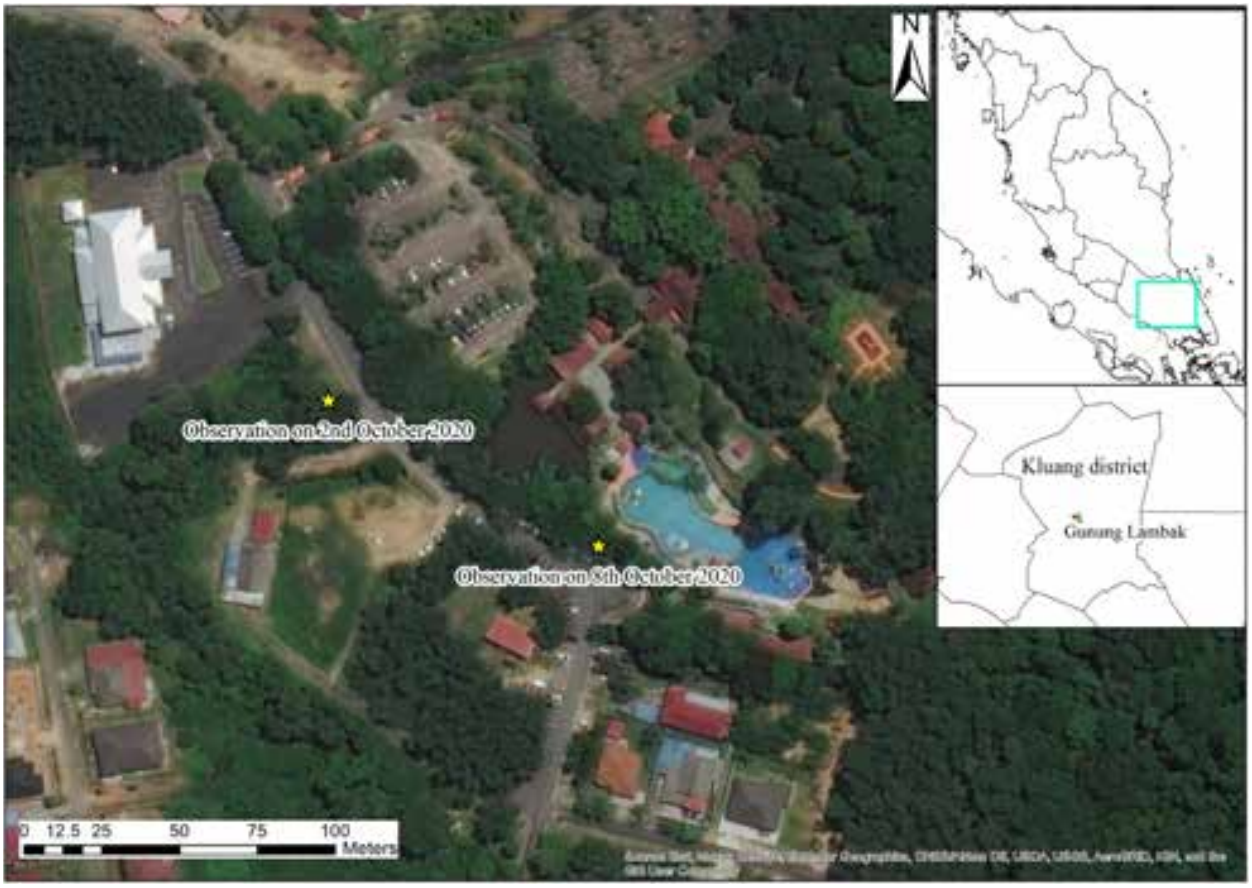


**Image 1. Forest edge environment where interspecies grooming was observed at Gunung Lambak in Kluang district, Johor, Malaysia.**

and Malaysian White-handed Gibbon *Hybolates l. lar*. Specifically, the Raffles' Banded Langur is Critically Endangered (Ang et al. 2020) due to its small population size and restricted distribution in fragmented habitats. This species is only found in southern Peninsular Malaysia (states of Johor and Pahang) and the Republic of Singapore with an estimated global population size of fewer than 400 individuals (Ang et al. 2020).

Gunung Lambak is a twin-peak hill (highest at 510 m) located in Kluang, Johor (2.0275° N, 103.3575° E). Also known as Gunung Lambak Recreational Forest, it has an area of 744 ha (i.e., Renggam Forest Reserve) (Image 1). The vegetation consists mainly of secondary forest with patches of old growth trees. Pioneer tree species, such as *Campnosperma auriculatum*, *Macaranga* spp. and non-native *Acacia* spp. are common at the foot of the recreation forest and along the trails (Lee Zan Hui pers. obs. 14.iv.2021). Despite being an isolated secondary forest, trees of the Fagaceae family, *Lithocarpus cantelyanus*, *L. sundaicus*, *Castanopsis acuminatissima*, *C. scortechinii*, and *C. inermis* have been observed fruiting at different times throughout the year providing a food source to the primate community at the site (Lee Zan Hui pers. obs. 14.iv.2021). All six species of primates in Johor can be found in Gunung Lambak. Renggam Forest Reserve also holds a high in situ conservation value for endangered Dipterocarpaceae species, with *Hopea glaucescens* and *H. johorensis* being listed as Critically Endangered, *Dipterocarpus sublamellatus* as Endangered, and *Shorea exelliptica*, *S. gibbose, S. gratissima*, *H. nutans,* and *Anisoptera megistocarpa* as Vulnerable (Chua et al. 2010).

Non-invasive opportunistic observations were made on a group of Raffles' Banded langurs (hereafter RBL) during the assessment of phenology transects for the study of the feeding ecology of this species. Footage of behaviour was recorded with a DSLR camera (Nikon D5600) with a telephoto lens (Nikkor 200–500 mm). The study group consists of 11 individuals (one adult male, five adult females with three dependent infants, and two juvenile females). Long-tailed Macaques (LTMs), which are observed in groups of up to 20 individuals in the area, range sympatrically with RBLs and can often be observed in close proximity to RBLs.

## RESULTS

The first interspecies grooming event was observed in the late afternoon of 02 October 2020 at the foot of Gunung Lambak during light drizzling rain. At 1715h, a group of ca. 20 LTMs were attracted to food provided by people with the intention to feed macaques at the roadside. Intragroup aggression among LTMs competing for the provisioned food was observed and some LTMs climbed up the trees nearby where the focal RBL troop of 11 individuals was resting, likely trying to avoid direct confrontation with dominant LTMs who guarded the food. At 1730h, RBLs moved from the forest toward the roadside, preparing to cross the road to their sleeping sites. At 1733h, two LTMs, who both appeared to be subadult males, approached an adult female RBL and groomed her (Image 2, Video 1). The grooming event was unidirectional and only LTMs engaged in grooming while the RBL female was solely receiving. This RBL was a lactating mother who had a dependent infant (which was out of sight during the grooming event). The rest of the RBLs who were not engaged with the LTMs were resting and feeding on flower buds and leaves of *Garcinia mangostana, Acacia mangium*, and other trees nearby. One of the two LTM groomers stopped grooming and moved onto a higher branch after ca. half a minute while the other LTM continued grooming for eight minutes. This LTM was observed picking substances from the RBL's fur and feeding on it. Without leaving its location, the LTM also occasionally fed on flower buds of the tree (species unidentified) that they sat on. No aggression was observed in this interspecies interaction. The female RBL was observed being vigilant, actively scanning the surrounding environment and responding to vehicles that passed by. At 1753h, the grooming event was interrupted by the alpha RBL male as he approached the female and displaced the LTM, before directing the RBL group to cross the road. The LTM group, including the two groomers, followed the RBLs to cross the road. Both species separated after the road crossing and headed to their respective sleeping sites.

The second observation of interspecies grooming was on 08 October 2020, around 1808h during clear, sunny weather. A female subadult LTM was observed actively seeking RBLs to groom while the RBL group was feeding on sprouting leaf buds of a tall Saga Tree *Adenanthera pavonina* at the same site (Image 3, Video 2). The RBL group was observed foraging on leaf buds, which were limited and sparsely distributed across the crown of the Saga Tree, then the LTM groomer approached for grooming. In contrast to the first observation with a fairly long grooming bout (around eight minutes) between the fixed groomer and recipient pair, RBLs actively terminated this grooming event by leaving the position for foraging, hence leaving the LTM groomer to seek another recipient. Having been rejected by some RBLs, the LTM female seemed cautious about approaching RBLs, especially female adults. She started by touching a RBL's tail from a distance with an extended hand, and only if the RBL stayed in position, she got closer to inspect (possibly for ectoparasites), also presenting her body in front of the RBL recipient. At least two RBL juvenile females and two adult females were eventually groomed at different timings by the same LTM (Table 1). The LTM groomer was also observed extracting substances from RBL's fur by hand-picking and feeding on it as well as directly biting the RBL fur with her mouth. Although no direct confrontation or aggressive behaviour was observed, some RBLs appeared impatient towards the groomer and prioritised feeding on the leaf

**Table 1. Interspecies grooming observation of Long-tailed Macaques (LTM) grooming Raffles' Banded Langurs (RBL) and possible reason (SR—stress relieve with oxytocin hormone | Co—post conflict consolation | ER—ectoparasite removal | Fo—foraging for ectoparasite by actors | na—non-applicable).**

| Date | Raffles' Banded Langur recipients | Long-tailed Macaque actors | Grooming duration | Possible reason or benefit from grooming |
|---|---|---|---|---|
| 02.x.2020 | Adult female 1 | Subadult male 1 & 2 | 8 minutes | LTM: SR, Co, Fo<br>RBL: ER |
| 08.x.2020 | Juvenile female 1 | Juvenile female 1 | 1 minutes 10 seconds | LTM: Fo<br>RBL: ER |
| 08.x.2020 | Juvenile female 2 | Juvenile female 1 | 50 seconds | LTM: Fo<br>RBL: ER |
| 08.x.2020 | Adult female (Unidentified) | Juvenile female 1 | 1 second | LTM: Fo<br>RBL: na |
| 08.x.2020 | Adult female (Unidentified) | Juvenile female 1 | 28 seconds | LTM: Fo<br>RBL: ER |
| 08.x.2020 | Adult female (Unidentified) | Juvenile female 1 | 1 minutes 10 seconds | LTM: Fo<br>RBL: ER |

Image 2. First observation of the interspecies allogrooming between Long-tailed Macaques and a Raffles' Banded Langur on 02 October 2020. © Lee Zan Hui.

Image 3. Second observation of the interspecies allogrooming between a Long-tailed Macaque and different individuals of Raffles' Banded Langur on 08 October 2020. © Lee Zan Hui.

buds. While being groomed, the RBLs seemed to pay high attention on locating the scarce food resources instead of being vigilant to the surroundings. It could not be observed whether the other individuals nearby and/ or the alpha male of the RBL group were engaged in the event or groomed by the LTM at any time but the troop was directed by his call to leave the Saga Tree and headed to the sleeping site by 1820h, eventually ending the grooming event as the LTM groomer was left behind.

## DISCUSSION

Interspecies grooming between RBL and other primate species has not been reported before. In Singapore, where the two species are also found sympatrically, grooming has been observed only once between the two species during more than four years of continuous research (A. Ang pers. obs. 13.ii.2021). However, interspecies grooming between Dusky Langurs *T. obscurus* and LTMs has frequently been observed between different individuals in mainland Penang, Malaysia with a mixed-species group reported from Cherok Tokun (Nadine Ruppert pers. obs. 2019–2020), and Dusky Langurs, LTMs and White-thighed Langurs *Presbytis siamensis* form tolerant foraging associations with juveniles being observed playing together near a residential area in Ampang Jaya, Selangor, Malaysia (N. Ruppert pers. obs. 08.ii.2020). Published information on interspecies grooming, with clear explanations, is often from studies conducted in captivity, such as zoos with mixed species displays, e.g., capuchin monkeys and spider monkeys grooming each other (Maple & Westlund 1975), or laboratory settings designed to test hypotheses in interspecies interactions, e.g., interspecies infant interactions between LTMs and Patas Monkeys (Baker & Preston 1973). There are only a handful of publications on interspecies grooming in the wild, such as the unidirectional grooming events by macaques toward non-primate species such as deers, mostly occurring during social coalition when the ungulates followed a primate troop and foraged on fallen food items (Tsuji et al. 2007; Vasava & Mahato 2013).

The reported interspecies grooming here was unidirectional in both observations, with young LTMs of both sexes being the groomers. As adult RBLs have larger body sizes (weight around 6 kg, 59 cm in body length and up to 84 cm with tail length), ca. two times the size of young LTMs (Ang et al. 2016), the LTMs likely groomed for rank-related benefits (Schino & Aureli 2008b), especially in the first observation where a macaque intragroup conflict was observed just before the grooming event when the young macaques were displaced from the food provisioning site. Post-conflict consolation is an affiliative interaction from the victim of aggression and individuals other than the former aggressor (Aureli 1992). Bystanders, who are not directly involved in the aggression may offer affiliative interactions to relieve stress of the victim by putting themselves at risk of receiving aggression from

the aggressor (Fraser et al. 2009). RBLs, as a different species, have no apparent relation with the aggressor, nor any long-term association with the macaque group. It is uncertain if post-conflict consolation happens between different primate species, yet genera (Kazem & Aureli 2005), but this might explain our observation. As the LTM groomers made their way to the higher strata and away from LTMs that competed for the provisioned food on ground, the LTM groomers might have found an opportunity to relieve stress by grooming the large female RBL who might simultaneously have deterred some other low-ranking macaques due to her body size (Schino & Aureli 2008a). In addition, there was no apparent competition between RBLs and LTMs over the provisioned anthropogenic food in this context. However, the possibility of LTMs solely seeking food, i.e. ectoparasite on langurs' skin, from grooming, and RBLs' desire for grooming for hygiene purposes, cannot be ruled out (Johnson et al. 2010).

The different duration of these interspecies grooming bouts during two independent observations was probably due to different extrinsic factors from the environment, and the intrinsic motivation of the primate individuals. The desire to be groomed usually follows a cyclical pattern of motivation and demotivation (Russell & Phelps 2013). Grooming is likely a crucial instigator of pleasure in primates, and the length of grooming time is the most available and applicable variable to reflect the quantity of the pleasurable effect (Russell & Phelps 2013). The female RBL recipient from the first observation was initially in a resting state before two young LTMs approached her and attempted to groom her. The relatively long grooming bout and her relaxed behaviour during the bout implied that she was not only tolerating but enjoying it. However, in the second observation, RBLs were already engaged in feeding while the young female LTM sought grooming opportunities, which were rejected or actively terminated by several individuals. It is unclear why the adult female RBLs tolerated the grooming in the first observation but not the second. A study on inter primates species interactions near Sungai Bernam, Malaysia, which included one of the closely related *Presbytis* langurs (older synonymization *P. melalophos* in the text; updated to either *P. robinsoni* or *P. s. siamensis* in the region) have concluded that intergenera interactions are typically non-competitive, and the association occurs with indication of selective preferences rather than by chance (Bernstein 1967).

In our study, both interspecies grooming events happened around dusk time, but there was a main difference in the RBL activities during both events. In the first observation, LTMs followed RBLs from the developed area back to the forest by crossing a road, and afterwards the two groups separated to reach their respective sleeping trees without further interaction. In the second observation, the female RBL was observed feeding and actively terminated the grooming session without aggression toward the groomer, ending the session as the RBLs headed to their sleeping trees. Judging from the several short grooming bouts in the second observation, RBLs likely prioritized feeding shortly before reaching their sleeping sites rather than losing foraging opportunities from being groomed by the macaques. Being groomed can also be painful as it involves pinching and pulling substances off the skin's surface (Dunbar 2010). It was not obvious if the RBLs were uncomfortable or experiencing pain, especially when the groomer directly bit ectoparasites off the langurs' skin.

Indeed, time spent on grooming is a significant part of primates' activity budgets, but not much information related to grooming is published for *Presbytis* langurs. A study on Hanuman Langurs showed that recipients determine grooming spots on the body during allogrooming, directing the groomer also toward inaccessible body parts (Borries 1992). From our observation, RBLs autogroom themselves mostly on limb parts while resting, but no allogrooming between adult female RBLs or between mother-infant pairs have been observed in this study so far. However, our study period is still considered short and the study troop is not fully habituated.

LTMs that have been regularly provisioned by humans may alter their natural behaviour exhibiting more flexibility and are likely more willing to engage in interspecies interactions (Sugiyama 2015). It is not uncommon to see interspecies interactions and grooming in captive environments, especially in zoos and sanctuaries (Silva 2017). In general, LTMs that regularly receive provisioning reduce their foraging distance, resulting in smaller home ranges, as concentrated food resources can be obtained nearby (Sha & Hanya 2013). This may increase the likelihood of interactions with humans and domestic animals in these anthropogenically modified environments (Bicca-Marques 2017). However, it also raises concerns about interspecies disease transmission as a spillover effect of the human-macaque interface (Gillespie et al. 2008; Rushmore et al. 2017; Balasubramaniam et al. 2020a,b). When macaques engage in interactions and close proximity with threatened primates, such as RBLs who are Critically Endangered, the risk of transmitting

zoonotic diseases adds to the factors that already threaten this rare species (Ang et al. 2012, 2020).

In future studies, the frequency and ecological significance of interspecies grooming should be examined more thoroughly. The authors believe that this behaviour is more common in the wild than reflected by almost non-existent reports in literature. The role of anthropogenic factors, such as food provisioning and potential edge effects from habitat degradation should be investigated for their impacts on behavioural flexibility, which may facilitate interspecies interactions in disturbed sites. Cross-species transmission of diseases and parasites as a potential consequence of interspecies grooming should also be studied to reveal vulnerability of different primate species to potential pathogens.

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# Photographic evidence of Red Panda *Ailurus fulgens* Cuvier, 1825 from West Kameng and Shi-Yomi districts of Arunachal Pradesh, India

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**Abstract:** Camera-trap photos of Red Panda *Ailurus fulgens* were obtained from three locations in the state of Arunachal Pradesh in northeastern India during a survey conducted from March to July 2019. Two of the locations are in West Kameng district and one location is in Shi-Yomi district (formerly West Siang). These records are important additions to the currently limited information available for species distribution in the state, and was gathered as part of a tri-country study on the status of tiger habitats in high altitude ecosystems of Bhutan, India, and Nepal.

**Keywords**: Ailuridae, camera trap, distribution, habitat, high altitude ecosystem, northeastern India, traits.

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**Author contributions:** MM and CS collated and analysed the camera trap data and wrote the manuscript. RG and MK conceptualised the tri-country GTF study. RG, MK and RS provided critical inputs to this manuscript. All authors reviewed the final manuscript.

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## INTRODUCTION

The Red panda *Ailurus fulgens* Cuvier, 1825 is a small carnivorous mammal with reddish-brown fur, placed under the monotypic family *Ailuridae*. Red Pandas are predominantly solitary and arboreal, and feed primarily on bamboo leaves plus seasonal supplements that include bird eggs, grubs, lichen, acorns, insects, and fruit (Yonzon & Hunter 1991; Choudhury 2001; Pradhan et al. 2001). Red Pandas are most active during the spring and summer-autumn during the day, and they rest for longer hours during winter as an adaptation to cold environmental conditions to conserve heat (Zhang et al. 2011). Such traits make it difficult to locate them during field surveys. Prime Red Panda habitats occur in temperate forests and bamboo mixed subtropical forests with a high density of fallen logs, high canopy cover, bamboo & shrub cover, and relatively steep slopes in close proximity to water sources (Thapa et al. 2018a).

The Red Panda is listed as 'Endangered' under the IUCN Red List of Threatened Species (Glatston et al. 2015). It is also listed in Appendix I of CITES, a category accorded to species threatened with extinction and whose trade is prohibited. In India, they are protected under Schedule I of the Indian Wildlife Protection Act (1972) (indiacode.nic.in). Red Panda numbers have been reported to be less than 15,000 in the wild (Wang et al. 2008; Glatston et al. 2015). Red Pandas are threatened due to poaching for their pelts and fur which is used for various clothing in China and elsewhere (Wei et al. 1999b, Dorji et al. 2012; Glatston et al. 2015). They are hunted by feral dogs, or get trapped in snares set up for other animals (Ghose & Dutta 2011; Dorji et al. 2012; Chakraborty et al. 2015). Anthropogenic pressure, large-scale deforestation, habitat loss, degradation around human settlements and consequently the expansion of agricultural areas has led to their decline in China, and these factors are probably applicable to the rest of the general red panda population (Yonzon & Hunter 1991; Glatston 1994; Wei et al. 1999b; Choudhury 2001; Pradhan et al. 2001).

### Global distribution of Red Panda

Red Pandas have a narrow range of occurrence. Their distribution spans from Api Nampa Conservation Area and Khaptad in western Nepal to India, Bhutan, Myanmar towards southcentral China of Sichuan and Yunnan province, encompassing the southern portion of Tibet, with Xiangling mountains being their easternmost extent (Glatston et al. 2015). Red Pandas occur in low densities, disjunct ranges, disconnected populations, and patchy distributions across the Himalaya-Hengduan mountains biodiversity hotspot (Glatston et al. 2015; Hu et al. 2020; Thapa et al. 2020). Their habitat consists of the sub-tropical and temperate forests of the Himalayan and Hengduan mountains, particularly in areas consisting of dense bamboo undergrowth (Yonzon & Hunter 1991; Wei et al. 1999a; Choudhury 2001; Pradhan et al. 2001; Chakraborty et al. 2015). Two subspecies are recognised, *A. f. fulgens* and *A. f. styani* west and east of the Nujiang River (Wei et al. 1999b), but a recent genetic study has identified Yalu Zangbu river as the geographic boundary, delineating the evidence for two phylogenetically different species and populations of Chinese Red Pandas and Himalayan Red Pandas (Hu et al. 2020).

### Distribution of Red Panda in India

In India, Red Pandas are found in the temperate belt of Sikkim, West Bengal and Arunachal Pradesh at altitudes ranging from 2,500 m to 5,000 m, and they have also been reported from sub-tropical Meghalaya at altitudes generally ranging from 1,500 m to 4,800 m, although Red Panda occurrence has also been recorded at lower elevations (Duckworth 2011; Glatston et al. 2015). The presence of a wild population in Meghalaya is debated (Duckworth 2011) and recent studies, including wildlife surveys using camera-traps, have not found evidence of occurrence (Ghose & Dutta 2011; Mukherjee et al. 2019). Kashmira Kakati (pers. comm. 15.v.2020) suggests that the older reports of Red Pandas may have been escaped or released pets of Nepali immigrants who had settlements in these areas.

### Records of Red Panda occurrence from Arunachal Pradesh

Arunachal Pradesh has around 11,300 km$^2$ of potential Red Panda habitat - the largest habitat in India, followed by Sikkim and West Bengal (Choudhury 2001; Ghose & Dutta 2011). As shown in Table 1, moving from west to east Red Pandas have been recorded in Tawang, West Kameng, East Kameng, Upper Subansiri, Lower Subansiri, Upper Siang, East Siang, Shi-Yomi (formerly West Siang), Dibang Valley, Lohit, Anjaw, and Changlang districts of Arunachal Pradesh. TRAFFIC's recent assessment for this species reported poaching and snaring in West Kameng, Shi-Yomi, Anjaw, and Dibang Valley districts of Arunachal Pradesh (Badola et al. 2020) thereby indicating that the species occurred in these districts. For the 20 districts surveyed in TRAFFIC's assessment, information on illegal trade of Red Panda skin or fur does not necessarily indicate presence of red panda in those districts unless it was confirmed as

a hunting or poaching incident from the district itself (Merwyn Fernandes, pers. comm., 29.xii.2020).

An ongoing study and work being carried out within one of WWF-India's priority areas known as the Western Arunachal Landscape (WAL), which spans across Tawang and West Kameng districts will help furnish additional information on the status of Red Panda in these areas (Kamal Medhi, pers. comm., 06.v.2020). By mobilizing strong support from local communities this work has already led to the delineation of 115 km$^2$ as habitat to conserve the Red Panda in West Kameng district. This area forms part of Mandala-Phudung-Khellong community-conserved area in the West Kameng district of Arunachal Pradesh (Chauhan 2019).

The state of Arunachal Pradesh is located in the eastern Himalaya and lies in a transition zone (Mani 1974; Rodgers & Panwar 1988) between the Himalayan (CEPF Ecosystem Profile 2005), and Indo-Burmese biodiversity hotspots (Myers et al. 2000) in India. Arunachal Pradesh along with other northeastern states of India is experiencing large-scale changes in land use and land cover due to shifting cultivation, illegal deforestation and indiscriminate felling of trees, which ultimately contributes to degradation of natural ecosystems (Roy & Tomar 2000; Tripathi et al. 2016). This state is experiencing rapid infrastructure economic developments on an unprecedented scale (Rahman 2014), and the trajectory of this development varies within the districts of Arunachal Pradesh (Sharma & Chakraborty 2016). The tourism potential of Arunachal Pradesh can provide stable economic and employment opportunities across the state (CES 2013). These developments invariably contribute to loss of forest cover and habitat degradation amidst socio-economic development of Arunachal Pradesh in the present time. According to India's State of Forest report Arunachal Pradesh has been experiencing habitat degradation and loss of forest cover over the years (FSI, State of Forest 2019).

Most of the land in Arunachal Pradesh has been under the traditional ownership of communities since decades. Such forests under community governance are called unclassed forests, which form 60% of the state's forest cover (FSI, State of Forest 2019). A recent study on the habitat suitability of the region for Red Pandas also identifies large portions of viable red panda habitat outside protected areas (Thapa et al. 2018b). The three locations where red pandas were recorded during this study are located within such unclassed forests. Habitat degradation and habitat loss have been major threats to Red Panda populations historically (Yonzon & Hunter 1991; Wei et al. 1999b; Pradhan et al. 2001), and this trend seemingly has not changed over the years.

## STUDY AREA AND METHODS

The Red Panda photographs were obtained during a larger study on the status of tiger habitats in high-altitude ecosystems of Bhutan, India, and Nepal (Global Tiger Forum 2019) with the objective to strengthen tiger conservation in high-altitude habitats in these three countries. For this study, literature review, questionnaire surveys, sign surveys, and camera trapping were conducted primarily in order to determine tiger presence across the study area. In India, the field surveys were conducted across the four states of Uttarakhand, Sikkim, northern West Bengal and Arunachal Pradesh from March 2019 to July 2019. The entire study area of 38,915km$^2$ in India was overlaid with 25km$^2$ grids. Specific forest divisions in all four states were identified for field surveys through workshops and consultations with the state forest departments during the early stages of this study.

In Arunachal Pradesh, as part of the larger study, seven administrative districts consisting of a total of 13 forest divisions (territorial and wildlife divisions) were surveyed. Questionnaire responses were received for 215 grids (of 25km$^2$ each) whereas sign surveys were carried out for a total length of 181 km covering 62 grids (of 25 km$^2$ each); each sign survey trail was 3 to 5 km in length. Camera traps were deployed in 47 grids (of 25km$^2$ each); with two pairs of cameras (4 cameras in total) placed in each 25km$^2$ grid.

## RESULTS

We report here three locations in Arunachal Pradesh (Figure 1) where Red Pandas were recorded through camera-trap photo captures. A total of three photographs of Red Pandas in India were obtained from this study.

During May–June 2019, camera trap photographs of Red Pandas 'thungmodongkar' (Mon language, with different local dialects) were obtained from two locations in the Dirang range of Bomdila Forest Division; one on the Jantsangpo trail (at 27.330 N, 92.158 E, 3,352 m altitude, Image 1), and the other along the Kishusegep trail (at 27.350 N, 92.183 E, 3,278 m altitude, Image 2). The survey team found red panda scat on the Kishusegep trail, and there was a rocky stream present

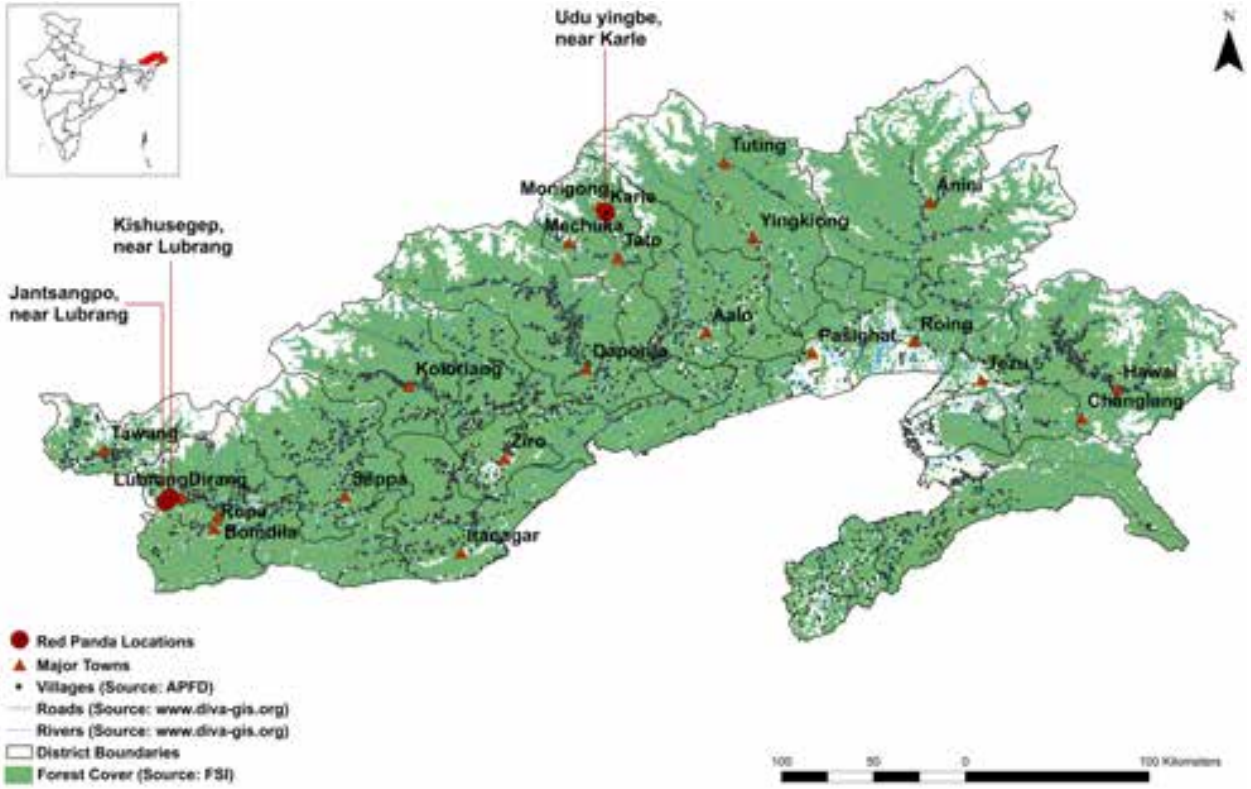


**Figure 1. Map of Arunachal Pradesh depicting the locations where red pandas were photo captured on the camera traps. Inset: Location of the state of Arunachal Pradesh in India. Map created in ArcMap 10.7.1.**

along the Jantsangpo trail. Both of these locations are around the Lubrang village of West Kameng district. Barking Deer *Muntiacus muntjack* and Yellow-throated Marten *Martes flavigula* were also photographed at the Red Panda *Ailurus fulgens* trap locations. This area predominantly consisted of different Bamboo sp., *Quercus* sp., *Acer* sp., and *Castanopsis* sp., as part of the vegetation of temperate broad leaved forests.

In June 2019, a Red Panda 'kopuling' (Adi language, with different local dialects) was photographed (at 28.747 N, 94.317 E, 2,478 m altitude, Image 3), at an approximate aerial distance of 1.5 km from Karle village in the Udu Yingbe locality, on the hilly route from Karle to Tayong. This village is part of the Mechuka range (also spelt Menchukha) of Along Forest Division, in the Shi-Yomi district. Wild Boar *Sus scrofa*, Mithun / Gayal *Bos frontalis*, Kalij Pheasant *Lophura leucomelanos*, humans, cattle, and domestic dogs were also photographed along with the Red Panda at this location. There was a stream running along the trail. The vegetation type consisted of temperate broad leave forest species dominated by Bamboo sp., *Quercus* sp., *Castonopsis echinocarpa* ('Hirang' in local dialect), and *Rhus semialata* or *R. chinensis* ('Taam' in local dialect). Upon enquiry by the team member who surveyed the area, the local guide reported human use of these habitats on a regular basis in the form of logging of wood and Bamboo using motorized saw, or manually using axes (locally known as 'daav'), typically used for local distribution.

The first record of red panda from the Monigong area (Shi-Yomi District) was its sighting on an oak tree along a steep hillside in the year 1999 (Ghose & Dutta 2011). Monigong is the last village of Arunachal Pradesh on this front - towards the Indo-Chinese border, and hence a landmark village, due to which these hilly ranges are known as Monigong hills or Monigong area. The hills surrounding Karle, Tayong and Jorang villages which are located near Monigong village were surveyed during this study. This photograph of the Red Panda is the second record from the hills of Monigong area, obtained near Karle village, Shi-Yomi district in Arunachal Pradesh.

## DISCUSSION

The photographic evidence of Red Panda obtained through this study from three locations in Arunachal Pradesh confirms the presence of this species near


Image 1. Camera trap photograph of Red Panda from Jantsangpo trail area of Bomdila Forest Division, West Kameng district, Arunachal Pradesh.


Image 2. Camera trap photograph of Red Panda from Lubrang area (Kishusegep trail), Bomdila Forest Division, West Kameng district, Arunachal Pradesh.


Image 3. Camera trap photograph of red panda near Karle village, Along Forest Division, Shi-Yomi district (formerly West Siang), Arunachal Pradesh.

**Table 1. District-wise presence of Red Panda reported in Arunachal Pradesh.**

| District of Arunachal Pradesh | Type of Records | Source |
|---|---|---|
| Tawang | Kills recorded as part of field interview surveys with communities, known to be traded locally. | Mishra et al. 2006 |
| | Sightings on 4 occasions between 1990 to 1997, skin being sold in Tawang market till 1998. | Ghose & Dutta 2011 |
| | At Pangchen valley through direct sightings, droppings, and feeding signs as part of a field survey. | Chakraborty et al. 2015 |
| | Interview and field surveys. | Choudhury 2001 |
| West Kameng | Kills recorded as part of field interview surveys with communities, known to be traded locally. | Mishra et al. 2006 |
| | Pelt shown as stuffed toy in market area. | Badola et al. 2020 |
| | Mandla-Phudung, directly through sightings, kills, carcasses) and indirectly through evidence of scats, pugmarks, scratch marks, pelts and secondary information confirmed by the local communities;<br>Nyukmadung, Ramacamp, Ramalingam camp, Chaku, Bompu, Sundarview, Nafra in the 1980s;<br>Eagle Nest Pass and Dirang in 1990s. | Ghose & Dutta 2011 |
| | Multiple live sightings, droppings, and reports of hunting red pandas between 1980 to 2000. | Srivastava & Dutta 2010 |
| | Two photographs obtained in 2019 as mentioned in the current paper; in the vicinity of Lubrang village. | Global Tiger Forum 2019 (details outlined in the current paper). |
| | Photographed at Chug Valley. | Choudhury 2020, Tribuneindia.com, 2 October 2020 |
| | Presence indicated through interviews and field surveys in Sessa Orchid Sanctuary, Eagle Nest Wildlife Sanctuary. | Choudhury 2001 |
| East Kameng | A record of one individual killed in 1999. | Ghose & Dutta 2011 |
| | Interview and field surveys. | Choudhury 2001 |
| Upper Subansiri | Interview and field surveys. | Choudhury 2001 |
| Lower Subansiri | One individual rescued near Kebi village. | Business-standard.com, 29 February 2016 |
| | Presence indicated through interviews and field surveys in Talley Valley Wildlife Sanctuary. | Choudhury 2001 |
| Upper Siang | Interview and field surveys. | Choudhury 2001 |
| | Presence indicated through interviews and field surveys in Mouling National Park. | Choudhury 2001 |
| East Siang | Interview and field surveys. | Choudhury 2001 |
| Shi-Yomi (formerly West Siang) | One sighting record and one kill record, Monigong area. | Ghose & Dutta 2011 |
| | One photograph obtained in 2019 as mentioned in the current paper; in the vicinity of Karle village. | Global Tiger Forum 2019 (details outlined in the current paper) |
| | Pelt found in market area. | Badola et al. 2020 |
| Dibang Valley | One kill, one skin and a live sighting record. | Ghose & Dutta 2011 |
| | Hunting recorded. | Sharma 2017 |
| | Pelt recorded during survey. | Badola et al. 2020 |
| | Presence indicated through interviews and field surveys in Dibang Valley Wildlife Sanctuary, Mehao Wildlife Sanctuary. | Choudhury 2001 |
| Lohit | Two sighting records, one in 1984, and another of 8 individuals in 1992. | Ghose & Dutta 2011 |
| | Presence indicated through interviews and field surveys in Kamlang Wildlife Sanctuary. | Choudhury 2001 |
| Anjaw | One poaching incident recorded. | Badola et al. 2020 |
| Changlang | Presence indicated in Namdapha Tiger Reserve. | Ghosh 1985 |
| | Interviews and field surveys. | Choudhury 2001 |

Lubrang village (Bomdila Forest Division, West Kameng district, Western Arunachal Pradesh) and Karle village (Along Forest Division, Shi-Yomi district, formerly West Siang, central-eastern Arunachal Pradesh). This is the first photographic and hence confirmatory evidence of red panda presence near Karle village, in Shi-Yomi district of Arunachal Pradesh. These locations are part of the unclassed forests of Arunachal Pradesh,

and are managed by the State Forest Department administratively as Forest Divisions.

Habitat suitability analysis predicts that Eastern Arunachal Pradesh harbours more suitable habitat for red pandas as compared to Western Arunachal Pradesh (Thapa et al. 2018b). While the Pangchen valley in Tawang district and the Chug valley in West Kameng district of Western Arunachal Pradesh have received some focus for community-based conservation efforts for Red Pandas (Srivastava & Dutta 2010; Chakraborty et al. 2015) districts in central and eastern Arunachal Pradesh have received less focus and there is very limited information available beyond the historical survey reports mentioned in Table 1.

Red Pandas are habitat specialists (Yonzon & Hunter 1991; Pradhan et al. 2001). In Bhutan their presence most often overlaps with the rural human population which is undergoing rapid socio-economic development (Dorji et al. 2012). Site-specific habitat degradation in high-altitude areas of Arunachal Pradesh probably occur due to anthropogenic disturbance in relation to firewood collection (mostly *Rhododendron* sp.) and unregulated grazing by local communities (Kalita & Khan 2013; Dutta et al. 2013; Paul et al. 2019). As observed in this study, site-specific habitat degradation is prevalent and such anthropogenic activity overlap with red panda habitat seems to be the case for some areas of Arunachal Pradesh as well.

It seems that Red Pandas have persevered in the forests of Arunachal Pradesh, but information on the population status and trends are lacking. Hunting by the local tribals in Arunachal typically has its roots in the need for basic subsistence, trade and commerce, and also for customary, religious and cultural practices (Aiyadurai et al. 2010; Selvan et al. 2013). Even though hunting is prevalent in many regions of Arunachal Pradesh, the hunting of Red Pandas has seldom come to light (Choudhury 2001; Aiyadurai et al. 2010; Srivastava & Dutta 2010). Encountering Red Panda is considered a good omen as per traditional beliefs in Arunachal (Janaki et al. 2020). There are very few records of illegal trading and limited demand of Red Panda parts from recent years (Badola et al. 2020). Enquiries regarding the presence of red panda in the survey locations of the current study did not indicate hunting as a threat. During the field survey, interaction with local people suggested that sightings of the Red Panda had become rare over time (Christi Sylvia pers. comm., 06.v.2020). This could be attributed to site-specific habitat disturbances, especially due to people's subsistence-related dependence on Bamboo vegetation and surrounding habitats. An intensive state-wide assessment for the population of Red Panda which could also uncover potentially connected or isolated habitats such as the ones identified by this study is recommended.

There is a stark difference in socio economic development of the West Kameng district of western Arunachal Pradesh and Shi-Yomi district that lies in central-eastern Arunachal Pradesh. The West Kameng district has many popular tourist destinations. But within Shi-Yomi district, while the Mechuka village and its hilly ranges are a popular nature and culture-based tourist destination with an economy driven by beautiful homestays, the Monigong village and its hilly ranges on the other hand lacks basic infrastructure, although it harbours the same scenic surroundings. The locals of this area rely on the surrounding forests for subsistence and most of them currently work as daily wagers labouring to build roads in this region. As observed during the study period, most large-scale infrastructure work in this region pertained to developing the linear infrastructure – the highways and roads. However, interaction with local people suggested a dire need for developing this remote region further (Christi Sylvia, pers. comm., 06.v.2020).

While development is inevitable and even necessary to a certain extent, largely to improve the livelihood of the marginalised communities of Arunachal Pradesh; nevertheless, grassroots-scaled, community-based conservation work and sustainable tourism initiatives that limit habitat destruction are recommended. Inclusive conservation has proved effective in Arunachal Pradesh time and again (Athreya 2006; Dutta et al. 2012; Rane & Datta 2015). Managerial interventions for maintaining high-altitude habitat biodiversity in the state as well as maintenance of community-owned forests is important for securing the in situ conservation of Red Panda, with benefits to communities for their stewardship under payment for ecosystem services (PES). This may also be complemented by ex situ conservation efforts for Red Panda, with an aim for their future re-introduction into wild habitats.

Community stewardship is crucial to promote the existence of a peculiar species like the Red Panda that thrives on bamboo, a flora on which dependency of the people of Arunachal Pradesh is also high. Inclusive conservation could ensure the continued persistence of this species in this state that boasts of the largest Red Panda habitat in India.

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# On the reproductive biology of the invasive Armoured Sailfin Catfish *Pterygoplicthys pardalis* (Castelnau, 1855) (Siluriformes: Loricariidae) from the natural drainages in Thiruvananthapuram, India

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**Abstract:** The present paper deals with the breeding biology of the invasive fish *Pterygoplicthys pardalis* from the natural drainages of Thiruvananthapuram, Kerala. The specimens were collected from Amayizhanchan Thodu, a natural drainage running through the heart of the city. A total of 145 males and 142 females were collected from January to December 2018. The sex ratio was determined monthly as the percentage of males to females (M: F). Monthly mean gonadosomatic index (GSI) values were compared using R stat, and GSI was plotted monthly to identify the spawning seasons. The gonads were examined and different stages of maturity were noted using standard methods. The length at first maturity was also found out. The fish exhibit courtship behaviour and the eggs are deposited in burrows and also along the crevices in the granite walls; the burrows are guarded by the male fish till the young ones are hatched out. The sex ratio showed an average mean value of 1.04: 1 and showed no significant departure. The size at first maturity was 23.9 cm standard length. The ova diameter studies show the presence of ripe ovaries throughout the year, with peaks during March and April and between August and September and in December, indicating the fish is a batch spawner. The absolute fecundity ranges from 923 to 14,777 eggs, and the relative fecundity ranges 0.0142–0.0015. Regression analysis showed a significant relationship (P <0.001) between absolute fecundity and the total length, the total body weight, and ovary weight. The strong breeding behaviour, the presence of accessory respiratory organs, the absence of natural enemies and parental care makes *Pterygoplichthys pardalis* a successful invader in the natural drainage. More biological studies are needed for the successful eradication of the species from the invaded ecosystem.

**Keywords:** Breeding biology, breeding behaviour, fecundity, invasive alien species, invasion biology.

Malayalam: കേരളത്തിൽ തിരുവനന്തപുരം നഗരത്തിലെ സ്വാഭാവിക നീർച്ചാലുകളിൽ ജീവിക്കുന്ന ആമസോൺ സക്കർ മത്സ്യത്തിന്റെ പ്റ്റെറിഗോപ്ലിക്ത്തിസ് പർഡാലിസ്(പ്രജനന ജീവശാസ്ത്രത്തെക്കുറിച്ചാണ് ഈ പ്രബന്ധത്തിൽ വിവരിക്കുന്നത്. നഗരത്തിന്റെ ഹൃദയഭാഗത്തുകൂടി ഒഴുകുന്ന പ്രകൃതിദത്ത ഡ്രെയിനേജ് ആയ അമയിഴഞ്ചാൻ തോട്ടിൽ നിന്നാണ് സാമ്പിളുകൾ ശേഖരിച്ചത്. 2018 ജനുവരി മുതൽ ഡിസംബർ വരെ മൊത്തം 145 ആൺ മത്സ്യങ്ങളെയും 142 പെൺ മത്സ്യങ്ങളെയും ശേഖരിച്ചു. ലിംഗ അനുപാതം പ്രതിമാസം ആൺ മത്സ്യങ്ങളുടെ ശതമാനം പെൺ മത്സ്യങ്ങളുടേതുമായി താരതമ്യം ചെയ്തു. പ്രതിമാസ ശരാശരി ഗോണാഡോസോമാറ്റിക് സൂചിക (GSI) മൂല്യങ്ങൾ R സ്റ്റാറ്റ് ഉപയോഗിച്ച് താരതമ്യം ചെയ്തു. മുട്ടയിടുന്ന സീസണുകൾ തിരിച്ചറിയാൻ GSI പ്രതിമാസം ഗ്രാഫുകളിൽ രേഖപ്പെടുത്തി. ജനനഗ്രന്ഥികൾ (ഗോണാഡുകൾ) പരിശോധിക്കുകയും ശാസ്ത്രീയ രീതികൾ ഉപയോഗിച്ച് വളർച്ചയുടെ വിവിധ ഘട്ടങ്ങൾ പരിശോധിക്കുകയും ചെയ്തു. ആദ്യമായി പ്രായപൂർത്തിയാകുന്ന ദൈർഘ്യവും കണ്ടെത്തി. മത്സ്യങ്ങൾ കോർട്ട്ഷിപ്പ് സ്വഭാവം പ്രദർശിപ്പിക്കുകയും മുട്ടകൾ മാളങ്ങളിലും കരിങ്കൽ ഭിത്തികളിലെ വിള്ളലുകളിലും നിക്ഷേപിക്കുകയും ചെയ്യുന്നു; കുഞ്ഞുങ്ങൾ വിരിയിക്കുന്നതുവരെ ആൺമത്സ്യം കാവൽ നിന്ന് മുട്ടകളെ സംരക്ഷിക്കുന്നു. ലിംഗാനുപാതത്തിന്റെ ശരാശരി മൂല്യം 1.04: 1 ആണ്. ആദ്യമായി പ്രായപൂർത്തിയാകുന്ന വലുപ്പം 23.9 സെന്റിമീറ്റർ സ്റ്റാൻഡേർഡ് നീളമായിരുന്നു. അണ്ഡത്തിന്റെ വ്യാസത്തെപ്പറ്റിയുള്ള പഠനങ്ങൾ വർഷം മുഴുവനും (മാർച്ച്, ഏപ്രിൽ മാസങ്ങളിലും ഓഗസ്റ്റ് മുതൽ സെപ്റ്റംബർ വരെയും ഡിസംബറിലും) പൂർണവളർച്ചയെത്തിയ അണ്ഡത്തിന്റെ സാന്നിധ്യം കാണിക്കുന്നു. ഇത് മത്സ്യം വർഷം മുഴുവനും മുട്ടയിടാനുള്ള (ബാച്ച് സ്പോൺ) സാധ്യത സൂചിപ്പിക്കുന്നു. മുട്ടയുടെ കേവലമായ എണ്ണം 923 മുതൽ 14,777 മുട്ടകൾ വരെയാണ്; ആപേക്ഷികമായ മൂല്യം 0.0142-0.0015 വരെയാണ്. മൊത്തം മുട്ടകളുടെ എണ്ണവും, മൊത്തം ദൈർഘ്യവും, മൊത്തം ശരീരഭാരവും അണ്ഡാശയ ഭാരവും തമ്മിൽ സാരവത്തായ ബന്ധം (പി <0.001) റിഗ്രഷൻ വിശകലനം ചൂണ്ടിക്കാണിക്കുന്നുണ്ട്. ശക്തമായ പ്രജനനരീതികളും, സഹായക ശ്വസനാവയവങ്ങളുടെ സാന്നിധ്യവും, സ്വാഭാവിക ശത്രുക്കളുടെ അഭാവവും രക്ഷാകർതൃ പരിചരണവും ആണ് ആമസോൺ സക്കർ മത്സ്യത്തെ പ്രകൃതിദത്ത നീർച്ചാലുകളിൽ വിജയകരമായി ആധിപത്യം സ്ഥാപിക്കുന്നതിന് സഹായിച്ചിരിക്കുന്നതെന്ന് അനുമാനിക്കാം. അധിനിവേശ ആവാസവ്യവസ്ഥയിൽ നിന്ന് ഇവയെ വിജയകരമായി തുടച്ചുനീക്കുന്നതിന് കൂടുതൽ ജീവശാസ്ത്രപരമായ പഠനങ്ങൾ ആവശ്യമാണ്.

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## INTRODUCTION

Reproductive biology is one of the key features considered for the invasion biology studies of fish (Feiner et al. 2012; Gutkowsky & Fox 2012; Zahorska et al. 2013; Horkova & Kovac 2015). The suckermouth armoured catfishes of the family Loricariidae, especially the genus *Pterygoplichthys* T.N. Gill, native to inland water bodies of South America, is an emerging invasive fish globally (Orfinger & Goodding 2018), also, one of the most popular and commonly traded aquarium fish in India (Knight 2010). The sailfin armoured catfish species recorded from the natural water bodies of India include *P. anisitsi, P. disjunctivus, P. multiradiatus, P. pardalis,* and possible hybrids (Sinha et al. 2010; Singh 2014; Kumar et al. 2015; Soundararajan et al. 2015; Sandilyan et al. 2016; Hussan et al. 2018).

The high invasiveness shown by this species is primarily because of its unique biological features, which include the ability to survive in water with varying levels of flow regimes (Nico & Martin 2001; Welcomme & Vidthayanom 2003; Chavez et al. 2006; Nico et al. 2012), temperature and dissolved oxygen using accessory respiration with diverticula of the gastrointestinal tract (Armbruster 1998; da Cruz et al. 2013), and pH (Mendoza et al. 2009; Parente et al. 2017), a broad range of diet (German et al. 2010) and the absence of natural predators (Nico & Martin 2001; Gibbs et al. 2008), which enable them to survive in the invaded ecosystems. They are salt-tolerant and survive well in brackish water regions (Mendoza et al. 2009; Kumar et al. 2018). They also have efficient reproductive strategies, including parental care and deter predation by possessing bony plates that cover their body (Hoover et al. 2004; Liang et al. 2005; Wei et al. 2017). One such extreme measure of parental care is exhibited by the male members of the genus *Pterygoplichthys.* It is the burrows they dig out on the river banks, and the female will lay eggs that are guarded by males (Nico et al. 2009; Alamdin & Jumawan 2016). Thus, site selection for spawning, nest building and caring of eggs and the young ones are a complex set of reproductive behaviour among loricariids (Covain & Fisch-Muller 2007).

The reproductive traits of *Pterygoplichthys* spp such as size at maturity, spawning, sex-ratio, ova diameter, fecundity and reproductive plasticity are studied to have a better knowledge on the reproductive dynamics (Jumawan and Herrera, 2014; Gibbs et al., 2017) which is a prerequisite for the management measures of an invasive species (Hoover et al., 2005; Kopp et al. 2009). The reproductive patterns of *P. disjunctivus* from Florida were extensively analysed by Gibbs et al. (2017) for 10 years. In contrast, studies on the particular aspects of reproduction have been published by Rueda-Jasso et al. (2013), Jumawa & Herrera (2014) on *P. disjunctivus* from Mexico and Philippines, Samat et al. (2016) on *P. pardalis* from Malaysian waters, and Cook-Hildreth et al. (2016) from Texas waters. Wei et al. (2017) studied the maturity of *Pterygoplichthys* spp., a hybrid from China and reported self-sustaining populations in the drainages of the area.

The negative impacts caused by *Pterygoplichthys* spp. in the invaded ecosystems, include siltation problems, bank erosion in rivers and streams, competition with native species for food and space, consumption of the eggs of native and threatened species, displacement of vegetation and disturbance to the breeding grounds of native fish and economic losses to the fishermen including damage to the fishing gears, are reported earlier by many researchers (see Bunkley-Williams et al. 1994; Hoover et al. 2004; Chavez et al. 2006; Wakida-Kusunoki et al. 2007; Hossain et al. 2008; Cook-Hildreth 2009; Krishnakumar et al. 2009; Mendoza et al. 2009; Nico et al. 2009; Capps & Flecker 2013).

The reproductive parameters of oviparous fish outside their natural range will supplement the evidence to comprehend their establishment in the invaded ecosystems (Samat et al. 2016). Such studies, especially on reproductive biology, are required to better understand the natural history and reproductive plasticity, which are necessary tools for effectively managing this emergent invasive species. Despite the increasing numbers of publications regarding the invasion range extension of *Pterygoplichthys* spp. in various biogeographic regions, a knowledge gap on the reproductive biology of this invasive fish persists in India. Hence to address this significant gap, we investigated the reproductive biology of invasive loricariid fish *Pterygoplicthys pardalis* with a description of their breeding behaviour in natural streams.

## MATERIALS AND METHODS

### Collection Site and Sampling

The fishes for the study were collected from Amayizhanchan Thodu, (8.484711 – 8.566293$^0$N; 76.933348 – 76.949982$^0$E), a natural drainage of 3.4 km$^2$ in Thiruvananthapuram city, Kerala (Figure 1; Image 1). A total of 145 males and 142 females were collected fortnightly from January to December 2018 using a cast net, 5-m long and 3.8-cm mesh size. The fishes were

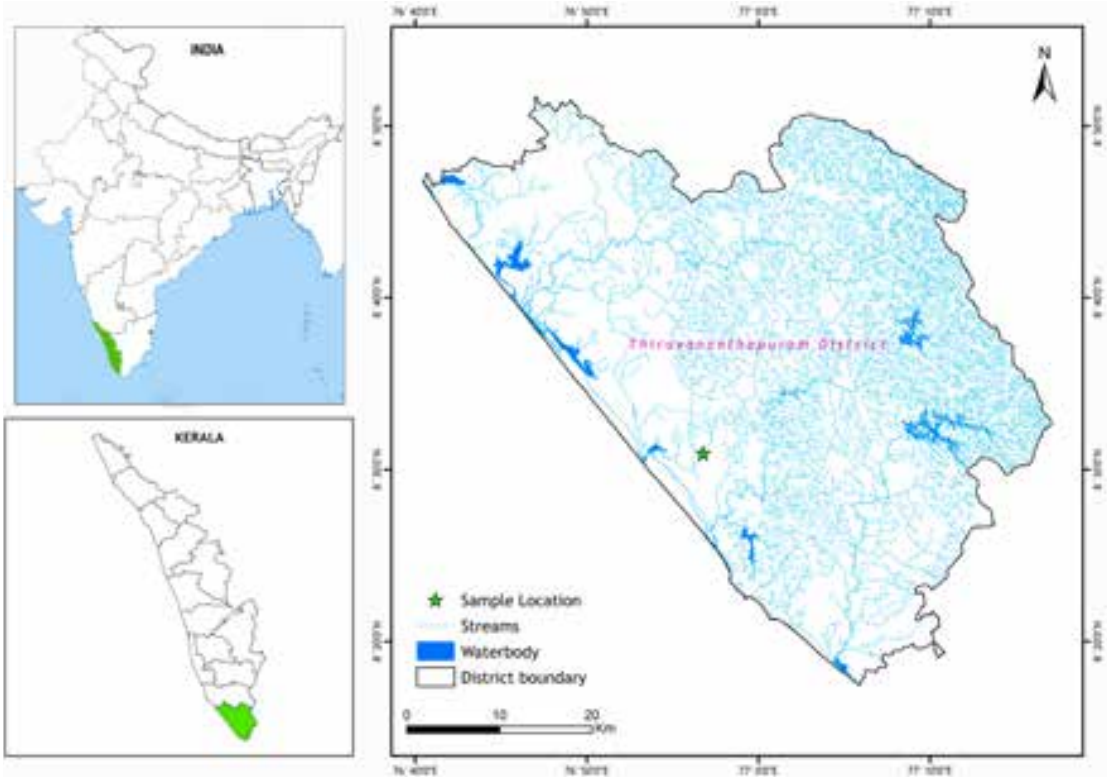


Figure 1. Sampling location at Amayinzhanthodu, Thiruvananthapuram, Kerala, India.


Image 1. *Pterygoplichthys pardalis*: A—lateral view | B—catch in cast net | C—specimens caught in single cast netting. © Biju Kumar

dissected, but before that, they were kept for four hours in a deep freezer. The sex ratio was determined monthly as the percentage of males to females (M: F). The burrow structure was captured with a digital camera, and its width, diameter, depth, the maximum height of entrance, shape of the tunnel, condition of the burrow, and occupancy of burrows were noted (Image 2).

Measurements of total length (TL, cm), standard length (SL), total weight (TW, g) and gonad weight (GW, g) were taken for male and female specimens. Total length and standard length were measured to the nearest 0.1 cm, and weight to the nearest gram 0.1 g using a digital balance. Gonadosomatic index (GSI) was calculated as GSI = [(gonad weight)/(total weight of fish)] × 100 (Vazzoler, 1996). Monthly mean GSI values were compared using R stat, and GSI was plotted monthly to identify the spawning seasons.

The fishes were dissected to remove their gonads. Stages of maturity were determined following (Mazzoni & Caramaschi 1997) and ova diameter observations. The number of fishes in various stages include: immature (16), maturing (33), ripe (45), regressing spent (18), and recovering spent (30). Ovaries were excised, weighed to the nearest gram, and preserved in 10 per cent formalin for later assessment. Spawning type was designated according to the stage of the ripe and spent ovaries. Testis was characterized using a visual-based macro scale of maturity based on testicular size, colour, and swelling (Lowerre-Barbieri et al. 2011).

The length at first maturity ($L_{50}$) was defined as the total length, where 50% of all individuals are predicted to be adults (Vazzoler 1996). For ova diameter studies, the diameter of maturing and mature eggs (Vitellogenic oocytes) was measured to the nearest 0.01 mm with digital calipers and from the photos taken using Leica stereo zoom dissecting microscope.

To evaluate the absolute fecundity (AF), ripe ovaries which are in late-maturing stages to ripe ones (mid to late vitellogenic phase- Patiño & Sullivan 2002) were taken for the studies, and 100 mg sub-samples of eggs from the anterior, middle, and posterior regions were weighed and counted under a binocular stereo microscope. The counted eggs were averaged and extrapolated for the entire ovaries using the formula: F= nG/g where F is the fecundity, n is the number of eggs in the sub-sample, G, ovary weight and g the subsample weight. The number and size of eggs were determined under a binocular dissecting microscope. The gonadal cycle also has been estimated based on macroscopic observation, and five stages have been described (Araújo et al. 1998; Duarte & Araújo 2002). To evaluate the relative fecundity (RF), the absolute fecundity is divided by the total weight of the fish (Bagenal 1978). The relationship between relative fecundity (RF) and the variables total body length (TL), the total fish weight (FW), and ovary weight (OW) were estimated.

## RESULTS

### Breeding behaviour

*Pterygoplichthys pardalis* that invaded the natural drainages in Thiruvananthapuram city (Images 1A–C) excavate burrows for breeding <https://www.youtube.com/watch?v=h5VZ-SVw7Wc>. Our observations reveal that the male fish excavate burrows (Image 2A, B) before spawning for laying eggs.

The burrows (older/used) above the water level are small and triangular to circular, measuring 10–20 cm in diameter. In contrast, those below water are larger without definite shape, measuring 30–50 cm in width. The horizontal burrows are 120–140 cm deep, with the slope extending downwards into the bank. Courtship behaviour was exhibited in the form of circular movements near the burrows (Images 2C–E), by rubbing their bodies with the flashing of water, and in a few cases, multiple males take part in the process, and the eggs are guarded till the young ones emerge from the nest (Image 2F).

It was also observed that this species also selects crevices in the granite walls of the stream to deposit eggs, which may be one of the reasons for their higher rate of survival in the drainages of Thiruvananthapuram city in Kerala.

### Sex ratio

A total of 145 males and 142 females of *P. pardalis* collected from the study site showed sex ratio (M: F) of an average mean value of 1.04: 1. The ratio was tested by chi-square analysis for differences from hypothetical ratio 1: 1, which showed no significant departure.

### Stages of the reproductive cycle

Females (N= 142) ranging from SL 17.2 cm (TL 24.4 mm) to 45.6 cm (TL 58.4 mm) were considered for ascertaining reproductive stages. Mature ovaries exhibited asymmetry, whereas immature ones were symmetrical. It was observed that the larger the size of the individual, the greater would be the occupancy of the ripe ovary in the abdominal cavity and vice versa. Based on macroscopic and microscopic examination (Table 1) and ova diameter studies, five developmental stages of

**Table 1. Macroscopic and microscopic characteristics of ovarian maturity in *Pterygoplichthys pardalis*.**

| Stages of maturity | Macroscopic and microscopic features |
|---|---|
| 1. Immature | Tiny ovaries, ranging 11.08–32.5mm, SL mostly less than 33.4 cm occupying only a tiny percentage of the body cavity. Ovary thin transparent to light pink, no visible oocytes |
| 2. Maturing | Size of the ovary ranges between 33–59.36 mm with tiny granules to less yolky oocytes with SL around 35 cm, colour opaque to pale yellow |
| 3. Ripe | Highly vascularised, thin-walled large asymmetrical ovaries occupying mostly half of the body cavity, brightly orange coloured fully yolked oocytes, size (1.88–2.81 mm) |
| 4. Regressing spent | Large flaccid thick-walled ovaries usually with very few or no vitellogenic oocytes, vascularisation still visible but less, thick brush-like fimbriae projects from the ovarian wall into the lumen. |
| 5. Recovering spent | Ovaries purple to dark pink with thick inner ovarian walls with slight vascularisation with small oocytes of different diameters, absence of ripe oocytes |

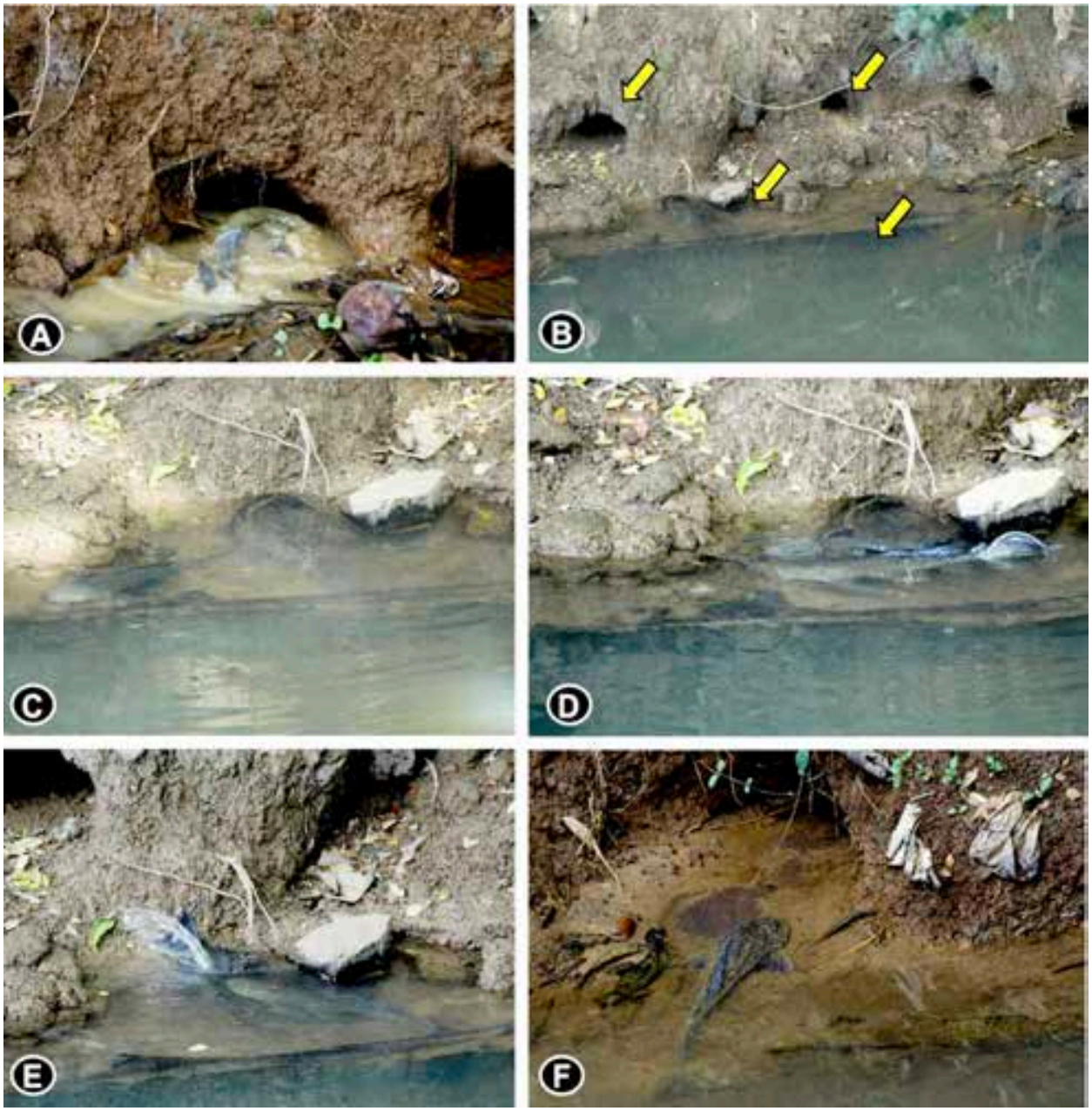


**Image 2. Breeding behaviour of *Pterygoplicthys pardalis*: A—*P. pardalis* making burrows in canal margins | B—old and new burrows above and below the water level | C, D, E—courtship behaviour of *P. pardalis* around the burrow opening | F—*P. pardalis* guarding the burrow. <https://www.youtube.com/watch?v=h5VZ-SVw7Wc> © Biju Kumar**

gonads (immature, maturing, ripe, regressing spent, and recovering spent) were identified in female fish (Table 1, Image 3 A–D, 4 A–F). In males, three maturity stages were identified: immature, maturing and mature, depending upon the colour and size of testes (Image 5 A–F).

The macroscopic and ova diameter studies showed *P. pardalis* has an intermittent spawning period with ripe ovaries throughout the year, maximum during March and April. Immature stages were noticed from May onwards, followed by maturing ones from June to November with a peak in July. The ripe ovaries were present in all months except February, with a maximum during March and April. Accordingly, the spent ovaries (regressive and recovering ones) and immature stages were noticed in the subsequent months, which mean the fish spawns during the rains (as summer rains occur during May). The second set of a large number of ripe ovaries was visible in August and December, with regressing and recovering spent in September and January, respectively showing the extended spawning season for the fish.

### Length at first maturity

The minimum length to attain sexual maturity with vitellogenic oocytes was noticed in females at a standard length of 23.9 cm. The length at which 50% of the fish gets matured is at 36.56 cm (Figure 3).

### Fecundity

To understand the absolute fecundity (AF), the ovary (left lobe) of ripe fishes were dissected, and the ripe ova were fully counted and extrapolated. The absolute fecundity of fish ranges from 923 (TL 393 mm; SL 294 mm) to 14,777 eggs (TL 516 mm; SL 414mm), and the relative fecundity ranges from 0.0142 (TL 459 mm) to 0.0015 (TL 393 mm). In mature fish, both the ovaries (left and right lobe) showed a clear asymmetry inside the abdominal cavity (Image 4A).

### Gonado-Somatic index and ova diameter

The GSI of females showed three peaks, with the first one in March–April, the second in August–September and a third in December, which indicates an extended batch spawning nature of the fish (Figure 4). Similar to GSI, three peaks could also be observed with regard to the mean ova diameter, confirming an extended spawning season for *P. pardalis* (Figure 5). The maximum ova diameter obtained in the present study was 3.75 mm. While comparing ova diameter frequencies corresponding to different maturity stages, maximum oocyte diameter (mean) was noticed in the ripe stage (Figure 6).


**Figure 2. The maturity stages of female *Pterygoplichthys pardalis* in various months under study: IM—Immature | M—Maturing | R—Ripe | REGSP—Regressing spent | RESP—Recovering spent.**

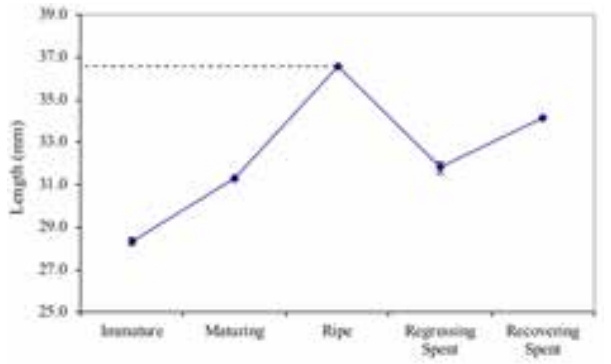


**Figure 3. *P. pardalis*: Length at first maturity of female in the present study.**

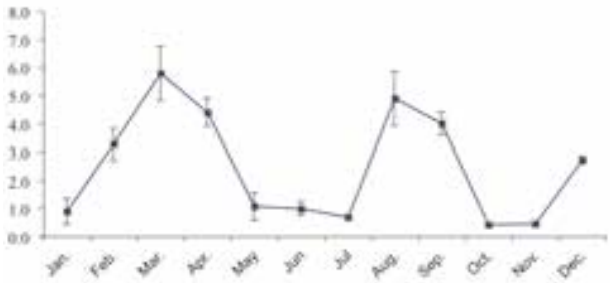


**Figure 4. Monthly variations of GSI in *P. pardalis* (female) from the present study. Error bars represent SD.**

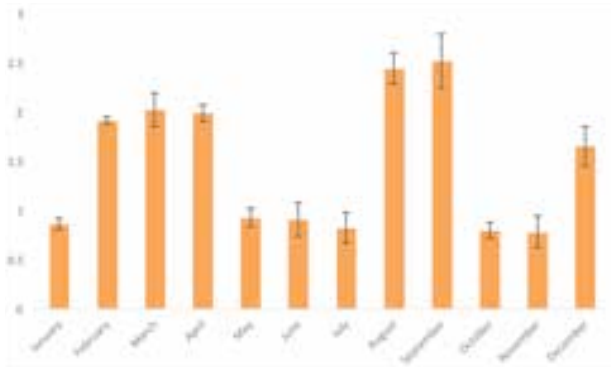

**Figure 5. Mean ova diameter (mm) of *P. pardalis* in different months during the present study. Error bars represent SD.**

Image 3. Maturity stages of female *Pterygoplichthys pardalis*: A—immature ovary in situ | B—immature ovary | C—maturing ovary in situ | D—maturing ovary. © Smrithy Raj

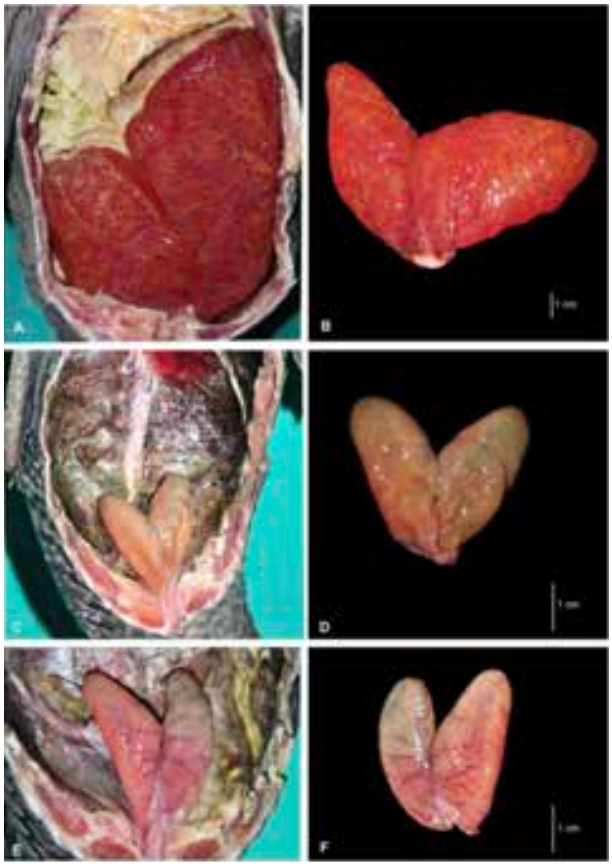

Image 4. Maturity stages of female *Pterygoplichthys pardalis*: A—ripe ovary in situ | B—ripe ovary | C—spent/regressing ovary in situ | D—spent/regressing ovary | E—recovering spent ovary in situ | F—recovering spent ovary. © Smrithy Raj

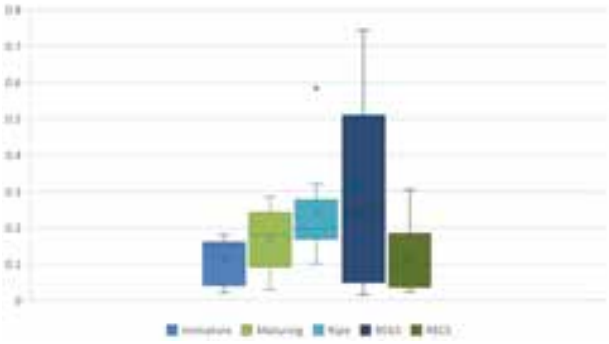

Figure 6. Ova diameter (mm) and maturity stages of *P. pardalis* in the present study. Error bars represent SD.

### Regression analysis

Regression analysis showed a significant relationship ($P < 0.001$) between absolute fecundity and the total length, the total body weight and ovary weight (Figures 7–9). As the total length, total body weight, and ovary weight of fish increases, the fecundity does not increase correspondingly due to lesser 'b' value (2.0482, 0.8214, 0.6944).

## DISCUSSION

Although the suckermouth armoured catfish of the genus *Pterygoplichthys* is an emerging global invader, the details of its invasion biology are also being studied from its extended invasion ranges (Orfinger & Goodding 2018), the unique breeding behaviour of *Pterygoplichthys* spp. by excavating burrows in river banks have been documented from Florida (Nico et al. 2009), Mexico (Lienart et al. 2013) and the Philippines (Almadin & Jumawan 2016). Similar breeding behaviour was also observed in the present study. The females use the burrows dug by the males to deposit eggs and are guarded by the males till the young ones emerge from the nest; similar behaviour was also noted by Mazzoni et al. (2002), Power (2003), and Liang et al. (2005), which establish that the males of this fish exhibit parental care by building nests, protecting eggs and as well as the juveniles. Lienart et al. (2013) observed egg clutches frequently inside active nests, and such observation was

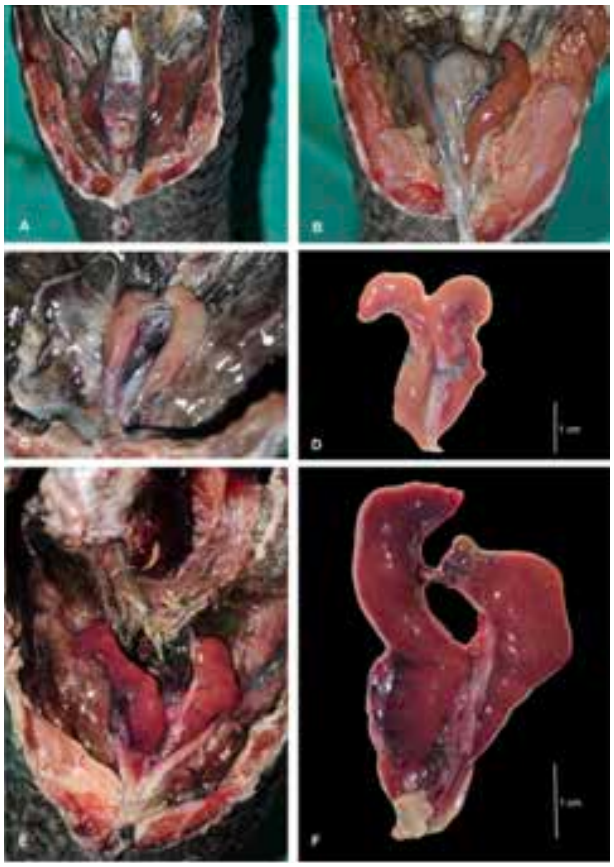

Image 5 A–F. Maturity stages of male *Pterygoplichthys pardalis*: A, B—immature testis | C, D—maturing testis | E, F—mature testis. © Smrithy Raj

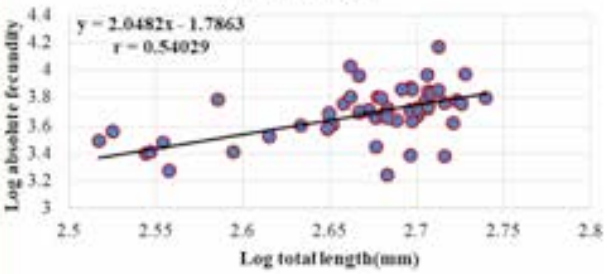


Figure 7. Logarithmic relationship between absolute fecundity and the total length of *P. pardalis* from the present study.

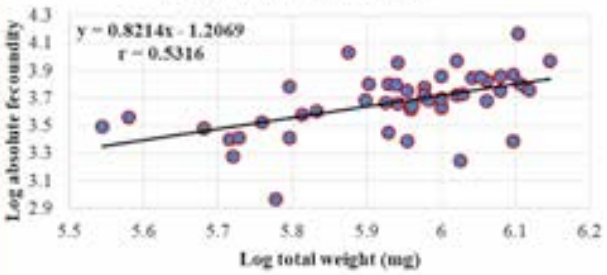


Figure 8. Logarithmic relationship between absolute fecundity and the total weight of *P. pardalis* from the present study.

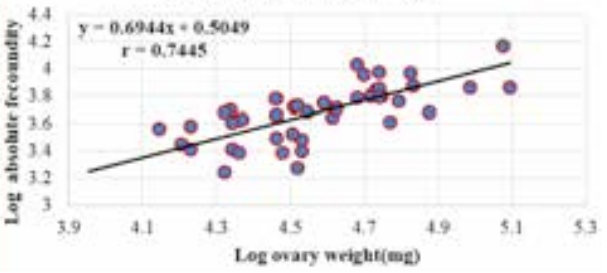


Figure 9. Logarithmic relationship between absolute fecundity and ovary weight of *P. pardalis* from the present study.

not observed in the present study. The present study observes that *Pterygoplichthys pardalis* use the crevices in the granite wall for breeding, which was the first record of breeding behaviour of the species in the Indian water bodies. The benefit of additional natural space also compounded the reproductive behaviour of the fish enhanced its invasive nature in the invaded ecosystem. The sex ratio (M: F) of *P. pardalis* showed an average mean value of 1.04: 1, indicating no bias, showing an equal representation of both sexes in the population.

The current study on the macroscopic and the ova diameter clearly showed different reproductive strategies, showing an extended spawning period with ripe ovaries throughout the year, mostly during March, April, August, and December. Spent ovaries (regressive and recovering ones) and immature stages were noticed in the subsequent months. Such reproductive plasticity was also reported for *P. disjunctivus* by Gibbs et al. (2017) from Volusia Blue Spring for a decade. The peak breeding season reported in *P. pardalis* by Wakida-Kusunoki, & Amador-del Angel (2011) was from June to September. GSI and ova diameter also showed the same results, which coincided with these months. Fish with ripe gonads were obtained throughout our study period except for February, which is consistent with the studies of Rueda-Jasso et al. (2013) for *P. disjunctivus* from Mexico. In the ripe ovaries itself, we came across oocytes with different diameters, consisting of several immature and maturing ova at the same time, which proves the fish as a determinate batch spawner. Similar to other congeners, *P. pardalis* also spawn in batches (Suzuki et al. 2000; Duarte & Araujo 2002). Studies on *P. disjunctivus* from the Philippines by Jumawan & Herrera (2014) also support this view. Batch spawning in *P. pardalis* and its congeners like *Loricariichthys platymetopon*, *Loricariichthys* sp., and *Loricaria* sp. (Suzuki et al. 2000),

and *Hypostomus affinis* (Duarte & Araujo 2002) have been reported, where the mature ovaries are seen along with immature and maturing ones with pre-vitellogenic eggs. All Loricariids do not spawn in batches, as *Hypostomus ternetzi*, *Megalancistrus aculeatus*, and *Rhinelepis aspera* are total spawners (Suzuki et al. 2000).

Changes in climatic events could disrupt the reproductive process in fishes (Yoneda & Wright 2005; Pankhurst & Munday 2011). Stable water temperature in tropical rivers is considered best instead of fluctuating waters in subtropical rivers and a shift in temperature could confine the spawning period as well (Samat et al. 2016). According to Humphries et al. (1999), flooding is likely the dominant factor in the breeding behaviour of fish. *Pterygoplichthys* may be adapted to take advantage of flooding by initiating reproduction before or at the time of the flood, which allows fry to feed and grow within inundated floodplain habitats (Kramer 1978; Humphries et al. 1999; Lienart et al. 2013). Based on the results of this work, it may be presumed that *P. pardalis* inhabiting the natural drainages without noticeable temperature variations is a batch spawner and temperature may not be an important limiting factor for spawning of fish that live in a habitat with stable or less fluctuating water temperature. The population assessment of *P. pardalis* from natural drainages of Thiruvananthapuram indicated rapid growth, high-performance index and continuous recruitment, which resulted in their successful invasion (Raj et al. 2020). Maximum reproductive activity of *P. disjunctivus* and *L. multiradiatus* were reported from July to September (Liang et al. 2005; Rueda-Jasso et al. 2013).

The size at first maturity of *P. pardalis* in our study was 23.9 cm standard length (TL 33.5 cm). The minimum size at sexual maturity with highly vitellogenic ova in *P. disjunctivus* was reported as 26.7 cm SL onwards by Jumawan & Herrera (2014) from the Philippines. The case of precocious maturation was also reported in smaller females during the peak spawning time. A report of sexual maturity in *P. disjunctivus* by Gibbs et al. (2008) was of 300 mm SL. The length at which 50% of fish gets mature is 36.56 cm. Gonadal development of male and females in the present study also corroborates with the observations of researchers from other parts of the world.

Absolute fecundity of fish ranges from 923 to 14,777 in the present study, and the fecundity reported for *P. pardalis* from Malaysian waters ranged between 1,297 and 18,791 (Samat et al. 2016). A linear relationship is also exhibited between fecundity and TL, TW, and GW of the fish (Bagenal 1978; Mazzoni & Caramaschi 1995; Duarte & Aroujo 2002). The highest degree of correlation was exhibited in the present study between fecundity and the total length of the fish (r= 0.7445).

The maximum ova diameter obtained in the present study was 3.75 mm, which was in accordance with the ova diameter of 3.3 mm for *P. pardalis* by Samat et al. (2016), 3.8 mm and 3.6 mm obtained for *P. disjunctivus* by Gibbs et al. (2008) and Jumawan & Herrera (2014) respectively. The largest mean ova diameter was 2.327 for ripe ova, as the ova samples contain vitellogenic oocytes of different sizes from the anterior, middle and posterior regions.

A clear case of asymmetry in the ripe ovary with the left lobe larger than the right in the abdominal cavity was observed in the present study. Similar asymmetry in the mature ovary was also observed in *P. disjunctivus* (Gibbs et al. 2008). This asymmetry may be due to the large area occupied by the intestine and the bulk of fat in the abdominal cavity as reported by Rounsefell (1957) in three female salmonids species.

There are no predators for *P. pardalis* in the natural drainages where they have established. This, coupled with the availability of plenty of detritus in the polluted drainages as food, provide them with a competitive edge over indigenous species, better reproductive strategies, including the ability to breed in burrows along the stream banks and crevices in the granite walls, accessory respiratory organs, batch spawning abilities and parental care assisted *P. pardalis* to colonize the system successfully. The population assessment of *P. pardalis* from the same habitat indicated that rapid growth, high growth performance index, and continuous recruitment are the reasons for their successful invasion, and targeting the young individuals would help in controlling the population of the invasive fish (Raj et al. 2020). We recommend more research on the invasion biology of invasive *P. pardalis*, incorporating long-term studies to fully understand the long-term strategies for their establishment and plasticity in the reproductive behaviour.

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# On the high bird diversity in the non-protected regions of Trashiyangtse District in Bhutan

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**Abstract:** Birds are ecological indicators of ecosystem health. Baseline information on bird diversity are, therefore, important for ecological monitoring. Such information is, however, sorely lacking for many areas outside the protected areas. Here, we explore the avian diversity and present a comprehensive checklist for the non-protected regions of Trashiyangtse District in northeastern Bhutan. We also categorise the bird species by their residency pattern, feeding guilds, abundance, and IUCN Red List status. We conducted an avifauna exploration for a period of four years from 2017 to 2020, mostly through opportunistic encounters coinciding with regular field visits. We recorded a total of 273 bird species belonging to 173 genera, 69 families and 19 orders. Passeriformes was the most dominant order with 41 families and 174 species and Muscicapidae was the most dominant family with 12 genera and 32 species. Most birds were altitudinal migrants (39%), insectivorous (45%), and occasional (44%) in terms of residency pattern, feeding guild, and abundance, respectively. Only one species (*Ardea insignis*) was listed as Critically Endangered and one (*Haliaeetus leucoryphus*) as Endangered. Our study identified the non-protected regions of Trashiyangtse District as an important bird diversity area in Bhutan.

**Keywords:** Avifauna, bird diversity, nonprotected area, northeastern Bhutan, threatened birds.

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## INTRODUCTION

Birds are the best known group of animal taxa at the global level, with the most extended time series data available (James et al. 2017). Their distribution is ubiquitous across all continents (Nyffeler et al. 2018), enabled by their preference to live in heterogeneous environments. Assessment of avifaunal communities is essential because they can serve as effective indicators of ecosystem status and health, in both qualitative and quantitative terms. This is because birds perform diverse ecological roles, ranging from disease regulation and, biomass recycling to environmental sanitation, seed dispersal, and pollination (James et al. 2017; Mukhopadhyay & Mazumdar 2017; Kiros et al. 2018). Birds are also sources of food and, spiritual inspiration, in addition to being important components of tourism industries (Kiros et al. 2018). Therefore, baseline information on birds of a particular locality, such as a species checklist, is vital for ecological monitoring, environmental assessments, conservation planning (Kandel et al. 2018; Sharma et al. 2018), and exploring eco-tourism potentials.

The first exploration of avifauna in Bhutan was conducted in 1837 by a British team (Gyeltshen et al. 2020). Later, several avifaunal expeditions and studies have been done in the country by Bhutanese nationals and foreign researchers, resulting in numerous online literature in the form of published articles, notes, and guidebooks. The number of publications on birds is expected to surge in the next few years with the current improvements in the institutional and personnel capacity and the concurrent emergence of citizen science that helps in building databases and species inventories.

Despite its small geographical size ~38,394km$^2$ (Thinley et al. 2021), Bhutan is a hotspot for bird diversity in the Himalaya with 23 important bird areas (IBA) (Banerjee & Bandopadhyay 2016) and is also part of the eastern Himalaya endemic bird area (Stattersfield et al. 1998; Bishop 1999). The latest record of confirmed bird species in the country stands at 748 species (Dendup et al. 2020; Gyeltshen et al. 2020) of which 31 are globally threatened and 18 are part of the 37 endemic bird species in eastern Himalaya (DoFPS 2020). This makes Bhutan a stronghold for bird diversity (Kandel et al. 2018). Currently, bird databases exist for most of the protected areas (PAs) in Bhutan. For instance, Avibase, the world bird database (Lepage 2020) has a checklist of 469 bird species for Trashiyangtse District which is inclusive of the areas falling inside the Bumdeling Wildlife Sanctuary (BWS). However, PAs occupy half of the country (Thinley et al. 2020; 2021) and databases are yet to be developed for the remaining half, which consists of the state reserved forests (SRF) administered by Territorial Forest Divisions. The areas outside the PAs are equally important for biodiversity conservation due to presence of vast tracts of relatively undisturbed forests that provide ideal habitats for a wide range of bird species. Thus, high bird diversity can be expected in some areas situated outside the PAs.

Here in this study, we explore the avian diversity and present a comprehensive bird checklist for the non-protected region of Trashiyangtse District, located in northeastern Bhutan. We also categorise the bird species by their residency pattern, feeding guilds, abundance, and conservation status.

## MATERIALS AND METHODS

### Study area description

The non-protected region of Trashiyangtse District (Figure 1; between 27.6116$^0$N and 91.498$^0$E) is bordered by the Tibetan Autonomous Region of China in the north and the Indian state of Arunachal Pradesh in the east. The district experiences a temperate climate, featured by warm & wet summers and cold & relatively dry winters, with an average annual temperature of 20.2 °C and precipitation of 1,065 mm (Norbu et al. 2019). Two major rivers, Kholongchu and Drangmechu, flow through the district and make it an important water catchment. Covering an area of approximately 1,449 km$^2$, the elevation ranges 800–6,000 m (FRMD 2017), and approximately 59% lies inside the BWS while the remaining 41% (600 km$^2$) is unprotected but managed as SRF land. The land cover in the non-protected region of Trashiyangtse is dominated by forest cover (70%) which is composed of major forest types of fir forest, mixed conifer forest (MCF), pine forest, mixed pine-cool broadleaved forest, chirpine forest, cool broadleaved forest (CBF), alpine shrubs, alpine meadows, and a few plantations (Koirala et al. 2021; FRMD 2017). Cool broadleaved forest is the most dominant forest type (44%) in this region, followed by MCF (15%). Although, several studies have been conducted on various taxonomic groups inside the protected region of the district, little is known about the biodiversity in the non-protected region which has potential for biodiversity conservation and ecotourism development.

### Data collection and organization

We conducted an avifauna exploration for a period of

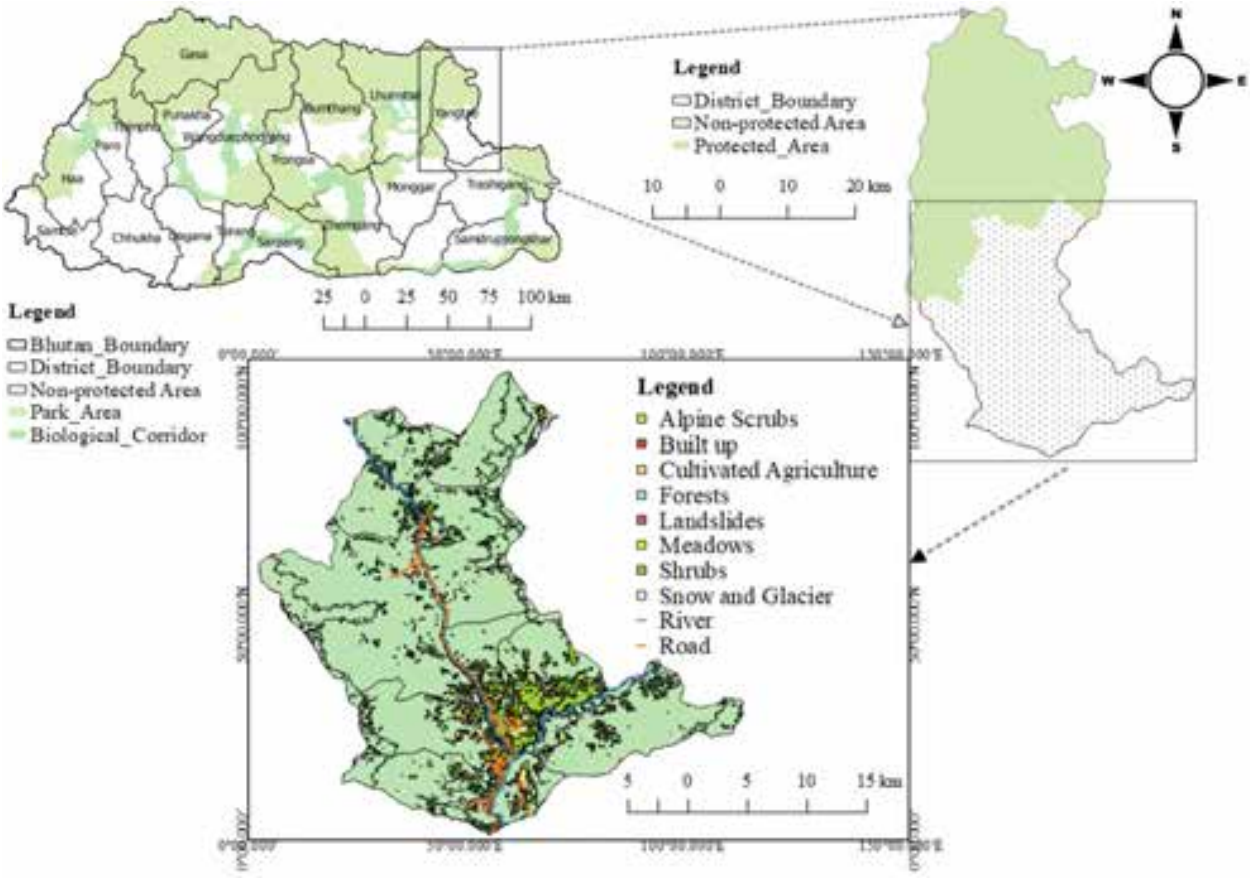


**Figure 1. The location of the study area in the non-protected region of Trashiyangtse District situated in northeastern region of Bhutan.**

four years (2017–2020) to maintain baseline data in the non-protected region of Trashiyangtse District. The data was collected mostly through opportunistic encounters coinciding with regular field visits to various locations in different seasons, including incidental rapid biodiversity surveys, site inspections, anti-poaching patrols, timber allotments, environmental impact assessments, anti-fishing patrols along the rivers, and forest inventories (for local forest management planning, heritage forests and community forests). The survey site covers all forest types and bird habitats, ranging from river sides, roadsides, and human settlements (rural and urban) to agriculture fields, plantations, meadows, rocky outcrops, and mountain tops, all within an elevation range of 800 m (at Jamkhardrang) to 4,050 m (at Dribla). In this way, terrestrial and water birds from lowland to high altitude uplands have been covered in the study. The birds were observed using binoculars (Nikon 10 x 40 mm) and were photographed using a digital camera (Cannon DC 18–135 mm lens). Bird photographs were compared with those on the latest guidebooks by Grimmett et al. 2011, 2019; Praveen et al. 2016, 2020) for species identification and species nomenclature. Additionally, bird calls were recorded (using an android phone) wherever possible and compared with the pre-recorded bird songs (e.g., Avibase bird call 2020) to further authenticate species identity. Online data bases (e.g., www.inaturalist.org/projects/birds-of-Bhutan) were also referred for species identification. For those in doubt, consultations were made with avian experts via email and social media.

We followed the IUCN Red List of Threatened Species for global conservation status of the recorded bird species. They were further categorized according to their residency pattern as residents, altitudinal migrants, summer visitors, winter visitors, and passage migrants, following Ali et al. (1996), Feijen & Feijen (2008), and Grimmett et al. (2019). Moreover, feeding guilds were assigned according to field observations (Kumar & Sharma 2018; Sharma et al. 2018; Singh et al. 2020), such that birds feeding on grains were categorized as granivorous, fruits as frugivorous, nectars as nectivorous, insects as insectivorous, vertebrates (amphibians, snakes, lizards, small mammals, small birds, and fishes) and invertebrates (crustaceans and

micro invertebrates) as carnivorous, and both plants and animals as omnivorous. Furthermore, birds were categorized as common, frequent, occasional and rare based on abundance and frequency of sightings during field investigation following Ali et al. (1996), Feijen & Feijen (2008), and Grimmett et al. (2019). Subsequently, the relative diversity (RDi) of families was calculated using the formula used by Singh et al. (2020): RDi= (Number of species in a family/Total number of species) x 100.

## RESULTS AND DISCUSSION

We recorded a total of 273 bird species belonging to 173 genera, 69 families, and 19 orders in the outside protected region of Trashiyangtse District (Table 1). The occurrence of diverse bird species in the non-protected region of Trashiyangtse District is because of the rich forest cover with diverse mosaic habitats (marshy areas, artificial ponds, and irrigated crop fields along the bank of Kholongchu and Drangmechu rivers) supporting high diversity of food resources for birds in different seasons. However, our species richness was comparatively lower than in the remaining areas of the district encompassed by BWS where a total of 355 species have been recorded (BWS 2018). Further studies are needed to understand the factors driving the difference in bird diversity within and outside the protected regions.

Among the total of 19 orders (Figure 2; Table 1), Passeriformes was the most dominant, comprising 63.7% (174 species in 41 families) of the total species count, followed by Piciformes (14 species in three families) which constituted only 5.1% of the total species count. Buceriformes, Caprimulgiformes, Falconiformes, Podicipediformes, and Suliformes were the least represented orders each having a single species. Overall, passerines dominated (64%, n= 174) the avian diversity as compared to non-passerines (36%, n= 99) which was also the trend observed in the adjoining BWS (BWS 2018) because of the similar forest types prevalent in both the cases. Dominance of Passeriformes was also reported elsewhere in Bhutan, particularly the SRF Land of Trongsa district (Gyeltshen et al. 2020), along the Bindu River in Samtse district (Pasang 2018), Sakteng Wildlife Sanctuary (Wangyel et al. 2018), and Phrumshingla National Park (Inskipp et al. 2000). A similar pattern of Passerine dominance was reported from some areas in the eastern Himalayan region, such as in the Kanchenjunga Conservation Landscape, which is a transboundary complex shared by Bhutan, India, and Nepal (Kandel et al. 2018). This makes sense because Passerines are globally the largest and most diverse order of birds (Koli 2014).

Comparing by families, Muscicapidae with RDi of 11.7% (32 species in 12 genera) was the most dominant of the total of 69 families (Figure 3; Table 1) documented in our study area, followed by Leiothrichidae (6.2%; 17/8), Accipitridae (4.0%; 11/9), Fringillidae (4.0%; 11/7), Picidae (3.6%; 10/7), Phylloscopidae (3.3%; 9/1), Anatidae (3.3%; 9/7), and Cuculidae (2.9%; 8/6). Similarly, many other investigators such as Pasang (2018), Wangyel et al. (2018), Tobgay (2016), and Inskipp et al. (2000) have also found Muscicapidae to be the dominant family in their respective study areas. Similar observations were made from the Kangchengjunga Conservation Landscape (Kandel et al. 2018) and India (Koli 2014). Muscicapidae, indeed, is the largest family of birds restricted to the Old World (Europe, Africa, and Asia) with 322 species (Daniels 2020). In contrast, Gyeltshen et al. (2020) found Timaliidae to be the dominant family in the SRF Land of Trongsa District in central Bhutan. This variation could be attributed to the differences in habitat conditions occurring in different longitudes and elevation gradients.

Classifying by residency pattern, our data revealed the majority 39% (n= 106) were altitudinal migrants (Figure 4; Table 1) which was closely followed by residents (36%; n= 98). Constituting minor proportions were summer visitors (11%; n= 31), and winter visitors and passage migrants (7%; n= 19 each). Similarly, Gyeltshen et al. (2020) also reported that 36.7% (n= 121) of bird species recorded in the SRF region of Trongsa District were residents, followed by 34.5% (n= 114) altitudinal migrants, 15.2% (n= 50) summer visitors, 8.2% (n= 27) winter visitors, 4.8% (n= 16) passage migrants, and only two vagrants. Overall, in the entire Trashiyangtse District, a number of winter visitors and passage migratory species are observed annually across Kholongchu and Drangmechu river basins. This is because Bhutan lies on the Oriental Zoogeographic Realm and the Central Asian Flyways (CAF) which supports approximately 279 migratory water birds for wintering, stopover and even breeding (CMS 2019). Moreover, the major river basins of the country also provide shortest transit corridor or migratory routes connecting the significant bird habitat of Indo-Malayan Zoogeographic realms and Palearctic realms (DoFPS 2020).

When bird species were grouped by six major feeding guilds (Figure 5; Table 1), a maximum number of species (45%; n= 124) was insectivorous, followed by omnivorous (27%; n= 74), carnivorous (13%; n= 36), granivorous (9%;

**Table 1. The avifauna checklist for the non-protected region of Trashiyangtse District in north-eastern Bhutan | categorized into feeding guild (Gra—Granivorous | Fru—Frugivorous | Nec—Nectivorous | Ins—Insectivorous | Car—Carnivorous | and Omn—Omnivorous) | residency pattern (R—Residents | AM—Altitudinal Migrants | SV—Summer Visitors | WV—Winter Visitors | and PM—Passage Migrants) | IUCN Red List status (CE—Critically Endangered | E—Endangered | VU—Vulnerable | NT—Near Threatened | and L—Least Concern) | and abundance (C—Common | F—Frequent | O—Occasional | R—Rare).**

| Order/ Family (no. of species)/ Common name | Scientific name | Feeding guild | Residency pattern | IUCN Red List status | Abundance |
|---|---|---|---|---|---|
| **Accipitriformes** | | | | | |
| **Accipitridae (11)** | | | | | |
| Shikra | *Accipiter badius* (Gmelin, JF, 1788) | Car | R | LC | O |
| Eurasian Sparrowhawk | *Accipiter nisus* (Linnaeus, 1758) | Car | AM | LC | R |
| Himalyan Buzzard | *Buteo burmanicus* (Hume, 1875) | Car | WV | LC | R |
| Common Buzzard | *Buteo buteo* (Linnaeus, 1758) | Car | AM | LC | O |
| Hen Harrier | *Circus cyaneus* (Linnaeus, 1766) | Car | AM | LC | R |
| Himalayan Griffon Vulture | *Gyps himalayensis* (Hume, 1869) | Car | R | NT | O |
| Pallas's Fish Eagle | *Haliaeetus leucoryphus,* (Pallas, 1771) | Car | R | EN | R |
| Black Eagle | *Ictinaetus malaiensis* (Temminck, 1822) | Car | R | LC | O |
| Black-eared Kite | *Milvus migrans* (Boddaert, 1783) | Car | PM | LC | R |
| Mountain Hawk Eagle | *Nisaetus nipalensis* (Hodgson, 1836) | Car | R | LC | R |
| Crested Serpent Eagle | *Spilornis cheela* (Latham, 1790) | Car | SV | LC | O |
| **Pandionidae (1)** | | | | | |
| Osprey | *Pandion haliaetus* (Linnaeus, 1758) | Car | WV | LC | R |
| **Anseriformes** | | | | | |
| **Anatidae (9)** | | | | | |
| Mandarin Duck | *Aix galericulata* (Linnaeus, 1758) | Omn | PM | LC | R |
| Northern Pintail | *Anas acuta* (Linnaeus, 1758) | Omn | PM | LC | R |
| Common Teal | *Anas crecca* (Linneaus, 1758) | Omn | PM | LC | R |
| Mallard Duck | *Anas platyrhynchos* (Linnaeus, 1758) | Gra | PM | LC | R |
| Bar-headed Goose | *Anser indicus* (Latham, 1790) | Gra | PM | LC | R |
| Eurasian Wigeon | *Mareca penelope* (Linnaeus, 1758) | Gra | PM | LC | R |
| Goosander | *Mergus merganser* (Linnaeus, 1758) | Omn | PM | LC | R |
| Red-crested Pochard | *Netta rufina* (Pallas, 1773) | Omn | PM | LC | R |
| Northern Shoveler | *Spatula clypeata* (Linnaeus, 1758) | Gra | PM | LC | R |
| **Apodiformes** | | | | | |
| **Apodidae (5)** | | | | | |
| House swift | *Apus nipalensis* (Hodgson, 1837) | Ins | R | LC | O |
| Fork-tailed Swift | *Apus pacificus* (Latham, 1801) | Ins | SV | LC | O |
| Himalayan Swiftlet | *Collocalia brevirostris* (Horsfield, 1840) | Ins | R | LC | O |
| Asian Palm Swift | *Cypsiurus balasiensis* (Gray, JE, 1829) | Ins | R | LC | O |
| White-throated Needletail | *Hirundapus caudacutus* (Latham, 1801) | Ins | SV | LC | O |
| **Buceriformes** | | | | | |
| **Upupidae (1)** | | | | | |
| Eurasian Hoopoe | *Upupa epops* (Linnaeus, 1758) | Omn | AM | LC | C |
| **Caprimulgiformes** | | | | | |
| **Caprimulgidae (1)** | | | | | |
| Grey Nightjar | *Caprimulgus indicus* (Latham, 1790) | Ins | R | LC | O |

| Order/ Family (no. of species)/ Common name | Scientific name | Feeding guild | Residency pattern | IUCN Red List status | Abundance |
|---|---|---|---|---|---|
| **Charadriiformes** | | | | | |
| **Charadriidae (4)** | | | | | |
| Little Ringed Plover | *Charadrius dubius* (Scopoli, 1786) | Omn | WV | LC | R |
| Long-billed Plover | *Charadrius placidus* (Gray, JE & Gray, GR, 1863) | Omn | WV | LC | R |
| River Lapwing | *Vanellus duvaucelii* (Lesson, 1826) | Ins | R | NT | R |
| Red-wattled Lapwing | *Vanellus indicus* (Roddaert, 1783) | Ins | SV | LC | R |
| **Ibidorhynchidae (1)** | | | | | |
| Ibisbill | *Ibidorhyncha struthersii* (Vigors, 1832) | Ins | WV | LC | R |
| **Laridae (1)** | | | | | |
| Brown-headed Gull | *Chroicocephalus brunnicephalus* (Jerdon, 1840) | Omn | PM | LC | R |
| **Scolopacidae (3)** | | | | | |
| Common Sandpiper | *Actitis hypoleucos* (Linnaeus, 1758) | Car | PM | LC | R |
| Solitary Snipe | *Gallinago solitaria* (Hodgson, 1831) | Car | WV | LC | R |
| Green Sandpiper | *Tringa ochropus* (Linneaus, 1758) | Car | PM | LC | R |
| **Tunicidae (1)** | | | | | |
| Barred Buttonquail | *Turnix suscitator* (Gmelin, JF, 1789) | Gra | R | LC | R |
| **Columbiformes** | | | | | |
| **Columbidae (6)** | | | | | |
| Barred Cuckoo Dove | *Macropygia unchall* (Wagler, 1827) | Gra | SV | LC | O |
| Speckled Wood Pigeon | *Columba hodgsonii* (Vigors, 1832) | Gra | AM | LC | O |
| Snow Pigeon | *Columba leuconota* (Vigors, 1831) | Gra | AM | LC | R |
| Spotted Dove | *Spilopelia chinensis* (Scopoli, 1786) | Gra | SV | LC | C |
| Oriental Turtle Dove | *Streptopelia orientalis* (Latham, 1790) | Gra | R | LC | C |
| Wedge-tailed Green Pigeon | *Treron sphenurus* (Vigors, 1832) | Gra | AM | LC | O |
| **Coraciiformes** | | | | | |
| **Alcedinidae (3)** | | | | | |
| Common Kingfisher | *Alcedo atthis* (Linnaeus, 1758) | Car | AM | LC | O |
| White-throated Kingfisher | *Halcyon smyrnensis* (Linnaeus, 1758) | Car | AM | LC | R |
| Crested Kingfisher | *Megaceryle lugubris* (Temminck, 1834) | Car | AM | LC | O |
| **Coraciidae (1)** | | | | | |
| Indian Roller | *Coracias benghalensis* (Linnaeus, 1758) | Ins | AM | LC | R |
| **Cuculiformes** | | | | | |
| **Cuculidae (8)** | | | | | |
| Common Hawk Cuckoo | *Hierococcyx varius* (Vahl, 1797) | Ins | SV | LC | O |
| Lesser Coucal | *Centropus bengalensis* (Gmelin, JF, 1788) | Ins | R | LC | O |
| Eurasian Cuckoo | *Cuculus canorus* (Linnaeus, 1758) | Ins | SV | LC | O |
| Indian Cuckoo | *Cuculus micropterus* (Gould, 1838) | Ins | SV | LC | C |
| Himalayan Cuckoo | *Cuculus saturatus* (Blyth, 1843) | Ins | SV | LC | C |
| Large Hawk Cuckoo | *Hierococcyx sparverioides* (Vigors, 1832) | Ins | SV | LC | O |
| Green-billed Malkoha | *Phaenicophaeus tristis* (Lesson, 1830) | Ins | R | LC | R |
| Square-tailed Drongo-cuckoo | *Surniculus lugubris* (Horsfield, 1821) | Ins | SV | LC | O |
| **Falconiformes** | | | | | |
| **Falconidae (1)** | | | | | |
| Common Kestrel | *Falco tinnunculus* (Linnaeus, 1758) | Car | R | LC | O |

| Order/ Family (no. of species)/ Common name | Scientific name | Feeding guild | Residency pattern | IUCN Red List status | Abundance |
|---|---|---|---|---|---|
| **Galliformes** | | | | | |
| **Phasianidae (7)** | | | | | |
| Blood Pheasant | *Ithaginis cruentus* (Hardwicke, 1821) | Omn | R | LC | R |
| Rufous-throated Partridge | *Arborophila rufogularis* (Blyth, 1849) | Omn | R | LC | R |
| Hill Partridge | *Arborophila torqueola* (Valenciennes, 1825) | Omn | R | LC | C |
| Common Quail | *Coturnix coturnix* (Linnaeus, 1758) | Omn | R | LC | R |
| Himalayan Monal | *Lophophorus impejanus* (Latham, 1790) | Omn | R | LC | R |
| Kalij Pheasant | *Lophura leucomelanos* (Latham, 1790) | Omn | R | LC | C |
| Satyr Tragopan | *Tragopan satyra* (Linnaeus, 1758) | Omn | R | NT | O |
| **Gruiformes** | | | | | |
| **Gruidae (1)** | | | | | |
| Black-necked Crane | *Grus nigricollis* (Przhevalsky, 1876) | Omn | WV | VU | R |
| **Rallidae (4)** | | | | | |
| White-breasted Waterhen | *Amaurornis phoenicurus* (Pennant, 1769) | Omn | R | LC | R |
| Eurasian Coot | *Fulica atra* (Linnaeus, 1758) | Omn | PM | LC | R |
| Slaty-breasted Rail | *Lewinia striata* (Linnaeus, 1766) | Omn | WV | LC | R |
| Black-tailed Crake | *Zapornia bicolor* (Walden, 1872) | Omn | R | LC | R |
| **Passeriformes** | | | | | |
| **Aegithalidae (2)** | | | | | |
| Black-throated Bush tit | *Aegithalos concinnus* (Gould, 1855) | Ins | R | LC | C |
| Rufous-fronted Bush tit | *Aegithalos iouschistos* (Blyth,1845) | Ins | AM | LC | C |
| **Alaudidae (2)** | | | | | |
| Oriental Skylark | *Alauda gulgula* (Franklin, 1831) | Omn | WV | LC | R |
| Horned Lark | *Eremophila alpestris* (Linnaeus, 1758) | Omn | WV | LC | R |
| **Alcippeidae (1)** | | | | | |
| Nepal Fulvetta | *Alcippe nipalensis* (Hodgson, 1837) | Ins | R | LC | O |
| **Calcariidae (1)** | | | | | |
| Lapland Longspur | *Calcarius lapponicus* (Linnaeus, 1758) | Omn | AM | LC | R |
| **Campephagidae (2)** | | | | | |
| Long-tailed Minivet | *Pericrocotus ethologus* (Bangs & Phillips, 1914) | Ins | R | LC | O |
| Scarlet Minivet | *Pericrocotus fammeus* (Forster, JR, 1781) | Ins | AM | LC | O |
| **Certhiidae (3)** | | | | | |
| Brown-throated Treecreeper | *Certhia discolor* (Blyth, 1845) | Ins | AM | LC | O |
| Hodgson's Treecreeper | *Certhia hodgsoni* (Brooks, WE, 1871) | Ins | AM | LC | O |
| Rusty-flanked Treecreeper | *Certhia nipalensis* (Blyth, 1845) | Ins | AM | LC | F |
| **Cettiidae (5)** | | | | | |
| Yellow-bellied Warbler | *Abroscopus superciliaris* (Blyth, 1859) | Ins | AM | LC | C |
| Chestnut-headed Tesia | *Cettia castaneocoronata* (Burton, E, 1836) | Ins | AM | LC | O |
| Aberrant Bush Warbler | *Horornis flavolivaceus* (Blyth, 1845) | Ins | AM | LC | C |
| Brown-flanked Bush Warbler | *Horornis fortipes* (Hodgson, 1845) | Ins | AM | LC | C |
| Grey-bellied Tesia | *Tesia cyaniventer* (Hodgson, 1837) | Ins | AM | LC | O |
| **Chloropseidae (1)** | | | | | |
| Orange-bellied Leaf bird | *Chloropsis hardwickii* (Jardine & Selby, 1830) | Fru | R | LC | O |
| **Cinclidae (2)** | | | | | |
| White-throated Dipper | *Cinclus cinclus* (Linneaus, 1758) | Ins | AM | LC | O |

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|---|---|---|---|---|---|
| Brown Dipper | *Cinclus pallasii* (Temminck, 1820) | Ins | AM | LC | C |
| **Cisticolidae (4)** | | | | | |
| Common Tailorbird | *Orthotomus sutorius* (Pennant, 1769) | Ins | R | LC | C |
| Black-throated Prina | *Prinia atrogularis* (Moore, F, 1854) | Ins | R | LC | C |
| Striated Prina | *Prinia crinigera* (Hodgson, 1836) | Ins | R | LC | C |
| Rufescent Prinia | *Prinia rufescens* (Blyth, 1847) | Ins | R | LC | C |
| **Corvidae (6)** | | | | | |
| Grey Treepie | *Dendrocitta formosae* (Swinhoe, 1863) | Omn | R | LC | C |
| Large-billed Crow | *Corvus macrorhynchos* (Wagler, 1827) | Omn | R | LC | C |
| Eurasian Jay | *Garrulus glandarius* (Linnaeus, 1758) | Omn | AM | LC | O |
| Red-billed Chough | *Pyrrhocorax pyrrhocorax* (Linnaeus, 1758) | Ins | AM | LC | R |
| Spotted Nutcracker | *Nucifraga caryocatactes* (Linnaeus, 1758) | Omn | R | LC | O |
| Yellow-billed Blue Magpie | *Urocissa flavirostris* (Blyth, 1846) | Omn | R | LC | C |
| **Dicaeidae (1)** | | | | | |
| Fire-breasted Flowerpecker | *Dicaeum ignipectus* (Blyth,1843) | Fru | AM | LC | O |
| **Dicruridae (3)** | | | | | |
| Ashy Drongo | *Dicrurus leucophaeus* (Vieillot, 1817) | Ins | AM | LC | C |
| Black Drongo | *Dicrurus macrocercus* (Vieillot, 1817) | Ins | AM | LC | O |
| Hair-crested Drongo | *Dicrurus hottentottus* (Linnaeus, 1766) | Ins | SV | LC | O |
| **Elachuridae (1)** | | | | | |
| Spotted Wren Babbler | *Elachura formosa* (Walden, 1874) | Ins | LC | LC | R |
| **Emberizidae (2)** | | | | | |
| Crested Bunting | *Emberiza lathami* (Gray, JE, 1831) | Omn | SV | LC | O |
| Little Bunting | *Emberiza pusilla* (Pallas, 1776) | Omn | PM | LC | O |
| **Estrildidae (1)** | | | | | |
| Scaly-breasted Munia | *Lonchura punctulata* (Linnaeus, 1758) | Gra | AM | LC | R |
| **Fringillidae (11)** | | | | | |
| Common Rosefinch | *Carpodacus erythrinus* (Pallas, 1770) | Gra | AM | LC | O |
| Pink-browed Rosefinch | *Carpodacus rodochroa* (Vigors, 1831) | Gra | SV | LC | O |
| White-browed Rosefinch | *Carpodacus thura* (Bonaparte & Schlegel, 1850) | Gra | AM | LC | C |
| Yellow-breasted Greenfinch | *Chloris spinoides* (Vigors, 1831) | Gra | AM | LC | F |
| Scarlet Finch | *Carpodacus sipahi* (Hodgson, 1836) | Gra | AM | LC | O |
| Red Crossbill | *Loxia curvirostra* (Linnaeus, 1758) | Gra | SV | LC | O |
| White-winged Grosbeak | *Mycerobas carnipes* (Hodgson, 1836) | Fru | AM | LC | O |
| Spot-winged Grosbeak | *Mycerobes melanozanthos* (Hodgson, 1836) | Fru | AM | LC | O |
| Dark-breasted Rosefinch | *Procarduelis nipalensis* (Hodgson, 1836) | Gra | AM | LC | F |
| Red-headed Bullfinch | *Pyrrhula erythrocephala* (Vigors, 1832) | Gra | AM | LC | O |
| Brown Bullfinch | *Pyrrhula nipalensis* (Hodgson, 1836) | Gra | SV | LC | O |
| **Hirundinidae (2)** | | | | | |
| Red-rumped Swallow | *Cecropis daurica* (Laxmann, 1769) | Ins | SV | LC | O |
| Barn Swallow | *Hirundo rustica* (Linnaeus, 1758) | Ins | SV | LC | O |
| **Laniidae (3)** | | | | | |
| Brown Shrike | *Lanius cristatus* (Linnaeus, 1758) | Car | WV | LC | C |
| Long-tailed Shrike | *Lanius schach* (Linnaeus, 1758) | Car | AM | LC | C |
| Grey-backed Shrike | *Lanius tephronotus* (Vigors, 1831) | Car | R | LC | C |

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|---|---|---|---|---|---|
| **Leiothrichidae (17)** | | | | | |
| Rusty-fronted Barwing | *Actinodura egertoni* (Gould, 1836) | Omn | R | LC | C |
| Hoary-throated Barwing | *Actinodura nipalensis* (Hodgson, 1836) | Omn | R | LC | O |
| Himalayan Cutia | *Cutia nipalensis* (Hodgson, 1837) | Fru | R | LC | O |
| White-throated Laughingthrush | *Garrulax albogularis* (Gould, 1836) | Omn | R | LC | C |
| White-crested Laughingthrush | *Garrulax leucolophus* (Hardwicke, 1815) | Omn | R | LC | C |
| Striated Laughingthrush | *Grammatoptila striatus* (Vigors, 1831) | Omn | R | LC | C |
| Rufous Sibia | *Heterophasia capistrata* (Vigors, 1831) | Ins | R | LC | C |
| Long-tailed Sibia | *Heterophasia picaoides* (Hodgson, 1839) | Ins | R | LC | C |
| Spotted Laughingthrush | *Ianthocincla ocellata* (Vigors, 1831) | Omn | R | LC | C |
| Rufous-chinned Laughingthrush | *Ianthocincla rufogularis* (Gould, 1835) | Omn | R | LC | C |
| Red-bellied Leiothrix | *Leiothrix lutea* (Scopooli, 1786) | Ins | AM | LC | C |
| Blue-winged Siva | *Minla cyanouroptera* (Hodgson, 1837) | Ins | R | LC | C |
| Red-tailed Minla | *Minla ignotincta* (Hodgson, 1837) | Ins | AM | LC | C |
| Bar-throated Siva | *Minla strigula* (Hodgson, 1837) | Fru | R | LC | C |
| Black-faced Laughingthrush | *Trochalopteron affine* (Blyth, 1843) | Omn | R | LC | C |
| Chesnut-crowned Laughingthrush | *Trochalopteron erythrocephalum* (Vigors, 1832) | Omn | AM | LC | C |
| Bhutan Laughingthrush | *Trochalopteron imbricatum* (Blyth, 1843) | Omn | R | LC | C |
| **Monarchidae (1)** | | | | | |
| Indian Paradise-flycatcher | *Terpsihone paradisi* (Linnaeus, 1758) | Ins | SV | LC | R |
| **Motacillidae (7)** | | | | | |
| White Wagtail | *Motacilla alba* (Linnaeus, 1758) | Ins | R | LC | O |
| Grey Wagtail | *Motacilla cinerea* (Tunstall, 1771) | Ins | WV | LC | O |
| Citrine Wagtail | *Motacilla citreola* (Pallas, 1776) | Ins | AM | LC | O |
| Yellow Wagtail | *Motacilla flava* (Linnaeus, 1758) | Ins | WV | LC | O |
| White-browed Wagtail | *Motacilla maderaspatensis* (Gmelin, JF, 1789) | Ins | R | LC | O |
| Olive-backed Pipit | *Anthus hodgsoni* (Richmond, 1907) | Ins | AM | LC | O |
| Tree Pipit | *Anthus trivialis* (Linnaeus, 1758) | Ins | AM | LC | O |
| **Muscicapidae (32)** | | | | | |
| Oriental Magpie Robin | *Copsychus saularis* (Linnaeus, 1758) | Ins | R | LC | C |
| Blue-throated Blue Flycatcher | *Cyornis rubeculoides* (Vigors, 1831) | Ins | SV | LC | O |
| Pale-blue Flycatcher | *Cyornis unicolor* (Blyth, 1843) | Ins | AM | LC | O |
| Black-backed Forktail | *Enicurus immaculatus* (Hodgson, 1836) | Ins | AM | LC | O |
| Spotted Forktail | *Enicurus maculatus* (Vigors, 1831) | Ins | AM | LC | R |
| Slaty-backed Forktail | *Enicurus schistaceus* (Hodgson, 1836) | Ins | R | LC | C |
| Little Forktail | *Enicurus scouleri* (Vigors, 1832) | Ins | AM | LC | R |
| Verditer Flycatcher | *Eumyias thalassinus* (Swainson, 1838) | Ins | AM | LC | C |
| Snowy-browed Flycatcher | *Ficedula hyperythra* (Blyth, 1843) | Ins | AM | LC | O |
| Rufous-gorgeted Flycatcher | *Ficedula strophiata* (Hodgson, 1837) | Ins | AM | LC | C |
| Ultramarine Flycatcher | *Ficedula superciliaris* (Jerdon, 1840) | Ins | SV | LC | O |
| Slaty-blue Flycatcher | *Ficedula tricolor* (Hodgson, 1845) | Ins | AM | LC | C |
| Blue-capped Rock Thrush | *Monticola cinclorhyncha* (Vigors, 1832) | Omn | R | LC | C |
| Chestnut-bellied Rock Thrush | *Monticola rufiventris* (Jardine & Selby, 1833) | Omn | R | LC | C |
| Blue Rock Thrush | *Monticola solitarius* (Linnaeus, 1758) | Omn | R | LC | C |
| Ferruginous Flycatcher | *Muscicapa ferruginea* (Hodgson, 1845) | Ins | SV | LC | C |

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|---|---|---|---|---|---|
| Blue Whistling Thrush | *Myophonus caeruleus* (Scopoli, 1786) | Omn | R | LC | C |
| Large Niltava | *Niltava grandis (*Blyth, 1842) | Ins | AM | LC | O |
| Small Niltava | *Niltava macgrigoriae* (Burton, E, 1836 | Ins | AM | LC | O |
| Rufous-bellied Niltava | *Niltava sundara* (Hodgson, 1837) | Ins | AM | LC | C |
| Blue-fronted Redstart | *Phoenicurus frontalis* (Vigors, 1831) | Omn | AM | LC | C |
| Plumbeous Water Redstart | *Phoenicurus fuliginosus* (Vigors, 1831) | Ins | AM | LC | C |
| Hodgson's Redstart | *Phoenicurus hodgsoni* (Moore, F, 1854) | Ins | WV | LC | C |
| White-capped water Redstart | *Phoenicurus leucocephalus* (Vigors, 1831) | Ins | AM | LC | C |
| Black Redstart | *Phoenicurus ochruros* (Gmelin, SG, 1774) | Ins | WV | LC | O |
| White-throated Redstart | *Phoenicurus schisticeps* (Gray, JE & Gray, GR, 1847) | Ins | WV | LC | F |
| Pied Bushchat | *Saxicola caprata* (Linnaeus, 1766) | Ins | AM | LC | R |
| Grey Bushchat | *Saxicola ferreus* (Gray, JE & Gray, GR, 1847) | Ins | AM | LC | C |
| Common Stonechat | *Saxicola torquatus* (Linnaeus, 1766) | Omn | WV | LC | O |
| Golden Bush Robin | *Tarsiger chrysaeus* (Hodgson, 1845) | Ins | SV | LC | O |
| White-browed Bush Robin | *Tarsiger indicus* (Vieillot, 1817) | Ina | AM | LC | O |
| Himalayan Bluetail | *Tarsiger rufilatus* (Hodgson, 1845) | Omn | AM | LC | O |
| **Nectariniidae (5)** | | | | | |
| Mrs Gould's Sunbird | *Aethopyga gouldiae* (Vigors, 1831) | Nec | AM | LC | C |
| Fire-tailed Sunbird | *Aethopyga ignicauda* (Hodgson, 1836) | Nec | AM | LC | C |
| Green-tailed Sunbird | *Aethopyga nipalensis* (Hodgson, 1836) | Nec | AM | LC | C |
| Black-throated Sunbird | *Aethopyga saturata* (Hodgson, 1836) | Nec | AM | LC | C |
| Crimson Sunbird | *Aethopyga siparaja* (Raffles, 1822) | Nec | R | LC | C |
| **Oriolidae (2)** | | | | | |
| Indian Golden Oriole | *Oriolus kundoo* (Skyes, 1832) | Fru | SV | LC | R |
| Maroon Oriole | *Oriolus traillii* (Vigors, 1832) | Fru | AM | LC | R |
| **Paradoxornithidae (2)** | | | | | |
| White-browed Fulvetta | *Fulvetta vinipectus* (Hodgson, 1837) | Ins | AM | LC | O |
| Fire-tailed Myzornis | *Myzornis pyrrhoura* (Blyth, 1843) | Omn | AM | LC | O |
| **Paridae (4)** | | | | | |
| Cinereous Tit | *Parus cinereus* (Vieillot, 1818) | Ins | AM | LC | O |
| Green-backed Tit | *Parus monticolus* (Vigors, 1831) | Ins | AM | LC | C |
| Rufous-vented Tit | *Periparus rubidiventris* (Blyth, 1847) | Ins | AM | LC | O |
| Coal Tit | *Periparus ater* (Linnaeus, 1758) | Ins | AM | LC | O |
| **Passeridae (3)** | | | | | |
| Russet Sparrow | *Passer cinnamomeus* (Gould, 1836) | Gra | AM | LC | C |
| House Sparrow | *Passer domesticus* (Linnaeus, 1758) | Gra | R | LC | C |
| Eurasian Tree Sparrow | *Passer montanus* (Linnaeus, 1758) | Gra | R | LC | C |
| **Pellorneidae (2)** | | | | | |
| Puff-throated Babbler | *Pellorneum ruficeps* (Swainson, 1832) | Ins | R | LC | O |
| Rufous-winged Fulvetta | *Schoeniparus castaneceps* (Hodgson, 1837) | Ins | AM | LC | O |
| **Phylloscopidae (9)** | | | | | |
| Tickell's Leaf Warbler | *Phylloscopus affinis* (Tickell, 1833) | Ins | SV | LC | C |
| Yellow-vented Warbler | *Phylloscopus cantator* (Tickell, 1833) | Ins | AM | LC | O |
| Chestnut-crowned Warbler | *Phylloscopus castaniceps* (Hodgson, 1845) | Ins | AM | LC | O |

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|---|---|---|---|---|---|
| Lemon-rumped Warbler | *Phylloscopus chloronotus* (Gray, JE & Gray, GR, 1847) | Ins | PM | LC | C |
| Ashy-throated Warbler | *Phylloscopus maculipennis* (Blyth, 1867) | Ins | AM | LC | C |
| Large-billed Leaf Warbler | *Phylloscopus magnirostris* (Blyth, 1843) | Ins | SV | LC | C |
| Blyth's Leaf Warbler | *Phylloscopus reguloides* (Blyth, 1842) | Ins | PM | LC | O |
| Whistler's Warbler | *Phylloscopus whistleri* (Ticehurst, 1925) | Ins | AM | LC | C |
| Grey-hooded Warbler | *Phylloscopus xanthoschistos* (Gray, JE & Gray, GR, 1847) | Ins | PM | LC | C |
| **Pnoepygidae (1)** | | | | | |
| Scaly-breasted Wren Babbler | *Pnoepyga albiventer* (Hodgson, 1837) | Ins | AM | LC | O |
| **Prunellidae (3)** | | | | | |
| Alpine Accentor | *Prunella collaris (*Scopoli, 1769) | Ins | AM | LC | O |
| Maroon-backed Accentor | *Prunella immaculata* (Hodgson, 1845) | Ins | R | LC | O |
| Rufous-breasted Accentor | *Prunella strophiata (*Blyth, 1843) | Ins | AM | LC | O |
| **Pycnonotidae (5)** | | | | | |
| Black Bulbul | *Hypsipetes leucocephalus* (Gmelin, JF, 1789) | Omn | AM | LC | C |
| Mountain Bulbul | *Ixos mcclellandii* (Horsfield, 1840) | Omn | AM | LC | C |
| Red-vented Bulbul | *Pycnonotus cafer* (Linnaeus, 1766) | Omn | AM | LC | C |
| Himalayan Bulbul | *Pycnonotus leucogenys* (Gray, JE, 1835) | Omn | AM | LC | C |
| Striated Bulbul | *Pycnonotus striatus* (Blyth, 1842) | Omn | AM | LC | O |
| **Rhipiduridae (1)** | | | | | |
| White-throated Fantail | *Rhipidura albicollis* (Vieillot, 1818) | Omn | AM | LC | O |
| **Sittidae (2)** | | | | | |
| Chestnut-bellied Nuthatch | *Sitta cinnamoventris* (Blyth, 1842) | Omn | R | LC | O |
| White-tailed Nuthatch | *Sitta himalayensis* (Jardine & Selby, 1835) | Omn | R | LC | O |
| **Stenostiridae (2)** | | | | | |
| Yellow-bellied Fantail | *Chelidorhynx hypoxanthus* (Blyth, 1843) | Ins | AM | LC | C |
| Grey-headed Canary Flycatcher | *Culicicapa ceylonensis* (Swainson, 1820) | Ins | AM | LC | C |
| **Timaliidae (6)** | | | | | |
| Rusty-cheeked Scimitar Babbler | *Erythrogenys erythrogenys* (Vigors, 1831) | Omn | R | LC | C |
| Spot-breasted Scimitar Babbler | *Erythrogenys mcclellandi* (Godwin-Austen, 1870) | Omn | R | LC | O |
| Streak-breasted Scimitar Babbler | *Pomatorhinus ruficollis* (Hodgson, 1836) | Omn | R | LC | O |
| Golden Babbler | *Cyanoderma chrysaeum* (Blyth, 1844) | Omn | R | LC | O |
| Rufous-capped Babbler | *Cyanoderma ruficeps* (Blyth, 1847) | Omn | R | LC | O |
| Grey-throated Babbler | *Stachyris nigriceps* (Blyth, 1844) | Omn | R | LC | O |
| **Trichodromidae (1)** | | | | | |
| Wall Creeper | *Tichodroma muraria* (Linnaeus, 1766) | Ins | WV | LC | F |
| **Troglodytidae (1)** | | | | | |
| Eurasian Wren | *Troglodytes troglodytes* (Linnaeus, 1758) | Ins | AM | LC | R |
| **Turdidae (6)** | | | | | |
| Orange-headed Thrush | *Geokichla citrina* (Latham, 1790) | Omn | SV | LC | R |
| Black-throated Thrush | *Turdus atrogularis* (Jarocki, 1819) | Ins | AM | LC | O |
| Grey-winged Blackbird | *Turdus boulboul* (Latham, 1790) | Omn | AM | LC | O |
| White-collared Blackbird | *Turdus albocinctus* (Royle, 1840) | Omn | R | LC | O |
| Scaly Thrush | *Zoothera dauma* (Latham, 1790) | Omn | AM | LC | O |
| Alpine Thrush | *Zoothera mollissima* (Blyth, 1842) | Ins | AM | LC | O |

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|---|---|---|---|---|---|
| **Vangidae (2)** | | | | | |
| Bar-winged Flycatcher-shrike | *Hemipus picatus* (Sykes, 1832) | Ins | R | LC | O |
| Large Woodshrike | *Tephrodornis virgatus* (Temminck, 1824) | Ins | R | LC | O |
| **Vireonidae (2)** | | | | | |
| Blyth's Shrike-babbler | *Pteruthius aeralatus* (Blyth, 1855) | Ins | R | LC | O |
| Black-eared Shrike-babbler | *Pteruthius melanotis* (Hodgson, 1847) | Ins | AM | LC | O |
| **Zosteropidae (5)** | | | | | |
| Whiskered Yuhina | *Yuhina flavicollis* (Hodgson, 1836) | Omn | AM | LC | C |
| Stripe-throated Yuhina | *Yuhina gularis* (Hodgson, 1836) | Omn | AM | LC | O |
| Black-chinned Yuhina | *Yuhina nigrimenta* (Blyth, 1845) | Omn | AM | LC | O |
| Rufous-vented Yuhina | *Yuhina occipitalis* (Hodgson, 1836) | Omn | AM | LC | O |
| Oriental White-eye | *Zosterops palpebrosus* (Temminck, 1824) | Ins | R | LC | C |
| **Pelecaniforms** | | | | | |
| **Ardeidae (4)** | | | | | |
| White-bellied heron | *Ardea insignis* (Hume, 1878) | Car | R | CR | R |
| Indian Pond heron | *Ardeola grayii* (Sykes, 1832) | Car | AM | LC | R |
| Cattle Egret | *Bubulcus ibis* (Linnaeus, 1758) | Car | SV | LC | R |
| Black-crowned Night Heron | *Nycticorax nycticorax* (Linnaeus, 1758) | Car | AM | LC | R |
| **Piciformes** | | | | | |
| **Indicatoridae (1)** | | | | | |
| Yellow-rumped Honeyguide | *Indicator xanthonotus* (Blyth, 1842) | Ins | R | NT | R |
| **Megalaimidae (3)** | | | | | |
| Golden-throated Barbet | *Psilopogon franklinii* (Blyth, 1842) | Fru | AM | LC | O |
| Blue-throated Barbet | *Psilopogon asiaticus* (Latham, 1790) | Fru | AM | LC | O |
| Great Barbet | *Psilopogon virens* (Boddaert, 1783) | Omn | R | LC | C |
| **Picidae (10)** | | | | | |
| Bay Woodpecker | *Blythipicus pyrrhotis* (Hodgson, 1837) | Ins | R | LC | O |
| Greater Yellownape | *Chrysophlegma flavinucha* (Gould, 1834) | Ins | R | LC | O |
| Darjeeling Woodpecker | *Dendrocopos darjellensis* (Blyth, 1845) | Ins | R | LC | O |
| Rufous-bellied Woodpecker | *Dendrocopos hyperythrus* (Vigors, 1831) | Ins | R | LC | O |
| Fulvous-breasted Woodpecker | *Dendrocopos macei* (Vieillot, 1818) | Ins | R | LC | O |
| Crimson-breasted Woodpecker | *Dryobates cathpharius* (Bylth, 1843) | Ins | R | LC | O |
| Speckled Piculet | *Picumnus innominatus* (Burton, E, 1836) | Ins | R | LC | O |
| Grey-headed Wookpecker | *Dendropicos spodocephalus* (Bonaparte, 1850) | Ins | R | LC | O |
| Lesser Yellownape | *Picus chlorolophus* (Vieillot, 1818) | Ins | R | LC | O |
| Grey-capped Pygmy Woodpecker | *Yungipicus canicapillus* (Blyth, 1845) | Ins | R | LC | O |
| **Podicipediformes** | | | | | |
| **Podicipedidae (1)** | | | | | |
| Great Crested Grebe | *Podiceps cristatus* (Linnaeus, 1758) | Car | PM | LC | R |
| **Strigiformes** | | | | | |
| **Strigidae (7)** | | | | | |
| Spotted Owlet | *Athene brama* (Temminck, 1821) | Car | R | LC | R |
| Spot-bellied Eagle Owl | *Bubo nepalensis* (Hodgson, 1836) | Car | R | LC | R |
| Collard Owlet | *Glaucidium brodiei* (Burton, E, 1836) | Car | R | LC | O |

| Order/ Family (no. of species)/ Common name | Scientific name | Feeding guild | Residency pattern | IUCN Red List status | Abundance |
|---|---|---|---|---|---|
| Asian Barred Owlet | *Glaucidium cuculoides* (Vigors, 1831) | Car | R | LC | O |
| Jungle Owlet | *Glaucidium radiatum* (Tickell, 1833) | Car | R | LC | O |
| Mountain Scops Owl | *Otus spilocephalus* (Blyth, 1846) | Car | R | LC | R |
| Brown Wood Owl | *Strix leptogrammica* (Temminck, 1832) | Car | R | LC | R |
| **Tytonidae (1)** | | | | | |
| Barn Owl | *Tyto alba* (Scopoli, 1769) | Car | R | LC | R |
| **Suliformes** | | | | | |
| **Phalacrocoracidae (1)** | | | | | |
| Great Cormorant | *Phalacrocorax carbo* (Linnaeus, 1758) | Car | WV | LC | O |
| **Trogoniformes** | | | | | |
| **Trogonidae (2)** | | | | | |
| Red-headed Trogon | *Harpactes erythrocephalus* (Gould, 1834) | Omn | SV | LC | R |
| Ward's Trogon | *Harpactes wardi* (Kinnear, 1927) | Omn | SV | NT | R |

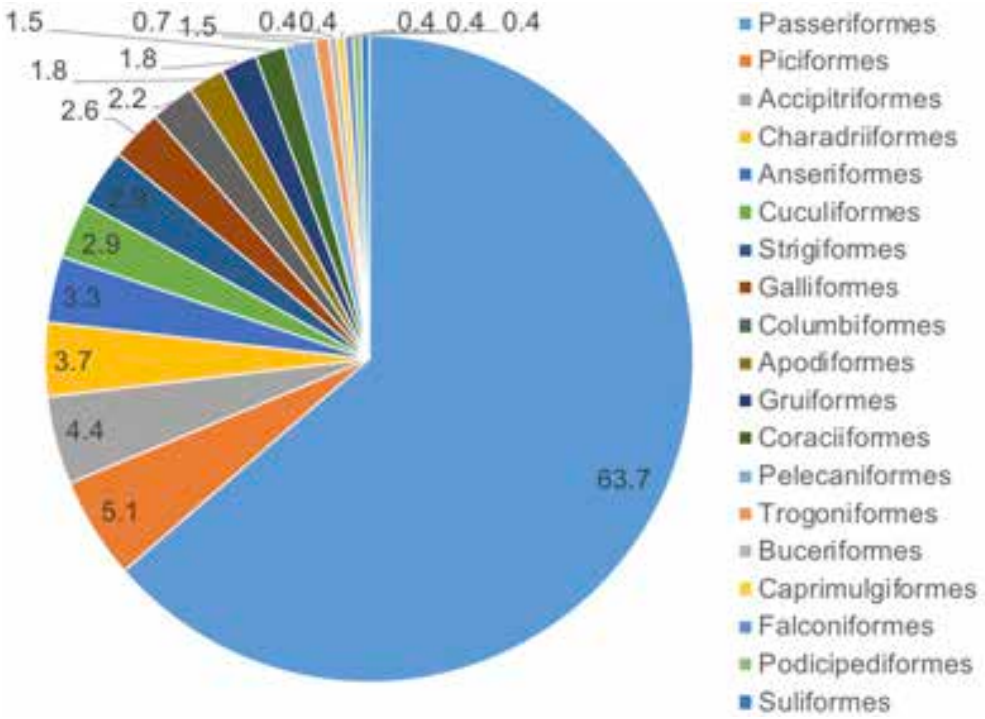


**Figure 2. Classification of the bird species by Order in the non-protected region of Trashiyangtse District in northeastern Bhutan.**

n= 24), frugivorous (4%; n= 10), and nectivorous (2%; n= 5). This representation of major trophic guilds indicates that the area holds a wide spectrum of food resources for birds due to the presence of a wide range of food niches, which reduces food competition among different species (Kumar & Sharma 2018). Most bird species are insectivorous, and the predominance of insectivore as a feeding style among birds is provisioned by diversity of insects prevalent in the agroecosystem mosaic comprised by croplands, settlements, grazing pastures, wetlands, and developed areas which represent a highly predictable food resources and diverse niches to birds (Nyffeler et al. 2018).

Upon classifying by abundance, the majority (44%; n= 121) of birds belonged to the occasional, exhibiting seasonal or altitudinal migration in the district while

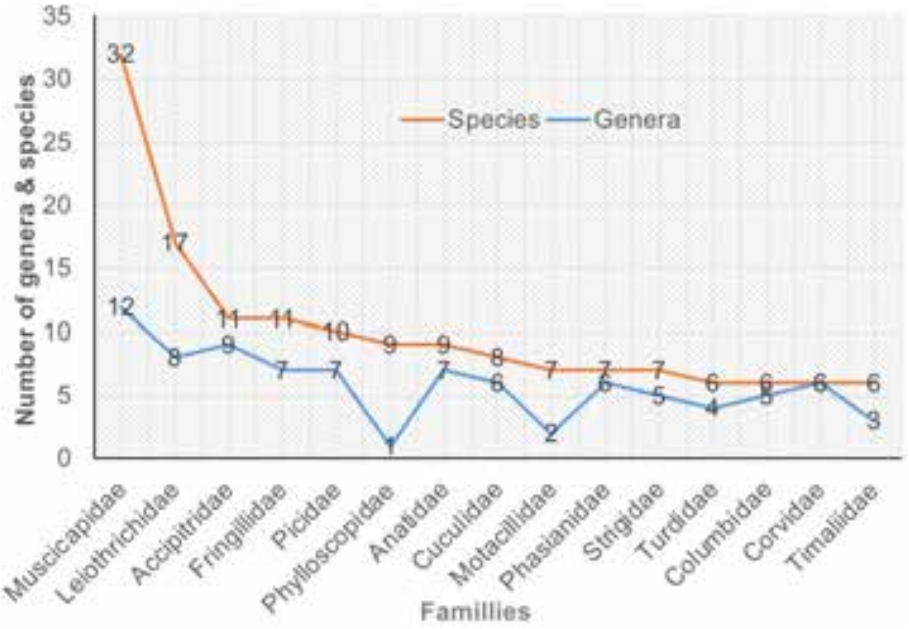


**Figure 3. The dominant families of birds (with more than five species) shown along with their corresponding number of genera and species recorded in the non-protected region of Trashiyangtse District in northeastern Bhutan.**

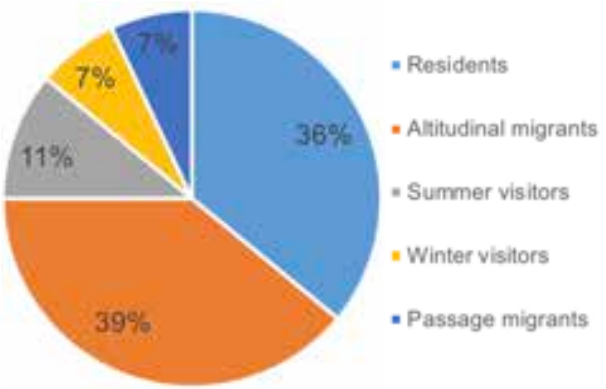


**Figure 4. Bird classification by residency pattern in the non-protected region of Trashiyangtse District in northeastern Bhutan.**

30% (n= 82) were common, whereas 24% (n= 65) and 2% (n= 5) were rare and frequent respectively (Table 1). Among the rare bird species encountered, the White-bellied Heron *Ardea insignis* and Indian Paradise Flycatcher *Terpsihone paradisi* sighted were only once in the study area. The former was sighted in 2019 behind the Dongtidzong and along the Dongdichu stream that feeds in to the Kholongchu River and later in 2018 near Yangtse town.

Finally, when bird species were categorized as per their IUCN Red List, only one species (White-bellied Heron) was listed as 'Critically Endangered', one (Palla's Fish Eagle *Haliaeetus leucoryphus*) as 'Endangered', one (Black-necked Crane *Grus nigricollis*) as 'Vulnerable', and five (Himalayan Griffon Vulture *Gyps himalayensis*, River Lapwing *Vanellus duvaucelii*, Satyr Tragopan *Tragopan satyra*, Yellow-rumped Honeyguide *Indicator xanthonotus*, and Ward's Trogon *Harpactes wardi*) as 'Near Threatened' (Table 1). Additionally, Himalayan Griffon Vulture, Black-necked Crane, and Palla's Fish Eagle are included in Appendix I and II of CITES (2019). Seven species (Palla's Fish Eagle, River Lapwing, White-bellied Heron, Yellow-rumped Honeyguide, Ward's Trogon, Black-necked Crane, and Himalayan Monal) are nationally protected and listed under Schedule I of the Forest and Nature Conservation Act 1995 (RGoB 1995) and Schedule II of the Forest and Nature Conservation Rules and Regulation of Bhutan 2017 (RGoB 2017).

Our study represents one of the few documented cases of complete bird inventory in areas adjoining a protected area in the eastern Himalayan region. Our data can be used as a baseline for future monitoring and survey. Aside from providing a comprehensive bird checklist along with their conservation status, our findings suggest the areas lying outside the protected areas with heterogeneous and mosaic landscapes of varying topography, elevation, weather, climate, and vegetation pattern offer ideal habitats and alternative conservation areas for birds. This bodes well with the current drive to identify and support conservation outside the protected areas (Kullberg et al. 2019; Kshettry et al. 2020). However, the current massive clearing of

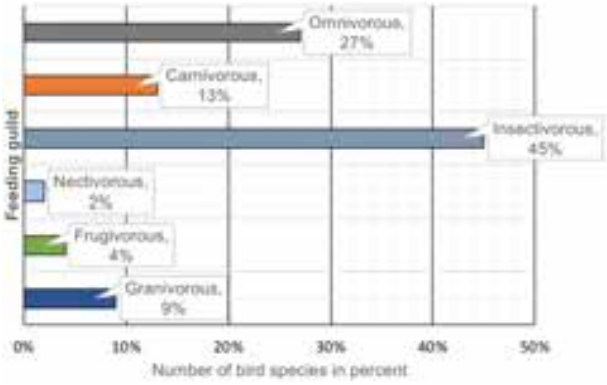


**Figure 5. Distribution of avian species according to their feeding guild in the non-protected region of Trashiyangtse District in northeastern Bhutan.**

forests along the Kholongchu River for a 600 megawatts hydro power construction, new power transmission lines, highway widening and also the increasing number of new farm road and trail constructions and increased resource collections, mainly due to less restrictions as opposed to a protected area, pose significant threats to the bird community in Trashiyangtse District.

We recommend conservation donors and wildlife managers to include non-protected areas such as ours as conservation priorities and accordingly provide funds to initiate bird conservation work for overall biodiversity conservation and eco-tourism. We also suggest similar studies to be conducted in other areas adjacent to protected areas in Bhutan as well as in the region.

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**Image 1A–O Birds in study area: A—*Upupa epops* | B—*Chroicocephalus brunnicephalus* | C—*Columba hodgsonii* | D—*Streptopelia orientalis* | E—*Alcedo atthis* | F—*Falco tinnunculus* | G—*Ithaginis cruentus* | H—*Tragopan satyra* | I—*Grus nigricollis* | J—*Gallirallus striatus* | K—*Pericrocotus ethologus* | L—*Chloropsis hardwickii* | M—*Prinia rufescens* | N—*Dendrocitta formosae* | O—*Garrulus glandarius*. Photo credits for image 'C, D, E & M' © T. Wangdi; Image 'J' © T. Wangchuck; Image 'A, B, F, G, H, I, K, L, N, O' © L. Norbu.**


**Image 1P—Ad. Birds in study area: P—*Nucifraga caryocatactes* | Q—*Dicaeum erythrorhynchosl* | R—*Emberiza pusilla* | S—*Loxia curvirostra* | T—*Lanius schach* | U—*Garrulax striatus* | V—*Heterophasia capistrata* | W—*Terpsihone paradisi* | X—*Motacilla maderaspatensis* | Y—*Anthus hodgsoni* | Z—*Cosychus saularis* | Aa—*Enicurus schistaceus* | Ab—*Enicurus scouleri* | Ac—*Eumyias thalassinus* | Ad—*Ficedula superciliaris*. Photo credits for image 'P, Q, R, T, U, V, W, X, Y, Z, Aa, Ab, Ac & Ad' © L. Norbu; Image 'S' © T. Wangdi**


Image 1Ae–As. Birds in study area: Ae—*Monticola cinclorhyncha* | Af—*Monticola solitarius* | Ag—*Niltava grandis* | Ah—*Niltava sundara* | Ai—*Saxicola ferreus* | Aj—*Saxicola torquatus* | Ak—Tarsiger rufilatus | Al—*Aethopyga nipalensis* | Am—*Prunella collaris* | An—*Pycnonotus leucogenys* | Ao—*Urdus albocinctus* | Ap—*Bubulcus ibis* | Aq—*Indicator xanthonotus* | Ar—*Dendrocopos hyperythrus* | As—*Parus monticolus*. Photo credits for image 'Ae, Af, Ag, Ah, Ai, Ak, Al, Am, An, Ao, Ar & As' © L. Norbu; Image 'Aj, Ap & Aq' © T. Wangdi

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COMMUNICATION

# Population status and distribution of the Critically Endangered Bengal Florican *Houbaropsis bengalensis* in the grassland of Koshi Tappu Wildlife Reserve, Nepal

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**Abstract:** The Bengal Florican *Houbaropsis bengalensis* is one of the most threatened terrestrial bird species, listed as 'Critically Endangered' by the IUCN. This species is protected globally and locally due to very low population (global population is approximately 250–999 individuals), and little is known about its distribution and habitat use. We assessed population status and distribution of floricans in Koshi Tappu Wildlife Reserve, Nepal (KTWR). We surveyed 57 1-km$^2$ randomly distributed blocks across the reserve to record as many individuals as possible during their breeding season (March–May). We walked 2,964 transects (52 transects on each block) each of length 1 km on 57 blocks of 1-km$^2$ to estimate their population. We surveyed when the birds are most active during early morning (0600–0930 h) and later afternoon (1530–1900 h). We calculated grass importance value index (IVI), grass species composition, grass height, relative frequency of grass species, relative density of grass species, percent of grass ground coverage, presence/absence of human activity, and presence/absence of livestock to assess the habitat condition. We recorded 18 individuals (16 males and 2 females) inside the core of the reserve, where the habitat is dominated by *Imperata cylindrica*. Human disturbance had a negative impact on occurrence of the florican. We recommend implementing a Bengal Florican-specific conservation action plan to promote community-based conservation and restrict human encroachment in the grassland habitat.

**Keywords:** Conservation, human-wildlife interaction, importance value index, species composition, threatened species.

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## INTRODUCTION

Bengal Florican *Houbaropsis bengalensis* is a 'Critically Endangered' bird species under the IUCN Red List (Brahma et al. 2013). A small and rapidly declining population due to widespread loss of habitat (Baral et al. 2013) renders it highly susceptible to extinction. BirdLife International estimated a global population of 250–999 individuals across the species' geographic range - India's Uttar Pradesh state towards the west through the northern range encompassing the Terai of Nepal to Assam and Arunachal Pradesh in India and historically up to Bangladesh ( Collar & Inskipp 1984; Baral et al. 2002; Gray et al. 2009; Collar et al. 2017). Owing to the small population size this species is legally protected globally and locally (Brahma et al. 2013). An early status survey of Bengal Florican in Nepal in 1982 showed the presence of 56–82 birds (Inskipp & Baral 1970; Collar & Inskipp 1984).

Bengal Florican males are territorial during their breeding season (Gray et al. 2009; Baral et al. 2013) and are easily detected as they perform frequent territorial flight displays (Gray et al. 2009). The breeding season of Bengal Florican starts during early February and lasts till July (MoEF 2011). During the breeding season, male floricans establish individual territories (40–60 m) in open areas of short grasslands (Baral et al. 2002; Brahma et al. 2013; Packman et al. 2014; Collar et al. 2017). In one clutch, Bengal Floricans lay one to two eggs (Gray et al. 2009). The females raise their young alone without any help from males (Baral et al. 2002).

The Bengal Florican has been recorded in different national parks of Nepal including Koshi Tappu Wildlife Reserve (KTWR), Bardia National Park, Shuklaphanta National Park, and Chitwan National Park (Baral et al. 2020). However, rapidly changing habitat condition calls for urgent conservation action and research examining the vulnerability and resilience of this species to the environmental changes (Baral et al. 2013). Extensive loss and modification of habitat due to anthropogenic activities (Aaranyak 2009), over-grazing (Gray et al. 2009), increased poaching (Baral et al. 2002; Poudyal 2008), inappropriate grass fires (Collar & Inskipp 1984), burning and ploughing regimes (Jha et al. 2018), and increasing dominance of invasive species like *Mikania micrantha* (Baral et al. 2020) comprise the major immediate threats to this species within their preferred habitat inside protected areas (Baral et al. 2013).

KTWR holds the highest population of Bengal Florican (around 40) among the protected areas of Nepal (Baral et al. 2020). Furthermore, the recorded density of adult male florican in KTWR is highest on the Indian subcontinent (Baral et al. 2020). As 46.6 % of its area, primarily grasslands, comprises suitable florican habitat, appropriate management of Koshi Tappu's grassland is essential for the conservation of the species (Baral et al. 2013). Therefore, the objectives of this study were to: (i) assess the biophysical condition of the Bengal Florican's habitat in the Koshi Tappu Wildlife Reserve and (ii) understand the relationship between the habitat attributes and the population status of the species.

## MATERIALS AND METHODS

### Study area

KTWR harbors the highest population of Bengal Florican among the protected areas of Nepal (Baral et al. 2013). KTWR is located between 26.65° N, 87.00° E in the lowland Terai region of Nepal (Figure 1). Our study area comprised 175 km$^2$ of the Saptakoshi river floodplains spanning 75–81 m from the mean sea level. The Saptakoshi river floodplain is the most northeasterly extension of the Gangetic Plain (Convention on Migratory Species 2020). It covers parts of Sunsari, Saptari, and Udayapur districts of the Eastern Development Region of Nepal. KTWR is divided into three management divisions - core area (CA), buffer zone (BZ), and outside protected area (OPA) (Poudyal et al. 2008) which are unequal in size.

An estimated 70% of the reserve's land area is covered by 'phantas' (patches of short grasslands) (Jha et al. 2018), water and riverine forests and 46.6% of the KTWR is suitable for florican population distribution (Baral et al. 2020). *Typha spp*. and *Saccharum* spp. are the dominant plant species here, although patches of *Imperata* spp. and *Phragmites* spp. are also seen (Baral et al. 2013). Riverine vegetation dominated *by Dalbergia sissoo* and *Acacia catechu* trees dominates the islands and edges of the reserve (Convention on Migratory Species 2020).

More than 50% of the area in KTWR is covered by wetland, and the remaining area is intensively cultivated throughout the year (Baral et al. 2013). During the dry season (October–March), several islands are vegetated with *Saccharum* spp., *Imperata cylindrica*, and *Typha elephantina* which are collected by locals for household purposes (Poudyal 2008). The climatic condition of this area is tropical monsoonal type and experiences three distinct seasons, i.e., summer (February–May), monsoon (June–September), and winter (October–January) (MoEF 2008). The reserve is the first Ramsar

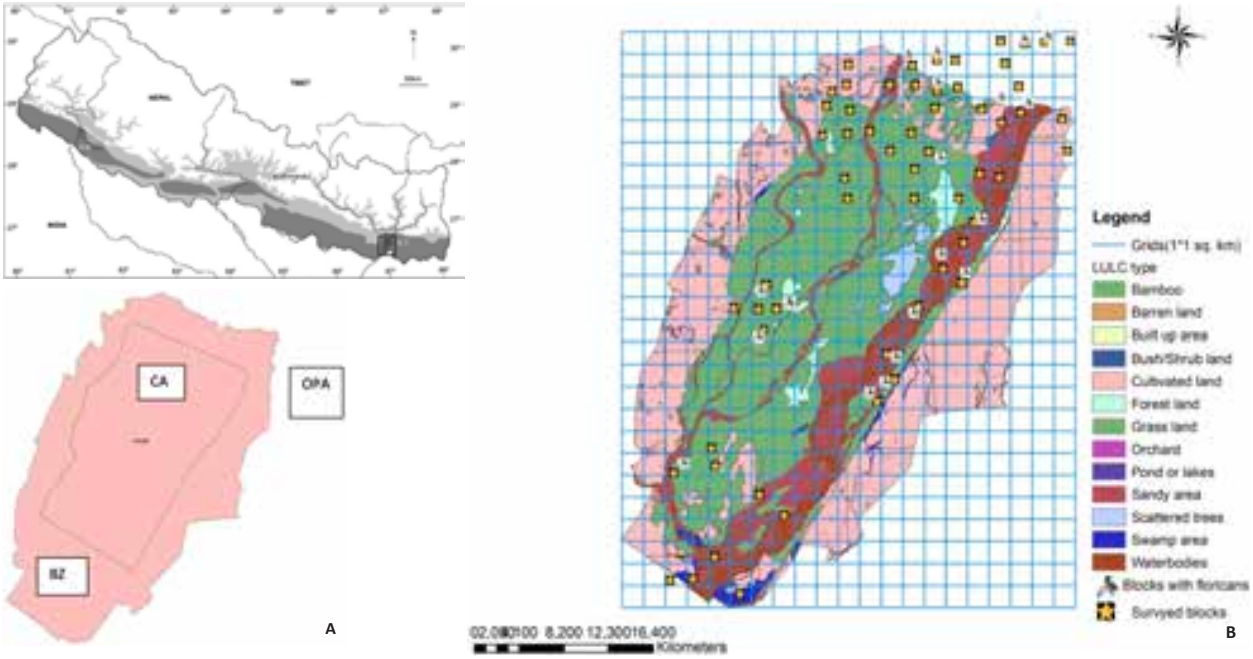


**Figure 1 (A, B). Map of Koshi Tappu Wildlife Reserve showing the core area, buffer zone and outside protected area, land use and land cover classification and surveyed grids of 1 x 1 km.**

site of Nepal declared in 1987 primarily for supporting more than 20,000 waterbird population and 200 species of fish (Baral et al. 2002). It serves as a breeding ground for many winter migratory birds due to favorable environmental and habitat characteristics. As nearly 20 globally threatened bird species have been recorded in this Reserve (Baral et al. 2013).

**Data collection**

Study area was divided into three categories based on the geographical locations and practiced conservation policies. CA is the innermost part of the reserve, where disturbance from external agents like people and livestock is restricted and wildlife policies and regulations are effectively implemented. BZ is partially restricted for locals to aid in conservation of CA. OPA is the area outside BZ and CA and is open to locals to conduct their daily activities and living.

Primary data was collected using 1 x 1 km random grids in the study area map using the fishnet tool in ArcGIS 10.9.1 software (ESRI Inc. year) (Figure 1). Nineteen grids from each management zones (CA, BZ, and OPA) were chosen for the survey. Those grids were named as blocks for our research study. Thus, 57 blocks were selected from the randomly designed grids to survey the grassland habitat condition and Bengal Florican population status in KTWR.

**Bengal Florican survey and population estimation**

A sweep count method (Baral et al. 2002) was used to survey presence/absence of the birds in each block. In the sweep count method, team members walked on total 2,964 transects (52 transects on each block) each of 1 km length on 57 blocks; 52 transects on each block were designed in such a way that 50 transects were spaced 20 m apart and the remaining two transects were walked on diagonals of the blocks. Only one member of the team walked a transect due to limited resources and there were 11 team members so in one survey occasion, 11 team members completed 11 transects. The survey team consisted of experienced observers and all observers used binoculars to confirm correct identification of the species and sex of the birds. All GPS locations and pictures of the birds were recorded for each sighting.

The study area was surveyed early in the morning (0600–0930 h) and later in the afternoon (1530–1900 h). In general, Bengal Floricans are active during dusk and dawn (Gray et al. 2009). Moreover, during the breeding season, male individuals are very conspicuous due to the active territorial displays (Gray et al. 2009). Male and female florican were distinguished from their physical appearance. Males have black plumage and appear completely white during their flight (MoEF 2008) (Image 1) except for the dark primary remiges, while females are buff brown and slightly larger than


Image 1. Bengal Florican *Houbaropsis bengalensis* flying through Koshi Tappu Wildlife Reserve, Nepal.

males (Poudyal 2008). In addition, only males show display characteristics during breeding season (Baral et al. 2002; Poudyal 2008; Jha et al. 2018; Convention on Migratory Species 2020) and their movements helped team members to count their population. Females are larger than males and easily distinguishable from males due to their body colour and size. Immature birds look like females but the experts can distinguish those from females based on their size and weight (Baral et al. 2002).

The total population was recorded based on equal sex ratio, i.e., 1:1 because female birds are extremely difficult to locate (Poudyal 2008; Brahma et al. 2009) and we had limited resources. However, for the future study we suggest to use the method as adopted by Baral et al. (2020).

**Habitat survey**

Six plots each spaced 200 m apart were made by dividing each block with the help of a measuring tape and a compass (Figure 2). This process was repeated inside every block. Further, 50 m radius circle was drawn inside each plot and the vegetation status inside each 50 m radius circle was studied to make the vegetation

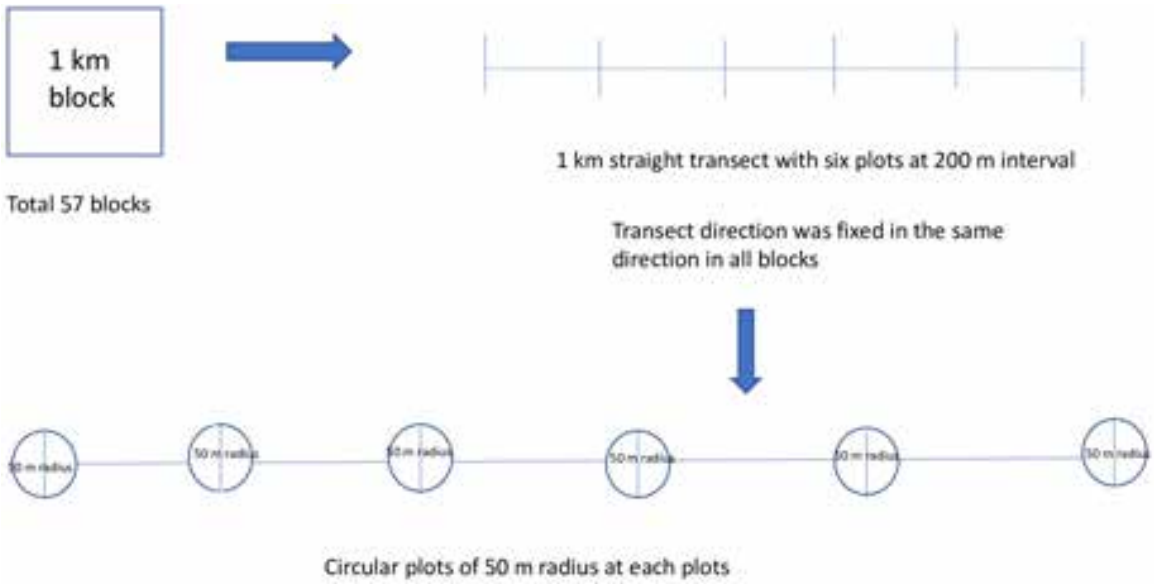


Figure 2. Habitat survey design for Bengal Florican.

survey easier as well as representative of each sample block. Information regarding grass height (cm), grass ground coverage (%), tree number, presence/absence of people, presence/absence of livestock, and dominant bird species were used to assess the habitat condition inside each 50 m radius vegetation plot. To measure the habitat disturbance due to humans and livestock we observed their movements within each block during the survey. If human or livestock movement was recorded inside the block it was recorded as a disturbed (Table 1). As floricans are extremely habitat specific and habitat sensitive birds, habitat disturbance due to external agents like people and livestock could impact in their occurrence (Baral et al. 2013).

Similarly, density, relative density, frequency, relative frequency, cover, and relative cover were used to compute important value indices of the grass species using the following standard formula (Thapa et al. 2020).

- Density of species A= Total number of individuals of species A in all sampling plots/ Total sampling plots
- Relative density of species A= Total number of individuals of species A / Total number of individuals of all species
- Frequency of species A= (Number of plots in which species A occurs x 100) / Total number of plot samples
- Relative Frequency of species A= (Frequency value of species A x 100) / Total frequency value of all species
- Cover %= (Approximate area covered by individual species) / (Total number of plots sampled) x 100
- Relative cover= (cover of individual species) / (Total cover of all species) x 100

Importance Value index (IVI)

- For grasses IVI = Relative density + Relative frequency + Relative cover

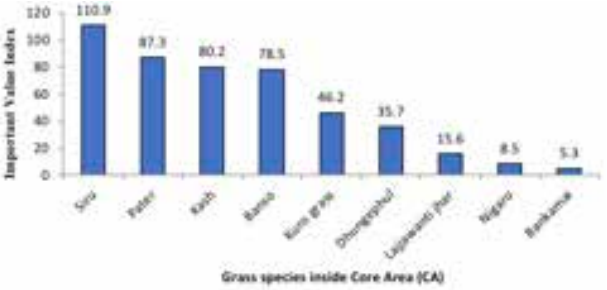


**Figure 3. Importance value indices (IVI) of different grass species inside the core area of Koshi Tappu Wildlife Reserve, Nepal.**


**Figure 4. Importance value indices (IVI) of different grass species inside the buffer zone of Koshi Tappu Wildlife Reserve, Nepal.**

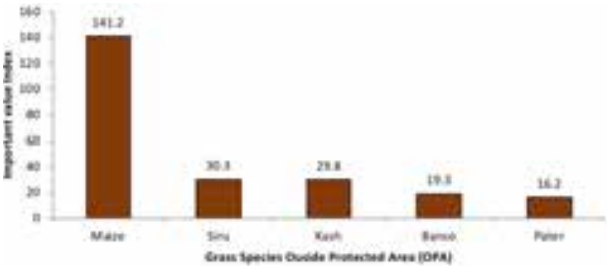


**Figure 5. Importance value indices (IVI) of different grass species outside protected area of Koshi Tappu Wildlife Reserve, Nepal.**

## RESULTS

Altogether nine species of grass were recorded inside the CA, where 'Siru' *Imperata cylindrica* was the dominant grass with importance value index of 110.9. Pater *Samyda dodecandra* had importance value index of 87.3 followed by Kash *Saccharum spontaneum* 80.2, Banso *Digitaria ciligara* 78.5 (Figure 3). Likewise, seven different grass species were observed inside the BZ, among which Kash *Saccharum spontaneum* had the highest IVI of 94.2, followed by Siru *Imperata cylindrica* 86.5, Banso *Digitaria ciligara* 84.3, and Pater *Samyda dodecandra* 82.4 (Figure 4).

Five different grass species were recorded in the OPA, and among them maize *Zea mays* had the highest IVI of 141.2, followed by Siru *Imperata cylindrica* 30.3, Kash *Saccharum spontaneum* 29.8, and Banso *Digitaria ciligara* 19.3 (Figure 5). A total of 18 floricans (16 males and 2 females confirmed from regular field visits, previous records and information from local guides (2017–2019)) were recorded in the study area, and the overall population was assessed to be 36 assuming equal sex ratio (1:1) (Table 1). Florican were recorded from 17 blocks out of 57 blocks (29.82%) - 18 in the CA, 12 in the BZ and 6 in OPA (Figure 2). Other bird species were also recorded in study area while counting florican's population. Dominant bird species that were observed during the florican count were: Black Drongo *Dicrurus macrocercus*, Intermediate Egret *Mesophoyx*

**Table 1. Florican population and record of people and livestock movement in studied blocks in Koshi Tappu Wildlife Reserve, Nepal.**

| Block | Plot descriptions | Status OPA, CA, BZ | Sighted Florican | Estimated Florican | People's presence/ absence | Livestock's presence/absence |
|---|---|---|---|---|---|---|
| 1 | Northern Radhabas | OPA | 1 | 2 | No | No |
| 2 | Jabdi waari | OPA | 1 | 2 | No | No |
| 3 | Jabdi paari | OPA | 1 | 2 | No | No |
| 4 | Jabdi | OPA | 0 | 0 | Yes | Yes |
| 5 | Jabdi paari | OPA | 0 | 0 | Yes | Yes |
| 6 | Chakadghatti Western | OPA | 0 | 0 | Yes | Yes |
| 7 | Chakadghatti | OPA | 0 | 0 | Yes | Yes |
| 8 | Srilanka Tapu | OPA | 0 | 0 | No | No |
| 9 | Srilanka Tapu | OPA | 0 | 0 | No | No |
| 10 | Srilanka Tapu | OPA | 0 | 0 | Yes | Yes |
| 11 | Bhakalpur | OPA | 0 | 0 | Yes | Yes |
| 12 | Bhakalpur | OPA | 0 | 0 | Yes | Yes |
| 13 | Bhakalpur | OPA | 0 | 0 | Yes | Yes |
| 14 | Bhakalpur | OPA | 0 | 0 | Yes | Yes |
| 15 | Bhakalpur (Bandhdanda) | OPA | 0 | 0 | Yes | Yes |
| 16 | Bhakalpur (Bandhdanda) | OPA | 0 | 0 | Yes | Yes |
| 17 | Bhakalpur (Bandhdanda) | OPA | 0 | 0 | Yes | Yes |
| 18 | Bhakalpur (Bandhdanda) | OPA | 0 | 0 | No | Yes |
| 19 | Bhakalpur (Bandhdanda) | OPA | 0 | 0 | Yes | Yes |
| 20 | Patthari, Saptari | CA | 0 | 0 | No | Yes |
| 21 | Patthari, Saptari | CA | 0 | 0 | No | Yes |
| 22 | Hawa Mahal | CA | 0 | 0 | No | Yes |
| 23 | Kushaha west | CA | 0 | 0 | No | No |
| 24 | Kushaha Katan | CA | 1 | 2 | No | No |
| 25 | Hawa Mahal | CA | 2 | 4 | No | Yes |
| 26 | Prakashpur Army post | CA | 1 | 2 | No | No |
| 27 | Madhuban Aapghanchi Western | CA | 1 | 2 | No | No |
| 28 | Madhuban Aapghanchi Western | CA | 1 | 2 | No | No |
| 29 | Hawa Mahal | CA | 1 | 2 | No | No |
| 30 | Bhakalpur | CA | 0 | 0 | No | No |
| 31 | Bhakalpur | CA | 0 | 0 | No | No |
| 32 | Bhakalpur | CA | 0 | 0 | No | No |
| 33 | Bhakalpur | CA | 0 | 0 | No | No |
| 34 | Bhakalpur | CA | 1 | 2 | No | No |
| 35 | Bhakalpur | CA | 1 | 2 | No | No |
| 36 | Patthari, Saptari | CA | 0 | 0 | No | No |
| 37 | Patthari, Saptari | CA | 0 | 0 | No | No |
| 38 | Patthari, Saptari | CA | 0 | 0 | No | No |
| 39 | Srilanka Tapu | BZ | 0 | 0 | No | No |
| 40 | Srilanka Tapu | BZ | 1 | 2 | No | No |
| 41 | Prakashpur | BZ | 1 | 2 | No | No |

| Block | Plot descriptions | Status OPA, CA, BZ | Sighted Florican | Estimated Florican | People's presence/ absence | Livestock's presence/absence |
|---|---|---|---|---|---|---|
| 42 | prakashpur | BZ | 1 | 2 | No | No |
| 43 | Radhabas West | BZ | 0 | 0 | No | No |
| 44 | Radhabas Western | BZ | 0 | 0 | No | No |
| 45 | Koshi-Barrage | BZ | 0 | 0 | Yes | Yes |
| 46 | Koshi-Barrage | BZ | 0 | 0 | Yes | Yes |
| 47 | Haripur | BZ | 1 | 2 | Yes | Yes |
| 48 | Haripur | BZ | 0 | 0 | Yes | Yes |
| 49 | Dakshin Duban, Saptari | BZ | 0 | 0 | Yes | Yes |
| 50 | Dakshin Duban, Saptari | BZ | 1 | 2 | Yes | Yes |
| 51 | Dakshin Duban, Saptari | BZ | 0 | 0 | Yes | Yes |
| 52 | Srilanka Tapu, Sunsari | BZ | 0 | 0 | Yes | Yes |
| 53 | Srilanka Tapu, Sunsari | BZ | 0 | 0 | Yes | Yes |
| 54 | Srilanka Tapu, Sunsari | BZ | 1 | 2 | No | Yes |
| 55 | Srilanka Tapu, Sunsari | BZ | 0 | 0 | No | Yes |
| 56 | Srilanka Tapu, Sunsari | BZ | 0 | 0 | No | Yes |
| 57 | Srilanka Tapu, Sunsari | BZ | 0 | 0 | No | Yes |

OPA— outside protected area | CA—core area | BZ— buffer zone.

*intermedia*, Little Egret *Egretta garzetta*, and Asian Pied Starling *Gracupica contra*.

From our field observation we found that there might not be any relationship between grass height and florican occurrence. However, the florican numbers may be affected by a particular grass species' composition in their habitat. The largest population (18) was recorded inside the CA among three different habitat conditions (CA, BZ, OPA). The highest male florican population (9) was recorded inside the CA where *I. cylindrica* grass was the dominant grass with the importance value index of 110.9. Fewer population of florican were recorded in the OPA where we recorded less ground coverage of *I. cylindrica.*

Human disturbance was impacting negatively the florican population occurrence as found from our field observation. The highest florican population was recorded inside the CA, where human disturbance was less, than the OPA was observed (Table 1). Large populations of feral cattle were recorded in most of our study areas (CA, BZ, and OPA) which needs urgent attention from the concerned authority. As we recorded very few trees growing in the grassland, no relationship could be ascertained between tree growth and florican occurrence.

## DISCUSSION

The distribution of Bengal Florican in different kinds of grassland habitat within KTWR was studied. Male and female florican were sighted from the tall grass of height 100–150 cm to the smaller grass height of 8–10 cm. However, female florican might prefer dense patches of tall grass for nesting purposes (Gray et al. 2009). Habitat selection of any grassland bird species primarily depends on bare ground exposure, vegetation height, litter depth (Fisher & Davis 2010). Increased grass height and reduced bare ground exposure can provide safety from their predators and protection from wind to the young and adult grassland birds (Fisher & Davis 2010). There are limited studies on explaining the biological relevance of litter depth in distribution of grassland bird species, litter depth might be useful for birds in building nests substrate, regulating soil microclimate, material for nutrient cycling (Fisher & Davis 2010). Floricans' preference to the lesser/no disturbance can be concluded when they have been sighted from the patches of tall grasses to open areas where there was very little or no disturbance from external agents/factors during our field surveys.

Bengal Floricans were sighted in 17 blocks out of 57 blocks and their population was estimated to be around 36. In contrast to this, the survey conducted by Baral et al. (2020) estimated the species' population to be 41 in

KTWR. Our study area covered a 57 km$^2$ area of florican habitat (81.55 km$^2$) while the survey conducted by Baral et al. (2020) covered 168.9 km$^2$ area during the survey. This could be the reason for the variation in estimated population size. In addition, the total population of floricans recorded in KTWR in 2012 survey was 47 (Baral et al. 2013) which demonstrates the trend of decreasing florican numbers even in their most suitable habitat in Nepal. Habitat degradation is considered as the major reason for florican population decline (Baral et al. 2013).

Only two out of 18 sightings during the survey were females. Inskipp and Inskipp's (1984) survey yielded a similar result when only 5–6 females were encountered among a total of 35–50 birds sighted. Marked differences between male and female florican' behaviour and habitat preference could explain this finding (Narayan 1992). In the site female florican mostly remain hidden and are rarely sighted during surveys (Baral et al. 2013).

The highest florican population was recorded inside the CA but the area cannot be claimed as the suitable habitat/preferred habitat for florican based on the population density only (Brahma et al. 2013). However, if the human presence/absence and the abundance of *I. cylindrica* highly account for florican occurrence, then the species' presence in the CA is favored by low human encroachment and higher dominance of *I. cylindrica* as observed from our field visits. Yet, robust investigation and detailed research focusing on impact of external agents in florican's occurrence is required to conclude this field observation. Increasing dominance of invasive species like *Mikania micrantha* even inside the CA is creating serious threats to florican in their present habitat (Baral et al. 2013). Further detailed studies focusing on other demographic factors (Baral et al. 2020), competition (Narayan 1992) and predation (Brahma et al. 2013) are necessary in order to understand the suitable habitat requirement of this species. Floricans are species with a highly specialized habitat and any severe disturbance in their habitat condition could cause their local extinction as observed in Bangladesh (Baral et al. 2013).

We noticed up to four Bengal Floricans (2 male and 2 female) in one block (1 km$^2$). From our regular visits and records, we found that this species has zero tolerance for habitat disturbance; a major reason for its population decline. The bird is extremely territorial (Gray et al. 2009) and shy and sensitive to its habitat condition (Narayan 1992). It is thought to occupy the same location until external disturbance prompts it to abandon its territory (Gray et al. 2009). In addition, detailed data on this species' association with other dominant bird species in the region is still lacking which is essential to understand its interspecific behaviour (Brahma et al. 2013). These kinds of associations are assumed to provide functional advantages and evolutionary benefits to the species involved (Brahma et al. 2013). Functional advantages include foraging advantages (to locate food resources) and anti-predator advantages (to detect and deter predators) (Brahma et al. 2013). Higher populations of florican were observed in the areas hosting the good populations of Black Drongo *Dicrurus macrocercus*, Intermediate Egret *Mesophoyx intermedia*, Little Egret *Egretta garzetta*, and Asian Pied Starling *Gracupica contra*.

We recommend implementation of effective habitat management policies and restricting anthropogenic activities, especially inappropriate burning and grass cutting, in the region to help these declining populations survive in the region. Detailed studies on their habitat requirements (Brahma et al. 2013), mating behavior (Gray et al. 2009) and intra- and inter-specific interactions (Narayan 1992) would greatly aid the effective protection of their remaining population.

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# Is habitat heterogeneity effective for conservation of butterflies in urban landscapes of Delhi, India?

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**Abstract:** The present study which was conducted in 2015–16 and 2016–17 emphasizes the nine different types of habitats used by 40 listed butterflies in six different urban landscapes of Delhi. Assessment of flowerbeds, grasses, hedges/crops/bushes, artificial light, wet soil/damp patches/humus, trees, open spaces/grounds, bird droppings, and roads/pavements/concrete spaces in conserving butterfly diversity in highly urbanized landscapes by testing the hypothesis that diversity of butterflies across all the habitats are similar, was the focal point of the study. Except for the artificial light and the paved roads or concrete spaces, all other habitats were natural in surroundings. The families Lycaenidae and Nymphalidae had the largest habitat share (26%), whereas the family Hesperiidae had the minimum share (9%). Aravalli Biodiversity Park, New Delhi maintained the serenity of natural ones. Species richness and diversity was the highest at flowerbeds and lowest at the artificial light. The study highlights the choice of heterogeneous habitats by city butterflies to integrate the concept of the urban green spaces into a wide variety of urban development projects which in turn can help their own sustenance.

**Keywords:** Community, diversity, ecology, generalist, green space, heterogenous, lepidoptera, protected, semi-urban.

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**Author contributions:** MP—research design, data collection, drafting manuscript, methodology design, critical review, revisions at different stages, editing. AS—conceptualization, data analysis and interpretation, map preparation, drafting manuscript, critical review, editing, revisions at different stages.

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## INTRODUCTION

Studies on urban biodiversity are booming in recent years (Shwartz et al. 2014). Urban ecology is an integral part of such studies, and urban areas have become a research topic due to the recognition that conservation and management of urban habitats and species pose particular challenges (McDonnell et al. 1997; Angold et al. 2006). Butterflies, being diurnal, have often been the focus of urban ecosystems (Ramirez-Restrepo & McGregor-Fors 2017) because they are thought to react rapidly to environmental changes due to their high mobility and short generation time (McIntyre 2000). They are a fundamental part of urban ecology (Rebele 1994; McDonnell et al. 2009), providing important ecosystem and helping people reconnect with nature (Soga & Gaston 2016). Recent research has highlighted the positive role of urban green infrastructure in terms of urban ecology and ecosystem services (De Groot et al. 2002; Tratalos et al. 2007), keeping butterflies in the pivotal point of study as tropical butterflies are disappearing at the fastest rates due to loss of suitable habitat (Brook et al. 2003; Koh 2007) especially in southern Asia.

Delhi is the second largest megacity in the world (Tickell & Ranasinha 2018) and one of the largest contributors to the urban population (about 7.6%) of India, with about 16.8 million inhabitants distributed over 1,485 km$^2$ area (Chandramouli & General 2011). Over the last two decades, the population density has increased from nearly 9,340 people/km$^2$ in 2001 to 11,297 persons/km$^2$ in 2011. Rising urbanisation has a strong influence over the butterfly diversity of the city (Paul & Sultana 2020). The present study was undertaken to understand the importance of different habitat types in the urban landscape of Delhi.

## METHODS

### Study area

The study area is NCT (National Capital Territory) of Delhi (Figure 1) 28.42 to 28.87 N and 76.83 to 77.35 E which lies in the northern India and spreads over an area of 1,484 km$^2$ (573 mi$^2$). It borders the Indian states of Uttar Pradesh to the east and Haryana in the north, west, and south. Two prominent features of the geography of Delhi are the Yamuna flood plains and Delhi ridge. The present study includes six sampling sites: industrial area Mayapuri (MP) 28.64 N,77.13 E, Nehru Park (NP), a city park 28.59 N,77.19 E, agricultural area IARI Pusa (PU) 28.64 N, 77.16 E, suburban residential and institutional area Dwarka (DW) 28.59 N,77.02 E, Aravalli Biodiversity Park (ABP) 28.56 N, 77.15 E restored degraded area as a biodiversity park, and a city forest Northern ridge (NR) 28.69 N,77.22 E.

### Data collection

The butterfly sampling was done using the 'Pollard walk' method (Pollard et al. 1993). For each site, the selection of transects was in a random stratified manner depending on the size of the area. Each site was sampled once in a month and thrice in a season using random stratified transects based on the dimensions of the area. At all the sampling sites, three random transects of each 0.5–1 km was selected and every transect was covered in one hour, but at the different time slots of the day: 1000–1200 h,1200–0200 h, and 0200–0400 h. Identification was done using the field guides (Kehimkar 2013; Singh 2017; Smetacek 2017). The classification is based on Kunte et al. (2020). Butterflies were not collected but only photographed for the identification. Field sampling was carried out between April 2015 to March 2017. Data were collected in three distinct periods each year, i.e., (a) pre-monsoon (mid-February to mid-June: comprises spring and summer), (b) monsoon (mid-June to mid-September), and (c) post-monsoon (mid-September to mid-February: comprises autumn and winter). Each site was visited during ideal weather conditions only. Rainy and windy days were avoided. Meteorological data for monthly rainfall and the diurnal temperature were obtained from Regional Meteorological Department of the Indian Meteorological Department, Delhi. Nine different habitats such as flowerbeds, grasses, hedges/crops/bushes, artificial light, wet soil/damp patches/humus, trees, open spaces/grounds, bird droppings, and roads/pavements/concrete spaces were chosen at different landscapes of Delhi during this study.

### Data analysis

The relationships of complex habitats were depicted using Venn diagram (Figure 2). '∩' symbol denotes intersection between two independent habitats which will include the common species between them. Hedges, crops, and bushes had been clubbed together under a same category (H) because they constitute a collective green cover irrespective of their usage in terms of urban greenery. Likewise, roads, pavements and concrete spaces had been put together in a single group (R) as well as wet soil, damp patches, and humus (W) had been grouped together.

Data analyses were carried out in two phases. First,

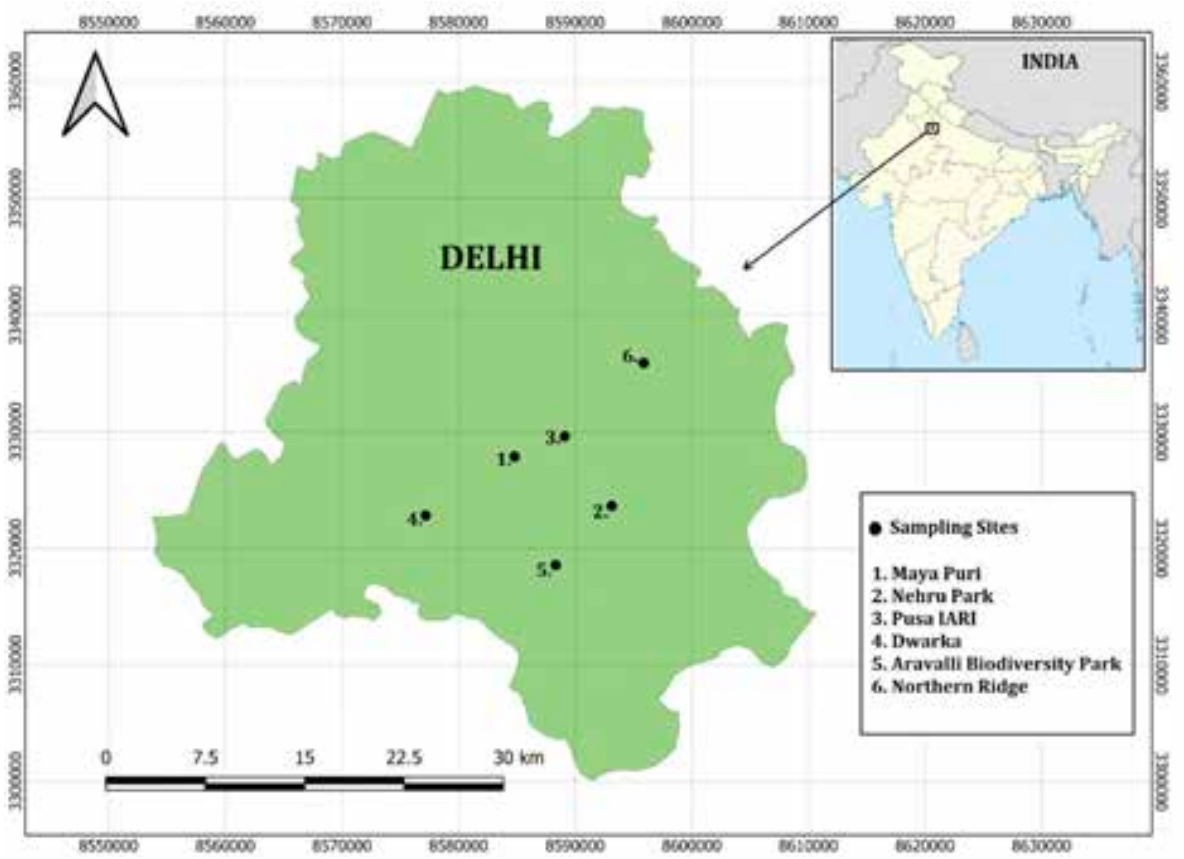


Figure 1. Map of study sites in Delhi.

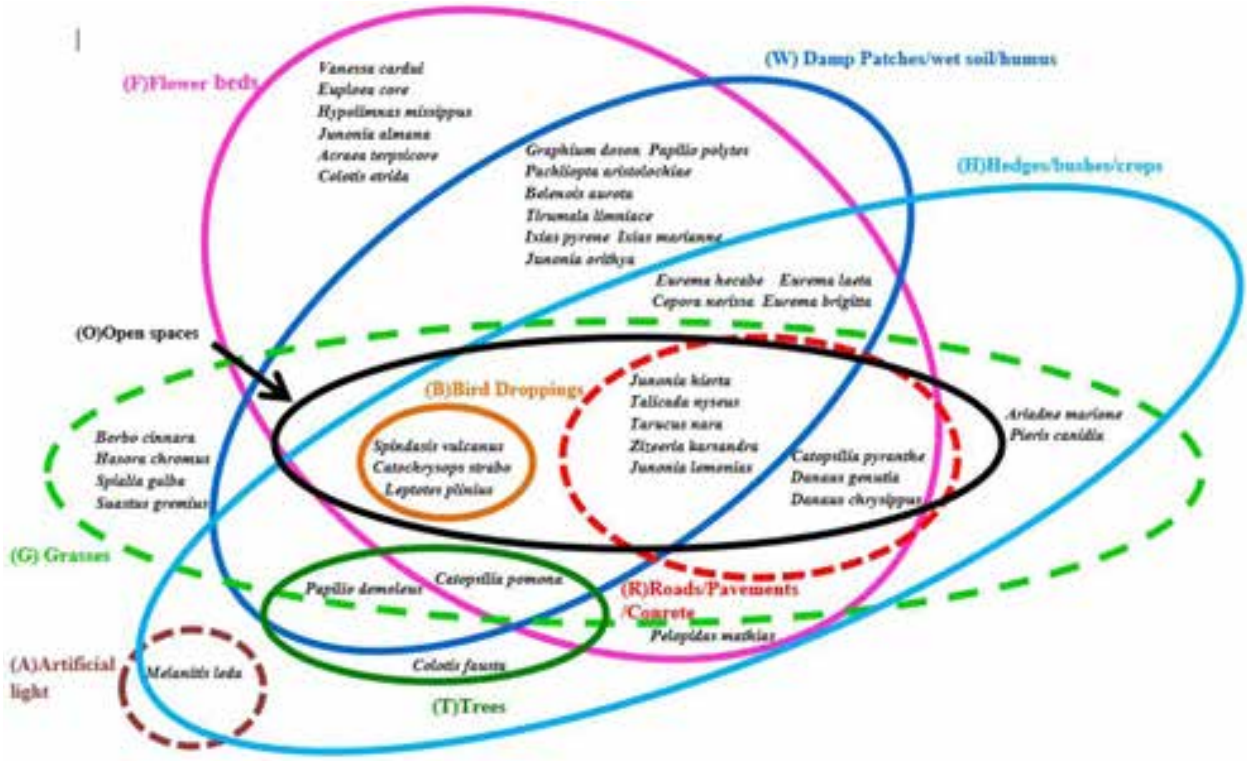


Figure 2. Venn diagram representing 40 species of butterflies in nine habitats across six urban landscapes.

to quantify the diversity of butterfly assemblage at nine different habitats, the following diversity indices, viz., Simpson index of diversity (1 – D) (Romos et al. 2006), Shannon-Wiener index (H') (Henderson 2005; Romos et al. 2006), and Shannon J or evenness index (Henderson 2005; Romos et al. 2006; were calculated using Microsoft Excel 2010.

The second phase of analysis involves statistical interpretation of data. Shapiro-Wilk test and Kolmogorov-Smirnov test were used to check the normality of the data. Further a null hypothesis was proposed that the diversity of butterflies across all nine habitats is similar, i.e., H1= H2= H3= H4= H5= H6= H7= H8= H9, to check the variance between the habitats. ANOVA test was applied over the data set using the software SPSS 23.0 to check the null hypothesis and further post hoc Dunnett T3 test was conducted to check exactly where the difference lies as the variances were not equal for all habitats.

## RESULTS

With 11,943 overall sightings, 40 species of butterflies belonging to 30 genera and five families were recorded in nine different habitats (Table 1). The results are summarized in a Venn diagram (Figure 2). The groups of butterflies which lie at the innermost zone exploit the maximum number of habitats as compared to the butterflies lying at the outer periphery. Lycaenidae and Nymphalidae families have 26% of the total share and Hesperiidae family has the least share of 9%. *Hypolimnas misippus* (Schedule I) despite it is widespread in India*, Euploea core* (Schedule IV) though this schedule has little or no importance, and *Cepora nerissa* (Schedule II) though its subspecies *dapha* which is found in northeastern India, is only legally protected (Table 1).

*Catochrysops strabo, Leptotes plinius*, *Talicada nyseus*, *Tarucus nara*, *Spindasis vulcanus*, & *Zizeeria karsandra* (family Lycaenidae) and *Junonia lemonias* & *J. hiertha* (family Nymphalidae) are the species of butterflies which are placed at the core of the habitat ellipses, indicate that these species choose up to a maximum of six different habitats. Intricate overlapping of the habitats suggests wide range of habitat usage by a species of butterfly.

Flowerbeds alone carry 15% of the total habitat share (Table 2), followed by grasses with 10%, while 2.5% was observed overlapping among various habitats such as hedges, flowerbeds, trees, grasses, and wet soil. *Melanitis leda* (rice crop pest) is the single candidate for the artificial light source, having 2.5% of the independent share, which accidently got noticed during another type of field study at dusk. Overall, the result showed that the generalists can exploit a greater number of habitats compared specialists found only at selected sites. Dwarka has all the nine habitats, and the other five study sites are missing one or more of them (Table 3). Similarly, out of all the nine habitats, bird droppings, trees, grasses, open spaces, damp patches/ wet soil/humus and crops/hedges/bushes were found in all six urban locations. Diversity indices for the habitats are shown in Table 4. The highest values for Simpson diversity index (0.96), Shannon-Wiener index (3.42), and Shannon evenness (0.94) were for the flowerbeds. The artificial light had just one species *Melanitis leda,* hence all diversity indices were 0.

Difference in the butterfly diversity between habitats was tested using ANOVA (SPSS version 23.0) where habitats were treated as independent variables and butterfly frequency as a dependent variable. This test showed that there was a statistically significant difference in butterfly diversity among nine habitats ($F= 8.41$, d.f.= 8, 450, $p= 0.000$). With p value </=0.05, it furthers rejects the null hypothesis of similar diversity of butterflies across all the nine habitats, hereby confirming the alternate hypothesis of considerable variation of butterfly diversity among habitats. Dunnett T3 test showed the pairwise comparisons of the habitats which rejected the null hypothesis (Table 5). Diversity in artificial light was significantly different with the flower beds, grass, hedges, and even with the roadside/ pavements. Similarly, differences in the diversity among bird droppings, grasses, and flowerbeds are significant too. Butterfly diversity in trees was not significantly different from any other habitats (Table 5).

## DISCUSSION

Habitat heterogeneity is an important factor for the survival and reproduction of butterflies (Nielsen et al. 2014; Sing et al. 2016). *Danaus chrysippus*, being a generalist species thrived very well in the disturbed habitats and has shown successful colonization in West Africa (Larsen 2005). Generalist species tend to survive better in an urban ecosystem compared with specialist species (Lizée et al. 2015). The species which can extract multiple habitats are best in sustaining themselves in heterogeneous topography (Dapporto & Dennis 2013; Slancarova et al. 2014). *Melanitis leda*, among the forty listed butterflies, is the only one active during dusk and

**Table 1. List of 40 butterflies with their respective habitats.**

| | Scientific name | Habitats visited | WPA 1972 Schedules | IUCN Status |
|---|---|---|---|---|
| 1 | *Borbo cinnara* (Wallace, 1866) | G | _ | NA |
| 2 | *Hasora chromus*(Cramer, 1780) | G | _ | NA |
| 3 | *Pelopidas mathias* (Fabricius, 1798) | F, H | _ | NA |
| 4 | *Spialia galba* (Fabricius, 1793) | G | _ | NA |
| 5 | *Suastus gremius* Fabricius, 1798 | G | _ | NA |
| 6 | *Catochrysops strabo* Fabricius, 1793 | B, F, G, H, O, W | _ | NA |
| 7 | *Leptotes plinius* (Fabricius, 1793) | B, F, G, H, O, W | _ | NA |
| 8 | *Spindasis vulcanus* (Fabricius, 1775) | B, F, G, H, O, W | _ | NA |
| 9 | *Talicada nyseus* Guerin–Méneville, 1843 | F, G, H, O, R, W | _ | NA |
| 10 | *Tarucus nara* (Kollar, 1848) | F, G, H, O, R, W | _ | NA |
| 11 | *Zizeeria karsandra* (Moore, 1865) | F, G, H, O, R, W | _ | NA |
| 12 | *Acraea terpsicore* (Linnaeus,1758) | F | _ | NA |
| 13 | *Ariadne merione* (Cramer, 1777) | G, H | _ | NA |
| 14 | *Danaus chrysippus* (Linnaeus, 1758) | F, G, H, O, R | _ | LC |
| 15 | *Danaus genutia* (Cramer, 1779) | F, G, H, O, R | _ | NA |
| 16 | *Euploea core* (Cramer, 1780) | F | Schedule IV | LC |
| 17 | *Junonia almana* (Linnaeus, 1758) | F | _ | LC |
| 18 | *Junonia hierta* (Fabricius, 1798) | F, G, H, O, R, W | _ | LC |
| 19 | *Junonia lemonias* (Linnaeus, 1758) | F, G, H, O, R, W | _ | NA |
| 20 | *Junonia orithya* (Linnaeus, 1758) | F, W | _ | NA* |
| 21 | *Hypolimnas misippus* (Linnaeus, 1764) | F | Schedule I | NA |
| 22 | *Melanitis leda* (Linnaeus, 1758) | A, H | _ | NA |
| 23 | *Tirumala limniace* Cramer, 1775 | F, W | _ | NA |
| 24 | *Vanessa cardui* (Linnaeus, 1758) | F | _ | LC |
| 25 | *Graphium doson* Felder & Felder, 1864 | F, W | _ | NA |
| 26 | *Pachliopta aristolochiae* (Fabricius, 1775) | F, W | _ | LC |
| 27 | *Papilio demoleus* Linnaeus1758 | G, H, T, W | _ | NA* |
| 28 | *Papilio polytes* Linnaeus 1758 | F, W | _ | NA |
| 29 | *Belenois aurota* (Fabricius, 1793) | F, W | _ | NA |
| 30 | *Catopsilia pomona* Fabricius, 1775 | F, G, H, T, W | _ | NA |
| 31 | *Catopsilia pyranthe Linnaeus, 1758* | F, G, H, O, R | _ | NA |
| 32 | *Cepora nerissa* (Fabricius, 1775) | F, H, W | Schedule II | NA |
| 33 | *Colotis etrida* (Boisduval, 1836) | F | _ | NA |
| 34 | *Colotis fausta* Olivier, 1801 | H, T | _ | LC |
| 35 | *Eurema hecabe* (Linnaeus, 1758) | F, H, W | _ | NA |
| 36 | *Eurema brigitta* (Cramer, 1780) | F, H, W | _ | LC |
| 37 | *Eurema laeta* Boisduval, 1836 | F, H, W | _ | NA |
| 38 | *Ixias pyrene* Linnaeus, 1764 | F, W | _ | NA |
| 39 | *Ixias marianne* Cramer, 1779 | F, W | _ | NA |
| 40 | *Pieris canidia* (Sparrman, 1768) | G, H | _ | NA |

F—Flowerbeds | G—Grass | H—Hedges/Crops/Bushes | A—Artificial light | W—Wet soil/Damp patches/Humus | T—Tree | O—Open spaces | B—Bird droppings | R—Roads/Pavements/Concrete spaces

Scheduled under Indian Wildlife Protection Act,1972- Schedule I and II: Absolute protection with the highest penalty | Schedule III and IV: Protection with low penalty.

IUCN Red List Status: NA—Not yet been assessed | NA*— Not Applicable | LC—Least Concern

**Table2. Overlapping of habitats and their percentage of share.**

| Butterfly habitats | No. of butterfly species | % Share |
|---|---|---|
| F | 6 | 15.0% |
| G | 4 | 10.0% |
| F∩W | 8 | 20.0% |
| H ∩ A | 1 | 2.5% |
| H ∩ G | 2 | 5.0% |
| H∩T | 1 | 2.5% |
| H∩F | 1 | 2.5% |
| H∩F∩W | 4 | 10.0% |
| H∩T∩G∩W | 1 | 2.5% |
| H∩T∩G∩W∩F | 1 | 2.5% |
| R∩O∩G∩H∩F | 3 | 7.5% |
| B∩H∩O∩G∩W∩F | 3 | 7.5% |
| R∩O∩W∩G∩H∩F | 5 | 12.5% |

F—Flowerbeds | G—Grass | H—Hedges/Crops/Bushes | A—Artificial light | W—Wet soil/Damp patches/Humus | T—Tree | O—Open spaces | B—Bird droppings | R—Roads/Pavements/Concrete spaces | ∩—Intersection/overlapping of two or more habitats.

attracted to artificial light. It is also a rice pest; hence most were found in the rice fields at IARI Pusa during opportunistic search. *Eurema hecabe* is not a very strong flier and prefers open dry areas and thorny vegetation patches. *Belenois aurota* and *Catopsilia pomona* are fond of sun and flowers hence, their habitat ranges from meadows to gardens to damp patches (Kehimkar 2013).

Increasing urbanization brings challenges from environmental impacts. With the outbreak of COVID-19, as the sky and air are getting unadulterated by the automobile pollutants, there are chances for the more specialist species to cope with the changing environment. With further division of COVID-19 hotspot zones into red (areas where large outbreaks and symptoms of corona infection were seen), orange (areas where no new cases were registered in the last 14 days), and green (non-infected areas of the country) the chances of reviving city butterflies increase manifold. Dwarka came under red zone according to the list of Delhi government containment areas, 2020. Hence, further investigation at the various sectors of Dwarka pertaining to different habitats of butterflies could be an interesting comparative study. Dwarka is a sub city which is planned in a way to accommodate surplus population of one million people by building residential societies that constitute 49% of total land use distribution. Hence, because of semi-urban developments, man-made habitats like paved roads or concrete spaces came along with the natural habitats. Similarly, Mayapuri, an industrial and commercial landscape has all the eight habitats except for the flowerbeds which are very prominent in attracting the butterflies for nectaring. Aravalli Biodiversity Park on the other end has been a protected area which minimizes the usage of non-natural manifestations to protect the serenity of the place. It is rich with lush green native vegetation and native nectar rich flowers suitable to act as butterfly attractants. Northern ridge being a city forest also share the similar kind of environment as of Aravalli Biodiversity Park but due to human encroachment and trespassing, flowerbeds were missing. IARI Pusa is an agricultural setup where crops were abundant. Seasonal flower beds of the ongoing crops were regularly seen. Concrete spaces were completely curtailed. Likewise,

**Table 3. Distribution of habitats across urban landscapes of Delhi.**

| Urban Landscapes / Habitats | Dwarka (DW) | IARI Pusa (PU) | Nehru Park (NP) | Mayapuri (MP) | Northern Ridge (NR) | Aravalli Biodiversity Park (ABP) |
|---|---|---|---|---|---|---|
| Tree | √ | √ | √ | √ | √ | √ |
| Flower beds | √ | √ | X | x | X | √ |
| Grass | √ | √ | √ | √ | √ | √ |
| Open Spaces | √ | √ | √ | √ | √ | √ |
| Roads/Pavements/ Concrete spaces | √ | X | √ | √ | X | X |
| Damp patches/ Wet soil/Humus | √ | √ | √ | √ | √ | √ |
| Artificial light | √ | √ | √ | √ | X | X |
| Crops/ Hedges/ Bushes | √ | √ | √ | √ | √ | √ |
| Bird Droppings | √ | √ | √ | √ | √ | √ |
| **Total number of butterflies recorded per site** | **3050** | **1456** | **1298** | **630** | **967** | **4542** |

**Table 4. Various diversity indexes for the habitats.**

| Diversity indices | F | G | H | A* | W | T | O | B | R |
|---|---|---|---|---|---|---|---|---|---|
| Shannon' | **3.42** | 3.3 | 3.23 | **0** | 3.08 | 2.75 | 2.84 | 2.37 | 3.03 |
| Shannon J | **0.94** | 0.92 | 0.93 | **0** | 0.94 | 0.88 | 0.94 | 0.87 | 0.91 |
| Simpson 1-D | **0.96** | 0.95 | 0.95 | **0** | 0.95 | 0.92 | 0.93 | 0.91 | 0.93 |

F—Flowerbeds | G—Grass | H—Hedges/Crops/Bushes | A—Artificial light | W—Wet soil/Damp patches/Humus | T—Tree, O—Open spaces | B—Bird droppings | R—Roads/Pavements/Concrete spaces | A*—Artificial light had only single species reported hence the diversity index is 0.

**Table 5. Pairwise comparison of habitats at alpha =0.05.**

| Habitats | Dunnett T3 value | Significance value |
|---|---|---|
| F and A | 5.227 | p = 0.000 |
| F and O | 3.57 | p = 0.003 |
| F and B | 4.609 | p = 0.000 |
| G and A | 4.661 | p = 0.000 |
| G and O | 3.003 | p = 0.029 |
| G and B | 4.042 | p = 0.000 |
| H and A | 3.74 | p = 0.001 |
| H and B | 3.122 | p = 0.010 |
| A and R | 4.205 | p = 0.000 |
| B and R | 3.586 | p = 0.004 |

F—Flowerbeds | G—Grass | H—Hedges/Crops/Bushes | A—Artificial light | W—Wet soil/Damp patches/Humus | T—Tree | O-Open spaces | B—Bird droppings | R—Roads/Pavements/Concrete spaces | Significant values are marked in red.

Nehru Park is a city park in the heart of Lutyen's Delhi. Though, lush green grass sheets and other eight habitats were suitably present, but flower beds were completely missing from such a park. Park adoption schemes by Delhi Developmental Authority (DDA) in 2019 envisages adoption of certain DDA parks by willing agencies for development and maintenance as per the norms of urban green belt. Municipal Corporation of Delhi (MCD) reports Delhi to have 18,000 parks constituting 20% of green cover that is further planned to increase to 33% in coming years. Hence, preservation of natural landscapes adjoining the city will likely to be crucial for effective urban butterfly conservation (Koh & Sodhi 2004). A well-researched land use planning should be done to ensure sustainability of urban green spaces and the habitats.

## CONCLUSION

During a two-year survey and examination of Lepidoptera from Delhi, it is enigmatic to know about the habitats supporting butterflies in urban ecosystem. This lockdown effect is an opportunity not only for the butterfly experts but also for the amateurs to cultivate a butterfly garden at home. This will not only act as a screen free time (no use of electronic device like laptops, mobile phones or television sets) to the youngsters but also prove to be a quality family time to engage with the nature. Further investigations with respect to ecology of butterflies and urban habitats could enlarge the vision of conservation of butterfly communities and help in implementing stern government policies to regulate irresponsible conducts. Therefore, it is not only the prime responsibility of the civic bodies of the city to increase green cover of Delhi but also the residents to glorify terrace gardening, window nurseries and verandah horticulture, keeping in mind the requirements of nectar plants for adult butterflies as well as the larval host plants for the sustenance of this magnificent lepidopteran group in urban nooks of Delhi.

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**COMMUNICATION**

# A preliminary checklist of moths (Lepidoptera: Heterocera) from Gangajalghati, Bankura, West Bengal, India

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**Abstract:** The present study was conducted at Gangajalghati, a village near the forest of Bankura district from West Bengal that has a tropical wet and dry climate where moth diversity has not been explored before. The village was surveyed between January 2016 and December 2018. The present study has recorded a total of 1,328 individual moths belonging to 13 families, 31 subfamilies, 80 genera, and 90 species. Of which four species viz. *Condylorrhiza diniasalis* (Walker, 1859), *Argyrocosma inductaria* (Guenée, 1858), *Oraesia emarginata* (Fabricius, 1794) and *Eublemma roseonivea* (Walker, 1863) have been reported for the first time from West Bengal, India.

**Keywords:** Conservation, diversity, Erebidae, *Eublemma roseonivea,* microlepidoptera.

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## INTRODUCTION

Moths constitute the vast majority of the insect order Lepidoptera and are present in all the continents except polar regions. This important component of biodiversity serves as nocturnal pollinators, herbivores of crops and wild plants, and food for numerous species of rodents, birds, and bats (Bates et al. 2014). Being dynamic, the biological diversity of a given area changes continually in response to biotic and abiotic fluctuations and other environmental pressures and therefore, close monitoring and recording of its status in time and space are necessary to assess their impacts (Green et al. 2009). Tropical regions of the world exhibit higher levels of endemism and great moth abundance and diversity in comparison to the temperate regions and need more explorations to determine their complete conservation status (New 2004; Green et al. 2009). Detecting, describing, and interpreting the results of an inventory of fauna from a specific region almost always remains a challenging task and the primary data collected in such studies can be used for the analysis by environmental agencies (Silveira et al. 2010). Documentation of species occurrence records in a data-poor but biodiversity-rich region like Bankura is important for determining the species distribution and abundance of the district which contribute significantly to the knowledge base of local biodiversity. Further, small-area inventories of relatively immobile or readily detected organisms from an unexplored region may provide both reliable presence and absence information of a species, but usually with limited spatial or temporal specificity (Jetz et al. 2019).

India harbours nearly 10,000 species of moths which is approximately 10 times higher than the number of butterfly species of the country (Smetacek 2013). The pioneering work on the moth diversity of West Bengal and India dates back nearly 100 years when extensive work was done by Hampson (1892, 1894, 1895, 1896) and Bell & Scott (1937). A total of 42 species of microlepidoptera (moths) from West Bengal was described by Meyrick (1912–1916, 1916–1923, 1923–1930, 1930–1936, 1937) and Sevastopulo (1945, 1956) reported several moth species from Calcutta. Subsequent studies by the Zoological Survey of India and others have enriched and extended the work on the moth fauna of West Bengal (Bhattacharya l997a,b; Ghosh & Chaudhury 1997a,b; Gupta 1997; Mandal & Ghosh 1997; Mandal & Maulik 1997; Sanyal et al. 2012; Biswas et al. 2017a,b). The studies by Bhattacharya (1997a,b) have reported 35 species and subspecies under 21 genera of Zygaenidae and 140 species of Pyralidae from different districts of West Bengal. The work by Ghosh & Chaudhury (1997a) has reported the presence of 52 species in 29 genera of Arctiidae in 14 districts of the state. Further work by Ghosh & Chaudhury (1997b) has described 18 species in five genera of the family Ctenuchidae from 11 districts of West Bengal and four species in a single genus of the family Hypsidae from six districts of the state. A study by Gupta (1997) recorded 20 species of Saturniidae from seven districts of the state. Mandal & Ghosh (1997) reported 47 species of Geometridae belonging to 32 genera from the state of West Bengal. A study by Mandal & Maulik (1997) has described 67 species of Sphingidae, 25 species of Lasiocampidae, 89 species of Lymantriidae, and only one species (*Ratarda marmorata*) of Ratardidae from the state. Arora (2000) studied several pyralid species of economic importance from the state. Several studies over the past decade have made a significant contribution to the moth study of West Bengal (Sanyal et al. 2012; 2017a,b; Shah et al. 2016, 2017, 2018). The work by Sanyal et al. (2012) has reported many moth species from different parts of West Bengal. Further work by Biswas et al. (2017a) has reported 94 species of moths from the Sunderban Biosphere Reserve. Shah et al. (2016) reported the occurrence of 198 species under 142 genera from the Kolkata Metropolitan Region. Further work by Shah et al. (2017) reported the occurrence of 40 species in Neora Valley National Park of West Bengal. Another work has enlisted the presence of 1,058 moth species in West Bengal (Shah et al. 2018). Recently a study by Nayak & Sasmal (2020) has reported 78 species of moths from the Midnapore town in West Bengal. In the present work, a preliminary inventory of the moth fauna of Gangajalghati village of Bankura district was performed and the findings of the study were summarized in an illustrated checklist. The study reports the occurrence of 90 species in 80 genera from the study area.

## MATERIALS AND METHODS

### Study area

Gangajalghati is a village under Bankura Sadar subdivision of Bankura district of West Bengal, India (Figure 1). It is located about 24 km north of Bankura town. The village is located at 23.42°N 87.12°E with very deep sandy loam to sandy clay loam soils (Das & Gupta 2019) and is surrounded by a number of landforms including an adjacent Sal forest, Damodar River (18km) on the north and north-east, Koro hill (122m, 5km) and Sali River (5km) on the south, Sali Reservoir or Gangdua

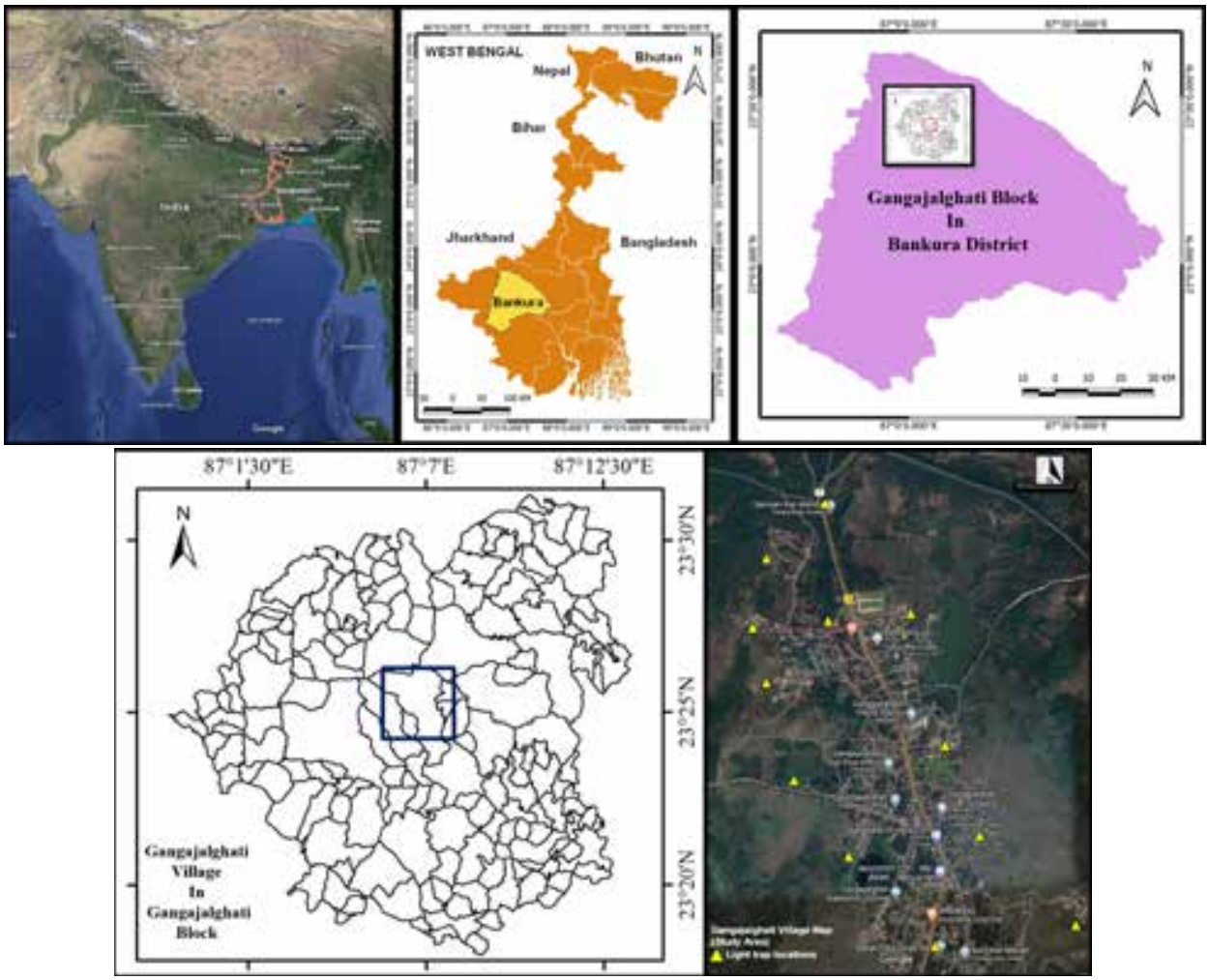


**Figure 1. Geographical location of the study area: Gangajalghati village in Gangajalghati community development block (Map data: India © 2021 Google map, West Bengal from Nayak (2020) with permission from the publisher; Bankura district was generated using QGIS and modified using Gangajalghati Block map; Gangajalghati Block modified after Das (2017); Gangajalghati village map ©2020 Google Earth).**

Dam (4km) on the south-west and Susunia hill (448m, 18km) on the west. Gangajalghati forest, locally also known as the jungle of Hanspahari is a small forest area located to the north of the village and ends near Mejia Thermal Power Station. *Shorea robusta* remains the most dominant species of the forest with other notable species like *Butea monosperma*, *Madhuca indica*, and *Phoenix sylvestris*. Besides forest associated zones, the study area encompasses a large number of ponds. Some other notable plants found in the village area are *Acacia auriculiformis*, *Azadirachta indica*, *Bambusa* spp., *Bombax ceiba*, *Eucalyptus tereticornis*, *Ficus benghalensis*, *Tamarindus indica*, and *Terminalia arjuna*. The common crops grown in the area are beans, Bitter Gourd, Bottle Gourd, Brinjal, Cabbage, Carrot, Cauliflower, Chillies, Cucumber, Potato, Ladies Finger, Maize, Onion, Pumpkin, Radish, Rice, Tomato, Snake Gourd, Squash, and Sugarcane and some of the common fruits are Black Plum, Common Fig, Custard Apple, Date Palm, Doub Palm, Guava, Jack Fruit, Jujube, Mango, and Papaya. The climate shows a hot summer (April–May), monsoon (June–September), and winter (November–February) with an annual rainfall between 1,200 to 1,500 mm. The maximum temperature varies 35–45°C in summer and 12–15°C in the winter season (Das & Gupta 2019). The study was conducted in different land-use types including localities near the forest area, roadside vegetations, vegetations around water bodies, grasslands, bushes of weeds, gardens, and agricultural lands (Image 91).

### Moth surveys and Identification

The sampling of the moth was conducted in 22 localities for three years from 2016 to 2018. Light trapping method was employed for 15 nights during 15 months in 12 different localities (Table 1), and collected the moth data through opportunistic surveys in all 22 localities. Table 2 provides the details of sampling nights in the study area from 2016 to 2018. However, due to frequent elephant attacks in the forest area for the last two decades, recording of moths was not possible in the core area of the forest. The trap (a hanging white cloth sheet) was illuminated from 1900 h to 2200 h and the moth counts were recorded and photographed using a Canon EOS 1200D DSLR Camera with a 55–250mm lens and a Sony DSC-H400 compact camera with 63x optical zoom to support further identification. Diurnal species were recorded and photographed during daylight hours. The survey data were analysed with Microsoft Office Excel, 2010.

Moths were identified based on morphological characters with the help of available literature including Hampson (1892–1896), Bell & Scott (1937), Holloway (1985–2009), Haruta (1992–2000), Robinson et al. (1994), Arora (2000), Schintlmeister & Pinratana (2007), Kononenko & Pinratana (2013), Kirti & Singh (2015, 2016), and Kirti et al. (2019). The classification used in the checklist follows van Nieukerken et al. (2011). Besides the above mentioned literature, a number of web resources including www.jpmoths.org; moths of India (http://www.mothsofindia.org/; Sondhi et al. 2020) were used for the purpose of identification.

**Table 1. Localities with their GPS coordinates with altitudes and habitat type.**

| | Locality or sampling site | GPS coordinate | Altitude in m | Habitat type |
|---|---|---|---|---|
| 1 | Samsan Kali Mandir | 23.433639°N, 87.109743°E | 138 | Sal forest |
| 2 | Forest Colony | 23.431835°N, 87.108471°E | 130 | Sal forest |
| 3 | Hospital Colony | 23.429576°N, 87.107968°E | 125 | Human habitation |
| 4 | Hospital Colony | 23.426922°N, 87.108723°E | 124 | Agriculture land |
| 5 | Gangajalghati Hospital | 23.429183°N, 87.111650°E | 125 | Human habitation |
| 6 | Natun Bandh | 23.430167°N, 87.114418°E | 127 | Agriculture land |
| 7 | Lachmanpur Road | 23.423847°N, 87.109794°E | 119 | Agriculture land |
| 8 | Purano Bandh | 23.421461°N, 87.112079°E | 118 | Agriculture land |
| 9 | Nayak Para Durga Bari | 23.417739°N, 87.115170°E | 120 | Human habitation |
| 10 | Beerkanali | 23.417700°N, 87.117130°E | 118 | Agriculture land |
| 11 | Bara Atchala | 23.421589°N, 87.116336°E | 123 | Human habitation |
| 12 | High School Colony | 23.424238°N, 87.115311°E | 124 | Human habitation |

## RESULTS

The present work has recorded a total of 1,328 individual moths belonging to 13 families, 31 subfamilies, 80 genera, and 90 species across different parts of the study area (Table 3, Images 1–90). Maximum species richness was recorded from the family Erebidae (31 species; 27 genera) followed by Crambidae (27 species; 24 genera), Sphingidae (seven species; seven genera), Geometridae (seven species; six genera), Noctuidae (five species; five genera), Notodontidae (three species; three genera), and others (Figure 2; Table 4). However, Crambidae (41.26%) was the family having highest proportion of moths recorded followed by Erebidae (33.05%), Geometridae (7%), Noctuidae (5.34%), Sphingidae (3.31%), and others. These results of the study were consistent with the previous finding that reported the dominance of these moth families from Jharkhand as well as from Gangetic plains with a tropical wet and dry climate similar to the present study area (Singh et al. 2017). However, Bombycidae, Euteliidae, Lasiocampidae, and Saturnidae were represented by single species in the study area.

Although the surveys were not undertaken uniformly throughout the year, data were recorded on the month-wise occurrence of these species. The results showed that the species richness (data not shown) and relative abundance increased significantly from May to October, peaked in October and decreased rapidly at the end of November with further declines in the early winter session (Figure 4). These results indicate that the highest numbers of moths were recorded during warm nights from June to October and it can be explained by the positive correlation between the activity of ectothermic species and ambient temperature (Jonason et al. 2014). The highest number of species (30) observed on 30 October 2016, which was the night of Kali Puja/Diwali festival. These observations are following previous studies, which showed that the number of moth individuals caught in the light trap are at their highest at periods of no moon or new moon and decrease with the fullness of the moon (Williams 1936; Yela & Holyoak 1997; Butler et al. 1999). The most abundant species were *Cnaphalocrocis medinalis* (Guenée, 1854) followed by *Diaphania indica* (Saunders, 1851), *Asota caricae* (Fabricius, 1775), *Chabula acamasalis* (Walker, 1859),

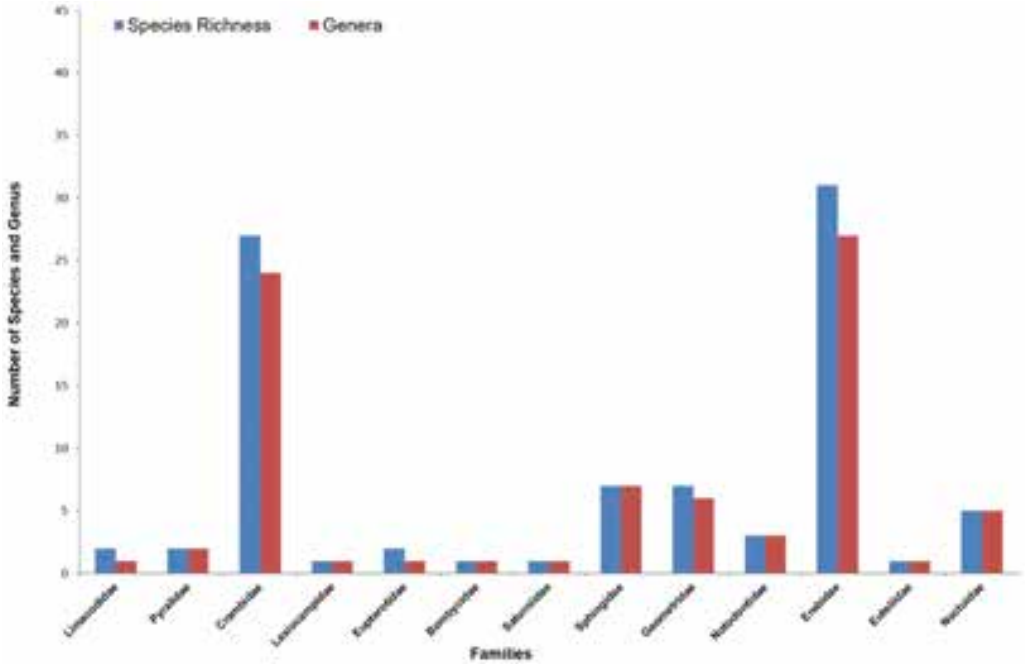


**Figure 2. Family-wise moth species richness and number of genera recorded in different habitats of Gangajalghati village of Bankura.**

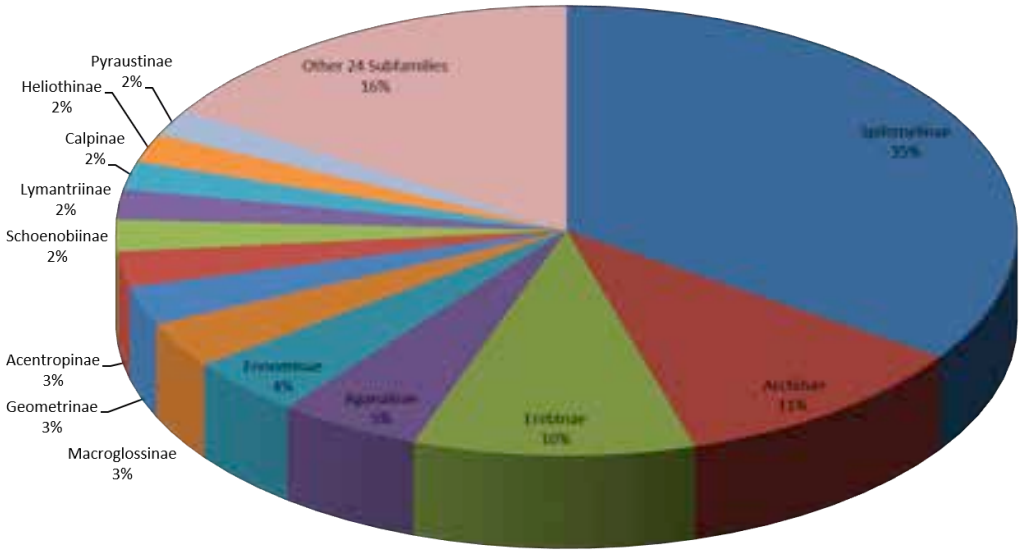


**Figure 3. Sub family-wise distribution of moth population from the study area.**

*Glyphodes bicolour* (Swainson, 1821), and *Pericallia ricini* (Fabricius, 1775). Some of the least abundant species recorded were *Agrius convolvuli* (Linnaeus, 1758), *Erebus hieroglyphica* (Drury, 1773), and *Eupterote undata* (Blanchard, 1844). A total of 18 species were documented exclusively by opportunistic occurrence records and 72 species were documented by both light trapping and opportunistic observations. The data also revealed that only three (Spilomelinae, Arctiinae, and Erebinae) out of 31 subfamilies constituted more than 50% of all moth individuals recorded, that includes a number of economic pest of crops and fruits (Figure 3). Therefore, the results of the study represent a species pool (Sphingidae, Eupterotidae, Saturniidae, Notodontidae) indicative of an assemblage of Sal dominated forest which is currently in a fragmented state and invaded by generalist or pest species group (Crambidae, Arctiinae) associated with highly altered open habitats.

**Table 2. Details of sampling nights and collected individuals.**

| Year and month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2016 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 |
| 2017 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| 2018 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| No. of individuals by light trapping | 0 | 0 | 9 | 18 | 40 | 116 | 68 | 80 | 189 | 268 | 121 | 0 |
| No. of individuals by opportunistic records | 4 | 2 | 0 | 5 | 10 | 23 | 46 | 89 | 79 | 134 | 20 | 7 |
| Total no. of individuals | 4 | 2 | 9 | 23 | 50 | 139 | 114 | 169 | 268 | 402 | 141 | 7 |

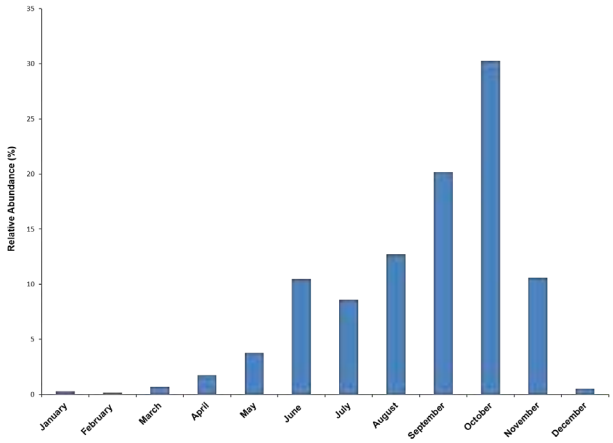


**Figure 4. A species-relative abundance histogram for all 90 species observed in the present study, showing the recorded occurrences by month.**

## DISCUSSION

Prior to this study, only 11 moth species had been reported from the Bankura district; *Acherontia styx* (Westwood, 1847), *Asota caricae* (Fabricius, 1775), *Creatonotos gangis* (Linnaeus, 1763), *Creatonotos transiens* (Walker, 1855), *Diaphania indica* (Saunders, 1851), *Eilema vicara* (Strand, 1922), *Macroglossum gyrans* (Walker, 1856), *Scirpophaga incertulas* (Walker, 1863), *Theretra oldenlandiae* (Fabricius, 1775), *Theretra silhetensis* (Walker, 1856), and *Trabala vishnou* (Lefèbvre, 1827) (Bhattacharya 1997b; Ghosh & Chaudhury 1997a,b; Mandal & Maulik 1997). The present study reports a total of 82 species from Bankura district in West Bengal that has not been reported earlier. However, the most important finding from the study was the documentation of four species, viz., *Condylorrhiza diniasalis* (Walker, 1859), *Argyrocosma inductaria* (Guenée, 1858), *Oraesia emarginata* (Fabricius, 1794) and *Eublemma roseonivea* (Walker, 1863) (Image 63), a very rare member of the family Erebidae for the first time from West Bengal. The species was spotted on 29 October 2016 at around 07:57h. It was attracted to a Tungsten halogen lamp mounted near a pond on the eve of Diwali/Kali Puja festival. Later the species was recorded three more times in different places of Gangajalghati village but no documentation was made on those occasions. The species was previously reported from China, Borneo, Indonesia, Malaya, Philippines, and Thailand (Ades & Kendrick 2004; Kononenko & Pinratana 2013). In India, the species has been recorded from Karimganj (Assam) (Sondhi et al. 2020). Therefore, the study reports the westernmost distributional record of the species in India.

Several species including *Acherontia styx* (Westwood, 1847), *Agrius convolvuli* (Linnaeus, 1758); *Achaea janata* (Linnaeus, 1758), *Creatonotos gangis* (Linnaeus, 1763), *Spodoptera litura* (Fabricius, 1775), *Helicoverpa armigera* (Hübner, 1809), and *Maruca vitrata* (Fabricius, 1787) were found to be an economic pest of common crops and fruits of the area. The highest abundance of the Crambidae family in the study is represented by the subfamily Spilomelinae (31%) that constitutes the most species-rich subfamily of Crambidae. Their abundance can be explained by the occurrence of diverse habitats rich in grasses and several crop plants preferred by the members of Crambidae.

## CONCLUSION

The present work has been carried out to elucidate a preliminary checklist of moth fauna from Gangajalghati village of Bankura which has not been explored previously. Erebidae remains the most species rich and Crambidae, the most abundant family from the village. Although preliminary, the present study will provide valuable baseline data for moth diversity of the area that has not been reported. There is an urgent need to assess the degree of deterioration of habitats for moth fauna

**Table 3. Preliminary checklist of moth fauna recorded during the study.**

| | Family | Subfamily | Species | Author, Year | Month of observation |
|---|---|---|---|---|---|
| 1 | Limacodidae | Limacodinae | *Parasa lepida* | Cramer, 1799 | Aug, Sep |
| 2 | Limacodidae | Limacodinae | *Parasa bicolor* | Walker, 1855 | Jun |
| 3 | Pyralidae | Pyralinae | *Hypsopygia mauritialis* | Boisduval, 1833 | Aug |
| 4 | Pyralidae | Pyralinae | *Tamraca torridalis* | Lederer, 1863 | Sep |
| 5 | Crambidae | Acentropinae | *Parapoynx fluctuosalis* | Zeller, 1852 | Apr, Oct, Nov |
| 6 | Crambidae | Acentropinae | *Parapoynx stagnalis* | Zeller, 1852 | Oct, Nov |
| 7 | Crambidae | Pyraustinae | *Orphanostigma abruptalis* | Walker, 1859 | Jul, Aug |
| 8 | Crambidae | Pyraustinae | *Tatobotys biannulalis* | Walker, 1866 | Aug, Sep, Oct |
| 9 | Crambidae | Schoenobiinae | *Scirpophaga incertulus* | Walker,1863 | Jan, Apr, Sep,Oct, Nov |
| 10 | Crambidae | Spilomelinae | *Aethaloessa calidalis* | Guenée, 1854 | Jul, Aug |
| 11 | Crambidae | Spilomelinae | *Agrioglypta itysalis* | Walker,1859 | Jul, Aug, Sep |
| 12 | Crambidae | Spilomelinae | *Condylorrhiza diniasalis* | Walker, 1859 | Oct, Nov |
| 13 | Crambidae | Spilomelinae | *Chabula acamasalis* | Walker, 1859 | Sep, Oct |
| 14 | Crambidae | Spilomelinae | *Cirrhochrista brizoalis* | Walker, 1859 | Oct |
| 15 | Crambidae | Spilomelinae | *Cnaphalocrocis medinalis* | Guenée, 1854 | Sep, Oct, Nov |
| 16 | Crambidae | Spilomelinae | *Conogethes punctiferalis* | Guenée, 1854 | Sep |
| 17 | Crambidae | Spilomelinae | *Diaphania indica* | Saunders,1851 | Jul, Sep, Oct, Nov |
| 18 | Crambidae | Spilomelinae | *Botyodes flavibasalis* | Moore, 1867 | Oct |
| 19 | Crambidae | Spilomelinae | *Eurrhyparodes tricoloralis* | Zeller, 1852 | Oct |
| 20 | Crambidae | Spilomelinae | *Glyphodes bicolor* | Swainson, 1821 | Jun, Jul, Aug, Sep, Oct |
| 21 | Crambidae | Spilomelinae | *Glyphodes caesalis* | Walker, 1859 | Sep, Oct |
| 22 | Crambidae | Spilomelinae | *Glyphodes onychinalis* | Guenée, 1854 | Sep, Oct |
| 23 | Crambidae | Spilomelinae | *Haritalodes derogata* | Fabricius, 1775 | Jul, Aug |
| 24 | Crambidae | Spilomelinae | *Hymenia perspectalis* | Hübner, 1796 | Oct |
| 25 | Crambidae | Spilomelinae | *Maruca vitrata* | Fabricius, 1787 | Sep, Oct |
| 26 | Crambidae | Spilomelinae | *Metoeca foedalis* | Guenée, 1854 | Oct, Nov |
| 27 | Crambidae | Spilomelinae | *Parotis* cf. *marginata* | Hampson, 1893 | Aug, Sep |
| 28 | Crambidae | Spilomelinae | *Pycnarmon cribrata* | Fabricius, 1794 | Oct |
| 29 | Crambidae | Spilomelinae | *Sameodes cancellalis* | Zeller, 1852 | May, Jun |
| 30 | Crambidae | Spilomelinae | *Spoladea recurvalis* | Fabricius, 1775 | Oct |
| 31 | Crambidae | Spilomelinae | *Syllepte straminalis* | Guenée, 1854 | Jun |
| 32 | Lasiocampidae | Lasiocampinae | *Trabala vishnou* | Lefèbvre, 1827 | Aug |
| 33 | Eupterotidae | Eupteroptinae | *Eupterote bifasciata* | Kishida, 1994 | Sep, Oct, Nov |
| 34 | Eupterotidae | Eupteroptinae | Eupterote undata | Blanchard, 1844 | May, Jun |
| 35 | Bombycidae | Bombycinae | *Trilocha varians* | Walker, 1855 | Oct, Dec |
| 36 | Saturniidae | Saturniinae | *Actias selene* | Hübner, 1806 | Oct |
| 37 | Sphingidae | Macroglossinae | *Daphnis nerii* | Linnaeus, 1758 | May |
| 38 | Sphingidae | Macroglossinae | *Hippotion rosetta* | Swinhoe, 1892 | Aug, Sep |
| 39 | Sphingidae | Macroglossinae | *Nephele hespera* | Fabricius, 1775 | May |
| 40 | Sphingidae | Macroglossinae | *Pergesa acteus* | Cramer, 1779 | Jul, Aug, Sep |
| 41 | Sphingidae | Macroglossinae | *Theretra silhetensis* | Walker, 1856 | Sep |
| 42 | Sphingidae | Sphinginae | *Acherontia styx* | Westwood, 1847 | May, Jun |
| 43 | Sphingidae | Sphinginae | *Agrius convolvuli* | Linnaeus, 1758 | Dec |
| 44 | Geometridae | Ennominae | *Hyperythra lutea* | Stoll, 1781 | Sep, Oct |
| 45 | Geometridae | Ennominae | *Hypomecis cineracea* | Moore, 1888 | Jun |

| | Family | Subfamily | Species | Author, Year | Month of observation |
|---|---|---|---|---|---|
| 46 | Geometridae | Ennominae | *Hypomecis transcissa* | Walker, 1860 | Sep, Oct |
| 47 | Geometridae | Ennominae | *Petelia medardaria* | Herrich-Schäffer, 1856 | Jul |
| 48 | Geometridae | Geometrinae | *Agathia laetata* | Fabricius, 1794 | Sep, Oct, Nov |
| 49 | Geometridae | Geometrinae | *Argyrocosma inductaria* | Guenée, 1858 | Aug |
| 50 | Geometridae | Sterrhinae | *Scopula emissaria* | Walker, 1861 | Jan, Apr, Oct |
| 51 | Notodontidae | Biretinae | *Saliocleta longipennis* | Moore, 1881 | Sep |
| 52 | Notodontidae | Phalerinae | *Antheua servula* | Drury ,1773 | Nov |
| 53 | Notodontidae | Phalerinae | *Phalera raya* | Moore, 1849 | Apr |
| 54 | Erebidae | Aganainae | *Asota caricae* | Fabricius, 1775 | Jul, Sep, Oct, Nov |
| 55 | Erebidae | Aganainae | *Asota ficus* | Fabricius, 1775 | Jul, Aug, Sep |
| 56 | Erebidae | Arctiinae | *Amata passalis* | Fabricius, 1781 | Jan, Oct |
| 57 | Erebidae | Arctiinae | *Brunia antica* | Walker, 1854 | Oct, Nov |
| 58 | Erebidae | Arctiinae | *Creatonotos gangis* | Linnaeus, 1763 | Jun, Jul |
| 59 | Erebidae | Arctiinae | *Creatonotos transiens* | Walker, 1855 | Jul, Aug |
| 60 | Erebidae | Arctiinae | *Eressa confinis* | Walker, 1854 | Jun |
| 61 | Erebidae | Arctiinae | *Pericallia ricini* | Fabricius, 1775 | May, Jun, Jul, Sep |
| 62 | Erebidae | Arctiinae | *Syntomoides imaon* | Cramer, 1780 | Jan, Oct, Nov |
| 63 | Erebidae | Boletobiinae | *Eublemma roseonivea* | Walker, 1863 | Oct, Nov |
| 64 | Erebidae | Calpinae | *Eudocima materna* | Linnaeus, 1767 | Jun, Jul, Sep |
| 65 | Erebidae | Calpinae | *Oraesia emarginata* | Fabricius, 1794 | Aug, Sep |
| 66 | Erebidae | Erebinae | *Achaea janata* | Linnaeus, 1758 | Aug, Sep |
| 67 | Erebidae | Erebinae | *Chalciope mygdon* | Cramer, 1777 | Nov |
| 68 | Erebidae | Erebinae | *Ercheia cyllaria* | Cramer, 1779 | Oct, Nov |
| 69 | Erebidae | Erebinae | *Erebus ephesperis* | Hübner, 1827 | Oct, Nov |
| 70 | Erebidae | Erebinae | *Erebus hieroglyphica* | Drury, 1773 | Aug, Sep |
| 71 | Erebidae | Erebinae | *Fodina pallula* | Guenée, 1852 | Aug, Sep |
| 72 | Erebidae | Erebinae | *Grammodes geometrica* | Fabricius, 1775 | Oct, Nov |
| 73 | Erebidae | Erebinae | *Scardamia* cf. *metallaria* | Guenée, 1858 | Oct, Nov |
| 74 | Erebidae | Erebinae | *Mocis frugalis* | Fabricius, 1775 | Oct, Nov |
| 75 | Erebidae | Erebinae | *Pericyma cruegeri* | Butler, 1886 | Aug, Sep |
| 76 | Erebidae | Erebinae | *Pericyma umbrina* | Guenée, 1852 | Apr |
| 77 | Erebidae | Erebinae | *Polydesma boarmoides* | Guenée, 1852 | Jun, Jul |
| 78 | Erebidae | Erebinae | *Sphingomorpha chlorea* | Cramer, 1777 | Oct |
| 79 | Erebidae | Erebinae | *Spirama retorta* | Clerck, 1764 | Apr, Jun, Nov |
| 80 | Erebidae | Erebinae | *Thyas coronata* | Fabricius, 1775 | Aug, Sep |
| 81 | Erebidae | Lymantriinae | *Arctornis cygna* | Moore, 1879 | Jul, Sep |
| 82 | Erebidae | Lymantriinae | *Lymantria marginata* | Walker, 1855 | Feb, Mar |
| 83 | Erebidae | Pangraptinae | *Egnasia ephyrodalis* | Walker, 1858 | Aug |
| 84 | Erebidae | Scoliopteryginae | *Anomis fulvida* | Guenée, 1852 | Oct, Nov |
| 85 | Euteliidae | Euteliinae | *Paectes subapicalis* | Walker, 1858 | Jun |
| 86 | Noctuidae | Bagisarinae | *Xanthodes intersepta* | Guenée, 1852 | Sep |
| 87 | Noctuidae | Condicinae | *Condica illecta* | Walker, 1865 | Jul, Aug |
| 88 | Noctuidae | Eustrotiinae | *Maliattha signifera* | Walker, 1858 | Oct |
| 89 | Noctuidae | Heliothinae | *Helicoverpa armigera* | Hübner, 1808 | May, Jun |
| 90 | Noctuidae | Noctuinae | *Spodoptera litura* | Fabricius, 1775 | Sep, Oct |

in the district and to raise positive public awareness for Lepidoptera conservation for future monitoring of their status. Further investigation is therefore warranted to make a detailed checklist for the better understanding of diversity of moth populations of the Gangajalghati block and Bankura district.

**Table 4. Family-wise number of species recorded during the survey.**

| | Family | Number of species recorded |
|---|---|---|
| 1 | Limacodidae | 2 |
| 2 | Pyralidae | 2 |
| 3 | Crambidae | 27 |
| 4 | Lasiocampidae | 1 |
| 5 | Eupterotidae | 2 |
| 6 | Bombycidae | 1 |
| 7 | Saturniidae | 1 |
| 8 | Sphingidae | 7 |
| 9 | Geometridae | 7 |
| 10 | Notodontidae | 3 |
| 11 | Erebidae | 31 |
| 12 | Euteliidae | 1 |
| 13 | Noctuidae | 5 |
| | **Total** | **90** |

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Images 1–24: 1—*Parasa lepida* | 2—*Parasa bicolor* | 3—*Hypsopygia mauritialis* | 4—*Tamraca torridalis* | 5—*Parapoynx fluctuosalis* | 6—*Parapoynx stagnalis* | 7—*Orphanostigma abruptalis* | 8—*Tatobotys biannulalis* | 9—*Scirpophaga* sp. | 10—*Aethaloessa calidalis* | 11—*Agrioglypta itysalis* | 12—*Condylorrhiza diniasalis* | 13—*Chabula acamasalis* | 14—*Cirrhochrista brizoalis* | 15—*Cnaphalocrocis medinalis* | 16—*Conogethes punctiferalis* | 17—*Diaphania indica* | 18—*Botyodes flavibasalis* | 19—*Eurrhyparodes tricoloralis* | 20—*Glyphodes bicolor* | 21—*Glyphodes caesalis* | 22—*Glyphodes onychinalis* | 23—*Haritalodes derogata* | 24—*Hymenia perspectalis*. © Ananya Nayak.


Images 25–48: 25—*Maruca vitrata* | 26—*Metoeca foedalis* | 27—*Parotis* cf. *marginata* | 28—*Pycnarmon cribrate* | 29—*Sameodes cancellalis* | 30—*Spoladea recurvalis* | 31—*Syllepte straminalis* | 32—*Trabala vishnou* | 33—*Eupterote bifasciata* | 34—*Eupterote undata* | 35—*Trilocha varians* | 36—*Actias selene* | 37—*Daphnis nerii* | 38—*Hippotion rosetta* | 39—*Nephele hespera* | 40—*Pergesa acteus* | 41—*Theretra silhetensis* | 42—*Acherontia styx* | 43—*Agrius convolvuli* | 44—*Hyperythra lutea* | 45—*Hypomecis cineracea* | 46—*Hypomecis transcissa* | 47—*Petelia medardaria* | 48—*Agathia laetata.* © Ananya Nayak.


Images 49–72: 49—*Argyrocosma inductaria* | 50—*Scopula emissaria* | 51—*Saliocleta longipennis* | 52—*Antheua servula* | 53—*Phalera* sp. | 54—*Asota caricae* | 55—*Asota ficus* | 56—*Amata passalis* | 57—*Brunia antica* | 58—*Creatonotos gangis* | 59—*Creatonotos transiens* | 60—*Eressa confinis* | 61—*Pericallia ricini* | 62—*Syntomoides imaon* | 63—*Eublemma roseonivea* | 64—*Eudocima materna* | 65—*Oraesia emarginata* | 66—*Achaea janata* | 67—*Chalciope mygdon* | 68—*Ercheia cyllaria* | 69—*Erebus ephesperis* | 70—*Erebus hieroglyphica* | 71—*Fodina pallula* | 72—*Grammodes geometrica*. © Ananya Nayak.

Images 73–90: 73—*Scardamia* cf. *metallaria* | 74—*Mocis frugalis* | 75—*Pericyma cruegeri* | 76—*Pericyma umbrina* | 77—*Polydesma boarmoides* | 78—*Sphingomorpha chlorea* | 79—*Spirama* sp. | 80—*Thyas coronata* | 81—*Arctornis cygna* | 82—*Lymantria marginata* | 83—*Egnasia ephyrodalis* | 84—*Anomis fulvida* | 85—*Paectes subapicalis* | 86—*Xanthodes intersepta* | 87—*Condica illecta* | 88—*Maliattha signifera* | 89—*Helicoverpa armigera* | 90—*Spodoptera litura*. © Ananya Nayak.

Image 91. The study area (a–d) and its surroundings (e–f): a—National Highway 14 passing through Gangajalghati Forest | b—Forest dominated area of the study site | c & d—Study sites located about two kilometers away from the forest area | e—Koro hill (122 m) located about five km away from the village | f—Sali Reservoir or Gangdua Dam and Susunia hill (448 m) located about four and 18 km away from the village, respectively. © Ananya Nayak.

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# First report of three species of the genus *Diaphanosoma* (Crustacea: Cladocera: Sididae) from Jammu waters (J&K), India

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**Abstract**: Cladocera, commonly known as 'water flea' due to the jerky movements produced by their second antennae, form an important food component for planktivorous fishes and other aquatic invertebrates. The present investigation comprising a collection of zooplankton samples from a shallow pond located in the Bishnah tehsil of Jammu district has revealed the presence of 13 Cladocera species belonging to the families Daphniidae, Chydoridae, Moinidae, Sididae, and Macrothricidae. Three species of the family Sididae belonging to the genus *Diaphanosoma*, namely, *senegal, sarsi* and *excisum* are new species records to the cladoceran fauna of Jammu & Kashmir. Presently, a detailed morphological analysis has been made on all the three *Diaphanosoma* species. They have shown major differences in their body size with *D. senegal* being larger than *D. sarsi* and *D. excisum*. All three species have well observable variability with reference to their head size, eye size, shell duplicature, shape of posterior valve margin, and the number of denticles so present on posterior valve margin. All the three species have also shown coexistence with each other, but *D. senegal* was dominant in terms of population density.

**Keywords:** *Diaphanosoma excisum, D. sarsi, D. senegal,* invertebrates, Jammu & Kashmir, morphology, variability.

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**Competing interests:** The authors declare no competing interests.

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**Author contributions:** NS—carried out the fieldwork, sampling, species identification, data collection, analysis & interpretation and manuscript writing. SK—supervision and guidance in sample collection, careful examination and confirmation of identified species, thorough checking, input of intellectual content and final approval to the manuscript.

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## INTRODUCTION

Zooplankton being an important component of aquatic biota, play an essential role in influencing all the functional aspects of an aquatic ecosystem like food web, food chain by occupying the position at primary consumer level and acting as the trophic link between bottom-up factors (primary producers) and top down regulators (higher trophic levels) (Murugan et al. 1998). They are of considerable value as bioindicators and aid in determining the trophic status of a water body. The freshwater zooplankton fauna is grouped into five major types: Rotifera, Cladocera, Copepoda, Ostracoda and Protozoa. Among these, Cladocera commonly known as water fleas due to the jerky movements produced by their swimming antennae are important contributors to diversity (Bronmark & Hansson 1998; Pandit et al. 2016). They graze on detritus, bacteria and algae that shows their significance in nutrient recycling; and serve as food for both juvenile and adult planktivorous fishes (Pennak 1978) thus have potential economic importance as fish food organisms in aquaculture.

The Indian subcontinent has been blessed with different lentic and lotic water systems inhabited by Cladocera. The taxonomic studies on Cladocera were initiated by Baird (1860) and about 137 valid species have been reported till now. Region of Jammu & Kashmir also encompasses lentic and lotic water bodies which are abode to a wide variety of zooplankton species, including diverse Cladocera. Presently studied lentic water body of Jammu showed the presence of various zooplankton comprising 13 Cladocera species belonging to the families Daphniidae, Chydoridae, Moinidae, Sididae, and Macrothricidae, particularly including three different *Diaphanosoma* (Fischer, 1850) species of the family Sididae of order Ctenopoda. *Diaphanosoma* is the largest genus of ctenopods in group Cladocera and many of the species of this genus are known to be distributed in the tropics and subtropics (Korovchinsky 1986; Han et al. 2011). The species of this genus can be divided into two groups based on their body size, head size, size of swimming antennae and width of ventral shell margin (Korovchinsky 1986).

Kashmir valley experiences a temperate-cum-Mediterranean climate (Yousuf & Qadri 1981; Pandit et al. 2016) while Jammu lies in the subtropical type of climatic zone. *Diaphanosoma brachyurum* is a temperate and northern species (Fernando & Kanduru 1984; Sharma & Michael 1987; Han et al. 2011) and its occurrence has been reported from many water bodies of Kashmir (Yousuf & Qadri 1981; Pandit et al. 2016; Naik et al. 2017). Ironically, an earlier report of *Diaphanosoma brachyurum* has also been done from Jammu waters, therefore, raising a query regarding its distribution and identification. Presently, *Diaphanosoma brachyurum* has not been recorded and other three species viz. *Diaphanosoma senegal, Diaphanosoma excisum* and *Diaphanosoma sarsi* have been observed in the study pond.

Investigations on Cladocera diversity from various regions of Jammu division have been contributed by Gupta (2002), Sharma et al. (2005), Sharma & Chandrakiran (2011) and Sharma & Kotwal (2011), but the presently selected region remained totally unexplored due to which knowledge regarding this important fauna of Jammu is insufficient. Thus, this work was aimed to study the Cladocera diversity of a previously unexplored water body. In this paper, Cladocera fauna of the studied water body has been enlisted while special attention has been given to the three species belonging to the Sididae family which is taxonomically discussed in detail. Therefore, the present work updates the Cladocera record of J&K with the addition of three species new to the union territory and it deals with taxonomic identification, detailed and illustrated description, distribution and morphological comparison among three *Diaphanosoma* species recorded for the first time in Jammu & Kashmir.

## MATERIAL AND METHODS

**Study area**: The present study area involves a subtropical pond located at 32.62˚N latitude and 74.87˚E longitude in tehsil Bishnah of Jammu district, J&K, India. It is a shallow pond surrounded by human habitation and agricultural fields. It is covered by vegetation all over its muddy embankment (Figure 1).

**Methodology**: Sampling was done for a period of one year from February 2019 to January 2020. Plankton samples were collected by filtering about 50 litres of water sample from the littoral zone through a plankton net made of bolting silk (no. 25). The filtrate was preserved by adding 4% formalin. The preserved specimens were stained with Rose Bengal stain and examined under an Olympus compound light microscope at 100x magnification. Minute structures were observed at 400x magnification. Measurements were taken with the help of an ocular micrometer and drawings were made with the help of camera lucida and Rotring Germany 1928 pens.

Quantitative estimation of zooplankton: For


Figure 1. Map showing the satellite view of the study station.

Table 1. List of Cladocera species reported from the study station.

| Family | Cladocera species |
|---|---|
| Chydoridae | 1. *Flavalona costata* (Sars, 1862) |
| | 2. *Biapertura karua* (King, 1853) |
| | 3.*Chydorus sphaericus* (Müller,1776) |
| | 4.*Dunhevedia* sp. |
| | 5. *Leydigia* sp. |
| Daphniidae | 6. *Ceriodaphnia cornuta* (Sars, 1885) |
| | 7. *Ceriodaphnia reticulata* (Jurine, 1820) |
| | 8. *Simocephalus* sp. |
| Macrothricidae | 9. *Macrothrix rosea* (Jurine, 1820) |
| Moinidae | 10. *Moina brachiata* (Jurine, 1820) |
| Sididae | 11. *Diaphanosoma excisum** |
| | 12. *Diaphanosoma sarsi** |
| | 13. *Diaphanosoma senegal** |

*:- First record in Jammu & Kashmir

quantitative analysis, the drop count method was used and zooplankton number was calculated using formula (Adoni 1985):

Organism/litre = A*1/L*n/V

Where, A= No. of organisms in one drop

L= Vol. of original sample (l)

n= Total vol. of concentrated sample (ml)

V= Vol. of one drop (0.05ml)

The identification of Cladocera species was done by following Michael & Sharma (1988), Battish (1992), Edmondson (1992) and Korovchinsky (1992, 1993, 2004).

## RESULTS

In the present investigation, 13 Cladocera species have been observed and morphologically identified. The recorded species belong to five families, viz., Daphniidae, Chydoridae, Moinidae, Sididae, and Macrothricidae. Among them, Daphniidae is represented by three species, Chydoridae by five species, Moinidae and Macrothricidae by a single species each, and Sididae by three species (Table 1). The species of family Sididae have been primarily focused and studied in detail.

### Description of three *Diaphanosoma* species:

### 1. *Diaphanosoma senegal* Gauthier, 1951

It was first recorded and described by Gauthier (1951) from Senegal (western Africa). In India, this species was reported for the first time by Brehm (1952) as a new species which he named *D. hydrocephalus* but later changed it to *D. senegal*. Venkataraman & Krishnaswamy (1984) changed its name to *D. senegalensis,* but Korovchinsky (1992, 2004) found this name inappropriate with respect to International Rules of Zoological Nomenclature, so considered *D. senegalensis* as a junior synonym of *D. senegal.*

**Female** (Image 1A, Figure 2A): Size 0.6–0.7 mm. Sixteen female specimens were studied for the morphological characters.

Head large with well developed, protruding dorsal part; slanting anteriorly. Eye large, situated close to the ventral margin of head (Image 1B). A small depression exists between the head and trunk. Antennules short and thick, with a thick sensory seta bearing thin setules distally. Antennules are usually concealed under the swimming antennae.

Swimming antennae (Figure 2B) are long and robust, their ends do not reach up to posterior valve margin. The antennal basipodite is powerful and larger than its two branches. Upper branch or exopodite is longer and 2-segmented, lower branch is short and 3-segmented (endopodite).

Both the branches bear setulated setae on their segments except the small proximal segment of lower 3-segmented branch. Antennal setae have the formula 4-8/0-1-4. A thin spine is present on the distal end of proximal segment of exopodite while stout spines are present on the distal ends of second exopodite segment and outer two endopodite segments of antenna.

The dorsal margin of body is arched due to the hump present over the trunk. The valves are elongated and somewhat rectangular in shape (Image 1A). The posterior valve margins are evenly straight with a row of

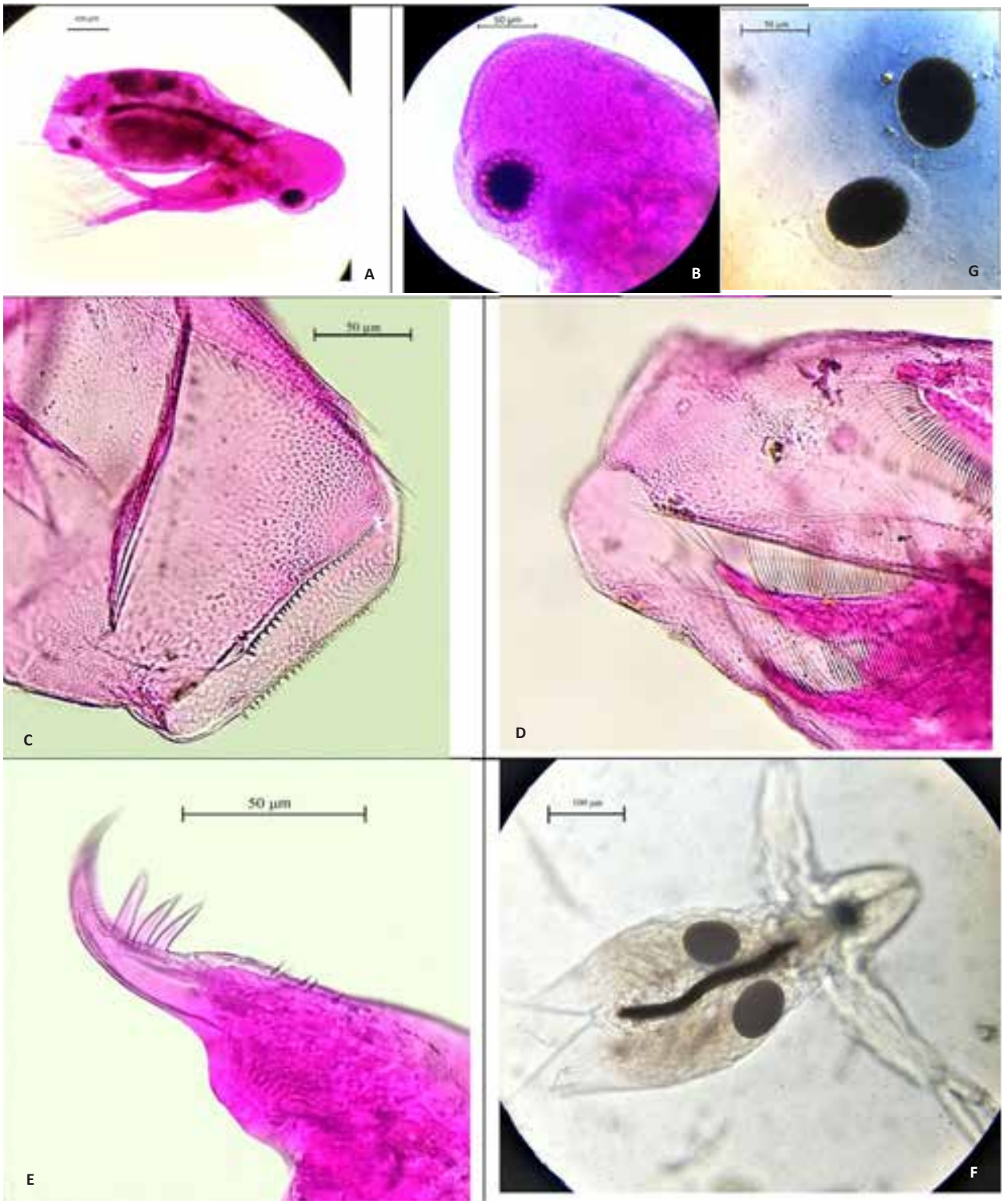


**Image 1. (A–G). *Diaphanosoma senegal* Gauthier, 1951: A—Parthenogenetic female, lateral view | B—Head, lateral view (400x) | C—Posterior valve margins | D—Ventral valve inflexion | E—Postabdomen showing anal spines and setules on claw margin (400x) | F—Female carrying resting eggs, dorsal view | G—Resting eggs, lateral view.**

27–55 (presently 25–35) denticles, dorsal or uppermost denticles larger and widely spaced than the lower ones (Image 1C, Figure 2C). The number of spines on both valves may vary in same individual. The ventral margin of valves has a wide inflexion narrowing distally and its edge bordered with many identical feathered setae

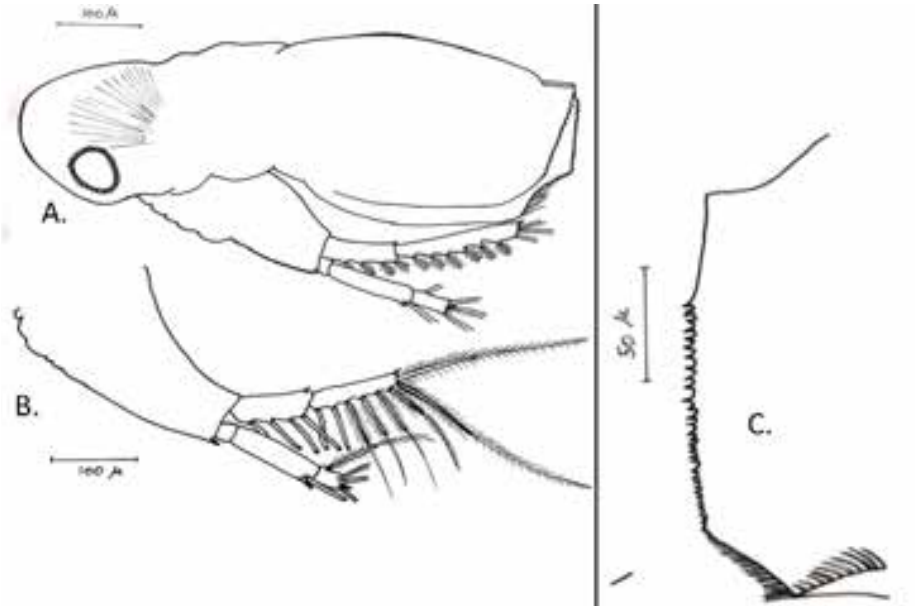


**Figure 2 (A–C). *Diaphanosoma senegal* Gauthier, 1951 (female): A—Adult female, lateral view | B—Second antenna of female | C—Posterior valve margin showing denticles and emargination.**

(Image 1D). The postero-ventral valve margins have deep emargination armed with about 10 short and thin feathered setae. Two small spines are present at the inner side of junction between posterior valve margins.

Postabdomen is small with sharp terminal claw bearing three robust basal spines. Setules are present at the concave margin of claw. About 6–7 anal denticles surrounded by many thin setules are present on the lateral sides of postabdomen (Image 1E, Figure 6A). These are usually present as doublets except one or two singlet also. Two long setae nanatoriae are present on the postabdomen.

**Male** (Image 2A): Size 0.40–0.45 mm. Seven male specimens were studied. Males are smaller in size than the adult females. They are easily distinguished from the females by the presence of very long antennules (about half of the body length) bearing thin setules on their surface being more numerous at the distal end (Image 2B, Figure 3B).

A very sharp, thick and large thorn is present at the outer distal end of antennal basipodite (Image 2C, Figure 3A). Two long, tubular copulatory appendages can be seen arising from near the postabdomen (Image 2D, 2E). These are broad proximally but get narrower at the distal end. The inner cavity of these appendages is clearly visible from outside (Figure 3C). Their posterior valve margins are seen armed with about 22–25 denticles (Figure 3D).

**2. *Diaphanosoma excisum* Sars, 1885**

Female (Image 3A): Size 0.45 – 0.51mm. Twelve female specimens were studied. Head is large, rectangular-shaped with well-developed dorsal part. Eye is relatively large and is situated antero-ventrally (Image 3B). Antennules short, but swimming antennae large and massive, not reaching at the posterior valve margins. A small spine is present at the distal end of basipodite. Short denticles are present at both the antennal branches.

Valves generally oblong but rather high in some of the individuals (Figure 4A). Posterior valve margins are rounded in outline, armed at the ventral corner with 4–18 (Korovchinsky 1992) large sharply pointed and backwardly directed denticles. Present specimens were bearing 8–14 such denticles (Image 3C).

The upper denticles are smaller in size than the lower ones. Number of denticles on both the valves of same individuals may vary. For instance, in one of the observed specimens, number of denticles were 11 on one valve while 14 on the other (Figure 4B).

The ventral valve margin is folded into a free flap that joins the valve at a right angle without any depression. It bears about 8–14 thin feathered setae (Image 3D).

The postabdomen is small with claw bearing three thin basal spines proximally decreasing in size (Image 3E, Figure 6B). Thin setules are present on the lateral sides of postabdomen (Image 3F).

**3. *Diaphanosoma sarsi* Richard, 1894**

Female (Image 4A, figure 5A): Size 0.37–0.42 mm. Nine female specimens were studied for their morphological characters. Head small, roundish-

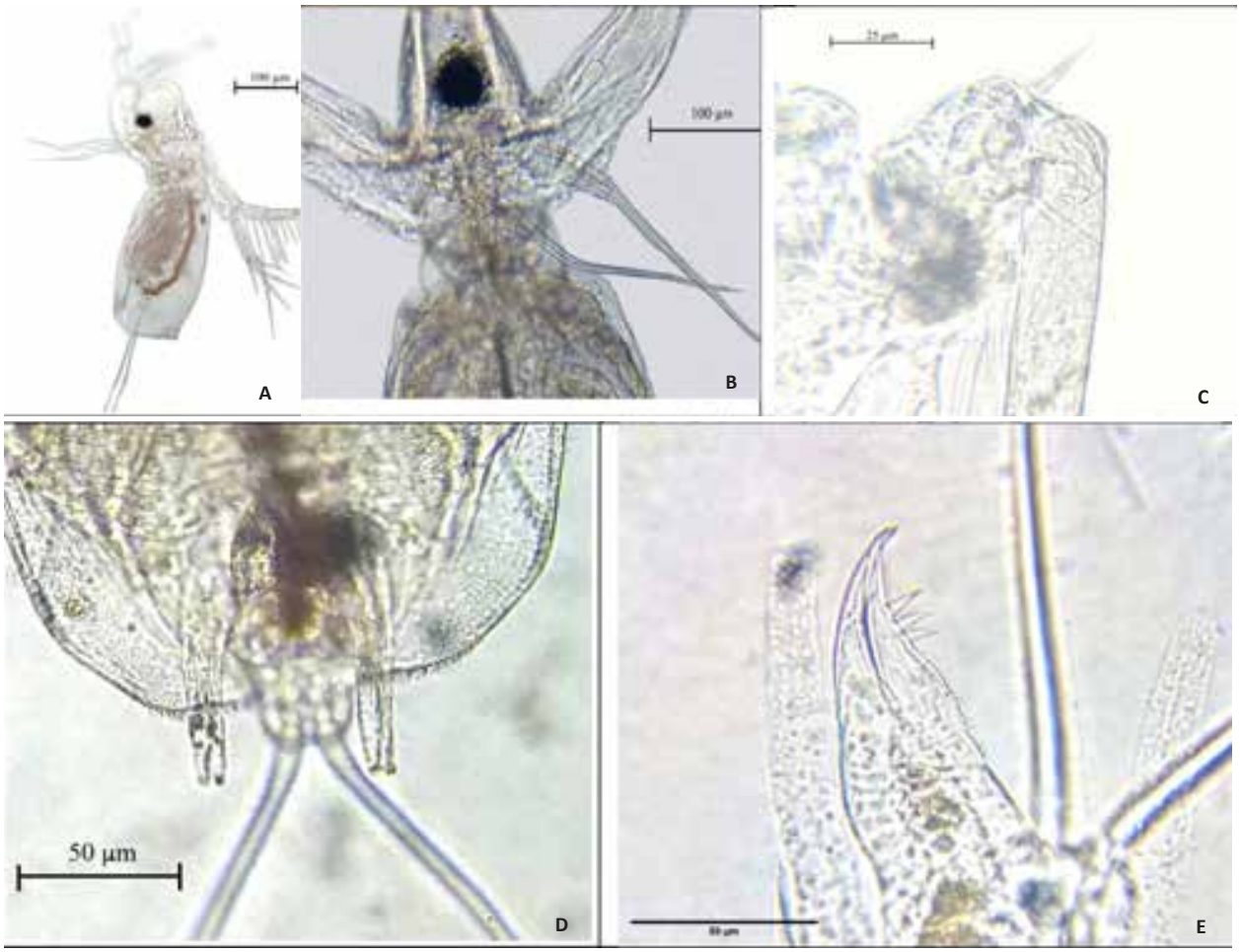


**Image 2 (A–E). *Diaphanosoma senegal* Gauthier, 1951: A—Male, general lateral view | B—Male's antennules | C—Thorn on antennal basipodite | D—Copulatory appendages | E—Postabdomen of male (400x magnification).**

rectangular with a little antero-ventral projection and sloping dorsal side. Eye very large covering most of the part of head (Image 4B). Antennules are short, covered by the second antennae. Swimming antennae are very long, but not reaching up to the posterior margin of the body. These are thin and weak (Image 4C).

A sharp spine and long seta are present at the outer and inner side of distal end of basipodite. Long denticles are present on the two branches of antenna in addition to the setae. Antennal setae have the formula 4-8/0-1-4.

The posterior valve margin is rounded and is armed with about 13–40 small denticles (Korovchinsky 1992) at the post-ventral region. Present specimens have shown the presence of 13–18 such denticles (Figure 5B). The size of the denticles gets reduced towards upper dorsal side (Image 4D). At the inner side of valve junction, two spines are present at both the valves.

Ventral part of valves is folded inwards forming a broad free flap, rounded distally and widens proximally. The inflexion is armed with 4–6 long thin feathered setae at the distal most region followed by 5–6 thorn like naked setae devoid of setules, which are again followed by long feathered setae (Image 4E).

Post abdomen is small and postabdominal claw is pointed, bearing three long thin basal spines and setules on its concave margin (Image 4F, Figure 6C).

**Faunistics of *Diaphanosoma* species in India**

Globally, the genus *Diaphanosoma* is dominant and abundant in the tropics and subtropics (Dumont 1994; Han et al. 2011) but few of the species belonging to this genus are confined to temperate region such as *D. brachyurum*. The presently recorded species of *Diaphanosoma* have been reported from many states of India (Figure 7) by several workers (Brehm (1952), Venkataraman & Krishnaswamy (1984), Michael & Sharma (1988), Venkataraman (1991, 1992, 2000), and Sharma & Sharma (2008). *Diaphanosoma sarsi* and *D.*

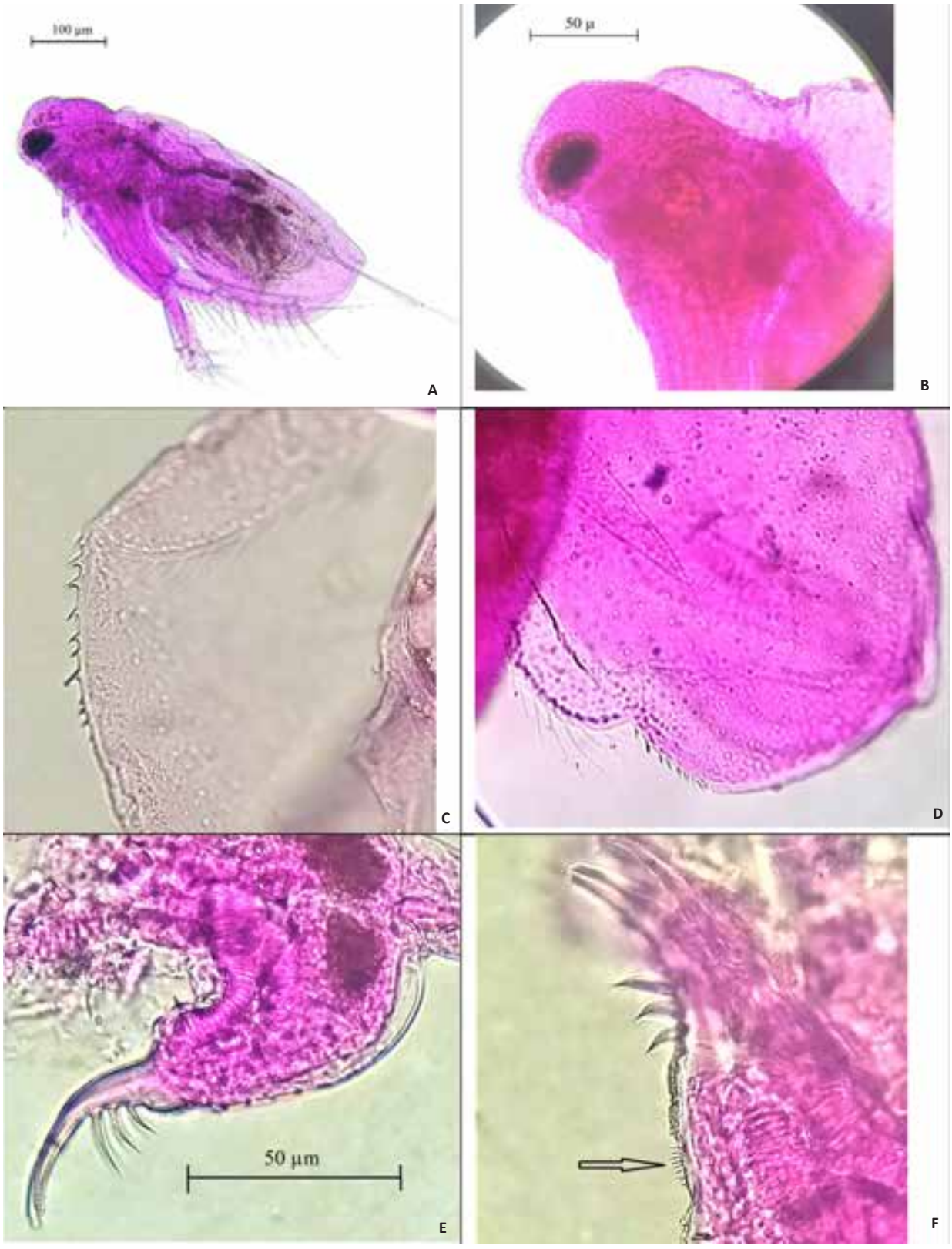


Image 3(A–F). *Diaphanosoma excisum*, Sars. 1885: A—Parthenogenetic female, lateral view | B—Head, lateral view (400x) | C—Posterior valve structure showing denticles | D—Ventral valve inflexion | E—Postabdomen, lateral view (400x) | F—Setules on postabdomen (400x).

*excisum* are widespread in their occurrence (Chatterjee et al. 2013). Sharma & Sharma (2009) reported these three species from Loktak lake, Manipur having subtropical environment similar to the region under study. Among northern states of India, it is the very first record of the three species from J&K.

Venkataraman & Krishnaswamy (1984) recorded *D. senegal* from reddish-brown ponds of Tamil Nadu under the name *Diaphanosoma senegalensis.* The present record is the northernmost record of this species. *D. excisum* was first described from Australia by Sars (1885). There is a report of occurrence of this freshwater species from intertidal sandy beach, Odisha by Chatterji et al. (1995). *Diaphanosoma sarsi* was first described from Indonesia by Richard (1894). Nearest to J&K, its reports are from Punjab (Battish & Kumari 1986) which has a subtropical climate much similar to that of Jammu. In India, both *D. excisum* and *D. sarsi* commonly occur and are found throughout all the latitudes (south of 32˚N) except Srinagar area of Jammu & Kashmir (Fernando & Kanduru 1984). From Jammu, they have been reported for the first time.

**Morphological comparison among the three species**

*Diaphanosoma senegal* has very specific morphological features that make it easily distinguishable from *D. excisum* and *D. sarsi*. But *D. excisum* and *D. sarsi* are morphologically close to each other whether it be the similarity in shape of valves or size (Table 2).

The presently examined specimens of all the three species are comparatively smaller in size than those described earlier by Korovchinsky (1992). The size of *D. senegal* recorded by Venkataraman & Krishnaswamy (1984) was 2.0 mm. According to Korovchinsky (1992), its size ranges 1.5–2.31 mm but in present sample, the largest female individual of *D. senegal* had attained a maximum size of 0.7 mm which is about half the size of the smallest adult female in the African (Korovchinsky 1991) and southeastern Asian samples (Korovchinsky & Sanoamuang 2008). According to Korovchinsky (1993), Asian individuals of *D. senegal* are comparatively smaller in size than the African ones.

Similarly, the sizes of *D. excisum* (0.45 – 0.51 mm) and *D. sarsi* (0.37 – 0.42 mm) are also small compared to that of Korovchinsky (1992), i.e., 0.63–1.30 mm and 0.64–1.20 mm, respectively.

**Remarks on Biology**

In the present study pond, *D. senegal* population was represented by juveniles, females and males while *D. sarsi* and *D. excisum* were represented by juveniles and females only. The month-wise population density of these three species has been given in Table 3.

Most of the mature females of *D. senegal* were carrying 2–3 embryos while a few were seen carrying about two resting eggs in their brood pouch (Image 1F).

The eggs were oval, dark greyish and surrounded by a transparent, thick jelly envelope (Image 1G). The purpose of this sticky jelly envelope is suggested to be the attachment to substrate like aquatic vegetation (Korovchinsky 1993).

Males were less in number (1 per two litres) than females (5 per two litres). The presence of males together with females can be attributed to the completion of sexual reproduction (Korovchinsky 1993) and production of resting winter eggs before the arrival of harsh and unfavourable winter season.

*D. senegal* individuals were present in the study pond in large density (about 30 individuals per litre) during the summer months. First appearance of *D. senegal* females was seen in the month of June when water was less turbid. Population density was the highest during the month of July when temperature and turbidity were high. Both males and females were present in August during monsoons. Its density (3 individuals per litre) remained high during monsoons, got reduced later in September and October when transparency was good, and disappeared in the following months (Table 3). It suggests the seasonality and their affinity for turbidity and high temperature.

Regarding the habitat, *D. senegal* is seen inhabiting temporary, shallow and highly fluctuating vegetated water bodies (ponds, rice fields) (Korovchinsky 1991, 1992, 1993). This further supports its existence in the present study pond which is shallow, vegetated, and fluctuates sometimes.

It has shown co-existence with *Moina brachiata* (Jurine, 1820), *D. excisum, D. sarsi, Ceriodaphnia cornuta* (Sars, 1885)*, Macrothrix rosea* (Jurine, 1820), ostracod-*Onchocypris pustulosa* (Gurney, 1916) and calanoid copepod *Phyllodiaptomus blanci* (Guerne & Richard, 1896). Co-occurrence with similar type of fauna is also evident in the Asian samples of Korovchinsky (1993). Furthermore, Korovchinsky (1991) has also reported its co-existence with Cladocera like *Macrothrix* and *Moina*.

Only females of *D. sarsi* and *D. excisum* were found inhabiting the study pond. *D. excisum* was seen in abundance along with *D. senegal* during summer in July (18 individuals per litre) when the water was turbid but *D. sarsi* population was represented by fewer individuals at that time. The latter appeared in large numbers during post-monsoon period in October (3 individuals per two

**Table 2. Comparison of morphological characters among three species of *Diaphanosoma*.**

| Morphological feature | *Diaphanosoma senegal* | *Diaphanosoma excisum* | *Diaphanosoma sarsi* |
|---|---|---|---|
| Size | 0.6–0.7 mm | 0.45–0.51 mm | 0.37–0.42 mm |
| Shell | Rectangular | Oblong | Oblong |
| Head | Massive and slanting in front | Rectangular, moderate sized | Roundish, small sized |
| Shape and armature of posterior valve margin | Almost straight, Armed with numerous (25–35) spines throughout the margin, diminishing in size ventrally | Round at ventral angle, 8-14 denticles on postero-inferior region, diminishing in size dorsally | Round at ventral corner, 13–18 denticles dorsally decreasing in size. |
| Anal spines on postabdomen | Present | Absent | Absent |
| Ventral free flap | Wide proximally but narrows distally, armed with many identical setulated setae. | Narrow flap joins ventral valve margin almost perpendicularly. | Broad free flap round at distal end, armed with feathered as well as naked setae. |

**Table 3. Monthly population density (No./litre) of the three *Diaphanosoma* species reported from the study pond (February 2019 - January 2020)**

| Month / *Cladocera* sp. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Diaphanosoma senegal* (female) | - | - | - | - | 1.6 | 30.4 | 2.56 | 0.64 | 0.08 | - | - | - |
| *Diaphanosoma senegal* (male) | - | - | - | - | - | - | 0.56 | - | - | - | - | - |
| *Diaphanosoma excisum* | - | - | - | - | - | 18.08 | 0.32 | 0.56 | 0.56 | - | - | - |
| *Diaphanosoma sarsi* | - | - | - | - | - | 0.96 | - | - | 1.68 | 0.16 | | - |

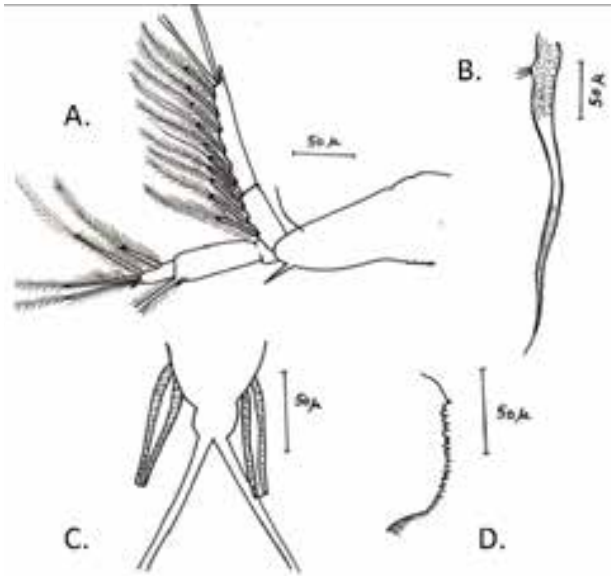


**Figure 3 (A–D). *Diaphanosoma senegal* Gauthier, 1951 (male): A—Second antenna of male showing thorn like spine on basipodite | B—Antennule of male | C—Copulatory appendages | D—Posterior valve margin of male.**

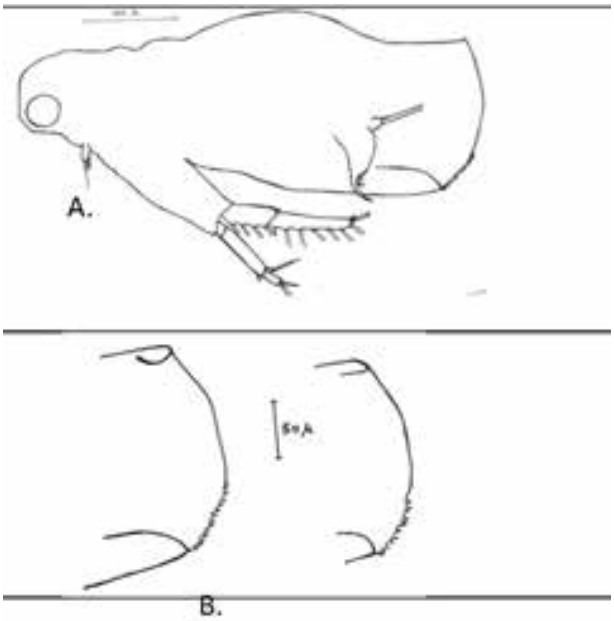


**Figure 4 (A–B). *Diaphanosoma excisum* Sars, 1885 (female): A—Adult female, lateral view | B—Postero-ventral valve margins showing variable number of denticles on both valves of same individual.**

litres) when water was clear and other two species were low in density.

*D. excisum* prefers different types of water bodies including the turbid ones or little brackish. *D. sarsi* generally inhabits the littoral zone of shallow and vegetated ponds, pools, rice fields etc. but can also be found in the pelagic zone of some large lakes (Korovchinsky 1992).

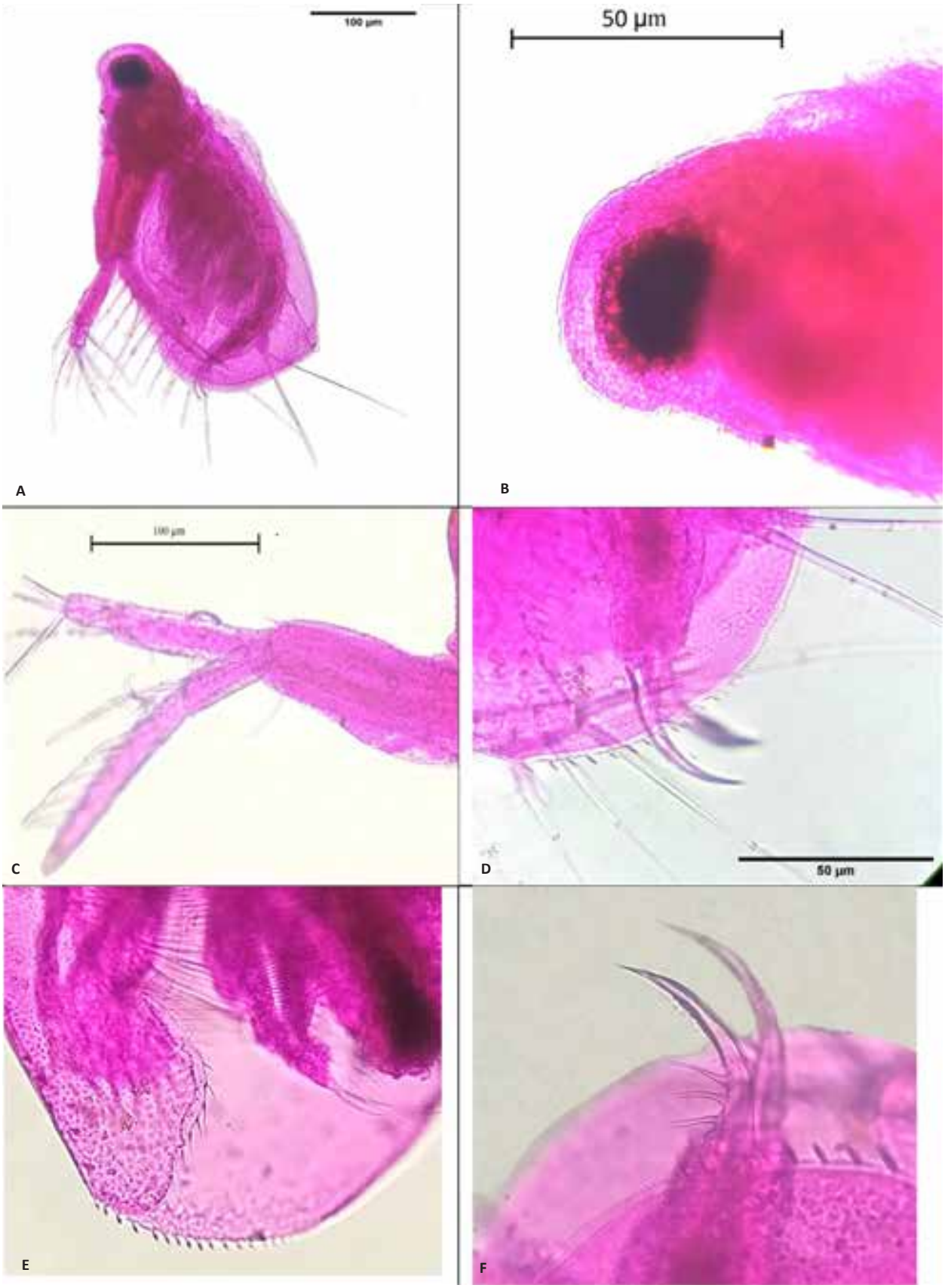


**Image 4 (A–F). *Diaphanosoma sarsi* Richard, 1894: A—Adult parthenogenetic female (lateral view) | B—Head, lateral view (400x) | C—Swimming antenna | D—Posterior valve margin showing denticles | E—Ventral valve flap like inflexion (400x) | F—Post-abdominal claws (400x).**

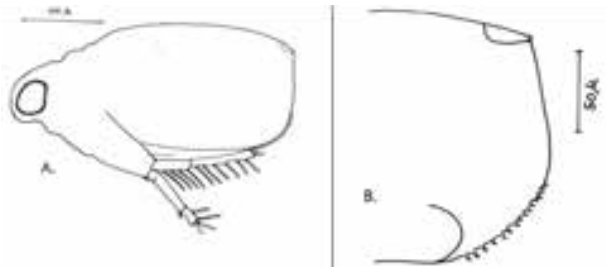


**Figure 5 (A–B). *Diaphanosoma sarsi* Richard, 1894 (Female): A—Adult female, lateral view | B—Posterior valve margin showing denticles on postero-ventral region.**

## DISCUSSION

It is well known that the relative abundance of cladocerans can be affected by the presence of suspended sediments (Kirk & Gilbert 1990). Suspended sediments may affect zooplankton population both directly and indirectly. Indirect effects of suspended particles are mediated by decreased light penetration leading to decreased algal biomass and productivity (Hoyer & Jones 1983). This decrease in phytoplankton biomass may affect cladoceran population as their population growth is often limited by the abundance of phytoplankton (Tessier 1986). Other indirect effect of high sediment concentration involves the decreased ability of visual predators to locate their plankton prey (Hart 1988; Kirk & Gilbert 1990). Inhibitory effects of suspended sediments can be observed from the fact that Cladocera are known to ingest suspended clay particles (Arruda et al. 1983) for example, *Daphnia* can ingest particles in the size range 1–15 µm (De Mott 1982). This results in their decreased ingestion rate of phytoplankton cells, thus decreasing their population growth rate (Arruda et al. 1983). Such inhibition of phytoplankton ingestion is not observed for calanoid copepods and they are considered selective feeders (Bogdan & Gilbert 1984, 1987). Hart (1988) found that phytoplankton ingestion rate of *Daphnia* sp. was inhibited, but not that of calanoid copepod. This finding strongly supports the present abundance of calanoid copepod *Phyllodiaptomus blanci* and its co-existence with *Diaphanosoma* species in turbid water.

Kirk & Gilbert (1990) argued that fine clay particles did not inhibit Cladocera population, this suggests that turbid water species may have undergone specific changes in their morphology and behaviour to avoid ingestion of clay. Perhaps *Diaphanosoma senegal* and *Diaphanosoma excisum* may have adopted such a mechanism for better survival in a turbid environment. Shiel (1985) found that the mesh size of filtering thoracic appendages of *Daphnia carinata* individuals taken from turbid environment were larger when compared to the ones from clear water. In contrast to the inhibitory effects of suspended sediments on Cladocera population, few works have supported the abundance of Cladocera in silt laden water. Threlkeld (1986) reported that population of two Cladocera spp., *Moina micrura* Kurz and *Diaphanosoma leuchtenbergianum* Fischer, was increased during the period of high turbidity and their life table experiments have shown that they were capable to grow well in muddy waters. This further supports our observations on abundance of *D. senegal* and *D. excisum* in muddy conditions. Hart (1988) ranked *Moina brachiata* first in the ranking of 'turbidity tolerance'; this species was present in our study also.

Dissolved organic matter is adsorbed by suspended clay and in limiting food concentration, it can be used as supplementary food resource for freshwater filter feeders (Arruda et al. 1983). It may also regulate the abundance and differential species composition of zooplankton in turbid waters. Cladocerans are considered selective feeders (Sterner 1989) in terms of characteristics of food particles especially particle size. Pagano (2008) documented that *D. excisum* could not consume large

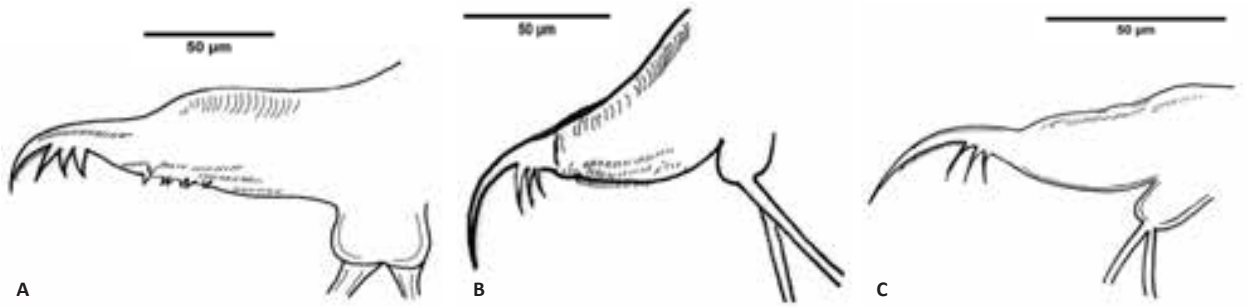


**Figure 6 (A–C). Post abdomen, lateral view: A—*Diaphanosoma senegal* Gauthier, 1951 | B—*Diaphanosoma excisum* Sars, 1885 | C—*Diaphanosoma sarsi* Richard, 1894.**


**Figure 7. Distribution of *Diaphanosoma senegal*, *Diaphanosoma excisum*, and *Diaphanosoma sarsi* in India.**

food particles but was restricted to smaller food items. Geller & Muller (1981) in their observations on the filtration apparatus of Cladocera, suggested that only one filter screen with a nearly constant filter mesh is present in *Diaphanosoma* species that restricts the size range of particles to be ingested. So, these species might have accepted only small sized clay particles adsorbed with organic matter and rejected large particles.

Now, from the above arguments, it can be inferred that higher abundance of *D. senegal* and *D. excisum* in turbid conditions can be due to the following reasons:

1. High turbidity provided greater protection from visual planktivore predators (Kirk & Gilbert 1990).

2. Due to high summer temperature, increased organic decomposition resulting into large concentration of detrital food might have reduced food constraints for them (Hart 1986), thus allowing them to attain large population size.

3. At limiting food concentration in turbid conditions, they might have employed different feeding strategy by ingesting small grains of silt adsorbed organic matter as additional source of carbon for maintaining their large population.

4. In order to be turbidity tolerant, they might have undergone adaptive changes in their feeding appendages.

It seems that the population of *D. sarsi* was controlled by the combined action of poor food availability and invertebrate predation. The possible influence of food limitation and invertebrate predation on the population size of *D. sarsi* can be examined by the findings that *D. sarsi* could not develop large population during lower food concentration at high turbidity but at higher transparency too, its population was not very large due to predation pressure by planktivore invertebrates (Dumont 1994) as increase in water transparency would have rendered it more vulnerable to visual predators. Similar results were obtained for *Daphnia gibba* Methuen population by Hart (1986).

Although temperature plays a major role in

determining community structure but the presence of more no. of *D. sarsi* individuals during autumn months when transparency was high and lesser no. during hot summer months indicates that turbidity had overriding effect upon temperature (Hart 1986).

Thus, paucity in *D. sarsi* population in July could be attributed to food limitation and associated interference in collecting this limited food caused by high turbidity.

All the three species were absent in winter months, the likely causes for their winter decline or complete absence can be low primary productivity and existence of diapause in them.

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**REVIEW**

# Wild ungulates in Jordan: past, present, and forthcoming opportunities

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**Abstract:** Twelve species of ungulates are reported from the wild in Jordan. Three of these, *Addax nasomaculatus* (Addax), *Bos primigenius* (Aurochs), and *Cervus elaphus* (Red Deer) are known only from archaeological excavations. *Dama mesopotamica* (Mesopotamian Fallow Deer), *Oryx leucoryx* (Arabian Oryx) and *Equus hemionus hemippus* (Syrian Wild Ass) have been regionally extirpated in the wild. A semi-captive population of Persian Onager (*E. h. hemionus*) is held in Shumari Wildlife Reserve. The Arabian Oryx is also managed in semi-captive conditions in two reserves. Except the commonly occurring Wild Boar (*Sus scrofa*), other surviving ungulate species continue to be under serious threat. *Gazella gazella* (Palestinian Mountain Gazelle), *Capreolus capreolus* (European Roe Deer), *Gazella marica* (Arabian Sand Gazelle), and *Gazella dorcas* (Dorcas Gazelle) are Critically Endangered, and *Capra nubiana* (Nubian Ibex) is Endangered in the region. This paper provides a review of the historical and current status of wild ungulates in Jordan, listing the threats and conservation measures and provides recommendations for management and conservation in the future.

**Keywords**: Arabian Oryx, Arabian Sand Gazelle, conservation actions, Dorcas Gazelle, Fallow Deer, historical background, Mountain Gazelle, Nubian Ibex, Persian Onager, population, status, Roe Deer, Wild Ass, Wild Boar.

الخلاصة: تم تسجيل 12 نوع من ذوات الحوافر البرية في الأردن تضمنت ثلاثة أنواع وثق تواجدها من خلال الدراسات الأثرية والأحافير التي تم العثور عليها وهي البقر الوحشي (*Addax nasomaculatus*) والأرخص (*Bos primigenius*) والأيل الأحمر (*Cervus elaphus*) بينما انقرضت ثلاثة أنواع أخرى من البرية وهي الأيل الأسمر الفارسي (*Dama mesopotamica*) والمها العربي (*Oryx Leucoryx*) والحمار البري السوري (*Equus hemionus hemippus*) ويتواجد حالياً مجموعة من الحمار البري الفارسي في محمية شومري للحياة البرية (*E. h. hemionus*) كما ويتم إدارة قطعان من المها العربي في مسيجات ضمن محميتين طبيعيتين في الأردن. باستثناء الخنزير البري (*Sus scrofa*) الذي يعتبر النوع الوحيد الشائع فإن ما تبقى من الأنواع مهددة بالانقراض كونها تتعرض للعديد من الضغوط وهي غزال الجبل الفلسطيني (*Gazella gazella*) والأيل الأسمر (*Capreolus capreolus*) والغزال العربي (*Gazella marica*) وغزال دوركاس (*Gazella dorcas*) والتي صنفت كأنواع مهددة بشكل حرج والوعل النوبي أو البدن (*Capra nubiana*) المصنف كنوع مهدد بالانقراض. قدمت هذه الورقة العلمية مراجعة تفصيلية للوضع التاريخي والحالي لأنواع ذوات الحوافر البرية في الأردن مع تبيان التهديدات التي تحيط بهم وتدابير الحماية المتوفرة وتم تقديم مجموعة من التوصيات للإدارة والحماية في المستقبل.

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**Author contributions:** EE developed the concept and produced the distribution maps; both authors participated in writing the manuscript.

## INTRODUCTION

Jordan is situated in the junction point of three major biogeographical realms, the Palearctic, Afrotropical, and Oriental (Amr et al. 2004), which support the existence of four distinct biogeographical zones in the country; Mediterranean, Irano-Turanian, Saharo-Arabian, and Afrotropical (Al Eisawi 1996). This results in the presence of a diverse range of habitats, which provide suitable niches for various species of fauna and flora (Image 1). The ungulate diversity includes species of Palearctic origin such as the Roe Deer (*Capreolus capreolus*) in the Mediterranean biome of northern Jordan and Nubian Ibex (*Capra nubiana*) in the western mountains, and widespread Middle Eastern desert species such as the Arabian Oryx (*Oryx leucoryx*) and gazelles (*Gazella* spp.) (Amr et al. 2004).

The presence of ungulates in Jordan is well documented in ancient rock drawings, and mosaics on the walls of desert palaces and churches in Madaba (Hatough-Bouran & Disi 1991). In addition, early travelers to the Levant provided incidental records of many species (e.g., Tristram 1884).

Twelve species of ungulates (defined as the mammalian orders Artiodactyla and Perissodactyla) have been reported to occur in Jordan (Quemsiyeh et al. 1996; Amr 2012) (Table 1). Three species are known only from archaeological excavations: Aurochs (*Bos primigenius*), Addax (*Addax nasomaculatus*), and Red Deer (*Cervus elaphus*), though some doubt exists over two of these. Of the remaining nine species, three have been extirpated from Jordan. The Roe Deer (*Capreolus capreolus*) has been reintroduced. An Arabian Oryx (*Oryx leucoryx*) reintroduction programme has begun, but the released populations in Shumari Wildlife Reserve and Wadi Rum Protected Area are held in semi-captive conditions, and they are not yet considered fully wild. The Syrian Wild Ass (*Equus hemionus hemippus*) formerly occurred across the northern part of the Arabian Peninsula, including Jordan, but became extinct in 1927. A small population of Persian Onager (*E. h. hemionus*) is kept in semi-captive conditions in Shumari Wildlife reserve. There have been no confirmed sightings of Mountain Gazelle (*Gazella gazella*) or the reintroduced population of Roe Deer (*Capreolus capreolus*) since 2015 (Eid et al. 2020). Of the remaining four species, Arabian Sand Gazelle (*Gazella marica*) Dorcas Gazelle (*G. dorcas*) and Nubian Ibex *Capra nubiana* are seriously threatened, while the Wild Boar (*Sus scrofa*) is still common and threats to its population are insignificant (Amr 2012). The aim of this paper is to summarize the history and status of wild ungulates in Jordan.

Ungulates have always been hunted for meat, hides, and trophies. In ancient times, elaborate stone corrals known as 'desert kites' were constructed to trap gazelles and other species. These are funnel-shaped, stone structures, with walls 25 to 70 m in length, into which animals were driven and killed (Bar-Oz et al. 2011). Desert kites allowed the capture of whole herds and slaughter of hundreds of gazelles. Many desert kites are located in the eastern desert of Jordan, some of them possibly dating from the Neolithic period (Betts & Burke 2015).

Declines in the numbers and diversity of ungulates began in the early 19$^{th}$ century (Quemsiyeh et al. 1996; Amr 2012). Meinertzhagen (1954) reported that the enormous decline in wildlife populations in the Arabian Peninsula and Jordan began during the First World War (1914–1918) when modern rifles and motor vehicles first arrived in the country, and these declines have continued since then (Kiwan et al. 2001; Amr 2012; Eid et al. 2020).

Arabian Oryx, Arabian Sand Gazelle, Dorcas Gazelle, and Nubian Ibex are included on Appendix I of the classification system for wild animals which prohibits hunting by virtue of paragraph (e) of Article (57) according to regulation No. 43 for the year 2008 of the Agriculture Law No. (13) for the year 2015. The addition of Mountain Gazelle and Roe Deer to Appendix I is currently under consideration by the government.

### Annotated checklist of the ungulates of Jordan

**(A.) Extinct in the region (Archaeological records)**

**(A1.) *Addax nasomaculatus* (de Blainville, 1816) Addax**

[Critically Endangered (IUCN), Extinct in the region, Archaeological records]

The presence of the Addax in Jordan during the Pleistocene has been in report (Tristram 1884; Bates 1937). However, Bodenheimer (1958) suggested that published accounts may be misidentifications or relied on information from Bedouins who used the Arabic common name (bakr al wahsh) for more than one species including the Aurochs. Harrison (1972) reported that the Addax may have formerly existed in the region but that there was no confirmed evidence of its presence in the region in recent times.

**(A2.) *Bos primigenius* (Bojanus, 1827) Aurochs**

[Extinct (IUCN), Extinct in the region, Archaeological records]

Bone remains belonging to this species have been

**Image 1. Some ungulate species which still survive in Jordan (top-left—*Gazella marica*; top-right—*Oryx leucoryx*; below—*Capra nubiana*). © Ehab Eid.**

excavated from archaeological sites in Jordan dating from different Paleontological eras, such as Ain Ghazal, Azraq, Wadi Hassa, Wadi Jilat, and Tel Hesbon (Boessneck & Van den Driesch 1978; Gerrard et al. 1988). Harrison (1972) reported that the Aurochs may have survived in the region until historical times. The species is Extinct.

**(A3.) *Cervus elaphus* (Linnaeus, 1758) Red Deer**

[Least Concern (IUCN), Extinct in the region]

Qumsiyeh (1996) referred to archaeological remains of this species but added that there was no information on when it got extirpated. Harrison & Bates (1991) did not include Red Deer in their account of the mammals of the Arabian Peninsula and its presence has never been confirmed in the region in historical times.

**(B.) Extinct in the region (presence in captivity or as different subspecies)**

**(B1.) *Dama mesopotamica* (Brooke, 1875) Mesopotamian or Persian Fallow Deer**

[Critically Endangered (IUCN), Extinct in the region]

**Table 1. Ungulate species recorded in Jordan, past and present.**

| Species name | Common name | IUCN Red List (global)[1] | Jordan National Red List[2] | Notes |
|---|---|---|---|---|
| *Addax nasomaculatus* | Addax | Critically Endangered | Regionally Extinct | Archaeological records |
| *Bos primigenius* | Aurochs | Extinct | Regionally Extinct | Archaeological records |
| *Cervus elaphus* | Red Deer | Least Concern | Regionally Extinct | Archaeological records |
| *Dama mesopotamica* | Mesopotamian Fallow Deer | Critically Endangered | Regionally Extinct | More than 250 in enclosures on a private farm |
| *Oryx leucoryx* | Arabian Oryx | Vulnerable | Regionally Extinct | 230 in total in enclosures within two protected areas |
| *Equus hemionus* | Wild Ass | Near Threatened | Regionally Extinct | Syrian Wild Ass (*E. h. hemippus*) is Extinct. 32 *E. h. onager* in a protected area |
| *Gazella gazella* | Palestinian Mountain Gazelle | Endangered | Critically Endangered | Not seen since 2015 |
| *Capreolus capreolus* | European Roe Deer | Least Concern | Critically Endangered | Not seen since 2015 |
| *Gazella marica* | Arabian Sand Gazelle | Vulnerable | Critically Endangered | Less than 50 individuals |
| *Gazella dorcas* | Dorcas Gazelle | Vulnerable | Critically Endangered | Less than 50 individuals |
| *Capra nubiana* | Nubian Ibex | Vulnerable | Endangered | Less than 500 individuals |
| *Sus scrofa* | Wild Boar | Least Concern | Least Concern | Numbers unknown but common |

[1] www.iucnredlist.org; [2] Eid et al. (2020)

**Distribution and status**

Mesopotamian Fallow Deer formerly occurred in forested hills of northern Jordan and the north of the Arabian Peninsula (Harrison & Bates 1991) but it was already rare by late 19th century (Tristram 1884). Qumsiyeh (1996) stated that the species disappeared from the eastern Mediterranean region 100 years earlier, although Bodenheimer (1958) reported seeing antlers in a shop in 1923 that reportedly came from Jerash. RSCN obtained four fallow deer in 1983, but it turned out that these were European Fallow Deer (*Dama dama*), a non-native species, so they were given to a private farmer (Harding 2007). Several private owners later obtained European Fallow Deer. More than 250 European Fallow Deer, which were originally introduced from Germany in 2003 were observed in enclosures at Zubia area near Irbid in northern Jordan (E. Eid, pers. obs., 2009). The presence of this non-native species would complicate any future restoration of *Dama mesopotamica* to Jordan.

**(B2.) *Oryx leucoryx* (Pallas, 1777) Arabian Oryx**

[Vulnerable (IUCN), Extinct in the region, 230 in total in enclosures within two protected areas]

**Distribution and status**

Tristram (1884) stated that this species was still common in northern Arabia and in Balka and Houran in Jordan in the 19th century. Schmitz collected it in Jordan in 1910 (Anon 1946) and the specimen is in a museum in Amman. According to Mountfort (1965), a hunter shot three animals at Qatraneh near Karak, southern Jordan in the 1920s. In the 1930s a British army unit kept one in captivity in southern Jordan (Dollman & Burlace 1935). Populations were reported to persist in Saudi Arabia, close to the Jordanian borders, near Jabal et Tubayq (Carruthers 1935) and in Al Busayta and Wadi Sirhan (Raswan 1935).

The exact date of the extinction of the Arabian Oryx in Jordan is unknown but several dates have been proposed. Clarke (1977) stated that the oryx became extinct in Jordan during the 1930s, while Talbot (1960) and Fitter (1967) stated that the last Arabian Oryx was shot in the 1940s. Hatough & Al Eisawi (1987) considered that this species was on the verge of extinction in the 1950s. Mountfort (1965) reported that the last wild oryx in Jordan was shot in the early 1960s near Qatraneh, c. 75 km south of Amman.

Arabian Oryx have been reintroduced to two sites in Jordan, Shumari Wildlife Reserve and Wadi Rum Protected Area (Figure 1). The RSCN initiated the first reintroduction into Shumari Wildlife Reserve in 1978 (Clarke 1979; Nelson 1985; Abu-Jafar & Hays-Shahin

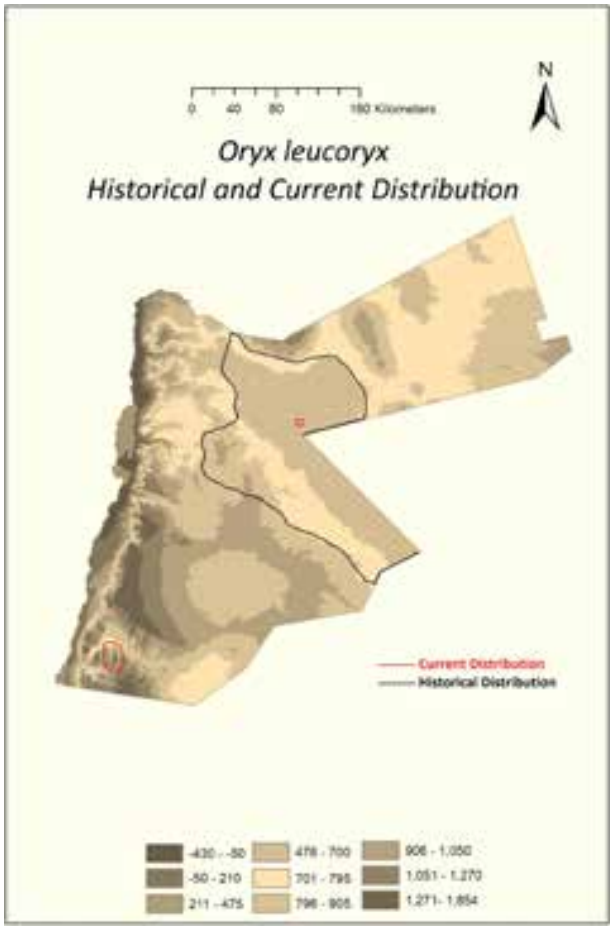


**Figure 1. Former and current range distribution of *Oryx leucoryx* in Jordan.**

1988; Hatough & Al-Eisawi 1988). Eight oryx from the San Diego Wild Animal Park in the United States (four males and four females) and three animals from the Royal herd in Qatar (one male and two females) were donated in 1978 to the RSCN (Hatough & Al-Eisawi 1988). In 1984, Zurich Zoo in Switzerland provided three additional males. The founders were from two separate bloodlines: those from San Diego and Zurich were of Yemeni-Saudi stock, whereas those from Qatar were from a separate line (Harding et al. 2007). This program was considered transitional to a truly wild, free-ranging population, which the RSCN planned to establish eventually (Mountfort 1965; Clarke 1977, 1979).

The Shumari Wildlife Reserve herd grew to 30 in 1983 and about 176 in 1995 (Qumsiyeh et al. 1996). By 2000 the population reached 313 but the lack of available habitat due to overgrazing prevented release of the animals outside the reserve, so as to reduce overcrowding, the RSCN donated some oryx to breeding collections in Qatar, Saudi Arabia, Syria, and the United Arab Emirates, while others were transferred to Wadi Rum Protected Area in the south of Jordan in 2002 and 2006 (Harding et al. 2007). Currently there are c. 70 individuals in Shumari wildlife reserve (A. Al Halal, pers. comm. 2020. Reserve manager).

In February 2020, the Environment Agency - Abu Dhabi (EAD) and RSCN signed a Memorandum of Understanding on a breeding and reintroduction project for the Arabian Oryx in Shumari Wildlife Reserve. The project aims to release 60 oryx in the reserve over 2021–2022. The Shumari Wildlife Reserve will also be expanded to ensure enough suitable grazing, by rehabilitating land outside the current boundaries (https://www.rscn.org.jo/abu-dhabis-environment-agency-release-60-arabian-oryx-jordans-shumari-wildlife-reserve).

Ten oryx were transferred from Shumari Wildlife Reserve to Wadi Rum Protected Area in 2002 and 50 more in 2006 (Harding et al. 2007). A new reintroduction project in Wadi Rum Protected Area was initiated in 2007, funded by H.H Sheikh Mohamed bin Zayed Al Nahyan. Sixty oryx (20 males, 40 females) were transferred from the United Arab Emirates to an enclosure inside the reserve in two batches: 20 in 2009, and 40 in 2012 (N. Zawaydeh. Former reserve manager. pers. Comm. 2019). The current population in Wadi Rum Protected Area numbers around 100 individuals (A. Alhasassein. Oryx reintroduction project manager. pers. comm. 2020.). The oryx are currently held in semi-captive conditions with a plan to release later in the wider area.

**Threats**

The main threat that led to the extinction of the species from Jordan was hunting, but pesticides used to control locusts across the Badia in the 1950s also killed some oryx (Hatough & Al Eisawi 1988; Qumsiyeh et al. 1996). Harding et al. (2007) reported that the main causes of mortality of young oryx in Shumari Wildlife Reserve were predation and flash floods. Illegal live capture of oryx for sale to private collections, and for food has been reported from Wadi Rum Protected Area (E. Eid unpub. data 2020).

**Conservation Actions**

This species is protected at Wadi Rum Protected Area and Shumari Wildlife Reserve. Since the Arabian Oryx populations in Shumari Wildlife Reserve and Wadi Rum Protected Area are still held within enclosures, they are not yet considered fully wild, so this species was assessed as Regionally Extinct in Jordan (Eid et al. 2020). Decisions are needed to be taken in releasing the Arabian Oryx into the wild by working on two levels; the first is regional,

by developing memoranda of understanding with neighboring countries, especially the Kingdom of Saudi Arabia to establish a protocol for conserving the released animals which cross the border. The second is at national level where awareness programs be implemented linked to strong enforcement and partnerships established with the hunters' association and the Royal Department for Environmental Protection.

**(B3.) *Equus hemionus hemippus* (I. Geoffroy, 1855) Syrian Wild Ass**

[Near Threatened (IUCN), Extinct in the region (Eid et al. 2020), Syrian Wild Ass (*E. h. hemippus*) is Extinct. But 32 numbers of *E. h. onager* are in a protected area]

**Distribution and Status**

The Syrian Wild Ass was formerly distributed across the whole of the northern part of the Arabian Peninsula (Harrison & Bates 1991), but this subspecies became extinct in 1927 when the last individual was reported shot near Sinjar in northern Iraq (Kaczensky et al. 2015). Musil (1927) reported that in Jordan Wild Ass occurred in the Sirhan depression 100 years earlier and that the last individual had been shot at Al Ghamr wells, south-east of Azraq. Harrison (1972) stated that it was formerly numerous in the Azraq region of Jordan. Qumsiyeh (1996) mentioned a well-preserved image of a wild ass hunt in Qasr Amrah, near Azraq. It is not known precisely when the wild ass disappeared from Jordan (Figure 2).

The Royal Society for the Conservation of Nature (RSCN), selected the Persian Onager (*E. h. onager*) for a reintroduction programme as it is the closest relative of the extinct subspecies, and thus in accordance with the principle of 'the nearest available subspecies' in the IUCN reintroduction guidelines (IUCN/SSC 2013). The main reason for establishing Shumari Wildlife Reserve was for captive breeding and reintroduction of the wild ass and other species (Amr et al. 2004).

Two immature Persian Onagers (male and female) were imported from Montpellier Zoo, France, in 1983 but these animals died, and an additional four individuals (two of each sex) were imported from Koeln, Stuttgart, and Whipsnade zoos in 1988–1989 and an additional male and five females were imported from Basel Zoo in 1997 (Abu Eid 2001; Khoury et al. 2012). Currently, 32 individuals are present in Shumari Wildlife Reserve (A. Elhalah, Reserve manager. pers. comm. 2020.).

**Threats**

There is no specific information on the reasons for extinction of the Syrian Wild Ass in Jordan, although hunting is likely to have been a major factor.

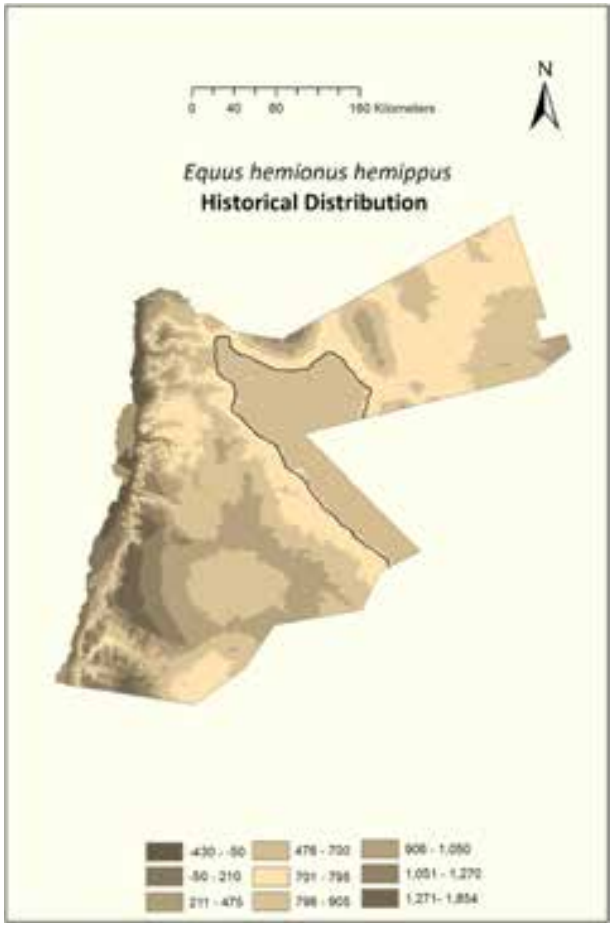


**Figure 2. Former range distribution of *Equus hemionus hemippus* in Jordan.**

**Conservation Actions**

The species is currently held in semi-captive conditions at Shumari Wildlife Reserve, which is fenced. Release into the wild is not currently considered a priority because of the lack of suitable habitat and the population is used for educational purposes and to raise awareness of the former fauna of Jordan. Wild Ass is considered Regionally Extinct in Jordan (Eid et al. 2020).

**(C.) Critically Endangered**

All three species of gazelles occurring in Jordan are critically endangered. These are, Palestinian or Mountain Gazelle (*G. gazella*), Arabian Sand Gazelle (*Gazella marica*), and Dorcas Gazelle (*G. dorcas*) (Harrison & Bates 1991; Quemsiyeh et al. 1996; Amr 2012). Tristram (1884) stated that gazelles were common and abundant in every part of Jordan. Besides, the European Roe Deer (*Capreolus capreolus*) is also Critically Endangered.

**(C1.) *Gazella gazella* (Pallas, 1766) Palestinian Mountain Gazelle**

[Endangered (IUCN), Critically Endangered in the region, Not seen since 2015]

**Distribution and status**

Archeological evidence suggests Palestinian Mountain Gazelle *Gazella gazella* was a common species throughout the Jordan mountain chain (Tchernov et al. 1986/7; Uerpmann 1987) and Amr & Disi (1988) reported that a specimen killed in the Salt mountains in summer 1986 is now in the Jordan University Museum of Natural History (JUMHN). The distribution extended down the Rift Valley of western Jordan with many records from the Jordan and Yarmouk valleys in the north (Qumsiyeh et al. 1996; Kiwan et al. 2001; Amr 2012; Figure 3). Clarke (1977) reported a population in the Mujib area. Quemsiyeh et al. (1996) described it as rare and reported relict populations in small pockets surrounded by *G. dorcas* in the southern part of Wadi Araba. Amr et al. (2004) stated that the species was declining at an alarming rate. Amr et al. (1987) stated that groups of gazelles could be observed on the Syrian border near the Yarmouk River, and on some occasions on the Jordanian side of the border. According to local people and army personnel, a few individuals still survive near the Yarmouk and Jordan Rivers, on both sides of the international borders. There are no current estimates of population size and there have been no sightings since 2015 (Eid et al. 2020).

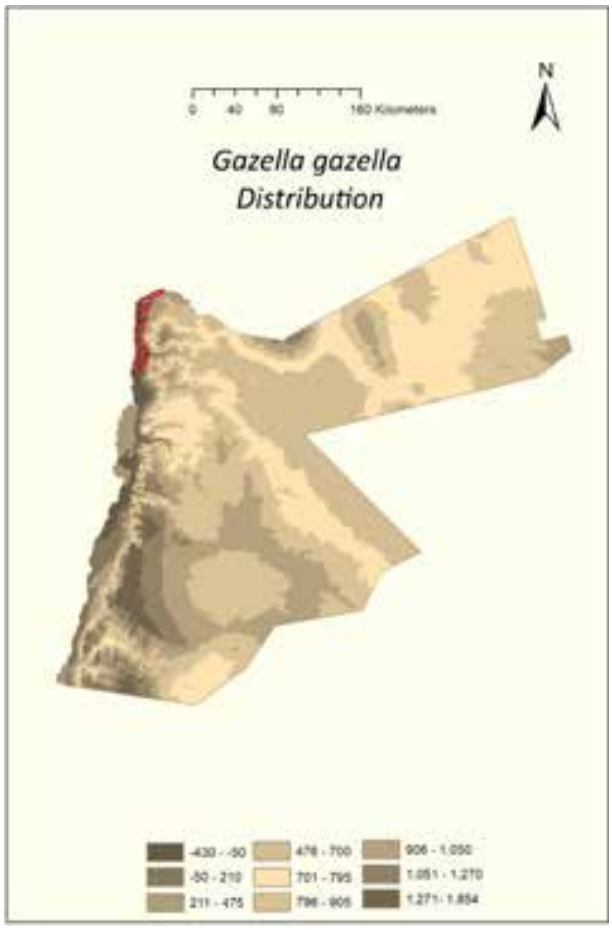


**Figure 3. Range distribution of *Gazella gazella* in Jordan.**

**Threats**

Illegal hunting represents the major threat (Quemsiyeh et al. 1996; Eid et al. 2020). Habitat loss and deterioration through agricultural development, fencing pasture for cattle, construction of roads and settlement are further threats. Despite the small numbers, illegal hunting still takes place and a photo of single specimen killed by hunters was posted on Facebook in 2015 (Eid & Handal 2018).

**Conservation Actions**

Mountain Gazelle is protected by law. Eid et al. (2020) listed this species as Critically Endangered (CR) in Jordan. Yarmouk Forest Reserve contains suitable habitat for this species, which provides potential for a reintroduction program, if effective protection can be assured.

**(C2.) *Capreolus capreolus* (Linnaeus, 1758) European Roe Deer**

[Least Concern (IUCN), Critically Endangered regionally, Not seen since 2015]

**Distribution and status**

European Roe Deer formerly inhabited forested regions in the northern Jordan valley and the hills of northern Palestine (Harrison & Bates 1991). The species probably disappeared from Jordan at the beginning of the 19th century (Amr 2012).

The Royal Society initiated a reintroduction program for the Conservation of Nature (RSCN) in 1996. Four Roe Deer (two males and two females) from the Turkish-Bulgarian border were donated to the RSCN in 1988 and seven more individuals were imported in 1996/1997, believed to be from the same source and including at least five adult females (Amr et al. 2004). The reintroduction program was initiated in Zubiya Nature Reserve in northern Jordan, but later transferred to Ajloun Forest Reserve. In 2006, the 26 animals in the breeding herd (11 males, 15 females) were released into the reserve where they expanded their range into vineyards outside the reserve (Qumsiyeh et al. 1996; Eid

& Ananbeh 2009; Khoury et al. 2012). In 2009, a survey of the reserve observed only four individuals (two males and two females) but mating was recorded (Eid & Ananbeh 2009). Despite annual monitoring, no Roe Deer have been observed since 2015 (Figure 4).

**Threats**

Harrison & Bates (1991) reported that the virtual extinction of the roe deer from northern Arabia was due to increased hunting pressure and deforestation. Eid & Ananbeh (2009) reported that habitat degradation, hunting, and urbanization were the major causes of extinction in Jordan. Illegal hunting remains a likely threat.

**Conservation Actions**

This species has been reintroduced into Ajloun Forest Reserve, but it is unclear whether the population has become established. Reinforcement or a new reintroduction program will be needed to ensure the survival of Roe Deer in Jordan. To ensure success, it is critical to strengthen law enforcement in the reserve and monitor the released animals using tracking technologies. It is listed as Critically Endangered in Jordan (Eid et al. 2020). The government is currently planning to add Roe Deer to the list of protected species.

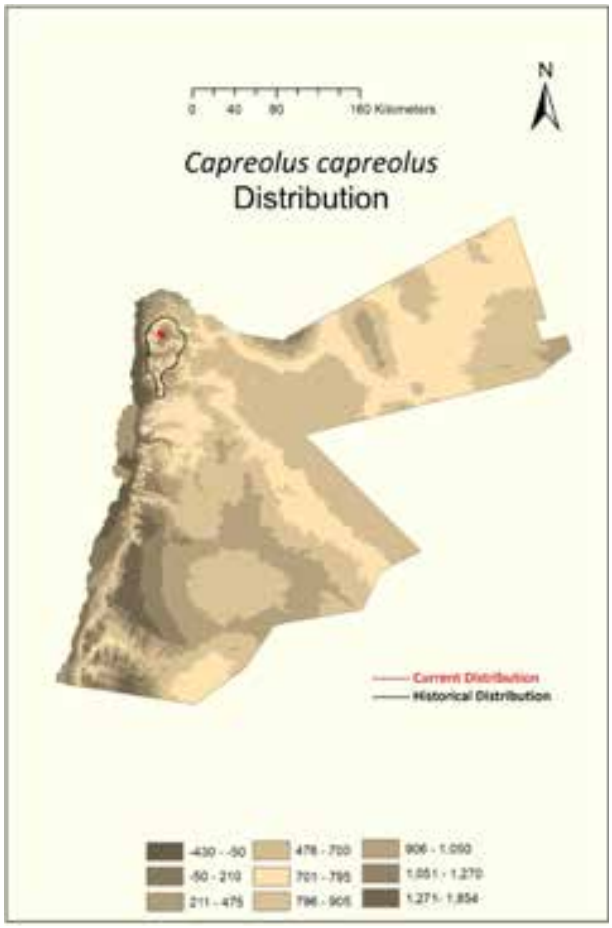


Figure 4. Range distribution of *Capreolus capreolus* in Jordan.

**(C3.) *Gazella marica* (Thomas, 1897) Arabian Sand Gazelle**

[Vulnerable (IUCN), Critically Endangered regionally, less than 50 individuals]

**Distribution and status**

The Arabian Sand Gazelle was formerly known as *G. subgutturosa marica* but is now considered to be a full species (Wacher et al. 2010). Harrison (1968) reported a specimen from Al Qatraneh in Karak which is now stored at the British Museum. One skull was collected from Safawy (H-5 station) in 1950 and Dr. Muller collected another skull from Qa'a Dhuweila in September 1983 (Amr & Disi 1988). The species was formerly widely distributed in the desert zones of the north-east of the country (Kiwan et al. 2001; Amr 2012; Figure 5). Kiwan et al. (2001) also pointed out that while the Arabian sand gazelle is indigenous to Jordan, other gazelles are occasionally imported illegally from Iraq and, as these females are hornless, they may represent either *G. s. subgutturosa* or intergrades.

Amr (2012) claimed a sharp decline in the population since the 1980s and listed positive records of *Gazella marica* from the Syrian-Jordanian border, specifically at Burqu' near Al Masmah and Hedlat. Kiwan et al. (2001) estimated there were less than 100 individuals in the wild in Jordan, but the population is now estimated at less than 50 (Eid et al. 2020).

A reintroduction program was initiated in 1978, when 10 individuals (nine females and one male) were donated to RSCN and transferred to Shumari Wildlife Reserve. The population increased to 34 in 1990, then declined to 22 individuals in 1990–1991 and 14 in 1994 (Harding 2007). Budieri (1995) stated infectious diseases and poorly designed enclosures contributed to the lack of success. Seven gazelles died during a flood in 1994 (Nelson 1985). Thirty Arabian Sand Gazelles are currently present in Shumari Wildlife Reserve (A. Al-Halah. Reserve manager. pers. comm. 2020).

**Threats**

The main threats are illegal hunting (for meat and to a lesser extent for trophies) and habitat loss (due to economic development, conversion to agriculture, and increasing numbers of domestic livestock) while some

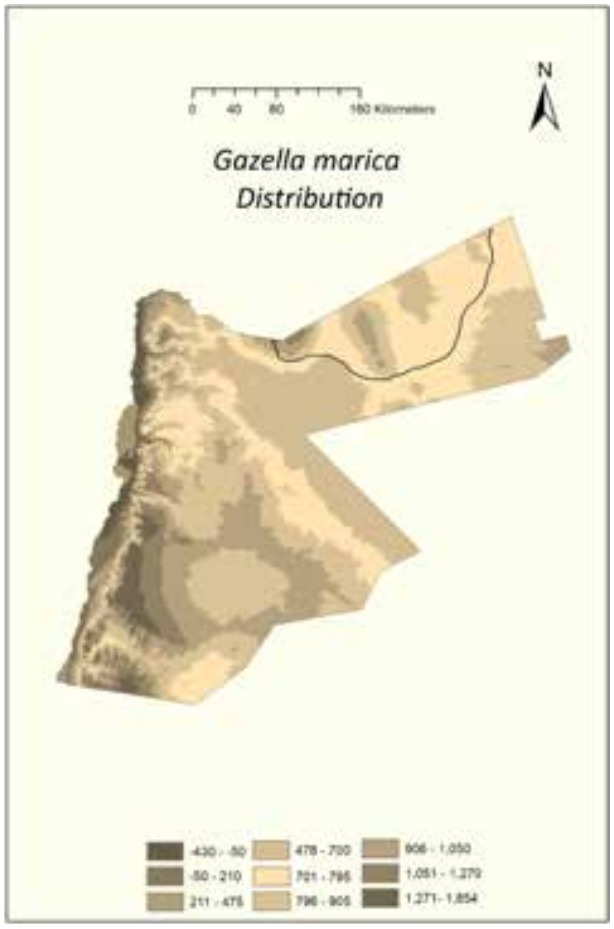


Figure 5. Range distribution of *Gazella marica* in Jordan.

specimens are live caught for private collections (Eid et al. 2020). Eid & Handal (2018) reported images of 23 specimens killed by hunters and posted on Facebook in 2015.

**Conservation Actions**

Arabian Sand gazelle is protected by law, and in-situ at Burqu nature reserve. A small captive-breeding herd is present in the fenced Shumari Wildlife Reserve, but breeding has not been very successful to date. A reintroduction program is needed to reinforce and conserve the remaining wild population, but strict enforcement of the law on hunting is required for any releases to succeed. Eid et al. (2020) listed this species as Critically Endangered in Jordan. Clarke (1976, 1977) proposed wadi Rajil and Burqu as potential reintroduction sites.

**(C4.) *Gazella dorcas* (Linnaeus, 1758) Dorcas Gazelle**

[Vulnerable (IUCN), Critically Endangered regionally, less than 50 individuals]

**Distribution and status**

Bones have been excavated from Neolithic sites in Jordan (Uerpmann 1987). The Schmitz collection has a specimen from Amman (Anon 1946). Recent records are from southern Jordan, from Mujib southwards, mainly in Wadi Araba (Amr & Disi 1988; Amr 2012; Figure 6). The total population in Jordan was estimated at 180–200 (Kiwan et al. 2001) but is now considered to number less than 50 (Eid et al. 2020).

**Threats**

Poaching and land encroachment are the main threats to the remaining populations (Kiwan et al. 2001). Eid & Handal (2018) reported images of two specimens killed by hunters posted on Facebook in 2015.

**Conservation Actions**

Dorcas Gazelle is listed as Critically Endangered in Jordan (Eid et al. 2020) and it is protected by law. Measures are urgently needed to safeguard the remaining small population and to restore the species

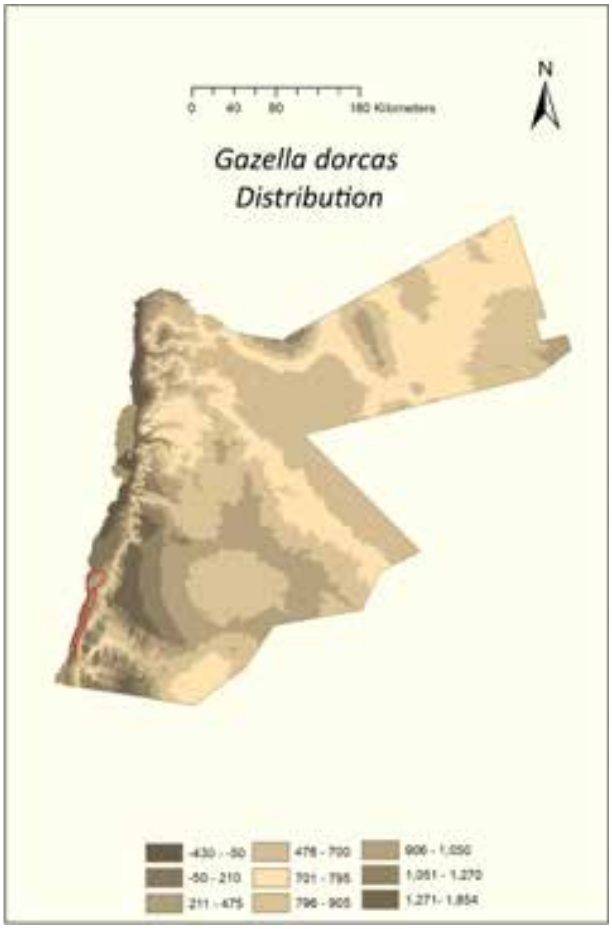


Figure 6. Range distribution of *Gazella dorcas* in Jordan.

through releases and reintroductions into former sites. Potential habitat for this species exists in the western parts of Dana Biosphere Reserves and Rahma Special Conservation Area.

**(D.) Endangered**

**(D1.) *Capra nubiana* (F. Cuvier, 1825) Nubian Ibex**

[Vulnerable (IUCN), Endangered regionally, less than 500 individuals]

**Distribution and status**

The Nubian Ibex is known from archeological sites at several localities across Jordan, in petroglyphs (rock drawings) in the Wadi Rum Protected Area and in mosaics and on the walls of desert palaces and churches in Madaba (Amr et al. 2004). Tristram (1884) reported the species as common from Moab (hills on the eastern side of the Dead Sea), and Jebel Hatrura (near Masada proposed protected area).

The distribution (Figure 7) extends along the western mountains of Jordan from Humrat Ma'ein south to Wadi Rum Protected Area (Amr 2012; Eid et al. 2020). Amr & Disi (1988) recorded ibex in Karak, Wadi Araba, and Ghor Safi. Hatough-Bouran & Disi (1991) stated that the Nubian ibex survived in a few localities along the western mountains of Jordan. Qumsiyeh et al. (1996) and Hays & Bandak (1997) reported ibex presence from Wadi Ibn Hammad Special Conservation Area and Wadi Rum Protected Area. Amr (2012) mentioned that it occurred from the mountains of Aqaba, Al Mazar Al Janobi, Ghawr Al-Mazraa'h, Karak, Al Qadeseyah. Current presence is concentrated in and around Dana and Mujib Biosphere reserves and Wadi Rum Protected Area.

Hatough-Bouran & Disi (1991) warned that ibex was on edge of extinction, but Amr (2012) reported that the ibex managed to persist, despite the rapid decline in its population since the mid-1800s. In 2011, a survey in Dana reserve estimated at least 250 individuals (Eid & Owaji 2011).

A captive-breeding program was initiated in the Raddas area of Mujib Biosphere Reserve in 1989, using 10 captive-bred Nubian Ibex from San Diego Zoo (born spring 1989) along with a locally captured sub-adult male (Khoury et al. 2012). By 1992, the herd had grown to 34 individuals and to 68 adults in 1995. The captive breeding program was terminated in 2006 and RSCN began releasing animals into the wild in 1997 (eight individuals of each sex). In February 1998, six males were released, followed by two main releases in October 1999 (19 individuals) and December 1999 (50 individuals). A survey conducted after the release

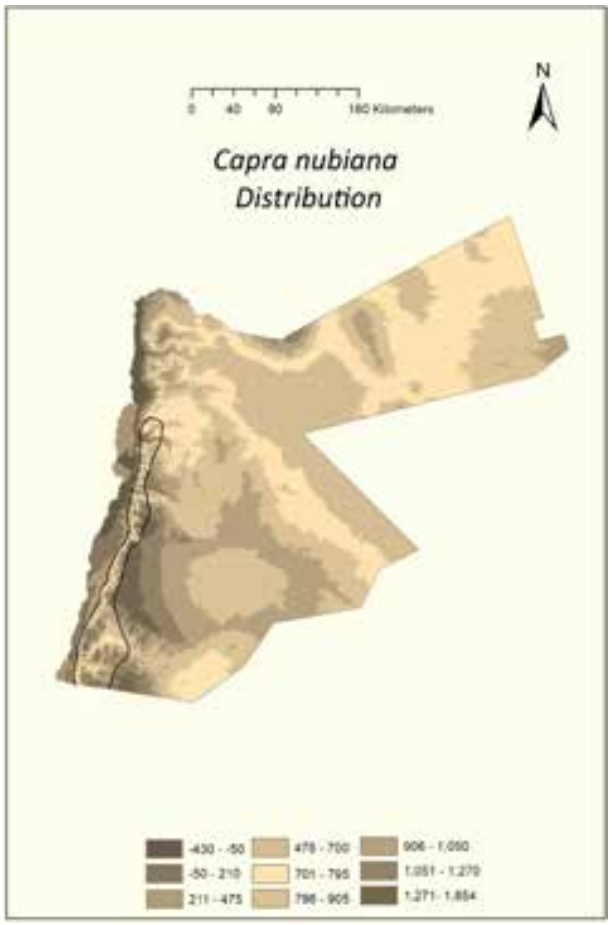


**Figure 7. Range distribution of *Capra nubiana* in Jordan.**

recorded 150 individuals from various localities within Mujib Biosphere Reserve, 143 of them in the Raddas area (Eid et al. 2020). Small numbers were found in several other parts of the reserve, 103 in total (RSCN, unpub. data).

A second captive breeding program was initiated at Wadi Rum Protected Area in 2014, when 100 Nubian Ibex (30 males and 70 females) were donated by the Environment Agency – Abu Dhabi. In October 2015, following appropriate veterinary and genetic tests, 60 individuals were released into the wild (E. Eid pers. obs. 2015). The population in Wadi Rum Protected Area in 2018 is estimated at 80 individuals. Thus, the current population in Jordan is currently estimated at around 480–500 (Dana Biosphere Reserve – 250, Mujib Biosphere Reserve – 150, Wadi Rum Protected Area – 80) (Eid et al. 2020).

**Threats**

Hunting of ibex was legal until 1978 and is considered the major cause of the sharp decline in Jordan (Eid et

al. 2020) and across its range in the Arabian Peninsula (Habibi 1994). Catullo et al. (1996) stated that competition for forage with domestic livestock and hunting for food and trophies were the major threats in Dana Reserve. Hatough-Bouran & Disi (1991) stated that the pressure on the ibex habitat was also becoming more acute because of decreased mobility of the Bedouin livestock herders. The availability and distribution of waterholes which are a key resource may fluctuate from year to year and thus impact on ibex populations (Amr 2012). Disturbance by high levels of tourists at watering, feeding and birthing sites may also threaten the population. Aloufi & Eid (2014) reported ibex trapped or collected from the mountainous and desert areas of the Tabuk region close to the Jordanian border and sold for USD 734–800. Eid & Handal (2018) reported that images of 115 Nubian Ibex that had been shot by hunters were posted on Facebook in 2015, which is a cause for serious alarm.

**Conservation Actions**

This species occurs in Dana and Mujib Biosphere Reserves, as well as Wadi Rum Protected Area (Eid et al. 2020). It is protected by law, but illegal hunting still poses a threat. Therefore, the Government of Jordan and the RSCN are highly recommended to enforce effective anti-poaching measures in reserves and consider further reintroduction programs following IUCN guidelines to support the wild population. Nubian Ibex is listed as Endangered in Jordan (Eid et al. 2020).

**(E.) Least Concern**

**(E1.) *Sus scrofa* (Linnaeus, 1758) Wild Boar**

[Least Concern (IUCN), Least Concern regionally, numbers unknown but common]

**Distribution and status**

Boessneck & Von den Driesch (1978) and Gerrard et al. (1988) stated that remains were excavated from several archeological sites dating back to the upper Paleolithic period. Tristram (1884), reported that the wild boar "is abundant in every part of Jordan, even in the desert habitats". *S. scrofa* was introduced to Azraq where it became common but later disappeared according to Meinertzhagen (1924). Wild Boars occur in river valleys, cultivated areas, and forested hills; they may be observed in desert areas but do not move far from water (Harrison & Bates 1991). Amr & Disi (1988) frequently saw this animal around north Shounah and the Yarmouk River. Qumsiyeh et al. (1996) reported a large population in Jordan and confirmed that this species is still common in the Jordan valley, south of Ghor Safi. Eid & Ananbeh (2009) reported this species as common in Ajloun Forest Reserve (Figure 8). Wild Boars are agricultural pests and have caused damage to citrus farms along the Jordan Valley (Rahamat 1982).

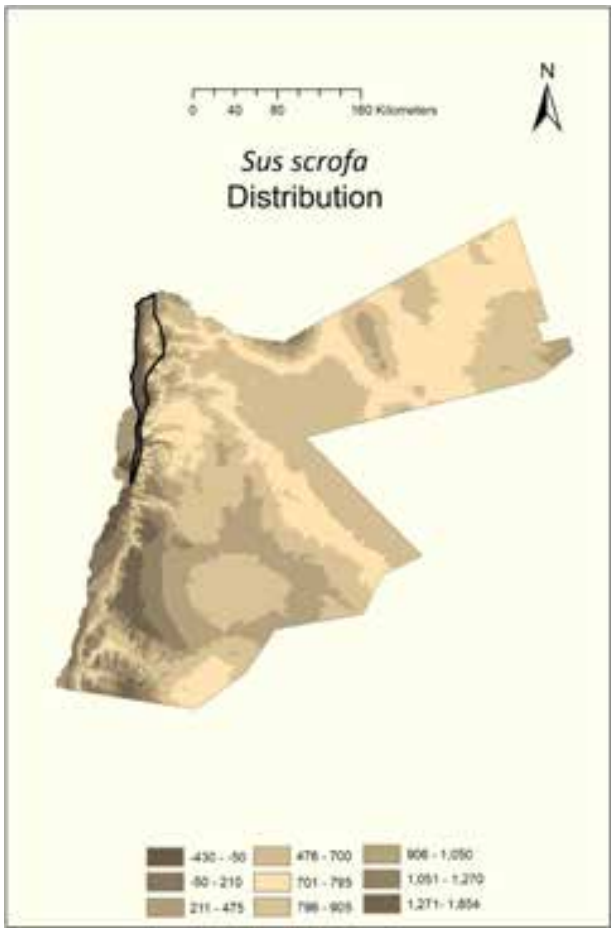


**Figure 8. Range distribution of *Sus scrofa* in Jordan.**

There is no accurate estimate for the population of the Wild Boar in Jordan, but it is not considered threatened and numbers are increasing (Quemsiyeh et al. 1996; Amr 2012; Eid et al. 2020). The government allowed hunting of Wild Boar in 2010 to control its numbers due to the increasing damage to crops, and as a precautionary step in controlling swine flu (Amr (2012). However, the population is increasing for various reasons, including their presence in border areas which are protected by the army, the fact that this animal is not allowed as a food for Muslims (Quemsiyeh et al. 1996), and the lack of interest by hunters.

**Threats**

There are no significant threats to the Wild Boar in Jordan. Eid & Handal (2018) reported 40 specimens

killed, based on Facebook posts by Jordanian hunters.

**Conservation Actions**

Wild Boar was listed as Least Concern in Jordan (Eid et al. 2020). The species occurs in Ajloun Forest Reserve, Dibeen Forest Reserve, and Yarmouk Forest Reserve (Eid et al. 2020). No specific conservation measures are required.

## DISCUSSION AND CONCLUSIONS

The majority of ungulate species in Jordan have been exposed to many pressures and threats that have significantly reduced their numbers and led to the extinction of several of them. The major threat is extensive and uncontrolled hunting, accelerated by the increased power of modern automatic weapons, and the development and use of all-terrain vehicles which enable people to venture into any part of the territory of Jordan. A second important factor is a significant increase in the numbers of domestic livestock, resulting in a serious deterioration in the quality of rangelands through depletion of palatable plants, soil erosion, and desertification. Feral dogs may also predate wild ungulates. These factors are considered the major challenges that need to be overcome to ensure the success of any future re-introduction projects in Jordan

Mesopotamian Fallow Deer has been extirpated from Jordan and populations elsewhere are so small that establishing a captive breeding program for reintroduction appears unrealistic at present. Arabian Oryx and Wild Ass have also been extirpated, although a small semi-captive population of Wild Ass is maintained in Shumari Wildlife Reserve, and larger populations of Arabian Oryx in Shumari Wildlife Reserve and Wadi Rum Protected Area. There are substantial global and regional ex situ populations of both species, especially Arabian Oryx, that could provide source stock but releases into the wild currently face formidable obstacles, principally the unavailability of an extensive area of good habitat and the difficulty in protecting such wide-ranging species from hunting.

Mountain Gazelle range in Jordan has contracted to the extreme north of the Jordan valley and no confirmed observations have been reported since 2015. Animals may cross into the country from adjoining areas, but a reinforcement and reintroduction programme appear the most reliable way to re-establish their permanent presence. Roe deer have been reintroduced but again no sightings have been confirmed since 2015 and it is unclear whether the animals have failed to establish or have dispersed.

Arabian Sand Gazelle and Dorcas Gazelle now occur only in very small populations (<50) in the north-eastern desert and southern Rift Valley (Wadi Araba), respectively. Such small populations are highly vulnerable to extinction from ongoing threats, stochastic events, and low genetic diversity. Both species appear close to extirpation in the wild in Jordan. Reinforcement of the surviving populations, and/or reintroductions to other sites within their former range are needed to ensure the persistence of these two species in Jordan.

Nubian Ibex is present in higher numbers (<500) and occurs in Mujib and Dana Biosphere Reserves as well as Wadi Rum Protected Area, and thus receives some protection. However, these sites are isolated from each other by physical barriers (Eid et al. 2020). So, efforts to identify, and then protect, corridors between them may become a priority.

There are breeding herds of some species at Shumari Wildlife Reserve, and animals held at Al Mawa' for Nature and Conservation, belonging to the Princess Alia Foundation, could also be used as a genetic reservoir. However, the current conditions at both these sites are not sustainable, since the breeding groups are increasing, and there is no long-term program for release into the wild due to the existing threats and land use issues, so this will place more financial burdens on the hosting institutions.

The growing interest in business-based conservation that relies on the eco-tourism sector rather than the previous modality of nature-based conservation is another factor that might hinder the establishment of new programs to reintroduce ungulate species. Enforcement has been strengthened following the establishment of the Royal Department for Environmental Protection (RDEP) in 2006, which was merged with the tourism police in 2020 to form the Royal Department for Environmental Protection and Tourism. However, increasing the number of protection staff, stronger logistical and financial support as well as capacity building programs, are required to ensure that enforcement and protection are effective. Financial resources may be allocated by the Government of Jordan represented by the Ministry of Environment to support the work of the RSCN, RDEP and other organizations in strengthening enforcement and conservation efforts as well as conducting research within Jordan's protected areas. Scientific research needs to be designed to support policies, development of legislation, and management of species and habitats. More collaboration

and coordination have to be developed between experts in this field, and the responsible entities in order to exchange information, and research outputs.

However, it would be preferable to begin by regarding these charismatic species as an aspect of natural capital in which to invest for the future. Successful re-introduction programs can be a key driver of nature-based tourism, instead of following a narrower, business-based tourism model. All international standards should be applied, especially the IUCN guidelines on reintroductions and translocations, before considering any species for re-introduction.

The latest red data book of the mammals in Jordan (Eid et al. 2020) highlighted the alarming situation, with four ungulate species assessed as Critically Endangered and three species Regionally Extinct or Extinct in the Wild in Jordan. This highlights the need to ensure effective enforcement and initiate measures to reverse habitat degradation and control of hunting in order to facilitate reintroduction programs and develop more collaboration and partnerships at regional and global levels, increase awareness of the importance of ungulates, and above all to enhance finance allocations for conservation purposes.

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VIEWPOINT

# The captive population of the Lion-tailed Macaque *Macaca silenus* (Linnaeus, 1758). The future of an endangered primate under human care

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**Abstract**: For conservation breeding, the endangered Lion-tailed Macaques have been maintained in North America under SSP since 1983 and in Europe under EEP since 1989. Based on a growing interest to support the species long-term survival, the SSP population increased considerably during the first few years of the programme but due to space problems and resulting birth control measures, it has drastically declined to small numbers and a non- breeding status at present. The EEP population continually increased till 2012, but due to the lack of spaces and birth control practises, it has gradually declined since then. It is emphasised that the knowledge gained from field studies on Lion-tailed Macaques in India and its incorporation for captive management under EEP has helped develop appropriate management strategies. Captive propagation of the Lion-tailed Macaque in India, the habitat country, can profit from the successes and drawbacks of the long-term management experiences of SSP and EEP.

**Keywords**: Captive breeding, SSP, EEP, Indian captive population, meta population management.

For most of its history, the captive population of the Lion-tailed Macaque (LTM) was mainly constituted by the North American and the European subpopulations and by a number of other small subpopulations (e.g., India and Japan). Figure 1 and Figure 2 provide an overview on its development, births, imports, and losses. They, like other data used for this paper, are based on the last edition of the international studbook for the LTM (Sliwa & Begum 2019). The North American breeding programme (Species Survival Plan, SSP) for the LTM was established in 1983 with 163 individuals in about 30 zoos (Gledhill 1985). The European programme (European Endangered Species Programme, EEP) was established in 1989, comprising 89 individuals in 12 institutions. Currently, the latter comprises 322 individuals in 44 institutions. The EEP was coordinated by Dr. Werner Kaumanns (German Primate Center; since 2000 curator of primates at Cologne Zoo) till his retirement in 2006. Dr. Alexander Sliwa, Cologne Zoo, is the coordinator since then. The European population grew slowly but steadily to a size of 338 individuals in 2012 but decreased to a current size of 322 individuals in 2018 (Figure 1). The number of births decreased drastically since 2011 (global- Figure 2, European- Figure 3, for more information see below). The American SSP population with its first coordinator and (International)

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**Population development**

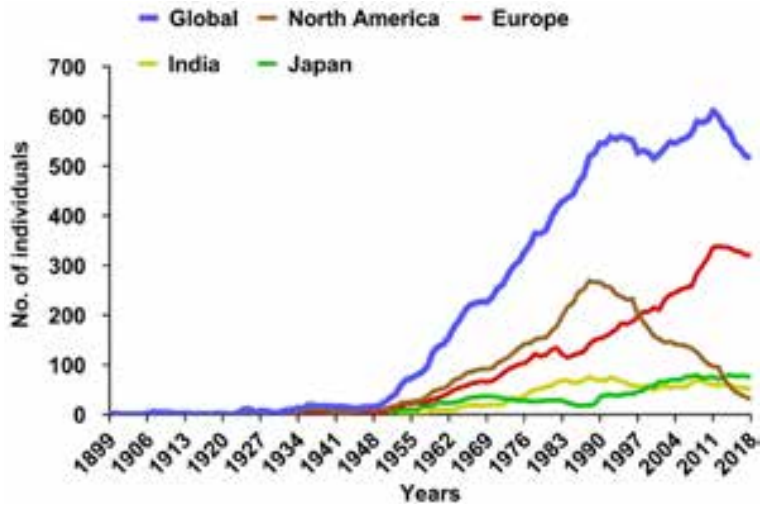


Figure 1. Development of the global historical population.

**Population dynamics**

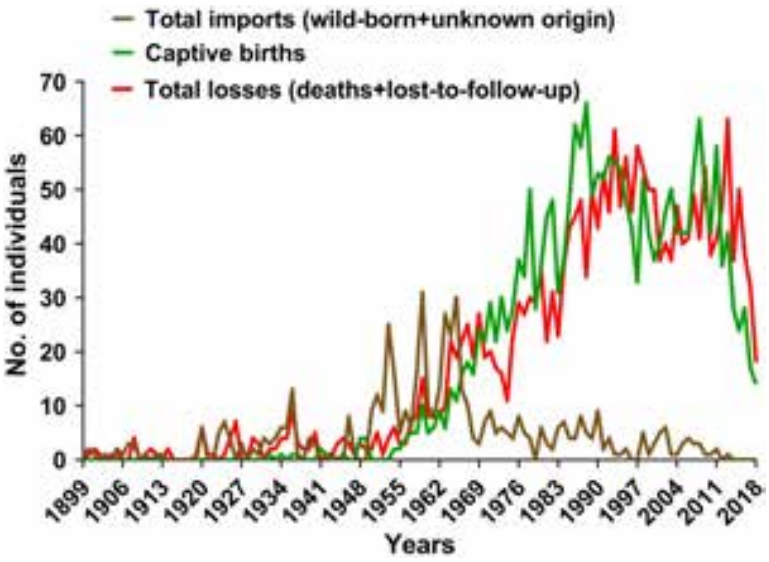


Figure 2. Annual number of imports, births and losses in the global historical population

studbook keeper Laurence Gledhill had its peak size and productivity in the decade after the start of the SSP, with about 269 individuals in 1988. Currently, there are only 31 individuals living (Sarno 2018). The reasons for the decrease were space problems, widely executed birth control measures in the 1990s, ageing, and possibly loss of interest (Lindburg 2001; Ness 2011, 2013). The Indian captive population currently comprises 51 individuals including 16 wild-born macaques. The Japanese Lion-tailed Macaque subpopulation has 76 individuals; other smaller stocks comprise 36 individuals totally.

The current global population comprises 516 individuals in 98 zoos. The wild population of the LTM at present is estimated to be about 4,000 individuals, distributed in 47 isolated subpopulations at seven locations (Singh et al. 2020), with less than 2,500 mature individuals in about 200 groups. The current captive population in 98 groups, therefore, constitutes about 11% of the global population.

The breeding programmes for the LTM always acted with a perspective on the species in the wild. The establishment of the SSP for the LTM was realised assuming that at that time only about 1,000 LTMs were left in the wild (see Hill 1971). To establish a

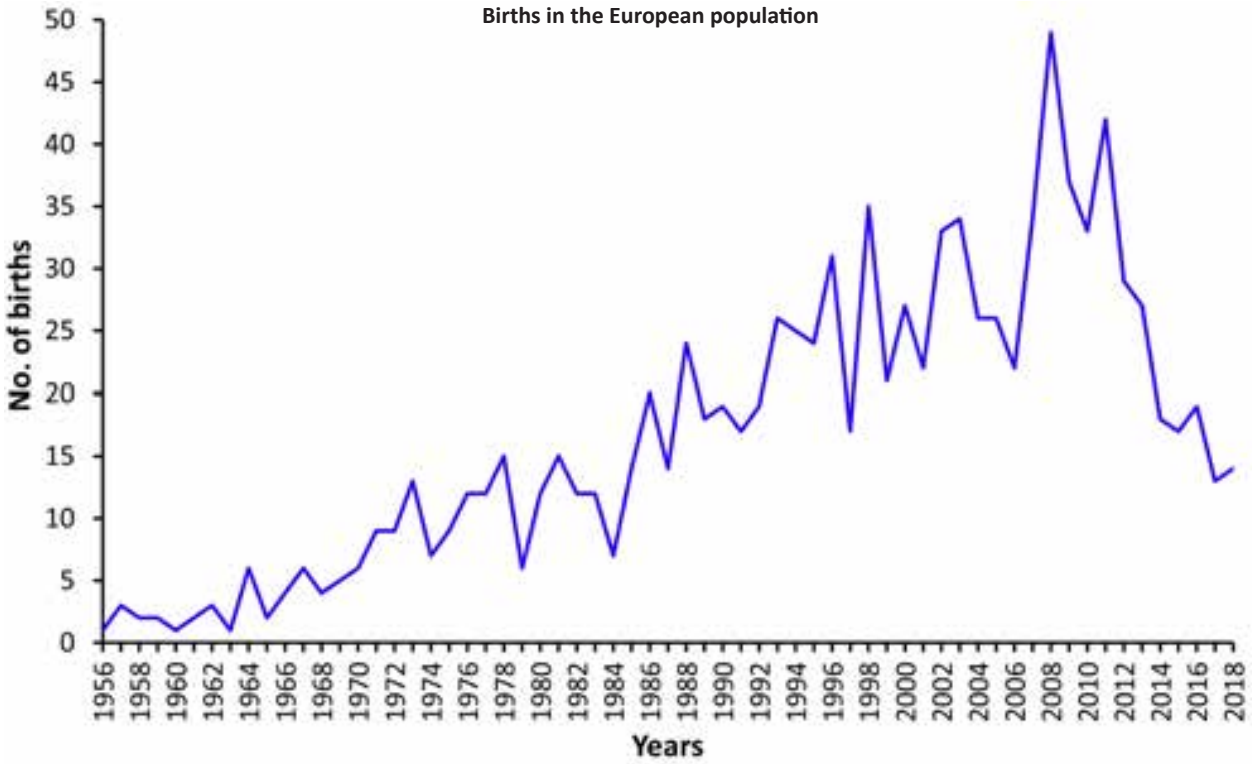


**Figure 3. Annual number of births in the European population.**

reserve in zoos was intended. Contacts and cooperation between American and Indian institutions were realised (including financial support for field studies). American scientists and especially Dr. Donald Lindburg, San Diego Zoological Society, contributed important studies both with reference to the biology of the species and its captive propagation (e.g., Lindburg et al. 1989; Lindburg & Gledhill 1992; Lindburg & Harvey 1996).

Almost since its establishment, the European LTM population was managed in contact with Indian wildlife biologists. Results from their studies on the wild population in its natural habitat (Western Ghats, southern India) were integrated. Since 1998 (till 2004) the annual reports for the captive population also reported on the status and other relevant aspects of the wild population. This was based on a close (ongoing) cooperation of the first EEP coordinator with Dr. Mewa Singh and Dr. Ajith Kumar. Prof. Mewa Singh, University Mysore, leading Indian primatologist, and wildlife biologist visited Germany to work on LTM matters with Dr. Werner Kaumanns since the 1990s more than 25 times. Mainly due to Mewa Singh and his working group, the conservation of the LTM became and is still an important issue in India. In addition to grants from major Indian sources, some of the studies were financially supported by German Primate Center, Volkswagen Foundation, various American and European zoos, and private persons. Due to this work, the current status of the species and conservation needs are well known, and the Lion-tailed Macaque is one of the best-studied macaque species, both in the wild and in captivity (for an overview see Singh et al. 2009 and Kaumanns et al. 2013). In situ and ex situ studies resulted in a large number of publications that cover aspects of husbandry and management, conservation and especially many aspects of the species biology. A number of Prof. Singh's students were involved in Lion-tailed Macaque studies and will continue working for the conservation of the species. Efforts to save the LTM in India got much support through the Fifth International LTM Conference in 1999, that was organised by Mewa Singh at the University of Mysore and supported by the EEP coordinator. Two volumes (58, 59) of German Primate Center's Primate Report (Schwibbe et al. 2000, 2001) report on the results of the conference. These reports provide an overview on the status of in situ and ex situ research and captive propagation efforts for the species.

The contact with Indian colleagues, the involvement in field studies on a number of aspects of the species biology, and the resulting knowledge, significantly influenced the management of the EEP population. From the beginning of the EEP's existence, the

importance of behavioural and especially social aspects, breeding patterns and aspects of life histories were emphasised. According to Singh et al. (2006), especially considering the reproductive system and social system of the species, is the key to the conservation of the species. EEP policy strongly went for this. Although close cooperation between EEP and SSP was initiated during the Third International LTM Conference (1990) in San Diego, the programmes developed differently. In the SSP population, birth control on a large scale, based on a strict genetic management was carried out from about 1988 onwards (Lindburg & Gledhill 1992; Lindburg et al. 1997; Lindburg 2001). Figure 1 demonstrates the effects on the development of the global historical population. It also shows the latter's "recovery" (2001–2011) and a new decline from 2012 onwards. This results from a strong decrease in the number of births (Figure 2). This decrease is induced by the development of the European population (Figure 3). Birth control has been carried out there, too, to deal with space problems. Under these pressurising conditions, the EEP long-term management plan edited in 2016 (Sliwa et al. 2016) recommends further birth control measures on a large scale.

Birth control on a large scale over long periods of time to control population size, however, can have enormous risks for the survival of a population. The example of the SSP population and a number of relevant studies (Kaumanns et al. 2013; Penfold et al. 2014; Kaumanns & Singh 2015; Kaumanns et al. 2020) demonstrate possible negative consequences and elaborate ways to stop negative trends.

We are afraid that under the conditions given, the EEP population's and therefore the global captive population's, long-term survival is threatened – given the trend in population development continues and no serious changes in management are initiated soon. The 'Endangered' status of the LTM in the wild (Singh et al. 2020) with increasing fragmentation of its range of distribution and habitat destruction, strongly recommend, to continue with preserving a reserve in zoos, especially in India. Measures to stabilise the European and thus the global captive population, and new steps towards achieving its long-term survival are urgently required in order to prevent a loss of reproductive potential, like it happened in the SSP population. The European population is the only captive population that is still large and potentially productive enough to be developed further as a reserve. It seems, that space problems and other infrastructural limitations currently hinder to achieve this goal. EEP participants should consider whether all means to allow more breeding again are *really* exhausted or whether stopping birth control or more moderate schedules are possible, at least. It is suggested that more should be done to preserve the population's breeding potential, size, and structure, with the goal to send European LTMs back to other regions and especially to their country of origin.

Zoos in India keep a small LTM population with a number of potential founders. Many zoos however report breeding problems. According to the last edition of the international studbook, totally 51 animals are kept in 10 Indian zoos, six of which keep less than three animals each. There are two zoos with more individuals – Chennai (n= 20) and Trivandrum (n= 10). These group sizes come close to group sizes in the wild. Historically, Chennai Zoo contributed to more than one-third (n= 64) of the captive births in India (n= 185) and between 2003 and 2018, it contributed to 75% (n= 45) of births in Indian zoos (n= 60) in this period. This might be due to an accumulation of husbandry know-how, personnel experience, and constancy in the management system. Delhi Zoo played an important role in the past by contributing to 49 births, many of them in the 1970s–80s. Judging from the experiences in the European breeding programme, successful breeding requires allowing groups to grow undisturbed, to larger sizes of around 20 individuals with differentiated demographic structures that allow the females to live permanently in their natal groups and to maintain strong social bonds (female-bonded system; see Kumar 1987). This would allow intergenerational overlap and to acquire the necessary social and cognitive competence to interact properly in a complex social system and to raise offspring (Kaumanns et al. 2013). According to field observations, only the males are the mobile elements of the Lion-tailed Macaque social system (Kumar 1987; Kumar et al. 2001). Under captive conditions only males should be transferred between groups (for details see Kaumanns et al. 2006). More information derived from the studies in the wild (e.g., Kumar 1987; Krishnamani & Kumar 2000; Umapathy & Kumar 2000; Sharma 2002; Sushma 2004; Singh et al. 2006) is available to be used in designing keeping systems for the species. It refers to the species' arboreal life, selective and individualised foraging on diverse plant and animal species, seasonal variations in diet, large time spent in foraging and exploration, maintenance of large interindividual distances, low reproductive turnover, and a number of special features of the reproductive system. Many aspects have been emphasised for the management of the species in the international breeding programmes. Their consideration would also support successful breeding in the country

of origin especially with its advantage of natural living conditions, availability of native food plants and large open-air enclosures.

The Indian zoo community is interested in building up a larger, more productive population in cooperation with the European Breeding Programme (Govindhaswamy Umapathy, pers. comm. 03.viii.2020). This constellation provides a chance to develop perspectives and solutions for problems on both sides. A cooperation could provide spaces for Lion-tailed Macaques from European zoos. Even more importantly, a larger and productive Indian population supported both in terms of animals and know-how from Europe could serve as an interface between the captive and the wild populations. It could be used for a number of conservation purposes – including providing animals for reintroductions in the long run. The establishment of an "Indo-European Lion-tailed Macaque reserve population" would require careful planning. An integrated (One-Plan) approach needs to be developed that aims at the integration of the know-how on the species and the conservation-oriented research interests as provided by the above-mentioned Indian scientists and their institutions. It furthermore should aim at the development of the infrastructural conditions in selected Indian zoos as required for an appropriate management and husbandry aiming at conservation breeding (for a more elaborated outline on this topic see Singh et al. 2012). Research institutions, selected Indian zoos in the range states of the species (like Chennai, Trivandrum, and Mysore) and the EEP should cooperate closely. A small board of experts from these institutions should be established to guide and supervise the project. Previous attempts to establish a breeding programme for the LTM in India and to transfer breeding groups from the USA and from Europe did not work out well due to bureaucratic issues and difficulties with local competence and motivation (see also Krishnakumar & Manimozhi 2000; Singh et al. 2009). The proposed new approach should be designed such that corresponding problems are minimised. It is of particular importance to 'institutionalise' captive propagation of the LTM in its country of origin more strongly. It should include to choose a competent coordinator who permanently overlooks and organises the work above the level of individual zoos and is supported by the Central Zoo Authority of India. A successfully carried out project would also serve as a model for other species and co-operations. It could help to establish Indian zoos as important partners in metapopulation management programmes especially concerning endemic Indian species like the LTM. It is important to note thereby, that time is running out for the development and establishment of international metapopulation management programmes (see Macdonald & Hofer 2011; Powell et al. 2019). They are needed to overcome the sustainability problems threatening many captive populations. Many of them are shrinking for instance due to breeding problems. In terms of climate, available space, and other resources, a number of zoos in India could establish very good keeping systems for the LTM. As elaborated by Singh et al. (2012), conservation breeding in Indian zoos, however, still requires a serious change in professional attitudes, training opportunities and infrastructural requirements. The future of the global captive population of the LTM, for instance, may depend on progress there.

Many zoos and many dedicated people in several countries worked for the survival of the LTM in the wild and for the establishment of a reserve population under human care over many decades. They achieved a lot. Currently, much of what has been achieved with the captive population is at risk. To allow a development ending with a captive LTM population without much breeding and thus with a low conservation potential would be against professional standards and simply sad.

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SHORT COMMUNICATION

# Jaguar *Panthera onca* (Linnaeus, 1758) (Mammalia: Carnivora: Felidae) presumably feeding on Flathead Catfish *Pylodictis olivaris* (Rafinesque, 1818) (Actinopterygii: Siluriformes: Ictaluridae) at Aros and Yaqui rivers, Sonora, Mexico

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***Abstract:*** Despite the abundant literature on the feeding preferences of the Jaguar *Panthera onca* throughout its range in America, few studies report fish consumed as prey by Jaguars. This paper reports two accounts of Jaguars presumably feeding on the introduced Flathead Catfish *Pylodictis olivaris* at the Aros and Yaqui rivers in Sonora, northwestern Mexico.

**Keywords**: Diet, feeding preferences, fish remains, northwestern Mexico.

The Jaguar *Panthera onca* is known to forage on over 85 prey species (Weckel et al. 2006), mainly on a large variety of mammals, birds, reptiles, and fish (Gudger 1946; Emmons 1987; Aranda & Sánchez-Cordero 1996; Polisar 2000; Garla et al. 2001; Polisar et al. 2003; Weckel et al. 2006; Azevedo & Murray 2007; Castañeda et al. 2013; Hayward et al. 2016). It preys on aquatic and semi-aquatic fauna, such as *Caiman* species in Brazil (Da Silveira et al. 2010), Morelet's Crocodile *Crocodilus moreletti* in Calakmul, Mexico (Aranda & Sánchez-Cordero 1996; Pérez-Flores 2018), large marine turtles such as *Chelonia mydas*, *Dermochelys coriacea*, *Eretmochelys imbricata*, and *Caretta caretta* throughout America (Arroyo-Arce & Salom-Pérez 2014; Fonseca et al. 2020), *Lepidochelys olivacea* and *C. mydas* on the Pacific coast of Costa Rica (Carrillo et al. 1994; Alfaro et al. 2016; Fonseca et al. 2020). One individual was observed scavenging on a dolphin carcass in Honduras (Castañeda et al. 2013). Other semi-aquatic prey consumed by Jaguars in the Amazon river basin are the Capybara *Hydrochoerus hydrochaeris* (Schaller & Vasconcelos 1978; Weckel et al. 2006; Da Silveira et al. 2010) and fauna associated with water bodies like the Baird's Tapir *Tapirus bairdii* in the Calakmul region (Pérez-Flores et al. 2020). Jaguars also hunt Giant Otters *Pteronura brasiliensis* in Guyana and Brazil (Shackley 1998; Ramalheira et al. 2015). Regarding fish, Jaguars feed on piranha *Serra salmus* in Alto Pantanal, Brazil (Da Silveira et al. 2010). Fish make 5% of Jaguar prey at Río Manu, Parque Nacional Manu

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in Peru (Emmons 1987). The Jaguar diet comprises 21 fish species at Llanos Altos, Venezuela (Polisar 2000). Although the Jaguar is adapted to exploit rivers, lagoons, and coastal areas where large prey species are available, it is also important to record fish as a key component of the Jaguar's diet. No published accounts of Jaguars preying on fish in Mexico are currently available.

The Jaguar is listed as an endangered species in Mexico (NOM-059-ECOL-2010) and as Near Threatened in the IUCN Red List of Threatened Species (Quigley et al. 2017). This felid species needs close and regular monitoring in key regions of the country to ascertain its status. The presence of Jaguars in the state of Sonora is highly important for representing the northernmost population of this large felid in Mexico and Latin America (López-González & Brown 2002; Rosas-Rosas & Bender 2012). Currently, Jaguar populations in northern Mexico have remained stable since large land areas are dedicated to preservation in several ranches. An example is the Northern Jaguar Project, which includes two ranches, Los Pavos and Zetasora, totalling 35,000ha. Other 17 nearby ranches participate in voluntary projects such as the 'Living with cats' initiative, comprising about 35,600 ha to support Jaguar conservation in this area of Sonora. In southern Sonora, the Monte Mojino Reserve dedicates 7,370 ha to Jaguar conservation (Blust 2019). Multiple camera traps record large amounts of information on individual Jaguars in these large areas of Sonora, which has led to the establishment of a Jaguar corridor in interior areas of Sonora, far from the arid landscapes of the Sonoran Desert (Rosas-Rosas & Bender 2012).

Here I describe two incidents of fish presumably caught by Jaguars at the Aros and Yaqui rivers in central Sonora, observed while monitoring Bald Eagles *Haliaeetus leucocephalus* and Neotropical Otters *Lontra longicaudis*.

## Observations

On 7 May 1995, my companion and I were surveying the confluence area of the Bavispe and Aros rivers that make the Yaqui river in northwestern Mexico (Figure 1). We travelled upstream in a canoe on the Aros river while searching the riverbanks for Neotropical Otter tracks and latrines, of which we found several. We noticed

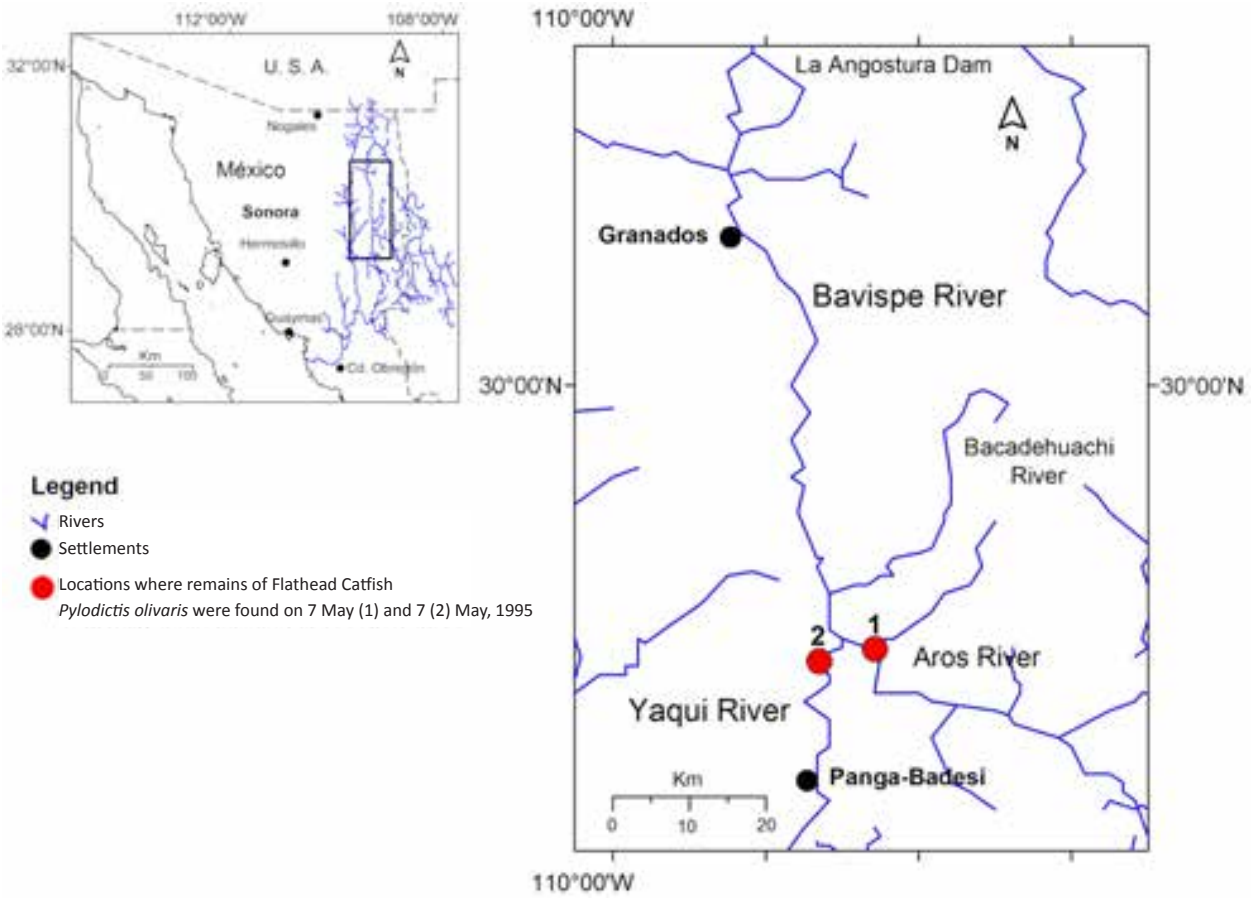


**Figure 1. Map of the study area in Sonora, Mexico.**

**Image 1. Flathead Catfish *Pylodictis olivaris* presumably preyed on by Jaguar *Panthera onca* and scavenged by Coyote *Canis latrans* and Black Vultures *Coragyps attratus* at Aros river, Sonora, Mexico. © J.P. Gallo-Reynoso.**

large tracks on the northern riverbank 3 km upstream that made us approach the shore, assuming they were of a Mountain Lion *Puma concolor*. Instead, the tracks observed resembled tracks of a Jaguar according to the field guide of animal tracks by Aranda-Sánchez (1981). These tracks, which seemed to be about a week old, showed that the individual had moved upstream along the riverbank. We followed the Jaguar tracks and lost them in a rocky area facing a large and deep pool, where the cat seemingly climbed. We found a Neotropical Otter latrine above those rocks and collected spraints. The otter tracks continued from the rocks to the riverbank, and we followed them to behind a rock. There, we again found the week-old Jaguar tracks coming from the water. We followed the tracks further up and found the almost entirely devoured carcass of a Flathead Catfish *Pylodictis olivaris* measuring about 1 m in length, which probably weighed 10 kg (Sergio Avila pers. comm. 11 October 2019) (Image 1). Avila had previously weighed one of these catfish individuals at the Aros river and recorded 10 kg. The inspection of both these large fish remains and the Jaguar tracks made us think that the catfish was taken out of the water and dragged to the sandy riverbank between tall vegetation composed of Jarilla *Baccharis salicifolia*, where it was eaten the previous week. The large size and estimated weight of the fish ruled out the possibility that a Neotropical Otter had captured and dragged it out of the water this far. The size of the catfish head and remains suggest it was a significantly heavy fish for an otter to take out of the water, although large fish have been recorded to be preyed upon by Neotropical Otters. There were no otter tracks around the carcass, but only those of the Jaguar and some tracks of a Coyote *Canis latrans*. From the inspection of the carcass, we determined that the fish was probably scavenged by the Coyote, as several bones were crushed and scattered. Tracks of Black Vulture *Coragyps attratus* and White-tailed Deer *Odocoileus virginianus* were also observed in the area.

Several hours later, after leaving our camp at the confluence of the Bavispe and Aros rivers to continue our monitoring of Bald Eagles and Neotropical Otters, we noticed a freshly killed partially eaten catfish some 7 km downstream, about 10 km away from the first location (Figure 1). It was submerged in a shallow area less than 50 cm deep in the middle of the Yaqui river. The fish was probably killed in this shallow and wide area of the river, but was not taken out of the water by the predator. We lifted it into the canoe for identification. It was a large Flathead Catfish, olive dorsally, yellowish ventrally, about the same size as the one previously found scavenged at the Aros river. We noticed several gashes on the body that appeared to have been made by raptor claws. Initially, we thought that it had been caught by a Bald Eagle *H. leucocephalus* that nested nearby, but it was not taken out of the water. We also determined that the probability of this catfish individual being killed by a Neotropical Otter was low because the marks on

its body were longer, and the slashes made by claws were more extended than would be expected from an otter. Upon a detailed inspection, we determined that the large and heavy fish probably weighed over 10 kg and was slashed by large paws on both flanks, the gills, and other parts of the body. The catfish suffered deep wounds on its head from large and widely separate incisors and was crushed by a powerful bite, most likely inflicted by a Jaguar. The bite certainly killed the catfish. We left the fish remains in the same spot, then moved to the western riverbank, where we found a set of fresh Jaguar tracks with old White-tailed Deer tracks nearby.

## Discussion

These two observations of large Flathead Catfish individuals presumably killed and eaten by Jaguars in two different rivers suggest that either a single or two different Jaguars roaming in the area preyed on these large introduced catfish, which are an available food resource (Campoy-Favela et al. 1989; Leibfried 1991; Varela-Romero et al. 2011). Schaller & Vasconcelos (1978) reported that Jaguars leave large portions of the prey uneaten when perturbed or satiated. The Flathead Catfish is an unexpected food source for Jaguars in this part of Sonora, an area where Jaguars have been documented to prey on White-tailed Deer, hares *Lepus*, rabbits *Sylvilagus audubonii*, Collared Peccary *Pecari tajacu*, White-nosed Coati *Nasua narica*, cattle and other smaller prey (Rosas-Rosas et al. 2008) locally available, as shown by the White-tailed Deer tracks. On the other hand, Neotropical Otters eat their prey near the edge of the water, mostly on rocky substrates (Gallo 1996). The analyses of spraints collected at the same area showed that they feed on a variety of fish species in these two rivers, which are also available as prey for Jaguars. Ninety percent of the otter's diet is composed of introduced fish, of which five are dominant: Channel Catfish *Ictalurus punctatus*, Yellow Catfish *Ameiurus melas*, Largemouth Bass *Micropterus salmoides*, Flathead Catfish, and Tilapia *Oreochromis* (Gallo 1996). These large fish are likely preyed on by Jaguars as well. For comparison, the Neotropical Otter also feeds on Flathead Catfish, but the bone remains found in otter spraints were smaller than the sizes of the individual fish presumably preyed upon by Jaguars. These felids are good swimmers capable of crossing large expanses of water; they swim across rivers and lagoons to gain access to places at the other margin of these water bodies searching for food (Da Silveira et al. 2010). This behaviour was observed in a coastal lagoon in Campeche, where Jaguars swam to an island more than 200 m away from the bank (Gallo-Reynoso 2012). At Chichankanab lagoon in Quintana Roo, we have observed large tracks of a Jaguar emerging from the water to a muddy riverbank following the tracks of a tapir after having swum across the lagoon, which harbours a high density of Morelet's Crocodiles (Gallo-Reynoso and Ortega-Padilla, pers. obs. 17 October 2018). Knowing that Jaguars can capture large prey from aquatic habitats, there is no doubt that they can catch large fish such as the Flathead Catfish and presumably consume them as prey.

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NOTE

# Life near a city: activity pattern of Golden Jackal *Canis aureus* Linnaeus, 1758 (Mammalia: Carnivora: Canidae) in a habitat adjoining Bhubaneswar, India

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Activity patterns of a species are shaped by its biological requirements (Wrangham & Rubenstein 1986), and are often influenced by its foraging behaviour, prey behaviour, predator pressure, physiological traits, vegetation cover, and climatic condition (Seidensticker 1976; Servin et al. 1991; Ilemin & Gürkan 2010; Kachamakova & Zlatanova 2014). Nature and intensity of various anthropogenic activities also greatly impact behaviour and activity patterns of wild animals (Barrueto et al. 2014; Thorsen 2016). In fact, the influence of human disturbances compels wild animals to be more nocturnal (Gaynor et al. 2018).

Golden Jackals are the commonly occurring wild canids in India and inhabit a wide range of habitats from forest to grasslands, mangroves, urban as well as semi urban areas (Menon 2014). Although the species is more generalist in habitat and diet preference, and tolerates human presence, its population has significantly declined in the recent past in many parts of the distributional range including India (Jhala & Moehlman 2004; Giannatos et al. 2005). Studies on the behavioural aspects focused on activity patterns of Golden Jackal are limited in India (Majumder et al. 2011; Gupta et al. 2016; Ojha et al. 2017; Mukherjee et al. 2018). Here, using camera trap photo capture rate I report the activity patterns of Golden Jackal from a protected habitat surrounded by densely human populated urban area in Odisha, eastern India.

The study was conducted in Bharatpur and Jagannathprasad forest sector of Chandaka-Dampara Wildlife Sanctuary in Odisha (Figure 1). The area lies between 20.286–20.360 °N & 85.756–85.810 °E covering an area of 19.27km² along the eastern side of the sanctuary adjoining Bhubaneswar, the capital city of Odisha. Vegetation of the area is composed of mixed dry deciduous forest and bamboo brakes and major portion of it is covered with shrubby vegetation. As the area adjoins the city, it experiences severe anthropogenic pressure from the growth and development of the city. I deployed nine camera traps (Cuddeback, USA) for four months from January to April 2019 as part of a study on monitoring the mammalian fauna in the study area. I first divided the area into 1 km² grids and deployed one camera in each grid for 25 to 30 days. Cameras were installed along motorable roads and foot paths by strapping them on trees approximately 50 cm above ground and set operational 24 hours/ day. Cameras were programmed to take two consecutive photos registering date, time, and temperature for each exposure with 30 seconds delay for the next exposure. I rated each photo

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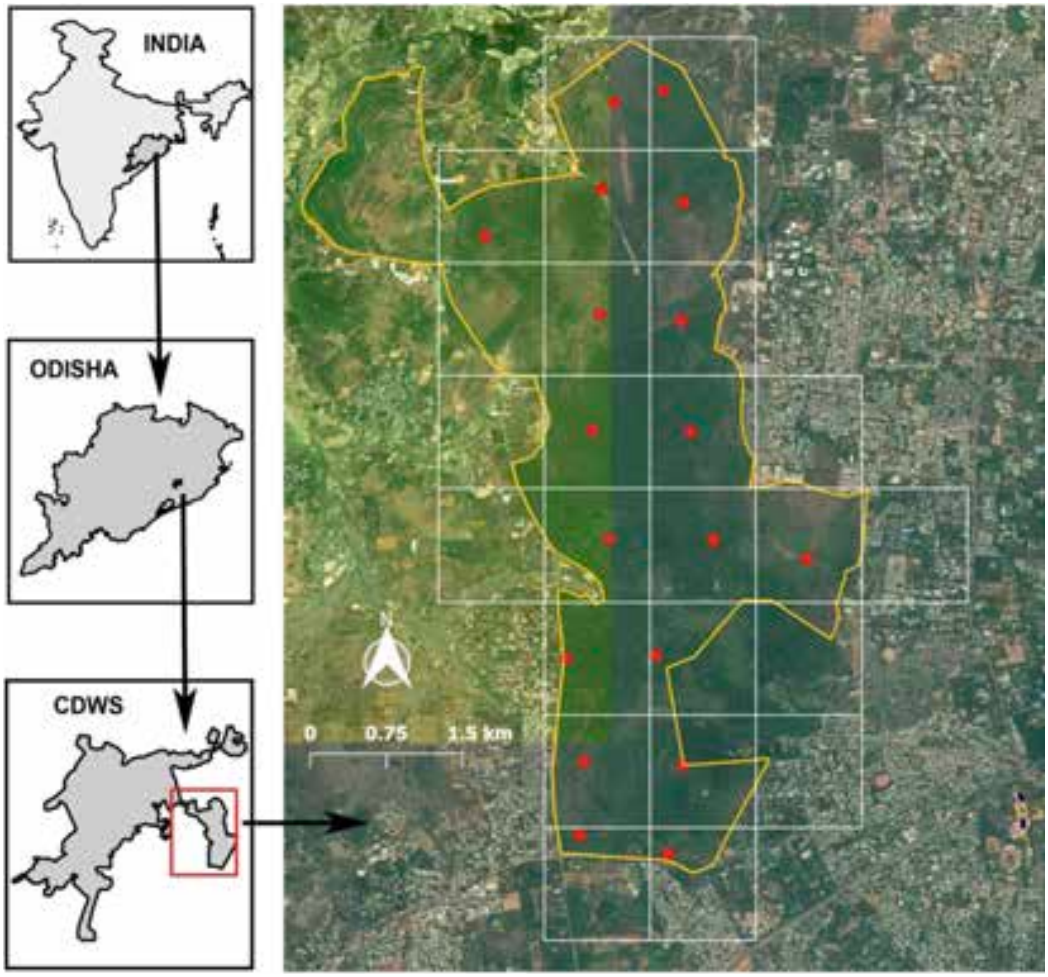


Figure 1. Study area within human dominated habitat and the camera trap locations.

as an independent capture, if the time between two consecutive photographs of the same subject was more than 30 minutes at a particular location (O'Brien et al. 2003).

For all the independent photos of Golden Jackal and human traffic, the times of captures were noted down in 24-hour format. Photographs depicting movement of departmental staffs, tourists, and vehicles were all categorised as human traffic. All the photographs captured in two hours of interval in each category were separated to examine the intensity of percent activity. To know the significant difference in percent activity level of Golden Jackal between day and night, I performed Student's t-test (t) and based on the percent activity level, the studied species behaviour was indicated as nocturnal, diurnal or crepuscular in the study area. The statistical test was carried out in windows based MS excel data analysis tool.

During the study, a total of 552 independent photos of Golden Jackals (Image 1) and 1,055 independent photos of human traffic were obtained from 771 trap nights. Based on the photographs, Golden Jackals were found to be mostly nocturnal and crepuscular and showed two major peaks in activity; the first peak during late evening after sunset and the second peak during early morning till sunrise (Figure 2). Overall, the percent activity was significantly higher during night than day ($t= 5.45$, $df=10$, $p <0.01$; Figure 2). Although Golden Jackals were active throughout the day, they showed reduced activity during day time when human traffic was much higher (Figure 2).

Golden Jackals are mostly crepuscular and nocturnal, although their activity has been reported throughout the day (Majumder et al. 2011; Katuwal & Dahal 2013; Gupta et al. 2016; Ojha et al. 2017). In the present study similar kind of activity pattern of Golden Jackal was observed and there could be several factors for this. First it could be due to the temporal activity of prey species. In India, some studies have reported that rodents, which contribute a major portion of Golden Jackal's

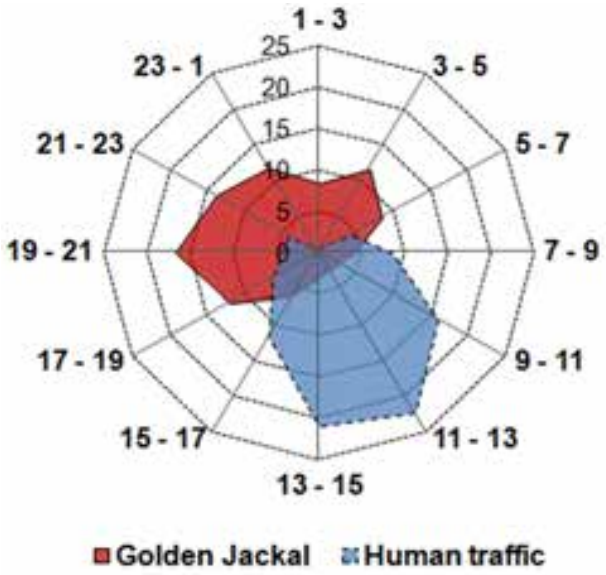


**Figure 2. Activity pattern of Golden Jackal and human traffic in Bharatpur and Jagannathprasad forest sector, Chandaka-Dampara Wildlife Sanctuary, Odisha, eastern India during 2019.**

diet, are nocturnal (Mukherjee et al. 2004; Majumder et al. 2011). Second, Golden Jackals might have reduced their activity during the day to avoid the intense heat. Daytime resting behaviour of Golden Jackal is common and reported earlier by Jaeger et al. (2007), Rotem et al. (2011), Georgiev et al. (2015), Jenks et al. (2015), and Ojha et al. (2017). Additionally human traffic might be a factor in the present study area affecting diurnal activity of the Golden Jackal. Studies have reported that when the species occurs near human habitation, it is more nocturnal, and in relatively less anthropogenic areas, it is largely diurnal (Sheldon 1992; Fox 2009). As the present study area is surrounded by densely populated human habitations, it receives maximum protection interventions throughout the day and night patrolling activities. Besides that, an ecotourism activity with facilities of trekking and wildlife safari has been implemented in the area very recently. All the above mentioned factors might have caused reduced diurnal activity of Golden Jackal. Golden Jackals are adapted to urbanisation and benefit from easily available food resources. However, in some parts of their range, they have either disappeared or their numbers are declining due to increasing anthropogenic pressure (Jhala & Moehlman 2004). Although the present study was for a limited time period, it helped to understand the activity of the species adjoining an anthropogenic habitat. Further, long-term studies may aid to understand the change in activity pattern of the species in response to various anthropogenic activities.


**Image 1. Cameratrap image of Golden Jackal from Bharatpur and Jagannathprasad forest sector, Chandaka-Dampara Wildlife Sanctuary, Odisha, eastern India during 2019.**

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# Chemical immobilisation of a Eurasian Lynx *Lynx lynx* (Linnaeus, 1758) (Mammalia: Carnivora: Felidae) with ketamine-dexmedetomidine mixture in Ladakh, India

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The Eurasian Lynx *Lynx lynx* is a species of global conservation importance (Breitenmoser et al. 2015). It ranges from Europe to eastern Asia, including the alpine steppe of the Tibetan plateau and northern Himalaya (Namgail 2004). In India, it has been recorded in the Trans-Himalayan region of Ladakh (Namgail 2004; Sharma & Dutta 2005; Kotia et al. 2011). Habitat loss and poaching have been identified as the major threats to the Eurasian Lynx in India (Kotia et al. 2011). However, little information is available about the species in India, especially regarding its ecology and conservation status (Namgail 2004).

Various wild animals face threats and even physical injury due to their interactions with humans and various anthropogenic activities and sometimes require rescue interventions. Such interventions are justified for their conservation value and importance for human-wildlife interaction mitigation (Pyke & Szabo 2018). Rescue and rehabilitation are treatments designed to facilitate the process of recovery and subsequent restoration of some or all of the individual's physical, sensory, and mental capabilities that were lost due to injury, illness, stress or disease (Jones 1961).

In this context, chemical immobilisation of individual animal is regarded as safe and effective as it causes minimal stress (Neilson 1999). In felids, ketamine and dexmedetomidine have been used as an anaesthetic agent for chemical immobilisation (Lamberski 2015).

Chemical immobilisation of a Eurasian Lynx: We report the successful chemical immobilisation of a female adult Eurasian Lynx (Image 1) whose age was estimated to be five years with an estimated weight of 25kg. It was trapped inside a traditional stone structure used to store grass and fodder in Kungyam village. This village is located at an elevation of 4,180m in Nyoma block of Leh district in Changthang, Union Territory of Ladakh (Figure 1). Villagers alerted the Department of Wildlife Protection. When the rescue team reached the village on 29 December 2020, they found the animal unable to escape from the stone structure. It was obviously under severe stress, most likely due to confinement to a small area for a long time and because of human presence. Thus, it was decided to intervene and chemically immobilise the individual so to be able to

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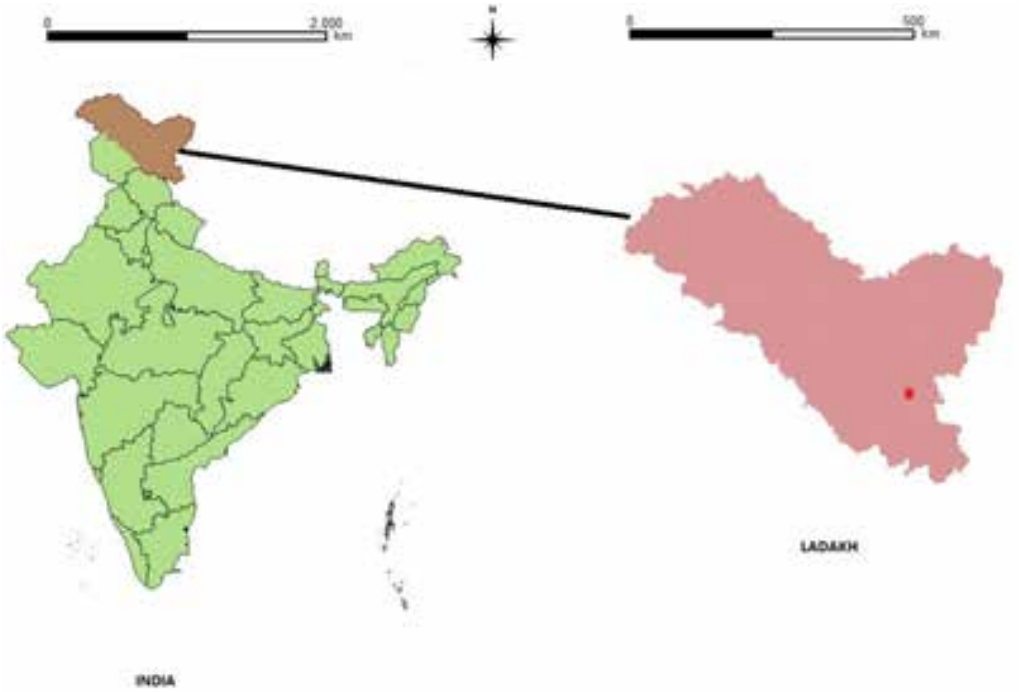


**Figure 1 . Map showing the location where the Eurasian Lynx was rescued in Leh, Ladakh (red dot).**

physically remove it from the structure and take it to the Rescue and Rehabilitation Centre in Leh for stabilisation. The ambient temperature was -10°C at the time of the operation.

Since the structure was located inside the village, the immediate release of the animal was not explored as it may have injured humans, become injured and even more stressed in the process. Initial efforts to capture it in a box trap were not successful. Subsequently, we attempted to chemically immobilise it using a remotely administered air pressurised syringe projector, model JM Syringe projector by Dan Inject. For this, two stones from the wall of the structure were removed and covered with a capture net made of cotton to prevent its sudden escape. However, the animal was not visible due to little light inside the structure, and the remote drug delivery system with ketamine (50 mg/ml; ANEKET, Neon Laboratories limited, India) and dexmedetomidine (0.5 mg/ml; DEXDOMITOR, Zoetis, US) mixture failed as we were unable to locate the animal in the dark. At this stage, it tried to escape through the hole and became entangled in the net. We placed a blanket on its head and immobilised it chemically using a combination of ketamine at 4 mg/kg body weight and dexmedetomidine at 0.02 mg/kg body weight with a 5ml disposable syringe (DISPOVAN; Hindustan syringes and medical devices Limited, India). The drugs were injected intra-muscularly in the right quadriceps muscle of the cranial thigh at 12:30h.

After four minutes of administering the injection, at 12:34h, the animal was deeply sedated. Its respiration was normal at 10 breaths/minute and eyes open with no palpebral reflex along with minimal salivation. It did not respond to stimuli such as pinching between digits and ears, showing excellent immobilisation and analgesia. It was carried to a transportation cage for transfer to the Rescue and Rehabilitation Centre in Leh for a thorough examination and subsequent rehabilitation. Examination did not reveal any external injury of the animal. Physiological parameters such as heart and respiratory rate, and body temperature were found normal at 42 beats/minute, 10 breaths/minute and 39°C, respectively, within 15 minutes of induction. Its actual weight was 20kg using a spring weighing scale. Thus, the actual dose received by the animal was ketamine at 5 mg/kg body weight and dexmedetomidine at 0.03 mg/kg body weight. After 30 minutes of injection of the drugs at 13:00h, atepamezole at 0.1 mg/kg body weight was injected into the left quadriceps muscle as reversal with the help of a 3ml disposable syringe (DISPOVAN; Hindustan syringes and medical devices Limited, India). A palpebral reflex was the first sign of recovery, noticed at 13:04h within four minutes of administering the reversal. The individual exhibited complete recovery after 30 minutes at 13:30h of administering the reversal injection. The whole capture time was 60 minutes from

**Image 1. Eurasian Lynx *Lynx lynx* rescued on 29 December 2020 in Kungyam village, Ladakh. © Animesh Talukdar.**

administering the ketamine and dexmedetomidine mixture until complete recovery.

There are no studies on chemical immobilisation of the Eurasian Lynx in Ladakh. The combination of ketamine and dexmedetomidine used in this incidence was found to be effective at a dose of 5 mg/kg body weight for ketamine and 0.03 mg/kg body weight for dexmedetomidine. The same drug mixture can be administered remotely. The drug dose used in this instance was similar to the combinations of ketamine and dexmedetomidine recommended by Schöne et al. (2002) for the Eurasian Lynx and by Lamberski (2015) for felids in general.

The drug combination in our rescue operation was used for the first time on a Eurasian Lynx in India. Our experience with this combination on a single individual does therefore not account for possible effects of differences in age and sex of individuals, or of variations in weather conditions. We recommend to reduce stress in future rescue operations by minimizing the presence of humans. We propose to develop a protocol for chemical immobilisations used in rescue and release operations based on a larger sample size.

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# White-bellied Heron *Ardea insignis* in Hkakabo Razi Landscape, northern Myanmar

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The White-bellied Heron *Ardea insignis* Hume, 1878 is a 'Critically Endangered' species with a highly fragmented distribution and a small population (BirdLife International 2018). Its range is considered small (56,300 km²) and extends from Bhutan through northeastern India to northern Myanmar, mostly with extremely low densities and few observations since 2010. It has a low reproduction rate, with a generation length estimated to be 10.5 years, and suffers comparatively high levels of mortality (BirdLife International 2018). In consequence, its population, which was never abundant, is in ongoing decline, although the causes of the recent decline are not fully understood. On the basis of habitat degradation and widespread disturbance, even in remote parts of the species' range (Stanley-Price & Goodman 2015; Menzies et al. 2020), the White-bellied Heron population is likely at high risk of extinction with a global population estimated somewhere between 70–400 individuals (IUCN 2018). Historic records show that the species was widely distributed in Myanmar (Stanley-Price & Goodman 2015), but recent records are only from Kachin (Image 1).

Based on observation, the preferred habitat of the White-bellied Heron is small to large rivers, adjacent to relatively large forest tracts and with low human impact (BirdLife International 2018). These habitats are decreasing rapidly throughout the species' range, but suitable habitat is still abundant in northern Myanmar, where the Hkakabo Razi Landscape is predicted to be one of the last refuges for

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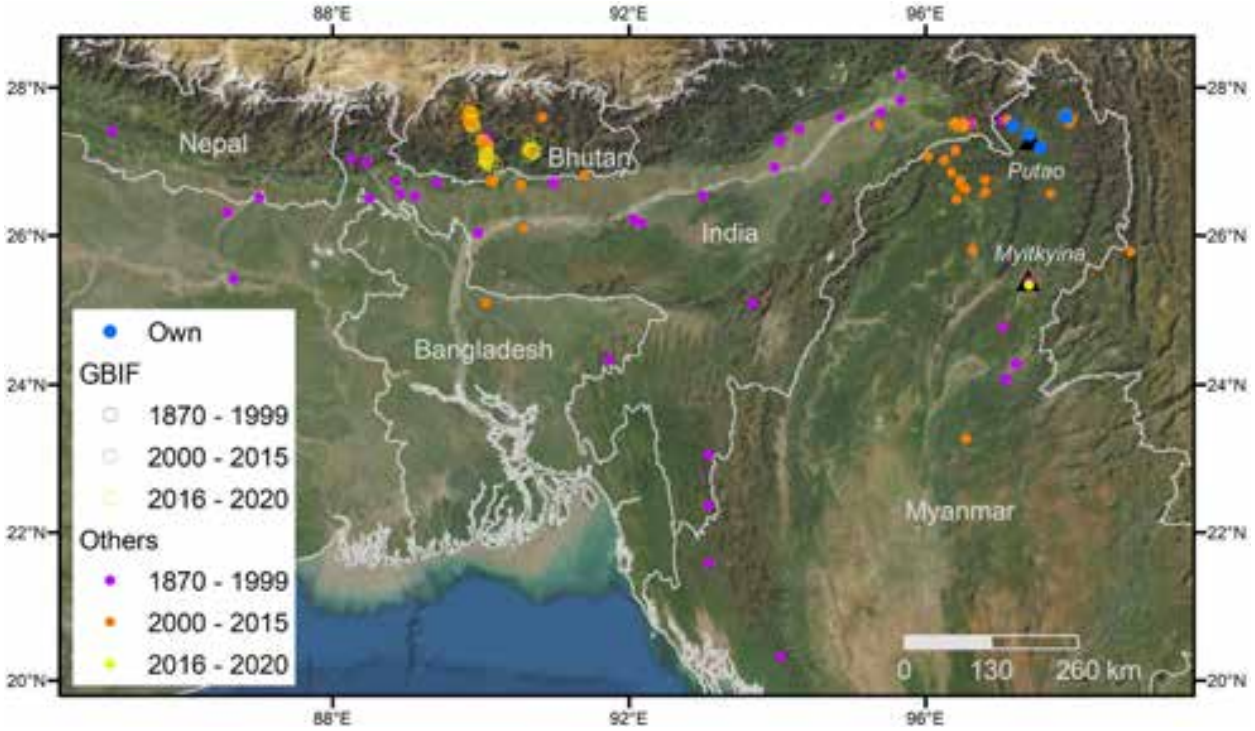


**Image 1. Records of *Ardea insignis* White-bellied Heron (own records; GBIF 2021; King et al. 2001; Stanley-Price & Goodman 2015; Zöckler et al. 2020). In addition, there are three historic records (1870–1999) from southern Myanmar, which are external to this map and omitted for illustrative purposes. Note: GBIF (2021) records have not been screened for correct localities nor correct species status. Map prepared by M. Suarez-Rubio.**

this species. The area has highly suitable habitats, which include streams and rivers, wetlands, and grasslands, all associated with almost untouched broadleaf forest in mountainous areas (Suarez-Rubio et al. 2020). However, even for northern Kachin, in 2016, the population is estimated at only between 26–28 birds and known localities are imprecise, such as "near Putao" or "observed in region" (Smythies 1986; BirdLife International 2001; King et al. 2001; Rappole et al. 2011). Since 2011, there have been no published records from the Hkakabo Razi Landscape (Stanley-Price & Goodman 2015; Renner & Bates 2020; GBIF 2021).

During a series of bird surveys (2001, 2004, 2005, 2006, 2014, 2016, 2017, 2018, 2020), our team observed the White-bellied Heron in Hkakabo Razi Landscape. Although our surveys targeted all water birds along the rivers, they show a consistent picture of the presence of the White-bellied Heron in the Hkakabo Razi Landscape, with all but one record documented with a photo:

(a) One foraging in the Shinsan stream about 2.5 km north of Gawlai on 10 and 11 March 2016 (three observations over several days in March 2016 of probably the same individual along a stretch of the Shinsan stream; Image 2); the species was also observed at this site on 26 February 2018;

(b) One on the Nam Ro Stream near Wasadam village at a potential roosting site on a tree in 2017 and 21 January 2018;

(c) One in grassland close to Tan Jar stream at Lone Shanyan village (= Long Shan Yang = Lung Sha Yang; south-east of Putao on the way to Myitkyina) on 01 November 2020;

(d) One individual and a pair observed in the Tan Jar stream in December 2020;

(e) One foraging in Ma Jaw War stream close to Putao in November 2020.

Worldwide, since 2015, there seem to be only a few small, isolated localities with regular observations of White-bellied Herons (Image 1): Bhutan, Namdapha area in India, and the Hkakabo Razi Landscape. Following the record from the Myitkyina to Sinbo stretch of the Ayeyarwady, including onwards to Bhamo (Zöckler et al. 2020), there needs to be further surveys to determine the current status. The absence of recent records from Hukaung Valley Wildlife Sanctuary probably results from the inaccessibility of the area to researchers rather than reflecting a natural decline in the White-bellied Heron population. The relatively small number of surveys in northern Kachin compared to recent surveys in Bhutan (GBIF 2021) is likely a contributory factor biasing the number of observations. We hypothesize that repeated monitoring at the explicitly same localities in Kachin could yield indications for a stable


**Image 2. *Ardea insignis* White-bellied Heron close to Gawlai (11 March 2016).**

source population of the species.

Within Myanmar, the White-bellied Heron has the highest level of legal protection under Myanmar's 'Protection of Wildlife and Conservation of Natural Areas Law-1994'. Nevertheless, wildlife law enforcement is difficult in rural Kachin for a broad range of reasons, including inaccessibility because of terrain, and disagreement between locals and central government on natural resources management. The White-bellied Heron is thought to be threatened by a combination of illegal fishing methods; pollution; sand, gravel, and gold mining; and human disturbance (Stanley-Price & Goodman 2015; IUCN 2018). Dam development is an ongoing and postulated future threat, particularly for the Mali Hka/ Nam Tamai river catchments (i.e., anything north of Myitkyina), whilst rapid illegal deforestation, often linked to illegal mining and illegal cross-border trade, is an ever-growing current threat, particularly in eastern Kachin. In addition, much of the range of the White-bellied Heron in Kachin coincides with areas occupied by diverse ethnic groups who have strong tendencies to hunt wildlife for subsistence.

The Hkakabo Razi Landscape is the meeting point of three biodiversity hotspots: Indo-Burma, Himalaya, and mountains of southwestern China. These hotspots overlap with the protected areas Hkakabo Razi National Park and Hponkan Razi Wildlife Sanctuary. The Hkakabo Razi Landscape possesses some of the least disturbed habitat of lowland wetlands, associated with forest, within mountainous areas. It is home to one of the largest remaining tracts of mainly intact forest in southeastern Asia (Suarez-Rubio et al. 2020) and therefore offers some of the most suitable habitat and reproductive conditions for the White-bellied Heron. In 2014, the Hkakabo Razi Landscape was proposed as a World Heritage Site under criteria (ix) and (x) for its high integrity and outstanding ecological values (World Heritage Centre 2014; Renner & Bates 2020; Suarez-Rubio et al. 2020; Bates et al. 2021). Unfortunately, our most recent records of White-bellied Herons from the Hkakabo Razi Landscape are located just outside the two formally protected areas (namely the Hkakabo Razi National Park and the Hponkan Razi Wildlife Sanctuary). Therefore, we suggest nominating the Nam Tisang River (passing through Naung Mung) and Rat Nam Ti or Nam Hat River (passing through Gahtu/Gawlai) as Ramsar sites, and we support plans for the nomination of the entire Hkakabo Razi Landscape as a World Heritage site.

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# Range extension of the Common Slug Snake *Pareas monticola* (Cantor, 1839) (Reptilia: Squamata: Pareidae): a new family record for Nepal

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The family Pareidae Romer, 1956 is composed of a small group of primarily nocturnal and partly arboreal snakes that have evolved to specialize in feeding terrestrial snails and slugs (Loredo et al. 2013; You et al. 2015; Hoso 2017; Uetz et al. 2021). The family is further divided into two subfamilies (Pareinae and Xylophiinae) and four genera (*Aplopeltura* Duméril, 1853; *Asthenodipsas* Peters, 1864; *Pareas* Wagler, 1830; and *Xylophis* Beddome, 1878) (Deepak et al. 2018; Uetz et al. 2021). The genus *Aplopeltura* and *Asthenodipsas* are endemic to southeastern Asia (Loredo et al. 2013; Uetz et al. 2021), *Xylophis* is endemic to the Western Ghats of peninsular India (Deepak et al. 2018, 2020), whereas *Pareas* has a relatively wide distribution in the tropical to subtropical regions of the Oriental biogeographic realm (Bhosale et al. 2020; Vogel et al. 2020; Wang et al. 2020).

There are 22 species described within *Pareas* making it the largest of all the four genera in the family (Bhosale et al. 2020; Liu & Rao 2021). The recent surge in the number of studies aiming to resolve the complex taxonomic and phylogenetic status of *Pareas* has led to the addition of several new species (Bhosale et al. 2020; Ding et al. 2020; Wang et al. 2020; Liu & Rao 2021). Yet, specialized feeding behavior and niche partitioning between the species has caused increased rate of speciation and sympatric co-occurrence of closely related *Pareas* species that appear morphologically similar (Hoso 2017; Ding et al. 2020; Vogel et al. 2020). Thus, despite the increasing research, information on the true diversity, distribution, and natural history of species belonging to this genus are still far from complete (Bhosale et al. 2020; Vogel et al. 2020).

*Pareas monticola* (Cantor, 1839) is one of the most widely distributed species of the genus *Pareas* (Vogel et al. 2020; Uetz et al. 2021). Occurrence of *Pareas monticola* sensu stricto has been established from northeastern India, northern Myanmar, China (Motuo in Tibet and Yunnan Province), Bhutan, and Bangladesh (Sylhet Division) (Hakim et al. 2020; Vogel et al. 2020; Koirala et al. 2021). It has not been reported from Nepal, but its presence in the Darjeeling and Sikkim of India (Uetz et al. 2021; Vogel et al. 2021) makes it likely for the species to occur in the adjoining areas of eastern Nepal, which share a similar biotope (Khatiwada et al. 2015). In this paper, we present the first evidence of occurrence of *Pareas monticola* sensu stricto from Nepal. Apart from

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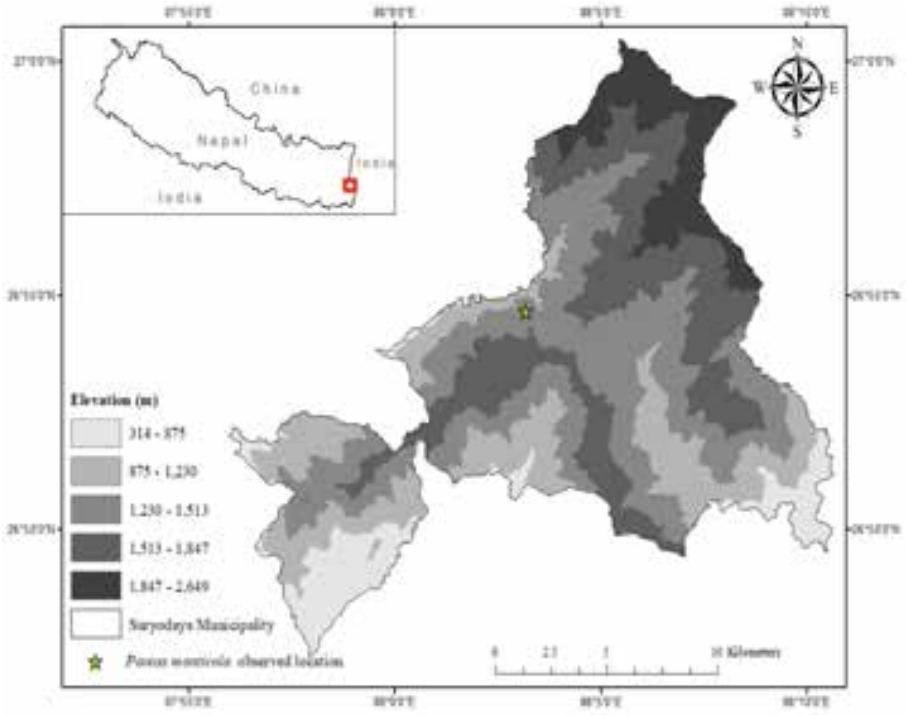


**Figure 1. Map showing *Pareas monticola* recorded location in Suryodaya Municipality of Ilam district. Inset map shows where the region lies in Nepal.**

adding a new species of herpetofauna to the list, this is a new family record for the snakes of Nepal.

An individual *Pareas monticola* (Image 1a,b) was encountered on 04 August 2020 at 2040 h during a herpetological survey in Arubote village of Suryodaya Municipality-10 in Ilam district of eastern Nepal (26.910°N 88.053°E; 1,400m) (Figure 1). The snake was observed approximately 1 m above the ground moving on a wooden stack along a trail. The substrate condition was moist due to recent rainfall and there was a high activity of snails and slugs in the vicinity. The snake had a laterally compressed slender body with large eyes and vertical pupils. Its body coloration was brown with the presence of distinct black bars in the dorsolateral part. A black line extended from eye to the nape and another similar line from behind the eye to the angle of the mouth (Image 1a,b). We took several photographs of the snake for identification and expert consultation. The snake was identified as *Pareas monticola* by Mr. Paul Freed based on its morphological characteristics. The key to the species is loreal and prefrontal contact with the eye, no preocular, and the presence of enlarged vertebral scales (Ding et al. 2020).

The present locality is approximately 25 km (aerial distance) south-west of Darjeeling in India. The region has a subtropical climate and is characterized by having high precipitation and humidity, especially during the monsoon (June–September) (Lillesø et al. 2005). Tea plantation dominates much of the landscape which is interspersed with human settlements and patches of forest having *Schima wallichi, Castanopsis indica,* and *Alnus nepalensis* as the major tree species (Image 2). Two perennial streams run through the landscape and join the Jogmai river a few kilometers downstream.

The present habitat and geographical features are in accordance with other areas where *Pareas* species are known to occur (Hauser 2017; Ding et al. 2020; Liu & Rao 2021). The nocturnal and partially arboreal habits of the species have also been supported by our observation. Snails and slugs mostly prefer moist areas and are highly sensitive to variation in water availability and temperature (Prior 1985). High rainfall during monsoon and the presence of perennial water sources should provide suitable habitat conditions for snails and slugs to thrive in this region, thereby supporting the occurrence of their predator like *Pareas monticola*. Moreover, due to significant genetic variations among the populations of *Pareas monticola* across their range, it has been identified as a species complex rather than a single species (Vogel et al. 2021). Furthermore, our inability to record detailed morphometry and molecular evidence of the observed specimen hindered us from making confirmation on its taxonomic status. Hence, we suggest further studies in the tropical to sub-tropical regions of eastern Nepal to collect meticulous morphological and molecular data on this species to understand its phylogenetic position.


**Image 1a,b. *Pareas monticola* recorded moving on a wooden stack in Suryodaya Municipality of Ilam district, Nepal. © Dipa Rai.**

**Image 2. A typical *Pareas monticola* habitat in Arubote village of Suryodaya Municipality in Ilam district, Nepal. © Dipa Rai.**

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# First record of *Mantispilla indica* (Westwood, 1852) (Neuroptera: Mantispidae) from the Western Ghats, India

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Order Neuroptera is a heterogeneous group of holometabolous insects with varying structure and biology. There are around 6,000 species of Neuroptera reported worldwide, but from India, only 327 species of Neuroptera under 115 genera and 12 families are reported (Singh et al. 2020; Oswald 2020).

Mantispidae is a family of Neuroptera which resembles the praying mantids (Order Mantodea), because of their raptorial forelegs that are inserted at the apical end of the elongated prothorax, so they are frequently called mantid-flies (Ohl 2007). Mantispidae is represented by four extant subfamilies and 410 species worldwide, of which only 17 species under seven genera representing a single subfamily, Mantispinae are known so far from India (Chandra & Sharma 2009; Ohl 2007). Among these, only five species (*Euclimacia nodosa* (Westwood, 1847) from Kerala, *Mantispa coorgensis* Ohl, 2004 from Coorg, Karnataka, *Mantispa cora* Newman, 1838 from Malabar, Kerala, *Mantispa maindroni* Navas, 1909 from Tamil Nadu, *Mantispilla salana* (Navas, 1931) from Maharashtra (Ghosh & Sen 1977; Bhattacharjee et al. 2010; Singh et al. 2020) were reported from Western Ghats as per the available literatures. Apart from this, Bijoy & Rajmohana (2012) reported an unidentified species of *Tuberonotha* Handschin, 1961 from Western Ghats (Wayanad, Kerala). Most of the larvae of Mantispinae are parasites of Hymenoptera and spiders and have a complicated development called hypermetamorphosis (Ghosh 2000b).

The subfamily Mantispinae in India comprises *Mantispilla* Enderlein, 1910 as the predominant genera with three species (Snyman et al. 2018). *Mantispilla* was synonymised under *Mantispa* Illiger in Kugelann, 1798 by Penny (1982), but Snyman et al. (2018) recognised *Mantispilla* as a valid genus. In this study, we report *Mantispilla indica* (Westwood, 1852) for the first time from the Western Ghats as well as from Kerala.

Specimens were collected using the light trap. The collected specimens were killed by using a killing jar with 2–3 drops of ethyl acetate. Later, the specimens were dried; Changes to, mounted and held on entomological pins with proper labelling. They were examined under Leica M205 stereomicroscope. The terminology of wing venation and identification followed Ghosh (2000b) and Snyman et al. (2018). The digital imaging of specimens was taken with Nikon Coolpix P900 with Raynox 250 lens. Distribution map of the species in India was plotted using QGIS 3.12.3 software. Specimens were deposited in the

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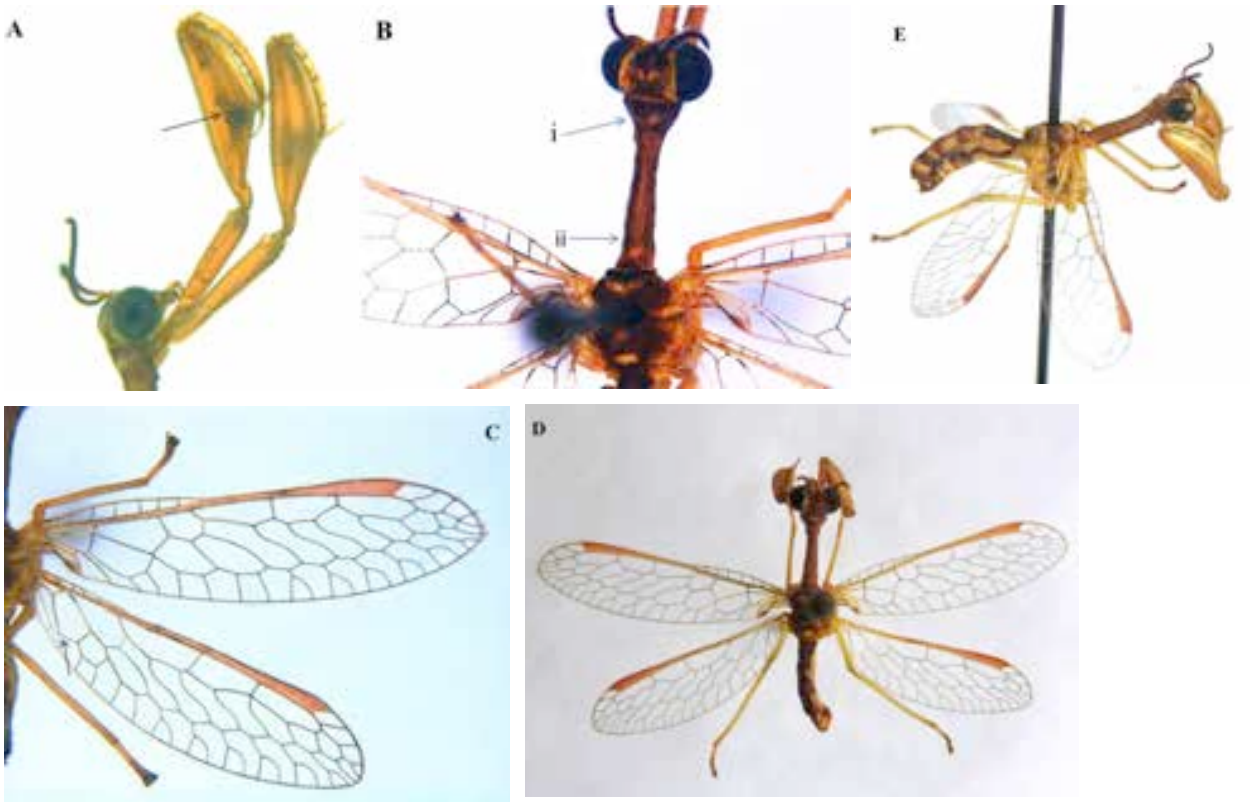


**Image 1. A—Pigmentation in Forecoxae. | B-i: Absence of short stout setae on pronotum, B-ii: Velvet appearance in the mesothorax | C—Reduced crossvein between A1 and CuP | D—Habitus of *Mantispilla indica* | E—Lateral view of *Mantispilla indica.* © A,B,C—T.B. Suryanarayanan | D,E— © A. Vivek Chandran.**

**Table 1. Type locality, distribution and literature source of *Mantispilla* species in India.**

| | Species | Type locality of Species | Distribution | Literature source |
|---|---|---|---|---|
| 1 | *Mantispilla salana* (Navas, 1931) | Maharashtra (MNHN) | Maharashtra | Ghosh & Sen 1977 |
| 2 | *Mantispilla lineolata* Westwood, 1852 | Nepal (BMNH) | Himachal Pradesh (Kullu) | Ghosh & Sen 1977 |
| 3 | *Mantispilla indica* Westwood, 1852 | Kolkata (BMNH OUMNH) | West Bengal, Meghalaya, Sikkim, Assam, Karnataka, Rajasthan, Himachal Pradesh | Ghosh 1977, 1998, 2000a,b, Ghosh & Sen 1977, Sharma & Chandra 2013 |

MNHN—National Museum of Natural History | BMNH—British Museum of Natural History | OUMNH—Oxford University Museum of Natural History.

insect collections of Shadpada Entomology Research Lab (SERL), Kerala, India.

### *Mantispilla* Enderlein, 1910

*Mantispilla* can easily be identified from other genera by the presence of longitudinal pigmentation on the anterior or inner lateral sides of forecoxae (Image 1A), absence of short stout setae on the pronotum (Image 1 B-i), but may have a few sparsely distributed setae, velvet appearance in the mesothorax (Image 1B-ii), reduced or absence of cross-vein between A1 and CuP (Image 1 C). The type locality, distribution and literature source of *Mantispilla* species' in India are plotted in Table 1.

### *Mantispilla indica* (Westwood, 1852)

*Mantispilla indica* is characterised by a black antenna except for two basal segments. The prothorax has two brown lines in the lateral sides but without transverse ridges and vertex with a transverse brown stripe. This species is widely distributed in India, but scanning of the literature revealed no record of this species from the Western Ghats. Thus, *Mantispilla indica* forms the first record in the Western Ghats.

Specimens are brownish in colour (Image 1 D,E). They measured 10.1 mm in length from head to abdomen and 2 mm wide. Forewing is 10 mm in length and 2 mm wide. Hindwing is about 9 mm in length and 2 mm wide. The

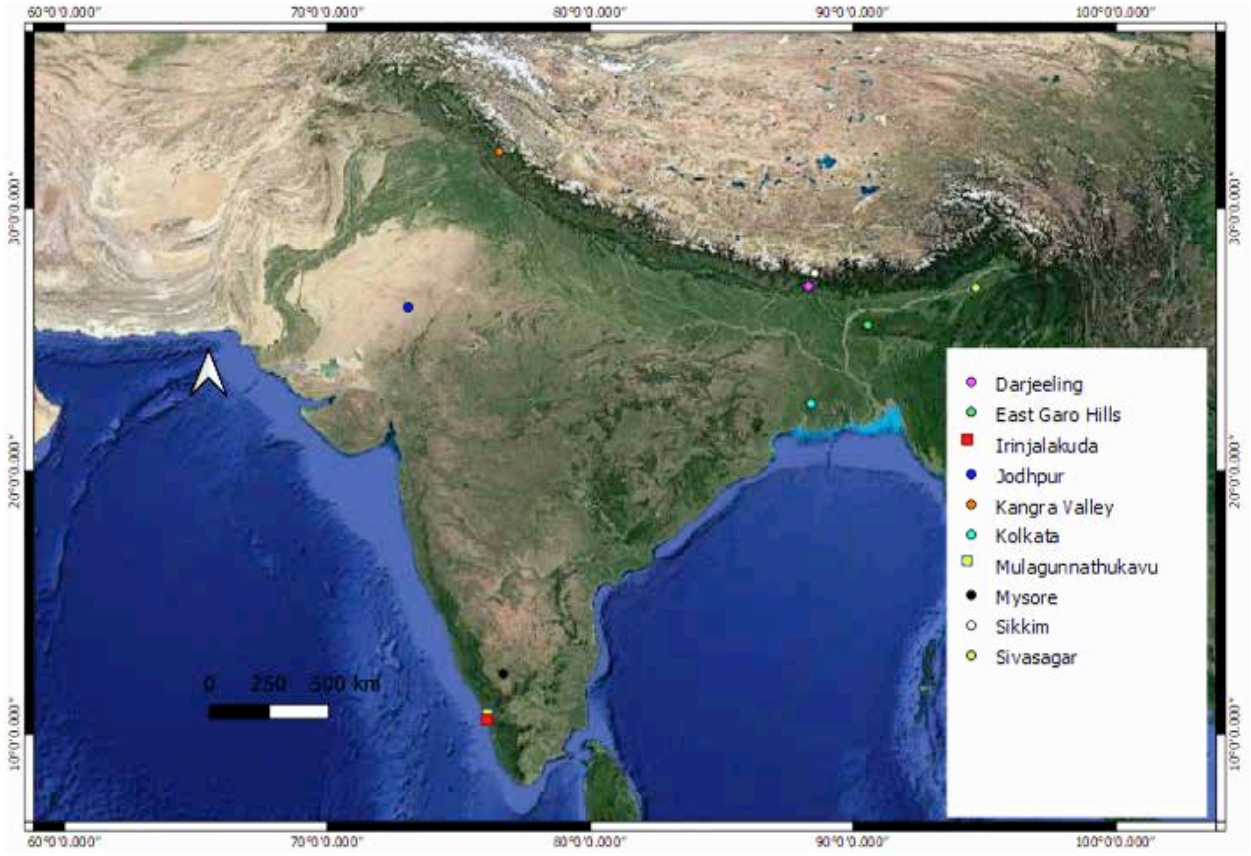


**Image 2. Distribution of *Mantispilla indica* in India.**

specimen characters look similar to the type specimen (Tauber et al. 2019) in Oxford University Museum of Natural History (OUMNH). Head dark yellow with brown patterns and with black flagellar segments. Prothorax brownish-yellow with two brown lines in lateral sides, but without transverse ridges. In the foreleg, a small black spot at tip anteriorly and mid and hind pair legs with dark brown claws. In both forewing and hindwing, longitudinal veins; costa, subcosta and radius dominantly yellow, radial veins are dark brown. Medial, cubital and anal veins yellow anteriorly and dark brown distally. Crossveins also dominant dark brown (Image 1C). Pterostigma elongate and red. Abdomen with alternate dark brown and light yellow bands in lateral view.

SERLNR054, SERLNR055, 18.iii.2020, 20.iii.2020, 2 females, Irinjalakuda, Kerala (10.355°N, 76.213°E), coll. Suryanarayanan T.B.; SERLNR056, SERLNR057, 03.vii.2020, 15.vii.2020, 1 female, 1 male, Mulamkunnathukavu, Kerala (10.598°N, 76.216°E), coll. Suryanarayanan T.B.

*Mantispilla indica* was reported from regions like West Bengal: Kolkata and Darjeeling, Meghalaya: East Garo Hills, Sikkim, Assam: Sibsagar, Karnataka: Mysore, Rajasthan: Jodhpur, Himachal Pradesh: Kangra Valley (Ghosh 1977, 1998, 2000a,b; Ghosh & Sen 1977; Sharma & Chandra 2013) (Image 2). (Note: The species is also reported from the western Himalaya but exact locality details are unavailable).

Mantispidae is a family of Neuroptera with very specialized lifestyle owing to their biology and structural resemblances to the praying mantis. The taxonomy of this group is least studied either due to the short lifespan of adults or due to their very low population density (Ohl 2007). Although 410 species are reported worldwide, because of the lack of specialists in India only 17 species are reported (Ohl 2007; Chandra & Sharma 2009). This paper aims to draw the attention of researchers for future exploration studies on Mantispidae family from different parts of India.

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# A new distribution record of the Western Ghats endemic damselfly *Melanoneura bilineata* Fraser, 1922 (Insecta: Odonata) from Maharashtra, India

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In India, the genus *Melanoneura* Fraser, 1922 is represented by only one species, i.e., *M. bilineata* Fraser, 1922. It is categorised as 'NearThreatened'on theIUCN Red List of Threatened Species (Subramanian 2011). The very first time, Fraser (1924) described the type series collected from Coorg (Kodagu) and Malabar hills at an altitude of 900–1,300 m. Subsequently, more observations were made from Kozhikode, Kannur, Peravoor, and Thiruvananthapuram (Subramanian 2011; Subramanian et al. 2018). In this note, we report *M. bilineata* for thefirst time from Maharashtra, based on one male and one female specimen.

The work was started in September 2020 at Myristica swamp (15.809$^0$N 74.121$^0$E, 73m), Hevale village, Dodamarg taluka of Sindhudurg district (Image 3). Yogesh Koli (YK) and Akshay Dalvi (AD) first observed *Melanoneura bilineata* on 8.x.2020. To confirm this genus, it was needed to check its wing venation and shape of caudal appendages (Image 1c,f). Therefore, one male and one female specimen (Image 1a)were collected from this locality. While sampling (8 October 2020), this region was not under legal protection, which was later in the exercise of the power conferred by sub-section (1) of section 37 of the biological diversity act 2002, the Government of Maharashtra, declared it as a world heritage site on 28 January 2021. The specimens were preserved in 70% alcohol and deposited at Zoological Survey of India (ZSI), Pune (male*:* ZSI, WRC, Ent.4/2825; Female*:* ZSI, WRC, Ent.4/2826). Photographs were taken usinga Canon 760D with a 100mm macro lens. Species identification was carried outwith the help of a standard field guide (Fraser 1924, 1933). Morphological terms refer to Garrison et al. (2010).The map used in Image 3 is created using a QGIS v3.10.2. Copula of *M.bilineata* (Image 1a) was found perching on vegetation along the water flow in myristica swamp. This locality is spread up to 11,000m$^2$ (2.70 acres), bordered by paddy fieldson one side and on the other side there's aroad across which there is a rubber plantation. This region is locally termed as 'Kanhalachi Rai'. The water flow in this swamp is from the northern to the southern side and the stream is partly diverted to paddy fields by local people for irrigation purposes.

*Melanoneura* Fraser, 1922 is a monotypic genus closely similar to *Caconeura* (Fraser 1922), *Phylloneura* (Selys 1860), and *Esme* (Fraser 1922). The male

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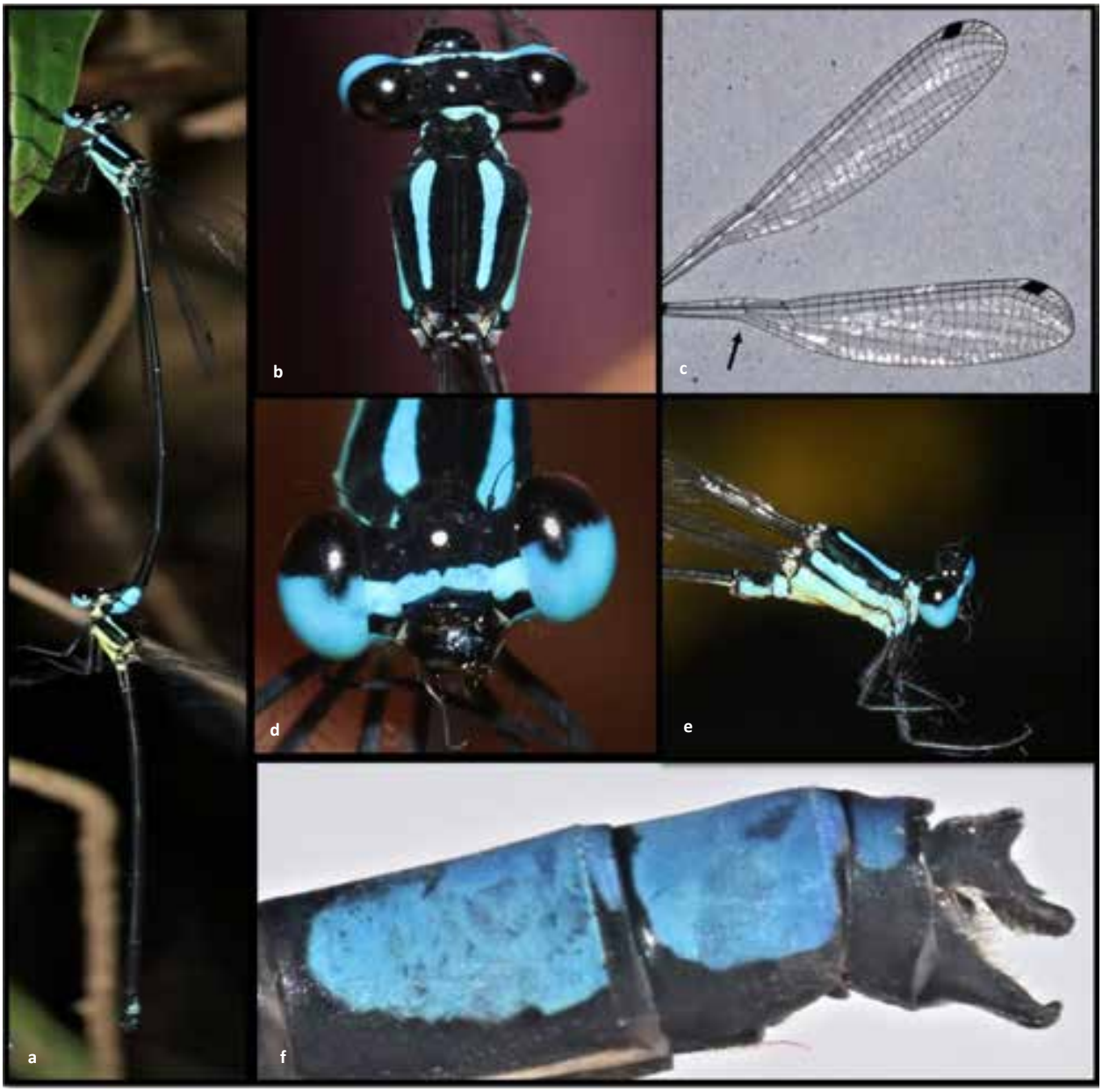


**Image 1. *Melanoneura bilineata* male: a—copula | b—thorax, dorsal view | c—right FW & HW | d—face | e—thorax, lateral | f—caudal appendages, lateral view. © Yogesh Koli.**

individual shows the following characteristics (Image 1a–f): vertex andocciput black, shows a broad blue band across the base of the postclypeus. Synthorax black with blue antehumeral stripe on each side of the mid dorsal carina. Wings hyaline, Pt brownish-black and anal bridge is absent. Abdomen marked with azure blue, S3–S6 have basal lunules over dorsum, S7 unmarked, S8–S10 blue with black stripe on lower half of lateral side. Caudal appendages black, cerci directed straight back and then down, paraprocts broad at base and slightly curved at the tip. Female (Image 1a): labium, labrum, and anteclypeus similar to the male in colour. Synthorax black dorsally with yellowish-blue antehumeral stripes. S3–S7 unmarked; S8 having azure blue vertical stripe on tergume. This speciescan be easily distinguished by absence of anal bridge in its wing venation (Image1c) (Fraser 1924, 1933). The genus *Caconeura* and *Phylloneura* haveincomplete anal bridge whereas genus *Esme* shows a complete anal bridge. Apart from wing venation, the genus *Melanoneura* also differs bythe absence of blue marking on S7 and with a slight variation in lateral blue marking on S2. Caudal appendages of all


Image 2. Habitat in the locality: a & b—Myristica swamp, Dodamarg. © Yogesh Koli.

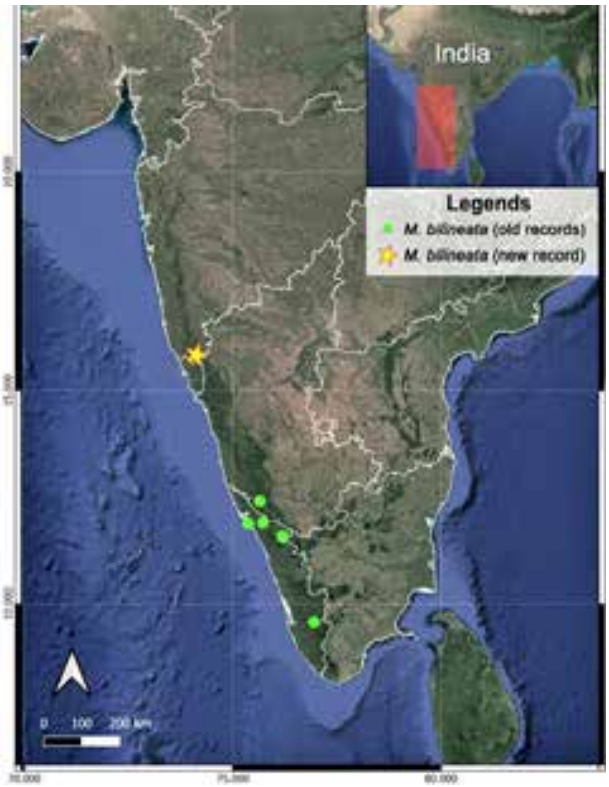


Image 3. The known distribution of *Melanoneura bilineata*.

the above generaare quite similar in colouration, almost longer than S10 but distinguished by a slight variation in their shape. Rather in *Melanoeneura*, the shape of the cerci is more like a 'wrist and hand held in the attitude of clasping a ball' (Fraser 1933).

The first record of *M. bilineata* from Maharashtra indicates that multiple observations are needed to study its distribution patterns in the entire Western Ghats. Myristica swamp of Dodamarg (Shredharan & Indulkar 2018) is poorly known in terms of biodiversity aspects. The presence of such infrequent species in this region signifies that the present locality still remains with many unreported species. Therefore, more surveys are required to document faunal diversity of this region, in order to make various conservation action plans.

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NOTE

# A new record of the Emerald Striped Spreadwing *Lestes viridulus* Rambur, 1842 (Zygoptera: Lestidae) from Nepal

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Dragonflies and Damselflies are amphibiotic insects found almost all over the world in subtropical to temperate regions depending on freshwater ecosystems. Globally, 6,332 species are reported (Schorr & Paulson 2020) of which 178 species are so far reported from Nepal (Kalkman et al. 2020). Including the recently recorded *Ishnura nursei* and *Agriocnemes femina* (Aryal 2019; Conniff et al. 2020). *Lestes* is represented by only two species in Nepal, *L. dorothea* Fraser, 1924 and *L. praemorsus* (Vick 1989; Thapa 2015). Nepal, however, has many regions and locations which have not yet been surveyed for odonate fauna.

Study area: The survey was carried out in Swathi (27.650 N & 83.657 E, 132 m), a region under Sunwal municipality of Nawalparasi, situated in the southern Terai of central Nepal (Figure 1). The average monthly temperature and rainfall (September 2020) was 28°C and 112mm.

Data collection: The odonatological survey was carried out mainly in the rice fields and their edges 20–23 September 2019. Observations were undertaken between 0800–1700 h. The specimens were photographed with a camera (Nikon D3400 with EOS 18–55 mm lens) and the GPS location was recorded. The species were identified using standard literature (Fraser 1933; Subramanian 2009; Nair 2011). Only one male specimen of *Lestes viridulus* was collected, for further laboratory investigation to confirm its identification. The next three days were reserved for observation in the same site and it was carried out to confirm and search for other possible habitats of *Lestes viridulus.*

***Lestes viridulus* Rambur, 1842 (Image 1 A–E)**

The medium-sized damselfly has been reported and described for the first time from Nepal on the basis of its morphological features. Both male and female were observed and photographed. The abundance was high at dusk as the species is crepuscular in nature. Females were found in the paddy fields and only two males were seen basking on a blade of grass on the edge of an artificial pond around the paddy field. The occurrence of *Lestes viridulus* is not surprising in Nepal as it has been well recorded from neighboring countries of India, China, and Bangladesh.

Early distribution range: *Lestes viridulus* Rambur, 1842 is confined to peninsular India (Fraser 1933). This species has been recorded from agricultural fields and temporary water bodies in tropical regions (Payra & Tiple 2019) and has been reported from India (Bihar, Chandigarh, Himachal Pradesh, Madhya Pradesh,

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Image 1. Location of the study area– Swathi.


Image 1 A–E. Emerald-Striped Spreadwing *Lestes viridulus*: A—female | B—female | C—male | D—male anal appendages | E—thorax. © Manoj Sharma

Maharashtra, Punjab, and Uttar Pradesh), Bangladesh (Biswas et al. 1990), and Thailand (Hamalainen & Pinratana 1999).

***Agriocnemis femina* (Brauer, 1868) (Image 1 F–I)**

Both the male and female of *Agriocnemis femina* were observed at the study site. An immature male was chasing a mature male of the same species at an irrigation canal while a female (red form-heteromorph) was perching on the stem of an aquatic plant. A green form female was perching on a leaf blade of a plant. Abundance and distribution was high at irrigation in the low lands of tropical areas (Nair 2011; Joshi & Kunte 2014). Both mature and immature males were observed in a mating wheel position. Non-contact guarding by males was observed during oviposition on leaves of aquatic plants. This species shows various morphological forms in different stages. The female shows red (heteromorph) and green form (androchrome) and the male is greenish-blue at an immature stage and with maturity gains a bluish-white pruinescence (Nair 2011). This is the record of *A. femina* in a new distribution area.

Early distributional range: Australia, Bangladesh, Bhutan, Brunei, China, Guam, Hong Kong, India, Indonesia, Japan, Laos, Malaysia, Micronesia, Myanmar, northern Mariana Island, Palau, Philippines, Singapore, Solomon Island, Sri Lanka, Thailand, Timor-Leste, and Vietnam. In Nepal it was reported from Parsa Wildlife Reserve, the Terai region of central Nepal and Haldi Bari, Jhapa district, eastern Nepal (Conniff et al. 2020).

***Ischnura nursei* (Morton, 1907) (Image 1J)**

The distribution region of *Ischnura nursei* in Nepal has been extended to Swathi, in central Nepal. Eight male individuals of *I. nursei* were photographed while they were basking on a blade of grass in the edge of a local pond (27.559 N & 83.657 E). Females were not seen. The presence of *I. nursei* in this location denotes that it is common in the tropical regions of central Nepal.

Early distributional range: India, Pakistan, Iran, the U.A.E., Bangladesh, Oman, and Nepal (Dumont et al. 2011; Nair 2011; Zia et al. 2011; Feulner & Judas 2013; Kunz 2015; Aryal 2019). In Nepal it was recorded from Jagadishpur lake and Baanganga river of Kapilvastu district (Aryal 2019).

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**Image 1 F–I. Pruinosed Dartlet *Agriocnemis femina*: F—immature male | G—mature male | H—mature female | I—copulation. © Manoj Sharma**


**Image 1 J. *Ischnura nursei* male. © Manoj Sharma**

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# Rediscovery of the Bhutan Primrose *Primula jigmediana* W.W. Smith (Angiosperms: Primulaceae) after 87 years in Bumdeling Wildlife Sanctuary, Bhutan

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The genus *Primula* L. of the family Primulaceae is one of the largest and widely spread of all genera with approximately 430 species distributed mainly in temperate and alpine regions of the northern hemisphere (Richards 2003). In Bhutan, there are about 71 species of *Primula* L. recorded in the country (Grierson & Long 1999). The first expedition of Ludlow & Sherriff to explore eastern Himalaya, particularly Bhutan and southeastern Tibet, was in 1933. During their expedition they discovered no less than 26 species of *Primula* new to science (Richards 2003). It was during that time the species *Primula jigmediana* was discovered for the first time and was named in honour of His Majesty the 2nd King of Bhutan for his kindness and courtesy during their visit to the country (Smith 1936).

*Primula jigmediana* is atypical compared to other *Primula* species and its distribution is still poorly studied (Smith & Fletcher 1942). Bawri et al. (2018) during botanical expedition in Arunachal Pradesh, India discovered *Primula jigmediana* for the first time. The species is found to be rare with few individuals (Bawri et al. 2018). The same species found in Arunachal Pradesh has narrower leaves as compared to species recorded in Bhutan (Bahrali et al. 2018). The present observation of the species from Bumdeling Wildlife Sanctuary, Bhutan records the rediscovery of this species after a lapse of 87 years, and presents additional morphological description along with conservation threat and distribution of the species.

*Primula jigmediana* was sighted in northeastern part of Bumdeling Wildlife Sanctuary, Bhutan (91.541°E, 27.906°N) on 18 July 2020 at an elevation of 4,490 m. The manual Flora of Bhutan (Grierson & Long 1999) was used for identification and morphological description of *Primula jigmediana*. The herbarium was prepared following Smith (1971). The specimen is deposited in the herbarium section of the Bumdeling Wildlife Sanctuary.

## Taxonomy

*Primula jigmediana* W.W. Smith (1936); Smith & Fletcher (1942); Grierson & Long (1999); Richard (2003); Bawri et al. (2018).

Type: Bhutan, Me La, 3.viii.1933, Ludlow & Sherriff 397 (Holotype- BM!). Seen as a photo.

Description: *Primula jigmediana* W.W. Smith is a perennial herb in the family Primulaceae. It has calyx

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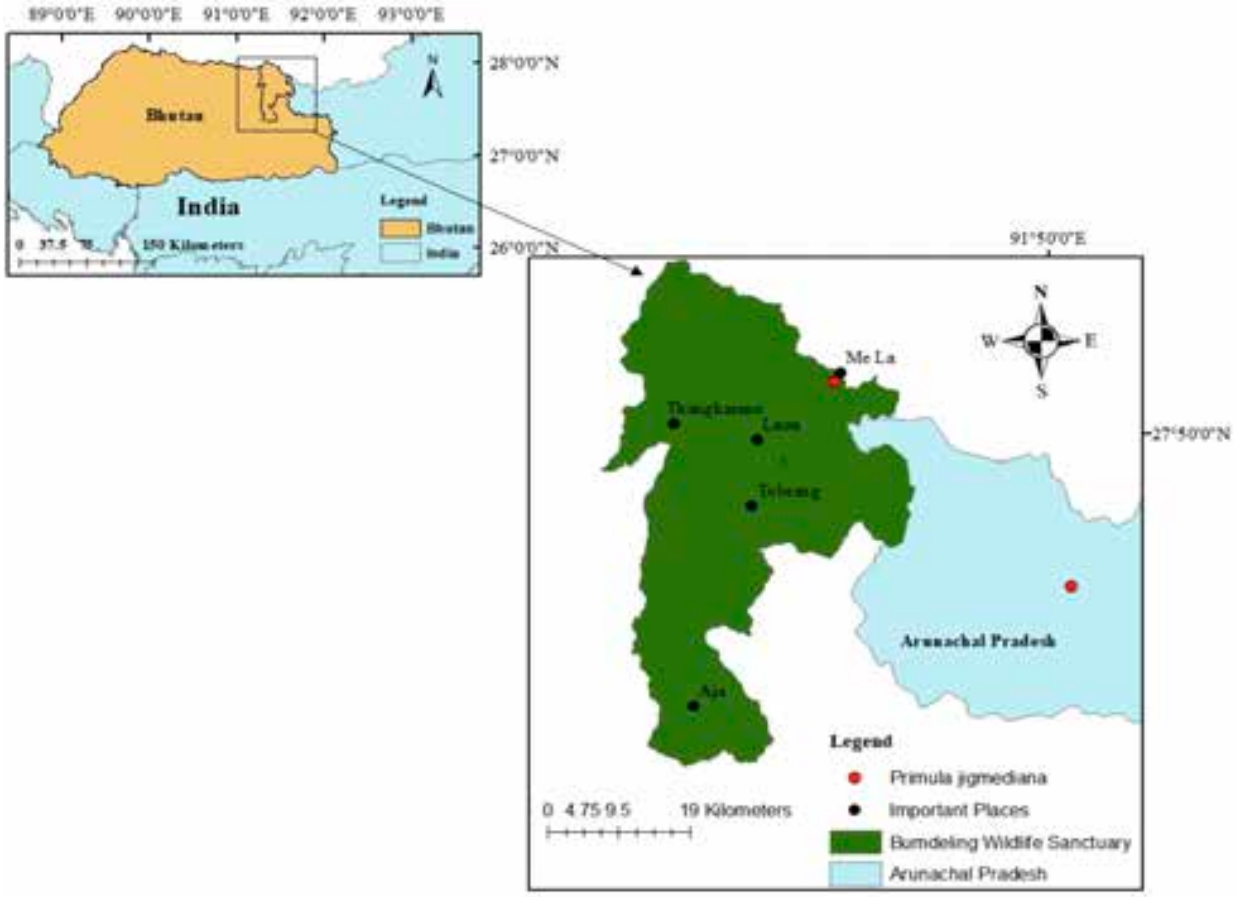


**Figure 1. Distribution record of *Primula jigmediana* in Bumdeling Wildlife Sanctuary, Bhutan.**

up to 2.5–3 cm tall. Leaves in compact rosettes, 6–11 mm. Petiole and leaf blade almost equal in length, 2–5 mm. Lamina oblanceolate, bluntly dentate at the margin, glabrous, efarinose, leaf apex obtuse, 5–6 pairs, alternate, yellowish-green. Scapes 2.5–3 cm tall with single heterostylous flower. Pedicel 1–3 mm and is curved and farinose. Single curved bract, 1–2 mm long. Calyx greenish or blackish-purple, 2-3 mm, cup shape with faintly farinose, parted to middle, lobes ovate, acute to obtuse. Corolla funnel shaped, 4–8 mm long, bluish-purple with dark wine purple annulus, lobes obovate (Image 1). Long style makes the stigma above the anther (pin flower), some flowers have short style making the anther above the stigma (Thrum flower). Capsule sub-globose (Smith 1936; Grierson & Long 1999; Richard 2003; Bawri et al. 2018).

Distribution: Bhutan, Bumdeling Wildlife Sanctuary (Figure 1) and India (Arunachal Pradesh).

Specimens examined: Bhutan, Bumdeling Wildlife Sanctuary, Rigsumlhatsho, (91.541°E, 27.906°N; 4,490 m), 18 July 2020, W.W. Smith, Me La, 1936 (Holotype BM, Photo!).

Habitat: *Primula jigmediana* in Bumdeling Wildlife Sanctuary was found growing in marshy and humid areas along the sides of streams and lakes. It was also found growing on wet stony slopes along with the mosses (Image 1). Associate species like *Potentilla penduncularis* D. Don, *Rumex nepalensis* Sprengel and the high value insect- pathogenic fungus *Ophiocordyceps sinensis* (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones, & Spatafora were found growing in the area. *Primula jigmediana* was found growing in Rigsum Gonpa, Ngangpatsho, Padmaling, and Goneyla area in Bumdeling Wildlife Sanctuary in between elevation of 4,300- 4,600 m. Bawri et al. (2018) described the ecology of this species in humid and marshy areas along the sides of streams and wet stony slopes of meadows. In Arunachal Pradesh the species was recorded at the altitude of 3,500- 4,500 m (Bawri et al. 2015) and later in between the elevation of 3,900- 4,000 m (Bawri et al. 2018). This indicates narrow growth territory of *Primula jigmediana* as it is restricted to specific locality.

Flowering: *Primula jigmediana* flowers in June–July. Similar flowering time was recorded in Arunachal

**Image 1 . *Primula jigmediana.* left—entire plant; right—habitat of a plant. © B.T. Ghalley.**

Pradesh, India (Bawri et al. 2015, 2018).

Conservation status: A few individuals of *Primula jigmediana* were found growing at critical stage in a narrow habitat in northeastern part of Bumdeling Wildlife Sanctuary. Despite of being rare, *Primula jigmediana* is still not listed in the IUCN Red list category. It is palatable and a fodder species for yaks in Himalaya. Nomadic inhabitants rear a large number of yaks and other breeds of cattle. These animals destroy the population by browsing and trampling impeding natural regenerations. Similar threats from grazing, developmental activities, and landslides were recorded from Arunachal Pradesh, India (Bawri et al. 2015, 2018). Every year these areas receive hundreds of *Ophiocordyceps sinensis* collectors, which is also one of the threats to its habitat. Hence, larger damage to the population of *Primula jigmediana* by trampling can be foreseen from *Ophiocordyceps sinensis* collectors. Since, prime habitat of the Bhutan Primrose is along the sides of streams and lakes, the landslides and runoff were observed affecting the habitat of the species. Therefore, it is very important that concerned authorities and agencies initiate appropriate strategies to conserve this species from anthropogenic and natural threats.

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# First report of *Golovinomyces* sp. causing powdery mildew infection on *Dyschoriste nagchana* in Western Ghats of India

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*Dyschoriste nagchana* is a perennial plant growing naturally in wet grassland, but quite often now found in secondary bushland and grassland, including lawns. In January 2019, severe powdery mildew infection was observed for the first time in the hills of Western Ghats of district Satara, viz., Yavateshwar and Varoshi, predominantly on the leaves and stem of *D. nagchana* (Image 1a). Due to severe infection, premature leaf fall was observed. The pathogen was observed in the anamorphic form only.

After collection and detailed study diseased specimen was deposited in the Ajrekar Mycological Herbarium (AMH 9659) housed at Agharkar Research Institute, Pune, Maharashtra, India. The teleomorph (chasmothecia) of this powdery mildew was not found. The anamorph is characterized as follows: mycelium caulicolous and foliicolous, amphigenous, thin-walled, effuse or thicker white patches, persistent; hyphae colourless, hyphal appressoria solitary, always nipple-shaped (Image 1f); conidiophores arising laterally and usually towards one end of the hyphal mother cell, foot-cell curved, 48–55x 7–10 µm (Image 1d). Conidia broadly ellipsoid doliiform without fibrosin bodies, 35x18 µm (Image 1b, c). Germ tubes terminal, short. Tips often with a swollen appressorium (Image 1e). Based on these morphological characters the pathogen is identified as *Golovinomyces* sp. (*Euoidium* sp).

A literature survey (Paul & Thakur 2006; Hosagoudar & Agarwal 2009; Braun & Cook 2012; Farr & Rossman 2016) reveal that no powdery mildew infection has been reported on *D. nagchana* from India and abroad. To our knowledge, this is the first report of *Golovinomyces* sp. (*Euoidium* sp). on *D. nagchana* from India.

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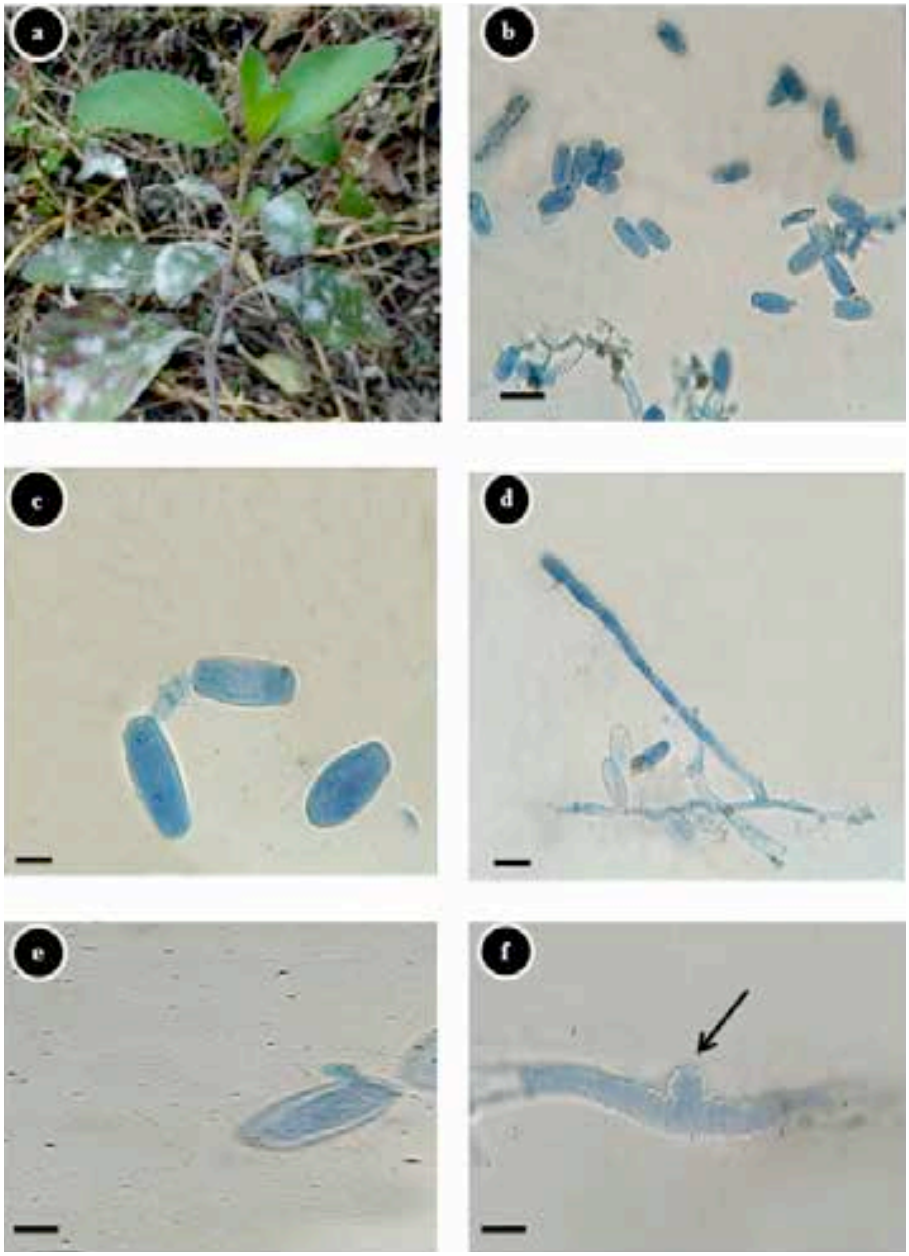


**Image 1. a—infected host | b—conidia at 45x | c—conidia 100x | d—conidiophore | e—germinated conidium | f—arrow indicates nipple shaped hyphal appressorium. Scale= 20µm.**

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