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Caption: Incrustations of *Terpios hoshinota* on *Acropora muricata* (*T. hoshinota* exhibiting osculum with radiating networks). © Rocktim Ramen Das

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ARTICLE

Elevational pattern and seasonality of avian diversity in Kaligandaki River Basin, central Himalaya

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Abstract: This study explored bird diversity, seasonal variation, and associated factors along an elevational gradient in an important biodiversity area (IBA) of central Nepal: the Kaligandaki River basin of Annapurna Conservation Area. The field survey was carried out in 2019 over two seasons, winter (January and February) and summer (May and June) using the point count method. A total of 90 sampling plots were set up from elevations of 800m (Beni) to 3,800m (Muktinath). Data for variables including the number of fruiting trees (indicator of resource availability) and distance to the road (indicator of disturbance) were collected, and their influence on avian diversity were assessed. The results revealed a diverse assemblage of avian fauna in the study area with consistent species richness over the two seasons. A decline in species richness and diversity with increasing elevation was observed. Of the different habitat types within the study area, forest and shrubland habitats showed the strongest association with bird species distribution and richness. We emphasize the need for long-term monitoring programs with standardized sampling approaches to better understand the avifauna in the central Himalaya.

Keywords: Biodiversity pattern, birds, elevational gradient, monotonic decline, species richness.

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Author details: Juna Neupane, MSc, is a 2019 graduate in zoology and her research interests include avian fauna (roles that spatial patterns and processes play in shaping avian communities), primatology and behavioral studies. Laxman Khanal's research interests include biodiversity exploration, phylogeny and phylogeography of mammals, molecular ecology and conservation ecology. Basant Gyawali's research interests include wildlife conservation, general ecology (mammals) and bird communities. Mukesh Kumar Chalise is a pioneer primatologist and renowned wildlife biologist in Nepal and has also worked as visiting professor in Kyoto University, Japan and Dali University, Yunnan, China.

Author contribution: JN, LK and MKC conceptualized the project. JN carried out the field work. JN, LK and BG analyzed the data and prepared the manuscript. MKC supervised the overall research and contributed in the manuscript improvement.

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INTRODUCTION

Patterns in the diversity and composition of species along elevation gradients are key issues in ecology (Lomolino 2001) that contribute to understanding global biodiversity (McCain 2009). The spatial and temporal aspects of species variation along such gradients provide clues to understanding mechanisms of species richness and diversity, a key challenge for ecologists and conservationists (Gaston et al. 2000). Global latitudinal diversity, a well-known pattern where species richness peaks in the tropics and drops towards the poles, has been extensively explored (Rosenzweig 1992; Hillebrand 2004; Pigot et al. 2016). While elevation gradients have not been studied as expansively, they also present prominent patterns in diversity (McCain 2010).

Many studies have demonstrated elevation-related patterns in diversity and have attempted to describe underlying mechanisms, but these aspects remain under debate (Sanders & Rahbek 2012; Quintero & Jetz 2018). In general, species richness has been reported to follow one of the four main diversity patterns: decreasing with elevation, low plateau, low plateau with a mid-elevation peak, and mid-elevation peaks. Of these, mid-elevation peaks are the mostly observed patterns among vertebrates (Colwell & Lees 2000; Bertuzzo et al. 2016; Chen et al. 2017; Pandey et al. 2020). These patterns can be explained by drivers that can be both spatial (area, mid domain effect) and environmental (temperature, precipitation, productivity, and habitat heterogeneity) (Colwell et al. 2004; Wu et al. 2013; Chen et al. 2017, 2020; Pandey et al. 2020). Numerous hypotheses have been proposed to explain relationships between species richness and altitude, such as species-area relationships, mid-domain effects, climate-richness relationships, and productivity-richness relationships (Rahbek 1995; Grytnes & Vetaas 2002).

Variations in species richness of birds with elevation are among the most commonly considered aspects of bird community structure (Stevens 1992), because elevation affects the condition of the physical environment and the types and amount of resources available for breeding and foraging activities. Thus, the composition and structure of bird communities may change along these gradients (Rahbek 2005; McCain 2009). As the elevation increases, availability of resources for birds changes with differences in forest stand structure, site productivity, vegetation species composition, and available land area (Rahbek 2005). Seasons also play a significant role in determining food and cover availability, influencing reproductive success and survival of bird species (Mengesha & Bekele 2008). The seasonal variability in the measure of precipitation and temperature and other conditions of spatial and temporal microhabitat are prime factors influencing resource accessibility for birds. Such distributions of food and cover resources determine the richness, abundance and habitat use of bird species (Waterhouse et al. 2002).

Mountains provide an extensive range of environmental factors, many of which vary with elevation (Becker et al. 2007). They often harbor a large number of species, including varied avifauna, presenting ideal situations for exploring variation in species diversity over relatively short distances (Korner 2007; Quintero & Jetz 2018). Many mountain areas are also global biodiversity hotspots for bird species (Renner 2011; Inskipp et al. 2013, 2016). Understanding the association between species richness and elevation gradients can support conservation efforts (Stevens 1992; Raman et al. 2005; Acharya et al. 2011).

The Kaligandaki River basin in the Annapurna Conservation Area (ACA) of central Nepal is a major tributary of the Ganges River basin, with a marked topographic variation originating at the border with Tibet at an elevation of 6,268m at the Nhubine Himal Glacier. The ACA is one of the Important Bird and Biodiversity Areas (IBA) of the central Himalayan region (BCN 2019). The Kaligandaki Valley is a migration corridor for birds moving south to India in winter. Around 40 species have been recorded moving along the valley, including Demoiselle Crane *Grus virgo* and several raptors (Inskipp & Inskipp 2003) including Steppe Eagles *Aquila nipalensis*, which migrate west through the ACA just south of the main Himalayan chain (de Roder 1989). The upper section of the Kaligandaki corridor, a road connecting Indian border in the south to the Chinese border in the north spanning along the Kaligandaki River axis, has heavily modified the pristine landscape of the ACA. A checklist for overall bird species of the ACA has been published (Inskipp & Inskipp 2003; Baral 2018; Neupane et al. 2020), but studies focusing on bird diversity, seasonal variation, elevation and associated factors have not been conducted. This study was carried out along Kaligandaki River basin in order to explore: i) avian diversity; ii) seasonal variation in species richness and diversity; iii) environmental factors (elevation, habitat types, number of fruiting trees and distance to the road) affecting avian species richness; and, iv) habitat association of different feeding guilds.

MATERIALS AND METHODS

Study area

This study was conducted in Kaligandaki River basin within Annapurna Conservation Area (Fig. 1). The Kaligandaki River basin is an important sub-basin of Narayani Basin in Nepal located between 27.716–29.316 ^{0}N and 82.883–84.433 ^{0}E. The area has marked topographic variation with elevation varying from 183–8,143 m. The upper ridges of the Kaligandaki River Basin are characterized by high altitude, low temperature, some glacier coverage, and dry climate with strong winds and intense sunlight receiving less than 300mm annual rainfall. Permanent snow covers about 33% of the basin, while over 50% of this snow cover occurs above 5,200m (Mishra et al. 2014). The middle region of the basin is mostly hilly with high altitude terrain; the plains in the south have a sub-tropical climate and high precipitation. The study area covered an elevation range of 800m (Beni, Myagdi District) to 3,800m (Muktinath, Mustang District) from sub-tropical to sub-alpine habitats for diverse avian fauna.

At the lowest elevations of the study area, there are subtropical forests of broadleaved Needle-wood Tree *Schima wallichii,* Indian Chestnut *Castanopsis indica*, with scattered Chir Pine *Pinus roxburghii* on dry slopes and Nepalese Alder *Alnus nepalensis* alongside rivers and streams. The temperate forests of mixed broadleaves and oaks *Quercus lamellosa, Q. lanata*, and *Q. semecarpifolia* with Rhododendrons *Rhododendron* spp. occupy the higher regions. Coniferous forests, mainly of Fir *Abies spectabilis*, Blue Pine *Pinus wallichiana* grow on the dry ridges and slopes. Above the temperate zone lie the subalpine forests of Birch *Betula utilis*, Blue Pine *Pinus wallichiana*, and junipers *Juniperus* spp.

DATA COLLECTION

Bird surveys

The point count method was used to count the number of birds in the study area. This method is used mostly in avian fauna to estimate population densities, define population trends, and assess habitat preferences. It is undertaken from a fixed location for a fixed time, and can be conducted at any time of the year (Sutherland 2006). Birds were recorded from 800–3,800 m within two districts of Annapurna Conservation Area, Myagdi, and Mustang along Kaligandaki River basin. The plots were set up with every 100m-rise in elevation, which was recorded using Garmin Etrex 10 GPS. Three fixed-point count plots were set up at each elevational plot, one on

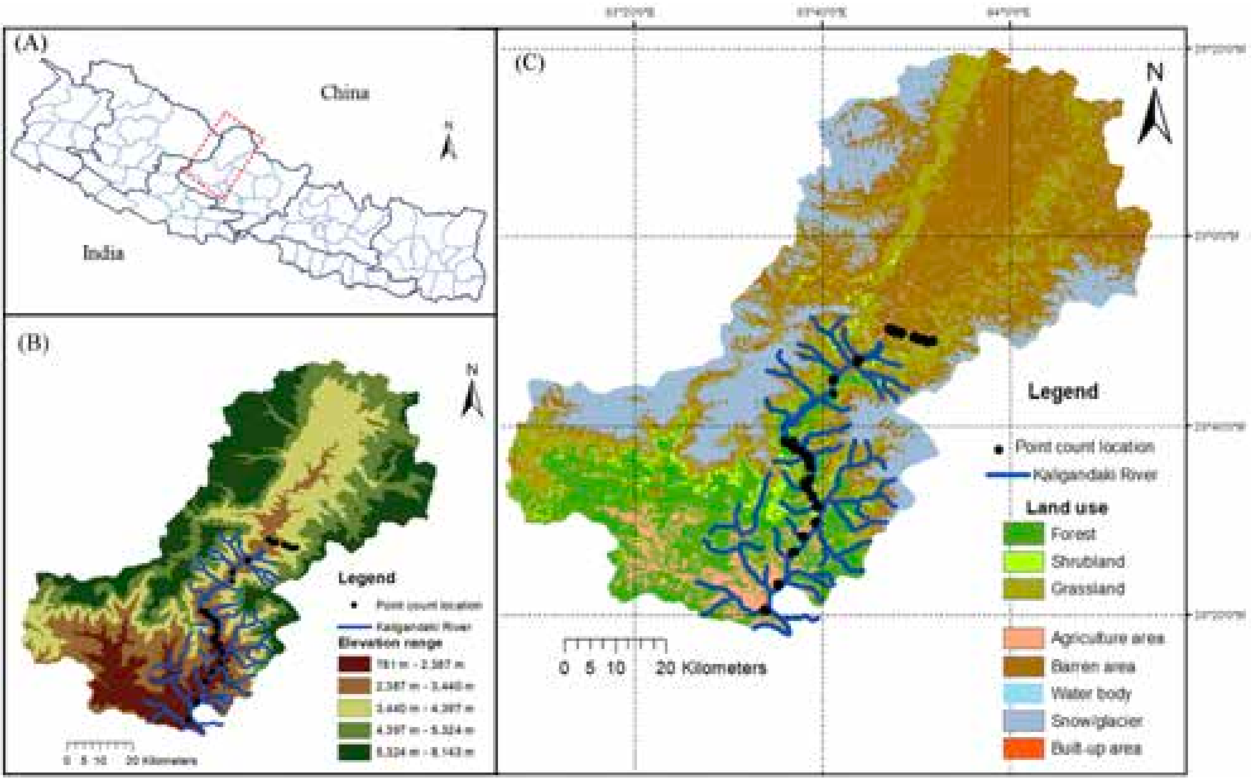

Figure 1. Study area with point count locations. A—map of Nepal showing study area | B–Annapurna Conservation Area showing elevational gradient | C—Annapurna Conservation Area showing the land-use pattern and point count locations.

the roadside and two on either side of the road about 250–350 m apart considering the site accessibility along the river basin. A total of 90 sampling plots were set up on 30 elevational points within the study area. At each plot, birds were recorded within a circle of 30m radius from the fixed point in a center, for 15min. The birds were observed directly using binoculars and photographs were taken whenever possible. For taxonomic identification, the field guide book Birds of Nepal (Grimmett et al. 2016) was used. Birds were observed in the plot from 06.00–11.00 h and 15.00–17.00 h. Data were collected in two seasons of 2019 – winter (January and February) and summer (May and June).

Call count method was also employed in the same point count locations to record all the birds seen as well as heard. This method helped for the identification of some birds that produced easily identifiable sounds that are familiar to the researchers. This approach is used for recording birds, which are difficult to see or capture in their preferred habitat. Those species which are shy and cryptic can be rarely observed even in open habitat. Similarly, in the dense habitat, it is impossible to observe the birds in the distance. Thus, the call count method is the approach of listening to the sound and noise produced by the birds and recording them.

Feeding guild classification

Observed bird species were categorized into five feeding guilds based on the field guide book Birds of Nepal (Grimmett et al. 2016) and following the literature (Katuwal et al. 2018): insectivores (feeding predominantly on insects, larva, worms, spiders, crustaceans, and mollusks), omnivores (feeding on both plants and animals), frugivores (feeding on fruits, berries, figs, drupes, and nectars), carnivores (feeding on fishes, amphibians, reptiles, birds, and mammals), and granivores (feeding on seeds, grains, and acorns).

Environmental variables

Habitats in 90 different point count sites were categorized into seven types as forest, riverbank, agricultural area, shrubland, grassland, scrubland and barren area. The GPS coordinates were overlaid in the land-cover map of ICIMOD (2010) for habitat categorization. As a proxy of resource availability for species richness and diversity, the number of fruiting trees was counted in each sampling site within the circular plot of 30m radius. Another predictor variable, distance to the road from the three-point count locations was taken as a proxy of human disturbance within the study area. These point count locations were set up in the road and either sides away from the road about 250–350 m apart in the river basin along elevational gradient. Distance to the nearest road for each sampling point was estimated in the field and confirmed in Google Earth (https://earth.google.com/web).

Data Analysis

Diversity measures

The alpha (α) diversity of bird species of the study area during seasons and across point count stations was measured as the species diversity index (H') by using the Shannon-Wiener Function (Shannon & Weaver 1949). Species richness gives the presence of the total number of species at a particular area, and it was calculated as the total number of species recorded. The abundance of each species was calculated as the frequency of occurrence in each plot. To calculate whether the species were evenly distributed among the different point count stations and the different seasons, the evenness index (E) was used. It was calculated as

$$E = \frac{H'}{H'_{max}}$$

where,

H' = Shannon-Wiener diversity index

H'_{max} = maximum possible value of H', if every species is equally likely and equal to ln(S)

S = species richness, the total number of species

Community similarity measurement

Sorenson's similarity index (SSI) was used for the qualitative data (presence/absence) to find the community similarity between the two study seasons. The Sorenson's Index of similarity was calculated as:

$$SSI = \frac{2C}{A + B} \times 100\%$$

where,

C = Common number of species shared by two communities (two seasons)

A = Number of species found in one community (one season)

B = Number of species found in another community (another season)

Analysis of variance

One-way ANOVA was used to test the significant variation in species richness of birds among point count stations in two seasons assuming the following null hypothesis- H_0 = there is no significant variation in species richness of birds between summer and winter seasons.

Generalized linear model

The generalized linear model was used to assess how the bird species richness and diversity change along the elevation gradient as well as to assess the influence of resource availability (number of fruiting trees) and human disturbance (distance to the road) on species diversity and richness. Predictor variables included elevation (measured in m at the centroid of 30m circular radius), resource availability (number of the fruiting tree within 30m radius) and human disturbance (distance from the nearest road). Plausible generalized linear models (GLMs) with Poisson error distribution and log link function was run as it is a powerful tool for analyzing count data for species richness in ecology. To assess the influence of predictor variables on species diversity, multiple linear regression was used since the response variable was continuous. Six priori set of models, including the null model, were defined. The models were then ranked using the corrected Akaike Information Criterion that is adjusted for small samples (AICc) (Burnham & Anderson 2002). The beta-coefficient (slope) of covariates was examined to test the significance of their effect on the response variable (species richness and species diversity). All analyses were carried out using 'Stats Package' in R 3.1.2 (R Core Team 2013).

Canonical correspondence analysis

The relationship of bird species richness and environmental factors were explored using Canoco v.4.56. A unimodal direct gradient analysis of partial canonical correspondence analysis (CCA) was used to relate the variation of bird communities (species richness) to habitat variables. Different habitat types were put in the matrix of independent environmental factors whereas, recorded bird species were grouped in the data matrix of dependent variables. Under the reduced model of the canonical axes, Monte Carlo permutation tests (499 permutations) were used to assess the statistical significance of the association between bird species composition and habitat variables.

RESULTS

Bird diversity in Kaligandaki River basin

A total of 1,036 individuals of 120 bird species from 33 families of eight orders were recorded by point count method in the Kaligandaki River basin (Annex I). Out of the eight orders, order Passeriformes had the highest species richness (98 species) and family Muscicapidae had the highest number of bird species (17 species). Guild structure analysis revealed that half of the total bird species were insectivores followed by omnivores, frugivores, granivores and carnivores (Fig. 2). Out of the 120 species recorded from the study area, 86 species (71.67%) were resident, 18 (15%) were summer visitors, and 16 (13.34%) were winter visitors.

Seasonal variation in species richness and diversity

A total of 459 individuals of 81 species of seven orders belonging to 27 families were recorded in the winter season and 577 individuals of 95 species of six orders belonging to 29 families were recorded from the summer season. Fifty-six species of birds were found in both summer and winter season (Table 1).

Shannon Wiener diversity index (H') for the winter season (January and February) was H' = 3.93 whereas more diverse bird assemblage was observed in the summer season (May and June) with the diversity index of H' = 4.006. The evenness index was found to be higher in winter (E = 0.6287) than in summer season (E = 0.5784) (Table 1).

Sorenson's similarity index (SSI) of species composition was observed to be 63.63% between summer and winter season. ANOVA revealed no significant variation in species richness (F = 0.487; df = 1, 175; *P* = 0.486] and abundance (F = 2.903; df = 1, 175; *P* = 0.090) of birds between two seasons among the point count locations.

Factors affecting bird diversity

The model selection results showed that elevation consistently had a negative influence on species richness and diversity; as the elevation increased the species richness decreased significantly (Estimate² = -0.21, *P* < 0.001) (Fig. 3A & B). Distance to the road as a predictor of human disturbance also had a negative influence on species richness and diversity (Fig. 3C & D). Both species richness and diversity were positively associated with the number of fruiting trees as a proxy of resource availability,

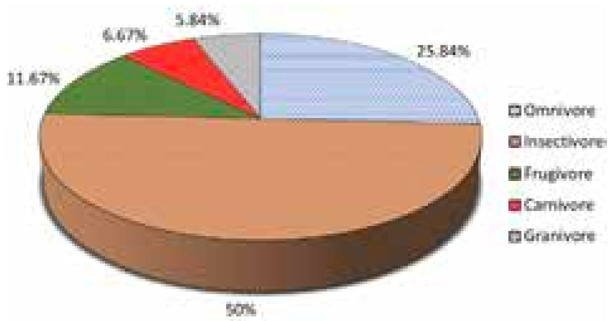

Figure 2. Species richness of birds (in percentage) among different feeding guilds.

Table 1. Seasonal variation in species richness, abundance, and diversity of birds.

Seasons	Orders	Families	Species richness	C	# of individuals	H'	E
Summer	6	29	95	56	577	4.006	0.5784
Winter	7	27	81		459	3.93	0.6287

Table 2. Regression models describing the bird species richness and diversity along the elevational gradient in the Kaligandaki River basin, ranked according to the Akaike information criterion adjusted for small sample size (AICc).

Candidate model	Poisson regression for bird species richness					Multiple linear regression for species diversity				
	AICc	delta	Weight	logLik	Df	AICc	delta	Weight	logLik	Df
Elevation	351.58	0.00	0.46	-173.72	2	127.95	0.00	0.42	-60.84	3
Elevation + Distance to road	352.63	1.05	0.27	-173.17	3	128.85	0.89	0.27	-60.19	4
Elevation + No. of fruiting trees	353.56	1.98	0.17	-173.64	3	129.62	1.67	0.18	-60.58	4
Elevation + No. of fruiting trees + Distance to road	354.65	3.07	0.10	-173.09	4	130.50	2.55	0.12	-59.89	5
No. of fruiting trees + Distance to road	402.02	50.44	0.00	-197.87	3	167.01	39.06	0.00	-79.27	4
No. of fruiting trees	404.69	53.11	0.00	-200.28	2	168.60	40.65	0.00	-81.16	3
Distance to road	415.80	64.22	0.00	-205.83	2	179.09	51.14	0.00	-86.41	3
Intercept only	428.13	76.55	0.00	-213.04	1	187.30	59.35	0.00	-91.58	2

however, the results lacked the statistical significance (Fig. 3E & F). The beta-coefficient or slope of elevation ($\beta_{elevation}$) was -0.48 (SE = 0.05) and distance to road ($\beta_{distance\ to\ road}$) was -0.22 (SE = 0.05). The slope estimates of number fruiting tree ($\beta_{fruiting\ trees}$) for species richness analysis was 0.14 (SE = 0.002). The positive beta coefficient showed that for every one-unit increase in the predictor variable (no. of fruiting trees), the response variable (species richness) increased by the beta coefficient value. For negative beta coefficient, species richness decreased by beta coefficient value for every one-unit increase in elevation and distance to road. Since the 95% confidence interval of the beta-coefficients did not overlap with zero, the effects of these variables (species richness, elevation, no. of fruiting trees and distance to road) are significant ($P<0.05$).

For both the species richness and diversity analysis, AICc based model selection predicted the elevation model having the least AICc value as the most plausible model in the candidate model set. The model with only elevation as a regressor with smallest AICc value (351.58) was the best fit as compared to other variable model sets (Table 2).

Feeding guild-wise habitat association of birds

The habitat variables that were selected to find the relationship between environmental variables and species were forest habitat, riverbank, agricultural area, shrubland, grassland, scrubland, and barren area. The Monte-Carlo permutation test of significance of all canonical axes revealed no significant relationship between the carnivorous species and habitat types (Trace=0.813, F-ratio=0.747, P=0.718) (Fig. 4A). Insectivores showed strong association (Trace= 0.843, F-ratio= 1.461, P=0.003) with shrubland and scrubland habitats, whereas grassland habitat showed less impact in their distribution. A large number of the insectivore bird species including Black-throated Tit *Aegithalos concinnus*, Greater Yellownape *Picus flavinucha*, Verditer Flycatcher *Eumyias thalassinus*, Black-lored Tit *Parus xanthogenys*, Grey-headed Woodpecker *Picus canus*, and Streaked Laughingthrush *Garrulax lineatus* were associated with forest habitat (Fig. 4B).

For frugivore species, shrubland habitat followed by the riverbank and grassland habitats had more significant impact on species distribution (Trace=0.362, F-ratio=0.125, P=0.034). Red-billed Blue Magpie *Urocissa erythrorhyncha*, Blue-throated Barbet *Megalaima asiatica*, Grey Treepie *Dendrocitta formosae*, and Black-throated Sunbird *Aethopyga saturata* showed strong association with shrubland habitat. Barbet species like Great Barbet *Megalaima virens* and Golden-throated Barbet *Megalaima franklinii* were associated with agricultural areas. Similarly, species like White-winged Grosbeak *Mycerobas carnipes* and Crimson Sunbird *Aethopyga siparaja* were associated with forest habitat (Fig. 4C).

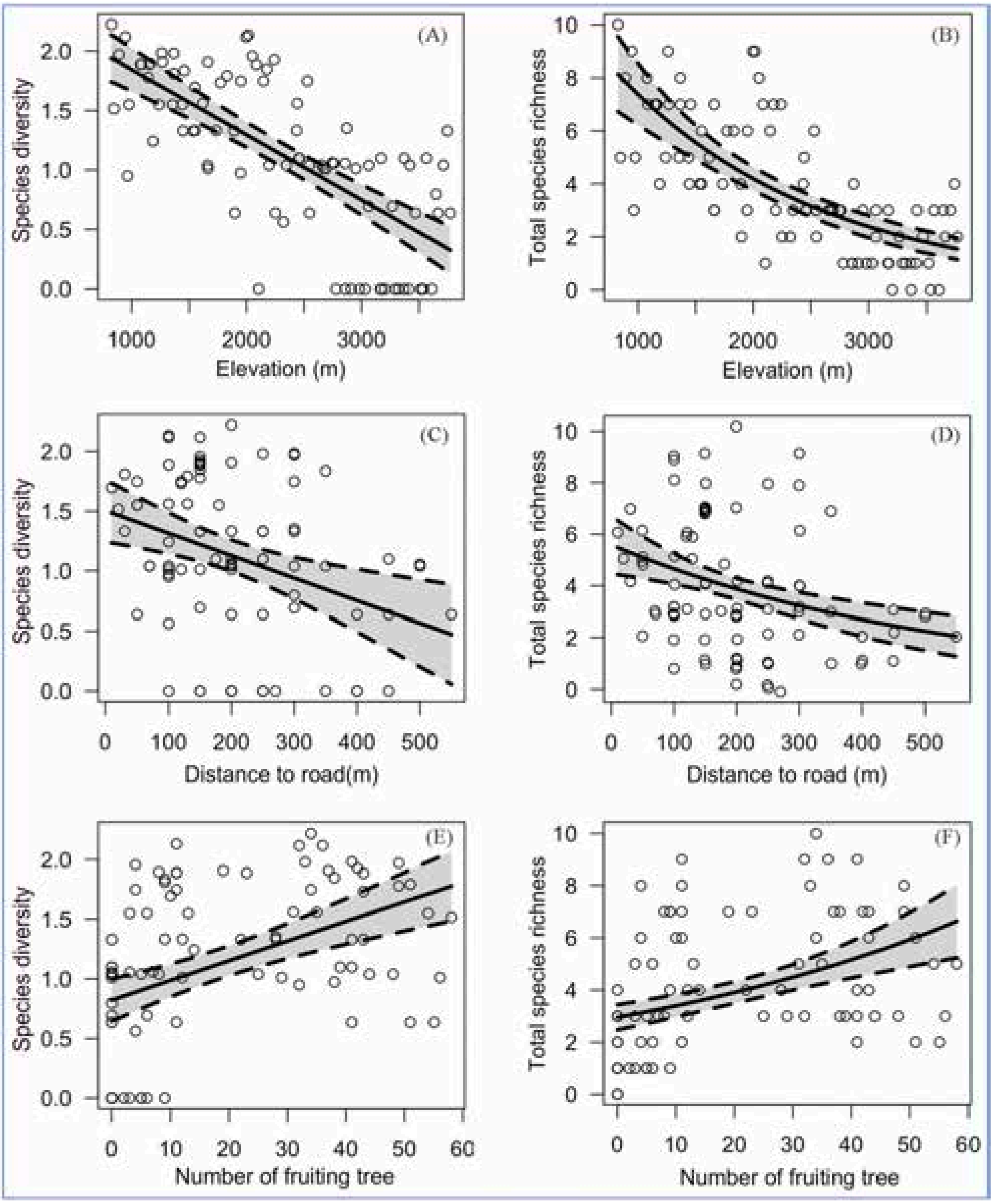

Figure 3. Relationship between bird species richness and diversity and environmental variables (elevation, distance to road, and number of fruiting trees) along an elevation gradient in the Kaligandaki River basin.

Granivore birds, represented by small number of species had no significant association (Trace= 0.459, F-ratio= 0.744, *P*= 0.828) with habitat types (Fig. 4D). Omnivore birds depicted a significant relationship (Trace= 0.948, F-ratio= 1.351, *P*= 0.006) with habitat variables (Fig. 4E). Bird species like Oriental White-eye *Zosterops* *palpebrosos*, Black Bulbul *Hypsipetes leucocephalus*, Asian Koel *Eudynamys scolopacea*, Scarlet Minivet *Pericrocotus flammeus*, Yellow-billed Blue Magpie *Urocissa flavirostris*, and Green Shrike Babbler *Pteruthius xanthochlorus* were associated with shrubland habitat. Similarly, bird species such as Common Tailorbird *Orthotomus sutorius*, Himalayan Bulbul *Pycnonotus leucogenys*, Red-billed Leiothrix *Leothrix lutea*, Beautiful Rosefinch *Carpodacus pulcherrimus*, and White-browed Fulvetta *Alcippe vinipectus* showed significant association with forest habitats. Very few species like Oriental Turtle Dove *Streptopelia orientalis* and Common Pigeon *Columba livia* showed association with other habitat variables such as scrubland, barren area and grassland habitat rather than forest and shrubland habitats. These variables appeared to have a strong impact on species distribution. Species richness in response to agricultural land as a habitat variable revealed very weak association.

DISCUSSION

Bird diversity in Kaligandaki River basin

This study recorded a highly diverse avian fauna dominated by Passeriformes in the Kaligandaki River basin. The high species richness might be attributed to habitat complexity/heterogeneity (MacArthur 1964; Pan et al. 2016; Hu et al. 2018) along an elevation gradient of the Kaligandaki River basin, comprising riverine *Alnus nepalensis* forest, *Schima wallichi* forest, mixed-forest with *Tooni ciliata* and *Bombyx ceiba*, *Pinus roxburghii* forest, *Pinus wallichiana* forest, *Betula utilis* forest including agricultural land, human settlement area, shrubberies, grassland and scrublands. The study area covered an elevation range of 800–3,800 m from sub-tropical to sub-alpine habitats supporting diverse avian fauna. At the lowest levels of the study area there were subtropical forests of broadleaved *Schima wallichii, Castanopsis indica*, and *Pinus roxburghii* on dry slopes, as well as Alder *Alnus nepalensis*, which mainly occurred along rivers and streams. Higher up were temperate forests of mixed broadleaves, oaks (*Quercus lamellosa, Q. lanata*, and *Q. semecarpifolia)* and rhododendrons. In the wettest places, bamboo jungles of *Arundinaria* species were dominant. Coniferous forests, mainly of Fir *Abies spectabilis,* Blue Pine *Pinus wallichiana*, and Hemlock *Tsuga dumosa* grow on the dry ridges and slopes. Above the temperate zone lie subalpine forests of Birch *Betula utilis*, blue pine, and junipers. Rhododendron and juniper scrub grow in the alpine zone (Inskipp & Inskipp 2003). Rivers and streams support a good variety of birds dependent on this habitat, notably Crested Kingfisher *Megaceryle lugubris*, four forktail species, Brown Dipper *Cinclus pallasii*, White-capped Redstart *Chaimarrornis leucocephalus* and Plumbeous Water Redstart *Rhyacornis fuliginosa*. The combination of highly varied topography, climate and wide altitude range has resulted in many habitat types and associated rich bird species diversity within the study area.

The avian assemblage in any area or habitat type often changes seasonally (Avery & Riper 1989; Moning & Müller 2008; Collins & Edward 2014), under the influence of microclimatic and environmental factors like temperature, humidity, rainfall, and food availability. Birds typically migrate from north to south in the winter, and most arrive for breeding in Nepal in the summer. We observed no significant difference in species richness between summer (95 species) and winter (81 species).

Factors affecting bird diversity

We observed a decline in species richness with increasing elevation in the Kaligandaki River basin. Similar observations have been reported for other taxa and regions (Rahbek 1995, 2005; Basnet et al. 2016; Santillan et al. 2018), but the few studies in the Himalaya have reported high species richness at middle elevations compared to higher and lower elevations (Bhattarai & Vetaas 2006; Acharya et al. 2011; Joshi & Bhat 2015; Hu et al. 2018; Ding et al. 2019; Xingcheng et al. 2019; Pandey et al. 2020). Our result is in line with previous studies showing a decline of species richness along elevational gradients (McCain 2009; Santhakumar et al. 2018), which has been attributed to limiting abiotic and biotic factors, such as harsh climatic conditions or reduced resource availability at high elevations. As elevation increases, the vegetation types and land topography gradually change from lower sub-tropical to sub-alpine, with decreasing forest cover and increased low-productivity scrub and meadows. Observed species richness was highest at 850m and 2,000m within the study area. At 850m the dense well-structured sub-tropical forest of *Schima wallichii*, *Alnus nepalensis*, *Bombyx ceiba*, and *Tooni ciliata* harbored a higher number of species. Additionally, the riverine area and cultivated land with human settlement at this elevation supported more avian fauna than in the higher altitudes. In general, richness peaks at intermediate elevations appear to correspond closely to transition zones between different vegetation types (Lomolino 2001). At 2,000m around the Ghasa forest, the transition zone between the two forest types, the sub-tropical forest and temperate forest predominately with *Pinus wallichiana*

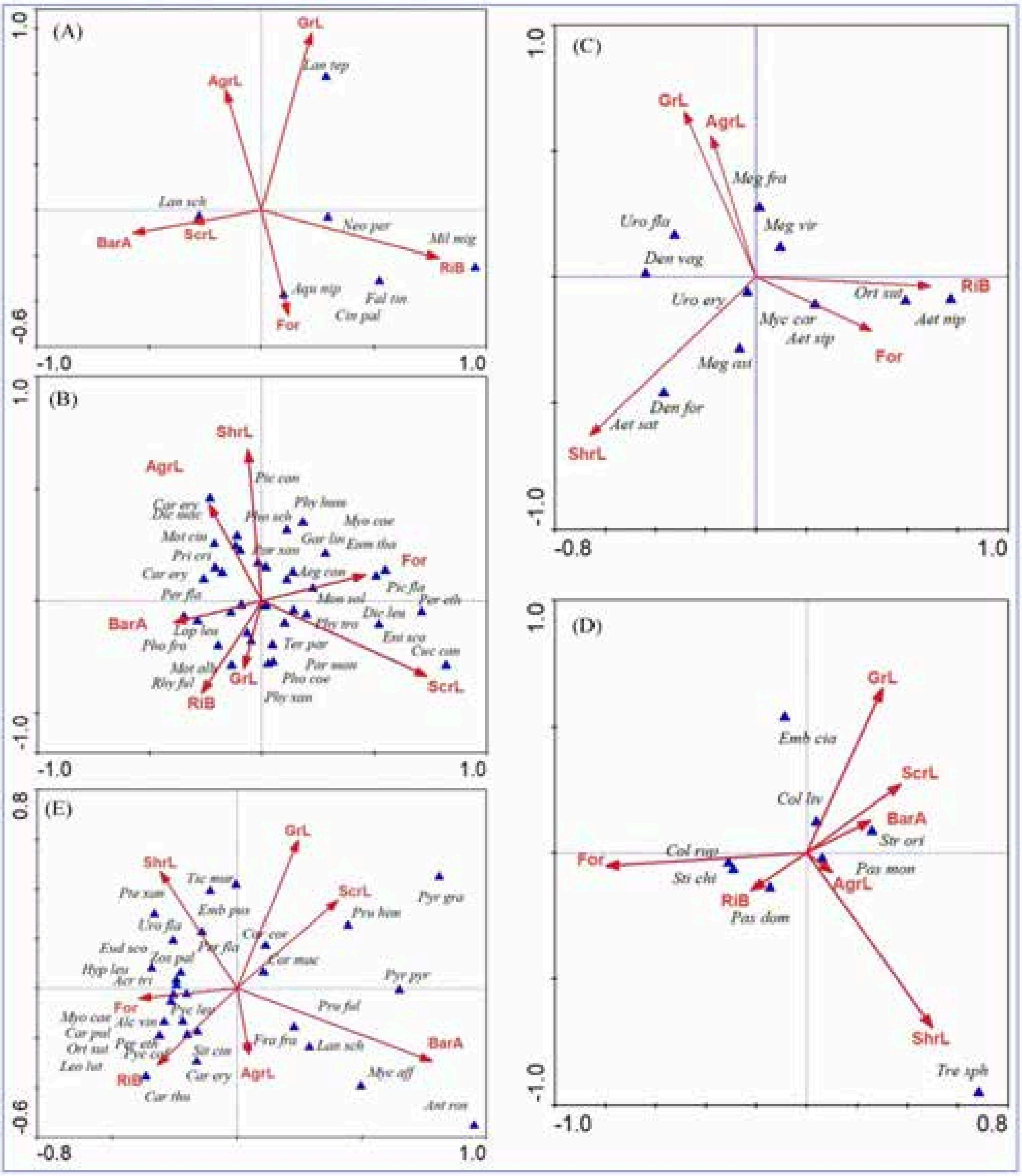

Figure 4. The CCA ordination diagram showing species response to different habitat types in the study area (Monte Carlo permutation test of significance with 499 permutations): A—carnivores | B—insectivores | C—frugivores | D—granivores | E—omnivores. Abbreviations: For—Forest habitat | RiB—River Bank | ShrL—Shrubland | GrL—Grassland | AgrL—Agricultural area | BarA—Barren area | ScrL—Scrubland. Triangle represents the particular species and the arrow indicates each of the habitat variables plotted to in the direction of maximum change in the explanatory variables. Species codes are given in Annex I.

might have contributed to the richness peak seen in this region. The gradual decline of species richness above 2,000 m might suggest an abrupt change in factors that limit avian richness, including poor vegetation and harsh climatic conditions. At higher elevations the stature of the forest decreased dramatically, and the climatic conditions became increasingly severe with heavy winds during summer and snowfall in winter. Such harsh and unproductive environment at higher altitudes cause a decline in abundance and distribution of invertebrate resources and scarcity of food items for birds, and favors a very small number of species (Blake & Loiselle 2000; Hu et al. 2018). Besides this, trees were replaced by bushes, shrubs and rocky-mountains, which negatively affected the avian fauna in this region.

Bird species richness and diversity suggested a positive association with the number of fruiting trees taken as proxy of resource availability within the study area. Food availability is considered one of the most important factors limiting bird richness and abundance (Strong & Sherry 2000; Wu et al. 2013; Douglas et al. 2014; Pan et al. 2016). As the number of fruiting trees increased, species richness was also higher, illustrating the positive impact of forest resources on avian diversity. This might be particularly a case for insectivorous species as the insectivore species constitute substantial pool of overall species richness. These results are consistent with previous studies which have supported the energy (resource)-diversity hypothesis (Hurlbert & Haskell 2003; Price et al. 2014; Pan et al. 2016), explaining that the sites with greater available energy can support more individuals and, hence, more species. Further, increase in number of trees provides food resources, roosting and nesting sites to most of the forest birds. Additionally, the fruiting trees with flowers, fruits, and seeds attract a number of insects and hence support the insectivores resulting in overall species richness increase. There was a significant relationship between bird species assemblages and tree species assemblages in the eastern forests of North America (Lee & Rotenberry 2005). This is consistent with the findings that the species richness of insectivorous feeding guilds was associated to vegetation structure and invertebrate biomass, while the richness of frugivores was linked with fruit abundance, both supported by the forest stand and cover (Ferger 2014). The distribution and abundance of many bird species are determined by the configuration and composition of the vegetation (trees species and number) that comprises a major element of their habitat (Morrison 1992; Block & Brennan 1993). As number of trees stands changes along geographical and environmental gradients, any particular bird species may appear, increase in abundance, decrease, and fade as habitat becomes more or less suitable for its existence (Pidgeon et al. 2007).

The impacts of roads on wildlife populations are extensive and well documented around the globe (Fahrig & Rytwinski 2009). Distance to road as a representation of disturbance variable with species richness and diversity was tested and strong negative correlation was observed, revealing increase in species richness near road and vice versa. Many studies on birds have shown negative association to the roads such that abundance, occurrence and species richness of birds are reduced near roads, with larger reductions near high-traffic roads than near lower traffic roads (Reijnen et al. 1995; Brotons & Herrando 2001; Fuller et al. 2001; Burton et al. 2002; Rheindt 2003; Peris & Pescador 2004; Pocock & Lawrence 2005; Palomino & Carrascal 2007; Griffith et al. 2010). Similar findings with road distance and species richness was discussed where empirical findings showed that there was a negative impact of roads and settlements on threatened birds of Chitwan National Park, Nepal (Adhikari et al. 2019). The main cause of the higher bird richness near roads in the Kaligandaki River basin may due to low traffic in newly constructed roads and sparse human settlements and movements. High species richness near the road may be due to higher detectability by the observers and possible preference of open habitats by the birds.

Habitat association of the birds

Canonical correspondence analysis showed that most of the feeding guilds including insectivores, omnivores and frugivores were associated with forest, shrubland, and agricultural area. The observed bird species preferred forest habitat in comparison to other habitat types within the study area. The main reason for such preference could be available resources supplement by forest area in comparison to other land use types. Forests provide the indispensable resources required for the accomplishment of life cycles of birds, including food for adults and nestlings and nesting sites. Avian fauna occurs on several trophic heights in forests from primary consumers to vertebrate predators, as well as omnivores and scavengers. Birds get nutrients from nectar, fruits, seeds, and vegetative tissues including roots, shoots, and leaves. Birds that consume the vegetative parts of plants may also supplement their diet with other sources of protein such as invertebrates found in different strata in forest habitat, supporting insectivore species (Stratford & Sekercioglu 2015). These findings are supported by many studies that explained increased structural complexity of vegetation is associated with increased avian species richness (MacArthur & MacArthur 1961; MacArthur et al. 1962; MacArthur et al. 1966; Orians & Wittenberger 1991).

One characteristic of forest structure is foliage height diversity and is defined by the variation in the layers of a forest which positively supports species richness. Increasing foliage height diversity is associated with increasing avian diversity, particularly insectivores (MacArthur & MacArthur 1961; MacArthur et al. 1962), with increasing foraging sites and increased niches available to exploit (MacArthur et al. 1966). Another study of avian communities in urban parks across Beijing showed that the vegetation structure and foliage height diversity was the most important factor influencing avian species diversity than park area (Xie et al. 2016). Rompre et al. (2007) found that plant species richness, precipitation, forest age, and topography strongly affected avian diversity in lowland, Panama rain forests. In the present study, lower number of species in scrubland and barren area in higher altitudes (above 2,600m) could be attributed to scarce vegetation and low productivity due to climatic constraints. The presence of forest stands, forest edges and shrubs, therefore, supports more bird species are important factors in driving species composition (Basnet et al. 2016). Similar results were described in farmland in central Uganda, where richness of forest-dependent bird species showed a positive relationship with the number of native tree species (Douglas et al. 2014). Significant association of species with river bank area can be explained by the presence of aquatic avian fauna such as Brown Dipper *Cinclus pallasii*, Blue Whistling Thrush *Myophonus caeruleus*, Plumbeous Water Redstart *Rhyacornis fuliginosa*, White-capped Redstart *Chaimarrornis leucocephalus*, forktails, and wagtails dwelling near and around streams and rivers depending mostly on aquatic invertebrates in or under the water, river banks, and riverine vegetation. Study on Tibetan region of the Himalaya indicated that the species richness of overall birds is positively correlated with forest habitat, productivity, and habitat heterogeneity (Pan et al. 2016). Higher species richness in forest habitats especially in lower elevations and strong association of birds with fruiting trees for resource utilization along the Kaligandaki River basin indicate that the existing primary forest in the basin is important for avian conservation.

Our survey of birds during summer and winter showed highly diverse avian fauna, but it did not cover all seasons, nor all of the Annapurna Conservation Area. A more extensive study is recommended to more comprehensively explore avian species within this area. Apart from developing checklists of birds, studies of patterns and processes affecting species, and diversity of avian fauna in other parts of the conservation area are recommended to assist conservation efforts.

CONCLUSIONS

The Kaligandaki Valley river basin, an important part of the Annapurna Conservation Area, one of the IBAs in central Himalaya has highly diverse avian fauna dominated by Passeriformes. High abundance of resident insectivores does not bring much variation in species richness between summer and winter. Restrictive abiotic and biotic factors, such as harsh climatic conditions or reduced resource availability at high elevations, cause a decline in bird species richness with elevation. The number of fruiting trees has a positive influence on avian species richness and diversity.

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Annex I. Checklist of bird species from Kaligandaki River basin, Annapurna Conservation Area, Nepal

Order, Family, Common name	Scientific name	Feeding guild	Migratory status	Species code used in ordination
GALLIFORMES				
Phasianidae				
Black Francolin	*Francolinus francolinus*	Omnivore	Resident	*Fra fra*
Kalij Pheasant	*Lophura leucomelanos*	Insectivore	Resident	*Lop leu*
PICIFORMES				
Megalaimidae				
Blue-throated Barbet	*Megalaima asiatica*	Frugivore	Resident	*Meg asi*
Golden-throated Barbet	*Megalaima franklinii*	Frugivore	Resident	*Meg fra*
Great Barbet	*Megalaima virens*	Frugivore	Resident	*Meg vir*
Picidae				
Greater Yellownape	*Picus flavinucha*	Insectivore	Resident	*Pic fla*
Grey-headed Woodpecker	*Picus canus*	Insectivore	Resident	*Pic can*
Fulvous-breasted Woodpecker	*Dendrocopos macei*	Insectivore	Resident	*Den mac*
Speckled Piculet	*Picumnus innominatus*	Insectivore	Resident	*Pic inn*
CUCULIFORMES				
Cuculidae				
Eurasian Cuckoo	*Cuculus canorus*	Insectivore	Summer visitor	*Cuc can*
Lesser Cuckoo	*Cuculus poliocephalus*	Insectivore	Summer visitor	*Cuc pol*
Asian Koel	*Eudynamys scolopaceus*	Omnivore	Resident	*Eud sco*
COLUMBIFORMES				
Columbidae				
Common Pigeon	*Columba livia*	Granivore	Resident	*Col liv*
Hill Pigeon	*Columba rupestris*	Granivore	Resident	*Col rup*
Oriental Turtle Dove	*Streptopelia orientalis*	Granivore	Summer visitor	*Str ori*
Spotted Dove	*Stigmatopelia chinensis*	Granivore	Resident	*Sti chi*
Wedge-tailed green Pigeon	*Treron sphenurus*	Granivore	Resident	*Tre sph*
CICONIFORMES				
Scolopacidae				
Green Sandpiper	*Tringa ochropus*	Insectivore	Winter visitor	*Tri och*
ACCIPITRIFORMES				
Accipitridae				
Black Kite	*Milvus migrans*	Carnivore	Winter visitor	*Mil mig*
Steppe Eagle	*Aquila nipalensis*	Carnivore	Winter visitor	*Aqu nip*
Egyptian Vulture	*Neophron percnopterus*	Carnivore	Resident	*Neo per*
FALCONIFORMES				
Falconidae				
Common Kestrel	*Falco tinnunculus*	Carnivore	Winter visitor	*Fal tin*
PASSERIFORMES				
Prunellidae				
Alpine Accentor	*Prunella collaris*	Omnivore	Resident	*Pru col*
Altai Accentor	*Prunella himalayana*	Omnivore	Winter visitor	*Pru him*
Brown Accentor	*Prunella fulvescens*	Omnivore	Winter visitor	*Pru ful*
Corvidae				
Alpine Chough	*Pyrrhocorax graculus*	Omnivore	Resident	*Pyr gra*

Order, Family, Common name	Scientific name	Feeding guild	Migratory status	Species code used in ordination
House Crow	*Corvus splendens*	Omnivore	Resident	*Cor spl*
Large-billed Crow	*Corvus macrorhynchos*	Omnivore	Resident	*Cor mac*
Northern Raven	*Corvus corax*	Omnivore	Resident	*Cor cor*
Red-billed Blue Magpie	*Urocissa erythrorhyncha*	Frugivore	Resident	*Uro ery*
Red-billed Chough	*Pyrrhocorax pyrrhocorax*	Omnivores	Resident	*Pyr pyr*
Rufous Treepie	*Dendrocitta vagabunda*	Frugivore	Resident	*Den vag*
Grey Treepie	*Dendrocitta formosae*	Frugivore	Resident	*Den for*
Yellow-billed Blue Magpie	*Urocissa flavirostris*	Frugivore	Resident	*Uro fla*
Dicruridae				
Ashy Drongo	*Dicrurus leucophaeus*	Insectivore	Summer visitor	*Dic leu*
Black Drongo	*Dicrurus macrocercus*	Insectivore	Resident	*Dic mac*
Spangled Drongo	*Dicrurus hottentottus*	Insectivore	Resident	*Dic hot*
Muscicapidae				
Asian Paradise-flycatcher	*Terpsiphone paradisi*	Insectivore	Summer visitor	*Ter par*
Blue-capped Redstart	*Phoenicurus coeruleocephala*	Insectivore	Winter visitor	*Pho coe*
Blue-fronted Redstart	*Phoenicurus frontalis*	Omnivore	Summer visitor	*Pho fro*
Common Stonechat	*Saxicola torquatus*	Insectivore	Resident	*Sax tor*
Himalayan Bluetail	*Tarsiger rufilatus*	Insectivore	Resident	*Tar ruf*
Hogdson's Redstart	*Phoenicurus hodgsoni*	Insectivore	Winter visitor	*Pho hod*
Little Forktail	*Enicurus scouleri*	Insectivore	Resident	*Eni sco*
Pied Bushchat	*Saxicola caprata*	Insectivore	Resident	*Sax cap*
Grey Bushchat	*Saxicola ferreus*	Insectivore	Resident	*Sax fer*
Plumbous Water Redstart	*Rhyacornis fuliginosa*	Insectivore	Resident	*Rhy ful*
Spotted Forktail	*Enicurus maculatus*	Insectivore	Resident	*Eni mac*
Verditer Flycatcher	*Eumyias thalassinus*	Insectivore	Summer visitor	*Eum tha*
White-capped Redstart	*Chaimarrornis leucocephalus*	Insectivore	Resident	*Cha leu*
White-browed Bush Robin	*Tarsiger indicus*	Insectivore	Resident	*Tar ind*
Oriental Magpie Robin	*Copsychus saularis*	Insectivore	Resident	*Cop sau*
White-tailed Rubythroat	*Luscinia pectoralis*	Insectivore	Resident	*Lus pec*
White-throated Redstart	*Phoenicurus schisticeps*	Insectivore	Winter visitor	*Pho sch*
Hirundinidae				
Barn Swallow	*Hirundo rustica*	Insectivore	Resident	*Hir rus*
Fringillidae				
Beautiful Rosefinch	*Carpodacus pulcherrimus*	Omnivore	Summer visitor	*Car pul*
Collared Grosbeak	*Mycerobas affinis*	Omnivore	Resident	*Myc aff*
Common Rosefinch	*Carpodacus erythrinus*	Omnivore	Summer visitor	*Car ery*
Spot-winged Grosbeak	*Mycerobas melanozanthos*	Frugivore	Resident	*Myc mel*
White-browed Rosefinch	*Carpodacus thura*	Omnivore	Summer visitor	*Car thu*
White-winged Grosbeak	*Mycerobas carnipes*	Frugivore	Resident	*Myc car*
Pycnonotidae				
Black Bulbul	*Hypsipetes leucocephalus*	Omnivore	Resident	*Hyp leu*
Himalayan Bulbul	*Pycnonotus leucogenys*	Omnivore	Resident	*Pyc leu*
Red-vented Bulbul	*Pycnonotus cafer*	Omnivore	Resident	*Pyc caf*
Timallidae				
Black-chinned Babbler	*Stachyridopsis pyrrhops*	Insectivore	Resident	*Sta pyr*

Order, Family, Common name	Scientific name	Feeding guild	Migratory status	Species code used in ordination
Green Shrike Babbler	*Pteruthius xanthochlorus*	Omnivore	Resident	*Pte xan*
Paridae				
Black-lored Tit	*Parus xanthogenys*	Insectivore	Resident	*Par xan*
Black-throated Tit	*Aegithalos concinnus*	Insectivore	Resident	*Aeg con*
Coal Tit	*Periparus ater*	Insectivore	Resident	*Per ate*
Great Tit	*Parus major*	Insectivore	Resident	*Par maj*
White-throated Tit	*Aegithalos niveogularis*	Insectivore	Resident	*Aeg niv*
Green-backed Tit	*Parus monticolus*	Insectivore	Resident	*Par mon*
Nectarinidae				
Black-throated Sunbird	*Aethopyga saturata*	Frugivore	Resident	*Aet sat*
Crimson Sunbird	*Aethopyga siparaja*	Frugivore	Resident	*Aet sip*
Fire-breasted Flowerpecker	*Dicaeum ignipectus*	Frugivore	Resident	*Dic ign*
Green-tailed Sunbird	*Aethopyga nipalensis*	Frugivore	Resident	*Aet nip*
Purple Sunbird	*Nectarinia asiatica*	Frugivore	Resident	*Nec asi*
Turdidae				
White-throated Laughingthrush	*Garrulax albogularis*	Insectivore	Resident	*Gar alb*
Blue-capped Rock Thrush	*Monticola cinclorhynchus*	Insectivore	Summer visitor	*Mon cin*
Blue Rock Thrush	*Monticola solitarius*	Insectivore	Summer visitor	*Mon sol*
Blue Whistling Thrush	*Myophonus caeruleus*	Omnivore	Resident	*Myo cae*
Streaked Laughing Thrush	*Garrulax lineatus*	Insectivore	Resident	*Gar lin*
Variegated Laughing Thrush	*Garrulax variegatus*	Insectivore	Resident	*Gar var*
Sylviidae				
Blyth's Leaf Warbler	*Phylloscopus reguloides*	Insectivore	Resident	*Phy reg*
Grey-hooded Warbler	*Phylloscopus xanthoschistos*	Insectivore	Resident	*Phy xan*
Greenish Warbler	*Phylloscopus trochiloides*	Insectivore	Resident	*Phy tro*
Hume's Leaf Warbler	*Phylloscopus humei*	Insectivore	Summer visitor	*Phy hum*
Lemon-rumped Warbler	*Phylloscopus chloronotus*	Insectivore	Winter visitor	*Phy chl*
Red-billed Leiothrix	*Leiothrix lutea*	Omnivore	Resident	*Leo lut*
Rufous Sibia	*Malacias capistratus*	Omnivore	Resident	*Mal cap*
Stripe-throated Yuhina	*Yuhina gularis*	Omnivore	Resident	*Yuh gul*
White-browed Fulvetta	*Alcippe vinipectus*	Omnivore	Resident	*Alc vin*
Yellow-browed Warbler	*Phylloscoppus inornatus*	Insectivore	Winter visitor	*Phy ino*
Cinclidae				
Brown Dipper	*Cinclus pallasii*	Insectivore	Resident	*Cin pal*
Laniidae				
Brown Shrike	*Lanius cristatus*	Carnivore	Winter visitor	*Lan cri*
Grey-backed Shrike	*Lanius tephronotus*	Carnivore	Summer visitor	*Lan tep*
Long-tailed Shrike	*Lanius schach*	Carnivore	Resident	*Lan sch*
Certhiidae				
Brown-throated Treecreeper	*Certhia discolor*	Insectivore	Resident	*Cer dis*
Sittidae				
Chestnut-bellied Nuthatch	*Sitta cinnamoventris*	Omnivore	Resident	*Sit cin*
Velvet-fronted Nuthatch	*Sitta frontalis*	Omnivore	Resident	*Sit fro*
Wall creeper	*Tichodroma muraria*	Omnivore	Winter visitor	*Tic mur*
Sturnidae				

Order, Family, Common name	Scientific name	Feeding guild	Migratory status	Species code used in ordination
Common Myna	*Acridotheres tristis*	Cmnivore	Resident	*Acr tri*
Cisticilidae				
Common Tailorbird	*Orthotomus sutorius*	Insectivore	Resident	*Ort sut*
Passeridae				
Eurasian Tree Sparrow	*Passer montanus*	Granivore	Resident	*Pas mon*
House Sparrow	*Passer domesticus*	Granivore	Resident	*Pas dom*
Russet Sparrow	*Passer rutilans*	Omnivore	Resident	*Pas rut*
Motacillidae				
Grey Wagtail	*Motacilla cinerea*	Insectivore	Summer visitor	*Mot cin*
Rosy Pipit	*Anthus roseatus*	Omnivore	Summer Visitor	*Ant ros*
Olive-backed Pipit	*Anthus hodgsoni*	Insectivore	Winter visitor	*Ant hod*
White Wagtail	*Motacilla alba*	Insectivore	Summer visitor	*Mot alb*
White-browed Wagtail	*Motacilla maderaspatensis*	Insectivore	Resident	*Mot mad*
Yellow Wagtail	*Motacilla flava*	Insectivore	Winter visitor	*Mot fla*
Campephagidae				
Long-tailed Minivet	*Pericrocotus ethologus*	Insectivore	Resident	*Per eth*
Scarlet Minivet	*Pericrocotus flammeus*	Insectivore	Resident	*Per fla*
Zosteropidae				
Oriental White-eye	*Zosterops palpebrosus*	Omnivore	Resident	*Zor pal*
Emberizidae				
Rock Bunting	*Emberiza cia*	Granivore	Resident	*Emb cia*
Little Bunting	*Emberiza pussila*	Omnivore	Winter visitor	*Emb pus*
Cisticolidae				
Striated Prinia	*Prinia crinigera*	Insectivore	Resident	*Pri cri*
Rhipiduridae				
White-throated Fantail	*Rhipidura albicollis*	Insectivore	Resident	*Rhi alb*
Yellow-bellied Fantail	*Chelidorhynx hypoxantha*	Insectivore	Summer visitor	*Che hyp*

Image 1. Blue-throated Barbet *Megalaima asiatica*

Image 2. Egyptian Vulture *Neophron percnopterus*

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COMMUNICATION

A highway to hell: a proposed, inessential, 6-lane highway (NH173) that threatens the forest and wildlife corridors of the Western Ghats, India

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Abstract: A globally, extensive road network combined with increasing vehicular traffic poses a significant threat to local wildlife, environment, economy, and socio-politics. India, with nearly 5.9 million kilometers of road, has the second-highest road network in the world; and has plans to exponentially increase its national highways. In this study, we use a combination of collation of official documents, literature review, and GIS mapping to outline the possible environmental and socio-economic impacts caused by a proposed 6-lane national highway (NH 173). This highway is set to cut through the low elevation evergreen forests of the central Western Ghats between Mudigere and Nelliyadi towns of Chikkamagaluru and Dakshina Kannada districts, of Karnataka State, respectively. We further outline the insignificance of the project and recommend workable alternatives that could be considered in the wider public's interest.

Keywords: Conservation, forest, India, linear intrusion, road, roadkill, wildlife.

Kannada abstract: ಜಾಗತಿಕ ಮಟ್ಟದಲ್ಲಿ, ವ್ಯಾಪಕವಾಗಿರುವ ರಸ್ತೆಗಳ ಸಂಪರ್ಕ ಮತ್ತು ಹೆಚ್ಚಾಗುತ್ತಿರುವ ವಾಹನಗಳ ಸಂಚಾರವು ಸ್ಥಳೀಯ ವನ್ಯಜೀವಿ, ಪರಿಸರ, ಆರ್ಥಿಕ ಮತ್ತು ಸಾಮಾಜಿಕ ವ್ಯವಸ್ಥೆಯ ಮೇಲೆ ವ್ಯತಿರಿಕ್ತವಾದ ಪರಿಣಾಮವನ್ನು ಬೀರುತ್ತದೆ. ಭಾರತದಲ್ಲಿನ ರಸ್ತೆಗಳು, ಸುಮಾರು 5.9 ದಶಲಕ್ಷ ಕಿಲೋಮೀಟರ್ ಗಳಷ್ಟು ವಿಸ್ತೀರಣವನ್ನು ಹೊಂದಿದ್ದು, ವಿಶ್ವದಲ್ಲಿ ಎರಡನೇ ಅತಿದೊಡ್ಡ ರಸ್ತೆ ಸಂಪರ್ಕ ಹೊಂದಿರುವ ದೇಶವಾಗಿದೆ. ಅಷ್ಟೇ ಅಲ್ಲದೆ, ಇನ್ನೂ ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಯಲ್ಲಿ ರಾಷ್ಟ್ರೀಯ ಹೆದ್ದಾರಿಗಳ ನಿರ್ಮಾಣ ಯೋಜನೆಯನ್ನು ಹಾಕಿಕೊಂಡಿದೆ. ಕೆಳಕಂಡ ಅಧ್ಯಯನದಲ್ಲಿ, ಪ್ರಸ್ತಾಪಿತ ಷಟ್ಪದಿ ರಾಷ್ಟ್ರೀಯ ಹೆದ್ದಾರಿ ಯೋಜನೆಯಿಂದ (NH 173), ಪರಿಸರ, ಸಾಮಾಜಿಕ ಮತ್ತು ಆರ್ಥಿಕ ವ್ಯವಸ್ಥೆಯ ಮೇಲೆ ಬೀಳಬಹುದಾದ ಪರಿಣಾಮಗಳ ರೂಪರೇಖವನ್ನು, ಸರ್ಕಾರಿ ಸಂಯೋಜಿತ ದಾಖಲೆಗಳು, ಲೇಖನ ವಿಮರ್ಶೆ ಹಾಗೂ ಜಿ ಐ ಎಸ್ ರೇಖಾಚಿತ್ರಗಳನ್ನು ಅಧ್ಯಯನ ಮಾಡುವುದರ ಮೂಲಕ ತಿಳಿಸಿರುತ್ತೇವೆ. ಭಾರತ ದೇಶದ ಕರ್ನಾಟಕ ರಾಜ್ಯದ ಚಿಕ್ಕಮಗಳೂರು ಜಿಲ್ಲೆಯ ಭಾಗವಾದ ಮೂಡಿಗೆರೆ ಹಾಗೂ ದಕ್ಷಿಣ ಕನ್ನಡ ಜಿಲ್ಲೆಯ ಭಾಗವಾದ ನೆಲ್ಯಾಡಿ ಮಧ್ಯೆ ಇರುವ, ಪಶ್ಚಿಮ ಘಟ್ಟಗಳ ಕಡಿಮೆ ಎತ್ತರದ ನಿತ್ಯ ಹರಿದ್ವರ್ಣ ಕಾಡುಗಳ ಮೂಲಕ ಈ ಹೆದ್ದಾರಿಯು ಹಾದು ಹೋಗುವುದನ್ನು ಪ್ರಸ್ತಾಪಿಸಲಾಗಿದೆ. ಅದಲ್ಲದೆ, ಇದು ಮಹತ್ವಹೀನ ಯೋಜನೆ ಎಂಬುದನ್ನು ತಿಳಿಸುತ್ತಾ, ಸಾರ್ವಜನಿಕ ಹಿತಾಸಕ್ತಿಯನ್ನು ಕಾಪಿಡುವ ದೃಷ್ಟಿಯಿಂದ, ಇದಕ್ಕೆ ಪರ್ಯಾಯ ವ್ಯವಸ್ಥೆಯನ್ನೂ ಸೂಚಿಸಲಾಗಿರುತ್ತದೆ.

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Author contribution: Both the authors conceived the idea, HSSCS primarily wrote the paper and both the authors contributed to the final manuscript.

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INTRODUCTION

India has the second-highest road network in the world with nearly 5.9 million kilometers of road (MRTH 2019). Between the years 2018 and 2019, with 10,855km added to the existing highway network, India had a 10% increase in national highways compared to the previous year (MRTH 2019). Even with increased fuel economy standards, technological advancements, and continued roadway constructions, India's vehicular traffic is expected to grow significantly beyond the year 2050 (Dulac 2013). Globally, such extensive road network combined with increasing vehicular traffic has been identified as a significant threat to local wildlife, environment, economy, socio-politics, and indigenous culture & traditions (Goosem et al. 2010; Alamgir et al. 2017).

One such road is the proposed 6-lane national highway (NH-173) between Mudigere and Nelliyadi towns of Chikkamagaluru and Dakshina Kannada districts, of Karnataka State, respectively (hereafter Shishila Byrapura (SB) highway) to connect the coastal town of Bantwal with Chitradurga in southern India, through an entirely new alignment (NHAI 2018) (Fig. 1). The entire project of 233km has been split into four workable packages, each under 100km (NHAI 2018). Among them is the 68.9km stretch between Mudigere and Nelliyadi, with no existing highway in the alignment. With a budget of 25 billion INR (330 million USD at 1 USD = 75.698 INR), the project is set to connect this stretch, currently without any motorable road between Byrapura Village near Mudigere and Shishila Village near Nelliyadi; where the mean elevation changes nearly 800m, within just 21.9km (Image 1). SB highway is set to cut across contiguous forest patches of central Western Ghats – a biodiversity hotspot and a UNESCO world heritage site (Myers et al. 2000; WHC 2012) (Appendix 1). Here we outline the inevitable socio-economic and environmental disaster expected to be caused by the project, its insignificance, and the recommendation of workable alternatives.

Environmental and socio-economic impacts

The highway is set to fragment a contiguous stretch of forest, protected under seven reserve forests (RFs), which connects Bhadra Tiger Reserve, Kudremukha National Park, and Pushpagiri Wildlife Sanctuary (Appendix 1). Building a 30m wide highway with crash barriers and other road safety features as proposed under the project could act as blockades for the movement and seasonal migration of wildlife (Raman 2011; Alamgir et al. 2017). These areas hold one of the highest populations of Asiatic Elephants and also has been identified as an important Tiger corridor (Appendix 2; Elephant Task Force 2012; Qureshi et al. 2014; Project Elephant Division 2017). Along with these charismatic and threatened mega-fauna, these RFs are home to five species of birds, nine species of reptiles, and 23 species of mammals (Appendix 4), listed under schedule I and II of the Indian Wildlife (Protection) Act 1972, giving them the highest protection under Indian law (WII-ENVIS 2014; IUCN 2019). In addition, this landscape hosts an array of globally threatened and endemic species of flora and fauna (Myers et al. 2000; UNESCO WHC 2012). The proposed highway, with high speeding vehicles, would disrupt wildlife movement, especially of Asiatic Elephants, potentially worsening the existing acute human-elephant interactions in the region (Fig. 2, Appendix 5); this threatens the safety of both the local community and wildlife (Puyravaud et al. 2019). Opening up this relatively undisturbed patch of forest with no current access would inevitably lead to an increase in wildlife mortality through collision with speeding vehicles (Baskaran & Boominathan 2010; Raman 2011) and could provide access to poachers and smugglers to indulge in the illegal trade of wildlife and deforestation (Wilkie et al. 2000; Hughes 2018). The construction of a highway has also been linked to the spreading of invasive species such as *Lantana camara* and Eupatorium *Chromolaena odorata* and cause forest fires due to an increase in fuel loads from invasive alien species (Goosem et al. 2010; Raman 2011). At the same time, roads and highways lead to a change in animal behaviour where a few species will be attracted to the roads for scrap food from travelers while others would avoid regular movement, affecting their genetic diversity (Trombulak & Frissell 2000; Holderegger & Di Giulio 2010).

The area between Mudigere and Nelliyadi that is proposed for the construction of the SB highway lies on the high and moderate landslide susceptibility areas (Gupta & Basu 2017) (Appendix 3). The highway is also planned to pass along the Kapila River, one of the main feeders for the Nethravathi River system – a major river that provides water to millions of people and agrarian systems. Road construction, particularly in steep landscapes are associated with increased frequency of landslides and soil erosion (Goosem et al. 2010), resulting in heavy pulses of sediment into streams (Beevers et al. 2012). Thus, construction of the SB highway would worsen the landslide susceptibility, also damaging the water catchment of the Nethravathi

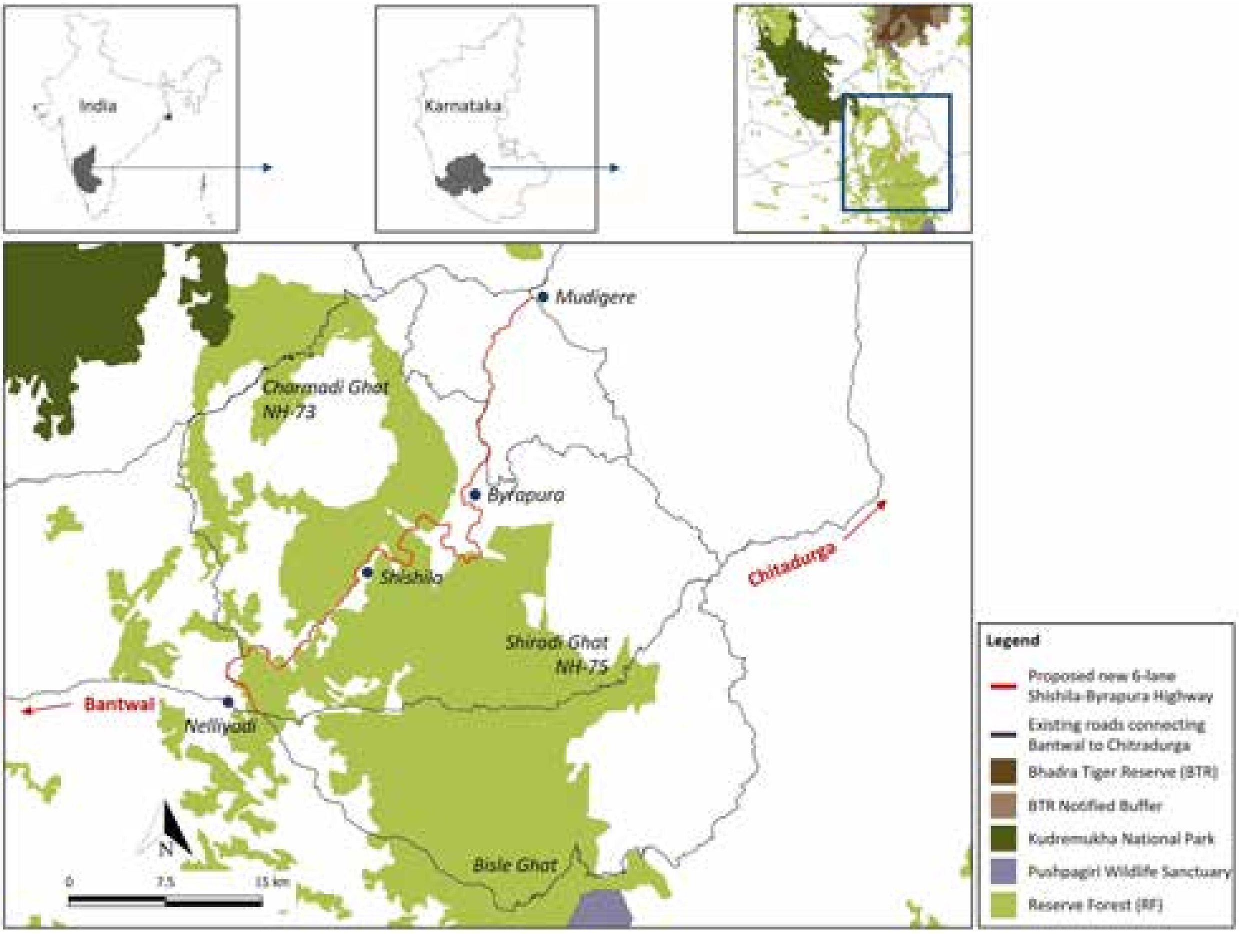

Figure 1. The proposed 6-lane Shishila Byrapura (SB) highway (coloured in red) between Mudigere in Chikkamagaluru District and Nelliyadi in Dakshina Kannada District, of Karnataka State. Three existing highways passing through the region that connects Chitradurga to Bantwal. The SB highway is set to further cut through a contiguous forest that connects Bhadra Tiger Reserve, Kudremukha National Park and Pushpagiri Wildlife Sanctuary. Details regarding SB highway were collected mainly from the open-access forest clearance web portal, submitted by the National Highway Authority of India (NHAI). All mapping was done using the QGIS software version 3.4.11-Madeira (QGIS Development Team 2019).

River system (Gupta & Basu 2017). The problem would escalate during the monsoon period, causing irreversible damage to wildlife, the local community, and economy as seen during the monsoon of 2018 and 2019 at various parts of the Western Ghats (Ghosh 2018; Mrunmayee & Girish 2019). Moreover, a 4-year long process of constructing a 70km highway through the forested landscape using earthmovers and blasting machinery, by itself, may permanently damage the area and disrupt wildlife movement. No amount of economic benefits, compensatory afforestation, or financial allowance can outweigh or equal the exceptional value of these old-growth natural forests (Watson et al. 2018).

Insignificance of the project and recommended alternatives

SB highway has been proposed for construction without due consideration of environmental and socio-economic factors, stating that habitat fragmentation is unavoidable; however, the proposed alignment of the highway is parallel to two existing highways (Fig. 1); and most other roads between Bantwal and Chitradurga, are being widened and upgraded to national highways. Furthermore, the alternative highway alignments that we propose are existing roads that are already being upgraded and almost trace the proposed highway. By tracing our proposed alignment, Nelliyadi – Sakaleshpura – Belur – Chikkamagaluru – Chitradurga (Fig. 3**,** Appendix 6), we could: a) halt the environmental and socio-economic impacts from the newly proposed SB highway; and b) save the needless expenditure of 25 billion INR of

Image 1. A picture of the old-growth lowland evergreen rainforest landscape through which the proposed 6-lane Shishila Byrapura (SB) highway is set to pass through.

taxpayer's money on an unnecessary project.

CONCLUSION

Under the current global biodiversity crisis and climate emergency, protection of natural forests and landscape is crucial now, more than ever before (Watson et al. 2018; Lewis et al. 2019). Increasing evidence also shows that inviolate spaces help in wildlife conservation and reduce human-wildlife conflict (Goswami et al. 2014; Srivathsa et al. 2014). It is evident that the construction of the proposed SB highway would lead to (a) habitat destruction and fragmentation (Appendix 1), (b) threaten the survival of 37 species of schedule I and II animals potentially found in the region (Appendix 4), (c) worsen the existing acute human-elephant interactions in the region (Fig. 2), and (d) cause an array of environmental and socio-economic disasters. We see no requirement for a parallel and a completely new 6-lane highway between Mudigere and Nelliyadi through the old-growth and sensitive forests, under a proposed new alignment. This is because, there are suitable alternatives with significantly lower impacts (Fig. 3, Appendix 6), which we strongly urge the Government of India to re-examine. Considering all the potential environmental and socio-economic impacts from the proposed SB highway, we request the concerned authorities to take necessary actions to consider alternative options.

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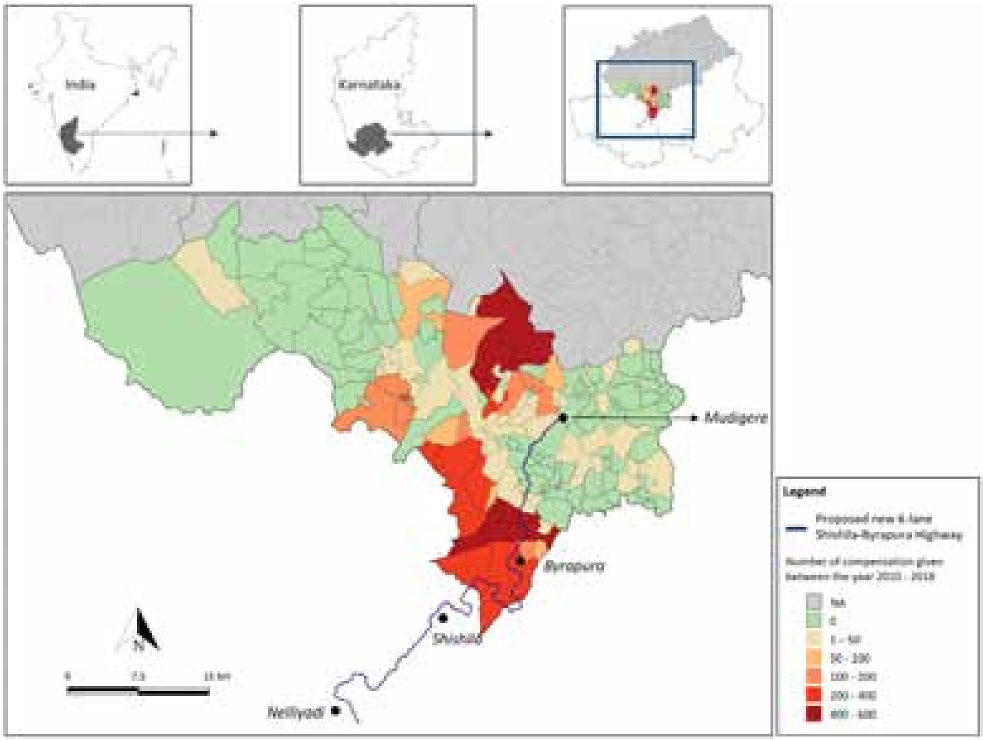

Figure 2. The number of compensations given at village level, by the Karnataka Forest Department (KFD), Government of India, for the elephant caused crop loss between the year 2010 and 2018. Here the compensation data is shown only for the taluk of Mudigere in Chikkamagaluru (light green to dark red), through which the proposed 6-lane Shishila Byrapura (SB) highway (dark blue line) is set to pass; all other villages are coloured in light grey. It is evident from the map that, the proposed highway cuts through the villages with high human-elephant conflict. If completed, the SB highway would potentially lead to an increase in the human-elephant negative interactions in the region. Details regarding the compensation were collated through written requests to KFD.

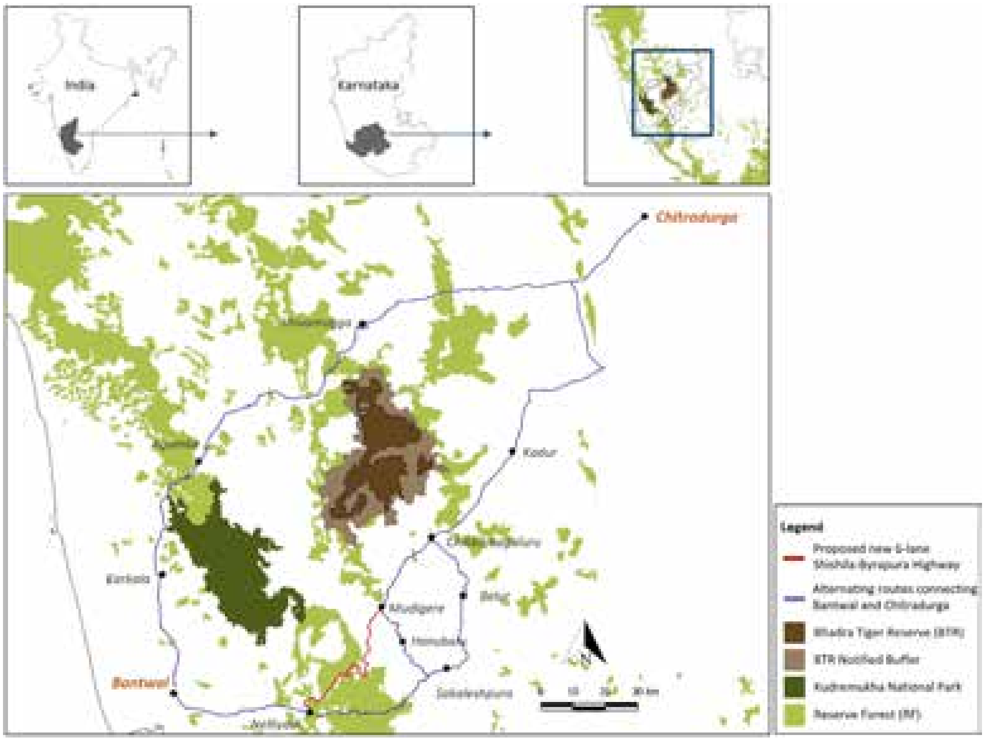

Figure 3. The existing highway routes that are being upgraded that can be used as an alternative (blue lines) to the proposed new 6-lane SB-highway (red line).

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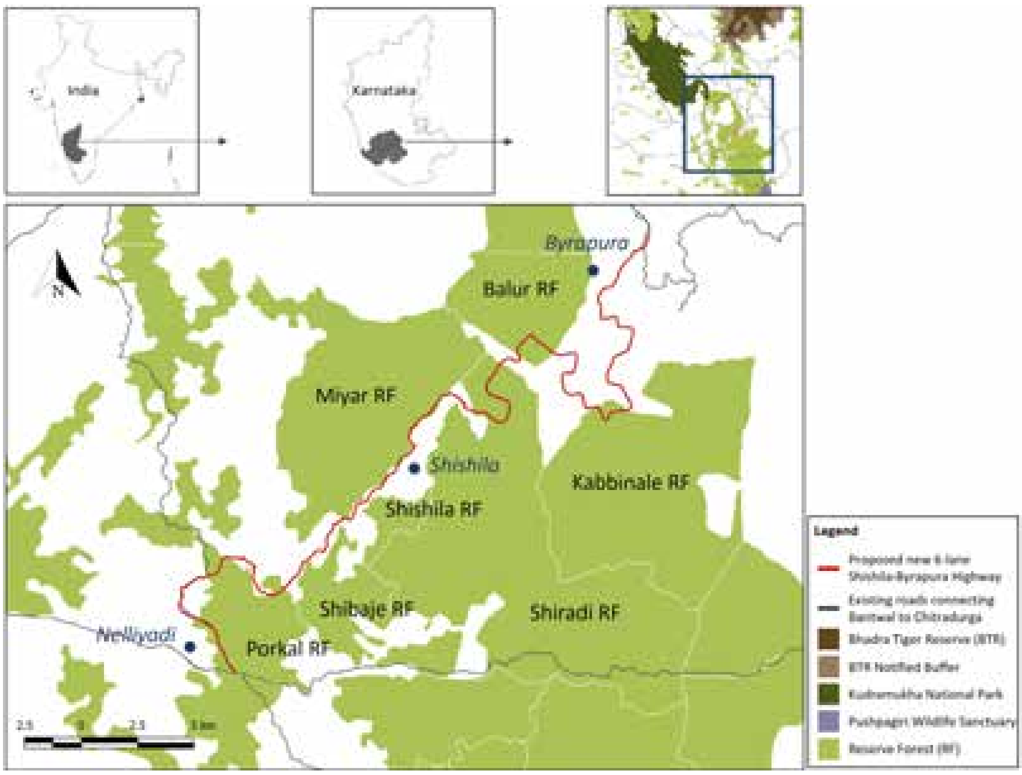
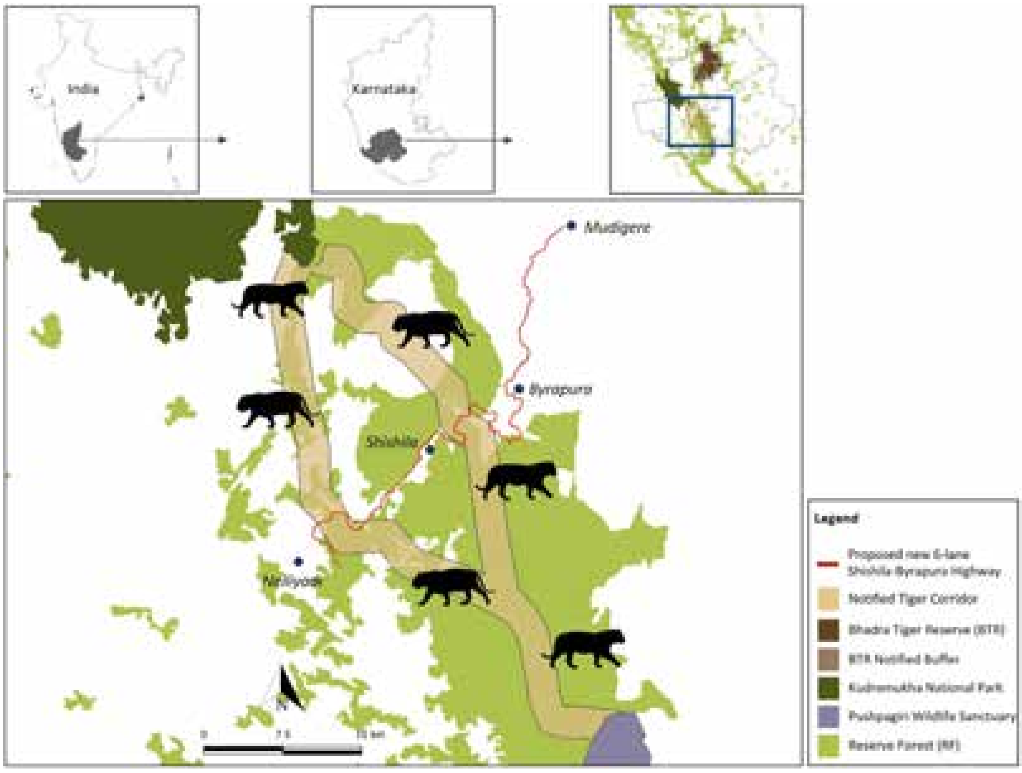
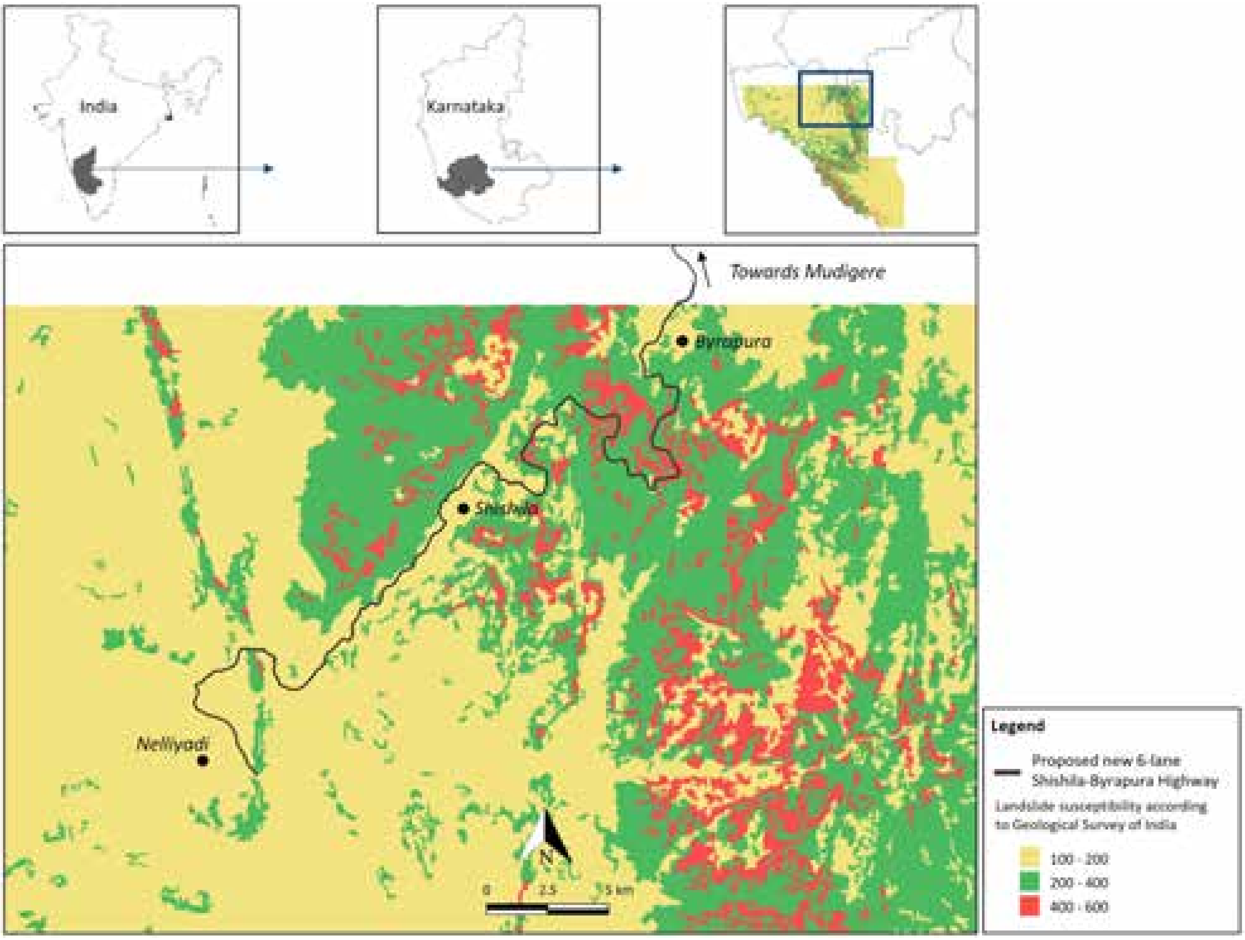


Appendix 1. The proposed Shishila Byrapura (SB) highway, which is set to cut through seven contiguous Reserve Forests (RF) in the Central Western Ghats namely: Balur RF, Kabbinale RF, Miyar RF, Porkal RF, Shiradi RF, Shishila RF, Shibaje RF. These RFs are contiguous and their various names are given by the Forest Department, Government of India, according to their administrative circles.



Appendix 2. The extent of the Tiger corridor notified by the National Tiger Conservation Authority (NTCA) of India as per the report submitted by Qureshi et al (2014).



Appendix 3. The landslide susceptibility of the proposed area through which the proposed Shishila Byrapura (SB) highway section of the NH173, is set to be newly constructed, as measured by the Geological Survey of India, Government of India. It is evident that the stretch passing through the Byrapura region passes almost entirely through Medium and High landslide susceptibility areas.

Appendix 4. Species listed under Schedule I and II of the Indian Wildlife (Protection) Act, 1972, that are found in the landscape where the proposed Shishila Byrapura (SB) highway section of the NH173, is set to be newly constructed.

Taxa	Common name	Scientific name	Schedule
Birds	Great Pied Hornbill	*Buceros bicornis*	I
Birds	Indian Pied Hornbill	*Anthracoceros malabaricus*	I
Birds	Peregrine Falcon	*Falco peregrinus*	I
Birds	Osprey	*Pandion haliaetus*	I
Birds	Southern Hill Myna	*Gracula indica*	I
Mammals	Gaur	*Bos gaurus*	I
Mammals	Malabar Civet	*Viverra civettina*	I
Mammals	Elephant	*Elephas maximus*	I
Mammals	Leopard	*Panthera pardus*	I
Mammals	Leopard Cat	*Prionailurus bengalensis*	I
Mammals	Gray Slender Loris	*Loris lydekkerianus*	I
Mammals	Indian Mouse Deer	*Moschiola indica*	I
Mammals	Indian Pangolin	*Manis crassicaudata*	I
Mammals	Asian Small-clawed Otter	*Aonyx cinereus*	I

Taxa	Common name	Scientific name	Schedule
Mammals	Sloth Bear	*Melursus ursinus*	I
Mammals	Tiger	*Panthera tigris*	I
Mammals	Bonnet Macaque	*Macaca radiata*	II
Mammals	Dark-legged Malabar Langur	*Semnopithecus hypoleucos*	II
Mammals	Dhole / Asiatic Wild Dog	*Cuon alpinus*	II
Mammals	Brown Palm Civet	*Paradoxurus jerdoni*	II
Mammals	Common Palm Civet	*Paradoxurus hermaphroditus*	II
Mammals	Small Indian Civet	*Viverricula indica*	II
Mammals	Indian Giant Squirrel	*Ratufa indica*	II
Mammals	Jackal	*Canis aureus*	II
Mammals	Jungle Cat	*Felis chaus*	II
Mammals	Brown Mongoose	*Herpestes brachyurus*	II
Mammals	Common Mongoose	*Herpestes edwardsii*	II
Mammals	Stripe-necked Mongoose	*Herpestes vitticollis*	II
Reptiles	Indian Flapshell Turtle	*Lissemys punctata*	I
Reptiles	Large Bengal Monitor Lizard	*Varanus bengalensis*	I
Reptiles	Indian Python	*Python molurus*	I
Reptiles	Indian Chameleon	*Chamaeleo zeylanicus*	II
Reptiles	Checkered Keelback	*Xenochrophis piscator*	II
Reptiles	King Cobra	*Ophiophagus hannah*	II
Reptiles	Indian Rat Snake	*Ptyas mucosa*	II
Reptiles	Spectacled Cobra	*Naja naja*	II

Appendix 5. The total number of compensation at the village level, for the elephant-caused crop loss within Mudigere Taluk of Chikkamagaluru District, given by the Karnataka Forest Department (KFD), Government of India. These villages are part of the region through with the proposed 6-lane highway Shishila Byrapura (SB) highway of NH173 is set to pass through. We collated the information on the compensation number through written requests to KFD. The economic value of each compensation might vary based on the intensity of the crop loss faced by individual farmers. At the village level, however, we have summed the number of cases to get the total number across eight years (2010–2018), irrespective of the economic value received.

Village names	Total number of compensation (2010–18)
Vurubage	580
B.Hosahalli	540
Kundhuru	492
Gutthi	386
Bankenahalli	290
Byrapura	285
Kogile	242
Bidarahalli	179
Hosakere	175
Saragodu	173
Kenjige	168
Binnadi	165
Mudhugundi	156
Palguni	135
Heggudlu	121

Village names	Total number of compensation (2010–18)
Meguru	101
Beranagodu	99
Maddrahalli	86
Mekanagadde	85
Tathkola	81
Tharuve	80
Koove	69
Byduvalli	49
Hesagodu	48
Darshana	46
Lokavalli	36
Hoysalalu	26
Bettagere	24
Baggasagodu	22
Jogannanakere	21

Village names	Total number of compensation (2010–18)
Kotragere	20
Kasaba Banaka	19
Hemmadhi	18
Halike	16
Indravalli	14
Hanumanahalli	11
Tripura	10
Hadhi Oni	10
Javali	9
Kannagere	9
Kollibylu	7
Angadi	7

Village names	Total number of compensation (2010–18)
Anajuru	7
Gowdahalli	6
Kelagodu	4
Kelaguru	4
Kademadakallu (naduvinamadakallu)	4
Kasaba Baluru	3
Halekote	3
Koluru	3
U. Hosahalli	3
Gonibeedu Agrahara	2
Kelluru	2
G Hosalli Agrahara	2

Appendix 6. A description of the alternative routes to the proposed Shishila Byrapura (SB) highway of NH173, using existing roads and highways that could be upgraded/are in due for an upgrade. National highways show the existing highways through which the proposed alternative route passes. The distance in kilometres is the distance between Bantwal in Dakshina Kannada District to Chitradurga in Chitradurga District, which spans the entire stretch of the project.

	Passing through Locations	National Highways	Distance (km)
1	Nelliyadi - Sakaleshpura - Belur- Chikkamagaluru -Chitradurga	75; 173	318
2	Nelliyadi - Sakaleshpura - Hanbal - Mudigere - Chikkamagaluru - Chitradurga	75; 173	329
3	Nelliyadi - Karkala - Agumbe - Shimoga - Chitradurga	169; 369	291

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PLATINUM OPEN ACCESS

COMMUNICATION

Species diversity and feeding guilds of birds in Malaysian agarwood plantations

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Abstract: In Malaysia, the current status of birds inhabiting agarwood *Aquilaria malaccensis* plantations has not been specifically studied, and little research has been conducted to investigate birds in other agricultural areas (e.g., rubber, acacia, and oil palm plantations) and disturbed areas. This study was conducted to assess bird species richness and relative abundance, as well as feeding guilds, in two agarwood plantation sites: Universiti Pendidikan Sultan Idris in Tanjong Malim (UPSI), and Slim River (SR). The presence of birds was recorded using a combination of techniques (mist-nets and point count), while various sources were used to compile feeding information. This study recorded 364 birds from 36 species in 24 families. Shannon diversity index (H') values for the UPSI and SR sites were 2.896 and 2.492 respectively, indicating high bird diversity. The Bray-Curtis index was 0.29, indicating these sites share few species. Insectivorous and omnivorous birds were dominant in UPSI (31%), and omnivores at SR (32%). The commonest insect order at both sites was Orthoptera (UPSI 48%, SR 25%). While agarwood plantations are relatively homogeneous, they provide a variety of food sources and shelter for a wide range of birds.

Keywords: Avian fauna, mist-net, point count, status.

Editor: Anonymity requested.

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Competing interests: The author declares no competing interests. The views expressed are those of the author.

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Author contribution: NNMJ—conducts, collect and analyze data from the research field. Contribute in giving ideas and writing the manuscript. HI—principal investigator of the research grant and responsible for the whole research, including designing and planning the data collection and main contributor for the manuscript. Revised the article before submission. HHMZ—co-researcher of the research grant and assist in designing and planning the research. Review and suggest some comments on the article. NHCM—assists in conducting and collecting data from the research field. Propose some ideas and comments on the article.

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INTRODUCTION

Peninsular Malaysia is home to 718 species of birds from 96 families (BirdLife International 2017). There has been considerable loss of natural habitat due to deforestation for commercial plantations such as oil palm, rubber, agarwood, and paddy field (Achondo et al. 2011). While plantations often decrease bird diversity, they can sometimes provide new food resources and areas of shelter (Benayas & Bullock 2012), showing similar species and the numbers of birds to nearby native forest fragments, particularly in the old plantation, while the bird species richness decreased when the young plantation was located far from the native forest (Styring et al. 2018).

The exploitation of natural resources in the forest not only causes their excessive consumption but also leads to a severe threat to the ecosystem (Hashim & Ramli 2013). The agarwood *Aquilaria malaccensis* industry is growing in Malaysia because of its high price in the worldwide market. Malaysia is one of the most suitable countries for planting agarwood trees as it has suitable climate (e.g., 50–80% exposure to sunlight and annual rainfall of 1000–2000 mm) and soil conditions (e.g., soil pH range from 4.0 to 6.0) which are the essential requirement for agarwood tree growth and development (Yahya 2011; Azahari et al. 2015). As the demand for agarwood supply increased globally, agarwood plantations have been established as an alternative to avoid the uncontrolled exploitation of agarwood resources resulting in their inadequacies in natural forests and large-scale production of agarwood (Azahari et al. 2015). The overexploitation of agarwood tree for its resin not only caused the extinction of agarwood species but also bird species in their natural forest habitat. The establishment of agarwood plantations, however, might play a crucial role in an agroforestry system by providing habitats favourable for native birds from natural forest.

A few kinds of research have been conducted to investigate the interaction of birds and their dynamic community at agriculture area such as acacia plantation (Styring et al. 2018), rubber plantation (Peh et al. 2006; Li et al. 2013; Sreekar et al. 2016), and oil palm plantation (Jambari et al. 2012; Amir et al. 2015) as well as logged forest (Ramly & Ramli 2009; Cosset & Edwards 2017). To date, however, no study about bird species diversity has been done in agarwood plantations. A complex habitat structure and plant diversity of forested habitats were important determinants of the bird species diversity and abundance (Azman et al. 2011). As majority of tree plantations are monocultures (homogeneous vegetation), they do not provide a great foraging opportunity to many bird species (Yahya et al. 2017). The conversion of forest to any plantation to some extent had annihilated nourishment sources that are available to birds (Subasinghe et al. 2014), while young and immature tree plantations are known to lack of food sources and may be an unfavourable habitat for birds (Sánchez-Oliver et al. 2014). As a result, the immigration of birds to another habitat will occur after their habitat decimated, caused the reduction of bird abundance and geographical distribution distance (Haddad et al. 2015), which may also lead to local extinction particularly for birds that cannot migrate and adapt (Mansor et al. 2018a).

Although the baseline data on the diversity of birds and their distribution had been collected all over the years, to date, there is still no study was done to examine the status of bird species inhabiting the agarwood plantation area in Malaysia. Hence, this study was done to document the bird species inhabiting in the two agarwood plantations to explore the present status of bird community, their composition and feeding guilds in ensuring a sustainable agroforestry and plantation management in the future. The purpose of this study, however, was not intended to compare bird data obtained in both areas, but rather only to collect data on the bird species richness, their abundance and to classify their feeding guilds by referring on comprehensive literatures, during a young stage and when the agarwood trees start to mature. The two study areas were chosen to cover both developmental stages of agarwood tree.

MATERIALS AND METHODS

Study Site

The study was carried out in two agarwood plantation areas:(1) Universiti Pendidikan Sultan Idris, Tanjong Malim (UPSI) (3.723N & 101.541E) from March 2016 until August 2017 (Image 1); and (2) Kg Tambak, Slim River (SR) (3.850N & 101.458E) from July 2017 until October 2017 (Figure 1). The plantations on both sites are monocultures surrounded by forest and near the lake or stream. The agarwood plantations in UPSI and SR are planted with young two and four years old agarwood trees respectively. The UPSI agarwood plantation consists of trees with a height of about 150–200 cm, the circumference between 9–15 cm, the numbers of main branches range between 11–18, the number of leaves within 100–200 and they lack canopy. Grasses and shrubs such as *Melastoma* sp., *Imperata cylindrical*

Figure 1. Agarwood plantation at Kg Tambak, Slim River (SR)

Image 1. Agarwood plantation at Universiti Pendidikan Sultan Idris (UPSI)

and *Cyperus esculentus* grow around this study area. Meanwhile, the SR agarwood plantation consists of trees that have a height of about 300–400 cm, circumference between 30–40 cm, the main numbers of branches are about 23–26 and number of leaves are within the range of 300–500 with slight canopy.

Bird Survey

A combination of two techniques (i.e., mist-net and point count) were used to survey the bird population (Zakaria & Rajpar 2010). The mist-netting method is apt to capture birds that are commonly unobtrusive and hardly give unique calls (Hashim & Ramli 2013). Mist-nets were opened daily at 0700h and closed at 18.00h. Nets were placed for three consecutive days every month and monitored every hour to extract captured birds. Three days of netting was enough to capture most of the birds at the site because birds may become aware of the mist net after three days (Zakaria & Rajpar 2010). The birds were marked on their tarsus using numbered aluminium ring upon capture, and standard biometric measurements were recorded and released close to the point of capture to lessen the disturbance. Recaptured birds were excluded from analyses.

Point count technique was used as a supplement to survey birds that were not captured in the mist nets. Five stations were surveyed in a 500m transect and each station was placed 100m apart while the starting and the end of the station were placed 50m from the edge of the plantation. The survey was done for 10 minutes at each station to record a sufficient number of individuals detected by sight within the 25m radius. The bird observed by point count method and captured by mist net method were then identified (Wells 2007; Robson 2008), photographed and recorded.

Feeding Guilds

This study did not apply a method to collect data on bird feeding guilds in the field. The identification and classification of bird feeding guilds, however, were done by referring to several comprehensive literatures (Zakaria & Rajpar 2010; Li et al. 2013; Tanalgo et al. 2015).

Insect Survey

There were two methods used to sample insect populations in agarwood plantations including pitfall traps and sweep net. For pitfall traps, four parallel transects measuring about 40m in length with a 10m inter-transect distance were set up in the plot, and five pitfall traps were placed 10m apart on each transect for three days and nights. Each pitfall trap consisted of a disposable cup, measuring about 10cm in height and 6cm in diameter. The cups were buried at ground level and contained detergent solution to prevent the insects from getting out of the trap. For the sweep net method, three straight–line transects of about 100m were marked out with a count station every 20m. This method was conducted by walking in a straight line, making two sweeps for every step, resulting in 40 sweeps per 20m. All of the sampled specimens in the pitfall traps were collected every 24h over three consecutive days. The number of insects collected by both methods was calculated and identified by their order based on Borror & White (1970), Weng & Yew (1983), and Walters (2013).

Data Analysis

The bird species richness and their relative abundance in the agarwood plantation were determined and presented in the number of percentages (%). Data analysis for diversity of birds was measured using Shannon's diversity index. Bray-Curtis index was used to calculate and quantify whether bird species composition is similar in both agarwood plantations. The Shannon's diversity index was calculated by:

$$H' = \sum Pi \ In \ Pi$$

Where P*i* is the proportion of each species in the sample and *ln* P*i* is the natural logarithm of this proportion. For similarity of the species occurring in the agarwood plantations, Bray-Curtis index was determined by:

$$\beta' = \sum \frac{(Xi - Yi)}{(Xi + Yi)}$$

Where X and Y are the compared areas, while X*i* and Y*i* is the number of individuals per species of compared areas.

RESULTS

A total of 36 species of birds represented by 364 birds belongs to 24 families were recorded in both of the agarwood plantations. *Geopelia striata* (Zebra Dove) made up the highest percentage of species captured in both study areas (UPSI = 12.3%, SR = 15.5%), and *Halcyon smyrnensis* (White-throated Kingfishers) was highest in SR site (15.5%) (Table 1; Image 1). Columbidae had the highest diversity in the both agarwood plantations, with four species (16.67%), followed by Estrildidae and Sturnidae with three species (12.5%), and Pycnonotidae, Nectariniidae, Cuculidae, and Apodidae with two species (8.33%) (Table 1). The remaining families were the least dominant families with only one species each. *Lonchura*

Table 1. Birds species in agarwood plantations.

Family	Species	Common name	Percentage (%)	
			UPSI	SR
Columbidae	*Geopelia striata*	Zebra Dove	12.3	15.5
	Streptopelia chinensis	Spotted-necked Dove	1.3	1.6
	Chalcophaps indica	Asian Emerald Dove	0.4	8.5
	Treron olax	Little Green Pigeon	0.9	-
Estrildidae	*Lonchura maja*	White-headed Munia	9.4	-
	Lonchura atricapilla	Chestnut Munia	11.5	-
	Lonchura punctulata	Scaly-breasted Munia	3.0	-
Pycnonotidae	*Pycnonotus goiavier*	Yellow Vented Bulbul	9.4	2.3
	Pycnonotus finlaysoni	Stripe-throated Bulbul	0.9	0.8
Hirundinidae	*Hirundo rustica*	Barn Swallow	8.9	6.2
Ploceidae	*Ploceus philippinus*	Baya Weaver	6.8	-
Sturnidae	*Aplonis panayensis*	Asian Glossy Starling	5.1	-
	Acridotheres tristis	Common Myna	4.7	12.4
	Gracula religiosa	Common Hill Myna	-	3.9
Motacillidae	*Anthus rufulus*	Paddy Field Pipit	4.3	-
Apodidae	*Collocalia esculenta*	Glossy Swiflet	3.4	-
	Aerodramus brevirostris	Himalayan Swiftlet	2.1	-
Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfishers	3.0	15.5
Aegithinidae	*Aegithina tiphia*	Common Iora	3.0	3.1
Eurylaimidae	*Cymbirhynchus macrorhynchos*	Black-and-red Broadbill	2.1	1.6
Muscicapidae	*Copsychus saularis*	Oriental Magpie-robin	1.3	14.7
Laniidae	*Lanius cristatus*	Brown Shrike	1.3	-
Meropidae	*Merops philippinus*	Blue-tailed Bee-eater	1.3	-
Phasianidae	*Synoicus chinensis*	Blue-breasted Quail	0.9	-
Oriolidae	*Oriolus chinensis*	Black-naped Oriole	0.9	-
Turnicidae	*Turnix suscitator*	Barred Buttonquail	0.4	-
Picidae	*Chrysophlegma miniaceum*	Banded Woodpecker	0.4	-
Nectariniidae	*Arachnothera longirostra*	Little Spiderhunter	0.4	-
	Anthreptes malacensis	Brown-throated Sunbird	-	1.6
Cuculidae	*Phaenicophaeus curvirostris*	Chestnut-breasted Malkoha	0.4	-
	Clamator coromandus	Chestnut-winged Cuckoo	-	0.8
Corvidae	*Platysmurus leucopterus*	Black Magpie	0.4	0.8
Motacillidae	*Dendronanthus indicus*	Forest Wagtail	-	0.8
Psittaculidae	*Psittacula longicauda*	Long-tailed Parakeet	-	6.2
Bucerotidae	*Anthracoceros albirostris*	Oriental Pied-Hornbill	-	1.6
Falconidae	*Microhierax fringillarius*	Black—highed Falconet	-	2.3

atricapilla and *L. maja* from Estrildidae family which had the highest abundance at UPSI site, however, were not recorded at SR site.

Present study recorded one Vulnerable species which is *Psittacula longicauda* (Long–tailed Parakeet) while the other species are classified as the Least Concern in the latest International Union for Conservation of Nature (IUCN) Red List classification (BirdLife International 2018). The major feeding guild was omnivorous and insectivorous. Agarwood plantation at UPSI site recorded the highest percentage of insectivorous and omnivorous birds from nine species each (31.03%) while at SR site, the most preferred feeding guilds were omnivorous from six species (31.58%) as shown in Table 2.

For insect survey, the highest abundance of insect in both study areas were Orthoptera (UPSI 47.9%, SR 24.6%), followed by Order Hymenoptera (UPSI 32.4%, SR 16.6%), while the lowest was Mantodea (UPSI 0.2%, SR 0.1%). The results of the Shannon's diversity index of bird species in both UPSI and SR agarwood plantations were 2.896 and 2.492, respectively. These result showed that UPSI agarwood plantation had higher species diversity of birds than SR agarwood plantation. Bray-Curtis index result showed the value is 0.29, indicating that there was some similarity in bird species present in both agarwood plantations.

Table 2. Classification of bird feeding guilds in agarwood plantations.

	Percentage (%)	
Feeding guild	**UPSI**	**SR**
Insectivore	31.03	26.31
Granivore	20.70	10.53
Frugivore	10.34	15.80
Omnivore	31.03	31.58
Carnivore	3.45	10.53
Nectarivore	3.45	5.26

Table 3. Relative abundance of insect orders in two agarwood plantation areas.

	Percentage (%)	
Order	**UPSI**	**SR**
Orthoptera	47.9	24.6
Lepidoptera	2.3	1.2
Coleoptera	4.7	2.4
Hymenoptera	32.4	16.6
Diptera	2.6	1.3
Hemiptera	0.8	0.4
Blattodea	0.7	0.3
Odonata	4.3	2.2
Mantodea	0.2	0.1
Isoptera	3.8	2.0
Tricoptera	0.3	0.2

DISCUSSION

The bird species and population, as well as their community structure, are influenced by habitat types and diet preferences (Khairuddin 2013; Hashim & Ramli 2013). In this study, the combination of two techniques (i.e., mist-net and point count) was an effective methodological approach to observe and monitor bird species in the agarwood plantation. The results showed that the species obtained in this study were typical species that can be found in other plantations and forests, namely, Oriental Magpie-Robin *Copsychus saularis*, White-throated Kingfisher *Halcyon smyrnensis*, Yellow-vented Bulbul *Pycnonotus goiavier*, Spotted Dove *Streptopelia chinensis*, and Zebra Dove *Geopelia striata*. Moreover, agarwood plantations in UPSI and SR also shared 12 similar species of birds including Black-and-red Broadbill *Cymbirhynchus macrorhynchos*, Asian Emerald Dove *Chalcophaps indica*, and Common Myna *Acridotheres tristis*.

Basically, most plantations may have nearby forest patches or fragments that act as wildlife corridors which can influence the presence of certain bird species (Wilson et al. 2006; Mansor et al. 2018a). This association makes these birds good indicators to study and examine the impact of agarwood plantations because they are easy to sample and highly responsive to the environmental changes (Gregory & Strien 2010). Although the UPSI agarwood plantation consists of only young trees, with no dense canopy, it still contributes to high bird species richness due to their proximity to the other forest (Styring et al. 2018). Obtaining this information can possibly be used to enhance bird populations in managed landscape plantations (Peh et al. 2006). Thus, bird populations occupying plantations near the native forest will increase in comparison to those found further away from the native forest (Styring et al. 2018).

A slight high number of bird species in agarwood plantation highlights such habitat can provide food resources for the birds . The presence of many insect groups in the agarwood plantation may attract insectivorous birds to utilize the agarwood plantation area (Table 3). The orders Orthoptera (e.g., crickets and grasshoppers) and Hymenoptera (e.g., bees and ants) are frequently consumed by insectivorous birds and some of the omnivorous birds for their diet (Wells 2007). This finding was similar as in Mansor et al. (2018b) where a high number of Hymenoptera was reported to be consumed by insectivorous birds in a Malaysian rainforest. The high number of insectivorous species feeding on harmful insects and pests in the agricultural area may convey that birds constitute a vital part in agriculture ecosystems which is worthwhile to farmers and owners of the agarwood plantations. Insectivorous bird species such as Glossy Swiflet *Collocalia esculenta*, Paddyfield Pipit *Anthus rufulus*, Oriental Magpie Robin *Copsychus saularis*, and Brown Shrike *Lanius cristatus* are assumed to be a biological control because of their role in retaining insect populations in the plantation (Achondo et al. 2011). Besides that, the presence of grasses such as *Imperata cylindrica* and *Cyperus esculentus* as well as shrubs such as *Melastoma* sp. at UPSI site influenced the presence of granivorous birds such as *Lonchura maja* and *Lonchura atricapilla* in the study area that consume seed of grasses and sedges (Payne 2019a,b).

CONCLUSION

This study is helpful in documenting the presence of bird species, as many of the studies focused more on other plantations, the present study revealed the capability of karas plantation to accommodate many

Image 2. Dominant bird species in agarwood plantations: A—*Geopelia striata* (UPSI & SR) | B—*Halcyon smyrnensis* (SR).

bird species, particularly insectivores and its associated insect groups. There is, however, more data that needs to be assessed to understand bird diversity in agarwood plantations which may be affected by tree maturity, proximity to other native habitats and climatic condition. This information can be used to develop sustainable management and conservation strategies of complex ecological networks in managed landscapes. Continuous efforts and more studies need to be conducted in this area to obtain detailed information on bird status and their community composition to conserve species from local extinction in modified landscape.

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PLATINUM OPEN ACCESS

COMMUNICATION

Evaluating performance of four species distribution models using Blue-tailed Green Darner *Anax guttatus* (Insecta: Odonata) as model organism from the Gangetic riparian zone

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Abstract: In this paper we evaluated the performance of four species distribution models: generalized linear (GLM), maximum entropy (MAXENT), random forest (RF) and support vector machines (SVM) model, using the distribution of the dragonfly Blue-tailed Green Darner *Anax guttatus* in the Gangetic riparian zone between Bijnor and Kanpur barrage, Uttar Pradesh, India. We used forest cover type, land use, land cover and five bioclimatic variable layers: annual mean temperature, isothermality, temperature seasonality, mean temperature of driest quarter, and precipitation seasonality to build the models. We found that the GLM generated the highest values for AUC, Kappa statistic, TSS, specificity and sensitivity, and the lowest values for omission error and commission error, while the MAXENT model generated the lowest variance in variable importance. We suggest that researchers should not rely on any single algorithm, instead, they should test performance of all available models for their species and area of interest, and choose the best one to build a species distribution model.

Keywords: Generalized linear model, Kappa statistic, maximum entropy model, omission and commission error, random forest model, receiver operating characteristic curve, sensitivity, specificity, support vector machines model, true skill statistic

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INTRODUCTION

Species distribution models (SDMs) are tools that integrate information about species occurrence or abundance with environmental estimates of a landscape, used to predict distribution of a species across landscapes (Elith & Leathwick 2009). When applied in a geographic information system (GIS), SDMs can produce spatial predictions of occurrence likelihood at locations where information on species distribution was previously unavailable (Václavík & Meentemeyer 2009). Though various types of algorithms are used to build different SDMs (Elith et al. 2006), they share common and general approaches (Hirzel et al. 2002) such as: (i) at a specified resolution, the study area is divided into grid cells; (ii) species presence localities (and sometimes absence localities) data are used as the dependent variable; (iii) several environmental variables (e.g., temperature, precipitation, soil type, aspect, land cover type) are collected for each grid cell as predictor variables; and (iv) the suitability of each cell for the species distributions defined as a function of the environmental variables (Stanton et al. 2012). The species distribution prediction is central to applications in ecology, evolution and conservation science (Elith et al. 2006) across terrestrial, freshwater, and marine realms (Elith & Leathwick 2009). But it remains a question for researchers which model should be selected for particular organisms and habitats of interest, particularly when few samples are present for large under-sampled areas (Mi et al. 2017).

Riparian zones are broadly defined as terrestrial landscapes with characteristic vegetation associated with temporary or permanent aquatic ecosystems (Meragiaw et al. 2018). These areas are highly complex biophysical systems, and their ecological functions are maintained by strong spatio-temporal connectivity with adjacent riverine and upland systems (Décamps et al. 2009). It has been observed that species distribution models are used more often for terrestrial environments than for aquatic or riparian ecosystems. Globally, odonates are used as model organisms to study climate change, data simulation, environmental assessment and management, effects of urbanization, landscape planning, habitat monitoring and evaluation, and conservation of rare species (Bried & Samways 2015). To date, no work has been done on the comparative use of species distribution models in India using insects as model organisms in riparian or freshwater ecosystems. With this background, in the present work we evaluated the effectiveness of four species distribution models using odonates from the Gangetic riparian zone as model organisms.

MATERIALS AND METHODS

Study area and field data collection

For the study, we selected *Anax guttatus* (Burmeister, 1839) commonly called Blue-tailed Green Darner (Image 1) as the model insect species. It is a dragonfly (suborder Anisoptera Selys, 1854) under the family Aeshnidae Leach, 1815 and superfamily Aeshnoidea Leach, 1815 (Dijkstra et al. 2013). The species can be identified in the field due to its large size, highly active behaviour, green colour of the thorax & first, second, & third abdominal segments, and presence of turquoise blue colour on the dorsal part of the second abdominal segment (Subramanian 2005).

We conducted the study during May 2019 from Bijnor, Uttar Pradesh to Kanpur, Uttar Pradesh (Fig. 1). The river flows through alluvial plain and covers a length of about 450km in this stretch. For the study we selected four sites, and the distance between each two successive sites was about 150km. In each site we chose a 10km river stretch and observed the presence of Blue-tailed Green Darner. We collected a total of 10 sighting locations.

Data processing and analysis

We derived the thematic layer of LULC (N.R.S.C. 2016) from multi-temporal advanced wide field sensor (AWiFS) images with 56m spatial resolution using digital and rule-based image classification methods, and forest

Image 1. *Anax guttatus* (Burmeister, 1839) – Blue-tailed Green Darner

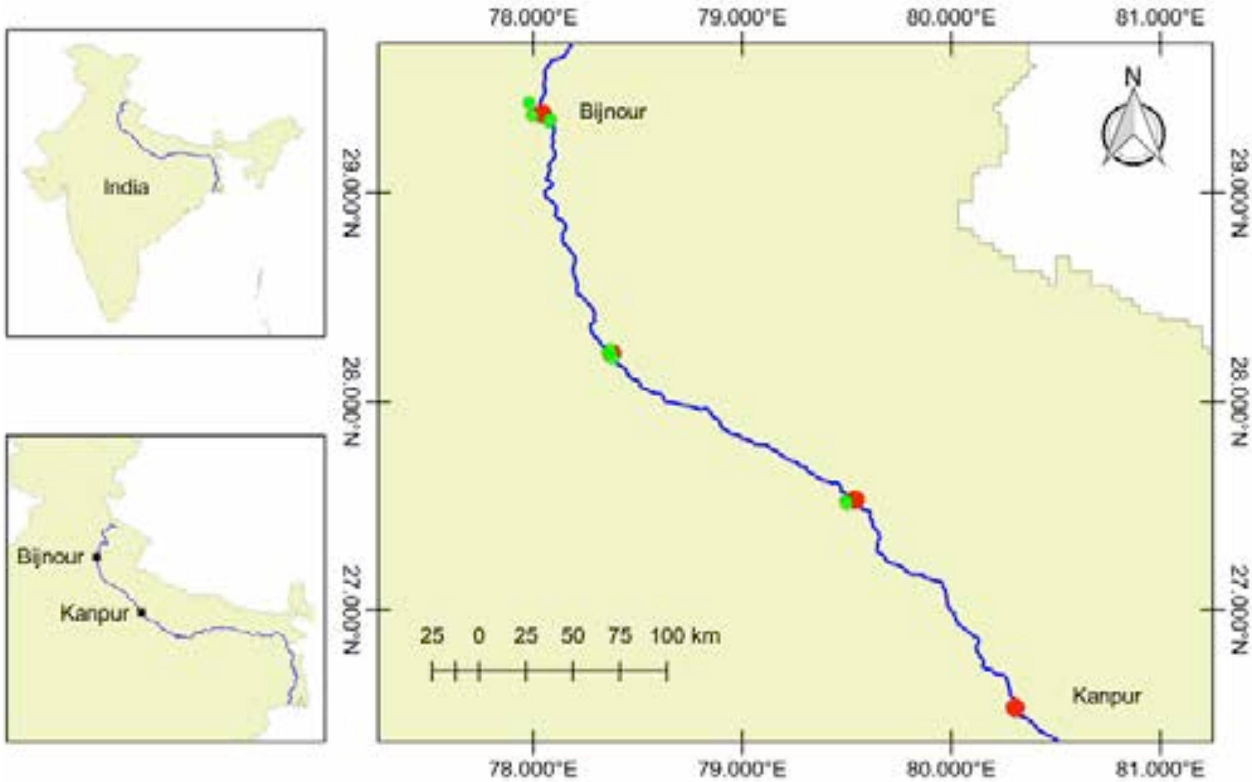

Figure 1. Study area on the river Ganga between Bijnour and Kanpur. The red circles represent sampling sites, and green circles represent species sighting locations.

cover type (F.S.I. 2009) from IRS P6 (Linear Imaging Self Scanning Sensor) LISS III with 23.5m spatial resolution using a combined method of digital and on-screen visual image classification and bioclimatic layers from worldclim gridded climatic data (Fick & Hijmans 2017) with 1km spatial resolution. For analysis, we took 2km buffer zones from the river bank and resampled all the layers to 1km spatial resolution.

We used 'stack' function of package 'raster' (Hijmans 2019) to stack all the 19 available bioclimatic variable, forest cover and land use land cover (LULC) layers. After that we used 'pairs' function of the package 'raster' (Hijmans 2019) to find the correlation coefficient between stacked layers. Then we selected the variables which had a correlation coefficient less than 0.60 (Pozzobom et al. 2020), and again stacked the selected layers with 'stack' function of package 'raster' (Hijmans 2019). These selected layers were LULC, forest cover and five bioclimatic layers: annual mean temperature (Bio 1), isothermality (Bio 3), temperature seasonality (Bio 4), mean temperature of driest quarter (Bio 9), and precipitation seasonality (Bio 15).

We built four species distribution models: generalized linear model (GLM), maximum entropy (MAXENT) model, random forest (RF) model, and support vector machines (SVM).

GLM is an extension of classic linear regression modeling, where the iterative weighted linear regression technique is used to estimate maximum-likelihood of the parameters, with observations distributed in terms of an exponential family and systematic effects made linear by the suitable transformation that allow for analysis of non-linear effects among variables and non-normal distributions of the independent variables (McCullagh & Nelder 1989; Chefaoui & Lobo 2008; Shabani et al. 2016).

RF modeling is a machine learning technique which is a bootstrap-based classification and regression trees method (Cutler et al. 2007). It is used to model species distributions from both the abundance and the presence-absence data (Howard et al. 2014). It is insensitive to data distribution (Hill et al. 2017) and also takes a large number of potentially collinear variables; it is robust to over-fitting which makes it very useful for prediction (Prasad et al. 2006; Segal 2004).

MAXENT modeling is a general-purpose machine learning method to estimate a target probability distribution by finding the probability distribution of maximum entropy and it has several aspects that make it well-suited for species distribution modelling (Phillips et al. 2006). It is relatively less sensitive to the spatial errors associated with location data and needs few locations to build useful models (Baldwin 2009) and it is one of the most accurate and trusted modelling methods for presence-only distribution data (Huerta & Peterson 2008; Srinivasulu & Srinivasulu 2016).

SVM modeling is developed from the theory of statistical learning, in which the error involved with sample size is minimized and the upper limit of the error involved in model generalization is narrowed, which solve the problems of nonlinearity, over-learning and the curse of dimensionality during modelling (Fielding & Bell 1997; Howley & Madden 2005; Huang & Wang 2006). It can be used on small data sets as it is independent of any distributional assumptions or asymptotic arguments (Wilson 2008).

We used 'load_var' function to normalize and load environmental variables, then used 'load_occ' function to load species occurrence data and then used 'modelling' function to build the models with 100 iterations by the package 'SSDM' (Schmitt et al. 2017) to plot the models.

We evaluated and compared four models by comparing values of area under the receiver operating characteristic curve (AUC), Kohen's Kappa, true skill statistic (TSS), model sensitivity, model specificity, and omission error.

The area under the receiver operating characteristic curve or AUC measures the ability of a model to discriminate between the sites where a species is present and the sites where a species is absent (Fielding & Bell 1997; Elith et al. 2006) and it provides a single measure of overall accuracy that is independent of a particular threshold (Fielding & Bell 1997). The evaluation criteria for the AUC statistic are as follows: excellent (0.90–1.00), very good (0.8–0.9), good (0.7–0.8), fair (0.6–0.7), and poor (0.5–0.6) (Swets 1988; Duan et al. 2014).

The Kappa statistic is based on the optimal threshold, measure the performance of the model by using the best of the information in the mixed matrix (Duan et al. 2014) ranges from −1 to +1, where +1 indicates perfect agreement and values of zero or less than zero indicate a performance no better than random (Allouche et al. 2006; Cohen 1960) and the evaluation criteria for the Kappa statistic are as follows: excellent (0.85–1.0), very good (0.7–0.85), good (0.55–0.7), fair (0.4–0.55), and fail (<0.4) (Duan et al. 2014; Monserud & Leemans 1992).

The true skill statistic (TSS) is expressed as Sensitivity + Specificity – 1 (Allouche et al. 2006) and ranges from −1 to +1, where +1 indicates a perfectly performing model with no error, 0 indicates the model with totally random error and -1 indicates the model with total error (Marcot 2012; Ruete & Leynaud 2015).

The model sensitivity denotes the proportion of correctly predicted presences, thus quantifying omission errors (Ward 2007; Shabani et al. 2016) and model specificity denotes the proportion of correctly predicted presences, thus quantifying commission errors (Shabani et al. 2016).

Omission error (1- sensitivity) is the under-prediction or false-negative result in areas being classified as unsuitable when they are not and commission error (1-specificity) is the over-prediction or false-positive result in areas being classified as suitable when they are not (Ward 2007) and for a good SDM, both of the omission error and commission error should be low.

For evaluation of model performance and variable importance we used 'knitr::kable(Modelname@evaluation)' function and 'knitr::kable(Modelname@variable.importance)' function of the package 'SSDM' (Schmitt et al. 2017), respectively.

We chose five probability classes (0 to <0.20, 0.20 to <0.40, 0.40 to <0.60, 0.60 to <0.80 and 0.80 to 1.00) to know what percentage of the area is being declared the best and worst by each of the models by 'ratify' function of package 'raster' (Hijmans 2019)

We performed all the analysis in the ArcMap 10.3.1, QGIS 2.14.7 and in R language and environment for statistical computing (R Core Team 2019).

RESULT

The plot for each of the four models is given in Fig. 2. We found that the AUC value was highest for GLM (0.983), followed by RF (0.833), MAXENT (0.829) and SVM (0.667); the value of Kappa statistic was highest for RF (0.667), followed by GLM (0.356), SVM (0.333) and MAXENT (0.049); the value of TSS was highest for GLM (0.965), followed by RF (0.666), MAXENT (0.658) and SVM (0.334); the value of model sensitivity was 1 for GLM, 0.833 for both MAXENT and RF and 0.667 for SVM; the value of model specificity was maximum for GLM (0.965), followed by RF (0.833), MAXENT (0.825) and SVM) (0.667); the omission error was lowest for GLM (0.00), for both MAXENT and RF models it was 0.167 and for SVM it was 0.333; the commission error was lowest for GLM (0.035), followed by RF model (0.167), MAXENT (0.175) and SVM (0.333) (Table 1, Fig. 3)

For GLM, RF, and SVM models the forest had

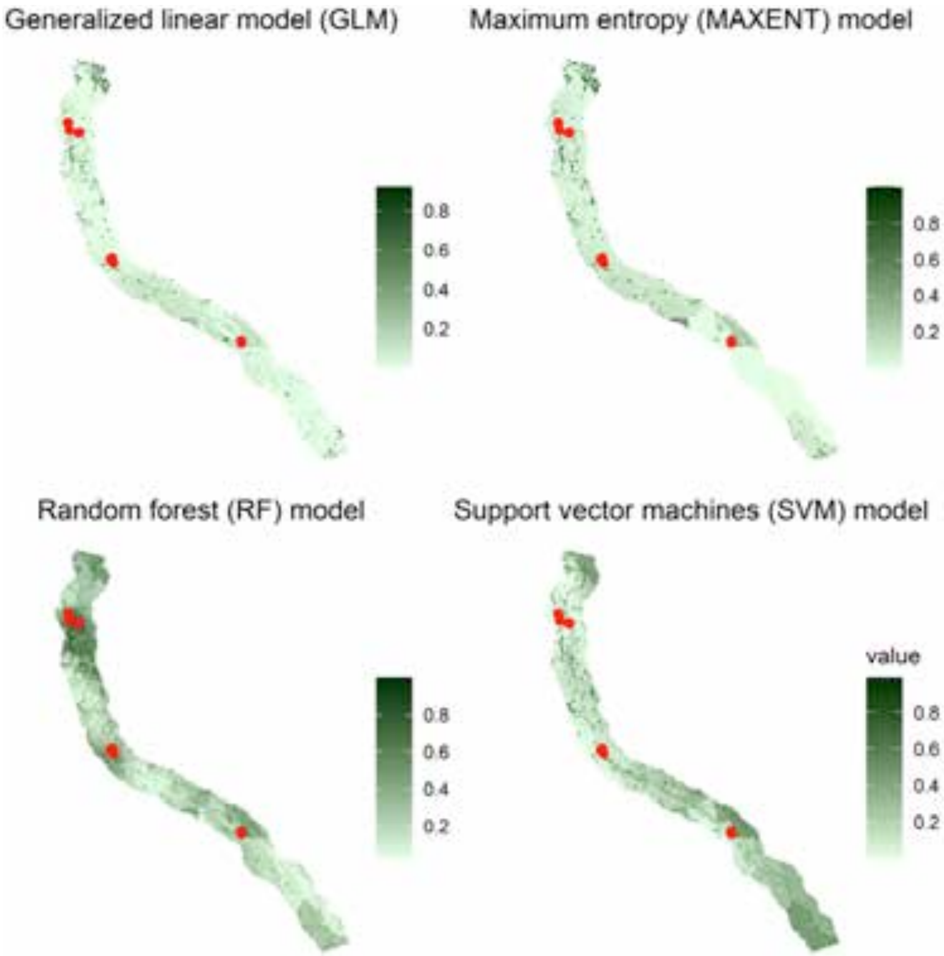

Figure 2. Comparative account of four species distribution models – generalized linear model (GLM), maximum entropy (MAXENT), random forest (RF), and support vector machines (SVM). The legend in each model shows probability of occurrence and the red dotes represents the occurrence location of the species.

the highest importance but for MAXENT model the Precipitation seasonality (Bio 15) had the highest importance (Table 2, Fig. 4). For GLM and SVM models the Precipitation seasonality (Bio 15) had lowest importance, for MAXENT forest had lowest importance, while for RF model Isothermality (Bio 3) had lowest importance (Table 2, Fig. 4). Overall, the variation in the variable importance was lowest in MAXENT model (SD = 3.367), followed by GLM (SD = 24.344), RF (SD = 30.868) and SVM (SD = 37.071) (Fig. 5).

By comparative analysis, we found that GLM showed 1.62% of total area as the best (occurrence probability, 0.80 to 1) and 65.50% of total area as the worst (occurrence probability, 0 to 0.20) for suitable habitat. MAXENT model showed 10.08% of total area as the best and 77.70% of total area as the worst for suitable habitat. RF model showed 5.39% of total area as the best and 23.79% of total area as the worst for suitable habitat. SVM model showed 4.53% of total area as the best and 27.68% of total area as the worst for suitable habitat (Table 3, Fig. 6).

Table 1. Values of AUC, Kappa statistic, TSS, sensitivity, specificity, omission error, and commission error generated by generalized linear model (GLM), maximum entropy (MAXENT) model, random forest (RF) model, and support vector machines (SVM) model.

	GLM	MAXENT	RF	SVM
AUC	0.983	0.829	0.833	0.667
Kappa statistic	0.356	0.049	0.667	0.333
True skill statistic	0.965	0.658	0.666	0.334
Sensitivity	1	0.833	0.833	0.667
Specificity	0.965	0.825	0.833	0.667
Omission error	0	0.167	0.167	0.333
Commission error	0.035	0.175	0.167	0.333

Table 2. Comparative importance (%) of seven variables from generalized linear model (GLM), maximum entropy (MAXENT) model, random forest (RF) model, and support vector machines (SVM) model.

	GLM	MAXENT	RF	SVM
Annual mean temperature (Bio 1)	11.831	16.352	2.254	0.198
Isothermality (Bio 3)	8.062	14.789	0.513	0.337
Temperature seasonality) (Bio 4)	5.709	15.405	4.076	0.239
Mean temperature of driest quarter (Bio 9)	3.241	13.638	0.907	0.069
Precipitation seasonality (Bio 15)	1.103	16.417	2.817	0.019
Forest	68.799	7.014	84.186	98.353
Land use land cover	1.252	16.384	5.247	0.785

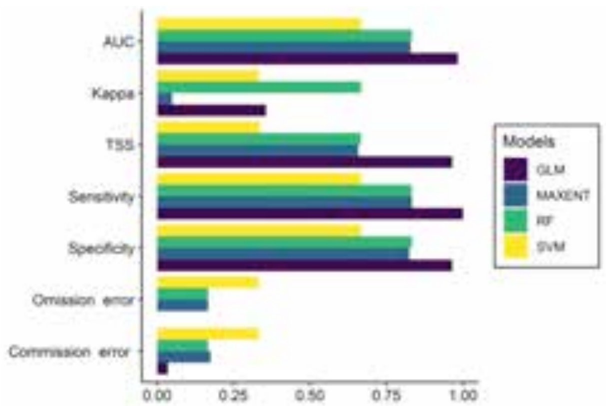

Figure 3. Bar diagram showing comparative account of values of AUC, Kappa statistic, TSS, sensitivity, specificity , omission error and commission error for four models – generalized linear model (GLM), maximum entropy (MAXENT) model, random forest (RF) model, and support vector machines (SVM) model.

Table 3. Comparison of percentage of total area obtained from each model for five occurrence probability classes,

Occurrence probability class	Models			
	GLM	MAXENT	RF	SVM
0 to <0.20	65.50	77.70	23.79	27.68
0.20 to <0.40	7.94	3.93	35.61	42.55
0.40 to <0.60	19.58	4.04	17.97	18.04
0.60 to <0.80	5.35	4.24	17.24	7.19
0.80 to 1.00	1.62	10.08	5.39	4.53

DISCUSSION

Freshwater ecosystems, which include rivers, lakes, peat lands, swamps, fens, and springs, are highly dynamic and host a great diversity of life forms, particularly freshwater endemic species (He et al. 2019; Tickner et al. 2020). They are among the most threatened ecosystems (He et al. 2019), as globally wetlands are vanishing more rapidly than forests and freshwater species are declining faster than terrestrial or marine populations (Tickner et al. 2020). Therefore, for proper conservation management, we should understand the distribution of plants and animals inhabiting aquatic ecosystems. Species distribution models can play an important role on such efforts, because they can produce credible, defensible and repeatable information and provide tools for mapping habitats to inform decisions (Sofaer et al. 2019). Species distribution models can forecast the potential impacts of future environmental changes (Howard et al. 2014) and predict how species will respond (Buckley et al. 2010). Yet debate remains over the most robust species distribution modelling approaches for making projections (Howard et al. 2014), because these models have sensitivity to data inputs and methodological choices. This makes it important to assess the reliability and utility of the model predictions (Sofaer et al. 2019).

In the present study we compared the GLM, MAXENT, RF, and SVM approaches. We found that GLM generated the highest values for AUC, TSS, specificity and sensitivity, and the lowest values for omission error and commission error. The value of Kappa statistic was highest for RF modelling. The MAXENT model used roughly all variables equally, which is not true of the other models which put more emphasis on forest cover.

The success of a model depends on many factors, such as sample size, spatial extent of the study area, and number of ecological and statistical significant variables which affect the distribution of species of interest. We acknowledge that there were some limitations to the current work, such as that our sample size was small (only 10 presence locations), we used only seven variables, we tested only four species distribution models, and we selected a species whose distribution depends on other factors, such as the physiochemical parameters of water and availability of resources. We did not include such

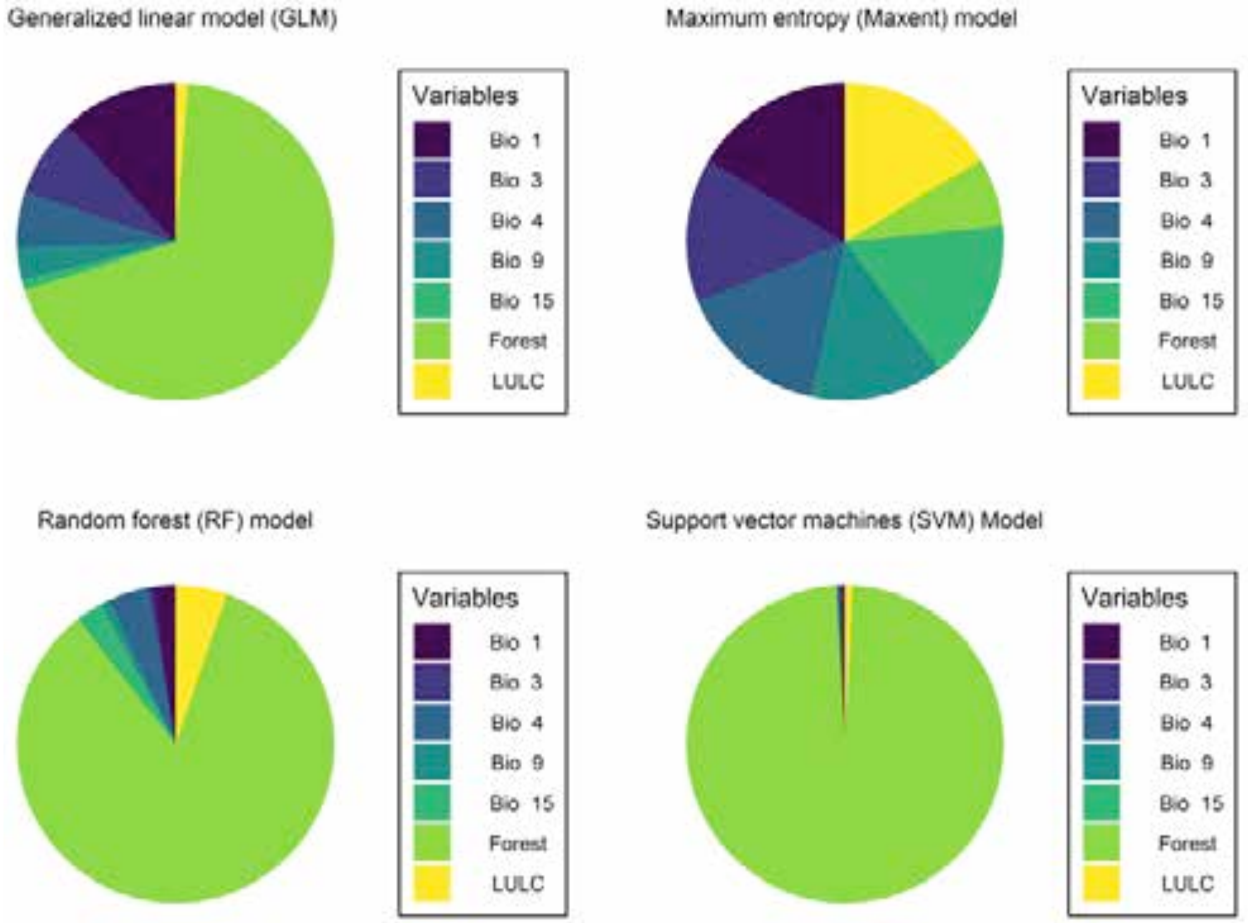

Figure 4. Pie diagram showing percentage importance for seven variables for four models – generalized linear model (GLM), maximum entropy (MAXENT) model, random forest (RF) model, and support vector machines (SVM) model.

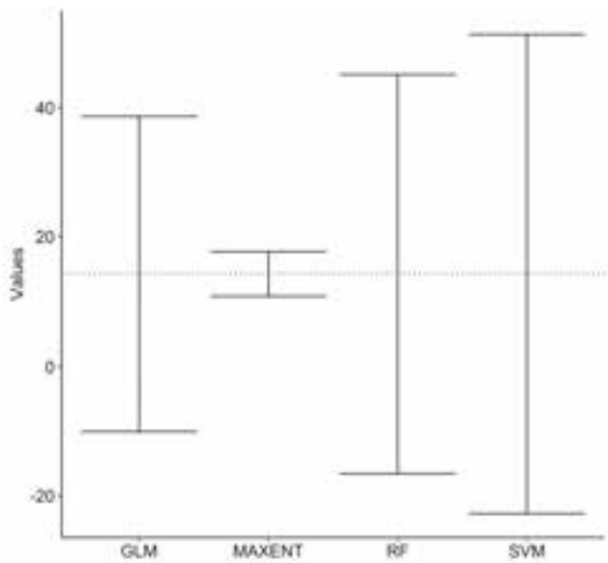

Figure 5. Comparison of standard deviation of variable importance for generalized linear model (GLM), maximum entropy (MAXENT) model, random forest (RF) model, and support vector machines (SVM) model. The black dotted line represents the mean value.

variables as this study was preliminary.

Collins & McIntyre (2015) reviewed 30 studies on species distribution modelling of odonates across the world, and found that 43% used GLM, 33% MAXENT and 20% RF models. Other models used were BIOMOD, general additive model (GAM), generalized boosted model (GBM), artificial neural networks (ANN), multivariate adaptive regression splines (MARS), classified tree analysis (CTA), flexible discriminant analysis (FDA), boosted regression trees (BRT), surface range envelopes (SRE), and mixture discriminant analysis (MDA). Different species distribution models produce different results (Shabani et al. 2016), and the same model can give different results for different species and areas. We urge researchers not to rely on just one model, rather they should compare different available species distribution models and select the best one. Our study was in India where an insect was used for comparative evaluation of species distribution models in a riverine riparian zone. We recommend that further

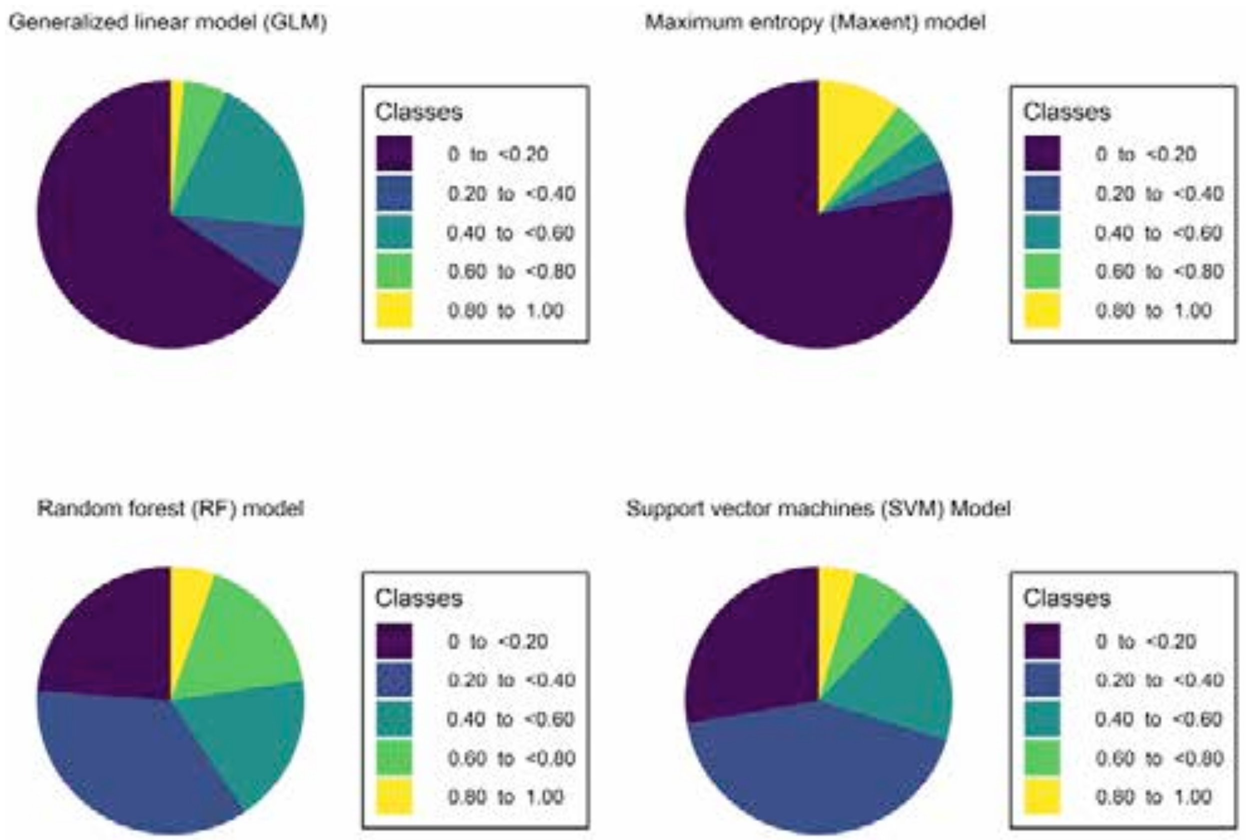

Figure 6. Pie diagram showing percentage area for five occurrence probability classes for four models – generalized linear model (GLM), maximum entropy (MAXENT) model, random forest (RF) model, and support vector machines (SVM) model.

studies on different species distribution models using different animals and ecological variables should be carried out in the riparian zones of Indian river systems for proper design and implementation of ecological habitat management plans.

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COMMUNICATION

Butterfly species richness and diversity in rural and urban areas of Sirajganj, Bangladesh

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Abstract: An appraisal of butterfly species diversity study was conducted in four selected parts of Sirajganj District, Bangladesh, as a part of an ecological research. The study was conducted from March 2015 to April 2016. A total of 19,343 butterflies belonging to five families and 12 subfamilies was recorded. A random sampling of forest, riverside rural, and urban areas in Sirajganj District revealed the presence of 65 butterfly species, dominated by Lycaenidae (37%) over Nymphalidae (33%) followed by Pieridae (19%), Hesperiidae (7%), and Papilionidae (4%). Butterfly fauna in Bangabandhu Sheikh Mujib Jamuna Ecopark (BJEP), compared with the percentage of other study sites, was very high (Hs= 4.03) and the percentage of hedge species was relatively higher (45%) than that of improved grassland and forest interior species. The relative abundance of the butterflies varied with the site, month, and family significantly. Considering the landscape of Sirajganj, steps to enhance riverside natural gardening should be adopted to maintain butterfly diversity and sustain the ecosystem services derived from them.

Keywords: Abundance, ecosystem, family, forest, natural gardening, landscape, riverside.

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Author contribution: All the authors have contributed equally to conduct this study; SMSI, MJR & MSH were responsible for the collection of data; AKN and SMSI did the analysis and write up of this manuscript.

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INTRODUCTION

Butterflies are known to be the indicator species for their interaction with the environment. Butterflies occupy a vital position in ecosystems, and their occurrence and diversity are considered to be good indicators of the health of terrestrial biota (Kunte 2000). They trigger some signal in response to the physical and chemical changes in the environment; they play a significant role in pollination and in community ecology. Evolutionary mechanism of pollination has largely depended on the scaly jewels (Pollard 1991). The compilation of species lists and identification of habitat preferences and abundances are the first steps in effectively conserving biodiversity through the establishment of species baselines and basic ecological requirements (Chowdhury et al. 2017). The butterfly fauna in the northeastern and southeastern parts of Bangladesh is relatively rich and diverse in contrast to favourable habitat, elevational gradients, and microclimatic regimes. Most of the studies on this group are primarily conducted on the evergreen and mixed evergreen forest areas of Bangladesh; however, other parts of Bangladesh lack baseline studies. Torban (2004) mentioned some locations in the northwestern and northern part of Bangladesh as potential territory for butterflies. Sirajganj is one of the 64 districts of Bangladesh situated in the northern part of this country, and this is an initial baseline for butterfly diversity in a mixed habitat setting where the urbanization process is prevalent.

MATERIAL AND METHODS

Study Area

Sirajganj District, situated in northern Bangladesh, has an area of about 2,497.92km². It is a part of Rajshahi Division, the gateway to northern Bengal. It is bordered on the north by Natore District and Bogura District by the Jamuna River on the east. In this current study, we chose four distinct study areas based on their floral diversity and distribution:

Bangabandhu Sheikh Mujib Jamuna Ecopark (BJEP)—this park was partially developed during the construction of the Jamuna Bangabandhu Sheikh Mujib Bridge on the Jamuna River. BJEP covers approximately 50.02ha and is situated in the western part of the Jamuna River. Natural vegetation, including small natural forests, is mainly covered with deciduous and semi-deciduous vegetation. This area has a rich diversity of weeds and bushes.

Belkuchi—this study site aligns with the catchment area of the Jamuna River. Embankments and some human settlements made the site stable. This area, with low disturbance from human interference, is composed of mixed vegetation lands cultivated for seasonal crops, grasses, flowers, and vegetables. The area consists of a variety of butterfly associate plants for nectaring, viz., *Pisum sativum*, *Brassica juncea*, *Ixora rosea*, *Catharanthus roseus*, *Clerodendrum viscosum*, *Atrocarpus lacucha, Citrus* spp., and *Tridax* spp.

Haidarpur—this study site is an urban area. It is a highly human-disturbed area. Urbanization process is prevalent in this study site. Most people run hand looms and power looms in their dwelling areas. Vegetation, mainly seedlings of fruit and flowering plants, are of mixed types.

Kodomtoli—Kodomtali is situated in the low-lying catchment area of the Brahmaputra-Jamuna river basin. Large low-lying paddy fields were found at this site. Vegetation mostly consists of *Brassica* sp. in addition to some areas for cultivating shrubs and vegetables. The soil is mostly muddy in texture. The present study was conducted during March 2015 to April 2016.

Data collection and identification of butterflies

The study has been conducted by line transect method. The authors covered one permanent transect at every study site each month. Observations were taken between 08.00h and 16.00h. Butterflies were primarily identified directly by watching and taking photographs using Canon-600D camera. Sometimes specimens were caught for identification and then released after photographing, viz., *Parnara* sp., *Pelopidus* sp., *Mycalesis* sp., and *Telicota* sp. In a few cases, specimens were collected with sweep nets and carried to the laboratory for further identification processes. Climatic conditions such as temperature, humidity were measured by Thermo Hygrometer (model 288 - ATH). Butterflies were identified based on physical features with the help of reference books viz., Evans (1932), Kehimkar (2013). The scientific name and common name of butterflies were followed by Larsen (2004).

RESULTS AND DISCUSSION

Over the study period, 65 species belonging to 50 genera and five families were recorded. Among those four areas, BJEP represented all the species (65 species) because of its high floral diversity and deep vegetation, followed by Haiderpur with 58 species, Belkuchi with 37

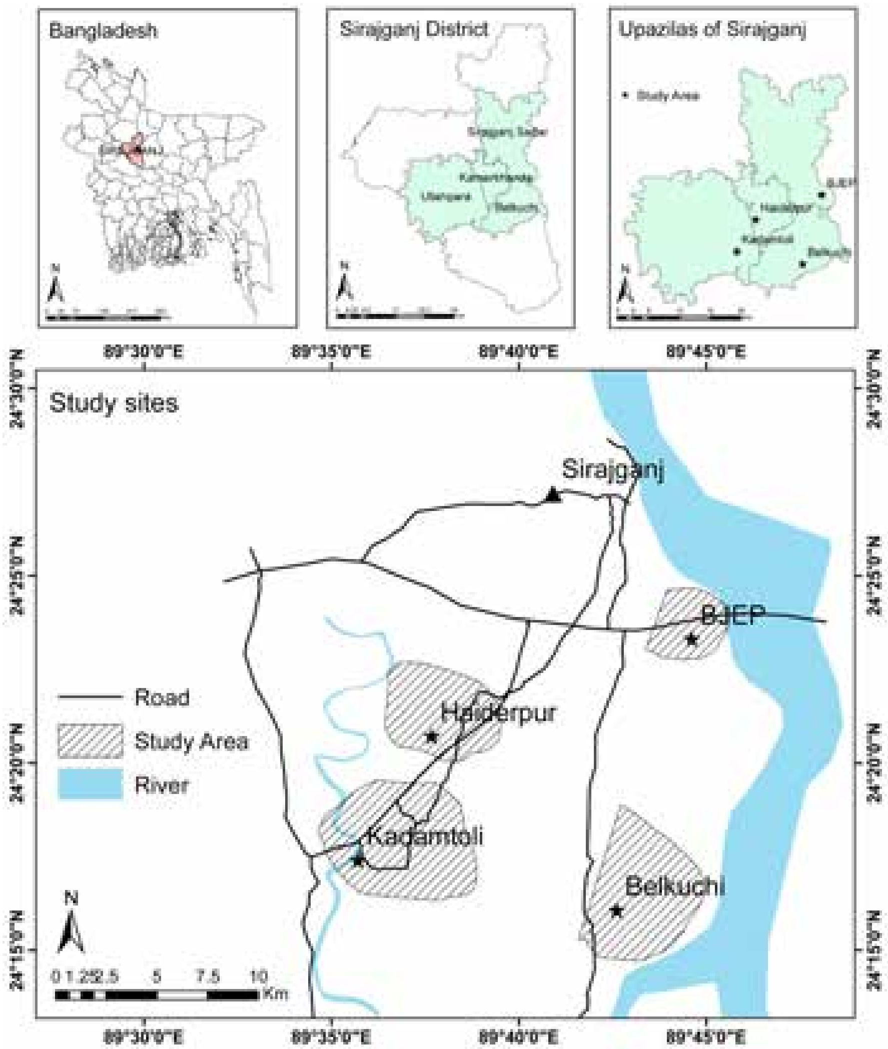

Figure 1. Sirajganj District including four study areas

species, and Kodomtoli with 33 species. All observed species and counted numbers are given in Table 1.

In this current study, we gave precedence to richness of butterfly species as our primary response variable. Changes in habitat quality caused by urbanization might alter insect richness, resulting in either a decrease or more rarely in increases, in the richness of specific insect groups (McKinney 2008). Among the four sites, BJEP and Haiderpur showed significant differences in species composition. Butterflies are found in both rural and urban habitats; diversity and richness are much lower in urban areas than in natural ones (Raupp et al. 2010). Overall, recorded species richness of this study showed how butterfly abundance and diversity remained low in the urban areas compared to the forest lands.

Among the five families of the observed species from Sirajganj District, the most dominant family was Lycaenidae having covered 37% of the total species (24, out of 65). Papilionidae was the least abundant family, with four species. The diversity profile of butterflies showed variations in the four sampling sites (Figure 3). In general, the four sampling sites showed richness in high species and high evenness of distribution (Table 2). Specifically, BJEP showed maximum diversity (Hs= 4.03) of butterflies, whereas Haiderpur showed minimum diversity (Hs = 3.74). Evenness of distribution in all the study sites was found to be high (e H/Ŝ = 0.7198 to 0.8653). Greater flowering resources increases species richness as well as survivability in an ecosystem (Wix et al. 2019). Floral diversity of BJEP has different flowering understory vegetation during the dry season (November–March) resulting in the most significant number of Lycaenidae accounted from this semi-natural forest (24 species out of 65, 37%), and hence, *Zesius chrysomallus* Hübner, 1819 was sighted as a new distributional record for Bangladesh from BJEP (Rahman et al. 2016).

Table 1. List of butterfly species sampling site-wise and their abundance at Serajganj District.

Family	Sub-family	Common name	Scientific name
Nymphalidae	Danainae	Plain Tiger	*Danaus chrysippus* Linnaeus, 1758
		Striped Tiger	*Danaus genutia genutia* (Cramer, 1779)
		Blue Tiger	*Tirumala limniace* (Cramer, 1775)
		Common Crow	*Euploea core* (Cramer, 1780)
	Nymphalinae	Common Eggfly	*Hypolimnas bolina* Linnaeus, 1758
		Common Leopard	*Phalanta phalantha* Drury, 1773
		Common Castor	*Ariadne merione* (Cramer, 1777)
		Common Baron	*Euthalia aconthea* (Cramer, 1777)
		Common Sailor	*Neptis hylas* Linnaeus, 1758
		Common Sergeant	*Athyma perius* Linnaeus, 1758
		Grey Pansy	*Junonia atlites* Linnaeus, 1763
		Peacock Pansy	*Junonia almana* Linnaeus, 1758
		Lemon Pansy	*Junonia lemonias* Linnaeus, 1758
	Satyrinae	Common Palmfly	*Elymnias hypermnestra* Linnaeus, 1763
		Common Five-ring	*Ypthima baldus* Fabricius, 1775
		Common Four-ring	*Ypthima huebneri* Kirby, 1871
		Common Bushbrown	*Mycalesis perseus* (Fabricius, 1775)
		Dark-branded Bushbrown	*Mycalesis mineus* Linnaeus, 1758
		Common Evening Brown	*Melanitis leda* Linnaeus, 1758
	Heliconiinae	Tawny Coster	*Acraea terpsicore* Linnaeus, 1758
Papilionidae	Papilioninae	Common Rose	*Pachliopta aristolochiae* Fabricius, 1775
		Common Mormon	*Papilio polytes* Linnaeus, 1758
		Common Jay	*Graphium doson* Felder & Felder, 1864
		Tailed jay	*Graphium agamemnon* Linnaeus, 1758
Pieridae	Coliadinae	Mottled Emigrant	*Catopsilia pyranthe* Linnaeus, 1758
		Common Emigrant	*Catopsilia pomona* Fabricius, 1775
		Three-Spot Grass Yellow	*Eurema blanda* (Boisduval, 1836)
		Common Grass Yellow	*Eurema hecabe* Linnaeus, 1758
	Pierinae	Common Gull	*Cepora nerissa* Fabricius, 1775
		Cabbage White	*Pieris canidia* (Sparrman, 1768)
		Psyche	*Leptosia nina* Fabricius, 1793
		Common Jezebel	*Delias eucharis* (Drury, 1773)
		Red-Spot Jezebel	*Delias descombesi* (Boisduval, 1836)
		Common Wanderer	*Pareronia hippia* (Fabricius, 1787)

Family	Sub-family	Common name	Scientific name
Lycaenidae	Polyommatinae	Common Pierrot	*Castalius rosimon* Fabricius, 1775
		Common Cerulean	*Jamides celeno* (Cramer, 1775)
		Pale Grass Blue	*Pseudozizeeria maha* Kollar, 1844
		Lesser Grass Blue	*Zizina otis* (Fabricius, 1787)
		Tiny Grass Blue	*Zizula hylax* (Fabricius, 1775)
		Dark Grass Blue	*Zizeeria karsandra* Moore, 1865
		Forget-me-not	*Catochrysops strabo* (Fabricius, 1793)
		Quaker	*Neopithecops zalmora* Butler, 1870
		Slate Flash	*Rapala manea* (Hewitson, 1863)
		Indigo Flash	*Rapala varuna* (Horsfield, 1829)
		Plains Cupid	*Chilades pandava* Horsfield, 1829
		Gram Blue	*Euchrysops cnejus* (Fabricius, 1798)
		Lime Blue	*Chilades lajus* Stoll, 1780
		Pea Blue	*Lampides boeticus* Linnaeus, 1767
		Common Lineblue	*Prosotas nora* (Felder, 1860)
		Tailless Lineblue	*Prosotas dubiosa* (Semper, 1879)
		Common Ciliate Blue	*Anthene emolus* (Godart, 1823)
		Pointed Ciliate Blue	*Anthene lycaenina* (Felder, 1868)
		Centaur Oakblue	*Arhopala centaurus* (Fabricius, 1775)
	Theclinae	Yamfly	*Loxura atymnus* Stoll, 1780
		Monkey Puzzle	*Rathinda amor* Fabricius, 1775
		Redspot	*Zesius chrysomallus* Hübner, 1819
		Chocolate Royal	*Remelana jangala* (Horsfield, 1829)
		Common Silverline	*Spindasis vulcanus* Fabricius, 1775
Hesperiidae	Hesperiinae	Straight Swift	*Parnara guttatus* Moore, 1865
		Dark Palm Dart	*Telicota bambusae* Moore, 1878
		Pale Palm Dart	*Telicota colon* Fabricius, 1775
		Bengal Swift	*Pelopidas agna agna* (Wallace, 1866)
		Conjoined Swift	*Pelopidas conjuncta* Herrich-Schäffer, 1869
	Pyrginae	Common Snow Flat	*Tagiades japetus* (Stoll, 1781)
	Coliadinae	Brown Awl	*Badamia exclamationis* (Fabricius, 1775)

The Whittaker plot according to the abundance of different butterfly species is shown in Figure 4. *Melanitis leda* and *Eurema blanda* show relative abundances of 4.02% and 3.91% respectively. Both these species account for 8.03% of total individuals encountered in this current study from the four areas. Species accumulation/rarefaction curves as a function of the number of samples shown in Figure 5 represent that most common species are found in the sampling area, where curves generally grow rapidly at first. The red solid curve represents samples in the BJEP followed by Kadamtoli with light blue, Belkuchi with blue, and Haiderpur with green. Correspondence analysis has greatly simplified the story in the data (Figure 6); formed with family-wise species abundance consisting of 65 species, representing four different habitat/sampled sites. Each curve represents a different butterfly species richness level in four different locations.

Some representative groups, viz., grass yellows (*Eurema* spp.) and bush browns (*Mycalesis* spp.), are

Table 2. Different diversity parameters measured based on the number of counts of butterfly's species compare to four study sites of Sirajganj District.

Diversity parameters	BJEP	Belkuchi	Haiderpur	Kodomtoli
Simpson (1-D)	0.9805	0.9738	0.9723	0.9764
Shannon (H)	4.03	3.8	3.74	3.89
Evenness (e^H/S)	0.8653	0.7578	0.7198	0.7986
Menhinick	0.7443	0.9277	1.08	0.8911
Chao-1	65	59	60.5	61

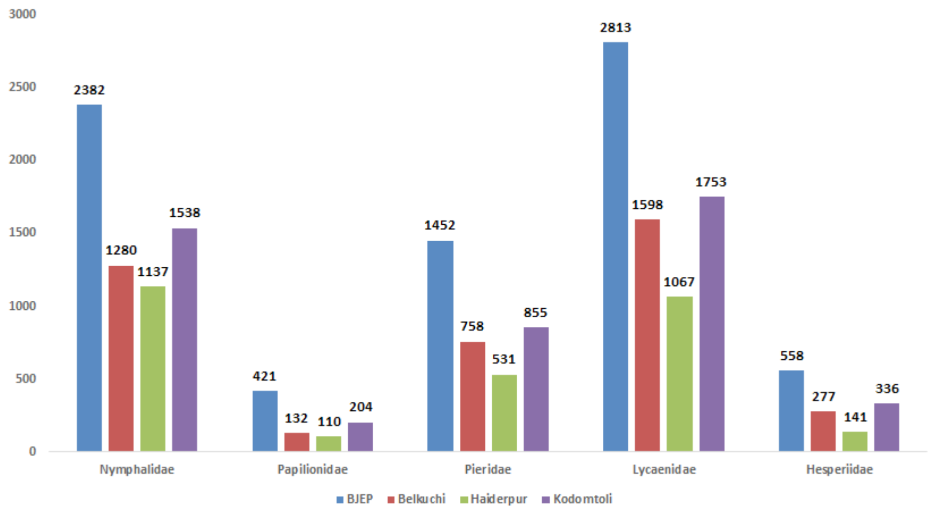

Figure 2. Family-wise trend of butterfly's species in four different habitats of Sirajganj District.

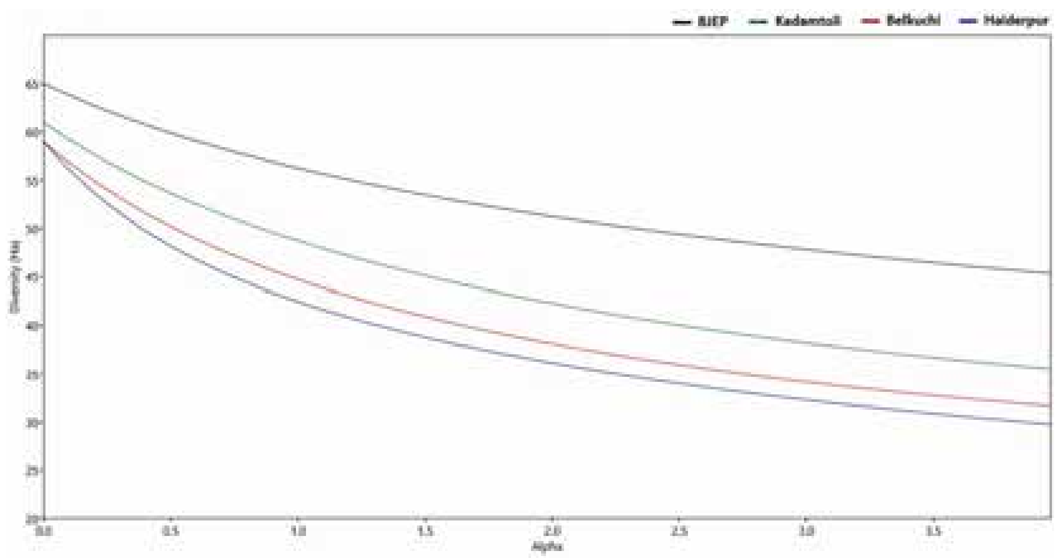

Figure 3. Diversity profile of butterflies' variations in the four sampling sites

observed to have high population in all seasons except in the monsoons, depending on the habitat. Most of the species of family Nymphalidae, viz., *Junonia* sp. and *Danaus* sp., are found in different stratification of forests due to their polyphagous character.

The compilation of species lists and identification of habitat preferences and counting of abundances are the first steps for effective conservation of biodiversity

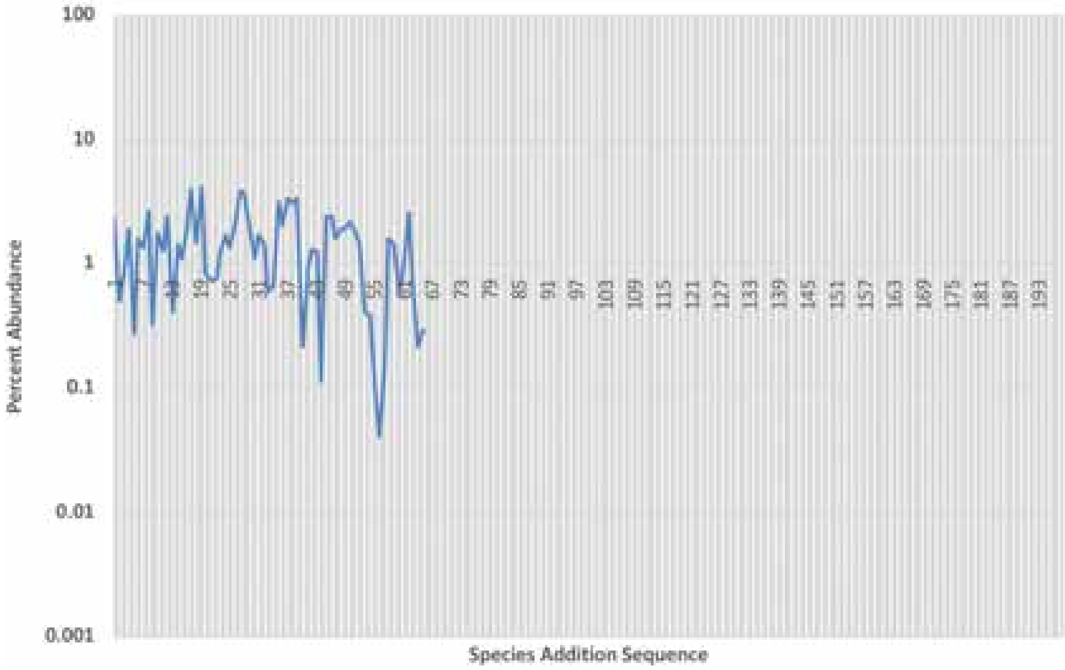

Figure 4. Rank abundance curve based on family-wise species abundances at four different sampled sites.

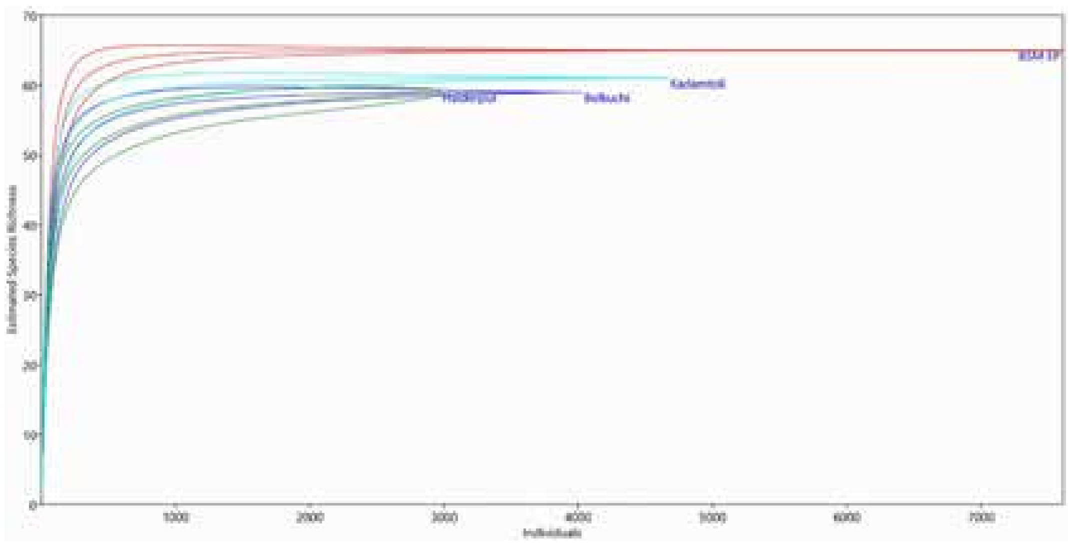

Figure 5. Species accumulation/rarefaction curves at four different sampled site.

through information of species baselines related data. Early successional forests have some valuable ecosystem services for insect population growth. It can support biodiversity at large (Chazdon 2008). BJEP covers some natural forests in the western part of the river Yamuna which support a good number of butterfly species throughout the seasons. The presence of their host plant may have resulted in the high species diversity. Butterflies show a strong response to the vegetation of their habitat (Oostermeijer & van Sway 1998). Besides, the use of chemicals causes damage to the natural environment (Sharma & Singhvi 2017). In urban areas, modification of landscape, establishment of factories, random cleanup of bushes reduces the potential habitat for butterflies. Thus, the chance of natural pollination decreases.

Butterflies in four habitats showed a highly seasonal trend in pre-monsoon (March–May) and winter season (October–November). Some species, viz., *Rapala manea*,

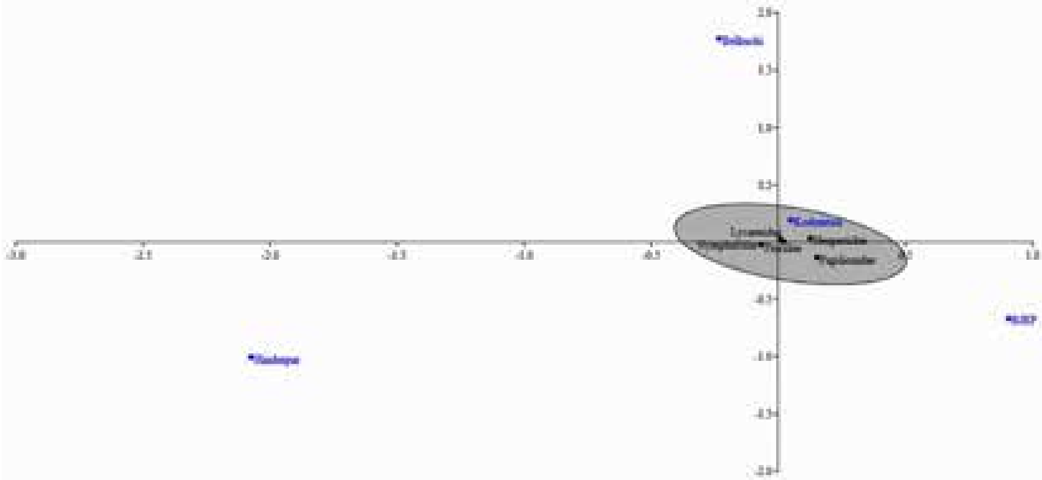

Figure 6. Corresponding analysis represents species richness level in four different locations

Chilades pandava, *Euchrysops cnejus*, *Chilades lajus*, *Lampides boeticus*, *Prosotas nora*, *Prosotas dubiosa*, and *Anthene emolus*, appeared abundant during post-monsoon and were not seen during the monsoon.

CONCLUSION

The present study address several unreported aspects of butterfly and their diversity in the study area as well as northern part which was not well explored previously. More detailed study is required to evaluate the habitat condition through butterfly diversity in the northern part of Bangladesh. The vegetation of the riverside area allows a functional variety of flora that are sources of host plants and nectar plants for butterflies, even home to different wild animals viz., birds, reptiles, and so on. The conservation of habitat and wild fauna remains a daunting task in Bangladesh due to overpopulation and a lack of knowledge about habitat conservation. It is suggested that greater emphasis be given on sustainable forest management and integrated conservation approaches in riverside rural as well as urban habitats to maintain the natural balance.

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PLATINUM OPEN ACCESS

COMMUNICATION

Chroococcalean blue green algae from the paddy fields of Satara District, Maharashtra, India

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Abstract: Blue green algae are the photosynthetic prokaryotes representing a wide distribution in habitat, i.e., temperate, tropical, and polar region. Paddy fields are the best studied aquatic ecosystems on earth which fulfill all the necessary demands required for blue green algal growth. Blue green algal role in enhancement of paddy yield has been studied worldwide. Sustainable utilization of an organism for community use depends on how successfully the ecology of that organism is understood. Twenty-eight chroococcalean blue green algal taxa were recorded from the study area. They were taxonomically investigated and found to belong to two families and 11 genera. The first family Chroococcaceae was the largest family with 10 genera and 26 species while the second family Entophysalidaceae had only one genus and two species. The genus *Gloeocapsa* from the family Chroococcaceae exhibited largest species diversity (21.42%), as well as taxa *Chlorogloea fritschii* of family Entophysalidaceae showed species abundance from the study area. All heterocystous blue green algal forms are capable of fixation of atmospheric N_2. Many of the non-heterocystous or unicellular blue green algae also have the capacity of N_2 fixation. The taxonomical documentation of chroococcalean blue green algae provide information about such indigenous unicellular blue green algae which will help in the development of niche specific inoculants as biofertilizers for rice fields of the study region.

Keywords: *Gloeocapsa,* unicellular, biofertilizer, nitrogen fixation, taxonomy.

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Author contribution: SJG—Conceptualized study, collected and analyzed data, wrote final version of menuscript translated in the field. VCK—Supervised study, helped in the revision of menuscript.

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INTRODUCTION

Blue green algae are important components of soil microflora in paddy fields. They play an important role in maintaining and improving soil fertility, as they have the ability to fix atmospheric nitrogen and transform it to nitrate/nitrite (Anand 1990). The rice fields provide ideal environment for luxuriant growth of blue-green algae. They are found in paddy field soil throughout the year at various growth stages of the rice crop (Nayak et al. 2001). There is huge structural diversity found in class Cyanophyta (blue green algae) which is the main reason for attracting algologists to develop a keen interest in their taxonomic study.

Extensive work on blue green algae of paddy fields got in various parts of India (West Bengal, Kerala, Chattisgarh, Manipur, Mizoram, Uttar Pradesh, Madhya Pradesh, Odisha, Tamil Nadu, and Maharashtra) and in Bangladesh (Banarjee 1935; Goyal et al. 1984; Anand & Revati 1987; Anand et al. 1987, 1995; Santra 1993; Sahu et al. 1997; Ahmed 2001; Nayak et al. 2001). There are some reports on growth and nitrogen fixation potentials of blue green algae (Gupta 1964; Parasad & Mehrotra 1980; Santra 1991). Some workers recorded marked variations among the species of blue green algae from rice field soils of different regions of India (Tiwari 1972; Sinha & Mukherjee 1975a,b, 1984; Anand et al. 1987). Several studies have been conducted on the blue green algal flora from the paddy fields of Maharashtra (Gonzalves et al. 1949; Sardeshpande & Goyal 1981; Kolte & Goyal 1985; Patil & Satav 1986; Madane & Shinde 1993; Auti & Pingle 2006; Patil & Chougule 2009). Ghadage & Karande (2008) and Kamble & Karande (2018) studied the unicellular blue green algae from various habitats of Satara District. Ghadage (2009), Karande (2009), Kamble (2010), and Ghadage & Karande (2019), however, studied the biodiversity of blue green algae from paddy fields of Satara District. Though substantial studies were available in Satara District, it seems that much attention was not paid to the study of chroococcalean blue green algae. Thus, the present study was designed to view the systematic enumeration of chroococcalean blue green algae of paddy fields from the study region.

MATERIALS AND METHODS

Two-hundred-and-eighty-eight paddy fields were selected from Patan and Karad tehsils of Satara, Maharashtra. Patan is 65km away to the south-west of Satara and is located at 17.370N & 73.900E. Most of Patan Tehsil is hilly with deep valleys while some parts are plains and receives heavy rainfall. The common soil is red lateritic soil, in the plains it is black cottony soil while at elevations it is the basaltic and lateritic type. This tehsil is famous for the cultivation of local varieties of paddy, viz.: Dombya, Dodkya, Kolambya, Bhados, Panwel, Indrayani, Champakali, Ghansal, Jiresal, Teliansh, Kaveri, Krishnakusal, Basmati, and Ambemohar.

Karad is 52km to the south-east of Satara and is located at 17.289N & 74.181E. Karad city situated at southern part of Satara District near Agashiva, at the confluence of Koyna and Krishna rivers called 'Preeti sangam'. The tehsil receives moderate rainfall and the common soil type is black cottony soil. It is famous for the cultivation of local varieties of rice, viz.: Indrayani, Rethare Basmati, Pusa Basmati, Hansa, Khadkil Kolhapuri, Kolhapuri R-24, and Kaveri.

Frequent and timely collection of soil and algal samples were undertaken during the rainy season (2012–2017). Soil samples were collected from paddy fields of the study area (Fig. 1). Soil from rice fields were collected randomly from both the tehsils as per Somawanshi et al. (1999). The collected soil samples were brought into the laboratory using polythene bags, dried at room

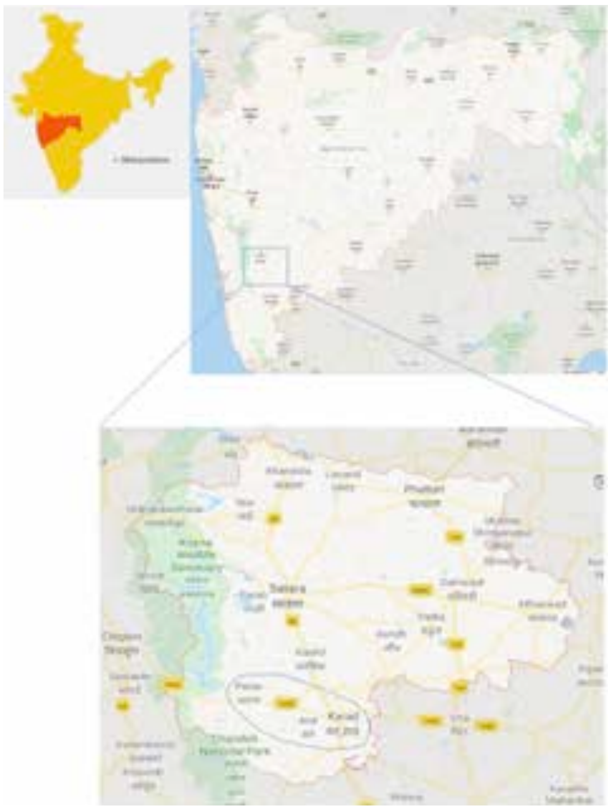

Figure 1. Study area—location of Karad and Patan Tahasils of Satara District. Source: Google maps.

temperature in diffused sunlight, and crushed with the help of a mortar and pestle. About 10g of sieved soil was inoculated in culture bottles containing 100ml culture media like BG – 11±, Foggs and Chu 10. We found good results in BG 11 medium, so for further culturing and sub culturing we prefer BG 11 ± medium. These cultures were incubated at 22±2˚c with 16/8 light dark cycle under 5 Klux intensity of light, after incubation algal growth appeared in the enriched cultures in laboratory. Cyanobacterial growth from enriched cultures were examined microscopically and identified with the help of standard literature (Dasikachary 1959; Anagnostidis & Komarek 1985; Anand 1990; Santra 1993). Photographs were taken by using photomicrography unit of Olympus CH20i (Photoplates I, II, III).

The species diversity % was calculated by using the following formula.

$$\text{Species diversity \%} = \frac{\text{Total no. of particular species recorded in that area}}{\text{Total no. of species recorded from that area}} \times 100$$

RESULT AND DISCUSSION

Systematic enumeration of Chroococcalean blue green algae

Order: Chroococcales Wettstein

Forms of this order are unicellular or colonial, not differentiated into base and apex; as well as trichome organization totally absent. Endospores or exospores not present.

Key to the families

A. Thallus forming small colonies .... Chroococcaceae

B. Forming pseudo filamentous thallus .... Entophysalidaceae

1. Family: Chroococcaceae Nageli

Cells single or forming shapeless, ellipsoidal or spherical colonies and cell shape may be spherical or cylindrical, ellipsoidal with thick mucilaginous membrane.

Key to the genera

A. Cells few in shapeless colony........................ (1)

1) Spherical cells ....(2)

1) Elongated cells with transverse cell division..(4)

B. Cells many in a colony...................................(6)

2) Absence of Individual envelope ....*Synechosystis*

2) Presence of Individual envelope..................(3)

3) Vesicular sheath.............................*Gloeocapsa*

3) Non vesicular sheath.....................*Chroococcus*

4) With firm vesicular sheath.............*Gloeothece*

4) Without such sheath...................................(5)

5) Few cells in common mucilage...*Synechococcus*

5) Cells with tapering ends in spindle shaped colonies.....................................*Dacylococcopsis*

6) Cells without definite arrangement.............(7)

6) Cells with definite arrangement...................(9)

7) Cells in small well packed colonies .... *Microsystis*

7) Cells loosely arranged in colonies.................(8)

8) Cells spherical...............................*Aphanocapsa*

8) Cells Ellipsoidal to Cylindrical ....*Aphanothece*

9) Cells in transverse longitudinal rows ....*Merismopedia*

A] Genus: *Aphanocapsa* Nag.

Loosely arranged spherical cells in a formless gelatinous mass. Cells having individual sheath which is more or less gelatinous.

Key to the species

1) In freshwater, planktonic................................(2)

2) Cells diameter 6.5–7.5µm................*A. roseana*

2) Cells diameter 1.42–2 µm...............*A. elachista*

1) *Aphanocapsa roseana* de Bary

Cyanophyta: Desikachary, T. V. 1959, p – 132, photoplate II, Fig-h

Thallus irregularly spherical, bluish green in color. Cells 6.5–7.5 µm diameter, somewhat oval, sheath mucilaginous.

Locality: Patan: Nawsari, Mhawshi.

2) *Aphanocapsa elachista* var *irregularis* W. et. G.S.West

Cyanophyta: Desikachary, T.V. 1959, p – 132, pl. 21, Fig. 5, photoplate II, Fig-i

Irregular thallus. Cells loosely and closely arranged. Single or in pairs, 1.42–2 µm in diam., blue-green in color.

Locality: Patan: Sangwad, Marul Haweli, Maldan, Tondoshi.

Karad: Undale.

B] Genus : *Aphanothece* Nag.

Cells embedded in a shapeless expanded thallus; ellipsoidal to cylindrical with lamellated individual envelope.

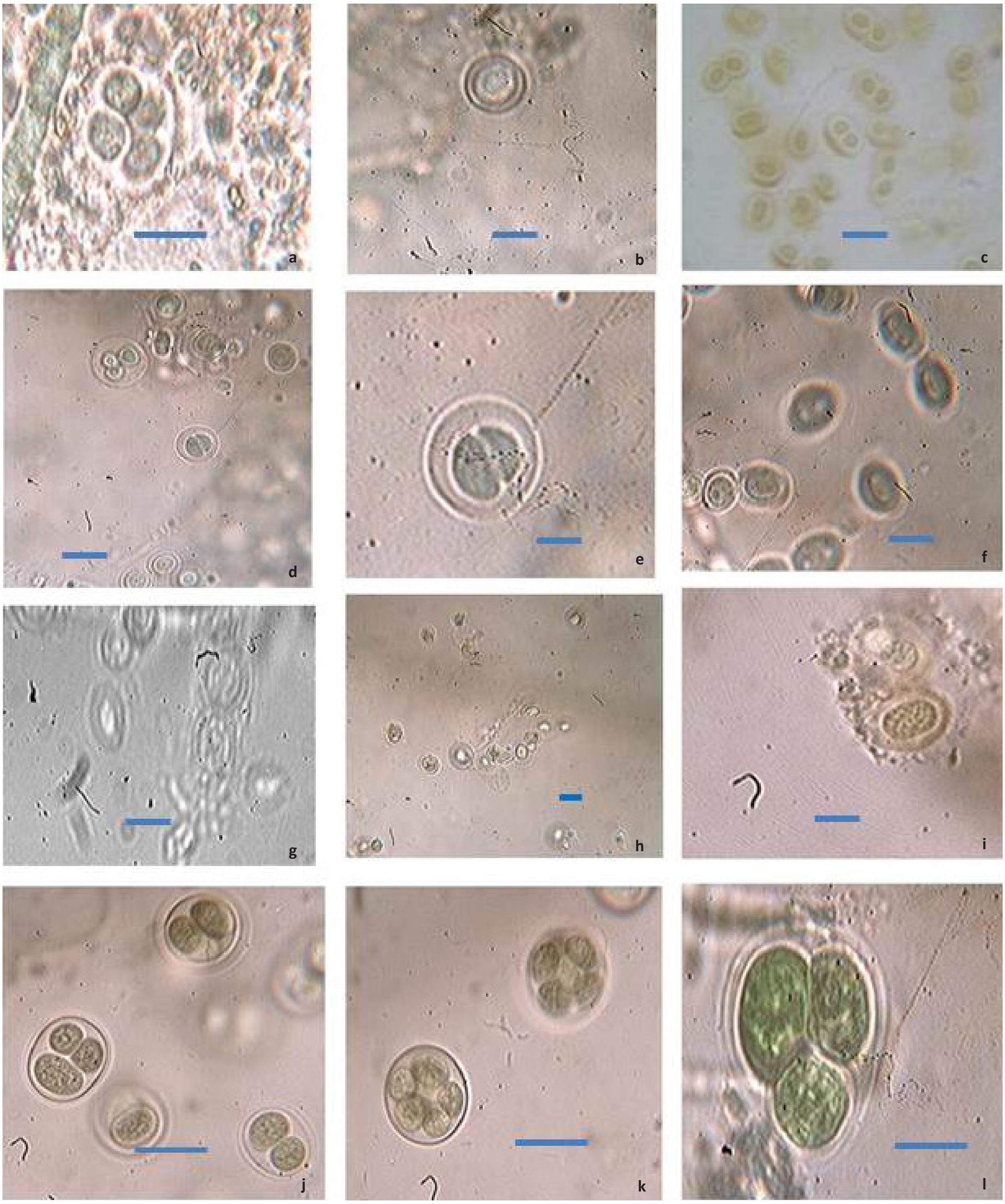

Image 1 Family 1 Chroococcaceae—Chroococcalean BGA: MS no. 5683: a—*Gloeocapsa livida* (Carm.) Kutz | b—*Gloeocapsa decorticans* (A. Br..) Richter | c—*Gloeocapsa nigrescens* Nag. | d–e—*Gloeocapsa polydermatica,* Kutz. | f—*Gloeocapsa areuginosa (Carm.)* Kutz. | g—*Gloeocapsaeothece atrata* (Turp) Kutz | h—*Gloeothece palea* (Kutz) Rabenh | i—*Gloeothece samoensis* Wille | j–k—*Gloeothece rupestris* (Lyngb) Bornet | l—*Chroococcus turgidus* (Kutz) Nag. Scale = 10µm. © Sharada Ghadage.

Key to the species

1) Mucilagenous expanded thallus....................(2)
2) 3.3–5.2 µm broad cells........................*A. pallida*
2) 3.8–4.3 µm broad cells.................................(3)
3) Subaerial ....*A. naegelli*
3) Submerged, non-thermal...........*A. microscopia*

1) *Aphanothece naegeli* Wartm

Cyanophyta: Desikachary, T. V. 1959, p -141, pl. 22, Fig. 7, photoplate II, Fig-e

Thallus gelatinous, olive green. After division cells appear spherical, latter on becomes oval, cell breadth 3.8–4.3 µm and length up to 6.6–7.8 µm; sheath diffluent.

Locality: Patan – Chavanwadi, Gokul tarf Patan, Kokisare, Palashi, Telewadi.

Karad – Pali.

2) *Aphanothece microscopia* Nag.

Cyanophyta: Desikachary, T.V. 1959, p - 142, pl. 22, Figs. 4,5,9. Photoplate II, Fig-f

Thallus small, gelatinous, at first rounded, but latter amorphous; cells cylindrical, 3.9–5 µm broad, 7.5–9 µm long with distinct individual sheath, bluish-green. The thallus in culture grows attached at the sides of culture bottles.

Locality: Patan – Kuthare, Nanegaon, Gokul tarf Marali, Vitthalwadi.

Karad – Atke, Sabalwadi, Riswad, Chinchni, Abaichiwadi, Supane, Sajur, Kole.

3) *Aphanothece pallida* (kutz.) Rabenh.

Cyanophyta: Desikachary, T.V. 1959, p -140, pl. 22, Fig. 3. Photoplate II, Fig-g

Thallus appear gelatinous and soft,cells oblong, 3.3–5.2µm broad, up to 7µm long, olive green in color, sheath lamellated, yellowish in color.

Locality: Patan - Yeradwadi, Shitapwadi, Pachgani.

Karad – Talgaon, Shiwade, Charegaon, Pal.

C] Genus: *Gloeocapsa* Kutzing.

Cells mostly 2–8 in a colony and spherical in shape. Colonies many together. Cells having lamellated individual sheaths.

Key to the species

1) Colorless sheath...(2)
2) Unlamellated sheath....................................(3)
2) Lamellated sheath... (8)
3) Without calcium impregnation......................(4)
4) Cells 3µm without sheath..............................(5)
4) 5µm broad cells without sheath......... *Gl. livida*
5)Thallus blue green........................*Gl. aeruginosa*
6) Lamellated sheath..............................*Gl. atrata*
6) Unlamellated sheath...................................(7)
7) 4.2–5.32 µm broad cells without sheath.......... .... *Gl. nigrescens*
8) Cell diameter 8µm without sheath.................. .... *Gl. decorticans*
8) Cells 3.9µm diameter without sheath.............. ....*Gl. polydermatica*

1) *Goeocapsa nigrescens* Nag.

Cyanophyta: Desikachary, T. V. 1959, p -117, pl. 24, Figs. 15, 17. Photoplate I, Fig-g

Thallus thin, blackish, cells spherical, without sheath 4.2–5.32 µm; and with sheath 9.31–11.6 µm diam., sheath broad, not lamellate.

Locality: Patan – Nade, Telewadi.

Karad – Karve, Dhanakwadi.

2) *Goeocapsa atrata* (Turp.) Kutz.

Cyanophyta: Desikachary, T.V. 1959, p - 116, pl. 24, Fig. 8. Photoplate I, Fig-c

Thallus blackish in color. Cells without sheath up to 5.68µm broad and with sheath 9.5–12.5µm in diam. Many cells in a single colony, sheath colorless, unlamellated.

Locality: Patan – Korivale, Bambavade, Govare, Jyotibachiwadi, Zakade.

Karad – Kaletake.

3) *Goeocapsa polydermatica* Kutz.

Cyanophyta: Desikachary, T.V. 1959, p - 114, pl. 25, Fig. 1, photoplate I, Fig-d-e

Thallus mostly compact and mucilaginous; cells spherical, without sheath 3.9µm and with sheath 6.65µm in diam., bluish-green to colorless sheath and thick, and lamellated.

Locality: Patan – Divashi, Kadhne, Marloshi, Vitthalwadi.

4) *Goeocapsa decorticans* (A. Br.) Richter

Cyanophyta: Desikachary, T.V. 1959, p -114, pl. 24, Fig. 9. Photoplate I, Fig-b

Cells spherical to oval, bluish in color, 2–4 together, with sheath up to 19µm in diam., and without sheath 8µm broad, sheath colorless, thick.

Locality: Patan – Jamdarwadi, Sangwad.

Karad - Pachwad, Yenke.

5) *Goeocapsa aeruginosa* (Carm.) Kutz.

Cyanophyta: Desikachary, T.V. 1959, p -115.

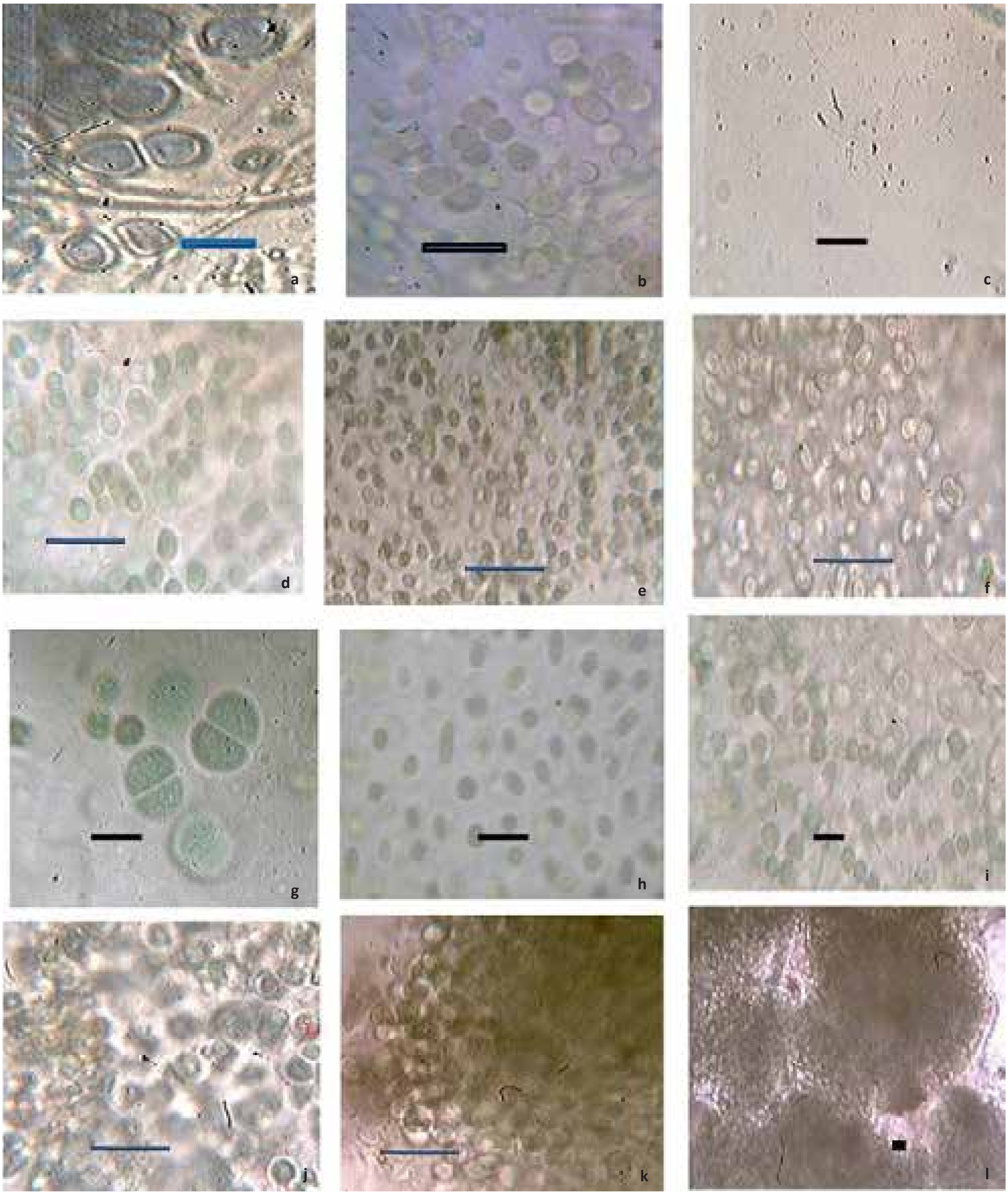

Image 2. Family 1 Chroococcaceae: *a—Chroococus Pallidus* Nag. | b—*Chroococcus minor* (Kutz) Nag. | c—*Chroococcus multicoloratus* Wood | d—*Chroococcus minutus* (Kutz) Nag. | e—*Aphanothece naegelli* Wartm. | f—*Aphanothece microscopia* Nag. | g—*Ahanothece pallida* (Kutz) Rabenh | h—*Aphanocapsa roseana* de Bary | i—*Ahanocapsa elachista* var *irregularis* W.et.G.S.West | *j—Microsystis robusta* (Clark) Nygaard | k–i—*Microsystis elabens* (Barb.) Kutz. Scale = 10µm. © Sharada Ghadage.

Photoplate I, Fig-f

Thallus mucilaginous, crustaceous. Cells with sheath 5.68µm broad and without sheath 2.84–3 µm broad. Cells in spherical colonies, sheath lamellated.

Locality: Patan – Urul, Surul, Gokul tarf Patan, Shiral, Telewadi.

6) *Goeocapsa livida* (Carm.) Kutz.

Cyanophyta: Desikachary, T. V. 1959, p - 116, pl. 27, Fig. 8.Photoplate I, Fig-a

Thallus mucilaginous greenish in color. Cells small, cells up to 5µm broad and colony diam. 11.8µm. Sheath hyaline, bluish-green.

Locality: Patan – Navadi, Gavanwadi, Kuthare, Ambavane, Jambhekarwadi, Govare, Jyotibachiwadi.

D] Genus**:** *Gloeothece* Nag.

Cells ellipsoidal, straight in small colonies. Sheath and colony structure same as that of *Gloeocapsa*.

Key to the species

1) Mucilage envelope colorless.......................(2)
2) Cells 2.5–4.5 µm without envelope............(3)
2) Cells 4–6 µm broad....................................(4)
3) Cells cylindrical.................................*Gl. palea*
3) Cells ellipsoidal ....*Gl. samoensis*
4) Cells ellipsoidal to cylindrical up to 15µm long ....*Gl. rupestris*

1) *Gloeothece palea* (Kutz.) Rabenh.

Cyanophyta: Desikachary, T. V. 1959, p -127. Photoplate I, Fig-h

Cells cylindrical and long, without envelope 2.5–4.5 µm in diameter. Cells with envelope 8.52µm broad and 9.94µm long, unlamellated, envelope lightly yellowish in color.

Locality: Patan – Ambeghar tarf Marali, Kusavade Khu.

Karad – Karve, Wadgaon haweli, Vadoli bhikeshwar, Korti, Bholewadi.

2) *Gloeothece rupestris*t (Lyngb.) Bornet

Cyanophyta: Desikachary, T.V. 1959, p - 127, pl. 25, Fig. 4. Photoplate I, Fig-j-k

Cells ellipsoidal, without envelope 4.2–5.5 µm broad, 7.5–8µm long, cells with envelope 9–12 µm broad, cells 2–4 together, envelope colorless, unlamellated.

Locality: Patan – Telewadi, Sawantwadi, Majgaon, Surul, Karate.

Karad – Rethre Bu., Charegaon.

3) *Gloeothece samoensis* Wille

Cyanophyta: Desikachary, T.V. 1959, p -128, pl. 23, Fig. 3. Photoplate I, Fig-i

Cells ellipsoidal, without sheath 4–4.2 µm broad and about 8µm long, cells yellowish in color, in ellipsoidal colonies, cells with unlamellated envelope.

Locality: Patan – Yeradwadi, Umarkanchan, Yerphale, Donichawada.

E] Genus : *Chroococcus* Nag.

Cells in small groups 2–4 together or sometimes 8–16 together. Cells spherical to hemispherical in shape with distinct and firm individual sheaths.

Key to the species

1) Cells single /8 (-16) later divided...................(2)
1) Large thallus formed.......................................(6)
2) Sheath lamellated ....(3)
2) Not lamellated ....(5)
3) Colorless envelope..(4)
4) Sheath distinct, cells with sheath less than 32µm broad ....*Chr. turgidus*
5) Cells 4–10 µm without sheath.......*Chr. minutus*
5) Cells 3–4 µm without sheath ....*Chr. minor*
6) Subaerial colonies..(7)
7) Unlamellated sheath.....................................(8)
8) Cells 4 –8 µm broad without sheath................ ....*Chr. Pallidus*
8) Cells less than 2µm broad without sheath ....*Chr. multicoloratus*

1) *Chroococcus minutus* (Kutz.) Nag.

Cyanophyta: Desikachary, T.V. 1959, p -103, pl. 24, Fig. 4 and pl. 26, Figs. 4, 15. Photoplate II, Fig-d

Cells spherical, single or in groups of 2, bluish-green, with sheath 7.8µm broad and without sheath 6.5µm in diameter. Colonies 12.78µm broad sheath not lamellated, colorless.

Locality: Patan – Awarde, Salave.

Karad – Kaletake, Shiwade, Koparde haweli, Charegaon, Bholewadi, Shelkewadi.

2) *Chroococcus minor* (Kutz.) Nag.

Cyanophyta: Desikachary, T.V. 1959, p - 105, pl. 24, Fig. 1. Photoplate II, Fig-b

Thallus olive green in color, gelatinous, cells spherical, 3.3–3.5 µm in diameter. Mostly single, sheath colorless, very thin.

Locality: Patan – Matekarwadi.

Karad – Kale, Hanbarwadi.

3) *Chroococcus multicoloratus* Wood.

Cyanophyta: Desikachary, T.V. 1959, p - 109. Photoplate II, Fig-c

Thallus mucilaginous mostly found among other algae; cells spherical, single or 2–4 together in a colony. Cells about 1µm in diameter. Sheath thick, unlamellated, hyaline, yellowish green.

Locality: Patan – Varekarwadi, Vajegaon.

Karad – Kaletake.

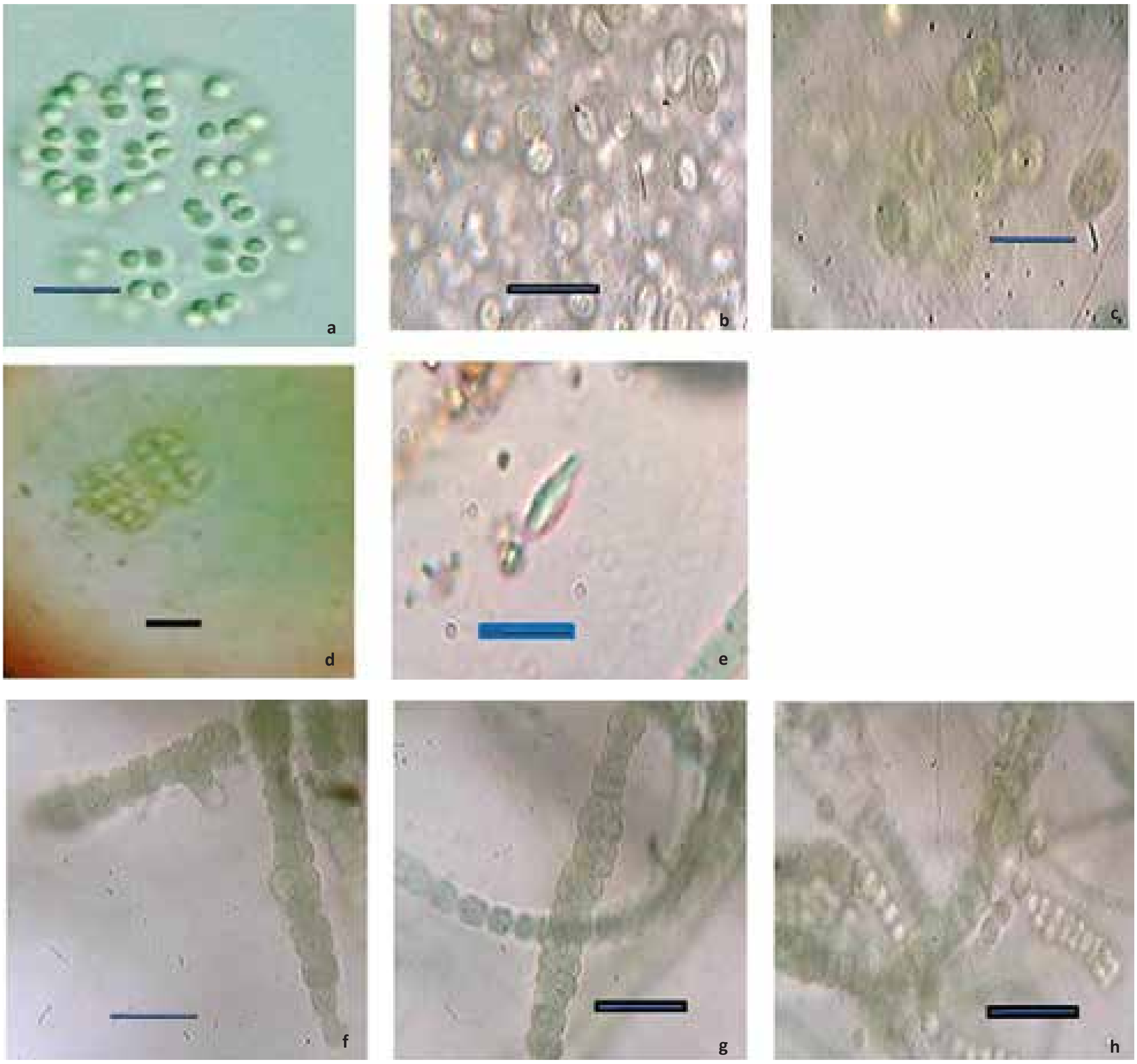

Image 3. Family 1 Chroococcaceae (a–e): a—*Synechosystis pevalekii* Ereegovic | b—*Synechococcus cedrorum* Sauvageau | c—*Synechococcus aeruginosus* Nag. | d—*Merismopedia tenuissima* Lemm. | e—*Dactylococcopsis raphidioides* Hansg. Family 2 Entophysalidaceae (f–h): f—*Chlorogloea microcystoides* Geitler | g–h—*Chlorogloea fritschii* Mitra. Scale bars = 10µm. © Sharada Ghadage.

4) *Chroococcus turgidus* (Kutz.) Nag.

Cyanophyta: Desikachary, T.V. 1959, p - 101, pl. 26, Fig. 6. Photoplate I, Fig-l

Cells spherical, mostly in groups of three, olive green in color, without sheath 8–15 µm broad, with sheath 16–25 µm broad; sheath colorless, not lamellated.

Locality: Patan – Kumbhargaon, Awarde, Kusavade.

5) *Chroococcus pallidus* Nag.

Cyanophyta: Desikachary, T.V. 1959, p - 108, pl. 26, Fig. 5. Photoplate II, Fig-a

Thallus gelatinous yellowish, cells in group of two, without sheath 5–6 µm broad and with sheath 7–8 µm broad bluish green in color.

Locality: Patan – Shidrukwadi, Budakewadi, Gaymukhwadi, Donichawada.

Karad – Charegaon.

F] Genus: *Synechosystis* Sauvageau

Cells spherical, single, after division found in colonies without mucilage envelope.

Key to the species

1) Cells diameter 2.8–3.5 µm……………..*S. pevalekii*

1) *Synechosystis pevalekii* Ercegovic

Cyanophyta: Desikachary, T.V. 1959, p - 145, pl. 25, Fig. 11, photoplate III, Fig-a

Thallus associated among other algae; cells spherical or hemispherical, 2.84–3.5 µm broad, and colony breadth 3–5.68 µm. content bluish-green in color and homogenous.

Locality: Patan - Adul, Sangwad, Gaymukhwadi.

Karad – Yevati.

G] Genus: *Synechococcus* Nag.

Cells ellipsoidal with rounded ends, mostly cells are single. Mucilage envelope very thin.

Key to the species

1) Cells broader than 5µm ……………………………..

……………………………………………*Syn. aeruginosus*

1) Cells 3–4.3 µm broad ellipsoidal …………………

………………………………………………*Syn. cedrorum*

1) *Synechococcus aeruginosus* Nag.

Cyanophyta: Desikachary, T. V. 1959, p - 143, pl. 25, Figs. 6, 12. Photoplate III, Fig-c

Cells cylindrical, 5.32–6.2 µm broad, up to 27µm long, single, pale bluish-green in color.

Locality: Patan – Nade, Jalu, Atoli.

Karad **–** Pachwad.

2) *Synechococcus cedrorum* Sauvageau

Cyanophyta: Desikachary, T. V. 1959, p - 144. Photoplate III, Fig-b

Cells single, elongate to rounded, up to 3.9µm broad; and 5.4–6 µm long, bluish-green in color.

Locality: Patan – Divashi, Dhadamwadi.

H] Genus: *Microsystis* Kutzing.

Cells spherical in shape and embedded in net-like colonies. Cells densely arranged and not having individual envelope.

Key to the species:

1) In fresh water…………………………………………(2)

2) Spherical cells…………………………………………(3)

2) Elongated cells………………………………………(4)

3) 6–9 µm broad cells………………………*M. robusta*

4) 2–4.5 µm broad cells……………………*M. elabens*

1) *Microsystis elabens* (Breb.) Kutz.

Cyanophyta: Desikachary, T.V. 1959, p - 97, pl. 18, Fig. 12 and pl. 20, Figs. 6, 7. Photoplate II, Fig-k-i

Colony flat, bluish-green in color, daughter colonies come close together when become old; cells 2.2–3.6µm broad and up to 6.6µm long.

Locality: Karad – Potale.

2) *Microsystis robusta* (Clark) Nygaard

Cyanophyta: Desikachary, T.V. 1959, p - 85, pl. 17, Figs. 7–10. Photoplate II, Fig-j

Colonies first globose latter on irregularly expanded; cells spherical, with distinct gelatinous sheath. Cells spherical and 6.65µm in diameter.

Locality: Patan – Navadi, Girewadi, Marul haweli, Padloshi, Konjavade, Varpewadi, Atoli.

Karad – Karve, Dhanakwadi, Belavde haweli, Bamanwadi.

I] Genus: *Dactylococcopsis* Hansgirg.

Cells are elongated, spindle-shaped with pointed ends. Ends somewhat bent.

Key to the species

1) Cells breadth 1.85µm and length 6.6µm ……..

………………………. *Dactylococcopsis raphidioides*

1) *Dactylococcopsis raphidioides* Hansg.

Cyanophyta: Desikachary, T.V. 1959, p - 158, pl. 29, Figs. 1, 2. Photoplate III, Fig-e

Cells spindle shaped, 1.85µm broad and 6.63µm long, light blue-green in color, mostly single in the mucilage of other algae.

Locality: Patan – Navsari, Nanegaon, Gokul tarf Patan, Telewadi.

J] Genus : *Merismopedia* Meyen

Cells in a homogenous mucilage and are 4–16 together in a tabular colonies. Arrangement of cells in a single plane.

Key to the specie

1) Cells about 5µm broad …………………………….

……………………….….. *Merismopedia tenuissima*

1) *Merismopedia tenuissima* Lemm.

Cyanophyta: Desikachary, T.V. 1959, p - 154, pl. 29, Fig. 7 and pl. 30, Figs. 8, 9. Photoplate III, Fig-d

Cells pale bluish-green in color, closely packed in colonies of sixteen cells, sub spherical, about 2µm broad, without distinct individual mucilage.

Locality: Patan – Keloli.

2. Family: Entophysalidaceae Geitler

Thallus mostly attached to the substratum, cell arrangement in regular or irregular group of rows. Cells spherical or ellipsoidal in shape without individual

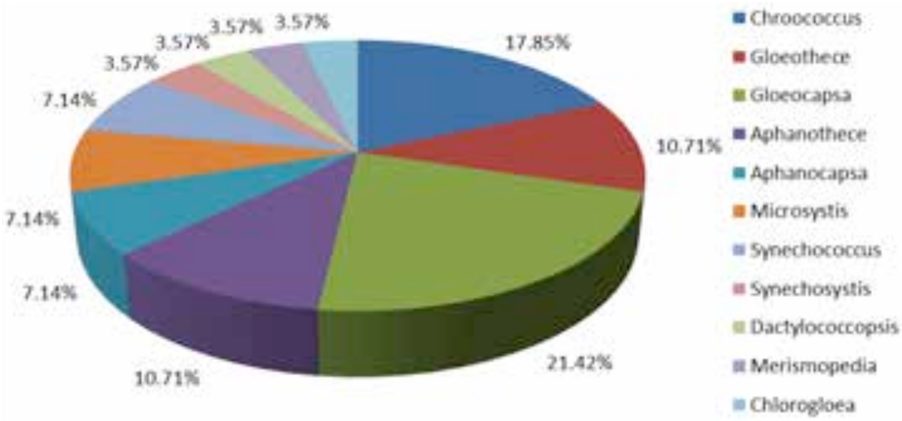

Figure 2. Species abundance of Chroococcalean taxa from study area.

sheath and not forming typical filament forms.

A] Genus: *Chlorogloea* Wille.

Cells mostly in straight erect rows, they are ellipsoidal to spherical in shape without individual envelopes. Cell divides in a single direction.

Key to the species

1) Cells diameter 2–3.8 µm…….*Chl. microcystoides*

1) Cells diameter 6–8 µm………………..*Chl. fritschii*

1) *Chlorogloea fritschii* Mitra

Cyanophyta: Desikachary, T.V. 1959, p - 163, pl. 31, Figs. 1–16. Photoplate III, Fig-g

Thallus deep bluish-green in color, cell arrangement vertical as well as horizontal rows like, cells usually about 8µm in diameter, cells single or in groups of two, or four or more cells.

Locality: Patan – Adul, Sangwad, Divshi, Tupewadi, Chavanwadi, Kadave b., Donglewadi, Natoshi,

Palashi, Gokul tarf Patan, Telewadi.

Karad – Karve, Pachwad, Dhondewadi, Kale, Botrewadi, Yenpe, Akaichiwadi, Saidapur, Wadoli nileshwar, Shahapur, Shiwade, Hanumanwadi, Varade, Umbraj, Andharwadi, Hingnole, Chore, Chorajwadi, Pal, Hanumannagar (Karad city), Tembu, Hajarmachi, Riswad, Gaikwadwadi, Potale, Kole.

2) *Chlorogloea microcystoides* Geitler

Cyanophyta: Desikachary, T. V. 1959, p - 163, pl. 19, Fig. 8. Photoplate III, Fig-f

Thallus gelatinous, thin, dull green in color; cells spherical, closely arranged in erect or radial rows of more or less indistinct rows without individual envelope. Cells 2.5–3.6 µm in diameter.

Locality: Patan – Jamdarwadi, Varekarwadi, Nanegaon.

Karad – Malkapur, Savade, Hanumanwadi, Antavadi, Mundhe, Vijaynagar.

Patan and Karad tehsils of Satara districts are famous for paddy cultivation. An extensive study was made in search of diversity, distribution and occurrence of chroococcalean cyanobacteria. Order chroococcales contains two families—Chroococcaceae and Entophysalidaceae. Eleven genera and 28 eight species were recorded by screening 288 paddy field localities of study area. From family chroococcaceae 10 genera and 26 species were recorded. Genus *Gloeocapsa* with six species; followed by genera *Chroococcus* with five species, *Gloeothece* and *Aphanothece* with three species were dominant. While from family Entophysalidaceae only one genus *Chlorogloea* with two species, i.e., *Chlorogloea fritschii* and *C. microcystoides* were reported. But these two forms were frequently recorded from the study area. Genus *Gloeocapsa* showed species diversity i.e., six species of single genera recorded in study area while genus *Chlorogloea* with two species reported to be dominant taxa i.e., reported in most of the paddy fields repeatedly.

Some interesting observations were made while isolating and culturing of unicellular forms from paddy field soils of Patan and Karad tehsils. Generally at the beginning filamentous forms appear in the culture bottles while unicellular forms appeared in old cultures. The members from family Chroococcaceae showed coccoid appearance, they form smooth gelatinous loose colonies while members of family Entophysalidaceae are also coccoid but show colonial growth habit. The cells grow to give dense parenchymatous mass. The growth habitat in culture condition of these taxa become helpful to differentiate them visually.

Wyatt & Silcey (1969) also studied nitrogen fixation of chroococcalean blue green alga *Gloeocapsa* species while Zhou & Chen (1991) recorded their efficiency for nitrogen fixation. Our study area also showed

Table 1. Species diversity percentage of Chroococcalean taxa from study area.

	Genera	Species	No. of particular species	Species diversity %
1	*Chroococcus*	*Chroococcus minutus*	05	17.85 %
2		*Chroococcus multicoloratus*		
3		*Chroococcus minor*		
4		*Chroococcus turgidus*		
5		*Chroococcus pallidus*		
6	*Gloeothece*	*Gloeothece palea*	03	10.71 %
7		*Gloeothece rupestris*		
8		*Gloeothece samoensis*		
9	*Gloeocapsa*	*Gloeocapsa atrata*	06	21.42 %
10		*Gloeocapsa nigrescence*		
11		*Gloeocapsa decorticans*		
12		*Gloeocapsa aeruginosa*		
13		*Gloeocapsa livida*		
14		*Gloeocapsa polydermatica*		
15	*Aphanothece*	*Aphanothece microscopia*	03	10.71 %
16		*Aphanothece naegelii*		
17		*Aphanothece pallida*		
18	*Aphanocapsa*	*Aphanocapsa roseana*	02	7.14 %
19		*Aphanocapsa elachista* var *irregularis*		
20	*Microsystis*	*Microsystis robusta*	02	7.14 %
21		*Microsystis elabens*		
22	*Synechococcus*	*Synechococcus cedrorum*	02	7.14 %
23		*Synechococcus aeruginosus*		
24	*Synechosystis*	*Synechosystis pevalekii*	01	3.57 %
25	*Dactylococcopsis*	*Dactylococcopsis raphidioides*	01	3.57 %
26	*Merismopedia*	*Merismopedia tenuissima*	01	3.57 %
27	*Chlorogloea*	*Chlorogloea fritschii*	02	7.14
28		*Chlorogloea microcystoides*		
		Total No. of species	**28**	**100 %**

predominance of *Gloeocapsa* species with high species diversity percentage (21.42%) denote species diversity from the study area; followed by *Chroococcus* with 17.85%, *Gloeothece* and *Aphanothece* with 10.71% and *Aphanocapsa*, *Microsystis,* and *Synechococcus* with 7.14%. This showed their moderate occurrence in the paddy fields of study region. Least species diversity percentage was recorded in *Chlorogloea, Merismopedia*, *Dactylococcopsis,* and *Synechosystis* (3.57%) (Table 1) (Figure 2). Nitrogen fixation by *Gloeothece* species was noted by Maryan et al. (1986). The least diverse species did not show their adaptability for changing pH condition of the cultures and they vanish very soon. But *Gloeocapsa*, *Chroococcus*, *Gloeothece*, and *Aphanothece* proved their adaptability to changing pH. *Chlorogloea fritschii* showed high dominance (reported from 11 localities of Patan Tehsil and 26 localities of Karad Tehsil) followed by *Microsytis*, *Chroococcus* & *Gloeothece*. This data would provide the knowledge about such indigenous chroococcalean species which showed species diversity and occur frequently in paddy soil cultures. This will help in development of niche specific inoculants as biofertilizers for rice fields of the study region.

The abundant growth of chroococcophyceae members in aquatic environment especially planktonic state than in terrestrial environment was recorded by Naz et al. (2003). They surveyed fresh water cyanophyta from certain areas of northern region of Pakistan and Azad Kashmir. Naz et al. (2004) reported 46 planktonic, edaphic, epipsammic, epioikotic, epilithic & epiphytic blue green algae belonging to class Chroococcophyceae (cyanophyta) from various fresh water habitats of Pakistan. They reported these chroococcalean forms from various habitalts; but we recorded 28 chroococcalean taxa from paddy field

Table 2. Distribution of Chroococcalean blue green algal species in study area.

Order	Family	Genera	Species	Taxa from Patan Tehsil	Taxa from Karad Tehsil	Common taxa (from both the Tehsils)
Chroococcales	1) Chroococc aceae	1) *Chroococcus*	*Chroococcus minutus*	-	-	+
			Chr. multicolor Ataus	-	-	+
			Chr. minor	-	-	+
			Chr. turgidus	+	-	-
			Chr. pallidus	-	-	+
		2) *Gloeothece*	*Gloeothece palea*	-	-	+
			Gl. rupestris	-	-	+
			Gl. samoensis	+	-	-
		3) *Gloeocapsa*	*Gloeocapsa atrata*	-	-	+
			Gl. nigrescence	-	-	+
			Gl. decorticans	-	-	+
			Gl. aeruginosa	+	-	-
			Gl. livida	+	-	-
			Gl. polydermatica	+	-	-
		4) *Aphanothece*	*Aphanothece microscopia*	-	-	+
			A. naegelii	-	-	+
			A.pallida	-	-	+
		5) *Aphanocapsa*	*Aphanocapsa roseana*	-	-	+
			A. elachista var *irregularis*	-	-	+
		6) *Microsystis*	*Microsystis robusta*	-	-	+
			M. elabens	-	+	-
		7) *Synechococcus*	*Synechococcus cedrorum*	+	-	-
			S. aeruginosus	-	-	+
		8) *Synechosystis*	*Synechosystis pevalekii*	+	-	-
		9) *Dactylococcopsis*	*Dactylococcopsis raphidioides*	+	-	-
		10) *Merismopedia*	*Merismopedia tenuissima*	+	-	-
	2) Entophysaledaceae	1) *Chlorogloea*	*Chlorogloea fritschii*	-	-	+
			Chl. microcystoides	-	-	+

Taxa Present = sign **+**
Taxa absent = sign **-**

soil cultures only. Nitrogen fixation by unicellular blue green algae *Aphanothece* was reported by Singh (1973). Majority taxa found in paddy in fresh form as well as in soil cultures was of filamentous heterocystous and filamentous non-heterocystous type. Non-heterocystous chroococcalean cyanobacteria, however, also fixes atmospheric nitroge (Wyatt & Silvery 1969). Huang & Chow (1988) showed comparative account of nitrogen fixing unicellular cyanobacteria from rice fields. Capacity of nitrogen fixation by chroococcalean blue green algae *Aphanothece pallida* was recorded by Van et al. (1988) by isolating it from paddy fields. Unicellular forms were not recorded from paddy fields in the study region (Not as field collected specimens). They showed their occurrence in paddy soil cultures only and especially when cultures become 3–4 weeks old. The reason behind less number of chroococcalean taxa is, majority of the chroococcalean forms occur in soil cultures; not in field conditions and especially when soil cultures becomes 3–4 weeks old.

At first filamentous heterosystous and filamentous non-heterosystous forms occur in cultures and when cultures became old (3–4 weeks) and when the nitrogen content of the medium slow down, chroococcalean forms grow upward direction in the culture bottles. Out of 28 chroococcalean blue green algal forms, 18 forms show common occurrence, nine restricted to paddy field soils of Patan Tehsil and only one taxa restricted to paddy field soils of Karad Tehsil. Detailed distribution of chroococcalean blue green algae in study area is given in tabular form (Table 2).

Taxonomic as well as ecological study of chroococcalean blue green algae was done from paddy fields of many regions of the world. Roger (1985) made a report on mucilaginous bloom of unicellular blue green algae and its application as a biofertilizer. Majority forms recorded at field and cultures are filamentous heterosystous and filamentous non-heterosystous type. Ahmed & Kalita (2002) recorded abundance of unicellular chroococcalean forms in paddy fields. They isolated 53 chroococcalean forms from paddy fields of Nagaon. Our observations differ from them, we did not find abundance of chroococcalean forms in the field, only paddy field soil cultures showed their presence and especially when cultures become old. Cyanobacterial distribution pattern from paddy field soils of Konkan region, Maharashtra has been studied by Sardeshpande & Goyal (1981). Roger & Reynaud (1979) reported luxuriant growth of blue green algae from rice fields of Japan. Mukhopadhyay & Chatterjee (1980) published a checklist of paddy field blue green algae from West Bengal. Nitrogen fixing potential in rice fields of Sri Lanka studied by Kulasooriya & De Silva (1978). Cyanobacterial taxa from Tripura was studied by Singh et al. (1997). Aerobic growth and nitrogenase activity of marine unicellular blue green alga *Synechococcus* was reported by Duerr & Mitsui (1980). Dhanya & Ray (2015) studied cyanobacterial diversity and ecology from Kuttanadu paddy wetlands of Kerala. Prasad & Prasad (2003) showed increase in rice yield up to 5–24 % by applying cyano-biofertilizers in paddy fields of Nepal. A large variety of cyanobacterial species fix nitrogen and their importance to improve soil fertility for sustainable agriculture in submerged and irrigated rice cultivation is well recognized by Saikia & Bordoloi (1994). The great majority of cyanobacteria that fixed atmospheric nitrogen were probably heterocystous (Rodrigo & Eberto 2007), however non-heterocystous unicellular cyanobacteria also fixed atmospheric nitrogen (Wyatt & Silvery 1969). Aerobic nitrogen fixation without heterocyst was studied by Carpenter & Price (1976) in Marine *Oscillatoria* (*Trichodesmium* species). In our study area we found high diversity of *Gloeocapsa* species and dominance of *Chlorogloea* species which could serve as the best nitrogen fertilizer for paddy. Our observations differed with those proposed by Chudhary (2009) that members of Chroococcaceae are dominant in paddy fields. We found least abundance of chroococcaceae members in field condition as well as in culture condition. Majority taxa recorded was filamentous type. Algae stabilize the surface layer of soil, prevent soil erosion, improve infiltration of water, produce organic matter in the soil by death and decay of algae & hence increase soil fertility (Dawes 1998). Thus the role of unicellular blue green algae in nitrogen economy of paddy fields is recorded by many studies all over the world. Culture study of these unicellular taxa showed that the rate of survival and N_2 fixing capacity of chroococcaceae members, viz., *Gloeocapsa, Oscillatoria* (*Trichodesmium* species & *Synechococcus* is more (Wyatt & Silvery 1969; Carpenter & Price 1976; Duerr & Mitsui 1980). Therefore taxonomic documentation of unicellular blue green algae will provide the knowledge about such sturdy and durable indigenous species of chroococcalean blue green algae which will help in development of niche specific inoculants as biofertilizers for rice fields in the study region

CONCLUSION

The present study showed diversity and dominance of chroococcalean blue green algae. Overall the data obtained by thorough screening of paddy field soils indicates the dominance of heterocystous filamentous taxa followed by non-heterocystous taxa; besides these unicellular taxa also showed diversity and abundance of taxa from paddy soil cultures of study region. Study reports also showed beneficial role of many unicellular blue green algae in nitrogen economy of paddy soil. Our study area showed genus *Gloeocapsa* with high species diversity (21.42%) followed by *Chroococcus*, *Aphanothece* & *Gloeothece* from family Chroococcaceae & species dominance with *Chlorogloea* followed by *Microsystis*, *Chroococcus* & *Gloeothece* from family Entophysalidaceae. This survey on chroococcalean blue green algae will help in developing niche specific inoculum of indigenous species of the study area. These local strains should be cultured on a large scale for their mass production which would serve the best and low cost biofertilizer especially for paddy fields.

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SHORT COMMUNICATION

Avifaunal diversity along the riverine habitats of Papikonda National Park, Andhra Pradesh, India

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Abstract: This study was carried out to record the avifaunal diversity of the riverine habitats along the Godavari River in Papikonda National Park, during a short survey conducted from 2017 to 2018. A total of 63 bird species belonging to 25 families were recorded during the survey. The study resulted in the recording of eight globally threatened avian species including the Endangered Black-bellied Tern *Sterna acuticauda,* and seven Near Threatened species, viz.: Painted Stork *Mycteria leucocephala*, Black-headed Ibis *Threskiornis melanocephalus*, Great Thick Knee *Esacus recurvirostris,* River Lapwing *Vanellus duvaucelli*, Malabar Pied Hornbill *Anthracoceros coronatus,* Grey-headed Fish Eagle *Haliaeetus ichthyaetus*, and Oriental Darter *Anhinga melanogaster*. Species including Black-bellied Tern *Sterna acuticauda,* Grey-headed Fish Eagle *Haliaeetus ichthyaetus*, Indian Eagle-owl *Bubo bengalensis,* and Black Eagle *Ictinaetus malaiensis* were recorded for the first time along the riverine habitats of Papikonda National Park. Sand mining of the riverbed and discharge of effluents into the Godavari River has already negatively impacted the associated habitats and avifaunal diversity.

Keywords: Birds, Godavari River, Polavaram Dam, protected area.

River channels and adjacent riparian zones play critical ecological roles, which include the supporting of rich biodiversity. Birds constitute an essential component of the biological community of a riverscape – an integrated landscape unit comprising streams, floodplains, and riparian zones along a river channel (Wiens 2002). Riparian zones also provide conducive dispersal pathways and sufficient cover for migrating birds, thereby often supporting a higher diversity of bird species (Sinha et al. 2019). Although several protected areas in India have major rivers flowing through their boundaries, very little or no attention is given to the health of these rivers and their biodiversity (Gupta et al. 2014). Freshwater habitats are considered to be among the most threatened (Dudgeon et al. 2006), with riverine habitats increasingly being subjected to large-scale modifications resulting in the loss of their ecosystem

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services and wider repercussions for associated biodiversity. Papikonda National Park (PNP), Andhra Pradesh, has been identified as an Important Bird and Biodiversity Area (IBA), where around 300 species of birds have been recorded (Rahmani et al. 2016). During the latest study conducted by Prashanth et al. (2014) on the bird diversity of the PNP and northern Eastern Ghats, nearly 145 species were documented with notable records of species including Jerdon's Baza *Aviceda jerdoni* and Brook's Flycatcher *Cyornis poliogenys*. While this study was carried out in the interior forested habitats of the national park, the main focus of the present study was to understand the bird diversity in the riparian and riverine habitats. In this context, we present the results of a short survey conducted between 2017 and 2018 on the bird diversity of riverine habitats along the Godavari River in Papikonda National Park (hereafter PNP). This survey is important considering that the species associated with the riverine and riparian habitats of PNP are vulnerable to changes brought about due to submergence by Polavaram Dam; a large dam (dams that are higher than 15m) that is currently under construction and located approximately 5km downstream of PNP near Polavaram Village.

Study area

Godavari River is the largest river of peninsular India that originates in Triambakeshwar near Nasik, Maharashtra, traverses eastwards for a distance of around 1,470km, and empties into Bay of Bengal near Kakinada, Andhra Pradesh. The river has a large catchment area of 312,812km^2 (Bharati et al. 2009; Rao et al. 2015), which is fed by several tributaries along the course, including Indravathi, Sabari, Sileru, Kinnersani, and Pranahita. Once the river enters Andhra Pradesh in the East Godavari District, it flows through the hills of Papikonda National Park (also popularly known as Papikondalu) for nearly 50km. These hills of Papikondalu form the southern edge of the northern Eastern Ghats – a largely unbroken chain of rugged hills and plateaus extending across the states of Odisha, Chhattisgarh, and Andhra Pradesh. After crossing through the Eastern Ghats, it emerges into the vast alluvium-rich plains and finally branches into two distributaries- Gouthami and Vashishta just downstream of the Dowlaiswaram Barrage near the city of Rajahmundry in Andhra Pradesh.

The Papikonda National Park (located between 8.491944–19.181389 N & 79.541111–83.233333 E), is an important protected area in this landscape. The altitude is 200–800 m and is characterized by southern tropical dry deciduous forest and southern tropical moist deciduous forest types intermingled with scrub vegetation (Champion & Seth 1968; Aditya & Ganesh 2017). Godavari River meanders through the hills of

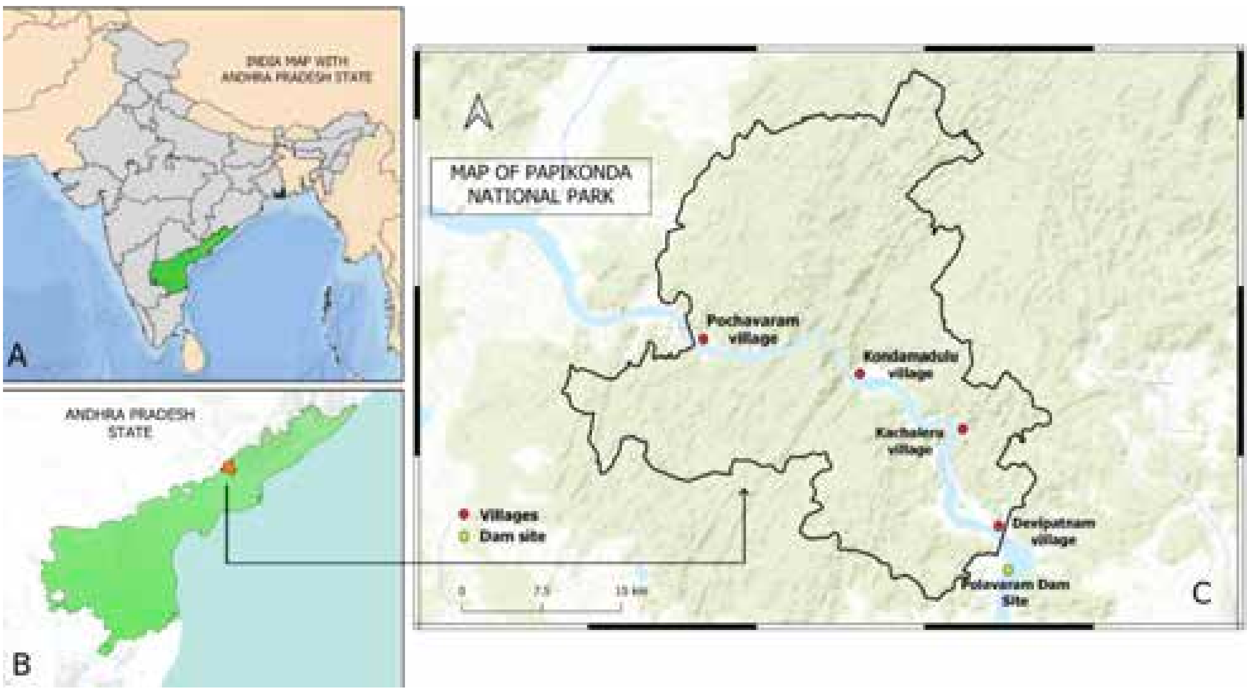

Figure 1. Location of Papikonda National Park in Andhra Pradesh: A—India map with Andhra Pradesh boundaries in green | B—showing location of Papikonda National Park in Andhra Pradesh | C—Papikonda National Park boundary, Polavaram Dam site and the main villages along the riparian habitats of Godavari River.

PNP, leading to the formation of sand bars and natural levees that provide essential habitats for riverine and riparian birds. At specific points along the stretches in PNP, the river is also lined by hills and rocky boulders.

Method

As part of a Conservation Leadership Programme (CLP) supported project in the northern Eastern Ghats, we had an opportunity to record opportunistic sightings of avifaunal diversity along the riverine habitats of the Godavari River inside Papikonda National Park and surrounding areas (Fig. 1). Most of the sightings were made during December 2017 to August 2018 using a locally available artisanal boat with the survey restricted only to the riverine habitats. Data were collected mostly during the morning time at 05.30–09.00 h and in the evening from 17.00–19.00 h. At a few random locations, we waited for about 10min to watch for any activity of birds foraging on the riverine habitats and took photographs using a Canon SX50 camera to aid with further identification. We followed Ali & Ripley (1983) and Grimett et al. 2013 to identify the species. The taxonomic order and nomenclature follows Howard & Moore (Dickinson & Remsen 2013; Dickinson & Christidis 2014).

Results

A total of 63 bird species belonging to 25 families were recorded along the riverine habitats of PNP (Table 1). For the first time, the Black-bellied Tern *Sterna acuticauda,* Grey-headed Fish Eagle *Haliaeetus ichthyaetus*, Indian Eagle-owl *Bubo bengalensis,* and Black Eagle *Ictinaetus malaiensis* were recorded along the riverine habitats of Papikonda National Park especially from the submergence zone of Polavaram dam. We also recorded several nests of River Lapwing *Vanellus duvaucelli* along the sandbars of Godavari River. Of the 63 species, eight are globally threatened species including the Endangered Black-bellied Tern *Sterna acuticauda,* and seven Near Threatened species, viz.: Painted Stork *Mycteria leucocephala*, Black-headed Ibis *Threskiornis melanocephalus*, Great Thick Knee *Esacus recurvirostris,* River Lapwing *Vanellus duvaucelli*, Malabar Pied Hornbill *Anthracoceros coronatus,* Grey-headed Fish Eagle *Haliaeetus ichthyaetus* and Oriental Darter *Anhinga melanogaster*.

One individual of Black Eagle *Ictinaetus malaiensis* was sighted near Kachaleru Village (Image 1) inside PNP, soaring over the hills for nearly 30 minutes before taking rest. Several nesting colonies (25–30) of the Blue-tailed Bee-eater *Merops philippinus* (Image 2) were found along the entire stretch on either side of the riverbanks from Devipatnam to Pochavaram Village. During our study period, higher nesting activity of Blue-tailed Bee-eaters was observed between April and June than the other survey months. Distribution of nesting colonies at a site varied from two to 30 nests potentially depending upon the availability of certain bank types, riverine vegetation, and biotic disturbances. In the same river stretch, multiple nestings of River Lapwing *Vanellus duvaucelli* on the sandbars of Godavari River were observed (Image 3). Black-bellied Terns *Sterna acuticauda,* were observed near the Devipatnam Village, but we could not notice any nesting activity during our survey. Two individuals of Indian Eagle-owl *Bufo bengalensis* were recorded near the village of Kondamadulu in PNP that were seen perching on rocks and crevices present along the river (Image 4). A few individuals of the Bar-headed Geese *Anser indicus* (Image 5), Ruddy Shelduck *Tadorna ferruginea*, Lesser Whistling Duck *Dendrocygna javanica*, and Northern Pintail *Anas acuta*, were also seen during the winter from December 2017 till March 2018 in PNP. The small Pratincole *Glareola lactea* (Image 6) was the most frequently recorded species across all the sampling sites along the river followed by River Lapwing. The Open-billed Stork, Painted Stork, and Blue-tailed Bee-eater were also seen mostly during winters and summers, but were visibly uncommon during the rainy season. During the summer months, we saw nearly ten individuals of Black Ibis *Pseudibis papillosa* engaged in courtship display and mating adjacent to the river near Pochavaram Village located just outside PNP (Image 7).

Discussion

This survey has led to quite a few fascinating discoveries of birds that occur in the riverine and riparian habitats of Eastern Ghats, especially inside Papikonda National Park. In addition to the species reported in this survey, we also recorded a population of Indian Skimmers *Rynchops albicollis* at a site nearly 80km downstream of PNP. In 2015, 15 individuals of Indian Skimmers were recorded from this site (Malla et al. 2015), while in 2016, 150 individuals of Indian Skimmers were recorded from the same site (Image 8). Since then, the birds have been recorded from the same site in every consecutive year that suggests that the Godavari Delta is a critical site for the conservation of this threatened species, although breeding or nesting sites of the species could not be recorded from the river delta during this study period. Sand mining in the riverbed and discharge of effluents into Godavari River are presently the major sources of disturbance with potential negative impacts

Table 1. A checklist of bird species recorded from riverine habitats of the Papikonda National Park and the submergence zone of Polavaram Dam.

Order: Anseriformes
Family: Anatidae
1. Ruddy Shelduck *Tadorna ferruginea*
2. Lesser Whistling Duck *Dendrocygna javanica*
3. Bar-headed Goose *Anser indicus*
4. Northern Pintail *Anas acuta*
Order: Galliformes
Family: Phasianidae
5. Red Junglefowl *Gallus gallus*
Order: Columbiformes
Family: Columbidae
6. Oriental Turtle Dove *Streptopelia orientalis*
7. Laughing Dove *Streptopelia senegalensis*
8. Spotted Dove *Streptopelia chinensis*
Order: Caprimulgiformes
Family: Caprimulgidae
9. Jerdon's Nightjar *Caprimulgus atripennis*
10. Indian Nightjar *Caprimulgus asiaticus*
Family: Apodidae
11. Asian Palm Swift *Cypsiurus balasiensis*
Order: Gruiformes
Family: Rallidae
12. White-breasted Waterhen *Amaurornis phoenicurus*
Order: Pelecaniformes
Family: Ciconiidae
13. Painted Stork *Mycteria leucocephala*
14. Asian Openbill *Anastomus oscitans*
Family: Ardeidae
15. Little Egret *Egretta garzetta*
16. Indian Pond Heron *Ardeola grayii*
17. Cattle Egret *Bubulcus ibis*
18. Grey Heron *Ardea cinerea*
19. Yellow Bittern *Ixobrychus sinensis*
20. Black-crowned Night Heron *Nycticorax nycticorax*
Family: Threskiornithidae
21. Black-headed Ibis *Threskiornis melanocephalus*
22. Indian Black Ibis *Pseudibis papillosa*
Family: Phalacrocoracidae
23. Little Cormorant *Microcarbo niger*
24. Great Cormorant *Phalacrocorax carbo*
Family: Anhingidae
25. Oriental Darter *Anhinga melanogaster*
Order: Charadriiformes
Family: Burhinidae
26. Great Thick-knee *Esacus recurvirostris*
Family: Charadriidae
27. River Lapwing *Vanellus duvaucelli*
28. Red-wattled Lapwing *Vanellus indicus*
29. Little Ringed Plover *Charadrius dubius*
Family: Scolopacidae
30. Common Greenshank *Tringa nebularia*
31. Green Sandpiper *Tringa ochropus*
32. Marsh Sandpiper *Tringa stagnatilis*
33. Common Redshank *Tringa totanus*
34. Common Sandpiper *Actitis hypoleucos*
Family: Glareolidae
35. Little Pratincole *Glareola lactea*
Family: Laridae
36. Black-bellied Tern *Sterna acuticauda*
37. River Tern *Sterna aurantia*
Order: Accipitriformes
Family: Pandionidae
38. Osprey *Pandion haliaetus*
Family: Accipitridae
39. Grey-headed Fish Eagle *Icthyophaga ichthyaetus*
40. Black Kite *Milvus migrans*
41. Black Eagle *Ictinaetus malaiensis*
42. Brahminy Kite *Haliastur indus*
43. Crested Serpent Eagle *Spilornis cheela*
44. Oriental Honey Buzzard *Pernis ptilorhynchus*
Order: Strigiformes
Family: Strigidae
45. Rock Eagle Owl *Bubo bengalensis*
Order: Bucerotiformes
Family: Bucerotidae
46. Malabar Pied Hornbill *Anthracoceros coronatus*
Order: Piciformes
Family: Megalaimidae
47. Brown-headed Barbet *Psilopogon zeylanicus*
48. Coppersmith Barbet *Psilopogon haemacephalus*
Order: Coraciiformes
Family: Meropidae
49. Blue-tailed Bee-eater *Merops philippinus*
Family: Coraciidae
50. Indian Roller *Coracias benghalensis*
Family: Alcedinidae
51. Pied kingfisher *Ceryle rudis*
52. White-throated Kingfisher *Halcyon smyrnensis*

Order: Falconiformes
Family: Falconidae
53. Peregrine Falcon *Falco peregrinus*
Order: Passeriformes
Family: Artamidae
54. Ashy Woodswallow *Artamus fuscus*
Family: Estrildidae
55. Black-headed Munia *Lonchura malacca*
Family: Motacillidae
56. White Wagtail *Motacilla alba*
57. White-browed Wagtail *Motacilla maderaspatensis*
58. Yellow Wagtail *Motacilla flava*
59. Grey Wagtail *Motacilla cinerea*
Family: Alaudidae
60. Ashy-crowned Sparrow Lark *Eremopterix griseus*
Family: Sturnidae
61. Asian Pied Starling *Gracupica contra*
62. Bank Myna *Acridotheres ginginianus*
63. Jungle Myna *Acridotheres fuscus*

on the associated habitats and biodiversity (Koehnken et al. 2019). The construction of Polavaram Dam would further lead to modification and destruction of the river's unique habitats (Dynesius & Nilsson 1994; Rosenberg et al. 1997; Nilsson & Berggren 2000; Sivakumar et al. 2014). Within Papikonda National Park, the valleys and sandbars adjoining the river will be submerged, which would lead to the loss of nesting and feeding habitats for several riverine birds, including the Near Threatened species River Lapwing and Black-headed Ibis. Regulation of the river flow and creation of reservoirs can also lead to changes in the avian community, particularly leading to negative impacts on riverine species (Kingsford 2000). The dam will act as a physical barrier to the movement of fishes, which would have a profound impact on the avifaunal communities that depend on it (Sivakumar et al. 2014).

A review on linkages between biodiversity and ecosystem services of the Godavari delta including the estuary and associated mangrove forests, and the flow of Godavari River has been carried out wherein some mitigative measures have been suggested (Sivakumar et al. 2014; Johnson et al. 2017), which include the conservation of riverine birds. This short-term study shows the importance of the riverine and riparian habitats of the Godavari River in supporting a vibrant avian community and in providing critical habitats for threatened riverine species. We further suggest additional studies as well as long-term monitoring of these riverine and riparian habitats along the submergence zone of the Polavaram Dam and the downstream stretches of Godavari River to identify and address the negative impacts on the associated avian community.

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Image 1. A Black Eagle is seen in the riparian habitats of Godavari River.

Image 2. Blue-tailed Bee-eater near its nest entrance and colony seen along the mudbanks of the Godavari River.

Image 3. River Lapwing near the Godavari River.

Image 4. Indian Eagle-owl on the rock-filled banks of the Godavari River.

Image 5. Bar-headed Goose near the sandbars in the Godavari River.

Image 6. Small Pratincoles on the sandbars in the Godavari River.

Image 7. Black Ibis feeding near the sandbars in the Godavari River near Kunavaram Village.

Image 8. Indian Skimmers seen on the banks of Gowthami Godavari River, near Neelapalli Village, Yanam that is located nearly 90km downstream of PNP.

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SHORT COMMUNICATION

Medetomidine may cause heart murmur in Cougars and Jaguars: case report

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Abstract: We report heart murmur in Jaguars and Cougars found during reproductive procedures for semen and oocyte collection. Two male Cougars (n=2) and three female Jaguars (n=3) were examined. Anesthesia was performed with ketamine and medetomidine in males. Females also received propofol and were maintained with isoflurane. The animals were evaluated during anesthetic monitoring with multiparameter monitor alongside clinical examination, ambulatory electrocardiogram and echocardiogram. All animals presented mitral valve regurgitation under anesthesia, but without morphological changes in the cardiac structure or hemodynamic changes. Medetomidine may cause transitory heart murmur in healthy Jaguars and Cougars.

Keywords: α-2 adrenoceptor agonist, mitral valve regurgitation, trivial tricuspid valve regurgitation.

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Objective

The objective of the present short communication is to report heart murmur as a secondary clinical finding in Jaguars *Panthera onca* and Cougars *Puma concolor* anesthetized for reproductive procedures with the association of ketamine and medetomidine.

Study design

This study was conducted in Brazil at NEX Santa Rosa (Amparo – SP; -22.588°S–46.786°W) with authorization for scientific activities issued by SISBIO/ICMBio/MMA under no. 57293-2 and approved by the Ethic Committee on Animal Use of the School of Veterinary Medicine and Animal Science of the University of São Paulo (CEUA/FMVZ/USP) under protocol nº. 6249300517. The experiment was conducted in conjunction with efforts to collect oocytes by laparoscopic ovum pick-up (LOPU) and pharmacological semen collection for different projects. Data partially shown for Jaguars (Jorge-Neto et al. 2020) and for semen biobank (Miranda et al. 2019).

Animals

To perform the reproductive procedure (semen and oocyte collection) five adult animals (n=5) from two different species were used: two male Cougars (n=2) and three female Jaguars (n=3), aged between one and 10 years old, weighing between 35 and 80 kg, all healthy, with good corporal score and no clinical signal of diseases.

Methods

Animals were fasted for 12h for water and 24h for food before procedures. Weights were estimated and chemical restraint was performed for both males and females using anesthetic darts fired with a blowpipe and containing Ketamine (5.0mg/kg; im) and Medetomidine (0.1mg/kg; im) (Araujo et al. 2018, 2020). Females also received intravenous administration of Propofol (2.0 to 3.0 mg/kg) (Jorge-Neto et al. 2020) for anesthetic induction and intubating were maintained with Isoflurane, as females were submitted to LOPU procedure (Jorge-Neto et al. 2020).

The procedure was performed at NEX Santa Rosa, where the two male Cougars and the three female Jaguars were evaluated during anesthetic monitoring with multiparameter monitor alongside clinical examination, ambulatory electrocardiogram and transthoracic echocardiogram (Figure 1 & 2). Electrocardiography recordings were performed during a five-minute period on lateral recumbency during chemical restraint and heart rate, rhythm and morphology were analyzed. Echocardiograph examinations were performed by three operators equipped with several phased-array transducers (GE Vivid IQ; General Electrics, Chicago, IL, USA) that matched the size of the animal. Echocardiograph assessment criteria included two-dimensional, M-mode and Doppler examinations using recommended imaging planes and adaptations for proper cardiovascular diagnostic purpose. The same standardized imaging protocol was used for each examination.

After all procedures – none less than 40 minutes due to Ketamine action – anesthesia was reverted using Yohimbine (0.4 mg/kg; im) (Araujo et al. 2015).

Results and Discussion

During cardiovascular evaluation two animals – one Jaguar and one Cougar – presented grade II/VI and III/VI left apical systolic heart murmur under anesthesia, auscultated on mitral focus. A six-year-old female Jaguar weighing 59kg presented mitral valve insufficiency with mean 5.46m/s velocity on color doppler flow measurement within 4.9cm^2 area of regurgitation on a 12.6cm^2 left atrium planimetric measurement in echocardiographic evaluation. A six-year-old male Cougar weighing 47.5kg presented mean 7.06m/s mitral valve insufficiency velocity on color doppler flow measurement within 0.9cm^2 area of regurgitation on a 10.6cm^2 left atrium planimetric measurement. The other animals, a male Cougar and two female Jaguars, presented mitral valve regurgitation during echocardiographic examination within a low range pressure gradient, without either morphological changes in the cardiac structure or hemodynamic changes.

Trivial tricuspid valve regurgitation was observed in one male Cougar with murmur and one female Jaguar with no apparent structural cause in the echocardiographic study. Those findings were reported on normal cats within dexmedetomidine use on anesthetic protocol (Carvalho et al. 2019). In a study conducted by Romagnoli et al. (2016), the preload increased, as expressed by increased left ventricular diastolic dimensions and atrial area. Considering left ventricular systolic function, cardiac output appeared reduced and left ventricular posterior wall thickness in systole decreased after sedation due to the medetomidine effect. The left ventricular dilation could have produced a mitral annulus stretch with the subsequent loss of complete closure of the mitral leaflets during left ventricular contraction.

In domestic cats, an insidious mitral murmur finding on cardiac auscultation is reported and is related to stress due to transient catecholaminergic stimulation in myocardial tissue. Associated with this physiological finding, dynamic right (Rishniw & Thomas 2002) and/or left outflow trac obstruction occurs, resulting in low grade murmur auscultated in left apical mitral focus (Cote et al. 2004). During late recovery, the murmur was not reevaluated in those animals.

All animals were stable during anesthesia, maintaining a heart rate of 75 ± 10 bpm; peripheral oxy-hemoglobin saturation (SpO2) >97%; systolic blood pressure (SBP) between 110 and 125 mmHg; and mean arterial pressure (MAP) between 75 and 85 mmHg. The pressure tended to get a little higher due to peripheral vasoconstriction.

Both Cougars and Jaguars returned safely from the anesthesia, with no changes – such as excitement and delirium stage – and returned to the enclosures, normally receiving food and water.

It is interesting to consider these parameters – heart murmur, mitral valve reflux and trivial tricuspid valve regurgitation – in order to make the procedure safer. In clinical procedures with anesthesia using alpha-2-adrenergic agonists, researchers frequently observe the occurrence of heart murmurs in apparently healthy cats. After recovery from anesthesia, they have no symptoms of heart disease. A comparative study with an anesthetic protocol without alpha-2-agonist will be conducted by this group for further clarification.

Conclusion

Medetomidine in large neotropical felids may cause heart murmur in healthy animals as a side effect, but without clinical or anesthetic concerns. Heart murmur showed no risk to the animal in this situation, as it is a transitory event.

Clinical relevance

The clinical relevance of these changes – heart murmur, mitral valve reflux, and trivial tricuspid valve regurgitation – is just to show that it can occur with use of medetomidine and without damage to the health of healthy animals. With the doses used, these changes are transient without compromising the cardiac hemodynamics of these individuals.

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SHORT COMMUNICATION

Description of a new species of *Omyomymar* Schauff from India with a key to Oriental species and first report of *Palaeoneura markhoddlei* Triapitsyn (Hymenoptera: Mymaridae) from the Indian subcontinent

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Abstract: *Omyomymar hayati* sp. nov. (Hymenoptera: Chalcidoidea: Mymaridae) is described from Tamil Nadu, India and key to Oriental species of *Omyomymar* is updated. *Palaeoneura markhoddlei* Triapitsyn, is reported from Indian subcontinent for the first time and key to Indian species is updated. The following known species, viz., *Acmopolynema incognitum* (Narayanan, Rao & Kaur), *Platystethynium glabrum* Jin & Li, *Polynema* (*Polynema*) *bengalense* Rehmat & Anis and *Palaeoneura vegis* Amer & Zeya are recorded from the Indian states of Rajasthan, Karnataka, Kerala, and Tamil Nadu, respectively.

Keywords: Chalcidoidea, key, new species, *Palaeoneura markhoddlei*, *Omyomymar*.

Abbreviations: fl—flagellar segments | gt—gastral tergite | mps—multiporous plate sensillum or sensilla | YPT—yellow pan trap.

The family Mymaridae is represented by 116 genera world-wide (Noyes 2019) and 39 from India. Totally, about 205 species are known from India (H. Sankararaman personal compilation upto August 2020). Of the two genera treated in this work, *Omyomymar* Schauff (1983) was erected by Schauff with descriptions of *O. alar* and *O. griselli* from U.S.A. and he also transferred *Paranaphoidea silvana* Oglobin and *P. clavata* Oglobin to *Omyomymar* and designated *P. silvanum* as the type species of *Omyomymar.* Presently, this genus contains six and seven species from New and Old World, respectively. In the Oriental region, Lin & Chiappini (1996) described three species from China, *O. glabrum*, *O. breve* and *O. longidigitum.* Manickavasagam & Rameshkumar (2011) reported this genus from India. Pricop (2014) reported this genus from Europe describing *O. andriescui* from Romania. So far, four species have been described from India: *O. insulanum* Zeya & Anwar and *O. yousufi* Anwar & Zeya by Anwar et al. (2014), followed by *O. huberi* Manickavasagam & Gowriprakash, and *O. noyesi* Manickavasagam & Gowriprakash by Gowriprakash & Manickavasagam (2016).

Palaeoneura was erected by Waterhouse (1915) with *P. interrupta* as the type species. Currently, this genus is represented by 53 species around the world, of which six species of *kusnezovi* group are known from India (Amer & Zeya 2019). Recently, *P. markhoddlei* was described by Triapitsyn (2018a) from USA. Members of this genus are known to parasitize eggs of Cicadellidae (Hemiptera)

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(Noyes 2019).

In the present paper, eighth Oriental species of *Omyomymar* is described from material collected from Tamil Nadu and Kerala, India. The previous key to the Oriental species of *Omyomymar* (Gowriprakash & Manickavasagam 2016) is updated. *Palaeoneura markhoddlei* is recorded from the Indian Subcontinent for the first time and key to Indian species of *Palaeoneura* (Amer & Zeya 2019) is updated.

Materials And Methods

Specimens were collected using yellow pan traps (Noyes 1982) from various Indian states. Recovered parasitoids were processed using hexamethyldisilazane (Brown 1993) and card or slide mounted for study. All the specimens are deposited with Entomology Department, Annamalai University (EDAU), Chidambaram, Tamil Nadu, India. All measurements are in microns. Habitus images were captured using Leica M205C stereozoom microscope (while specimens were in ethanol before slide mounting) and the slide mounted parts using Leica DM 750 phase contrast microscope. Images were stacked using montage and Combine ZP software, and then processed using Adobe Photoshop version 7.0. Terms used in the description follow Gibson (1997).

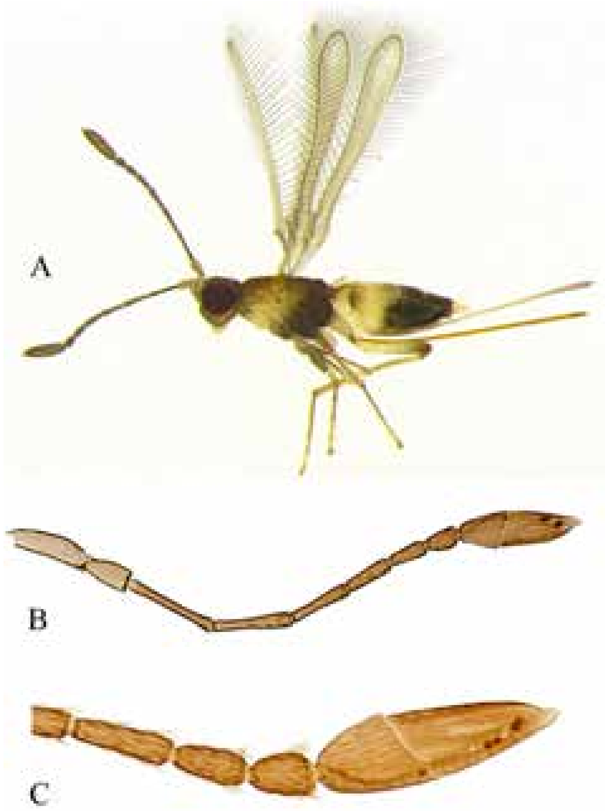

Image 1. *Omyomymar hayati* sp. nov. female, holotype: A—Habitus | B—antenna | C—Fl_{4-6} and clava magnified. © Sankararaman. H.

Results

Omyomymar Schauff, 1983

Omyomymar Schauff 1983: 543–551. Type species: *Paranaphoidea silvana* Ogloblin, 1935.

Omyomymar hayati
Manickavasagam & Sankararaman sp. nov.
(Images 1–2)

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Materials examined: Holotype: EDAU/Mym34/2020, Female, 01.viii.2019, Kunjappanai, Coimbatore, Tamil Nadu, India, 11.305N & 76.929E, on slide under four coverslips, labeled "India: Tamil Nadu, Kunjappanai, Coimbatore, YPT, tea plantation, coll. H. Sankararaman".

Paratypes: EDAU/Mym34/2020, two females, 08.vi.2019, Siruvani, Coimbatore, Tamil Nadu, India, 10.937N & 76.687E, coll. H. Sankararaman, on card, labeled "India: Tamil Nadu, Siruvani, Coimbatore, YPT, forest, coll. H. Sankararaman"; three females, 23.viii.2019, Palakkad, Mannarkkad, Kerala, India, 10.993N & 76.461E, on card, Malaise trap, forest, coll. Prashanth.

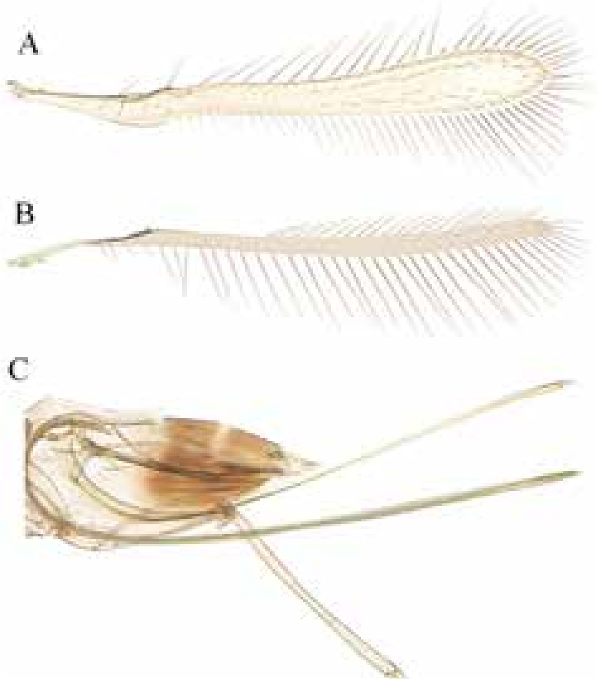

Image 2. *Omyomymar hayati* sp. nov female, holotype: A—fore wing | B—hind wing | C—metasoma showing ovipositor. © Sankararaman. H.

Key to Oriental species of *Omyomymar*, females (modified from Gowriprakash & Manickavasagam 2016)

1. Clava without apical incision (Anwar et al. 2014: Figs. 1–2) 2
- Clava with an apical incision (Anwar et al. 2014: Fig. 7) 3

2. Clava about 3.5× as long as wide and shorter than $fl_{4–6}$ combined [0.73×] (China) .... *O. glabrum* Lin & Chiappini
- Clava 2.5× as long as wide and a little longer than fl_{4-6} combined (India) .... *O. yousufi* Anwar & Zeya

3. Exserted part of ovipositor at most 0.4× gaster length (China) .... *O. breve* Lin & Chiappini
- Exserted part of ovipositor at least 0.6× gaster length 4

4. Fl_1 shorter (0.75×) than pedicel (Exserted part of ovipositor 0.6× gaster length) (India) .... *O. insulanum* Zeya & Anwar
- Fl_1 at least as long as pedicel 5

5. Fl_5 and fl_6 excised dorsally (Lin & Chiappini 1996: Fig. 3) (Fl_1 1.35× pedicel length; exserted part of ovipositor at least 0.85× gaster length) (China) .... *O. longidigitum* Lin & Chiappini
- Fl_5 and fl_6 straight, not excised dorsally 6

6. Clava at most 3.1× as long as wide (Image 1C); clava as long as $fl_{4–6}$ combined (Image 1B–C); fore wing disc almost bare with two lines of thick setae in distal half, running parallel to its wing margin (Image 2A) (India) .... ***O. hayati* Manickavasagam & Sankararaman sp. nov.**
- Clava at least 3.6× as long as wide; clava longer than $fl_{4–6}$ combined (1.3×); fore wing disc densely setose 7

7. Clava 4× as long as wide; exserted part of ovipositor 0.6× gaster length (Gowriprakash & Manickavasagam 2016: Fig. 5); fl_1 the longest and 1.5× as long as pedicel; propodeum finely strigulate (India) .... *O. huberi* Manickavasagam & Gowriprakash
- Clava 3.6× as long as wide; exserted part of ovipositor 0.9× gaster length (Gowriprakash & Manickavasagam 2016: Fig. 10); fl_2 the longest; fl_1 as long as pedicel; propodeum smooth (India) ... *O. noyesi* Manickavasagam & Gowriprakash

Description

Female (Holotype): (Image 1A) Length, 585µm (excluding exserted part of ovipositor). Head, flagellum, pronotum, mesoscutum, propodeum, brown. Antenna with scape and pedicel yellow. Mesosoma with lateral lobe of mesoscutum yellow. Wings subhyaline. Legs including coxae yellow. Metasoma, basal one third of gaster yellow (rest brown), ovipositor brown.

Head 1.1× as wide as high; antenna with (Image 1B, C) scape about 3.5× as long as wide; pedicel about 1.8× as long as wide; fl_1 the longest; fl_2 longer than fl_3; clava 2-segmented, 3.1× as long as wide, with apical incision and as long as $fl_{4–6}$ combined. Basal segment of clava with one mps and one placoid sensilla, apical segment with three mps and four placoid sensilla.

Mesosoma (Image 1A) 0.7× gaster length, pronotum, mesoscutum, anterior scutellum faintly reticulate; frenum substrigulate; propodeum smooth. Mid lobe of mesoscutum with two pairs of setae and lateral lobe of mesoscutum with one pair of setae; anterior scutellum with one pair of setae. Fore wing (Image 2A) about 9.4× as long as wide, proximal half or so of wing disc almost bare, distal half with two lines of setae running parallel to wing margins; longest marginal seta about 1.75× as long as maximum wing width. Hind wing (Image 2B) 26.5× as long as wide, longest marginal seta about 5.0× as long as maximum wing width.

Metasoma (Image 2C) ovipositor about 1.9× as long as gaster, 2.5× as long as mesotibia and 2.3× as long as metatibia, exserted part 0.9× as long as gaster.

Measurements (length: width; or length) antennal segments: scape, 77:22; pedicel, 40:22.5; $fl_{1,}$ 90; fl_2, 75; fl_3, 62.5; fl_4, 45; fl_5, 40; fl_6, 33; clava, 117:37.5; mesosoma, 250; fore wing, 750: 80; longest marginal seta, 140; hind wing, 730: 27.5; longest marginal seta, 140; mesotibia, 256; metatibia, 288; gaster, 350; ovipositor, 650; exserted part, 320.

Male: Unknown.

Etymology: The species is named after Prof. Mohammad Hayat, Aligarh Muslim University, for his contributions to the taxonomy of Indian Chalcidoidea.

Distribution. India: Tamil Nadu and Kerala.

Hosts: Unknown.

Comments: *Omyomymar hayati* sp. nov. looks similar to *O. glabrum* and *O. yousufi* in having fore wing with very few setae. However, it differs from both of them by having clava with apical incision (*O. glabrum* and *O. yousufi*, clava without apical incision). This new species differs from *O. glabrum,* by having following characters: clava as long as fl_{4-6} combined; exserted part of ovipositor shorter than gaster (In *O. glabrum*, clava shorter than fl_{4-6} combined [0.7×] and exserted part of ovipositor longer than gaster [1.3×]). It differs from *O. yousufi* by having clava 3.1× as long as wide; fl_2 longer than fl_3; exserted part shorter than gaster (In *O. yousufi,* clava 2.5× as long as wide; fl_2 subequal to fl_3; exserted part as long as gaster).

First report of *Palaeoneura markhoddlei* Triapitsyn from India (Image 3)

Material examined: EDAU/Mym35/2020, three females, 22.ix.2018, Yercaud, Salem, Tamil Nadu, India, 11.774N & 78.209E, YPT, coffee ecosystem, coll. S. Palanivel, two on slide under four cover slips, another female on card, EDAU.

Brief diagnosis

Vertex with sparse, short setae; scape as long as wide and smooth; pedicel shorter than Fl_1; Fl_3 the longest and fl_6 the widest; fore wing disc notably narrow, hyaline with brownish tinge along apical margin and also anterior margin sub apically. Ovipositor occupying almost entire length of gaster, notably exserted beyond gastral apex (Image 3B) (Triapitsyn 2018a).

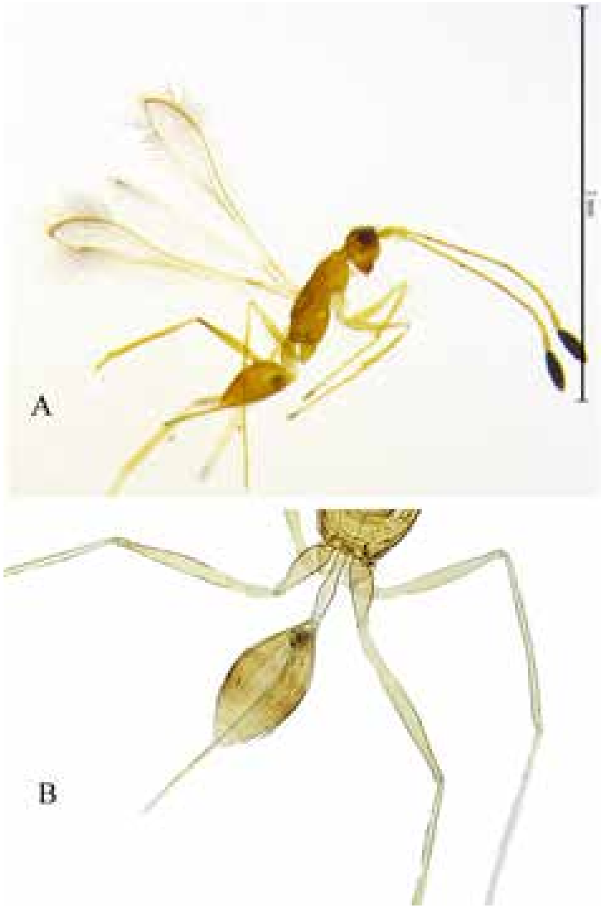

Image 3. *Palaeoneura markhoddlei* female: A—habitus | B—part of mesosoma and metasoma showing ovipositor. © Sankararaman. H.

Distribution: USA: California & Hawaii [Hawaiian Islands, Maui island] (Triapitsyn 2018a), India: Tamil Nadu (New report).

Hosts: Unknown, but is assumed to be egg parasitoid of leafhopper from tribe Nirvanini Baker (Hemiptera: Cicadellidae: Evacanthinae) (Triapitsyn 2018a).

Comments: All three specimens collected from India exactly match with description given by Triapitsyn (2018a).

Distributional records

1. *Acmopolynema incognitum* (Narayanan, Rao & Kaur, 1960)

Material examined: EDAU/Mym/DR1/2020, five females, 4.iii.2019, Udaipur, Rajasthan, India, 24.585N & 73.712E, YPT, grassland and vegetable ecosystems, coll. H. Sankararaman (one on slide under four coverslips and four on card, EDAU).

Brief diagnosis: Scape with cross-ridges on inner surface; fore wing with one brownish spot in the middle and marginal vein with one dorsal macrochaeta; propodeal carinae do not extend to half the length of propodeum; ovipositor exserted beyond gastral apex. (Triapitsyn & Berezovskiy 2007).

Distribution: India: Delhi, Karnataka, Uttar Pradesh (Hayat & Anis 1999) and Rajasthan (new record).

2. *Platystethynium glabrum* Jin & Li 2016

Material examined: EDAU/Mym/DR2/2020, two females, 08.ii.2019, Palakkad, Kerala, India, 10.786N & 76.654E, pitfall trap, grassland, coll. Prashanth (two on card, EDAU).

Brief diagnosis: Ovipositor about 0.49× as long as gaster, 1.8× of metatibia and originating at the level of gt_4 (Triapitsyn 2018b; Sankararaman et al. 2019).

Distribution: *Platystethynium glabrum,* India: Meghalaya (Sankararaman et al. 2019) and Kerala (new record)

Comments: Jin & Li (2016) described *P. glabrum* without examining the type species *P. onomarchicidum,* based on the absence of setae on eyes and lengths of fl_2, fl_6 and ovipositor. Triaptisyn (2018b) examined few

Key to Indian species of the *kusnezovi* group of *Palaeoneura,* females (modified from Amer & Zeya 2019)

1. Fore wing hyaline or subhyaline without brown patch 2
- Fore wing hyaline with one or two brown patches 3

2. Fore wing subhyaline, without patches (Amer & Zeya 2019: Fig. 1C), except slightly infumate in basal third and along anterior margin of the blade; ovipositor hardly exserted and 0.57× as long as metatibia .... *P. vegis* Amer & Zeya
- Fore wing hyaline, without brown patch; ovipositor exserted distinctly beyond gastral apex and 1.39× as long as metatibia [Image 3B]) .... *P. markhoddlei* Triapitsyn

3. Fore wing disc with an infuscated, round spot in distal fourth in anterior half of disc; scape with cross-ridges on inner surface .... *P. unimaculatum* (Hayat & Anis)
- Fore wing disc with two brown patches; scape smooth, without cross-ridges on inner surface 4

4. Fore wing less densely setose; face below toruli with six setae on each side; pronotum entire (Amer & Zeya 2019: Figs. 2C, A & G) .... *P. farmani* Amer & Zeya
- Fore wing densely setose; face below toruli with at least 11 setae on each side; pronotum divided mediolongitudinally (Amer & Zeya 2019: Figs. 4C, E; 5D, 7A) 5

5. Fore wing apical brown patch with proximal margin almost straight, the patch as wide as anteriorly and posteriorly; face below toruli with 11 setae on each side; ovipositor slightly longer than metatibia (Amer & Zeya 2019: Figs. 4C, 5A, 4F) .... *P. sophoniae* (Huber)
- Fore wing apical brown patch with proximal margin strongly oblique, the patch much wider along anterior margin than along posterior margin; face below toruli with 15 setae on each side; ovipositor at most 0.94× to about 1.02× as long as metatibia (Amer & Zeya 2019: Figs. 6C & A) 6

6. Body length 1.4 mm; head reddish-brown; antenna pale brown except clava and bases of F2 and F3 black; clava subequal in length to preceding two funicular segments combined; malar space with about 15 setae ....*P. indopeninsularis* (Mani & Saraswat)
- Body length 0.6–0.97 mm; head yellowish-brown; antenna with funicular segments pale yellow to pale brown except clava dark brown; clava longer than preceding two funicular segments combined; malar space with 10 setae (Amer & Zeya 2019: Fig. 6) .... *P. bagicha* (Narayanan, Subba Rao & Kaur)

non-type materials of *P. onomarchicidum* (having similar data as in holotype) from Indonesia and indicated that the only potential difference between these two taxa is the relative length of ovipositor (0.84× as long as gaster, 3.0× of metatibia in *P. onomarchicidum* and 0.49× as long as gaster, 1.8× of metatibia in *P. glabrum*). Now it is further noted that ovipositor arises at the level of gt_3 in *P. onomarchicidum* (Fig. 106, p.161 of Triapitsyn 2018b) and gt_4 in *P. glabrum*. This was incorrectly quoted as gt_2 in *P. onomarchicidum* by Jin & Li (2016) and Sankararaman et al. (2019).

3. *Polynema* (*Polynema*) *bengalense* Rehmat & Anis, 2015

Material examined: EDAU/Mym/DR3/2020, two females, 29.xii.2018, Nanjangud, Mysore, Karnataka, India, 12.116N & 76.678E, YPT, finger millet and weed ecosystems, coll. K. Surya (on card, EDAU).

Brief diagnosis: Face narrow, subantennal grooves carrying setae; torulus slightly above mid-level of eye and touching preorbital trabeculae; ocelli in obtuse triangle. Scape with striations; fore wing disc slightly infuscate; propodeum smooth and without any ridges or carinae; ovipositor very slightly exserted; five conical sensillae on fore tibia (Rehmat & Anis 2015).

Distribution: India: West Bengal (Rehmat & Anis 2015) and Karnataka (new record).

4. *Palaeoneura vegis* Amer & Zeya 2019

Material examined: EDAU/Mym/DR4/2020, two females, 23.ix.2018, Yercaud, Salem, Tamil Nadu, India, 11.774N & 78.209E, YPT, coffee ecosystem, coll. K. Surya (on card, EDAU).

Brief diagnosis: Face below toruli with 12 setae on each side; wings subhyaline; fore wing slightly infumate in basal third and along anterior margin; pronotum entire; ovipositor hardly exserted beyond gastral apex (Amer & Zeya 2019).

Distribution: India: Uttar Pradesh (Amer & Zeya 2019) and Tamil Nadu (new record).

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SHORT COMMUNICATION

Incursion of the killer sponge *Terpios hoshinota* Rützler & Muzik, 1993 on the coral reefs of the Lakshadweep archipelago, Arabian Sea

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Abstract: Our study documents the outbreak of a coral-killing sponge *Terpios hoshinota* in the coral reefs of Lakshadweep archipelago and highlights that it has further extended its territory into the isolated atolls of Arabian Sea and maybe a growing threat to the existing coral reefs in the region.

Keywords: Atoll, Black disease, Indian Ocean.

Abbreviations: GOM—Gulf of Mannar | PB—Palk Bay | QGIS—Quantum Geographic Information System.
*The terms Black disease and Killer sponge are used synonymously.

Coral killing sponges have the potential to overgrow live corals, eventually killing the coral polyps, and thus leading to an epidemic (Bryan 1973). The cyanobacterio sponge *Terpios hoshinota* Rützler & Muzik, 1993 also known as the black disease* (Liao et al. 2007) first reported from Guam (Bryan 1973) and later described from the coral reefs of the Ryukyu archipelago (Japan) (Rützler & Muzik 1993) is identified by its gray to blackish encrustations. Since its first occurrence, it has been observed in several coral reef localities around the globe, viz., the Great Barrier Reef (Fujii et al. 2011), Papua New Guinea (Ekins et al. 2017), Taiwan (Liao et al. 2007), Philippines (Plucer-Rosario 1987), Indonesia (De Voogd et al. 2013), South China Sea (Shi et al. 2012; Hoeksema et al. 2014; Yang et al. 2018) , Thailand (Plucer-Rosario 1987), Palk Bay (PB)/Gulf of Mannar (GOM) (India) (Thinesh et al. 2015, 2017; Raj et al. 2018a), Maldives

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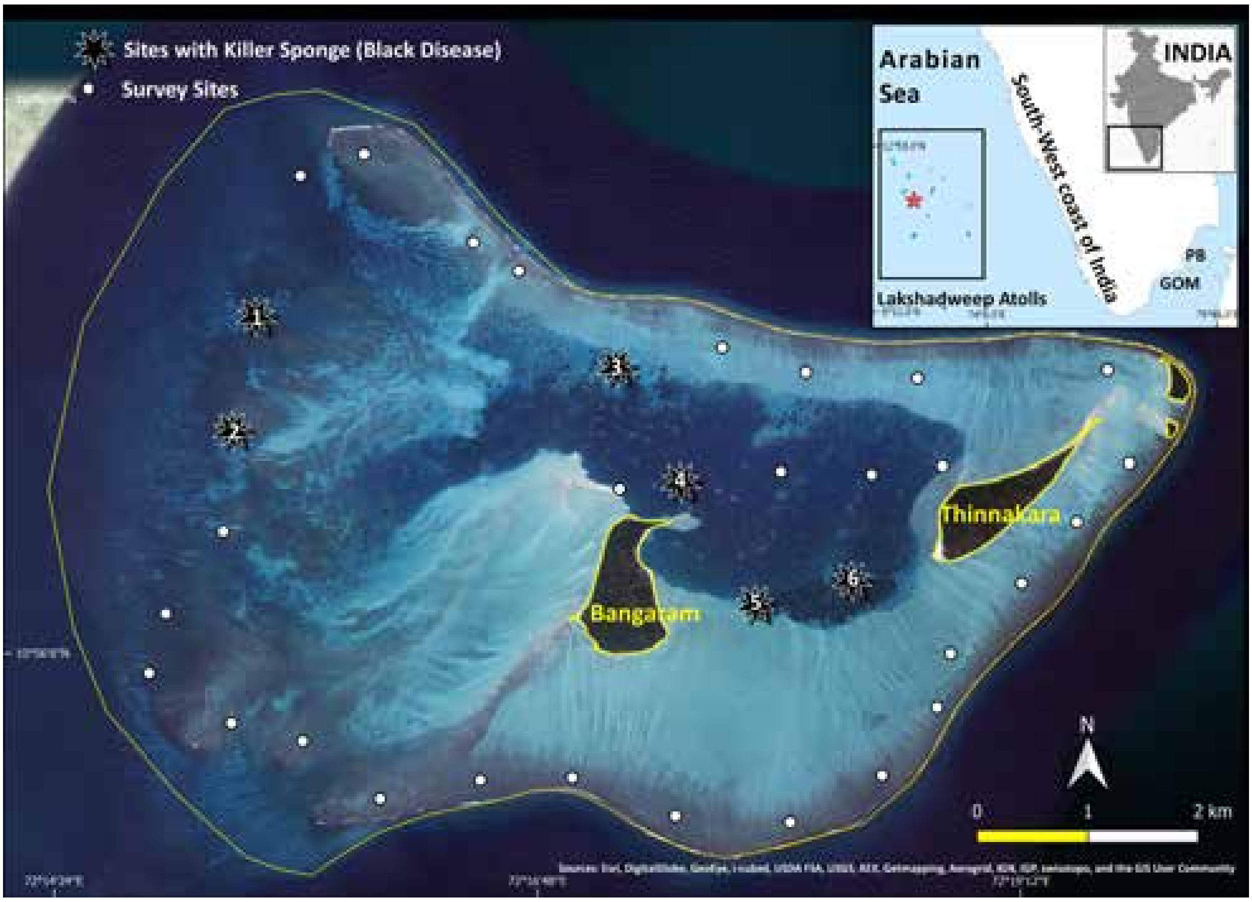

Image 1. Bangaram & Thinnakara atoll (Inset - red star) (QGIS 3.6).

(Montano et al. 2015), Mauritius (Elliott et al. 2016) and our present observation, confirms that the species has further extended its habitat into the pristine atolls of Lakshadweep (Image 1) (Arabian Sea) and requires urgent attention.

During the coral reef surveys conducted at Lakshadweep in November 2016, *T. hoshinota* was observed overgrowing on several colonies of *Acropora muricata, Isopora palifera, Cyphastrea* sp., *Dipsastraea lizardensis* and *Porites lutea* (Image 2 and 3) in the atoll encircling Bangaram and Thinnakara Islands. Out of 34 sites surveyed, six exhibited the presence of *T. hoshinota* (Image 1). The coral colonies in atoll were patchy and the depth of the atoll varied between 2 and 12 meters. As depth increased, (i.e., >5m) large boulder corals were observed whereas the shallow regions (<5m) had greater coral diversity. Certain areas consisting of large *Acropora* beds, rocks, rubbles, and dead reef were also observed. The affected corals displayed grayish/blackish encrustations of *T. hoshinota* forming a mat-like layer on live corals taking the shape of the coral in all cases. The osculum in the sponge, a primary character with a radiating network of canals, was clearly visible and the thickness of the mat was less than 1mm (Image 2). It was observed that the encrusting sponges were propagating laterally and infecting the other live coral colonies. Other associated communities such as ascidians and clams remain unaffected but interestingly the calcareous serpulid tubes, though overgrown by the *Terpios*, the animal was unharmed (Elliott et al. 2016) (Image 2d). Further, in some colonies along with *T. hoshinota*, algal presence was noted (Image 3a) but the sponge was absent in the colonies which were completely covered with turf algae (Image 3b). Environmental parameters assessed with a multiparameter water quality probe (YSI optic probe no. 15K100034) revealed that the area was unpolluted with an optimum level of dissolved oxygen (5.04~8.21 mg/l), and low turbidity (0.3 to 0.8 NTU). Sea surface temperature (SST) during the survey was 28.2°~30.1°C. It is important to note that, Bangaram and Thinnakara is one of the few atolls in Lakshadweep where tourism is permitted, as a result, limited amounts of diving and other water-related recreational activities can be seen in the area.

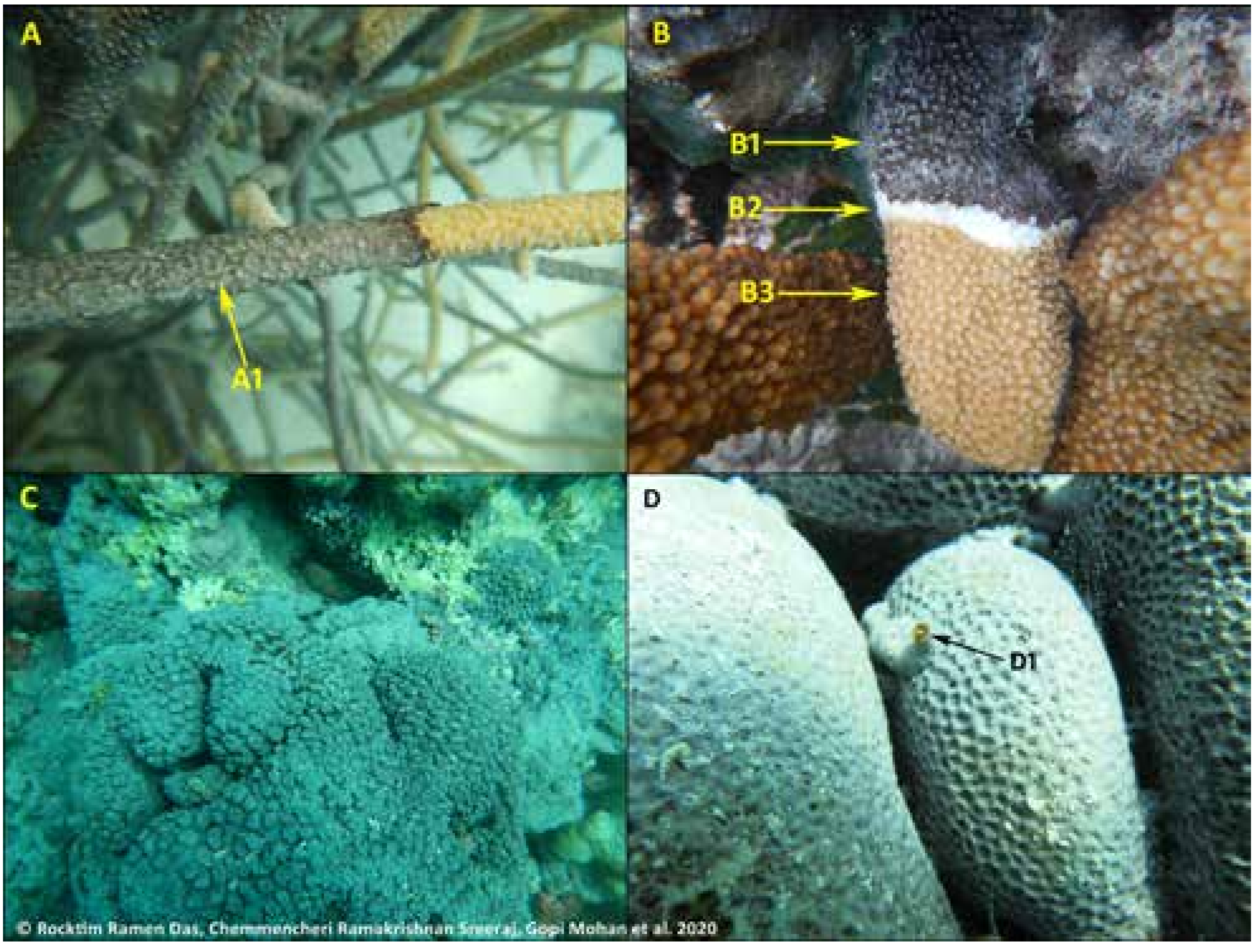

Image 2. A—Incrustations of *T. hoshinota* on *A. muricata*, A1. *T. hoshinota* exhibiting osculum with radiating networks | B—Incrustation on *I. palifera*, B1. *T. hoshinota* mat, B2. Bleached ring, B3. Live coral | C—*T. hoshinota* taking shape of a Coral (*Cyphastrea* sp.) | D—*T. hoshinota* overgrowing calcareous serpulid tubes, D1. animal unaffected.

Previous studies (Rützler & Muzik 1993; Thinesh et al. 2015) suspected that the outbreak of *T. hoshinota* is related to increased water turbidity or due to high anthropogenic stress/pollution its close proximity to mainland, as reported in the south eastern reefs of India (~800km from Lakshadweep) (Thinesh et al. 2015, 2017; Raj et al. 2018a), Guam (Plucer-Rosario 1987; Rützler & Muzik 1993) and in Green island (Chen et al. 2009). A similar conclusion, however, cannot be applied in the case of Lakshadweep because of its isolated geography (Arthur et al. 2005) and with comparatively less anthropogenic activities. As a result, our observation contradicts the above statements and is more in line with the findings of Shi et al. (2012) who observed *T. hoshinota* outbreak in unpolluted areas of Yongxing Island (South China Sea), highlighting the difficulty in establishing a negative co-relationship between water quality and black disease outbreak (Sung-Yin Yang pers comm. 2020). In terms of host selectivity, the killer sponge has affected several coral species in different parts of the world (Bryan 1973; Thinesh et al. 2015; Elliott et al. 2016; Raj et al. 2018a) and in the reefs of Palk Bay (PB), it has affected all genus surveyed (Thinesh et al. 2015). In Vaan Island (GOM) the dominant genus *Montipora* was the most susceptible (Raj et al. 2018a). Our observation though could not reveal any specific host coral selectivity, we can speculate that the dense branching *Acropora* coral beds (ACB) in site 3, 5 and 6 were more easily overgrown because the killer sponge prefers branching corals as reported from Mauritius (Elliott et al. 2016). We would further conclude that the coral composition in any specific location may play an important role in determining its host.

T. hoshinota is a belligerent contender for space (Plucer-Rosario 1987) and is known to overgrow corals from its base where it interacts with turf algae (Elliott et al. 2016). Branching *Acropora* beds in site 3, 5 and 6 (Image 3a) consisted both algae (e.g., *Dictyota* sp.)

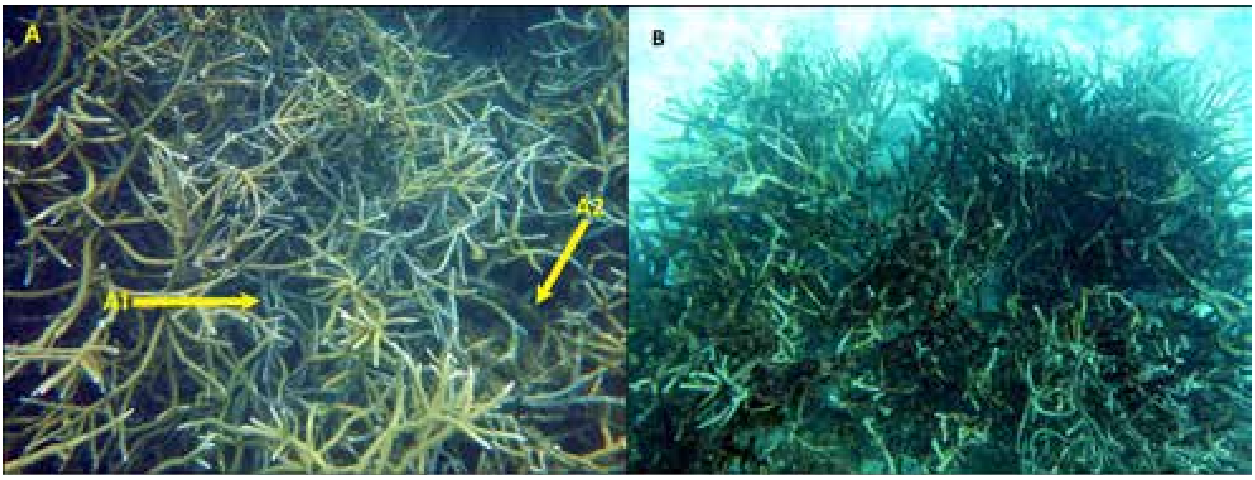

Image 3. *Acropora* colonies (Site 3): A—A1. *T. hoshinota* A2. Algae | B—*Acropora* colonies (Site 5) completely over grown by turf algae, killer sponge/black disease absent.

and the killer sponge. Additionally, a massive turf algae covered area of ~0.35km in *T. hoshinota* occurrence site (5, 6) highlights a complex ecological scenario (Image 3b). Such complexity between sponges, corals and algae can be only understood through long term monitoring. González-Rivero et al. (2011) stated that sponges can act as a potential group that can facilitate and influence coral-algal shifts by acting as a "third antagonist" as observed in Glover's atoll (Belize).

Based on our knowledge of the life history of *T. hoshinota* we can hypothesize site 5/6 scenario as follows: - (1) *T. hoshinota* invades and overgrows the *Acropora* beds → (2) The coral dies which is followed by the death of the killer sponge → (3) Turf algae takes over (Image 3a, b). Moreover, reports of turf algae being a dominant component in the atolls (Arthur et al. 2005) might indicate a faster transition. Globally Elevated SST is a major threat to coral reefs (Hughes et al. 2018), and the reefs of India (Edward et al. 2018; Krishnan et al. 2018; Raj et al. 2018b) including the atolls (Vinoth et al. 2012) are no different. With reports indicating that elevated SST has already depleted the coral ecosystem of Lakshadweep, which was evident during 1998 (Arthur et al. 2005), 2010 (Vinoth et al. 2012), and 2016 (Hughes et al. 2018) mass bleaching events, it can provide an opportunity for sponges to invade (Bell et al. 2013). The dynamics of waterflow (Arthur et al. 2005) may also play a crucial role in this regard.

Our findings confirm that the infestation of *T. hoshinota* on the coral colonies of Lakshadweep is currently limited to only Bangaram and Thinnakara as it was not observed in the other atolls surveyed. Although there is a possibility that the killer sponge could invade nearby atolls as seen in other regions (Bryan 1973; Reimer et al. 2011), large-scale damage cannot be concluded at this stage. This is in fact the first documentation of *T. hoshinota* on the reefs of Lakshadweep and can be regarded as a baseline for subsequent studies. Further, to protect the reefs of Lakshadweep, a long term coral health monitoring program is required which will allow us to understand the nature of occurrence, distribution, the impact and the causative factors of the killer sponge and to understand it's larger threat to the reefs. Black disease along with other coral associated diseases needs enlarged emphasis according to which various coral reef management plans can be initiated.

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SHORT COMMUNICATION

Contribution to the macromycetes of West Bengal, India: 63–68

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Abstract: West Bengal, a significant landmass of eastern India with its varied topography, edaphic, and climatic conditions facilitates diversified forest types and conducive microhabitats for a wide array of macro-fungal wealth and the members of Aphyllophorales in particular. Detailed macro-microscopic characterizations and chemical reactions were performed to systematically identify the specimens using standard key and literatures. Six members of Aphyllophorales collected from different parts of West Bengal, India and four species belonging to the family Polyporaceae [*Hexagonia tenuis* (Fr.) Fr., *Polyporus arcularius* (Batsch) Fr., *P. tricholoma* Mont. and *Lenzites elegans* (Spreng.) Pat.] were identified, and a single species was identified under Meripiliaceae [*Physisporinus lineatus* (Pers.) F. Wu, Jia J. Chen & Y.C. Dai] and Meruliaceae [*Bjerkandera fumosa* (Pers.) P. Karst.]. The detailed description along with field and herbarium photographs, macro-morphology, and microscopic features of six species are provided in this article.

Keywords: Aphyllophorales, Basidiomycota, hymenophore, taxonomy, West Bengal.

During the macrofungal survey in different parts of West Bengal with various forest types (viz., mountain temperate forest, tropical mixed evergreen forests of the foothills, the deciduous forests of the plateau fringe, and the tidal forests of Sundarbans), edaphic and climatic conditions (average annual rainfall 175cm and humidity 71%), six species of the order Aphyllophorales (Basidiomycota) were identified. In continuation to our earlier publications (Acharya et al. 2017; Tarafder et al. 2017; Bera et al. 2018, Saha et al. 2018a, b, Das et al. 2020) the species are being contributed to the Macromycetes of West Bengal, with more detailed descriptions with necessary remarks.

Material and Methods

The macro-fungal specimens were collected during monsoon and post monsoon season from June to November (2000–2018) from different parts of West Bengal, India. Field study of the collected specimens like date and collection place, habit, habitat, types of fruiting body and their attachment to the substratum, pileus upper surface, presence or absence of hairs,

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hymenophore surface, types of hymenophore, margin, presence or absence of stipe and stipe attachments were noted carefully in the field book. Colour photographs of the upper surface of the pileus, hymenophore region, context and tube layers were taken for future references. The fruiting bodies were carefully separated with the help of scalpel and chisel from the substratum. Then each collection was wrapped with tissue papers and isolated in a box to avoid contamination. The collected specimens were dried in a hot air drier prior to microscopic study. Microscopic characters were noted by crushing and making transverse sections of these dried materials by mounting and staining in 10% KOH, Congo red and Melzer's reagent and observing it under a microscope. Amyloidity/non-amyloidity/dextrinoidity of the microscopic features were observed using Melzer's reagent. Microscopic characters like hyphal system, presence or absence of clamp connections, basidia, basidiospores, cystidia, cystidioles were noticed under Carl Zeiss AX10 Imager A1 phase contrast microscope for systematically identifying the specimens. Standard keys and published literatures have been referred to in order to compare our specimens and identify them correctly (Roy et al. 1996; Sharma 2012). For colour terms and codes of specimens, the Methuen Handbook of Colour was used (Kornerup et al. 1978). To calculate the dimensions of basidiospores, 30 measurements were taken from each sample. The Q value is denoted by Length/breadth ratio. The measurement of mean Q value (Q_m) was done by dividing total sum of Q value by total number of spores observed. Outline of all identifying characters were drawn using camera lucida and 0.1mm rotring pen was used to trace the lines. Standard protocol was followed to preserve the specimens (Pradhan et al. 2015). The voucher specimens were systematically deposited at CUH (Calcutta University Herbarium) (Image 1a–f), Kolkata, India.

Results and Discussions

Hexagonia tenuis (Fr.) Fr.

Epicr. syst. mycol. (Upsaliae): 498 (1838) [1836-1838]

(Image 2a, Figure 1)

Basidiocarp annual, pileate, sessile. Pileus semicircular 25–41 mm broad and wide 1–2 mm thick near the base, thin, flexible. Upper surface glabrous with concentric zones, brown (7E5, 7E7); greyish violet (17D6) in KOH when fresh and blackening in KOH when dry. Margin white (1A1), thin, entire, sometimes lobed. Pore surface light brown (7D4) in colour, pore hexagonal, 1 per mm. Tubes light brown (7D4), 1mm deep. Hyphal peg absent. Context 1mm thick, brown (7E5).

Hyphal system trimitic; generative hyphae clamped, 2.8–3.58 µm wide, hyaline, thin walled; skeletal hyphae 3.58–5.37 µm wide, hyaline, thick-walled, branched; binding hyphae 1.79–3.58 µm wide, hyaline. Cystidia absent. Basidia clavte, 29.52–35.8 × 7.1–10.74 µm in diameter, hyaline, thin walled, 4-sterigmate. Basidioles clavate, 20.41–28.64 × 7.16–8.59 µm in diameter, hyaline, thin walled. Basidiospores cylindrical, (13.60–)14.32–16.38–18.26(–22.19) × 3.58–3.77–4.29 µm in diameter, Q=3.42–5.63, Q_m=4.33, hyaline, thin walled, non-dextrinoid.

Habit and habitat: Solitary to gregarious, grown on dead wood of *Mangifera indica* L.

Specimen examined: CUH AM559, 27.vi.2017, 22.527°N & 88.362°E, elevation 13m, Ballygunge Science College, Kolkata, West Bengal, India, coll. R. Saha & K. Acharya.

Geographical distribution: India (Leelavathy et al. 2000; Sharma 2012), eastern Africa (Ryvarden & Johansen 1980), and Malawi (Morris et al. 1990).

Remarks: The present specimen is characterized by its sessile basidiocarp, semicircular, glabrous pelius with concentric zones; greyish violet (17D6) in KOH when fresh and blackening in KOH when dry; hexagonal shaped pores, 1 per mm; trimitic type of hyphal system; clamped generative hyphae; basidiospores measuring 13.60–22.19 × 3.58–4.29 µm in diameter with mean Q value of 4.33.

The description of our collection matches with the description reported from Uttarakhand (Sharma 2012) and East Africa. The specimen from Kerala (Leelavathy et al. 2000) differs from the present collection with regard to slightly smaller basidiospores (9–15.5 × 3–4.5 µm vs 13.60–22.19 × 3.58–4.29 µm).

Among morphologically closely related species, *Hexagonia hirta* (P. Beauv.) Fr. differs by the presence of long, dark stiff, erect or branched hairs; *Hexagonia papyracea* Berk. differs by the presence of smaller basidiospores (up to 13µm long) (Sharma 2012).

Polyporus arcularius (Batsch) Fr.

Syst. mycol. (Lundae) 1: 342 (1821)

(Image 2b, Figure 2)

Basidiocarp pileate, centrally stipitate. Pileus round 13–14 mm in diameter, funnel shaped, depressed at disc. Upper surface light brown (6D4) when young and dark brown (9F4) at maturity. Margin thin, ciliated, inrolled when dry. Pore surface greyish-orange (5B3)

Image 1. Herbarium photographs of the specimens: a—*Hexagonia tenuis* | b—*Polyporus arcularius* | c—*Polyporus tricholoma* | d—*Lenzites elegans* | e—*Physisporinus lineatus* | f—*Bjerkandera fumosa.*

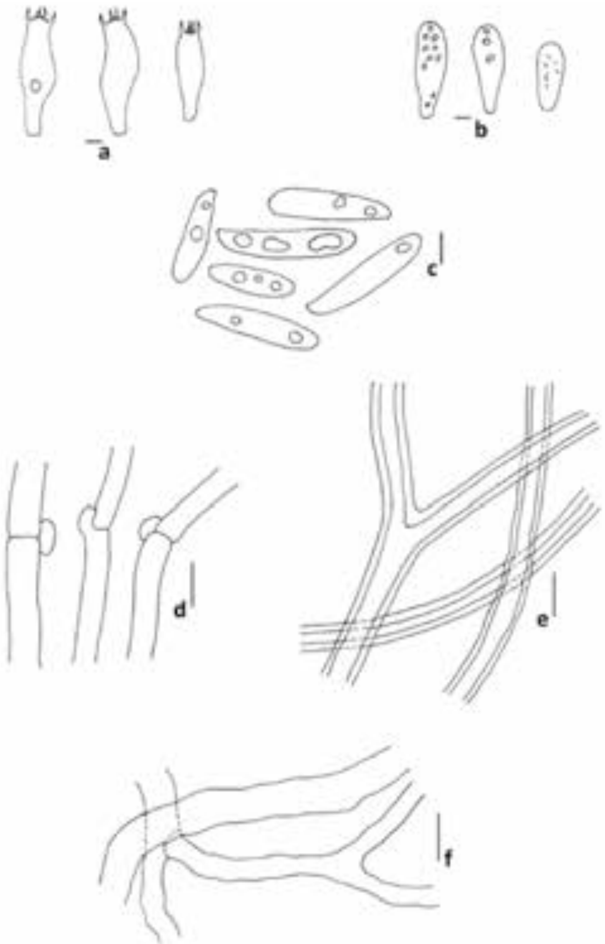

Figure 1. *Hexagonia tenuis*: a—basidia | b—basidioles | c—basidiospores | d—generative hyphae | e—skeletal hyphae | f—binding hyphae. Bars = 5µm. Drawing by Rituparna Saha.

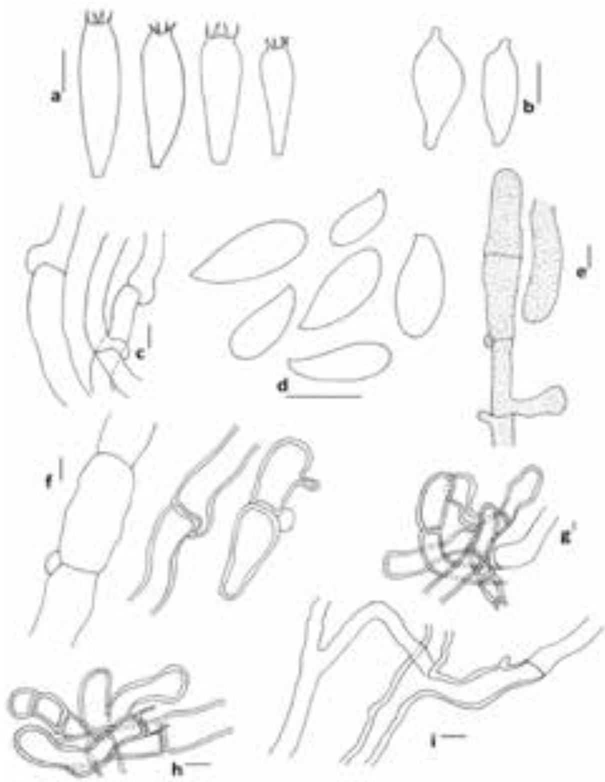

Figure 2. *Polyporus arcularius*: a—basidia | b—cystidioles | c—generative hyphae of context | d—basidiospores | e—gloeopherous hyphae | f—generative hyphae of pileus surface | g—interwined generative hyphae of pileus surface | h—interlocking generative hyphae of stipe | i—binding hyphae. Bars = 5µm. Drawing by Rituparna Saha.

when young, orange gray (5B2) at maturity, pores 1–2 per mm, angular to pentagonal. Pore tubes greyish-orange (5B3) to orange grey (5B2), tubes up to 1mm deep. Context 0.5–1 mm, thin, greyish-orange (5B3) to orange grey (5B2). Stipe straight, cylindrical, broad towards base, 24–44 × 14–20 mm in diameter, slightly pubescent towards base, brownish-orange (5C4) when young, greyish brown (8E3) at maturity, base strigose, solid.

Hyphal system dimitic; in context region generative hyphae clamped, branched, mostly thin-walled, some with thick-walled, 3.5–6.6 µm wide, hyaline; gloeopherous hyphae 3.58–7.16 µm wide with clamp connection. On the pileus upper surface generative hyphae much wider, swelled, 4.9–11.6 µm wide, thin to thick walled; some thin to thick walled, intertwined generative hyphae also present, usually 7.16–14.32 µm in diameter. Binding hyphae hyaline, thick-walled to solid, dendritic, branched, 3.5–6.5 µm wide. Some thin to thick-walled, interlocking generative hyphae present at brownish base of stipe, 4.99–8.33 µm wide. Cystidiole 12.53–14.32 × 3.58–5.37 µm in diameter, hyaline, thin-walled. Basidia 4-sterigmate, clavate, 12.5–17.9 × 3.5–4.29 µm in diameter, hyaline, thin walled. Basidiospores cylindrical with apiculate, guttulate, (5–)6.4–7–7.88 × (1.7–)2.5–2.9–3.58 µm in diameter, Q=1.67–4, Q_m=2.48, hyaline, thin walled.

Habit and habitat: Solitary to gregarious, grown on dead wood of angiosperm.

Specimen examined: CUH AM560, 5.vi.2017, 26.885°N & 88.182°E, elevation 1650.22m, Mirik, Darjeeling District, West Bengal, India, coll. S. Paloi & E. Tarafder. CUH AM555, 17.vii.2017, 26.192°N & 89.273°E, elevation 47m, Debhibari, New Coochbehar District, West Bengal, India, coll. R. Saha & K. Acharya.

Geographical distribution: India (Roy et al. 1996; Leelavathy et al. 2000), East Africa (Ryvarden & Johansen 1980), Malaya (Corner 1984), Austria (Krüger et al. 2004), USA (Krüger et al. 2004) and China (Krüger et al. 2004).

Remarks: *Polyporus arcularius* (Batsch) Fr. possesses characteristic features like centrally stipitate basidiocarp; thin, ciliated margin; pores 1–2 per mm, angular to pentagonal; slightly pubescent stipe towards the base; dimitic type of hyphal system; clamped generative hyphae; dendritic type of binding hyphae; hyaline, cylindrical, apiculate, guttulate basidiospores measuring 5–7.88 × 1.7–3.58 µm in diameter with mean Q value of 2.48.

The description of our collection agreeably matches with the previous report from Malaya and Bardwan (Roy et al. 1996). The specimen reported from eastern Africa and Uttarakhand (Sharma 2012) differs by having larger spores (7–11 × 2–3.5 µm, Ryvarden & Johansen (1980) and 7–9 × 2–3 µm, Sharma (2012)) that may be attributed to the reason of climatic and geographical variations. The specimen reported from Kerala (Leelavathy et al. 2000) varies a bit from the present collection with regard to the absence of cystidiole.

Among macro-microscopically alike species of *Polyporus arcularius* (Batsch) Fr., *P. umbellatus* (Pers.) Fr. differs by having basidiocarp with several pilei from a common base; *Polyporus grammocephalus* Berk. differs by having laterally stipitate basidiocarp; and *Polyporus tricholoma* Mont. differs by having 6–8 pores per mm (Sharma 2012).

***Polyporus tricholoma* Mont.**

Ann. Sci. Nat., Bot., sér. 2 8: 365 (1837)

(Image 2c, Figure 3)

Basidiocarp annual, centrally stipitate. Pileus 5–11 mm in diameter, upper surface reddish brown (9D4), smooth, glabrous, centrally depressed. Margin thin, ciliated. Pore surface whitish (1A1), pores round to angular, 5–7 per mm. Context thin, 1 mm thick, whitish (1A1). Tubes whitish (1A1), 1mm thick. Stipe 4–10 mm long and 1–2 mm thick, pale reddish brown (8D4), glabrous, solid and cylindrical.

Hyphal system dimitic; in the context generative hyphae clamped, thin walled, 3.58–5.73 µm wide hyaline, branched, sometimes thick walled, 6.44–7.88 µm wide. On the pileus surface generative hyphae thin to thick walled, 6.44–7.88 µm wide, hyaline, branched. Some strongly interwoven to skin like appearance; gloeopherous hyphae 3.58–5.37 µm wide, hyaline; binding hyphae dendritic, thick walled, 3.58–5.37 µm wide, branched, solid, hyaline, septate, some are gradually swelled, 7.16–9.67 µm wide. Basidia not observed. Basidiospores cylindrical, 5.01–6.57–7.16 × 1.79–2.98–3.58 µm in diameter, Q=1.5–3, Q_m=2.29, hyaline, thin walled.

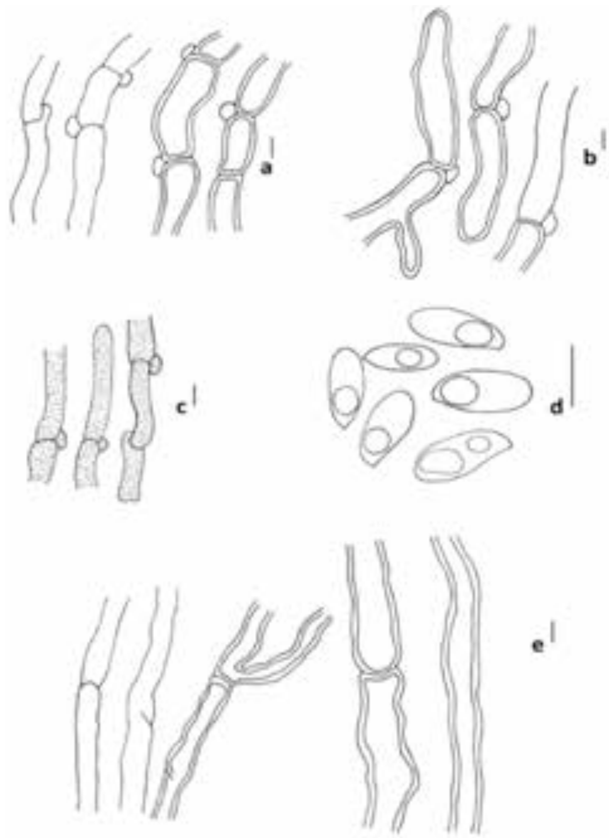

Figure 3. ***Polyporus tricholoma*****: a—generative hyphae of context | b—generative hyphae of pileus surface | c—gloeopherous hyphae | d—basidiospores | e—binding hyphae. Bars = 5µm. Drawing by Rituparna Saha.**

Habit and habitat: Solitary to gregarious, grown on dead wood of angiosperm.

Specimen examined: CUH AM591, 15.x.2017, 26.684^{0}N & 88.350^{0}E, 124.57m, Sukna, Siliguri District, West Bengal, India, coll. K. Acharya, R. Saha & A. Roy.

Geographical distribution: India (Roy et al. 1996; Leelavathy et al. 2000), Brazil (Núñez et al. 1995), eastern Africa (Ryvarden & Johansen 1980), Costa Rica (Krüger et al. 2004), Mexico (Krüger et al. 2004), and USA (Krüger et al. 2004).

Remarks: The present specimen is characterized by its centrally stipitate basidiocarp; ciliated margin; 5–7 per mm pores; dimitic hyphal system, clamped generative hyphae and dendritic type of binding hyphae; basidiospores measuring 5.01–7.16 × 1.79–3.58 µm diam. with mean Q value of 2.29. Our present specimen satisfactorily matches with the earlier report of Burdwan (Roy et al. 1996), Uttarakhand (Sharma 2012), Brazil and East Africa. The species reported from Kerala (Leelavathy et al. 2000), as described, slightly differs from our collection by having a bit larger basidiospores

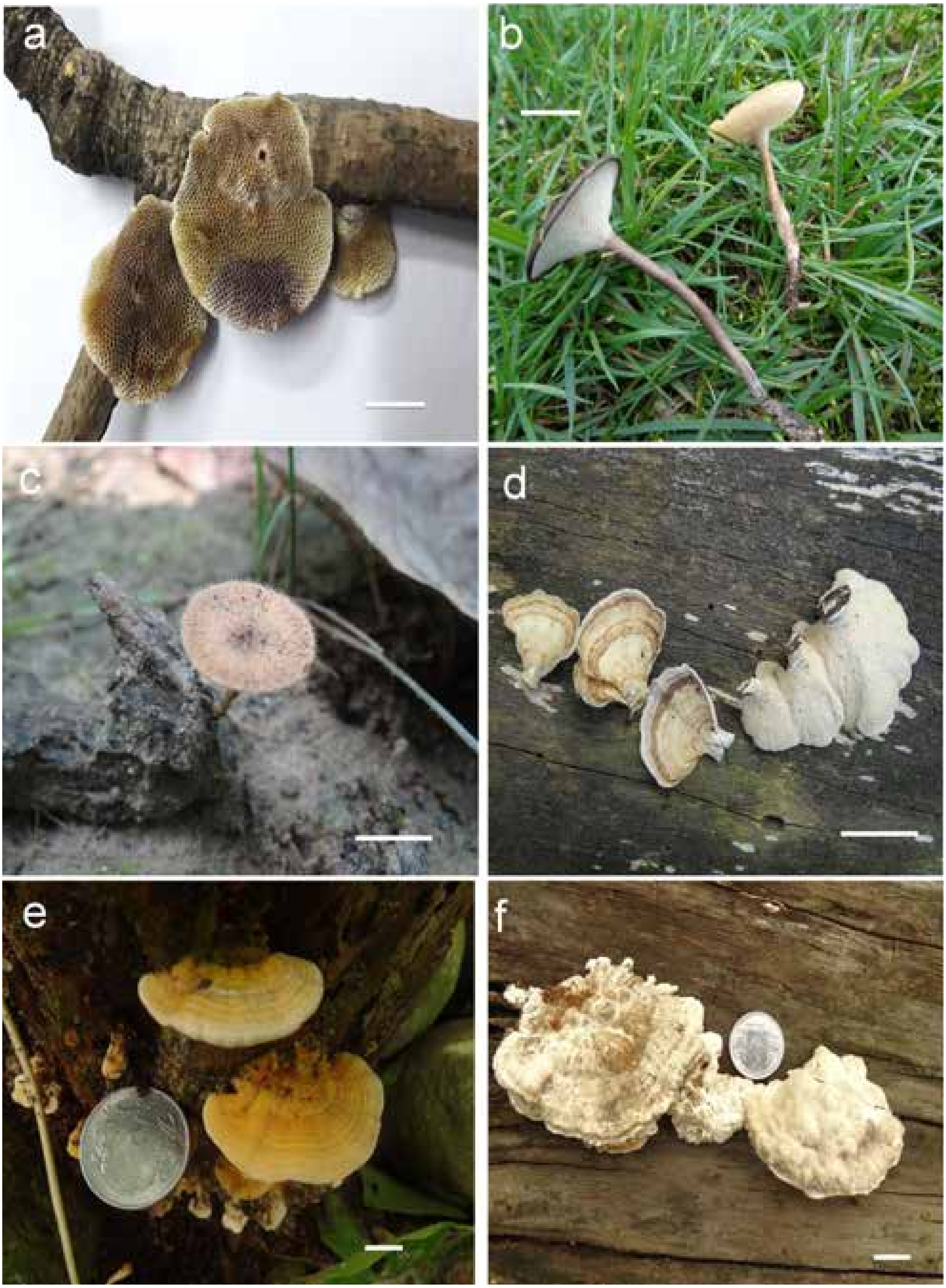

Image 2. Field photographs of the basidiocarp: a—*Hexagonia tenuis* | b—*Polyporus arcularius* | c—*Polyporus tricholoma* | d—*Lenzites elegans* | e—*Physisporinus lineatus* | f—*Bjerkandera fumosa*. Bars = 10mm. © Rituparna Saha.

(7.5–8.7 × 3–3.7 µm vs 5.01–7.16 × 1.79–3.58 µm).

Among macro-microscopically closely related species, *Polyporus umbellatus* (Pers.) Fr. differs by having basidiocarp with several pilei from a common base; *Polyporus grammocephalus* Berk. differs by having laterally stipitate basidiocarp; and *Polyporus arcularius* (Batsch) Fr. differs by having 1–2 pores per mm (Sharma 2012).

Lenzites elegans **(Spreng.) Pat.**

Essai Tax. Hyménomyc. (Lons-le-Saunier): 89 (1900)

(Image 2d, Figure 4)

Fruit body annual, sub-stipitate, laterally attached, 20–50 × 21–25 mm in diameter, 2–6 mm thick towards base, hard, glabrous. Upper surface of pileus orange white (6A2) with dark coloured violet brown (10E4, 10F4) concentric zonations. Margin grey (1D1), sulcate, thin. Hymenophore orange white (6A2), hymenophore irpicoid to daedaloid, partly lamellate, lamellae 3–4 per mm, 1–2 mm thick, orange white (6A2). Context single layered, white (1A1), 1–5 mm thick towards base.

Hyphal system trimitic; generative hyphae clamped at septa, 2.51–3.58 µm wide, thin, hyaline walled; skeletal hyphae solid, thick-walled, 3.58–7.16 µm wide, hyaline; binding hyphae branched, hyaline, solid, septate, 1.43–3.58 µm wide. Cystidia absent. Basidia not observed. Basidiospores cylindrical, smooth, (4.65–)5.73–6.66–7.52 × 1.79–2.97–3.58 µm, Q=1.6–3.49, Q_m=2.23, hyaline.

Habit and habitat: Solitary to grerarious, grown on dead wood of *Shorea robusta* C.F. Gaertn.

Specimen examined: CUH AM593, 15.vii.2017, 26.32°N & 89.32°E, 115m, Damanpur kathgola, Alipurduar District, West Bengal, India, coll. K. Acharya, R. Saha & A. Roy.

Geographical distribution: India (Sharma 2012), eastern Africa (Ryvarden & Johansen 1980), and North Carolina (Grand 2011).

Remarks: *Lenzites elegans* (Spreng.) Pat. is characterized by its lateral stipe; daedaloid to lamellate hymenophore; single layered white context, trimitic type of hyphal system; basidiospores measuring 4.65–7.52 × 1.79–3.58 µm diam. with mean Q value of 2.23.

In the Indian context, the present taxon was previously reported from Uttarakhand (Dehra Dun). Our collection mostly matches with the specimens reported from Dehra Dun (Sharma 2012) except having slight variations in basidiocarp size. The present specimen is smaller in size with respect to the specimen of Dehra Dun i.e., 100–200 mm wide and 10–30 mm thick (Sharma 2012) that may be attributed due to the reason of climatic and geographical variations. The collection, however, reported from eastern Africa (Ryvarden & Johansen 1980) and North Carolina (Grand 2011) matches with the description of our collected specimen.

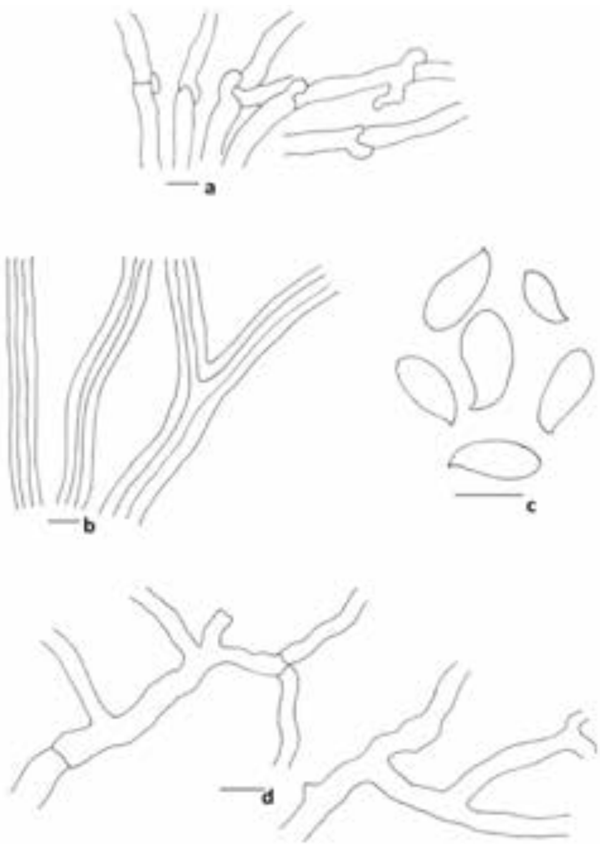

Figure 4. ***Lenzites elegans*****: a—generative hyphae | b—skeletal hyphae | c—basidiospores | d—binding hyphae. Bars = 5µm. Drawing by Rituparna Saha.**

Among macro-microscopically similar taxa, *Lenzites betulinus* (L.) Fr. differs by the presence of finely hirsute and concentrically zonate pileus surface; and *Lenzites stereoides* (Fr.) Ryvarden differs by the presence of whitish to wood coloured with pinkish tint basidiocarp and spiny to toothed hymenophore; and *Lenzites acutus* Berk. differs by having 3–6 lamellae per cm (Sharma 2012).

Physisporinus lineatus **(Pers.) F. Wu, Jia J. Chen & Y.C. Dai**

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(Image 2e, Figure 5)

Basidiocarp annual, pileate, sessile. Pileus dimidiate, 23–31 × 15–20 mm in diam., 1–6 mm thick at base. Pileus upper surface glabrous, greyish orange (5B6) to brownish-orange (7C7) towards base and with brownish-orange (6C7) concentric zones. Margin entire, thin,

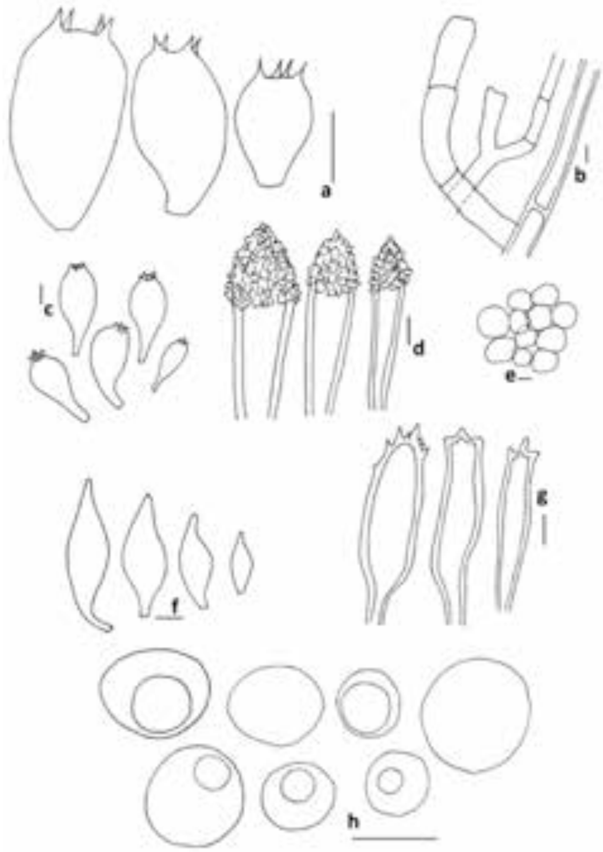

Figure 5. *Physisporinus lineatus*: a—basidia | b—generative hyphae | c—apically encrusted cystidia | d—strongly encrusted cystidia | e—pseudo-parenchymatous cells | f—cystidioles | g—acanthophyces | h—basidiospores. Bars = 5µm. Drawing by Rituparna Saha.

decurved on drying, greyish-orange (6B3). Pore surface greyish-orange (6B3), pores circular to angular, 7–10 per mm. Context up to 1mm thick, greyish-orange (6B3) in colour. Tubes 1–2 mm deep, not stratified, concolorous with the context.

Hyphal system monomitic; generative hyphae 3.58–7.88 µm wide, simple septate, hyaline, solid, thin to thick-walled. Cystidia are of two types– one is apically encrusted club shaped cystidia with hyaline, thick- walled, 14.68–21.48 × 4.29–8.95 µm in diameter, apical part wide and basal part tube-like, and the other is strongly encrusted cystidia with highly thick-walled, solid, 6.04–11.09 µm wide, embedded in the trama and sometimes partly projecting into the hymenial region. Cystidioles mucronate, tips pointed, 10.74–26.85 × 3.58–7.16 µm in diameter, hyaline. Acanthophyces thick walled, 5.37–8.95 µm wide, hyaline, solid. Pseudo-parenchymatous cell present just below the context region; cells globose to subglobose, thin-walled, 7.16–11.09 × 6.44–7.52 µm in diameter, hyaline. Basidia short, barrel shape, 7.88–14.32 × 5.37–7.88 µm in diameter, hyaline, 4-sterigmate, sterigmata short. Basidiospores thin-walled, globose to subglobose, often with one oil droplet, 3.94–4.58–5.37(–6.44) × 3.58–4.03–5.01 µm in diameter, Q=1–1.27, Q_m=1.13, hyaline, (–) ve in Melzer's reagent.

Habit and habitat: Solitary to gregarious, grown on dead wood of angiosperm.

Specimen examined: CUH AM604, 19.ix.2017, 26.28^{0}N & 88.63^{0}E, 137m, Targhera, Jalpaiguri District, West Bengal, India, coll. R. Saha, K. Acharya & A. Roy.

Geographical distribution: India (Leelavathy et al. 2000; Sharma 2012), eastern Africa (Ryvarden & Johansen 1980) and Europe (Ryvarden & Gilbertson 1994).

Remarks: *Physisporinus lineatus* (Pers.) F. Wu, Jia J. Chen & Y.C. Dai possesses characteristic features of an annual habit; sessile basidiocarp coloured greyish-orange (5B6) to brownish-orange (7C7) towards base and with brownish-orange (6C7) concentric zonations; pores 7–10 per mm; monomitic type of hyphal system; simple septate generative hyphae; two types of cystidia- one being apically encrusted club shaped, apical part wide and basal part tube like, 14.68–21.48 × 4.29–8.95 µm in diameter and the other being strongly encrusted, highly thick-walled; mucronate cystidioles; thick-walled acanthophyces; and thin-walled, globose to sub-globose basidiospores measuring 3.94–6.44 × 3.58–5.01 µm diam. with mean Q value of 1.13.

Our collection appropriately matches with the previous reports of Uttarakhand (Sharma 2012), Kerala (Leelavathy et al. 2000) and eastern Africa (Ryvarden & Johansen 1980). The specimen reported from Europe bears most resemblances with our collection except for having a larger basidiocarp.

Among the macro and micro-morphologically closely related species, *Physisporinus vitreus* (Pers.) P. Karst. differs from *P. lineatus* (Pers.) F. Wu, Jia J. Chen & Y.C. Dai due to absence of cystidia (Sharma 2012).

Bjerkandera fumosa **(Pers.) P. Karst.**

Meddn Soc. Fauna Flora Fenn. 5: 38 (1879)

(Image 2f, Figure 6)

Basidiocarp annual, effused reflexed, sessile, broadly attached to the substratum. Pileus dimidiate, 46–55 × 29–46 mm in diameter and 2–17 mm thick towards base. Upper surface white (1A1) to purplish grey (13D2), glabrous, azonate, irregular. Margin concolourous, 1–2 mm thick. Pore surface grey (7B1) to greyish red (7B3); pores 2–6 per mm, circular to angular towards margin and radially elongate from centre to base. Context

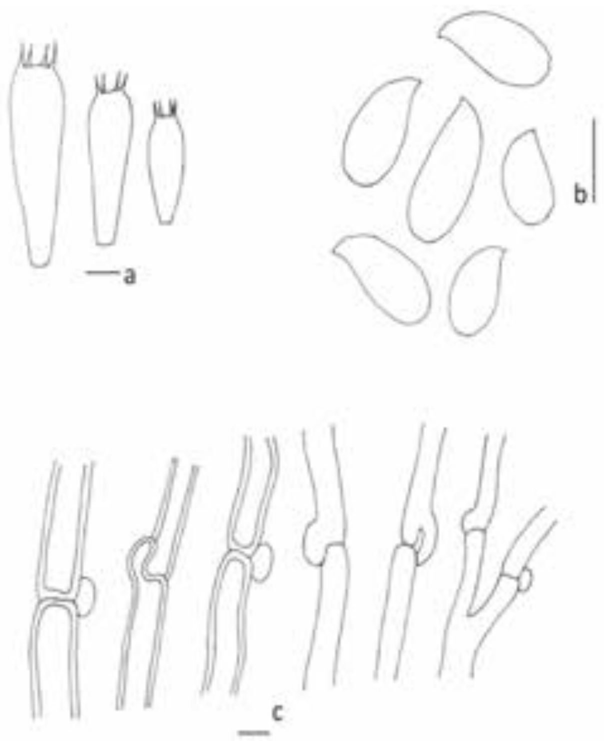

Figure 6. *Bjerkandera fumosa*: a—basidia | b—basidiospores | c—generative hyphae. Bars = 5µm. Drawing by Rituparna Saha.

double layered, upper layer whitish and lower layer greyish orange (6B3) near the base, 3–14 mm thick towards base. Tubes 1–3 mm deep, grey (7B1).

Hyphal system monomitic; generative hyphae 3.22–7.16 µm wide, hyaline in water and KOH, thin to thick walled, branched, clamped at septa. Cystidia absent. Basidia clavate, 4-sterigmate, 14.32–25.06 × 5.37–7.16 µm in diameter, hyaline, thin walled. Basidiospores thin-walled, cylindrical, (5.37–)6.44–6.89–7.16(–8.59) × 3.22–3.48–3.58 µm in diameter, Q=1.5–2.39, Q_m=1.98, hyaline, smooth.

Habit and habitat: Solitary to gregarious, dead wood of *Shorea robusta* C.F. Gaertn.

Specimen examined: CUH AM606, 19.ix.2017, 26.28°N & 88.63°E, 137m, Targhera, Jalpaiguri District, West Bengal, India, coll. R. Saha, K. Acharya & A. Roy.

Geographical distribution: India (Roy et al. 1996; Sharma 2012), Russia (Ryvarden & Gilbertson 1993), Korea (Jung et al. 2014), America (Jung et al. 2014), and Europe (Zmitrovich et al. 2016).

Remarks: *Bjerkendera fumosa* (Pers.) P. Karst. is well characterized by its white (1A1) to purplish-grey (13D2) pileus upper surface; grey (7B1) to greyish-red (7B3) hymenophore; double layered context, upper whitish and lower greyish-orange (6B3) near the base; thin to thick-walled clamped generative hyphae; hyaline, cylindrical, smooth basidiospores measuring 5.37–8.59 × 3.22–3.58 µm diam. with mean Q value of 1.98.

Considering morphological features, the description of our collected specimen matches with the earlier report of Uttarakhand (Sharma 2012) and the collection reported from Bardwan (Roy et al. 1996) and America (Jung et al. 2014) varies a bit from the present collection with regards to the longer size of the basidiospores (4–6.5 × 2–3.5 µm and 5–5.5 × 2–3.5 µm respectively). The description reported from Russia and Europe, however, matches well with the description of our collected specimen.

Among macro-microscopically closely related taxa, *Bjerkandera adusta* (Willd.) P. Karst. differs by having thinner context (up to 6mm) and a greyish-black zone between the context and tube layer which is concolorous with the tube layer (Sharma 2012).

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NOTE

A rare camera trap record of the Hispid Hare *Caprolagus hispidus* from Dudhwa Tiger Reserve, Terai Arc Landscape, India

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Lagomorpha encompasses small and medium-sized mammals including pikas and rabbits which belong to Ochotonidae and Leporidae families, respectively. These mammals have been known to inhabit all continents except Antarctica (Chapman & Flux 2008). In India, members of this group are found in a variety of landscapes ranging from high elevation regions of Ladakh and Arunachal Pradesh to tall grassland habitats of the Himalayan foothills (Aryal & Yadav 2019; Dahal et al. 2020; Maheswaran 2020). One among these, the Hispid Hare *Caprolagus hispidus* (Pearson, 1839) is a member of the Leporidae family, and is characterized by its small ears, long fore legs and very short hind legs. The dark brown hair on the dorsal side and a very short tail help distinguish them from other lagomorphs (Aryal & Yadav 2019). This threatened and elusive lagomorph was historically known to be found along the entire Terai starting from Uttarakhand in India to southern Bangladesh in Dhaka (Blanford 1888; Dawson 1971). Its current distribution, however, is restricted to the tall floodplain grasslands of northern India, southern Nepal, and Bhutan (Nidup 2018) within an elevational range of 100–250 m (Aryal & Yadav 2019).

These floodplain grasslands of the Terai region are the primary habitats of the Hispid Hare, which are different from the typical dry and scrub grasslands found across the subcontinent. They are predominantly alluvial grasslands comprising tall grasses like *Saccharum spontaneum*, *Desmostachya bipinnata*, *Narenga porphyrocoma*, and *Themeda arundinacea* among others. These dynamic and highly productive grasslands, maintained by annual flooding of rivers and controlled annual dry season burning (Lehmkuhl 1994; Peet et al. 1999; Singh & Prasad 2013), serve as critical habitats for many faunal species, including the Hispid Hare (Maheswaran 2013; Aryal & Yadav 2019).

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Dudhwa Tiger Reserve is one of the only three tiger reserves in the state of Uttar Pradesh, India, which lies close to the international border with Nepal. It comprises three protected areas: Dudhwa National Park, Kishanpur Wildlife Sanctuary and Katerniaghat Wildlife Sanctuary. These three protected areas, which were once contiguous, currently comprise an area of around 2,200km^2, inclusive of both core and buffer areas (Singh & Prasad 2013).

Dudhwa Tiger Reserve is part of the larger Terai Arc Landscape, a global ecoregion of high conservation significance (Olson & Dinerstein 2002). It forms a part of the Terai-Bhabar system, which are the floodplains of the river Ganga and its tributaries that extend from the state of Uttarakhand in the north-west to Assam in the north-east (Dinerstein 1979; Johnsingh et al. 2004). The reserve is interspersed by a mosaic of floodplain grasslands, riverine forests and wetlands (Kumar et al. 2002) and dominated by Sal trees *Shorea robusta*. The park is home to a variety of threatened fauna including One-horned Rhinoceros *Rhinoceros unicornis*, Asiatic Elephant *Elephas maximus*, Bengal Tiger *Panthera tigris*, Gharial *Gavialis gangeticus*, Swamp Deer *Rucervus duvaucelii duvaucelii*, Hog Deer *Axis porcinus*, Bengal Florican *Houbaropsis bengalensis*, and Hispid Hare.

Photographic records of Hispid Hare are extremely limited. They have been documented from the grasslands of Chitwan National Park in Nepal Terai, where the species was rediscovered after nearly three decades (Khadka et al. 2017). Though the lagomorph has been studied to some extent in the lowland regions of Nepal (Aryal 2010; Aryal et al. 2012), there have been only two ecological assessments of the species in the Indian Terai from the grasslands of Jaldapara National Park and Manas Tiger Reserve (Maheswaran 2013; Nath & Machary 2015). Although some anecdotal evidence exists for their presence in Dudhwa National Park, there are possibly only two published photographic records (Jha & Chauhan 2018; Maheswaran 2020) from the reserve.

Here, we present photographic evidence of this lagomorph from the tall grasslands of Dudhwa Tiger Reserve. These photographs were obtained using automated motion-triggered digital camera traps (Cuddeback C1, www.cuddeback.com) installed in different grasslands of the park as part of a research project on ungulates. We intensively sampled multiple one hectare patches in different grasslands in the park for animal signs and vegetation characteristics. In order to reduce false positives and confirm animal presence from sign surveys, we also installed a camera trap inside our sampling plots for a duration ranging between 20 and 30 days. In total, our survey effort was 1,261 camera trap nights between December 2019 and April 2020 across all our sampling plots.

During our field work in different grasslands of Dudhwa National Park and Kishanpur Wildlife Sanctuary, we encountered indirect signs of Hispid Hares, i.e., pellets and grazing signs, in eight different tall grassland patches only in Dudhwa National Park (Image 1).

Hispid Hare pellets are distinctive given their tablet-like, dorsoventrally flattened, shape (Image 2). In addition, we observed signs of grazing by Hispid Hares at the base of the stem of tall grasses like *Themeda arundinacea*, *Narenga porphyrocoma*, and *Sclerostachya fusca* which has been confirmed by dietary studies from Nepal Terai (Aryal et al. 2012; Maheswaran 2013).

The photograph, however, (Image 3,4) came from a 1.2km^2 grassland patch called Churaila 'phanta' (Nepali: grassland) (80.86°E & 28.41°N) (Image 1). This grassland dominated by *Desmostachya bipinnata* and *Narenga porphyrocoma* grasses, lies in the Laudaria beat of Belraiyaan range of Dudhwa National Park. In total, we got 10 photographs of hares from the Churaila grassland on two different days. To our knowledge, these are among the few confirmed camera trap captures of the species from the tall grasslands of Dudhwa National Park.

Grasslands in the park have traditionally been managed through the use of annual controlled burns. Such grassland fires date back over a century to the early 1920s, when British forest officers started this as a management practice to keep tall grasses in check (Singh & Prasad 2013). Burning also removes moribund plant material and fosters regrowth of tender grasses which is widely known to benefit large-bodied grassland dwelling herbivores such as the One-horned Rhinoceros, Hog Deer, and Swamp Deer, among others. The extent to which such controlled fires impact smaller-bodied species like the Hispid Hare, Swamp Francolin *Francolinus gularis* and the Bengal Florican remains unclear (Kumar et al. 2002; Jha et al. 2018). There is an urgent need for future studies that investigate these impacts in greater detail. The forest department in Dudhwa Tiger Reserve is currently evaluating grassland management practices in the reserve and has set up management plots with different interventions including cutting, harrowing and burning in different combinations, and control plots with no interference. These initiatives will provide us with key insights into optimal grassland management strategies both in the reserve as well as the broader Terai Arc Landscape, not just for large ungulates but

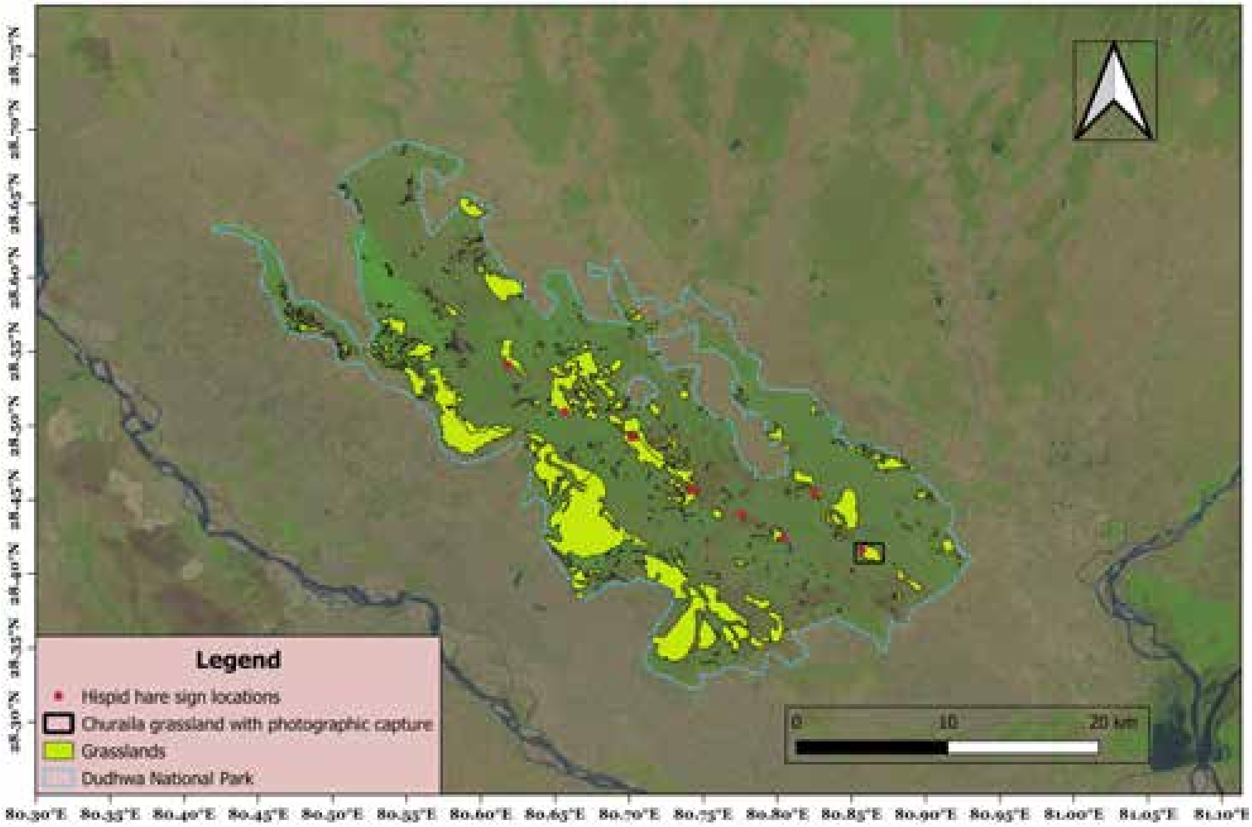

Image 1. Grassland map of Dudhwa National park; not all grasslands harbour Hispid Hare populations since the signs of the lagomorph were found in patches marked with red in the map above.

Image 2. Hispid hare pellets were the most common signs detected in the tall grasslands.

also for smaller bodied species such as the Hispid Hare. Further, there is also a need to better understand the impacts of reduced inundation and frequent fires over the years on the tougher and drier grasses like *Narenga porphyrocoma* and *Desmostachya bipinnata* which dominate these grasslands presently (Kumar et al. 2002; Sankarshan Rastogi pers. obs. January, 2020).

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Image 3. Hispid Hare *Caprolagus hispidus* camera trap capture in Churaila grassland of Dudhwa National Park; the shorter fore legs are one of the characteristics of these lagomorphs. © WWF-India.

Image 4. Hispid Hare photographic capture six days later at the same location. © WWF-India.

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NOTE

First distributional record of the Lesser Adjutant *Leptoptilos javanicus* Horsfield, 1821 (Ciconiiformes: Ciconiidae) from Sindhuli District, Nepal

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Globally the Lesser Adjutant (LA) *Leptoptilos javanicus* (Horsfield, 1821) is categorized as Vulnerable in the IUCN Red List of Threatened Species and has been recorded from Bangladesh, Bhutan, Brunei, Cambodia, China, India, Indonesia, Laos, Malaysia, Myanmar, Singapore, Sri Lanka, Thailand, and Vietnam (BirdLife International 2020). In Nepal, a few studies on the ecology and behavior of the LA have been conducted by Inskipp & Inskipp (1991), Baral (2004, 2005), Subba et al. (2009), Poudyal & Nepal (2010), Karki & Thapa (2013), Inskipp et al. (2016), Bajagain & Pradhan (2018), Nepal & Thapa (2018) and Sundar et al. (2016, 2019a,b). These studies provide records on LAs from 14 different important birds areas (IBAs) within and outside protected areas (Birdlife International 2020). Yet there is no documented record of this stork from Sindhuli District. With this study, we have provided a new record of LA from this district which will offer an opportunity for additional exploration and research survey throughout the recorded localities to explain its population in Sindhuli.

We conducted the survey along the Kamala River basin in Dudhauli Municipality and Kamalamai Municipality of central Nepal. Dudhauli Municipality lies between 27.072°N–27.029°N & 86.049°E–86.386 °E covering an area of 390.39km^2 with a total human population of 65,302 (CBS 2011). Kamalamai Municipality lies between 27.237°N–27.037°N & 85.830°E–86.030°E with an area of 482.57km^2 and a population of 77,845 (CBS 2011).

A team composed of five members surveyed wooded areas, agricultural fields, and rural villages in Dudhauli and Kamalamai Municipality of Sindhuli

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Competing interests: The authors declare no competing interests.

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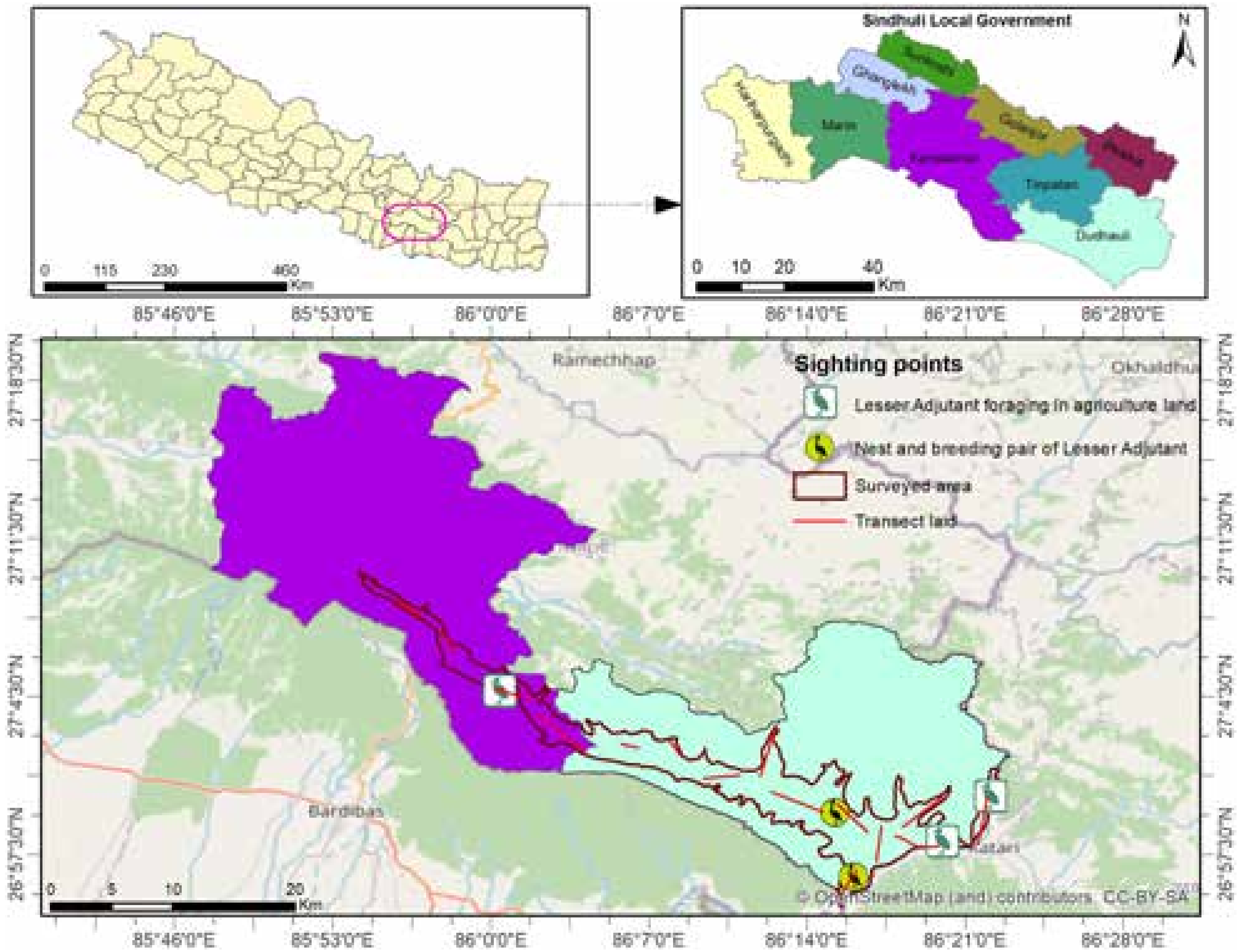

Figure 1. Lesser Adjutant sighting in Sindhuli District

between November 2017 and March 2018. An area of 156.3km^2 was surveyed for 15 days. A total of 15 transect surveys were done randomly in the Kamala River flood plains. The length of transects varies between 1.63 to 4.3 km depending upon the width of the flood plains. Afterwards, agricultural fields, forested areas and residential areas in the flood plains were searched for LAs. *Acacia catechu*, *Bombax ceiba*, *Dalbergia latifolia*, *Dalbergia sissoo*, *Dendrocalamus strictus*, *Ficus benghalensis*, and *F. religiosa* were the major vegetation in those forested and adjoining areas. Wheat was found to be intercropped with lentil and chickpeas & maize with beans & soya beans in sequential cropping patterns (rice-maize-fallow, rice-fallow-maize, and rice-wheat-fallow) in the survey area of the Kamala River valley of Sindhuli District. Because the species is large and conspicuous, and the colonies are relatively small, individuals foraging on either side of the transect, hovering in the sky and nests with breeding parents were counted and noted. A Canon Powershot SX 50 camera was used to photograph individuals, nests, and the chicks. Co-ordinates of localities were ascertained using a hand-held Garmin eTrex10 GPS.

A total of 12 individual LA storks with chicks on two active nests were recorded from these sites. All sightings with dates, time, altitude, activities, and number are presented in Table 1.

LA had been not previously recorded from Sindhuli District. This work has led to the discovery of an unknown population, a new breeding and foraging location for LA, in Sindhuli District, Bagmati Province, central Nepal. In our study, we counted 12 individual storks with chicks on two active nests in these sites. There is still a chance of double counting which we believe would not create a big impact on our result because two active nests with two breeding pairs confirms the breeding colony in the district. But the observation of chicks could not be considered as a breeding success as we failed to affirm if chicks had been fledged. This study in Sindhuli adds information on its distribution range in the country

Table 1. Records of Lesser Adjutant during November 2017 & March 2018 from Sindhuli District, Nepal.

Date	Sites/Localities	Altitude	Activities	Number
19.iii.2018	Kauchhe, Kamalamai Municipality	330m	Foraging in the agricultural fields.	Three
10.iii.2018	Helipad region, Dudhauli Municipality	190m	Nesting on *Dalbergia sissoo.*	One with its chicks
08.iii.2018	Tandi, Dudhauli Municipality	180m	Nesting on *Bombax ceiba.*	A breeding pair with their chicks
12.i.2018	Floodplains of Tawa River, Dudhauli Municipality	180m	Soaring above Tawa River before landing in agricultural fields.	Two
21.xi.2017	Floodplains of Kakurthakur River, Dudhauli Municipality	245m	Foraging in the agricultural fields.	Four

Image 1. Foraging in the agriculture fields in the flood plains of Kakurthakur River, Dudhauli Municipality.

and can be used to draw the attention of the wider conservation community towards effective conservation of this site. Annual monitoring of the population and nest with increased community participation and detailed ecological studies are strongly recommended.

The LAs had their heronries on large tall *Bombax ceiba* and *Dalbergia sissoo* trees amid multi-cropped agricultural fields dominated by cereal while in eastern lowlands they were also found to use Karam *Adina cordifolia* trees (Karki & Thapa 2013), and in Rupandehi and Kapilvastu, on *Bombax ceiba* and *Ficus religiosa* (Sundar et al. 2019b). This report on heronries of LAs compare favorably with the habitats described by Sundar et al. (2019b), which was previously assumed to be avoided for breeding (Sundar et al. 2016, 2019a). Besides, this information on habitat features, this study further highlights the need to study key aspects such as tree-selection for nesting, the factors that allow these storks to breed in Sindhuli, and factors affecting its breeding success.

The country total estimated population of LAs ranged between 300 and 1000 individuals with major population in the east (Inskipp et al. 2016) and between 200 and 700 (BirdLife International 2020) based on the information gathered over a period of time from different observations. But these estimates failed to take into account new work across Nepal. A total of 27 individuals (19 juvenile individuals from Sai Khola, four from Chanp and four from Saraswati Khola) and 21 nests (18 from Sai Khola and three from Chanp areas) have been recorded at two colonies in Triyuga Watershed, Udayapur in May 2015. Likewise, Bajagain et al. (2019) recorded 24 LA nests with 39 adults to provide information on breeding colonies of the species in Sarlahi District in Nepal.

This present record locations of LAs lie in between Triyuga Watershed, Udayapur in the east and Siraha

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Image 2. A breeding pair of Lesser Adjutant at their nest on *Bombax ceiba* tree at Tandi, Dudhauli Municipality.

District in the south and hence, shows that either the species has previously been overlooked or that it has extended its range towards Kamala River floodplains in Dudhauli and Kamalamai Municipality of Sindhuli. The confirmed presence of breeding population of this stork from Sindhuli District is important because it connects the LA population of Triyuga Watershed, Udaypur in the east and Siraha in the south reducing information gaps.

Based on sightings of individuals, heronries in small spatial scale over a short period of time, it would be impractical to conclude anything about population status in Sindhuli District. In the meantime, as the distribution range of these heronries are restricted with even more restricted breeding populations, these sightings are adequate to highlight on the need for well-planned long-term research to give better population estimate and to understand if the population is threatened, and to come up with proper long-term conservation initiatives for species conservation in Sindhuli and all the putative habitats including Siraha and Udaypur districts as well.

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NOTE

First record of African Sailfin Flying Fish *Parexocoetus mento* (Valenciennes, 1847) (Beloniformes: Exocoetidae), from the waters off Andaman Islands, India

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The family Exocoetidae comprises of 74 species belonging to seven genera and four subfamilies (Collette et al. 1984; Fricke et al. 2019). These fishes are distributed from the tropical to temperate waters (Lewallen et al. 2010; Nelson et al. 2016). This family is characterized by a prominently enlarged paired fins, which assist in gliding over the water (Davenport 1994). Based on the number of enlarged fins (either pectoral or both pectoral and pelvic) the species known to monoplane glider and biplane glider (Breder 1930). The subfamily Parexocoetinae, a monoplane glider consists of a single genus (*Parexocoetus*) with three species. The genus *Parexocoetus* is distinguished from the other members of the family by the presence of strongly protrusible mouth and having a process on theex-occipital directly articulating with the cleithrum.

Andaman & Nicobar archipelago, a biodiversity-rich Island ecosystem, harbours around 1,434 fish species under 576 genera belonging to 165 families and 33 orders (Rajan et al. 2013). Only five species of flying fishes belonging to four genera were reported from the islands (Rajan et al. 2013). Only one species of genus *Parexoceotus*, *P. brachypterus,* commonly known as sailfin flying fish, familiar in the Andaman Islands, is captured in sardine gillnet ('tharni net') and marketed in the local market. *P. mento,* a species originally described from the eastern Indian ocean near Pondicherry, is recorded for the first time in the Andaman Islands showing an extended geographical distribution. A brief description of the species recorded is descried herein.

Twenty-three specimens were collected from the gill net fishermen of Junglighat marine fish landing centre (11.659^{0}N & 72.721^{0}E), Andaman & Nicobar Islands. The specimens were caught as bycatch of sardine gill net of mesh size of 20mm and hanging coefficient of 0.55. The specimens collected were of poor quality due to the improper handling practices and their low market value. The specimens were preserved in 5% formalin solution. The morphometric measurements were taken in nearest 0.01 mm using the MitutoyoCD-6"ASX digital calliper. The terminologies used in the present study follow Parin (1996). The morphometric measurements

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were transformed into ratios for size independent comparison. Both morphometric and meristic characters were compared with relevant literature. A total of 23 specimens examined are deposited in the Fisheries Museum of ICAR-CIARI, Port Blair.

Systematics

Order: Beloniformes L.S. Berg, 1937

Family: Exocoetidae Risso, 1827

Genus: *Parexocoetus* Bleeker, 1865

Species: *Parexocoetus mento* (Valenciennes, 1847) (Fig. 1; Table 1)

Materials Examined: CIARI/MF 06¬29, 23.iii.2019, 23ex, 91.0–108.0mm SL, Junglighat Fish Market, Port Blair, Andaman Islands, India (11.659°N & 72.721°E), coll. Gladston & Ajina.

Description: The body is elongated and moderately compressed laterally with blunt and short snout (Fig 1A). The upper jaw is protrusible (Fig. 1B) and the lower jaw little extended when closed (Fig 1B). The entire body is covered with deciduous ctenoid scales. Caudal fin lobes unequal, and lower lobe is large and elongated. Lateral line scales well developed and passing though lower part of mid-lateral region. A well-developed lateral-line branch is present and descending from the pectoral fin base. Greatest body depth is 20–23 % of the standard length and head 22–29 % of standard length. Morphometric measurements of *P. mento* are given in Table 1. Body proportions are expressed as a percentage of standard length and head length.

Pectoral fins long, reaching to or beyond the origin of the dorsal fin, it is about 48 to 55 % of the standard length. Pectoral fin rays 10–12, mostly 12, middle elongated. Single dorsal fin with all soft rays, originated posterior to the body same line of anal fin origin. Dorsal fins with about 10–11 fin rays (mostly 10) with middle ones are elongated and reach up to the origin of upper caudal fin lobe. Pelvic fins as same as the length of

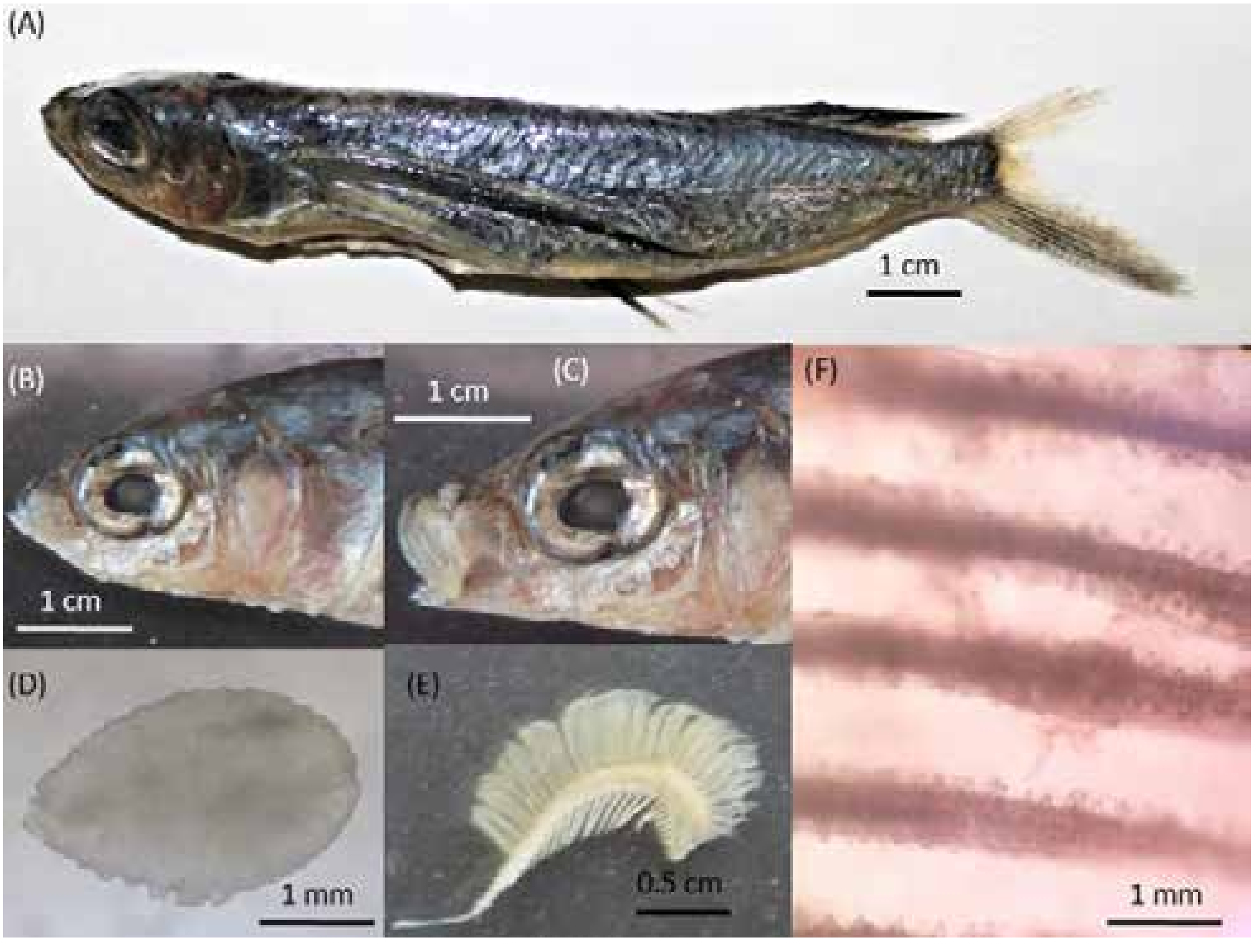

Image 1. *Parexocoetus mento* collected from Junglighat market of Andaman Islands:
A—whole specimen | B—extended lower jaw when mouth closed | C—protrusible mouth | D—otolith (Sagitta, the largest otolith) | E—first gill with rakers | F—spinules in gill rakers. © S.M. Ajina & Y. Gladston.

Table 1. Morphometric measurements of *Parexocoetus mento* (N=23). Body proportions are expressed as a percentage of standard length and head length.

Characters	Mean	Range	CV
TL(cm)	12.10	11.00–13.40	5.68
SL(cm)	9.91	9.10–10.80	4.58
PDL/SL	0.70	0.66–0.74	2.73
PPeL/SL	0.53	0.50–0.54	2.67
PPL/SL	0.29	0.25–0.31	5.61
PAL/SL	0.72	0.69–0.75	2.72
BD/SL	0.21	0.20–0.23	5.11
PpiL/SL	0.28	0.26–0.32	5.93
pAiL/SL	0.22	0.20–0.24	5.78
PL/SL	0.51	0.47–0.55	4.15
PFL/SL	0.20	0.17–0.22	6.47
AL/ SL	0.18	0.16–0.20	6.32
HOD/SL	0.23	0.20–0.28	10.54
HL/SL	0.26	0.22–0.29	7.04
SnL/HL	0.21	0.15–0.27	14.86
ED/HL	0.36	0.31–0.43	7.54
IOL/HL	0.39	0.33–0.48	9.65
IOL/ED	1.09	1.00–1.38	7.72
SnL/ED	0.58	0.44–0.78	14.02

CV—coefficient of variation: TL—total length | SL—standard length | PDL—pre-dorsal length | PPeL—pre-pelvic length | PPL—pre-pectoral length | PAL—pre-anal length | BD—body depth | PpiL—distance from pectoral fin origin to pelvic fin origin | pAiL—distance from pelvic fin origin to anal fin origin | PL—pectoral fin length | PFL—pelvic fin length | AL—Length of anal fin base | HOD—height of dorsal fin | HL— Head length | SnL—snout length | ED—eye diameter | IOL—interorbital length.

anal fin base with 5–6 rays (mostly 6), with third ray is longest, inserted near to anal fin origin than the pectoral fin origin. Anal fin originated the same line or after 2–3 rays of dorsal fin, base length is same or nearer to height of dorsal fin. The anal fin number equal to the number of dorsal fin rays, 10–11 (mostly 10). Predorsal scales 16 to 20 (mostly 18). Gill rakers elongated and serrated (Fig 1F.), on first arch 18–24 (mostly 21) numbers present (Fig 1E). Vomerine teeth present.

Otoliths are comparatively large and oval (Fig. 1D).

Colour: Dark bluish-green dorsally, silver on ventral side. A large black spot present in the dorsal fin which touches the fin base, pectoral fin greyish white to transparent in colour.

Range: Pelagic in nearshore and neritic waters, rare in open ocean, found in the Atlantic, Indian, and Pacific Ocean (Parin 1986; Russell & Houston 1989; Sommer et al. 1996).

The present study records *P. mento,* the first time from the Andaman Islands. The species has earlier known Red Sea, Africa, Marshall Islands, Fiji, Japan, Australia, and Mediterranean Sea (Russell & Houston 1989; Parin 1986). The original description of the species in from southeastern coast of India near Pondicherry. The existence of *P. mento* revealed additional biodiversity of fish in Andaman Islands and also shows the new geographical distribution in this region.

The earlier distribution of the species known from Mediterranean coast of Palestine (Bruun 1935), Aegean Sea (Kosswig 1950; Ben-Tuvia 1966; Fischer & Bianchi 1984; Parin 1986) Gulf of Sidra (Ben-Tuvia 1966; South-east Mediterranean Sea (Ben-Tuvia 1966, 1985; Fischer & Bianchi 1984; Parin 1986; Golani 1996) and from Albania (Fischer & Bianchi 1984; Parin 1986).

This species was originally described from the Pondicherry waters by Valenciennes in 1847. The further taxonomic description, systematic position, and distribution of the species from the Mediterranean Sea given by Ben-Tuvia (1966) and Parin (1986). According to Parin (1986) the adults of *P. mento* can be distinguished by a combination of characters including elongate, compressed body rounded ventrally, with the presence of pectoral branch of the lateralline, protrusible upper jaw and subequal rays in dorsal and anal fins. Since it is a characteristic of the genus, these characters are similar in *P. brachypterus* (Fischer & Bianchi 1984). The major difference between the two species is the dorsal fin height which reaches till caudal fin lobe in *P. mento*, whereas it extends far beyond in *P. brachypterus*. In both the species, middle ray is longest in dorsal and pectoral fins. Similarly the lower jaw of the *P. mento* is little extended while in *P. brachypterus* both the jaws are sub equal when closed. The dark black spot in the dorsal fin is also a comparable character between the species; it is big and dark in *P. mento* reaching the base while smaller in *P. brachypterus* which not extended to the base of fins. In both the species, however, pectoral fins long but not reaching beyond the posterior part of anal fins. Pelvic fins medium-sized, reaching not far beyond anal fin origin, their insertion closer to anal fin origin than to pectoral fin insertion in both the species.

Dorsal and anal fin rays of *P. mento* in the present collection is 10 to11 which is within the range of 9–12 by Parin, 1986 while in *P. brachypterus* it is reported as 12–14 (Fischer & Bianchi 1984). Pre-dorsal scale of 16–20 was recorded in the present study, while it is 20–24 in *P. brachypterus* (Fischer & Bianchi 1984). According to this comprehensive examination and comparison of diagnostic morphological characters, it is confirmed the distribution of *P. mento* in Andaman waters.

Although the species is known to Western Pacific and Indian ocean from Marshall island to Japan to southern Africa and Red Sea; eastern Mediterranean from port Said to Gulf of Sirda and Near Rhodes Islands (Ben- Tuvia 1966; Fischer & Bianchi 1984; Parin 1986), the present study records a new geographic distribution of *P*. *mento*. Hence the Andaman waters as mentioned previously may harbour two *Parexocoetus* species, *P*. *brachypterus* and *P*. *mento*, similar as per the conclusion of Fischer & Bianchi (1984) from the Mediterranean Sea.

In Andaman & Nicobar Islands, both the species are caught in selective lesser sardine gill nets as bycatch. The present record on the species is an additional species to biodiversity database of fishes of Andaman waters.

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NOTE

A first distribution record of the Indian Peacock Softshell Turtle *Nilssonia hurum* (Gray, 1830) (Reptilia: Testudines: Trionychidae) from Mizoram, India

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The trionychid turtle species composition remains poorly documented in Mizoram. So far, only three turtle species under this family have been reported by previous workers. Here, we report the occurrence of the Indian Peacock Softshell Turtle *Nilssonia hurum* (Gray, 1830) based on two individuals collected from Buhchangphai and Serlui, Mizoram, India.

Chelonians are by far the most ancient quadruped vertebrates on Earth and are widely distributed in India (Das 1985, 1995, 2002). Having one of the most diverse chelonian fauna in the world, India is currently inhabited by 30 species of freshwater turtles and tortoises and six marine turtles (Ahmed et al. 2009; Das & Gupta 2015) including the recent record of *Manouria impressa* by Mital et al. (2019). Eight species of turtles belonging to the family Trionychidae (Reptilia: Chelonia) are known to occur in the country, viz., *Nilssonia gangetica*, *N. hurum*, *N. leithii*, *N. nigricans*, *Chitra indica*, *Amyda cartilaginea*, *Pelochelys cantorii*, and *Lissemys punctata* which comprises three subspecies—*L. punctata punctata*, *L. punctata andersonii*, and *L. punctata vittata* (Das 1990, 1996; Bhupathy et al. 1992; Frazier & Das 1994; Choudhury 1995; Datta 1998; Sengupta et al. 2000; Pawar & Choudhury 2000; Praschag & Gemel 2002; Praschag et al. 2011). Till date, little is known about the distribution pattern and the actual species composition of trionychid turtles in Mizoram State, however, three distinct species are currently known to occur, namely, *L. punctata*, *P. cantorii* (Matthew 2007), and *A. cartilaginea* (Pawar & Choudhury 2000; Hmar et al. 2020).

The conservation status of *N. hurum* is presently listed as Vulnerable in the IUCN Red List (Das et al. 2010), Appendix I in CITES, and is also categorized as Schedule I under Wildlife Protection Act, 1972 in India (Das & Gupta 2011). In India, it was first reported by Annandale (1912a) from Puri, Orissa (Odhisha). It is commonly

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known as the Indian Peacock Softshell Turtle, widely distributed in the northern and central parts of the Indian sub-continent; at tributaries of the rivers Indus, Ganga, Brahmaputra, and Subarnarekha (Smith 1931; Moll & Vijaya 1986). It was also reported from isolated water bodies of Maharashtra (Varghese & Tonapi 1986), Madhya Pradesh (Das 1987), Rajasthan (Bhupathy & Kumar 1988), Uttar Pradesh (Pai & Basu 1988), and Manipur (Singh 1995). There are records of *N. hurum* from several protected areas in the country such as the Pakhui Wildlife Sanctuary (Arunachal Pradesh), Mupa-Lanteng Reserve Forest (Assam), Bherihari Wildlife Sanctuary (Bihar), Hastinapur Wildlife Sanctuary and Sarnath Turtle Sanctuary (Uttar Pradesh), National Chambal Sanctuary (Madhya Pradesh), Keoladeo National Park (Rajasthan) (Rao 2001), Patbausai and Sundaridia (Assam) (Das & Saikia 2007), Kamakhya (Assam) (Purkayastha et al. 2013), Kaziranga National Park (Assam) (Basumatary & Sharma 2013), and Van Vihar National Park (Madhya Pradesh) (Manhas et al. 2018). Outside India, its distribution ranges include eastern Pakistan, Bangladesh, and Nepal (Mertens 1969; Das 1989; Mitchell & Rhodin 1996; Schleich & Kastle 2002; Noureen et al. 2008). In this paper, we report two individuals, male and female of *Nilssonia hurum* from Kolasib District which represents the first record for Mizoram State, northeastern India.

While surveying the chelonian diversity in different drainages of Kolasib District (24°–24.25° N & 93.5°–92.75° E), Mizoram, the first individual of the adult freshwater turtle was encountered and collected from Serlui drainage (24.237°N and 92.745°E; 94m), near Builum Village at around 10.30h on 27 June 2020, (Image 1). The specimen was found basking on a wooden log on the bank of a small island in the Serlui B Dam. The collection site is covered by a secondary forest type, dominated by different species of trees like *Gmelina arborea*, *Tectona grandis*, *Ficus semicordata*, *Michelia champaca*, *Bischofia javanica*, and bamboo species like *Meloccanna baccifera* and *Dendrocalamus hamiltoni*.

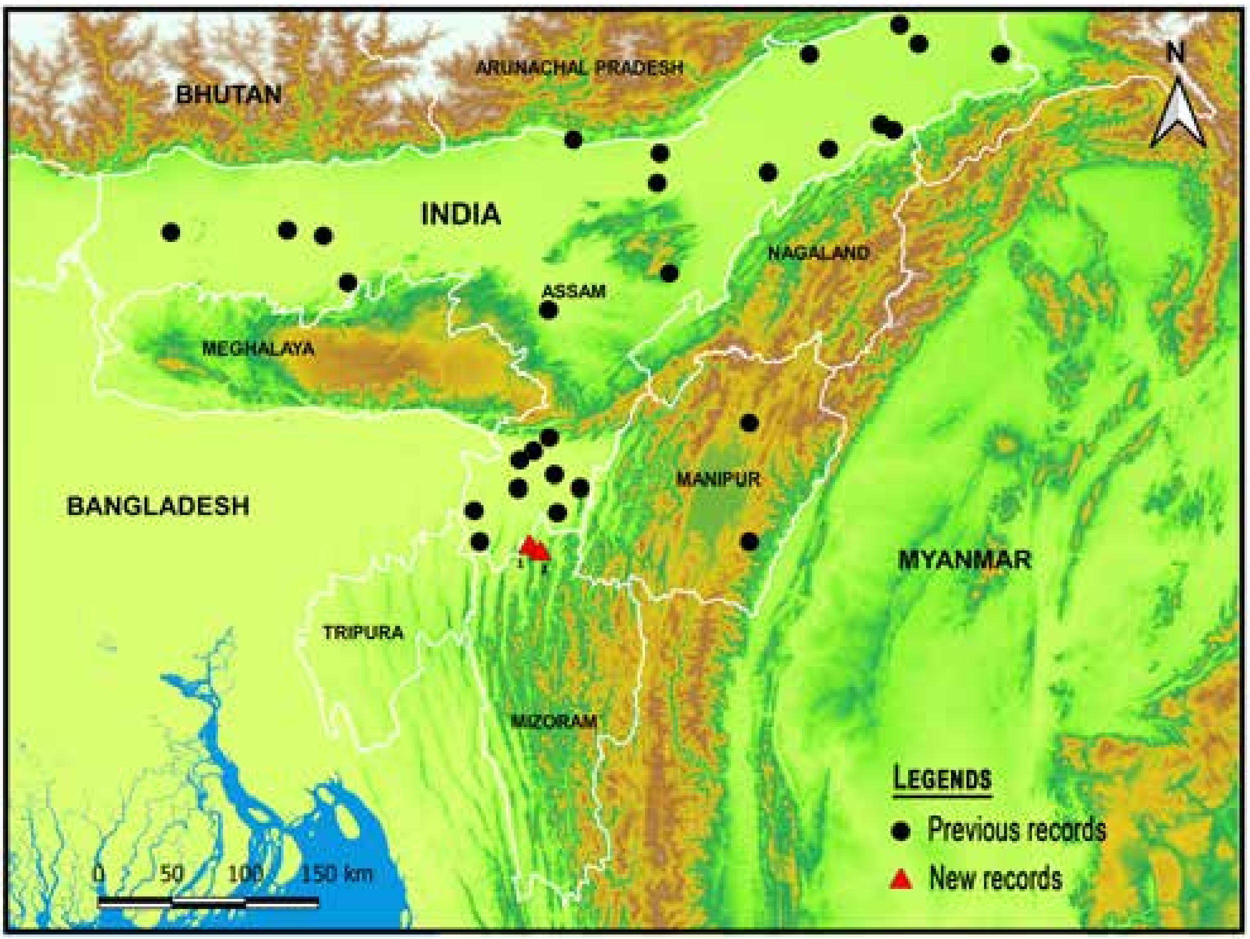

Figure 1. The distribution of *Nilssonia hurum* in northeastern India (Previous records in solid dark circles; new records in solid red triangles, i.e., 1 – Buhchangphai and 2 – Serlui).

Image 1. A—a female *Nilssonia hurum* (© Tlauliana) | B—collection site at Serlui (© Lalmuanawma).

The second individual was sighted on 23 July 2020 from a fish pond (24.324°N & 92.657°E; 52m), near Chhimluang River, Buhchangphai Village located ca. 11km to the west from the first collection site (Image 2). It was found burrowed in mud beneath the roots of *F. semicordata* on the banks of a fish pond at around 01.40h. The surrounding vegetation was mostly dominated by *T. grandis*, *F. semicordata*, *Artocarpus heterophyllus*, *M. champaca*, *Duabanga grandiflora*, and a species of bamboo like – *M. baccifera*, *D. hamiltonii* and *Bambusa tulda*.

The two individuals were identified as the Indian Peacock Softshell Turtle *Nilssonia hurum* based on the identification key provided by Annandale (1912b), Rashid & Swingland (1997), Praschag et al. (2007), and Das et al. (2010). According to Das et al. (2010), the sex of the first individual was identified as a female due to its short tail and cloaca positioned close to the base of the tail and the second one as a male as the tail is thick, long and edgeless; also, the cloaca positioned close to the

Table 1. Morphometric measurement of the observed *Nilssonia hurum* from Mizoram, India.

	Sex	Morphometric measurement (in mm)				Weight (in kg)
		Carapace length	Carapace width	Plastron length	Plastron width	
1	Male	270	185	250	180	3.16
2	Female	390	315	310	325	7.17

Image 2. A—a male *Nilssonia hurum* (© Tlauliana) | B—collection site at Buhchangphai (© Lalmuanawma).

tip of the tail. After morphometric measurements were taken with the help of a measuring tape nearest to 1mm, both individuals were handed over to the field staff to be released into the natural habitat with the permission issued by the Chief Wildlife Warden, Department of Environment, Forest and Climate Change, Government of Mizoram. Details of both individuals are given in Table 1. The individuals have a large head and snout strongly turned down; the head and limbs are olive-green; forehead with dark reticulations and large yellow or orange patches or spots, especially behind the eyes and across the snout, that are larger than those in its sister species, *N. nigricans*; carapace low and oval, dark olive green to nearly black sometimes with a yellow rim and the anterior edge has blunt tubercles. The juveniles have four striking, orange ringed dark-centered ocelli that are subequal and symmetrically positioned on an olive green carapace with dark reticulation; the markings becoming obscured with growth. The plastron is dark in juveniles, turning light grey in adults. Males possess relatively longer and thicker tails than females, with the cloaca situated close to the tail-tip. No sexual dimorphism in shell colour or patterns or size has been reported (Das et al. 2010).

Das et al. (2010) reported that the Indian Peacock Softshell Turtle utilizes rivers, lakes, and ponds, from the upper reaches of the rivers, to the lowest, while apparently avoiding the saline river mouths. Its ability to burrow into the mud may be associated with its ability to inhabit ponds and other lentic environments that may dry up during the dry season. Adults were observed to utilize deeper sections of the river, while yearlings appear to stay in the shallower parts. Rashid & Swingland (1997) mentioned that the species migrates from drying ponds, and are known to bask on the surface of the water.

The vegetation of the present surveyed area falls under the tropical wet evergreen forest and tropical semi-evergreen forest associated with moist deciduous forest corresponding to the Cachar tropical evergreen 1B/C3 and semievergreen 2B/C2 forest (Champion & Seth 1968) (Fig 1). The average annual rainfall of Kolasib District is 2,703mm and temperature ranges 23°C–35°C (NIC 2020). The closest published locality record for this species is in Rukri River, Hawaithai, Cachar District, Assam (24.5°N & 92.8° E) (Das & Gupta 2011), which is approximately 29.9km from the first distribution record and 24.9km from the latter to the south. Being the components of Barak drainage system, the three collection sites, Chhimluang, Serlui, and Rukri rivers join later in Assam that suggested the possibility of dispersal in between these two states. Due to construction of Serlui B Dam for hydroelectric power in 2006 that was completed in 2009, the dam creates a reservoir catchment area of ca. 53km^2 that drastically altered the natural habitat of these valuable species. Moreover, it had been reported that turtles and tortoises in these areas are commonly hunted for meat and trade by the local people and we suggest that a proper assessment on their conservation measures needs to be initiated.

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NOTE

A frog that eats foam: predation on the nest of *Polypedates* sp. (Rhacophoridae) by *Euphlyctis* sp. (Dicroglossidae)

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Predation is one of the most widespread foraging behaviour prevalent in the animal kingdom (Curio 1976; Taylor 1984). Amphibians, with respect to predation, generally prefer waiting for prey while being stationary as a method for foraging (i.e., ambush predation) (Duellman & Trueb 1986). It is to be noted here that visual detection is the primary method with which anurans spot prey (Freed 1988).

At least six families of amphibians are known to produce foam nests for egg laying, namely: Hylidae, Hyperoliidae, Leptodactylidae, Microhylidae, Myobatrachidae, and Rhacophoridae (Haddad et al. 1990; Andreone et al. 2005; Haddad & Prado 2005). Various hypothetical functions have been attributed to foam nests of frogs. These include inhibition to the growth of tadpoles (Pisano & Del Rio 1968), resistance to desiccation (Ryan 1985; Downie 1988), improvement towards the supply of respiratory gases (Seymour & Lovebridge 1994), regulation of temperature (Downie 1988), predator defense (Downie 1988, 1990), as a source of food (Tanaka & Nishihira 1987), and also growth acceleration (Prado et al. 2005). Predation on foam nest has previously been reported, where non-anuran species have been seen to predate on these nests in various conditions (Villa et al. 1982; Lingnau & Di-Bernardo 2006).

In this note we report a predation behaviour on the foam nest of one species of anuran (*Polypedates* sp.) by another species (*Euphlyctis* sp.).

Observations: An individual of *Euphlyctis* sp. was observed feeding on a foam nest of *Polypedates* sp. on 14 March 2020 at 09.42h (Image 1). The observation was made on top of Barunei Hills, in the Khurda District of the state of Odisha in India (20.157°N & 85.643°E, 227m). The weather was clear and sunny with an ambient temperature of 32ºC. It was an opportunistic observation made while inspecting amphibians in an ephemeral pool of water inside a small cave on top of a stunted hill. The pit was observed to harbour a community of three species of anurans—*Euphlyctis* sp., *Polypedates* sp. and a *Duttaphrynus* sp. We observed an individual of *Euphlyctis* eating, with gulping motion, from one of the foam nests of the *Polypedates* sp. that was at the side of the water pool on a rock substratum, intermittently. The observation was captured in video and photographs were created using the snapshot from the videos for visual reference. The image and video files were submitted to the Lee Kong Chian Natural

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Image 1. A—Cave on top of the stunted hill top, a habitat shot | B—Inside of the cave | C—The community of amphibian species shown | D—*Euphlyctis* sp. | E—*Euphlyctis* in the act of eating the foam nest. © Pranoy Kishore Borah & Avrajjal Ghosh.

Table 1. Accession numbers of files deposited in Lee Kong Chian Natural History Museum, Zoological Reference Collection, National University of Singapore.

File type	Accession number
Video files	ZRC(IMG) 1.195a
	ZRC(IMG) 1.195b
	ZRC(IMG) 1.195c
	ZRC(IMG) 1.195d
	ZRC(IMG) 1.195e
	ZRC(IMG) 1.195f
Snapshots from the videos	ZRC(IMG) 1.194a
	ZRC(IMG) 1.194b
	ZRC(IMG) 1.194c
	ZRC(IMG) 1.194d
	ZRC(IMG) 1.194e
Images	ZRC(IMG) 1.196a
	ZRC(IMG) 1.196b
	ZRC(IMG) 1.196c
	ZRC(IMG) 1.196d
	ZRC(IMG) 1.196e
	ZRC(IMG) 1.196f
	ZRC(IMG) 1.196g
	ZRC(IMG) 1.196h
	ZRC(IMG) 1.196i
	ZRC(IMG) 1.196j
	ZRC(IMG) 1.196k

History Museum of the National University of Singapore digital repository for reference. The accession numbers are provided in Table 1 given below. The video files have also been deposited into figshare repository (https://figshare.com/ with the following DOI: https://doi.org/10.6084/m9.figshare.12720617). After recording the aforementioned behaviour, the frog was left undisturbed. Identification of the observed individuals was conducted till genus level as it was in a field setting and no morphometrics and meristic data were collected for comparison. Hence, in that respect, it would be difficult to identify the organisms up to the species level.

Discussion: Scavenging has been reported in some species of anurans (Nishikawa & Ochi 2016; Gazdar et al. 2019). Besides predation and scavenging, oophagy and cannibalistic behaviour have also been reported from some species (Crump 1983, 1992; Rajput et al. 2011; Mahapatra et al. 2017). Predation on anuran foam nest has been reported from arthropods and snakes (Villa et al. 1982; Menin & Giaretta 2003); however, this behaviour has not been reported from anurans till date. Generally, amphibians are considered to be opportunistic in their feeding habits, in contrast, empirical studies have suggested that some species may be selective (Duellman & Trueb 1986). Feeding mechanisms in adult anurans involves a flick of the lingual region where the postero-dorsal surface becomes antero-ventral surface of the fully extended tongue (Regal & Gans 1976). In this recorded observation, however, we notice a gulping mechanism of feeding on the foam nest without the use of the lingual region.

Anurans are key components in an ecosystem serving both as predator and prey thus linking a variety of trophic levels and maintaining the trophic structure in the ecosystems (Duellman & Trueb 1986). Similar observations and further focus on these behaviours would help us understand the diversity in the range of foraging behaviour in amphibians. This will in turn help us acknowledge ecosystem dynamics in terms of interaction of trophic levels as well as interrelationships among different families of amphibians with respect to predator and prey relationships.

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Threatened Taxa

Erratum

Marler, T.E. & A.J. Lindstrom (2020). Leaf nutrients of two *Cycas* L. species contrast among in situ and ex situ locations. *Journal of Threatened Taxa* 12(13): 16831–16839. https://doi.org/10.11609/jott.6205.12.13.16831-16839

Table 2. Green leaf nitrogen concentration (mg·g^{-1}) of *Cycas micronesica* and *Cycas nongnoochiae* plants in various locations. Ex situ sites included Chonburi, Thailand (curated by Nong Nooch Tropical Botanical Garden) and Angeles City, Philippines (curated by University of Guam).

Header should read:

Cycas Genotype	Site	In situ	Ex situ	t	p

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NOTE

New distribution record of two endemic plant species, *Euphorbia kadapensis* Sarojin. & R.R.V. Raju (Euphorbiaceae) and *Lepidagathis keralensis* Madhus. & N.P. Singh (Acanthaceae), for Karnataka, India

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Euphorbia L., sensu lato is a cosmopolitan genus distributed almost throughout the world. It comprises 1,836 species in the world, of which 84 species indigenous or naturalized and three species are cultivated in India (Binojkumar & Balakrishnan 2010, 2012). Recently *Euphorbia kadapensis* Sarojin. & R.R.V. Raju (2014), *Euphorbia gokakensis* S.R. Yadav, Malpure & Chandore (2016), and *Euphorbia seshachalamensis* Prasad & Prasanna (2016) were added to the Indian flora as new species.

Lepidagathis Willd. comprises about 100 species, mainly distributed in the tropical and warm regions of the world (Mabberley 2017). In India, the genus is represented by 23 species and eight varieties, among them 15 species are endemic to the Western Ghats and Eastern Ghats of southern India (Nayar et al. 2014; Singh et al. 2015).

During a recent botanical exploration in Karnataka State, we collected specimens of two interesting species of the genera *Euphorbia* and *Lepidagathis*. After thorough scrutiny in previously published Floras and research articles (Binojkumar & Balakrishnan 2010, 2012; Sarojinidevi & Reddivenkatraju 2014; Madhusoodanan & Singh 1992), they were identified as *E. kadapensis* Sarojin. & R.R.V. Raju (Euphorbiaceae), endemic to Andhra Pradesh and *L. keralensis* Madhus. & N.P. Singh (Acanthaceae), an endemic species of Kerala. *Euphorbia kadapenis* was described by Sarojinidevi & Raju in 2014 from the Kadappa District of Andhra Pradesh while *L. keralensis* was described by Madhusoodanan & Singh in 1992 from the west coast of Kerala and so far has not been reported from Karnataka. Hence the present collections form new distributional records of the species for Karnataka. A brief description, distribution and photographs are provided here for easy identification.

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Euphorbiaceae

Euphorbia kadapensis Sarojin. & R.R.V. Raju
Phytotaxa 181(3): 179, ff. 1–2. 2014. (Image 1, 2)

Slender herb, erect–decumbent, 10–25 cm long. Stem terete, dichotomously branched, greenish-pink, glabrous–sparsely pubescent, nodes thickened, latex milky; stipules scaly, 1mm long, shortly laciniate. Leaves simple, opposite, oblong, 5–20 × 3.5–9.5 mm, base oblique, apex obtusely acute, margins distantly serrulate, apiculate, glabrous, glaucous beneath, mid-nerve prominent, lateral nerves 4–7 pairs. Petioles 1–1.5 mm long. Cyathia terminal and subterminal. Involucre turbinate, ca 4 × 2 mm, glabrous; lobes 5, laciniate; glands 4, yellow, appendages of glands 2 × 2 mm, white–pink. Pistillate flowers 5.5 × 3.0 mm, glabrous, pedicel 2.5–3 mm long; pistil tricarpellary; style 3, free from base, 2mm long; stigma simple. Fruiting pedicel pendulous. Capsule trigonus, glabrous, 3–4 mm long; seeds 3, brownish, 2 × 1.5 mm, oblong–ovate, tetragonal, transversely ridged, truncate at base,

Specimens Examined: Karnataka: Yadgiri District, Royangole, 16.280°N & 76.393°E, 484m, 01.ix.2017, *P. Raja* 2586. Belagavi District, Midukanatti, 16.022°N & 74.768°E at 742m, 07.x.2017, P. Raja 2407.

Flowering & Fruiting: September to November.

Habitat & Ecology: This species is located at dry deciduous forests and are associated with *Dodonaea viscosa* (L.) Jacq., *Mundulea sericea* (Willd.) A.Chev., *Cyanotis tuberosa* (Roxb.) Schsult. & Schult.f., *Phyllanthus maderaspatensis* L. and *Oropetium thomaeum* (L.f.) Trin.

Distribution: Endemic to peninsular India previously known only from the Kadappa District of Andhra Pradesh. Now its distribution is extended up to Karnataka.

IUCN status: Not evaluated.

Acanthaceae

Lepidagathis keralensis Madhus. & N.P. Singh
Kew Bull. 47: 301, f.3. 1992. (Image 3)

Prostrate herb, rootstock woody. Stem quadrangular, much branched, rooting at nodes, glabrous. Leaves oblong–lanceolate, 10 × 3 mm, base acute, apex acute–acuminate, margins entire with purple, glabrous, nerves prominent, 3–4 pairs. Spikes 1–3, terminal, procumbent, 2cm long. Flowers pink with yellow palate, sessile, 1cm

Image 1. *Euphorbia kadapensis* Sarojin. & R.R.V. Raju.

Image 2. Herbarium sheet of *Euphorbia kadapensis.*

Image 2. Herbarium sheet of *Lepidagathis keralensis.*

long; sterile bracts many, oblong–lanceolate, 10–13 × 3.5–4.0 mm, densely pubescent, 5-nerved, sharply pointed mucronate at apex, ca 1.5mm long, persistent. Calyx deeply 5-lobed; lobes unequal, 8–8.5 × 2–2.5 mm, persistent, similar to bracts, villous. Corolla 8.5–10.0 mm long, densely pubescent in bud, tube cylindric below, ca 3mm long, 2-lipped; upper lip 2-lobed, erect or reflexed; lower lip 3-lobed. Stamens 4, didynamous, ca 6 mm long, sparsely hairy, anthers 2-celled, 1.5–2.0 mm long, pubescent. Disc annular. Pistil ca 8 mm long; ovary subglobose–ovoid, 1.5–2.0 mm long, 2-celled, glabrous, ovules 2; style slender, 6.5–8.0 mm long, pubescent at lower ventral region with glands; stigma capitate, slightly bifid. Capsule compressed, ca 6mm long, glabrous; seeds 2, flat, soft, pubescent with white aril.

Specimens examined: Karnataka, Udupi District, Hiriadica, 13.303°N & 74.855°E at 37m, 25 March 2018, P. Raja, 2529.

Flowering & Fruiting: February to April.

Habitat & Ecology: This species is found growing in open places at the forest border, with *Naregamia alata* Wight & Arn., *Ixora coccinea* L., and *Canthium coromandelicum* (Burm.f.) Alston.

Distribution: Endemic to peninsular India in the western coast of Kerala and Karnataka at low elevations.

IUCN status: Not evaluated

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NOTE

Cirsium wallichii DC. (Asteraceae): a key nectar source of butterflies

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In general, both larvae and adult butterflies depend on plant resources (Kitahara et al. 2008; Nimbalkar et al. 2011). Adult butterflies forage on a wide variety of plant species for floral nectar (Courtney 1986; Raju et al. 2004). Butterflies, however, do not collect nectar extensively from all the available flowers (Kunte 2000). Thus, the diversity of the butterfly community of a region is associated with the availability of host plants (Murphy & Wilcox 1986; Kitahara et al. 2008). Also, the diversity and abundance of pollinators such as butterflies are crucial for the reproductive success of flowering plants (Mukherjee et al. 2015). Several wild plants considered as weeds serve as important nectar sources for butterflies (Mukherjee et al. 2015; Kapkoti et al. 2016). One such wild weed, *Cirsium* Mill. (Thistle) of the family Asteraceae has been well recognized as a nectar source of butterflies (Robertson 1928; Tooker et al. 2002; Kapkoti et al. 2016). *Cirsium* is a speciose genus of Asteraceae, with about 200 species distributed in Europe, Asia, North & Central America, and northern Africa (Mabberley 2008; Sahli et al. 2017). Among the species of this genus known from India, *Cirsium wallichii* DC. has been extensively used as a traditional medicinal plant in the Himalaya (Uniyal et al. 2011). Interestingly, owing to a lack of information on *Cirsium wallichii* DC. as a nectar source of butterflies, the current communication aims to address the value of Wallichii's Thistle not only as a weed, but also as a nectar source of butterflies.

The present study was conducted from May to August, 2019 in Benog Wildlife Sanctuary (30.467°N & 78.027°E), Mussoorie, Uttarakhand, India. The sanctuary is characterized by Banj Oak *Quercus leucotrichophora* forests, Chirpine *Pinus roxburghii* forests and grasslands (Champion & Seth 1968) which harbour at least 335 species of vascular plants (Kumar et al. 2012). The survey was done between 08.00h and 11.00h to record the butterfly species visiting *Cirsium wallichii*. We photographed representatives of each butterfly species from the area. Based on the photographs, identification of the species was carried out using Evans (1932) and Kehimkar (2016).

Cirsium wallichii grows along open and modified stream habitats in the sanctuary as well as near human settlements and agricultural lands at the peripheral area (Image 1A). Leaves are stalkless and pinnately lobed with long spines at the margin. The plant blooms from May–July. Capitula are many-flowered, solitary or clustered and borne on leafless stalks. They are 2–3.4cm

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Table 1. List of butterfly species foraging on *Cirsium wallichii*

	Scientific name	Common name
A.	**Family: Papilionidae**	
1.	*Graphium sarpedon* (Linnaeus, 1758)	Common Bluebottle
2.	*Graphium cloanthus* (Westwood, 1841)	Glassy Bluebottle
3.	*Graphium agamemnon* (Linnaeus, 1758)	Tailed Jay
4.	*Papilio protenor* Cramer, [1775]	Spangle
5.	*Papilio bianor* Cramer, [1777]	Common Peacock
6.	*Papilio polytes* Linnaeus, 1758	Common Mormon
B.	**Family: Pieridae**	
7.	*Aporia agathon caphusa* (Moore, 1872)	Garhwal Great Blackvein
8.	*Aporia agathon agathon* (Gray, 1831)	Nepalese Great Blackvein
9.	*Aporia leucodice* (Eversmann, 1843)	Himalayan Blackvein
10.	*Colias erate* (Esper, 1805)	Pale Clouded Yellow
11.	*Colias fieldii* Ménétriés, 1855	Dark Clouded Yellow
12.	*Pieris brassicae* (Linnaeus, 1758)	Large Cabbage White
13.	*Pieris canidia* (Linnaeus, 1768)	Indian Cabbage White
14.	*Gonepteryx rhamni* Linnaeus, 1758	Common Brimstone
15.	*Pontia daplidice* (Linnaeus, 1758)	Bath White
16.	*Belenois aurota* (Fabricius, 1793)	Pioneer
C.	**Family: Lycaenidae**	
17.	*Heliophorus sena* (Kollar, [1844])	Sorrel Sapphire
18.	*Spindasis nipalicus* (Moore, 1884)	Silver-grey Silverline
19.	*Rapala selira* (Moore, 1874)	Himalayan Red Flash
20.	*Rapala varuna* (Horsfield, [1829])	Indigo Flash
21.	*Rapala manea* (Hewitson, 1863)	Slate Flash
22.	*Aricia agestis* (Denis & Schiffermüller, 1775)	Orange-bordered Argus
23.	*Lycaena phlaeas* (Linnaeus, 1761)	Common Copper
24.	*Lampides boeticus* (Linnaeus, 1767)	Pea Blue
25.	*Chilades pandava* (Horsfield, [1829])	Plains Cupid
26.	*Celastrina huegelii* (Moore, 1882)	Large Hedge Blue
27.	*Deudorix epijarbas* (Moore, [1858])	Cornelian
D.	**Family: Nymphalidae**	
28.	*Vanessa indica* Herbst, 1794	Red Admiral
29.	*Vanessa cardui* Linnaeus, 1758	Painted Lady
30.	*Kaniska canace* Linnaeus, 1763	Blue Admiral
31.	*Aglais caschmirensis* Kollar, 1844	Indian Tortoiseshell
32.	*Callerebia annada caeca* Moore, 1857	Ringed Argus
33.	*Callerebia hybrida* Butler, 1880	Hybrid Argus
34.	*Callerebia nirmala* Moore, 1865	Common Argus
35.	*Argynnis hyperbius* (Linnaeus, 1763)	Indian Fritillary
36.	*Ypthima nareda* Kollar, 1844	Large Three-Ring
37.	*Ypthima nikaea* Moore, 1874	Moore's Five-Ring
38.	*Parantica aglea* (Stoll, [1782])	Glassy Tiger
39.	*Tirumala limniace* (Cramer, [1775])	Blue Tiger
40.	*Tirumala septentrionis* (Butler, 1874)	Dark Blue Tiger
41.	*Danaus genutia* (Cramer, [1779])	Striped Tiger
42.	*Danaus chrysippus* (Linnaeus, 1758)	Plain Tiger
43.	*Euploea mulciber* (Cramer, [1777])	Striped Blue Crow
44.	*Argynnis childreni* Gray, 1831	Large Silver stripe
45.	*Libythea lepita* Moore, [1858]	Common Beak
46.	*Lasiommata schakra* Kollar, 1844	Common Wall
47.	*Acraea issoria* (Hübner, [1819])	Yellow Coster
48.	*Cyrestis thyodamas* Doyère, [1840]	Common Map
49.	*Junonia iphita* Cramer, 1779	Chocolate Pansy
E.	**Family: Hesperiidae**	
50.	*Seseria dohertyi* Watson, 1893	Himalayan White Flat
51.	*Potanthus dara* (Kollar, [1844])	Himalayan Dart
52.	*Celaenorrhinus leucocera* (Kollar, [1844])	Common Spotted Flat
53.	*Lobocla liliana* Atkinson, 1871	Marbled Flat
54.	*Celaenorrhinus dhanada* (Moore, [1866])	Himalayan Yellow-banded Flat
55.	*Pseudocoladenia dan* (Fabricius, 1787)	Fulvous Pied Flat
56.	*Tagiades menaka* Moore, 1865	Spotted Snow Flat
57.	*Celaenorrhinus munda* Moore, 1884	Himalayan Spotted Flat
58.	*Aeromachus stigmata* Moore, 1878	Veined Scrub Hopper
59.	*Notocrypta feisthamelii* Boisduval, 1832	Spotted Demon
60.	*Pedesta masuriensis* Moore, 1878	Mussoorie Bush Bob
61.	*Polytremis discreta* (Elwes & Edwards, 1897)	Himalayan Swift
62.	*Parnara* sp.	Swift sp.

Image 1. *Cirsium wallichii*: A—habit | B—inflorescence | C—flower. © Bitupan Boruah.

across, homogamous, bisexual, discoid, and clustered in corymbose racemes (Image 1B). Florets are about 2cm long, pale-white, corolla tube long, limb five-toothed and pappus hair pale-white. Outer involucre bracts are lanceolate with spreading erect or recurved spines; inner bracts dilated, lanceolate-ovate and incurved near the apex (Image 1C).

During recent field explorations in the Benog Wildlife Sanctuary, a total of 62 species and sub-species of butterflies belonging to 45 genera and five families foraging on *Cirsium wallichii* for nectar were documented (Table 1 and Images 2–5). The species assemblage includes Nymphalidae (35.5%), Hesperiidae (22.6%), Lycaenidae (17.7%), Pieridae (16.1%) and Papilionidae (9.7%). Among the recorded butterflies, five species such as *Aporia agathon*, *Gonepteryx rhamni*, *Celaenorrhinus munda*, *Vanessa cardui*, and *Vanessa indica* frequently visited the flowers for nectar while *Pontia daplidice* and *Callerebia nirmala* were recorded only once visiting the flowers. We also observed *Vanessa cardui* (Nymphalidae) utilizing *C. wallichii* as a larval host plant. During the study period, *C. wallichii* was the only species that attracted diverse butterfly species.

Cirsium has been studied in terms of nectar source by several workers such as Robertson (1928) who reported 14 species of Lepidoptera foraging on *C. vulgare*, eight species on *C. altissimum* and nine species each on *C. discolor* and *C. pumilum*. Thirty-three pollinators including 15 species of butterflies visiting *C. verutum* have been reported from the western Himalaya (Kapkoti et al. 2016). Although, it is used as a medicinal plant by the tribal people of the Himalaya (Uniyal et al. 2011), *C. wallichii* has never been reported as an important forage. The present communication highlights the importance of *C. wallichii* as a key nectar source for a large number of butterfly species though the plant is considered as a weed. The visits of several species of butterflies to *C. wallichii* could be attributed to the

Image 2. Butterfly species visiting *Cirsium wallichii*: A—*Celaenorrhinus dhanada* | B—*Seseria dohertyi* | C—*Lobocla liliana* | D—*Celaenorrhinus munda* | E—*Aeromachus stigmata* | F—*Pedesta masuriensis* | G—*Potanthus dara* | H—*Notocrypta feisthamelii* | I—*Polytremis discrete* | J—*Parnara* sp. | K—*Celastrina huegelii* | L—*Chilades pandava*. © Bitupan Boruah.

Image 3. Butterfly species visiting *Cirsium wallichii*. A—*Rapala manea* | B—*Lycaena phlaeas* | C—*Heliophorus sena* | D—*Spindasis nipalicus* | E—*Deudorix epijarbas* | F—*Lampides boeticus* | G—*Belenois aurota* | H—*Pontia daplidice* | I—*Gonepteryx rhamni* | J—*Pieris brassicae* | K—*Aporia leucodice* | L—*Colias fieldii*. © Bitupan Boruah.

Image 4. Butterfly species visiting *Cirsium wallichii*: A—*Colias erate* | B—*Aporia agathon caphusa* | C—*Aporia agathon agathon* | D—*Papilio bianor* | E—*Graphium agamemnon* | F—*Graphium sarpedon* | G—*Graphium cloanthus* | H—*Papilio protenor* | I—*Danaus genutia* | J—*Parantica aglea* | K—*Argynnis childreni* | L—*Lasiommata schakra*. © Bitupan Boruah.

Image 5. Butterfly species visiting *Cirsium wallichii*: A & B—*Vanessa cardui* | C—*Ypthima nareda* | D & E—*Argynnis hyperbius* | F—*Aglais caschmirensis* | G & H—*Vanessa indica* | I—*Callerebia annada caeca* | J—*Callerebia nirmala* | K & L—*Euploea mulciber*. © Bitupan Boruah.

hexose-rich sugar and strong amino acid content in the florets. This characteristic of the plants belonging to the family Asteraceae has been reported by Baker & Baker (1983). As observed on *Wendlandia tinctoria* (Raju et al. 2011), clustered flowering of *C. wallichii* also have benefited the butterflies thus, reducing searching time. Thistle in the Himalaya such as *C. verutum* has been found as an important forage (Kapkoti et al. 2016) and it proves to be an important resource for butterflies in the Benog Wildlife Sanctuary, Mussoorie. This study indicates that there is a need for further studies to understand the role of *C. wallichii* in sustaining butterfly diversity at landscape level during summer season.

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NOTE

Hypecoum pendulum L. (Papaveraceae: Ranunculales): a new record for the flora of Haryana, India

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Genus *Hypecoum* Tourn. ex L. is the only member of subfamily Hypecooideae Prantl & Kundig belonging to the family Papaveraceae Juss. (Stevens 2001). It is represented by 15–20 species all over the world, with its distribution range from southern France, the Mediterranean region, northern Africa to southwestern Asia (Mabberley 2017; POWO 2019). In India, the genus is represented by three taxa within two species: *Hypecoum leptocarpum* Hook.f. & Thomson, *H. pendulum* L. var. *pendulum* and *H. pendulum* var. *parviflorum* (Kar. & Kir.) Cullen (Debnath & Nayar 1984; Ellis & Balakrishnan 1993; Kundu 2008). Debnath & Nayar (1984, p.46) have mentioned two varieties of *H. pendulum* as closely allied with overlapping characters. Currently, *H. pendulum* var. *pendulum* and *H. pendulum* var. *parviflorum* are considered synonyms of *H. pendulum* in POWO (2019), WFO (2020). Two known species in India (*H. leptocarpum* and *H. pendulum*) can be easily differentiated based on distinctly yellow flowers, mid lobe of inner petal being fimbriate, fruits larger, 30–75 mm long, and drooping on curved pedicel in *H. pendulum* in comparison to pinkish-violet to white flowers, mid lobe of inner petal being non-fimbriate, fruits smaller, 12–30 mm long, and erect at maturity in *H. leptocarpum* (Ellis & Balakrishnan 1993).

During a botanical exploration, the first author came across an interesting wild herb growing around the cultivated fields, near Satrod Kalan Village of Hisar District, Haryana State. The number of individuals were very few and scattered, thus only three specimens were collected for reference and photographs were recorded in the field. After a detailed study of the relevant literature (Debnath & Nayar 1984; Ellis & Balakrishnan 1993), and studying the available herbarium records, these specimens were identified as *Hypecoum pendulum* L. This species was recorded for the first time in India from Kashmir (Singh 1975) and later from Rajasthan (Sharma 1976). As there is no previous record of *H. pendulum* L. in the published botanical literature for Haryana State (Jain et al. 2000; Kumar 2001), it is hereby being reported as the first authentic distribution record from the state. The collected voucher specimens (Image 2), have been deposited in the herbarium of Department of Botany, Kurukshetra University, Kurukshetra, Haryana.

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Hypecoum pendulum L.,

Sp. Pl. 124, 1753; Singh in Geobios 2: 91. 1975; H.S. Debnath & M.P. Nayar, Fasc. Fl. India 17: 45. 1984; J.L. Ellis & N.P. Balakr. in B.D. Sharma & N.P. Balakr., Fl. India 2: 87. 1993. *H. procumbens* auct non. L.; Hook. f. & Thomson in Fl. Ind. 275, 1855 and in Hook. f., Fl. Brit. India 1: 120, 1872; Sharma in J. Bombay Nat. Hist. Soc. 73: 422–423, 1976.

Annual, procumbent, glaucous herb, about 5–30 cm tall, tap root well developed. Radical leaves many, forming a rosette at base, 3–10 cm long, petiole flat; lamina 2–3 pinnatisect, segments linear to setaceous, 2–6 mm long, apex acute; cauline leaves sub-opposite, palmatisect. Flowering stems many, dichotomously branched; inflorescence terminal, few-flowered cyme. Flowers small, ca. 5mm across, yellow, pedicellate; pedicel 5–12 mm long, nutant after flowering; bracts narrowly lobed; sepals two, 1.5–2 mm, broadly obovate, deciduous; petals four, yellow, two-whorled; outer one rhomboid, inner one tripartite; middle lobe fimbriate, spathulate, longer than the lateral two; lateral lobes elliptic-oblong, partially divergent, spotted with maroon-black dots. Stamens four, opposite to petals, filaments black-spotted, two glands at the base of each filament, anthers yellow, linear; ovary cylindrical, stigmas two, recurved. Fruits 3–7 cm long, pendulous, lomentaceous; seeds very small, brown in colour (Image 1).

Specimens examined: KUK- NP 127, 19.iii.2017, 29.107°N & 75.815°E, 210m, Satrod Kalan, Hisar, Haryana, coll. Naina; KUK- NP 151, 20.iv.2020, 29.084°N & 75.795°E, 210m, Tibba, Ladwa, Hisar, Haryana, coll. Naina; K000283528!; K000283530! (Digital images at Kew Herbarium); E00392708! (Digital image at Edinburgh Herbarium).

H. pendulum L. naturally grows in dry and sandy soils along with some other herbs like *Arnebia hispidissima* (Lehm.) A. DC., *Heliotropium curassavicum* L., *Asphodelus tenuifolius* Cav. etc. The plant is rare in the area, and may usually remain unnoticed due to dissected, grass-like foliage and small, dull yellow flowers. In the vegetative phase, it can easily be overlooked for being any monocot. Besides, the fragmented or patchy distribution, the very short flowering-fruiting period also forms the cause behind this being unnoticed. During a recent visit in April, 2020 to a surrounding area, 50–60 individuals were found growing on sandy cliffs, locally

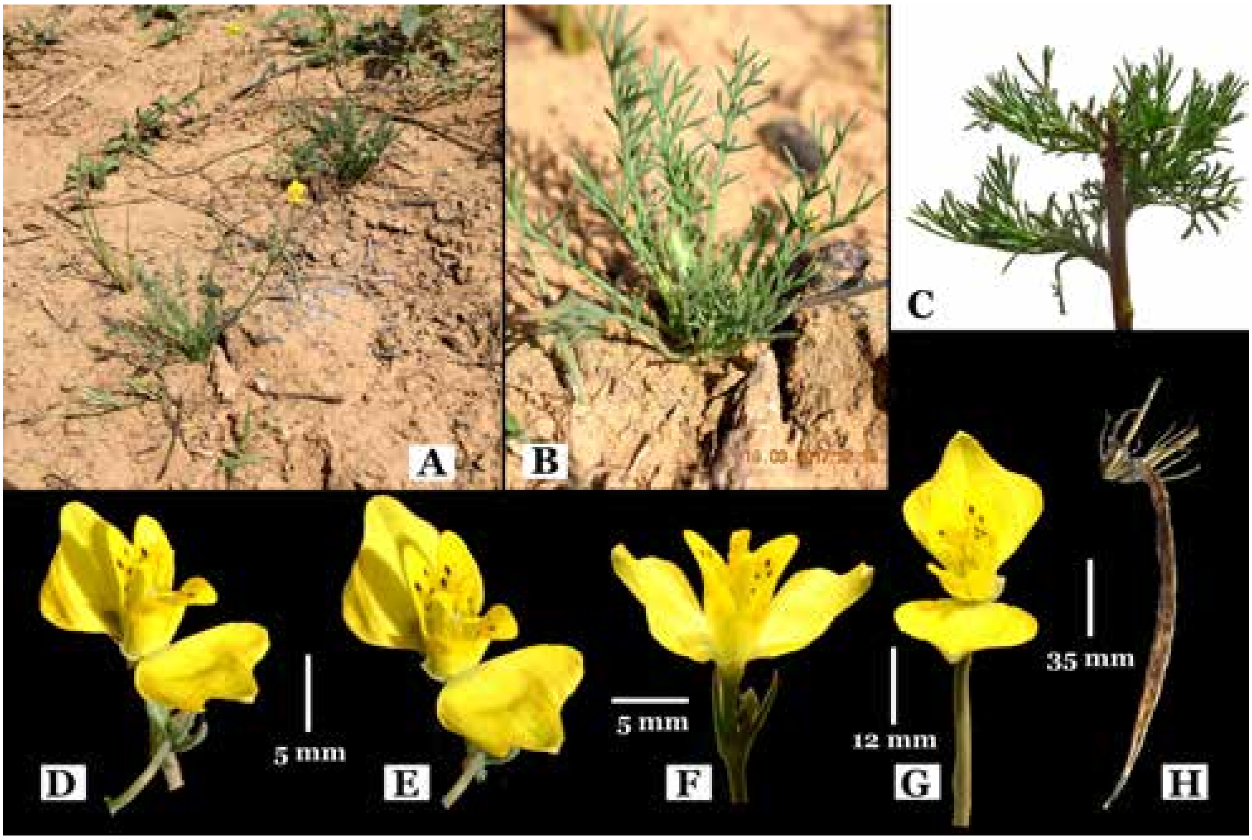

Image 1. A–H—*Hypecoum pendulum* L.: A—habitat | B & C—habit & leaves | D & E—flower-anterio-posterior view | F—flower-lateral view | G—pedicel-bearing flower | H—fruit (dried, image recorded from collection). © Naina Palria.

Image 2. Voucher specimen of *Hypecoum pendulum* L. from the locality of study. Photo by Naina Palria.

named as "Tibba", in Ladwa Village, Hisar District.

Flowering: April–May; Fruiting: May–August.

Distribution in India: Haryana, Jammu & Kashmir, Rajasthan.

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ADDENDUM

Erratum and addenda to the article 'A history of primatology in India'

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Erratum

Suraj Mal Mohnot should be read as Surendra Mal Mohnot.

Addenda

In 1968, Robert H. Horwich of the Chicago Zoological Society, USA, came to India and studied the devastating impact of replacing Eucalyptus trees in the place of natural forest in the evergreen shola areas of the Nilgiri Mountains, causing the decline of indigenous fauna such as Nilgiri Langur (Horwich 1972). After that, he joined the Golden Langur Conservation Project to extend the work of the Indo-US Primate Project of 1994–2001, and was involved in community-based conservation programs in the Manas Biosphere Reserve (Horwich et al. 2010, 2013).

Awadhesh Pratap Singh University

Shivesh Pratap Singh (Singh 1984) carried out studies in Mand Reserve Forest, Madhya Pradesh, on habitat use and feeding by Hanuman Langurs and Rhesus Macaques. Later, his students worked on langurs and Rhesus Macaques in various parts of Satna District of Madhya Pradesh. Ravish Vachaspati Gautam (Gautam 2003) studied the feeding ecology and habitat utilization of langurs and Chetna Sharma (Sharma 2018) studied habitat utilization and feeding habits of Rhesus Macaques. A population survey was conducted from 2014 to 2015 in which a population density of 34.5 per km^2 was estimated in 2014, while 37.5 per km^2 was estimated in 2015 in Kardmeshwerdham Hill and 23.2 per km^2 was estimated in 2014, and finally 24.8 per km^2 was estimated in 2015 in Babupur Kaniyari. The adult male-female sex ratio of the Babupur Kaniyari group ranged from 1:3 to 1:3.5, while the Kardmeshwerdham group was found with an adult male-female sex ratio of 1:2.75 to 1:3.25.

Saurashtra University

S.F. Wesley Sunderraj (Sunderraj 1998) studied the ecology of Nilgiri Langur in Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu. Groups were uni-male with an average size of 18.5. Births peaked in May and November. These langurs fed on 219 food items from 102 plant species.

Arizona State University

Kaberi Kar-Gupta (Kar-Gupta 2008 (http://copus.org/meet-kaberi-kar-gupta/)) studied the ecology of Slender Loris *Loris tardigradus* in Kalakkad-Mundanthurai Tiger Reserve (KMTR), India. She observed that males have different mating strategies that include roamers with

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large ranges and with access to many females, and settlers either without any female or associated with a female as a pair. These observation dispelled the previous notion that Slender Loris had a simple mating system.

Assam University

Anup Dey (Dey 2015) studied the status and distribution of Hoolock Gibbon in select reserve forest of Karimganj District, Assam. The level of anthropogenic disturbance (poaching, logging, jhum cultivation, and agricultural encroachment) had a significant impact on gibbon population. The study identified that the Patharia Reserve Forest was a better site for gibbon survival among all the forests in the district.

Mitrajit Deb (Deb 2018 (https://www.researchgate.net/profile/Mitrajit_Deb)) reported that Western Hoolock Gibbons that are known to be frugivores are consuming more leaves due to a dearth of fruiting trees. Loss of fruiting trees diminish habitat quality, and this may lead to severe nutritional stress in future. The study recommends taking up conservation programmes at a village council level (gram panchayats) to arrive at a participatory biodiversity conservation plan.

Pondicherry University

S. Rajeshkumar (Rajeshkumar 2017) reported that Nicobar Long-tailed Macaques inhabit natural habitats much of the time and consume food from a wide variety of plant species, but human settlements and agricultural activities often lead to numerous human-macaque hostilities that can enhance agonistic activities leading to severe fatality among individuals.

North Eastern Regional Institute of Science and Technology, Nirjuli, India

Parimal Chandra Ray (Ray 2017 (https://www.researchgate.net/profile/Parimal_Ray4)) identified the population structure of 10 preferred food tree species of the Western Hoolock Gibbon, of which only two, *Chukrasia velutina* and *Alianthus integrifolia*, had a reasonably good population structure. The level of anthropogenic disturbance had a significant impact on the variation of the population and regeneration status of those food plants of the gibbon.

Diana Ethel Amonge (Amonge 2019) studied various reproductive aspects of Eastern Hoolock Gibbon in Conservation Breeding Centre, Biological Park, Itanagar. She documented 94 mating attempts in which there were maximum attempts in January and minimum attempts in July. The estimated duration of each copulation was 28.4±1.2 seconds. The period of gestation was 189±0.92 days (n=14) and the average interval of birth for females whose infants survived or died after birth was 3.1±0.3 years and 1.5±0.2 years, respectively.

Tezpur University

Bidyut Sarania (Sarania 2019 (https://www.researchgate.net/profile/Bidyut_Sarania3)) recorded a total of 969 individuals comprising 41 troops (mean troop size was 23.63±1.21) of *Macaca munzala* from western Arunachal Pradesh within the altitudinal range of 1,400–3,000 m. The behavioral activities and the ranging pattern of *M. munzala* are significantly influenced by the seasonal availability of food items. It was found that only 2.4% of the landmass of the state was the possible habitat of the species.

Gauhati University

Anindita Chakravarty (Chakravarty 2020 (http://www.bijnicollege.ac.in/Departments/Science/Employee%20Profile.aspx?did=12&eid=54)) studied the habitat utilization pattern, feeding, and population ecology of the Golden Langur in Kakoijana Reserve Forest, Assam. A total of 121 plant species comprising trees, shrubs, herbs and climbers used by Golden Langur as food items were recorded. Langurs were found to feed actively on *Cyathea gigantea* (Tree fern) along with *Diplazium esculentum* (Dhekia, a well-known edible fern of Assam), and mature leaves of *Lygodium microphyllum*.

Mizoram University

Abinash Parida (Parida 2020 (https://www.researchgate.net/profile/Abinash_Parida2)) found that Phayre's Leaf Monkeys feed on eight different plants spending ≥90% of their feeding time on *Musa ornata*, *Melacanna baccifera*, and *Dendrocalamus longispathus* and about ≥80% *Musa balbisiana*, *Gmelina arborea*, and *Buettneria pilosa*. The male-female ratio was 1:7 and the group size was 15.1±1.1.

Phoebe Laremruati (Laremruati 2020 (https://www.researchgate.net/profile/Phoebe_Lalremruati)) studied the behavior of the Pig-tailed Macaques *Macaca leonina* in captivity. Adult females spent most of their time grooming, followed by juvenile females, juvenile males, and adult males. The male infants attain independence earlier than the female infants. The rate of infection with gastrointestinal parasites was 61.82% in spite of all the anthelmintic treatments given. The monkeys breed during October and March.

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