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Caption: *Cyrtodactylus myintkyawthurai*, endemic to Myanmar. Medium: Water colours on watercolor sheet. © Aakanksha Komanduri

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ARTICLE

Estimating the completeness of orchid checklists and atlases: a case study from southern Italy

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Abstract: Checklists and atlases are important tools for knowledge of the biodiversity of a geographic unit. Nevertheless, they often suffer from bias due to preferential sampling. It is important to assess the level of completeness of the data collected during such research to allow comparison of the biodiversity of different areas, or to use them for macroecology, biogeography or conservation purposes. This assessment is not trivial, especially when information from heterogeneous sources is used (e.g., herbaria specimens, field observations, literature data). The author suggests some simple methods to assess the completeness of floristic database and to represent the distribution of the completeness at a scale level appropriate to the size of the studied area or, on another hand, to the precision level of the available data. Such information is useful to direct the surveys identifying less explored areas or habitats and thereby correcting the sampling biases. Adding information about sampling effort or completeness could be very useful to make floristic research more objective.

Keywords: European orchids, floristic studies, sampling effort, species richness estimators, completeness, citizen science.

Riassunto: le checklist e gli atlanti floristici sono strumenti importantissimi per la conoscenza della biodiversità. Tuttavia essi sono realizzati senza un design sperimentale e sono soggetti a bias dovuto soprattutto al campionamento preferenziale. E' comunque importante, soprattutto quando questi studi si basano su informazioni derivanti da fonti eterogenee (campioni d'erbario, osservazioni in campo, dati bibliografici, ecc.) valutare il loro grado di completezza per poter confrontare la biodiversità di diverse aree geografiche o per eseguire analisi macroecologiche, biogeografiche e per la valutazione dello stato di conservazione. L'autore propone alcuni semplici metodi per stimare l'esaustività dei dati floristici, rappresentare la distribuzione della completezza a scale adeguate da una parte alla dimensione dell'area oggetto di studio e dall'altra al livello di precisione dei dati a disposizione. Tali informazioni sono utili anche per orientare le ricerche nel territorio, individuando aree o habitat meno esplorati e correggendo i bias di campionamento. L'aggiunta di informazioni sullo sforzo di campionamento e la completezza delle ricerche può essere utile a conferire agli studi floristici di base una maggiore oggettività.

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INTRODUCTION

Floristic inventories or check lists and atlases are important tools for assessing biodiversity and addressing its conservation (Vallet et al. 2012). They are often the result of careful and time-consuming researches conducted in specific geographic units, focused on vascular plants or on smaller taxonomic group such as Orchidaceae, one of the largest and most widespread family of flowering plants (Dressler 1981; WCSPF 2019). The presence and distribution of species of this family have been assessed at different scales as most of them are rare, threatened or endangered (Cribb et al. 2003). A checklist is a "card collection" aiming at listing all the taxa belonging to the studied taxonomic group and reporting whether they are observed, collected or reported in literature for a given area (e.g., Mathew & George 2015; Aung et al. 2020; Popovich et al. 2020). The taxa are typically identified at species or subspecies level, some sites of growth are reported together with other information on the habitats, variety, rarity, ecology, chorology, systematic or taxonomic issues. Atlases are more focused on the geographic distribution of the taxa, instead. To be accomplished they require a field work aiming not only at listing all the different taxonomic entities, but also at detecting as more sites of growth as possible for each taxon. The result of such work is a checklist with cartographic references or distribution maps and, sometimes, their elaborations (e.g., Crain & Fernández 2020; Efimov 2020). Due to the long time needed for exhaustive surveys, at a local scale this kind of research is increasingly carried out by non academics, the so called 'citizen scientists'. This is particularly true for the inventories and atlases of the European terrestrial orchids, often published in specialized journals (e.g., Galesi & Lorenz 2010; Frangini et al. 2019; Katopodi & Tsiftsis 2019; Marrero et al. 2019).

The huge amount of work, even when results in detailed distribution maps, almost never follows an experimental design, and currently data are affected by bias caused by a preferential sampling approach, e.g., data collector tends to sample protected areas or to collect more data along the roads (Croce & Nazzaro 2017). Furthermore, none of the above mentioned floristic studies is usually provided with a clear reference to the sampling effort or to the level of completeness of the surveys. The absence of a repeatable background and of a standardized approach is not a trivial issue, as such collections of data are of great value for macroecology, ecology, biogeography or conservation research (Soberón et al. 2000, 2007; Rocchini et al. 2011; Weigelt et al. 2020).

In order to make inventories and atlases useful tools for biogeographical or ecological research it is thus necessary to take into account these issues and support floristic works with appropriate measures of the degree of uncertainty (Rocchini et al. 2011). In the same context, maps of floristic richness should be accompanied by maps of knowledge, "maps of ignorance" or maps of completeness. These can be realized considering that the number of species (namely the species richness) recorded in a given period and in a given area is partial and lower than the real number of species present (Gotelli & Colwell 2011). The more the sample effort increases the more the number of observed species approaches the theoretical, real number of species. On the contrary, a sampling activity carried over a too long time could detect the species turnover (e.g., for habitat change due to socio-economic or ecological reasons or for climate changing) resulting in an overestimation of the number of species than the existing habitats could theoretically host in a given time. The real floristic richness and its distribution in an area can be estimated with different methods (Gotelli & Colwell 2001; Vallet et al 2012). The most suitable for the kind of data recorded in the field by orchidologists is the use of 'sample based species rarefaction-curves' (Gotelli & Colwell 2001). Given that the sampling order in an area is not important, data are resampled and curves are built. While the shape of accumulation curves depends upon the order in which the samples are considered, the rarefaction curves show smoother lines facilitating the comparison among entire datasets or subsets. A species rarefaction curve is plotted starting from the mean number of species of the smallest sample size. Then the mean number of species is calculated for all combinations of the next sample size (i.e., the mean number of species of two random samples, then three random samples, etc.).

This paper analyzes some typical aspects of local scale inventories and atlases hitherto neglected. Here, we propose simple approaches, accessible even for the non-academic, citizen scientists to answer the following specific questions:

i. How can the richness of a floristic database be assessed and how can different database be compared?

ii. Which richness estimator is more suitable for terrestrial European orchids, given its intrinsic difficulties of observation in field?

iii. When is the sampling of an area sufficiently complete?

iv. How can completeness maps be realised and how they can be useful to identify where to address further explorations?

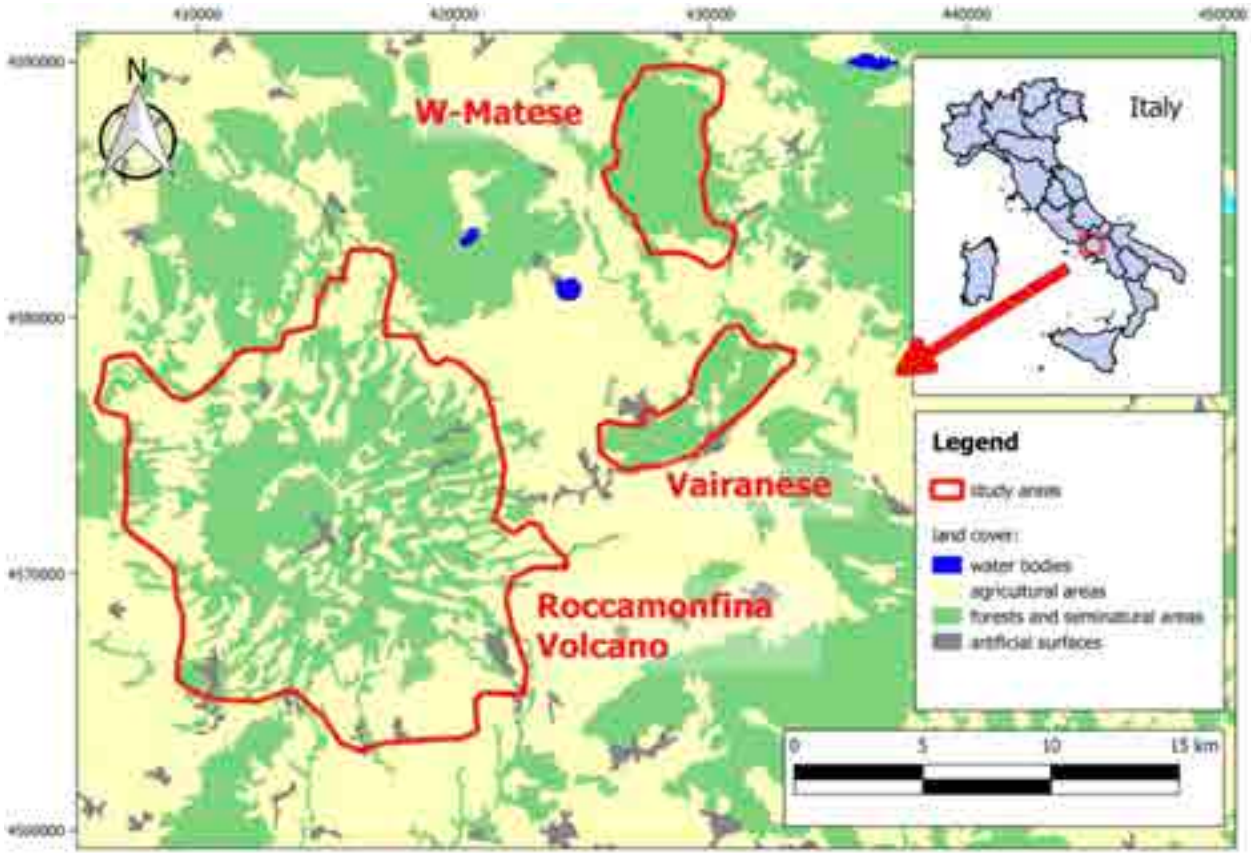

Figure 1. Location of the study areas (red lines) and land cover map. Coordinates are expressed as WGS84 UTM 33N (EPSG 32633).

MATERIALS AND METHODS

Source of the data and study areas

We used three datasets reporting the presence of orchids in three areas in southern Italy, in northern Campania region, (Figure 1; Table 1) about 50 km north of Naples and 150 south of Rome. The first dataset includes 3,046 records collected from 1996 to 2019 on the Roccamonfina volcano (Croce & Nazzaro 2012 and following observations). It covers an area of about 210 km^2 and lists 46 taxa (species and subspecies). The second dataset consists of 278 records collected from 2002 to 2005 on the little limestone mountain range of Vairano Patenora and Pietravairano municipalities (Croce 2012 and following observations), hereafter called "Vairanese". It covers an area of 17 km^2 and lists 32 taxa. The third dataset consists of 305 records collected mainly in 2005 and then from 2013 to 2019 on the limestone mountain ranges of the western Matese area, hereafter called "W–Matese". It covers an area of 20 km^2 and lists 33 taxa.

Data collection

Only the observations geolocated with a precision level lower than 100 m (punctual data according to Croce & Nazzaro 2017) were included in the analysis. Nomenclature was revised and, when needed, standardised and hybrids were excluded from the analysis. To avoid the oversampling bias (i.e., a single population of plants sampled in different sampling units) the records have been clumped to represent the presence of the taxa in 100 x 100 m squares, connected to the geographic grid of the used coordinates system (WGS 84 / UTM zone 33N, EPSG 32633). Each sampling unit (plot) is univocally identified, therefore, by the geographic position of the square and by the sampling date so that two sampling activities that took place in two different date but inside the same square have been considered as two different plots. In this way, I take into account the sampling effort in terms of time, very important for species requiring observations at different times to be correctly observed and identified. In the end I get, for each dataset, a matrix taxon × plot that I used for the elaborations and further analysis.

Data analysis

To compare the three datasets in terms of sampling effort and observed specific richness (S_{obs}), I have mapped the specific richness for each area using a grid with 1 km^2 resolution (i.e., 1 x 1 km UTM cells) intersecting the study areas (i.e., the three geographic units as defined above) and calculating both the number of plots and the number of observed species in each cell. A regression analysis between the number of plots and the number of species per each cell has been performed to correlate the sampling effort to the observed species richness and therefore to validate the density of plots as an indicator of the sampling effort. Then for each area I built a sample-based rarefaction curve using the plots as samples. The curves have been limited to the lower number of plots in the three datasets for a better comparison of the observed species richness and its pattern among the three studied areas. Being drawn with resampling statistical methods, the curves allow the calculation of the 95% confidence limits or the standard deviations.

Among the methods used to estimate the species richness of an area starting from presence-absence data, the most appropriate for floristic inventories and atlases is the relation between number of species and sampling effort (Vallet et al. 2012). This relation is investigated mainly using non parametric estimators, less sensitive to the sampling effort (Palmer 1990; Brose et al. 2003). Such indexes give an estimate of the species richness for a given geographic unit, based upon the considered sample and, therefore, upon its species assemblage. Once an estimate value is obtained, the completeness for each of the three datasets can be calculated by means of the completeness index proposed by Soberón et al. (2000). Such index (C) is expressed as a percentage value of the ratio between the number of observed species (S_{obs}) and the number of estimated species (S_{est}):

$C = S_{obs}/S_{est}$

The most used non parametric estimators for presence/absence data or incidence data are Jackknife, Chao, Bootstrap, and ICE (Gotelli & Colwell 2011; Vallet et al. 2012). While the first of these indexes could represent a good compromise (Brose et al. 2003), several other authors prefer to compare more than one index (Martinez-Sanz et al. 2010; Bruno et al. 2012; Garcia-Marquez et al. 2012; Vallet et al. 2012; Archer 2019). It is therefore noted that the Jackknife estimator gives higher values of estimated richness and, accordingly, lower completeness values than the Bootstrap estimator (Garcia-Marquez et al. 2012). Nevertheless, it is particularly effective in estimating the richness of small sample size (Hortal et al. 2006). Another very used estimator is Chao2 (Ugland et al. 2003; Chao & Chiu 2016; Idohou et al. 2015; Asase & Peterson 2016) that gives more emphasis to the presence of singletons species (i.e., present in only one plot of the set or subset) or doubletons (i.e., present in only two plots). Considered that many orchid species are locally rare and the number of rare species increases with decreasing the size of the sampled area, I calculated the completeness index (C) choosing as value of estimated richness (S_{est}) the maximum value between Chao2 (S_{Chao2}) and Jackknife1 (S_{jack1}) estimates. For each of the three study areas I calculated the total value of completeness (C) and the completeness of each cell of the 1 km^2 UTM grid, using the plots as sampling units. Only for Roccamonfina area the completeness has been calculated also for each cell of a 4 km^2, 9 km^2, 16 km^2, 25 km^2, and 36 km^2 UTM grid intersecting the study area. Then I aggregated the data into 1 x 1 km cells and the obtained taxon × cells matrix has been used to recalculate the estimated species richness and the completeness of each study area. This was intended to test the reliability of such atlases built mapping the presence of the species in grids with cells of 1 km^2 or more, to estimate the species richness of the study areas. In order to test the estimators robustness when even larger sample units are used, the above mentioned aggregation method has been repeated using grids of 4 km^2, 9 km^2, 16 km^2, 25 km^2, and 36 km^2 cells, only for the larger area of Roccamonfina volcano. In other terms, I used increasing size cells as sampling units. Such cells size can be useful to analyse atlases produced with bibliographic data whose precise geolocation is not possible. The completeness of each cell, for all the grids of different cells size, has been classified into four levels: 0–25 %, 25–50 %, 50–75 %, and 75–100 %. The cell with less than six plots have not been analysed and have been classified as "not evaluable" (n.e.). These limits have been set considering for all the datasets used an average number of five plot sampled in a day. According to the method used in Bruno et al. (2012), the cells with completeness >65% have been considered sufficiently studied squares (SSS).

Once I knew the less explored cells, to which priority in the future research should be given, I could assess the level of completeness of our datasets among different habitats. So, I assigned a kind of vegetation to each plot on the basis of the collected field information and therefore I estimated the completeness of each vegetation type for each study area as explained above.

The cartographic elaborations have been performed by the software Qgis3 (QGIS Development Team 2019),

the rarefaction curves and the calculation of the richness estimators have been produced by means of the software Estimates 8.20 (Colwell 2013) performing 1000 permutations. Statistical analyses have been performed using the software PAST (Hammer et al. 2001). All the used software is open source or free.

RESULTS

In Table 1 the data about the three study areas are reported, including the list of the taxa considered. The Roccamonfina area has the highest species richness, average number of records/plot and plot/km^2. Vairanese and W-Matese show comparable values of the number of records/plot (higher values for W-Matese) and number of plots/km^2 (higher values for Vairanese). Nevertheless, the distribution of the number of plots (Figure 2a) and observed species richness (Figure 2b) in the 1km^2 cells is extremely heterogeneous with a very high standard deviation of the plots/cells ratio (6.9 for Roccamonfina, 6.5 for Vairanese and 5.9 for Matese areas). Such values underline a sampling effort not uniformly distributed in the studied areas.

The regression analysis (Figure 3) shows, for all the three areas, a statistically significant ($p < 0.001$) positive correlation between the number of plots and the number of species inside the 1 km^2 cells. The two variables are statistically correlated according to the Kendall's tau test.

The rarefaction curves (Figure 4) indicate a similar pattern for all the three areas: limited to 121 plots, they show slight differences with a higher species richness for the W-Matese area (32.84 average observed species) followed by the Vairanese area (32 average observed species) and the Roccamonfina volcano (31.32 average observed species).

The total estimated floristic richness, computed using the plots as sampling units (Table 2) for each of the three areas, gives completeness values between 78.2% (Vairanese) and 88.5% (Roccamonfina). Using the 1 km^2 cells as sampling units (Table 3), we get identical values for Roccamonfina area, a slightly higher value for Vairanese area and slightly lower for W-Matese area.

The completeness of the 1km^2 cells in the three areas (Figure 2c) is distributed in a similar way in the Roccamonfina and Vairanese areas (Table 4): the 35.6% and 33.3% of the 1 km^2 cells, respectively, have a completeness higher than 65% and therefore are considered as Sufficiently Studied Squares (SSS). For the W-Matese area only the 25% of the 1 km^2 cells are SSS. It is relevant, for each area, the great number of cells with data not allowing further elaborations ('n.e.' cells).

The estimated richness for the Roccamonfina area, calculated using sampling units of increasing size (Figure 5) shows a general stability of the two estimators chosen, always with higher values for Jackknife1 estimator (51.82–53.47) compared to Chao2 estimator (48.11–49.34). Both the estimators feature variations included within 1.65 unity, a value lower than the standard deviations calculated by the software. The completeness of the cells of increasing size, calculated for Roccamonfina area (Table 5) using the plots as sampling units, gives a gradual increase of the number of SSS, up to over 50% of the 9 km^2 cells and 80% of the 36 km^2 cells.

In Table 6 the observed and estimated species richness and the completeness of the different habitats using the plots as sampling units are reported. For the Roccamonfina area the completeness of the habitats is high except for agricultural environments. The chestnut orchards host the higher species richness (38 species, 82% of the whole area), followed by the open habitats such as meadows and shrublands (33 species). In the other study areas the completeness is relatively low for the broadleaved woodlands of Vairanese and open habitats of the W-Matese, indicating a still not adequate sampling for such habitats. For a better comparison of the species richness among the different habitats, considering that more than 70% of the plots are located inside chestnut orchards, the rarefaction curves were plotted for Roccamonfina habitats (Figure 6), limited to 100 plots. The richness curve rises in a steeper way in the chestnut orchards but it is overtaken by artificial habitats around 30 plots and by open habitats around 50 plots. The richness of broadleaved woodlands and chestnut coppices is always lower, as expected.

DISCUSSION

The higher species richness is correlated to the sampling effort, expressed as number of plots, as well as the ecological features of the areas and their extension. This parameter is known, in ecology as the species/area relationship (SAR - Preston 1962) and it could be used to compare and estimate species richness of floristic atlases only under certain conditions that, if disregarded impede its extrapolation (Vallet et al. 2012). The correlation analysis here performed confirms that the higher is the number of sampling units (plot) in an area, the higher will be the observed species richness. Comparing the richness of the three studied areas plotted by rarefaction curves, highlights that with the same sampling effort

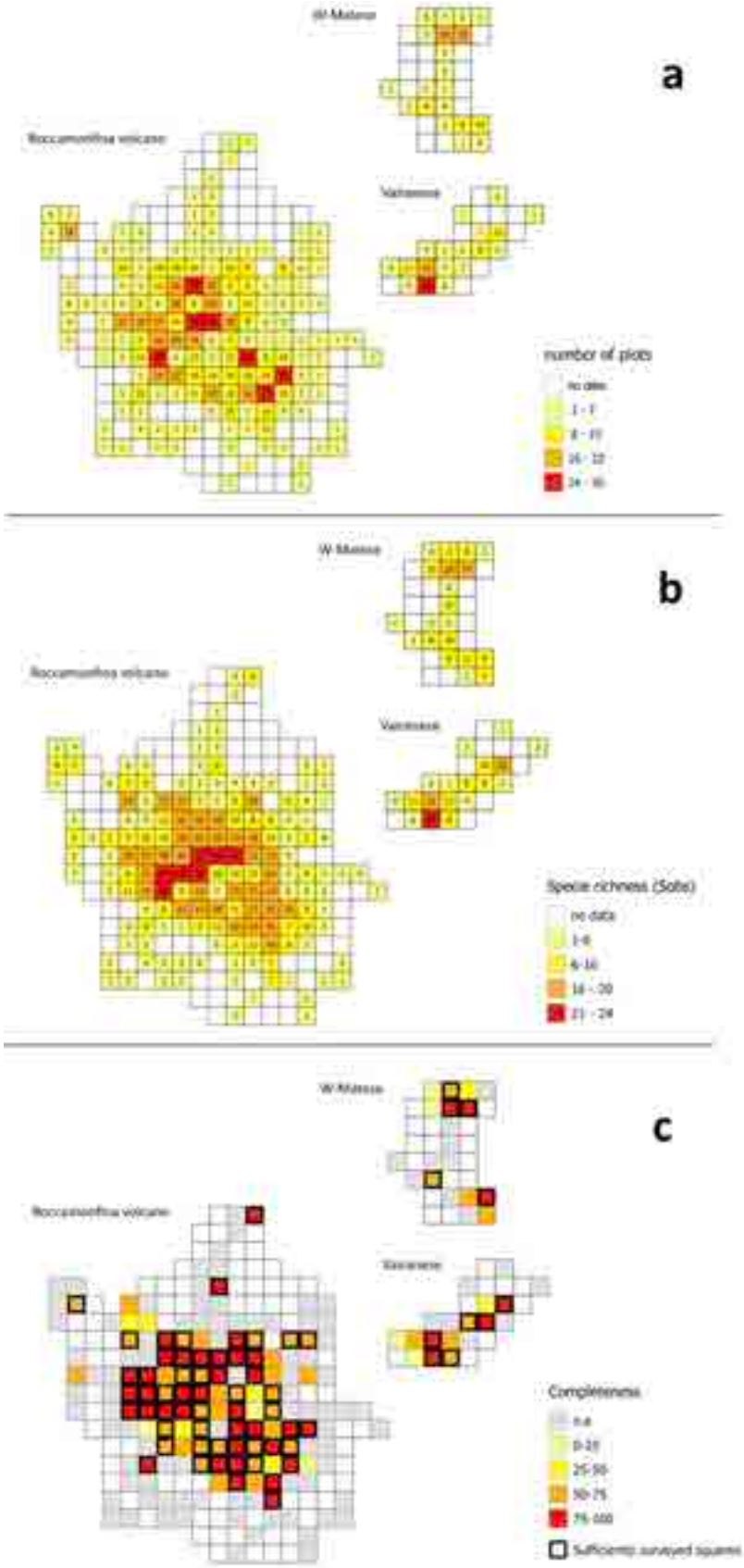

Figure 2. Distribution maps: a—number of plots | b—number of observed species | c—Completeness level, for the 1 km² cells covering the three study areas.

Table 1. Data of the three study areas and list of the taxa considered for the analysis.

	Roccamonfina	Vairanese	W-Matese
Sobs	**46**	**32**	**33**
Area (km²)	**210**	**18**	**20**
1 km² cells	**163**	**18**	**20**
altitude (min-max)	**150–1005**	**125–588**	**150–811**
Number of Plots	**1184**	**121**	**124**
Database-records	**3046**	**263**	**296**
records/plot	**2.57**	**2.17**	**2.39**
Plot/km²	**7.26**	**6.72**	**6.2**
Anacamptis coriophora (L.) R.M.Bateman, Pridgeon & M.W.Chase	x	x	x
Anacamptis morio (L.) R.M.Bateman, Pridgeon & M.W.Chase	x	x	x
Anacamptis papilionacea (L.) R.M.Bateman, Pridgeon & M.W.Chase	x	x	x
Anacamptis pyramidalis (L.) Rich.	x	x	x
Cephalanthera damasonium (Mill.) Druce	x	x	x
Cephalanthera longifolia (L.) Fritsch	x		x
Cephalanthera rubra (L.) Rich.	x		
Dactylorhiza maculata (L.) Soó subsp. *saccifera* (Brongn.) Diklić	x	x	
Dactylorhiza romana (Sebast.) Soó subsp. *romana*	x	x	
Dactylorhiza sambucina (L.) Soó	x		
Epipactis exilis P.Delforge	x		
Epipactis helleborine (L.) Crantz subsp. *helleborine*	x	x	
Epipactis microphylla (Ehrh.) Sw.	x	x	x
Epipactis muelleri Godfery	x	x	
Epipactis maricae (Croce, Bongiorni, De Vivo & Fori) Presser & S.Hertel	x		
Epipactis placentina Bongiorni & Grünanger	x		
Gymnadenia conopsea (L.) R.Br.	x		
Himantoglossum adriaticum H.Baumann	x		x
Limodorum abortivum (L.) Sw.	x	x	x
Neotinea maculata (Desf.) Stearn	x	x	x
Neotinea tridentata (Scop.) R.M.Bateman, Pridgeon & M.W.Chase	x	x	x
Neottia nidus-avis (L.) Rich.	x		
Neottia ovata (L.) Bluff & Fingerh.	x		
Ophrys apifera Huds.	x	x	x
Ophrys argolica H.Fleischm. ex Vierh. subsp. *crabronifera* (Mauri) Faurh.	x	x	x
Ophrys bertolonii Moretti subsp. *bertolonii*	x	x	x
Ophrys bombyliflora Link			x
Ophrys exaltata Ten. subsp. *montis-leonis* (O.Danesch & E.Danesch) Soca	x		
Ophrys holosericea (Burnm.f.) Greuter subsp. *gracilis* (Büel, O.Danesch & E.Danesch) O.Danesch & E.Danesch		x	
Ophrys holosericea (Burnm.f.) Greuter subsp. *holosericea*	x	x	x
Ophrys incubacea Bianca	x		
Ophrys insectifera L.		x	x
Ophrys lutea Cav.	x	x	x
Ophrys promontorii O.Danesch & E.Danesch	x		x
Ophrys sphegodes Mill. subsp. *sphegodes*	x	x	x
Ophrys sphegodes Mill. subsp. *minipassionis* (Romolini & Soca) Biagioli & Grünanger			x

	Roccamonfina	Vairanese	W-Matese
Ophrys tenthredinifera Willd. subsp. *neglecta* (Parl.) E.G.Camus	x		
Orchis anthropophora (L.) All.	x	x	x
Orchis italica Poir.	x	x	x
Orchis mascula (L.) subsp. *mascula*	x		x
Orchis pauciflora Ten.		x	x
Orchis provincialis Balb. ex Lam. & DC.	x	x	x
Orchis purpurea Huds.	x	x	x
Orchis simia Lam.	x		x
Platanthera bifolia (L.) Rich.	x	x	
Platanthera chlorantha (Custer) Rchb.	x	x	x
Serapias cordigera L.	x	x	
Serapias lingua L.	x		x
Serapias parviflora Parl.	x	x	x
Serapias vomeracea (Burm.f.) Briq. subsp. *longipetala* (Ten.) H.Baumann & Künkele	x	x	x
Spiranthes spiralis (L.) Chevall.	x	x	x

Table 2. Total completeness values for the three study areas using 100 x 100 m plots as sampling units.

	Roccamonfina	Vairanese	W-Matese
n. Plots (100 × 100 m)	1184	121	124
Sobs	46	32	33
S_{Chao2}	49	35.72	37.9
S_{Jack1}	51.99	40.93	39.94
Completeness %	**88.5**	**78.2**	**82.6**

Table 3. Total completeness values for the three study areas using 1 km² cells as sampling units.

	Roccamonfina	Vairanese	W-Matese
No. of 1 km² cells	163	18	20
Sobs	46	32	33
S_{Chao2}	48.98	40.5	36.33
S_{Jack1}	51.96	40.5	40.3
Completeness %	**88.5**	**79.0**	**81.9**

Table 4. Levels of completeness values of the 1 km² cells, for the three study areas.

	Roccamonfina		Vairanese		W-Matese	
Completeness level %	n. cells	%	n. cells	%	n. cells	%
n.e.	84	**51.5**	7	**38.9**	9	**45.0**
0–25	3	**1.8**	2	**11.1**	2	**10.0**
25–50	5	**3.1**	1	**5.6**	1	**5.0**
50–75	35	**21.5**	4	**22.2**	5	**25.0**
75–100	36	**22.1**	4	**22.2**	3	**15.0**
Total	163		18		20	
SSS	58	**35.6**	6	**33.3**	5	**25.0**

(i.e., the same number of plots), the richest area can host a relatively lower number of species than the less rich area. Nevertheless, such kind of analysis requires the same exhaustivity of the studies for each area. The overall completeness of the study areas gives values close to 90% and consistently above 70%. Also, very interesting is the data emerging from the estimates of the richness and the completeness calculated using the 1 km² cells of the UTM grid as sampling units. Such size could be very useful to study larger areas or to include lower precision data in the analysis and the completeness values did not differ significantly from the resulting estimates obtained using 100 x 100 m sampling units (plots). For the Roccamonfina area, in addition, even using increasing size cells as sampling units, the estimates do not vary significantly. This result can be taken into account whenever we have to choose the better grid resolution to draw atlases from non punctual data (e.g., literature data or observations with low location accuracy). The elaborations should follow, in this case, a reverse path: starting from a large sampling unit (e.g., a 10 x 10 km cells UTM grid), decreasing the size of the sampling units and calculating the completeness for the study area. Since small size cells will have more probability to hold 'singletons' (unique presence data) for a bigger number of species, the used estimators will

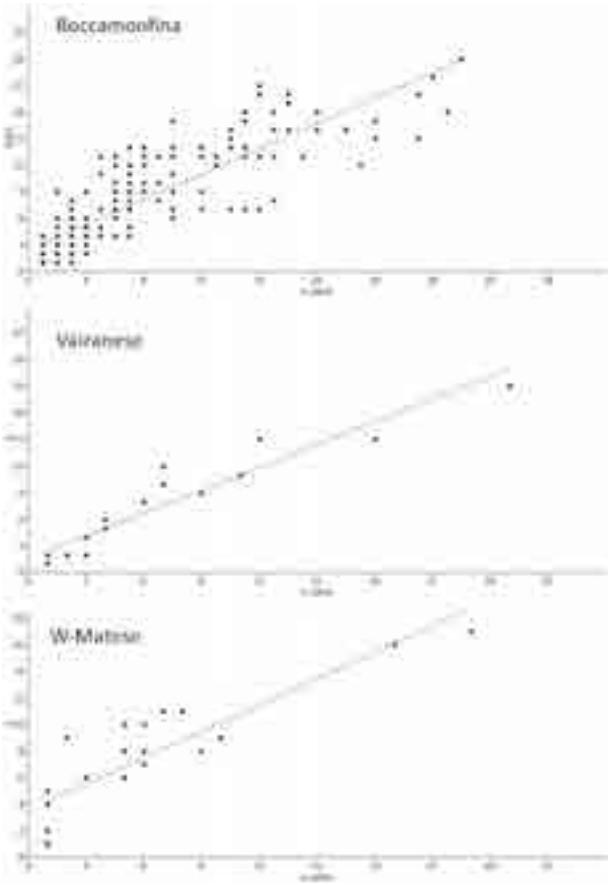

Figure 3. Correlation between number of plots and number of observed species for each of the 1 km² cells.

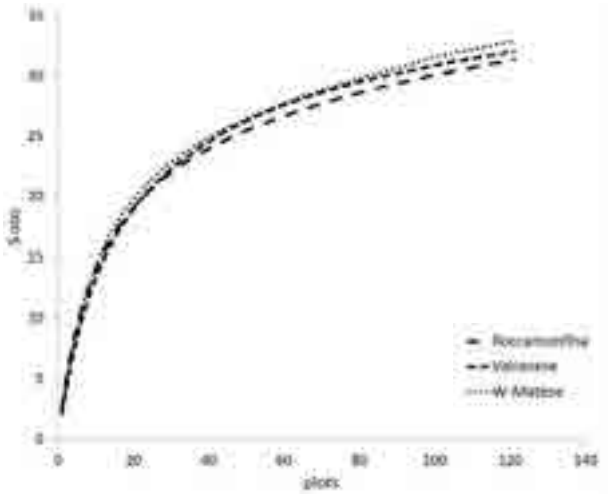

Figure 4. Rarefaction curves based on the number of sampling units (sample-based rarefaction curves) for the three study areas.

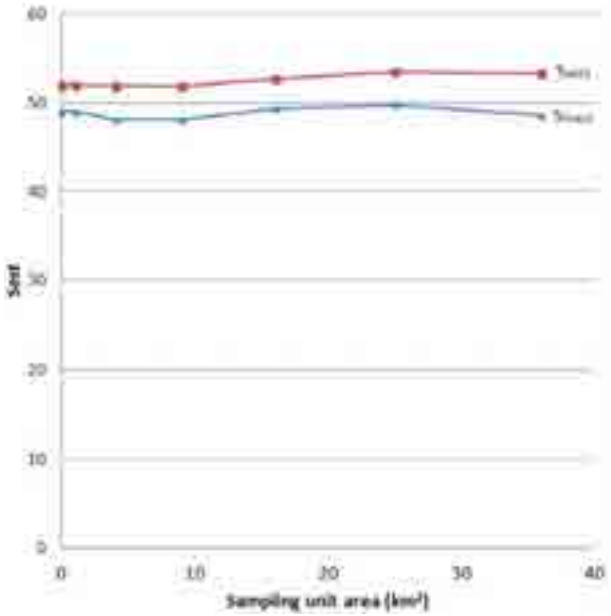

Figure 5. Completeness values using Chao2 e Jackknife1 estimators, using cells of different size (100 x 100 m, 1 km², 4 km², 9 km², 16 km², 25 km², and 36 km²) as sampling units for the Roccamonfina area.

give higher estimates of richness and, therefore, lower values of completeness.

For the same reason linked to the presence of singletons, in our study the number of sufficient studied squares (SSS) increases as their size become bigger. In the case of Roccamonfina area, using a grid of 9 km² cells, a half of them are classified as SSS. The distribution of the completeness for a grid of 1 km² cells (Table 4), on the other hand, is comparable for Roccamonfina and Vairanese, with more than 33% of the squares classified as SSS while for W-Matese area this value reaches only 25%. To assess whether these rates represent a good result (i.e., the area is exhaustively well studied), we can refer to the choice of the limit of 65% to consider a cell as sufficiently studied. In Bruno et al. (2012) this completeness limit has been chosen to select a useful number of squares to perform further analysis. These authors, for all the four considered taxonomic groups, get lower portion of squares SSS compared to the portion we get for our studied areas. Nevertheless, the absolute number of SSS for both Vairanese and W-Matese areas (respectively six and five squares) is too low and recall the need to continue the study in these two areas. The stratified analysis by habitat types underlines firstly what habitats need more studies or are less suitable for orchids. For example, agricultural habitats for Roccamonfina would need further sampling since their completeness is only 55% (Table 6). It could be expected that, adding further sampling, the completeness would increase even without an increasing of the species

Table 5. Levels of completeness values of the cells of different size, for the Roccamonfina area (n.e. = not evaluated).

	1 km²		4 km²		9 km²		16 km²		25 km²		36 km²	
C	**n. cells**	**%**	**n. cells**	**%**	**n. cells**	**%**	**n. cells**	**%**	**n. cells**	**%**	**n. cells**	**%**
n.e.	84	**51.5**	23	**37.7**	10	**16.4**	5	**22.7**	3	**20**	1	**9.1**
0–25	3	**1.8**	1	**1.6**	0	**0**	0	**0**	0	**0**	0	**0**
25–50	5	**3.1**	4	**6.6**	5	**8.2**	1	**4.5**	1	**6.7**	0	**0**
50–75	35	**21.5**	14	**23**	6	**9.8**	7	**31.8**	4	**26.7**	2	**18.2**
75–100	36	**22.1**	19	**31.1**	12	**19.7**	9	**40.9**	7	**46.6**	8	**72.7**
tot	163		61		33		22		15		11	
SSS	58	**35.6**	28	**45.9**	17	**51.5**	11	**50**	9	**60**	9	**81.8**

Table 6. Completeness values of the main habitats in the three areas.

Roccamonfina					
Habitats	S_{obs}	**Plots**	S_{Chao2}	S_{Jack1}	**C %**
Artificial (incl. Road verges)	25	50	28.9	33.8	73.9
Agriculture	11	18	20.0	16.7	55.0
Open habitats	33	158	36.5	40.9	80.6
Broadleaved woodlands (excl. Chestnut woods)	25	82	27.1	30.9	80.9
Chestnut coppices	18	62	19.0	21.0	85.9
Chestnut orchards	38	839	44.0	44.0	86.4
Vairanese					
Habitats	S_{obs}	**Plots**	S_{Chao2}	S_{Jack1}	**C %**
Open habitats	26	89	26.5	29.0	89.8
Broadleaved woodlands	24	33	42.0	35.6	57.1
Evergreen woodlands	6	8	6.7	8.6	69.6
W-Matese					
Habitats	S_{obs}	**Plots**	S_{Chao2}	S_{Jack1}	**C %**
Open habitats	28	60	100.0	39.8	28.0
Broadleaved woodlands	27	57	28.6	32.0	84.4

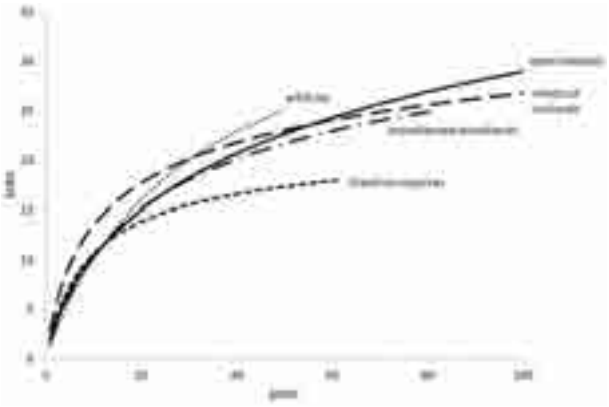

Figure 6. Rarefaction curves for the different habitats of the Roccamonfina area.

richness. These habitats are in fact less suitable to host orchids as they are affected by frequent and strong ecological changes (e.g., soil tillage, switching to other crops, supply of nutrients). Such considerations could be made for the broadleaved woodlands of the Vairanese area, mostly represented by Holm oaks woodlands with very low light in the understory since orchids abundance is highly correlated to light regime (Djordjević & Tsiftsis 2020; Hrivnák et al. 2020). On the contrary we expect that the low completeness value for the open habitats of the W-Matese area is due to a high theoretical richness of such habitats, not fully detected by the sampling activity. In other words, the sampling effort for the open habitats of the W-Matese area is still insufficient.

Also, the rarefaction curves allow ecological considerations (Figure 6). The chestnut orchards represent an ecosystem made of a mosaic between woodlands and meadows, so they are a suitable habitat for the most heliophilous species as well as for the nemoral ones. This explains why their average species richness increases steeply even with a few plots (it is possible to observe more than 20 species in one plot). Nevertheless, on a larger scale, the richness of chestnut orchards is higher than the richness in open habitats only because of the higher area occupied by the former. When the curves are limited to 50 plots, surprisingly the richest habitats are the artificial areas. This result can be explained with the apophyte behavior of many orchids species (Adamowski 2006) and with the fact that we considered the roadsides as artificial habitats. Such environments can host many species characteristics of open habitats such as meadows and grasslands, and constitute important refuge areas for native species (Auestad et al. 2011).

Overall, the analysis of the three datasets allowed the sampling effort to be evaluated and gave useful indications to where and how to conduct the future researches. Moreover, some suggestions on the use of statistical tools to compare different study areas were given. For two areas (Roccamonfina and Vairanese), there is a sufficient level of knowledge of how the orchids richness is distributed, if we assume that a low completeness value in two squares out of three could be due to the lack of suitable habitats (i.e., urban areas or intensive agriculture areas) and to the difficult to locate a sufficient number of sampling units or plots. The squares with no data or with a lower completeness should be regarded as the highest priority areas for the future floristic research. Sampling these areas could increase the level of knowledge (i.e., the completeness value) and could lead to detect new species for the squares or for the studied area. The analysis of the floristic richness and the completeness of every habitat in a less known area would be very useful to prioritize, in each cell of a chosen grid, where to focus the research.

CONCLUSIONS

In conclusion, this study highlights that the quality of a floristic research can benefit from the evaluation of the completeness. Its calculation allows the creation of knowledge/ignorance maps for orchids at different scale using grids at different resolutions (e.g., from cells of 1 km^2 for small islands and reserves to cells of 100 km^2 for regions). A randomized and stratified sampling design would reduce the sampling bias, enable the use of abundance indices rather than presence/absence data and allow the investigation on the relation between species richness and environmental variables. It is often necessary, however, to take into account a large amount of data lacking accuracy or uniformity as is the case of data from literature or collected by different and sometimes occasional contributors (e.g., in citizen science projects).

In any case it is desirable in each modern floristic study and particularly orchids distribution study, a quantitative analysis of the work expressing the results not only as the total number of species observed and their distribution but focusing more on the sampling methods and on the distribution of the knowledge. Even if a sampling design avoiding preferential sampling would be desirable but not always possible (e.g., when using data from online platforms or literature), the proposed methods would help the authors to evaluate the sampling effort, identify the less studied areas or postpone the publication of their checklists and atlases until an acceptable level of exhaustivity, or completeness, would be reached.

REFERENCES

Adamowski, W. (2006). Expansion of native orchids in anthropogenous habitats. *Polish Botanical Studies* 22: 35–44.

Archer, M.E. (2019). Using non-parametric statistical analysis to estimate the numbers of solitary wasp and bee species (Hymenoptera: Aculeata) at study sites. *Entomologist's Monthly Magazine* 155(4): 263–270. https://doi.org/10.31184/M00138908.1554.3953

Asase, A. & A.T. Peterson (2016). Completeness of digital accessible knowledge of the plants of Ghana. *Biodiversity Informatics* 11: 1–11. https://doi.org/10.17161/bi.v11i1.5860

Auestad, I., K. Rydgren & I. Austad (2011). Road verges: potential refuges for declining grassland species despite remnant vegetation dynamics. *Annales Botanici Fennici* 48: 289–303. https://doi.org/10.5735/085.048.0401

Aung, Y.L., A.T. Mu, M.H. Aung, Q. Liu & X. Jin (2020). An annotated checklist of Myanmar orchid flora. *PhytoKeys* 138: 49–112. https://doi.org/10.3897/phytokeys.138.36144

Brose, U., N.D. Martinez & R.J. Williams (2003). Estimating species richness: sensitivity to sample coverage and insensitivity to spatial patterns. *Ecology* 84(9): 2364–2377. https://doi.org/10.1890/02-0558

Bruno, D., D. Sánchez-Fernández, A. Millán, R.M. Ros, P. Sánchez-Gómez & J. Velasco (2012). Assessing the quality and usefulness of different taxonomic groups inventories in a semiarid Mediterranean region. *Biodiversity and Conservation* 21(6): 1561–1575. https://doi.org/10.1007/s10531-012-0263-9

Chao, A. & C.H. Chiu (2016). Species richness: estimation and comparison, pp 1–26. In: Balakrishnan, N., T. Colton, B. Everitt, W. Piegorsch, F. Ruggeri & J. Teugels (eds). *Wiley StatsRef: statistics reference on-line*. John Wiley & Sons, Hoboken, New Jersey. https://doi.org/10.1002/9781118445112.stat03432.pub2

Colwell, R.K. (2013). EstimateS: Statistical estimation of species richness and shared species from samples. Version 9 and earlier.

User's Guide and application. http://purl.oclc.org/estimates/ Accessed on 1 March 2020.

Crain, B.J. & M. Fernández (2020). Biogeographical analyses to facilitate targeted conservation of orchid diversity hotspots in Costa Rica. *Diversity and Distributions* 26: 856–866. https://doi.org/10.1111/ddi.13062

Cribb, P.J., S.P. Kell, K.W. Dixon & R.L. Barrett (2003). Orchid Conservation: A global perspective, pp 1–25. In: Dixon, K.W., S.P. Kell, R.L. Barrett & P.J. Cribb (eds). *Orchid Conservation*. Natural History Publicatons, Kota Kinabalu, Sabah.

Croce, A. (2012). Le Orchidaceae dei monti S. Angelo, Caievola, S. Nicola (Vairano Patenora e Pietravairano, Caserta). *Giros Notizie* 49: 60–67.

Croce, A. & R. Nazzaro (2012). The orchid Flora of Roccamonfina-foce Garigliano Regional Park. *Journal Europäischer Orchideen* 44(3): 509–583.

Croce, A. & R. Nazzaro (2017). An atlas of orchids distribution in the Campania region (Italy), a citizen science project for the most charming plant family. *Italian Botanist* 4: 15–32. https://doi.org/10.3897/italianbotanist.4.14916

Djordjević, V. & S. Tsiftsis (2020). The role of ecological factors in distribution and abundance of terrestrial orchids, pp 1–71. In: Merillon, J.& H. Kodja (eds.). *Orchids Phytochemistry, Biology and Horticulture*. Reference Series in Phytochemistry, Springer International Publishing: Basel, Switzerland. https://doi.org/10.1007/978-3-030-11257-8

Dressler, R.L. (1981). *The orchids: natural history and classification*. Harvard University Press, Cambridge, MA, USA, 332pp. https://doi.org/10.2307/1219717

Efimov, P.G. (2020). Orchids of Russia: annotated checklist and geographic distribution. *Nature Conservation Research* 5(Suppl. 1): 1–18. https://doi.org/10.24189/ncr.2020.018

Frangini, G., R. Romolini, F. Sodi, M. Bisti, L. Forbicioni, M.A. Rusci & G. Cortesi (2019). Orchidee dell'isola di Gorgona (Arcipelago Toscano). *Giros Orchidee Spontanee d'Europa* 62(1): 17–31.

Galesi, R. & R. Lorenz (2010). Le Orchidaceae della Riserva Naturale Orientata "Oasi faunistica di Vendicari (Sicilia sud-orientale). *Journal Europäischer Orchideen* 42(1): 149–166.

García Márquez, J.R., C.F. Dormann, J.H. Sommer, M. Schmidt, A. Thiombiano, S.S. Da, C. Chatelain, S. Dressler & W. Barthlott (2012). A methodological framework to quantify the spatial quality of biological databases. *Biodiversity & Ecology* 4: 25–39. https://doi.org/10.7809/B-E.00057

Gotelli, N.J. & R.K. Colwell (2001). Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecological Letters* 4: 379–391. https://doi.org/10.1046/j.1461-0248.2001.00230.x

Gotelli, N.J. & R.K. Colwell (2011). Estimating species richness, pp. 39–54. In: Magurran, A.E. & B.J. McGill (eds.). *Biological Diversity: Frontiers in Measurement and Assessment*. Oxford University Press, Oxford, United Kingdom, 345 pp.

Hammer, Ø., D.A. Harper & P.D. Ryan (2001). PAST: paleontological statistics software package for education and data analysis. *Palaeontologia electronica* 4(1): 9. https://palaeo-electronica.org/2001_1/past/issue1_01.htm Accessed on 01 March 2020.

Hortal, J., P.A.V. Borges & C. Gaspar (2006). Evaluating the performance of species richness estimators: sensitivity to sample grain size. *Journal of Animal Ecology* 75: 274–287. https://doi.org/10.1111/j.1365-2656.2006.01048.x

Hrivnák, M., M. Slezák, D. Galvánek, J. Vlčko, E. Belanová, V. Rízová, D. Senko & R. Hrivnák (2020). Species Richness, Ecology, and Prediction of Orchids in Central Europe: Local-Scale Study. *Diversity* 12(4): 154. https://doi.org/10.3390/d12040154

Idohou, R., A. Arino, A. Assogbadjo, R.G. Kakai & B. Sinsin (2015). Diversity of wild palms (Arecaceae) in the Republic of Benin: Finding the gaps in the national inventory combining field and digital accessible knowledge. *Biodiversity Informatics* 10: 45–55. https://doi.org/10.17161/bi.v10i2.4914

Katopodi, E. & S. Tsiftsis (2019). Contribution to the knowledge of the orchid flora of Lefkas island (Ionian Islands, Greece). *Botanika Chronika* 22: 127–143.

Marrero, Á., M. Claessens, D. González, C. Santiago, & J. Claessens (2019). Chorological additions and distribution of the native orchids of Gran Canaria. *Botánica Macaronésica* 30: 65–88.

Martínez-Sanz, C., F. García-Criado, C.F. Alaez & M.F. Alaez (2010). Assessment of richness estimation methods on macroinvertebrate communities of mountain ponds in Castilla y León (Spain). *Annales de limnologie - International Journal of Limnology* 46 (2): 101–110. https://doi.org/10.1051/limn/2010008

Mathew, J., & K.V. George (2015). Checklist of Orchids of Kottavasal Hills in Achancoil Forests, southern Western Ghats, (Kollam, Kerala), India. *Journal of Threatened Taxa* 7(10): 7691–7696. https://doi.org/10.11609/JoTT.o3859.7691-6

Palmer, M.W. (1990). The estimation of species richness by extrapolation. *Ecology* 71(3): 1195–1198. https://doi.org/10.2307/1937387

Popovich, A. V., E.A. Averyanova & L.M. Shagarov (2020). Orchids of the Black Sea coast of Krasnodarsky Krai (Russia): current state, new records, conservation. *Nature Conservation Research* 5(Suppl 1): 46–68. https://doi.org/ 10.24189/ncr.2020.047

Preston, F.W. (1962). The canonical distribution of commonness and rarity: Part I. *Ecology* 43(2): 185–215. https://doi.org/10.2307/1931976

QGIS Development Team (2019). QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org/. Downloaded on 01 march 2020

Rocchini, D., J. Hortal, S. Lengyel, J.M. Lobo, A. Jimenez-Valverde , C. Ricotta, G. Bacaro & A. Chiarucci (2011). Accounting for uncertainty when mapping species distributions: the need for maps of ignorance. *Progress in Physical Geography* 35(2): 211–226. https://doi.org/10.1177/0309133311399491

Soberón, J.M., J.B. Llorente & L. Oñate (2000). The use of specimen-label databases for conservation purposes: an example using Mexican Papilionid and Pierid butterflies. *Biodiversity and Conservation* 9(10): 1441–1466. https://doi.org/10.1023/A:1008987010383

Soberón, J.M., R. Jiménez, J. Golubov & P. Koleff (2007). Assessing completeness of biodiversity databases at different spatial scales. *Ecography* 30(1): 152–160. https://doi.org/10.1111/j.0906-7590.2007.04627.x

Ugland, K.I., J.S. Gray & K.E. Ellingsen (2003). The species-accumulation curve and estimation of species richness. *The Journal of Animal Ecology* 72(5): 888–897. https://doi.org/10.1046/j.1365-2656.2003.00748.x

Vallet, J., M. Rambaud, L. Coquel, L. Poncet & F. Hendoux (2012). Effort d'échantillonnage et atlas floristiques-exhaustivité des mailles et caractérisation des lacunes dans la connaissance. *Comptes Rendus Biologies* 335(12): 753–763. https://doi.org/10.1016/j.crvi.2012.11.005

WCSP (2019). World Checklist of Selected Plant Families. Facilitated by the Royal Botanic Gardens, Kew. http://wcsp.science.kew.org/home.do Downloaded on 20 November 2020.

Weigelt, P., C. König & H. Kreft (2020). GIFT–A global inventory of floras and traits for macroecology and biogeography. *Journal of Biogeography* 47(1): 16–43. https://doi.org/10.1111/jbi.13623

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ARTICLE

A floristic survey across three coniferous forests of Kashmir Himalaya, India – a checklist

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Abstract: This study presents a checklist of the flora of three coniferous forests of the Himalayan biodiversity hotspot in Kashmir: low-level blue pine (BP), mixed coniferous (MC) and subalpine (SA) forests. The list includes altitudinal distribution and conservation status of 272 vascular plant species representing 196 genera and 64 families. Excluding neophytes (70 taxa, 62 genera, and 27 families), Magnoliophyta comprised 190 taxa, 139 genera, and 50 families; Pinophyta seven taxa, six genera, and three families; and Pteridophyta three taxa, three genera, and two families. Most speciose families from Magnoliophyta include Compositae, Apiaceae, and Rosaceae. Genera such as *Artemisia*, *Potentilla*, *Viola*, and *Saussurea* contributed the maximum number of species. In case of Pinophyta, the principal families are Pinaceae with four taxa followed by Cupressaceae (2 taxa), whereas genus *Juniperus* comprised two species. In Pteridophyta, Pteridaceae (2 taxa) formed the most speciose family. The herbs contributed 177 taxa, followed by tress (15 taxa), shrubs (8) and subshrubs (2). The maximum number of taxa belongs to SA (136 taxa) followed by MC (134 taxa) and BP (83 taxa) forests. The species distribution reveals 20, 30, and 46 taxa are exclusive to BP, MC, and SA forests. More than 16% of taxa are categorized in the International Union for Conservation of Nature (IUCN) Red List, and 24 taxa are endemic to the Himalayan landscape. The checklist provides a roadmap for research, protection and conservation of plant diversity, especially the threatened taxa.

Keywords: Compositae, coniferous forest, conservation, elevation, floristic survey, hotspot, Kashmir Himalaya, mountains, threatened taxa.

Abbreviations: Afg.—Afghanistan | Ah—Annual herb | APG—Angiosperm Phylogeny Group | Bh—Biennial herb | BP—Low-level blue pine forest | C—Central | CBD—Convention on Biological Diversity | CR—Critically Endangered | DD—Data Deficient | DS—Deciduous shrub | DT—Deciduous tree | E—Eastern | EC— Eastern-central | EN—Endangered | ES—Evergreen shrub | ET—Evergreen tree | IHR—Indian Himalayan Region | IUCN—International Union for Conservation of Nature | LC—Least Concern | MC—Mixed coniferous forest | Medit.—Mediterranean | Mya.—Myanmar | N—Northern | NA—Not assessed | NC—North-central | NE—North-eastern | NW—North-western | OER—Observed elevation range | Pak.—Pakistan | Ph—Perennial herb | Phip.—Philippines | S = Southern | S—Shrub | SA—Subalpine forest | SC—South-central | SE—South-eastern | SS—Subshrub | SW—South-western | Temp.—Temperate | Thail.—Thailand | TPL—The Plant List | VU—Vulnerable | W—Western.

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Author details: Ashaq Ahmad Dar is a research scholar/junior research fellow. His areas of interest are forest ecology and plant taxonomy. Dr. Akhtar Hussain Malik, junior scientist, works in the field of plant taxonomy, biodiversity, and ethnobotany. N. Parthasarathy, professor, has expertise in forest ecology, biodiversity conservation, and plant taxonomy.

Author contributions: AAD carried out the fieldwork, gathered, processed & stored the specimens, and prepared the manuscript. AHM identified the plant specimens. NP directed the work and examined the manuscript.

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INTRODUCTION

Research on biodiversity became an essential aspect of biological research immediately after the Convention on Biological Diversity (CBD), with the goal of determining the implications of rapid depletion, management and climate change on species composition and diversity. Biodiversity-related data provide a foundation for species conservation and habitat protection (Cadotte 2006). With only 2.2% of global land area, India houses over 18,000 plant species, including 5,000 endemic flora, and is recognized among the 17 global mega-biodiverse countries (Nayar 1996; Singh et al. 2015). About half of the biodiversity hotspots representing 25% of the known biota are reported from mountain ecosystems (Wester et al. 2019). However, until recently, mountains acquired the attention of researchers, policy-makers, and conservationists.

Currently, diverse habitats supporting distinct flora are experiencing the threat of destruction due to fragmentation, rapid human population growth and climate change (Janssen et al. 2016; IUCN 2017). Consistent reductions in plant diversity call for continuous exploration of the population status of flora using systematic (IUCN) criteria, as this is acknowledged as the most rigorous strategy/technique for evaluating the global status of biodiversity and categorizing plants based on their projected risk of extinction (Maes et al. 2015; Orsenigo et al. 2018; Nowak et al. 2020).

The Himalaya, extending from Afghanistan to Myanmar, is one of 36 biodiversity hotspots harbouring a diverse range of flora and fauna, resulting from the phytogeographical complexity of the region (Zachos & Habel 2011). About half of the known biodiversity in India, particularly endemics, is contributed by the 13% land area of the Indian Himalayan Region (IHR). The phytogeographical complexity in the present Jammu & Kashmir, located on the northwestern side of the Himalaya, contributes significantly to various life forms. On account of its floristic status, the Kashmir Himalaya is a part of Himalayan biodiversity hotspot, and it is also considered to be vulnerable to climate change and thus species extinction (Rashid et al. 2015).

Several scholars over the course of time have made significant contributions to floristic knowledge of the Himalayan region: Hooker (1872–1897); Lambert (1933); Javeid (1966, 1978, 1979); Hajra (1983); Polunin & Stainton (1984); Kachroo (1993); Singh & Kachroo (1994); and Malik et al. (2010). However, critical taxonomic knowledge about the Kashmir Himalaya is still poor. In addition, a detailed study on the altitudinal distribution of taxa across the forest types is lacking. Consequently, the present study was undertaken to document the floristic diversity of the area, and to highlight its conservation significance.

MATERIALS AND METHODS

Study area

The study area spans over five districts of the Kashmir valley (33.513–34.659 ^{0}N & 74.497–75.019 ^{0}E) in the present Jammu & Kashmir, India (Figure 1; Image1). Kashmir valley exhibits a warm summer and humid continental climate (Dfa; Peel et al. 2007) with four distinctive seasons, i.e., spring, summer, autumn, and winter. Climate data from the last 38 years revealed that Kashmir valley experiences an annual mean minimum and maximum temperature of 5.4 ± 0.4 °C and 17.6 ± 0.8 °C (Dad et al. 2021). Furthermore, the mean annual rainfall is 1005.5 ± 197.6 mm (Dad et al. 2021). About 46% of precipitation occurs during pre-monsoon, followed by south-west monsoon (27%), winter monsoon (25%), and post-monsoon (8%). Disturbances posed by the Mediterranean Sea during winter lead to frequent rain and snowfall in the valley. The period of snowfall extends from October–March. Geologically, the study area consists of rocks chiefly composed of slates, phyllites and quartzites (Krishnan 1982). The predominant soil orders are entisols, inceptisols, alfisols, and mollisols (Mahapatra et al. 2000; Sidhu & Surya 2014).

Low-level blue pine (BP) forest ranges from 1,500–2,400 m on gentle to moderate slopes. Even-aged stands of the blue-pine, *Pinus wallichiana* A.B.Jacks intermixed with deodar, *Cedrus deodara* (Roxb. ex D.Don) G.Don and the spruce, *Picea smithiana* (Wall.) Boiss., occur depending upon the aspect. Since the ground surface is covered with litter, understorey herb vegetation is less comprising of *Poa alpina* L., *Fragaria nubicola* (Lindl. ex Hook.f.) Lacaita, *Viola canescens* Wall. in summer season (Shaheen et al. 2012). Dominant shrub species include *Viburnum grandiflorum* Wall. ex DC., *Berberis lycium* Royle, *Indigofera heterantha* Brandis depending upon aspect and canopy cover. Anthropogenic disturbances include land encroachment (for cultivating *Zea mays* L. and *Solanum tuberosum* L.), non-timber forest product extraction (fruits of *Viburnum grandiflorum* Wall. ex DC., medicinally important herbs, honey, nutritious and medicinally important fungus – *Morchella esculenta* (L.) Pers. etc.), lopping, firewood collection, grazing, and fire.

Mixed coniferous (MC) forest, commonly referred to

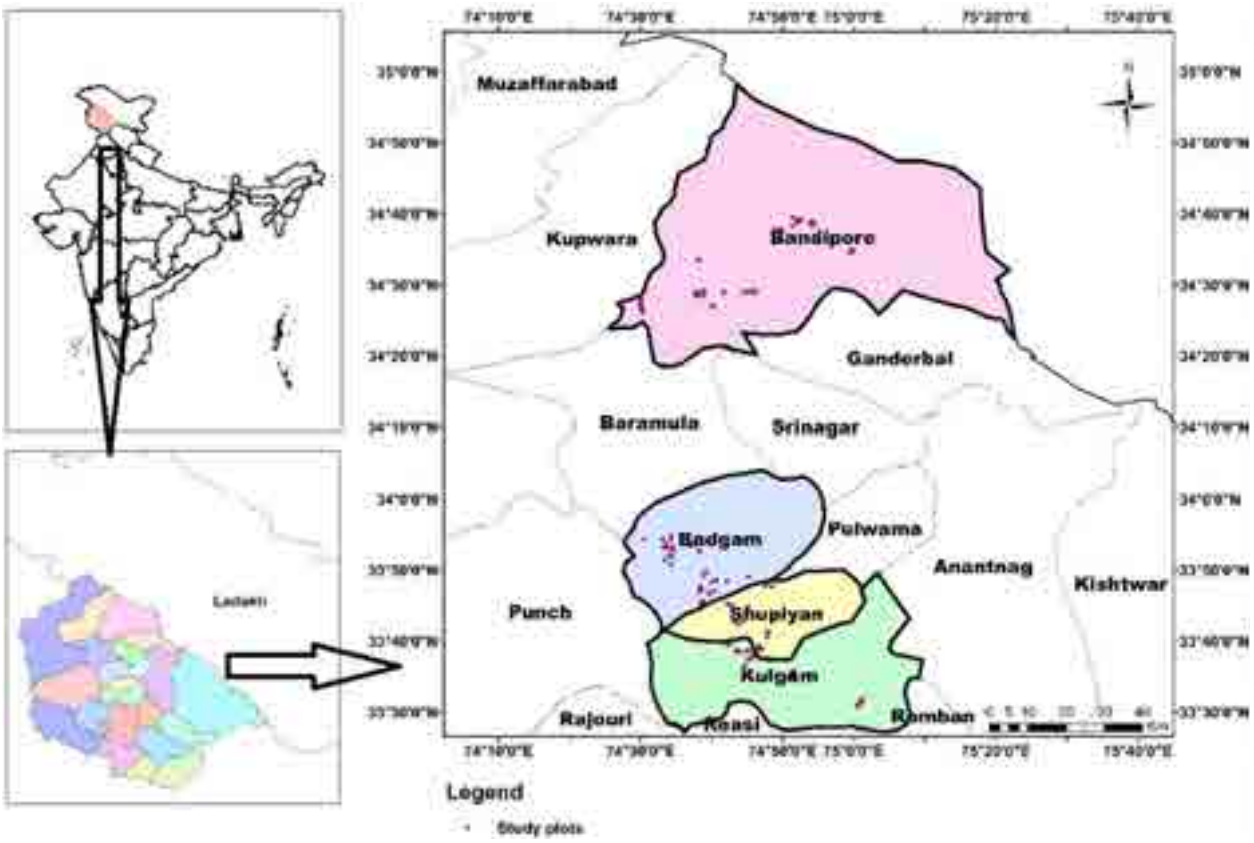

Table 1. Map of India, Jammu and Kashmir state, four districts shown in different colours, and the sampled locations in red dots.

as fir forest, occupies the central and western Himalaya from an elevation of about 2,400–3,000 m. Tree species such as evergreen coniferous (*Abies pindrow* (Royle ex D.Don) Royle, *Picea smithiana* and *Pinus wallichiana*) and deciduous broad-leaved tree species (*Acer caesium* Wall. ex Brandis, and *Prunus cornuta* (Wall. ex Royle) Steud.,) predominate. The regeneration of tree species is low or absent, as indicated by the presence of few saplings and seedlings. Understorey vegetation blossoms after the snowmelt during the spring season and is quite dense and diverse. The dominant shrub and herb species include *Viburnum grandiflorum* and *Stipa sibirica* (L.) Lam., (Dar & Sundarapandian 2016). Epiphytic moss and lichen cover the trunk and lower branches of emergent tree species. Activities such as grazing, extraction of plants and plant materials of economic and medicinal value, firewood collection, illegal logging, etc., contribute to forest degradation.

The subalpine forest (SA) forms a transition between MC forest and alpine scrub or grassland from 2,900–3,500 m. *Abies pindrow* is a characteristic and dominant species intermixed with *Betula utilis* D.Don. *Rhododendron* spp. occur as undergrowth or form individual stands. The species of Primulaceae, Ranunculaceae, and Compositae constitute the main understory herbaceous vegetation. The subalpine forest is equally subjected to anthropogenic disturbances like the other forest types besides heavy winter snowfall as a natural disturbance (Gairola et al. 2009).

Sampling, herbarium preparation, and data analysis

A reconnaissance floristic survey was undertaken in the landscape between the elevation gradient of 1,500 m and 3,800 m to understand the forest types and composition. Three coniferous forests of Kashmir Himalaya: BP, MC, and SA (Champion & Seth 1968) were identitifed in the region. Botanical explorations were undertaken during 2019 (March–July) and 2020 (May–August) by employing a random sampling approach considering the accessability and forest types. During the survey, plants such as trees, shrubs and herbs were documented and voucher specimens were collected. Specimens were processed (pressing, drying, chemical treatment, and mounting) following recommended standard techniques (Rao & Sharma 1990), and examined and identified at the Centre for Biodiversity

and Taxonomy, University of Kashmir. The voucher specimens were deposited at the Department of Ecology and Environmental Sciences Herbarium, Pondicherry University. The Plant List (TPL; http://www.theplantlist.org/) was referred for updated binomial nomenclature and the author names. Angiosperm Phylogeny Group III (APG III) Classification (2009) and Chase & Reveal (2009) for angiosperms and Gymnosperms were followed for categorizing families. Khuroo et al. (2007) was referred for the origin and alien status of flora. Various information sources were explored to acquire Himalayan and global records of inventoried taxa, including Himalayan flora literature (Hooker 1872–1897; Polunin & Stainton 1984), Tropicos (http://www.tropicos.org/), India Biodiversity Portal (https://indiabiodiversity.org/), Flowers of India (http://www.flowersofindia.net/) and Plants of the World online (http://www.plantsoftheworldonline.org/).

RESULTS

Species composition and distribution

A total of 272 taxa belonging to 196 genera and 64 families were recorded across the three Kashmir Himalayan coniferous forests (Table 1). Of the total vascular plants, neophytes (aliens) represent 70 (25.73%) taxa within 27 and 62 families and genera (Table 2). This includes invasive aliens (IA; 51.42%), naturalised aliens (NZ; 38.57%), casual/naturalised aliens (C/NA; 8.57%) and cultivated unescaped aliens (CU; 1.43%). Among the aliens, woody flora accounted five (7.14%) species (*Robinia pseudoacacia* L., *Syringa emodi* Wall. ex Royle, *Crataegus songarica* K. Koch, *Rosa brunonii* Lindl., *Aesculus indica* (Wall. ex Cambess.) Hook.). All the neophytes are excluded hereafter from further analysis.

Most of the native taxa belong to Magnoliophyta (192 taxa, 139 genera, and 50 families), whereas Pinophyta (seven taxa, six genera, and three families) and Pteridophyta (three taxa, three genera, and two families) are less represented (Table 2). Within Magnoliophyta, 177 taxa (92%) belong to Magnoliopsida and 15 (7.8%) to Liliopsida. Among these, there are 177 herb taxa (174 Magnoliophyta and three Pteridophyta), eight shrub taxa (Magnoliophyta only), 15 tree taxa (eight Magnoliophyta and seven Pinophyta) and two subshrubs (Magnoliophyta only). Herbs are dominated by perennials (150 taxa, 85%), followed by annuals (17 taxa, 9.6%), biennials (two taxa, 1.1%) and evergreen (one taxon, 0.56%). Moreover, seven (3.9%) herbaceous taxa are either perennials, annuals or biennials (Table 2). Of the 15 reported tree taxa, most of them are deciduous (8, 59%), followed by evergreen conifers (seven, 41%). Similarly, among the shrubs, seven (88%) are deciduous (including one climber), and one (12.5%) is evergreen. The images of selected plant taxa are provided (Images 2–7).

Three families in Magnoliophyta with greater contribution to species richness include Compositae (28 taxa, 13.86%) and Apiaceae and Rosaceae (13, 6.44% each). Families with ten or more species (besides above three) include Lamiaceae, Leguminosae, Poaceae (11, 5.45% each), and Ranunculaceae (10, 4.95%) (Figure 2). Species-rich genera, i.e., *Artemisia*, *Potentilla*, *Viola*, and *Saussurea* contributed 16 (7.92%) taxa. Majority of families (26, 47.27%) and genera (108, 72.97%) are monotypic with a single taxon. Among Pinophyta, Pinaceae (four taxa) and Cupressaceae (two taxa) are predominant families, whereas *Juniperus* is the principal genus contributing two taxa. Pteridophyta is represented by Pteridaceae (two taxa) and Equisetaceae (one taxon), and all the three genera (*Adiantum*, *Equisetum*, and *Pteris*) contributed equally, i.e., one species. In contrast to tree and understory herb vegetation, all shrub families and genera contributed one species each.

The number of taxa varied among the forest types and corresponding elevation due to the uneven distribution of taxa (Table 1). The SA and MC forests represent greater number of taxa, i.e., 136 and 134, followed by BP forest (83 taxa). The species distribution revealed that 20 taxa are exclusive to BP forest, whereas 30 and 46 taxa are limited to MC and SA forests. However, 22.77% of taxa with a wide distributional range are shared among forest types. Furthermore, BP & MC, BP & SA, and MC

Table 1. Distribution of taxa among various taxonomic groups in three coniferous forests viz., low-level blue pine forest (BP), mixed coniferous forest (MC), subalpine forest (SA) of Kashmir Himalaya, India.

Phylum	Taxon	Genera	Family	Trees	Shrubs	Subshrub	Herbs
Magnoliophyta	262	187	59	10	10	3	239
Pinophyta	7	6	3	7	–	–	–
Pteridophyta	3	3	2	–	–	–	3
Total	272	196	64	17	10	3	242

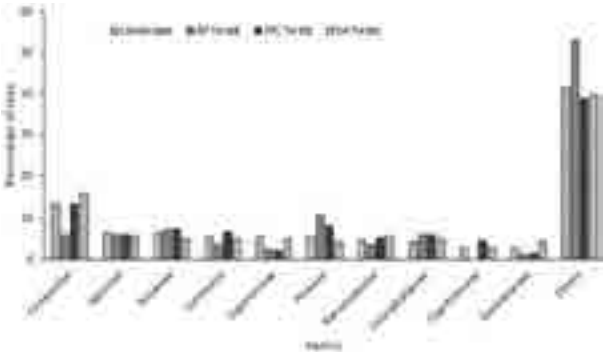

Figure 2. Percentage contribution to taxa across three coniferous forests of Kashmir Himalaya, India by families.

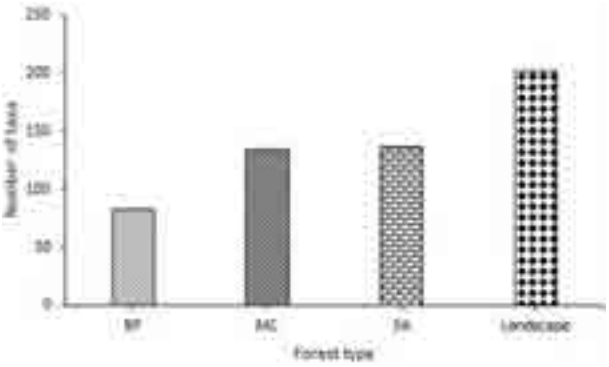

Figure 3. Number of taxa in three coniferous forests of Kashmir Himalaya, India.

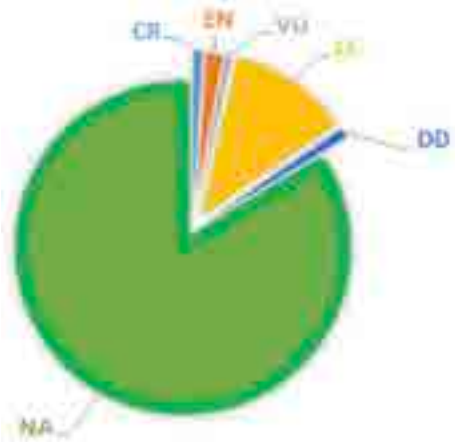

Figure 4. Pie-chart showing IUCN category of species across the three coniferous forests of Kashmir Himalaya, India.

& SA forests shared 16, two, and 43 taxa, respectively. The SA forest harbours greater number of species of Compositae (16.18%) and Caryophyllaceae (5.15%) than to landscape-scale flora (13.86% and 4.46%) in top 10 families. Similarly, Poaceae, and Rosaceae in BP (10.84% & 7.23%) and MC forests (8.21% & 7.46%) contributed greater number of taxa than to the overall landscape (5.45% & 6.44%).

Determination of phytogeographic distribution and taxa status

The distribution of most of the recorded taxa is confined to the northern temperate regions. However, 24 taxa restricted their distribution to the Himalayan landscape (Table 2). Despite the considerable research on plant conservation in Kashmir Himalaya, the analysis of the conservation status of the flora revealed that 169 taxa are not assessed (NA), and the remaining 33 (16.37%) taxa are included under IUCN Red List category (Table 2). Among them, two species *Saussurea costus* (Falc.) Lipsch. and *Aconitum chasmanthum* Stapf ex Holmes are Critically Endangered (CR); four species *Trillium govanianum* Wall. ex D.Don, *Aconitum heterophyllum* Wall. ex Royle, *Taxus wallichiana* Zucc. and *Atropa acuminata* Royle ex Lindl. are Endangered (EN); one species *Cypripedium cordigerum* D.Don is Vulnerable (VU), two species *Asparagus filicinus* Buch.-Ham. ex D.Don and *Corylus jacquemontii* Decne. fall under Data Deficient (DD) category and 24 species are Least Concern (LC). With regard to the forest type and vertical distribution, the maximum number of threatened taxa (VU+EN+CR) occur in SA forest at high altitudinal zones.

DISCUSSION

The floristic survey revealed 272 taxa from 196 genera and 64 families categorized in three life-forms, i.e., trees and understorey shrubs and herbs (Table 1 & 2). The number of taxa reported in the present study was greater than most of the floristic studies in temperate Kashmir Himalaya (Shaheen et al. 2012; Mir et al. 2019; Malik et al. 2021) and other Himalayan studies (Ahmad et al. 2020; Asif et al. 2020; Tiwari et al. 2020) and also elsewhere (Bai et al. 2011). Compositae and Apiaceae constituted species-rich families in this survey. These families were also well represented in other studies of the Kashmir Himalaya: Asif et al. (2020) *Betula* forests in northwestern Kashmir Himalaya; Dar & Sundarapandian (2016) forests of western Himalaya, and elsewhere Devi et al. (2014) northwestern Himalaya. Variation in species distribution among the forest types/altitudinal zones could be due to micro-climatic heterogeneity resulting from a change in elevation, slope, and other ecological gradients (Körner 2007), besides evolutionary

Table 2. List of plant species in three temperate coniferous forests, viz., low-level blue pine forest (BP), mixed coniferous forest (MC), subalpine forest (SA) of Kashmir Himalaya, India.

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
Acanthaceae					
Pteracanthus alatus (Nees) Bremek.[1]	Erect S	BP	2200–2300	PU/EES/KH-1210	E. Afg. to S. China, N. Indo-China & Taiwan
Adoxaceae					
Sambucus wightiana Wall. ex Wight & Arn.[1*]	Erect Ph	BP/MC/SA	2200–3310	PU/EES/KH-15201	India, Pak., W. Himalayas
Viburnum grandiflorum Wall. ex DC.[1]	DS	BP/MC/SA	1890–3000	PU/EES/KH-1206	Himalayas from Kashmir to SE Tibet
Amaranthaceae					
Achyranthes aspera L.[1*]	Ph	MC/SA	2600–3000	PU/EES/KH-15001	Tropical & Subtropical Old World; throughout India
Chenopodium album L.[1*]	Ah	MC/SA	2650–2990	PU/EES/KH-15065	Temp. Eurasia to Indian Subcontinent
Chenopodium foliosum Asch.[1*]	Ah or Ph	SA	2910–3160	PU/EES/KH-15066	C. & S. Europe to Nepal; W. Himalayas in India
Amaryllidaceae					
Allium humile Kunth[1]	Bulbous Ph	MC/SA	2700–3015	PU/EES/KH-15013	N. Pak. to C. Himalayas & China
Apiaceae					
Aegopodium alpestre Ledeb.[1]	Ph	MC	2500–2600	PU/EES/KH-15008	Temp. Asia; W. Himalayas in India
Bunium cylindricum (Boiss. & Hohen.) Drude[1]	Ph	SA	3100–3150	PU/EES/KH-15045	Turkey to C. Asia & Pak. to W. Himalayas
Bupleurum falcatum L.[1]	Ph	BP	2200–2300	PU/EES/KH-15046	Europe to Himalayas
***Bupleurum longicaule* Wall. ex DC.[1]**	Ph	SA	3750–3800	PU/EES/KH-15047	Himalayas from Pak. to Bhutan
Carum carvi L.[1]	Ph	BP	2350–2400	PU/EES/KH-15054	Palearctic region; throughout India
Chaerophyllum reflexum Aitch.[1]	Ph	BP/MC	1927–2450	PU/EES/KH-15063	Himalayas from Pak. to SW China
Chaerophyllum villosum Wall. ex DC.[1]	Ph	BP/MC/SA	2050–2920	PU/EES/KH-15064	N. Pak. to China; Himalayas in India
Eryngium billardieri Delile[1*]	Ph	BP	2120–2130	PU/EES/KH-15103	EC Turkey to Lebanon & W. Pak.; W. Himalayas in India
Heracleum candicans Wall. ex DC.[1]	Climbing Ph	MC/SA	2400–3810	PU/EES/KH-15119	Himalayas from Pak. to SW China
Pimpinella acuminata (Edgew.) C.B. Clarke[1]	Ph	BP/MC/SA	2200–3120	PU/EES/KH-15170	N. Pak. to China; Himalayas in India
Pimpinella diversifolia DC.[1]	Ph	MC	2460–2770	PU/EES/KH-15171	E. Afg. to China & Indo-China; Himalayas in India
Prangos pabularia Lindl.[1]	Ph	MC/SA	2720–3140	PU/EES/KH-15189	Turkey to C. Asia & W. Himalayas
Sanicula elata Buch.-Ham. ex D.Don[1]	Ph	SA	2910–2930	PU/EES/KH-15202	SE Asia from Pak. to W. China & S. Japan to SE Africa
Scandix pecten-veneris L.[1*]	Tall robust Ph	SA	3300–3310	PU/EES/KH-15207	Europe to NW India
***Selinum vaginatum* C.B. Clarke[1]**	Ph	SA	3790–3800	PU/EES/KH-15211	NE Pak. to W. Himalayas
Seseli libanotis (L.) W.D.J.Koch[1]	Ph	MC/SA	2740–2920	PU/EES/KH-15214	Europe, Turkey, Iran, W. Pak. & India
Apocynaceae					
Vincetoxicum hirundinaria Medik.[1]	Prostrate erect or climbing Ah	BP/MC	1980–2760	PU/EES/KH-15244	Europe to W. Siberia & N. Turkey, NW Africa, Himalayas
Araceae					
Arisaema jacquemontii Blume[2]	Rhizomatous Ph	BP/MC/SA	2250–2950	PU/EES/KH-15028	Afg. to Mya.
Arisaema propinquum Schott[1]	Ph	MC/SA	2450–2950	PU/EES/KH-15029	Pak. to Himalayas & Tibet
Araliaceae					
Hedera nepalensis K.Koch[1]	Ph	BP/MC	1980–2610	PU/EES/KH-15118	Afg. to Thail.; Himalayas in India

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
Asparagaceae					
Asparagus filicinus Buch.-Ham. ex D.Don[4]	Erect or twining Ph	BP	1800–1900	PU/EES/KH-15036	Himalayas to C. China
Polygonatum multiflorum (L.) All.[1]	Tufted Ah	BP/MC	2270–2440	PU/EES/KH-15181	Eurasia; W. Himalayas in India
Polygonatum verticillatum (L.) All.[1]	Rhizomatous Ph	BP/MC/SA	1980–3120	PU/EES/KH-15183	Europe to China; Himalayas in India
Balsaminaceae					
Impatiens brachycentra Kar. & Kir.[1]	Ph	BP/MC/SA	2120–3310	PU/EES/KH-15122	Afg. to C. Asia & W. Himalayas
Berberidaceae					
***Berberis lycium* Royle[1]**	Semi-DS	BP	2100–2150	PU/EES/KH-1203	W. Himalayas from Pak. to Nepal
Epimedium elatum C.Morren & Decne.[1]	Rhizomatous Ph	MC/SA	2520–3120	PU/EES/KH-15095	N. Pak. to W. Himalayas
Podophyllum hexandrum Royle[1]	Rhizomatous Ph	BP/MC/SA	2370–3310	PU/EES/KH-15176	NE Afg. to C. China; Himalayas in India
Betulaceae					
Betula utilis D.Don[2]	DT	SA	2910–3300	PU/EES/KH-1004	Afg. to N. & C. China; Himalayas in India
Corylus jacquemontii Decne.[4]	DT	MC	2560–2790	PU/EES/KH-1006	Europe, Himalayas from Afg. to W. Nepal
Boraginaceae					
Arnebia benthamii (Wall. ex G. Don) I.M. Johnst.[1]	Rhizomatous Ph	SA	3800–3900	PU/EES/KH-15024	NE Pakistan to W. & C. Himalaya
Cynoglossum glochidiatum Wall. ex Benth.[1]	Bh	BP/MC/SA	2120–3000	PU/EES/KH-15084	Afg. through Kashmir to Sikkim & W. China
Cynoglossum lanceolatum Forssk.[1*]	Bh or Ph	BP/SA	2230–3800	PU/EES/KH-15085	Tropical & S. Africa to Tropical & Subtropical Asia; throughout India
Hackelia uncinata (Benth.) C.E.C.Fisch[1]	Ph	SA	2910–3120	PU/EES/KH-15117	Himalayas from Pak. to SW China
Myosotis alpestris F.W. Schmidt[1]	Ph	SA	3150–3310	PU/EES/KH-15148	Europe, Himalayas from Pak. to Bhutan
Myosotis sylvatica Ehrh. ex Hoffm.[1]	Ph	BP/MC/SA	2260–3150	PU/EES/KH-15149	Temp. Eurasia; W. Himalayas in India
Brassicaceae					
Arabis amplexicaulis Edgew.[1]	Ph	BP/MC	2200–2410	PU/EES/KH-15021	Afg. to Mongolia & Himalayas
Arabis pterosperma Edgew.[1]	Ph	MC	2700–2800	PU/EES/KH-15023	Kashmir to China
Capsella bursa-pastoris (L.) Medik.[1*]	Erect Ah or Bh	MC/SA	2420–2950	PU/EES/KH-15053	Temp. Eurasia, N. Africa; throughout India
Chorispora tenella (Pall.) DC.[1]	Ah	MC	2750–2770	PU/EES/KH-15067	SE & E. Europe to China; W. Himalayas in India
Lepidium apetalum Willd.[1]	Rhizomatous Ph	BP	2120–2130	PU/EES/KH-15134	E. Europe to temp. Asia; Himalayas in India
Turritis glabra L.[1*]	Ah or Bh	BP/MC	2300–2650	PU/EES/KH-15022	Temp. N. Hemisphere; W. Himalayas in India
Campanulaceae					
Campanula cashmeriana Royle[1]	Ph	SA	3150–3200	PU/EES/KH-15050	Afg. to W. Himalayas to Nepal
Campanula latifolia L.[1]	Ph	MC/SA	2525–2920	PU/EES/KH-15051	SW Siberia, W. Asia to C. Himalayas
Codonopsis ovata Benth.[1]	Ph	MC/SA	2720–3800	PU/EES/KH-15076	C. Asia, Himalayas from Pak. to Kashmir
Codonopsis rotundifolia Benth.[1]	Twining Ph	BP	2200–2340	PU/EES/KH-15077	Pak. to Himalayas & S. Tibet
Cannabaceae					
Cannabis sativa L.[1*]	Ah	BP/MC	1920–2650	PU/EES/KH-15052	Native to C. Asia now cosmopolitan
Caprifoliaceae					
***Dipsacus inermis* Wall.[1]**	Ph	MC/SA	2700–3810	PU/EES/KH-15092	Himalayas from Afg. to SW China & Mya.
Lonicera quinquelocularis Hard.[1]	ES	MC	2500–2700	PU/EES/KH-1209	E. Afg. to Himalayas
Morina longifolia Wall.[1]	Ph	MC/SA	2700–2920	PU/EES/KH-15147	N. Pakistan to Himalaya & S. Tibet

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
***Scabiosa speciosa* Royle**[1]	Ah	MC	2720–2730	PU/EES/KH-15208	Himalayas from Pak. to Uttarakhand
Valeriana hardwickii Wall.[1]	Dioecious Ph	MC/SA	2570–3140	PU/EES/KH-15238	N. Pak. to S. China & W. Malesia, Himalayas in India
Valeriana jatamansi Jones[1]	Ph	MC/SA	2700–3150	PU/EES/KH-15239	Himalayas from Afg. to SW China
Caryophyllaceae					
Arenaria orbiculata Royle ex Edgew. & Hook.f.[1]	Ah	MC	2500–2600	PU/EES/KH-15026	Afg. to China; Himalayas in India
Cerastium cerastoides (L.) Britton[1]	Ph	BP/MC/SA	1920–3160	PU/EES/KH-15060	Temp. Eurasia, E. Canada to Greenland; W. Himalayas in India
Cerastium dahuricum Fisch.[1]	Scrambling Ph	BP/MC/SA	2520–3000	PU/EES/KH-15061	European Russia to Mongolia & W. Himalayas
Cucubalus baccifer L.[1]	Ph	BP/MC/SA	2400–2950	PU/EES/KH-15082	Temp. Eurasia & Himalayas
Lepyrodiclis holosteoides (C.A. Mey.) Fenzl ex Fisch. & C.A. Mey.[1]	Ah or Bh	MC/SA	2630–3120	PU/EES/KH-15135	Turkey to Mongolia & Himalayas
Lychnis coronaria Desr.[1*]	Ph	BP/MC	2070–2780	PU/EES/KH-15141	EC & SE Europe to N. Iran & C. Asia to W. Himalayas
Silene himalayensis (Rohrb.) Majumdar[1]	Ah	SA	2810–2820	PU/EES/KH-15218	NE Afg. to C. China; Himalayas in India
Silene vulgaris (Moench) Garcke[2]	Ph	BP/MC/SA	2200–2920	PU/EES/KH-15219	Palearctic; W. Himalayas in India
Spergularia diandra (Guss.) Heldr.[1]	Ph	MC	2700–2710	PU/EES/KH-15221	Canary Islands, Medit. to SW Siberia & N. China; W. Himalayas in India
Stellaria decumbens Edgew.[1]	Ph	BP/MC/SA	2200–3150	PU/EES/KH-15225	E. & NE Afg. to China; Himalayas in India
Stellaria media (L.) Vill.[1*]	Densely or laxly caespitose Ph	BP/MC	2250–2780	PU/EES/KH-15226	Temp. Eurasia, N. & NE Tropical Africa; throughout India
Compositae					
Achillea millefolium L.[2*]	Rhizomatous Ph	BP/MC/SA	2200–3800	PU/EES/KH-15002	Subarctic & temp. N. Hemisphere to Guatemala; W. Himalayas in India
Anaphalis contorta (D.Don) Hook.f.[1]	Rhizomatous under-S	BP/MC/SA	1900–3300	PU/EES/KH-15014	Himalayas from Afg. to SW China & Mya.
Anaphalis staintonii Georgiadou[1]	Ph	MC	2700–2800	PU/EES/KH-15015	N. Pak. to W. Himalayas
Anaphalis virgata Thomson[1]	Ph	BP/MC/SA	2200–3200	PU/EES/KH-15016	Afg. to Xinjiang & Himalayas
Arctium lappa L.[1*]	Bh	BP/SA	2300–2950	PU/EES/KH-15025	Temp. Eurasia; Himalayas in India
Artemisia absinthium L.[1*]	Ph	MC/SA	2750–2920	PU/EES/KH-15030	Europe to Siberia & W. Himalayas
Artemisia brevifolia Wall. ex DC.[1]	SS	MC	2450–2720	PU/EES/KH-15031	Afg. to W. Tibet & W. Himalayas
Artemisia dubia Wall.[1]	SS	BP	2300–2400	PU/EES/KH-15032	Himalayas from Pak. to C. Nepal & China
Artemisia scoparia Waldst. & Kitam.[1]	Bh or Ph	MC/SA	2450–3300	PU/EES/KH-15033	Palearctic region; throughout India
Artemisia vestita Wall. ex Besser[1*]	SS	SA	3200–3400	PU/EES/KH-15034	Pak. to Mongolia & China, W. Himalayas in India
Artemisia vulgaris L.[1]	Ph	SA	2830–2916	PU/EES/KH-15035	Temp. Eurasia to Indo-China & N. Africa
Carduus edelbergii Rech.f.[1*]	Ph	BP/MC	2010–2550	PU/EES/KH-15056	Afg. to Nepal
Carpesium abrotanoides L.[1*]	Ph	BP/MC	2200–2570	PU/EES/KH-15057	S. & C. Europe to Japan & Himalayas
Carpesium cernuum L.[1]	Ah	MC/SA	2750–2930	PU/EES/KH-15055	Eurasia; W. Himalayas in India
Centaurea iberica Trevir.[1*]	Ph	BP	2250–2300	PU/EES/KH-15059	SE & E. Europe to Xinjiang & W. Himalayas
Cichorium intybus L.[1*]	Ph	BP/MC	2050–2490	PU/EES/KH-15068	N. Africa, C & SW Asia & Europe
Cirsium arvense (L.) Scop.[1*]	Dioecious Ph	BP	2200–2210	PU/EES/KH-15070	Temp. Eurasia, NW Africa; Himalayas in India
Cirsium falconeri (Hook.f.) Petr.[1]	Ph	SA	2840–2990	PU/EES/KH-15071	N. Pak. to S. Tibet & N. Mya.

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
Cirsium vulgare (Savi) Ten.[1]	Bh	SA	2940–2950	PU/EES/KH-15072	Europe to Siberia & Arabian Peninsula; W. Himalayas in India
Cirsium wallichii DC.[1*]	Ph	BP/MC/SA	1920–3210	PU/EES/KH-15073	Afg. to Indian Subcontinent
Conyza canadensis (L.) Cronquist[1*]	Ah	BP	2010–2210	PU/EES/KH-15079	Native to Neotropic & Nearctic regions
Crepis sancta (L.) Bornm.[1*]	Ah	SA	2910–2920	PU/EES/KH-15081	E. Europe, W. Asia eastwards in Himalayas up to Nepal
Doronicum roylei DC.[1]	Ph	SA	3800–3810	PU/EES/KH-15093	NE Pak. to Himalayas & S. Tibet
Erigeron multiradiatus (Lindl. ex DC.) Benth. ex C. B. Clarke[1]	Rhizomatous Ph	MC/SA	2530–3800	PU/EES/KH-15101	Afg. to China
Lactuca macrorhiza (Royle) Hook. f.[1]	Rhizomatous Ph	MC/SA	2570–3130	PU/EES/KH-15125	Afg. to Himalayas
***Lactuca dolichophylla* Kitam.[1]**	Ph	MC	2530–2540	PU/EES/KH-15126	Himalayas from Afg. to SW China
Lapsana communis L.[1]	Ah	BP/MC	2315–2710	PU/EES/KH-15129	Europe to Siberia & Iran; W. Himalayas in India
Ligularia amplexicaulis DC.[1]	Ph	MC/SA	2790–2930	PU/EES/KH-15137	Himalayas to S. Tibet
Ligularia fischeri (Ledeb.) Turcz.[1]	Ph	MC/SA	2570–3540	PU/EES/KH-15138	NE Pak. to S. Siberia & Japan; Himalayas in India
Myriactis nepalensis Less.[1]	Ph	BP/MC/SA	1980–3000	PU/EES/KH-15150	Himalayas from Afg. to SW China, & SE Asia
Picris hieracioides Sibth. & Sm.[1]	Ph	MC/SA	2430–3000	PU/EES/KH-15169	Temp. Eurasia; Himalayas in India
Saussurea albescens Hook. f & Thomson[1]	Ph	SA	3010–3020	PU/EES/KH-15203	NE Afg. to Nepal
***Saussurea costus* (Falc.) Lipsch.[3]**	Ph	SA	3050–3060	PU/EES/KH-15206	W. Himalayas
***Saussurea roylei* C.B. Clarke[1]**	Ph	SA	3130–3140	PU/EES/KH-15204	NW Himalayas
Saussurea taraxacifolia (Lindl.) Wall. ex DC.[1]	Ph	SA	3800–3810	PU/EES/KH-15205	Himalayas from Kashmir to Bhutan, Xizang
Senecio chrysanthemoides DC.[1]	Ph	MC/SA	2420–3150	PU/EES/KH-15212	Afg. to SC China & Indo-China
Serratula pallida DC.[1]	Ph	MC	2430–2440	PU/EES/KH-15213	N. Pak. to Nepal
Sigesbeckia orientalis L.[1*]	Tufted Ph	BP	2200–2210	PU/EES/KH-15217	E. Europe to Asia & Australia
Solidago virga-aurea L.[1]	Ph	MC/SA	2670–3810	PU/EES/KH-15220	W. Europe to C. Siberia & Phip.; Himalayas in India
Tanacetum multicaule Sch.Bip.[1]	Ph	SA	3010–3810	PU/EES/KH-15229	Kashmir to SW China
Taraxacum officinale (L.) Weber ex F.H.Wigg.[1*]	Semi-prostrate Ph	BP/MC/SA	1920–3410	PU/EES/KH-15230	Cosmopolitan
Tussilago farfara L.[1]	Ph	MC/SA	2670–3130	PU/EES/KH-15236	Palearctic region; Himalayas in India
Xanthium spinosum L.[1*]	Rhizomatous Ph	BP	2230–2240	PU/EES/KH-15128	C. & E. Canada to Mexico, Peru to S. South America
Convolvulaceae					
Convolvulus arvensis L.[1*]	Climbing & prostrate Ah or Ph	MC	2440–2460	PU/EES/KH-15078	Eurasia; throughout India
Crassulaceae					
Sedum ewersii Ledeb.[1*]	Ph	SA	3790–3810	PU/EES/KH-15210	Siberia to Afg. & N. China; W. Himalayas in India
Cupressaceae					
Juniperus semiglobosa Regel[2]	Monoecious ET	MC	2450–2500	PU/EES/KH-1008	SE Iran to C. Asia, Himalayas from Pak. to Uttarakhand
Juniperus squamata Buch.-Ham. ex D.Don[2]	Monoecious bushy, semi-prostrate S/ET	SA	3150–3440	PU/EES/KH-1015	N. Afg. to China
Cyperaceae					
Carex stenophylla Wahlenb.[2]	Rhizomatous creeping Ph	SA	2800–2920	PU/EES/KH-15058	From Caucasus & Iran to Pak., Kashmir & Mongolia
Dioscoreaceae					
Dioscorea deltoidea Wall. ex Griseb.[1]	Climbing Ph	BP/SA	1880–2810	PU/EES/KH-15091	Himalayas to SC China & Indo-China

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
Elaeagnaceae					
Hippophae rhamnoides L.[1]	Dioecious DT	MC	2400–2500	PU/EES/KH-1204	Palearctic region; W. Himalayas in India
Equisetaceae					
Equisetum arvense L.[2]	Erect or prostrate rhizomatous Ph	BP/SA	2320–3060	PU/EES/KH-15100	Subarctic & temp. N. Hemisphere
Euphorbiaceae					
Euphorbia esula L.[1]	Erect Ph	MC	2600–2760	PU/EES/KH-15104	Palearctic; W. Himalayas in India
Euphorbia pilosa L.[1]	Ph	SA	2920–2930	PU/EES/KH-15105	C. Asia, N. Pak. to Himalayas
Euphorbia wallichii Hook.f.[1]	Ph	SA	3140–3540	PU/EES/KH-15106	Himalayas from Afg. to W. Himalayas to Sikkim
Gentianaceae					
***Gentiana carinata* (D.Don) Griseb.**[1]	Ph	MC/SA	2570–3000	PU/EES/KH-15111	Himalayas from Pak. to Uttarakhand
***Gentiana moorcroftiana* Wall. ex G.Don**[1]	Aromatic, dwarf, creeping mat forming herb	SA	3790–3800	PU/EES/KH-15251	Himalayas from Kashmir to Nepal
Gentiana tianschanica Rupr. ex Kusn.[1]	Ah	SA	3790–3800	PU/EES/KH-15112	Himalayas & China
***Lomatogonium caeruleum* (Royle) Harry Sm. ex B.L. Burtt**[1]	Tufted Ph	SA	3790–3810	PU/EES/KH-15140	Himalayas from Kashmir to Nepal
Swertia speciosa D.Don[1]	Ah	SA	2810–2820	PU/EES/KH-15146	Himalayas from Pak. to Bhutan
Swertia petiolata D. Don[1]	Rhizomatous Ph	BP/MC/SA	2310–3210	PU/EES/KH-15228	E. Afg. to W. & C. Himalayas
Geraniaceae					
Geranium pusillum L.[1]	Ph	BP/MC/SA	1920–2920	PU/EES/KH-15113	Europe to W. Himalayas
Geranium wallichianum D.Don ex Sweet[2]	Ah	BP/MC/SA	1920–3810	PU/EES/KH-15114	E. Afg. to Himalayas & Tibet
Hamamelidaceae					
Parrotiopsis jacquemontiana (Decne.) Rehder[1]	DS/small DT	BP	2100–2300	PU/EES/KH-1201	E. Afg. to W. Himalayas
Hypericaceae					
Hypericum perforatum L.[1*]	Ah or Bh	BP/MC/SA	1980–3540	PU/EES/KH-15121	Europe to China, NW Africa, SW Sudan; W. Himalayas in India
Iridaceae					
Iris hookeriana Foster[1]	Ah	MC/SA	2560–3810	PU/EES/KH-15123	Afg. to W. Himalayas
Juglandaceae					
Juglans regia L.[2]	DT	BP	2000–2390	PU/EES/KH-1007	West Asia, W. China & Himalayas
Lamiaceae					
Clinopodium umbrosum (M.Bieb.) Kuntze[1*]	Ph	BP/MC/SA	2200–3000	PU/EES/KH-15074	Caucasus to N. Mya.; W. Himalayas in India
Clinopodium vulgare L.[1*]	Ph	BP/MC/SA	1920–3280	PU/EES/KH-15075	Medit., Europe to Siberia & W. Himalayas
Lamium album L.[1]	Ph	MC/SA	2560–2930	PU/EES/KH-15127	Palearctic region; W. Himalayas in India
Nepeta erecta (Royle ex Benth.) Benth.[1]	Ph	MC	2700–2770	PU/EES/KH-15151	E. Afg. to W. Himalayas
Nepeta laevigata (D.Don) Hand.-Mazz.[1]	Ph	BP/MC	2200–2410	PU/EES/KH-15152	Himalayas from Afg. to SW China
Nepeta linearis Royle ex Benth.[1]	Ph	MC/SA	2720–3810	PU/EES/KH-15153	E. Afg. to W. Himalayas
Origanum vulgare L.[1*]	Ph	BP/MC/SA	2310–3210	PU/EES/KH-15155	Eurasia; Himalayas in India
Phlomis bracteosa Royle ex Benth.[1]	Rhizomatous Ph	SA	2920–3800	PU/EES/KH-15166	E. Afg. to Himalayas
Phlomis cashmeriana Royle ex Benth.[1]	Ph	BP/MC/SA	2310–2910	PU/EES/KH-15167	Afg. to W. Himalayas
Prunella vulgaris L.[2*]	Ph	BP/MC/SA	1920–3150	PU/EES/KH-15191	Europe, N. Africa, N. America & Asia
***Salvia hians* Royle ex Benth.**[1]	Erect Ph	MC	2590–2600	PU/EES/KH-15198	Himalayas from Kashmir to Nepal

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
***Salvia moorcroftiana* Wall. ex Benth.**[1]	Aromatic Ph	MC	2720–2730	PU/EES/KH-15199	Himalayas from Pak. to W. Nepal
Salvia nubicola Wall. ex Sweet[1]	Ph	MC/SA	2700–2920	PU/EES/KH-15200	E. Afg. to Himalayas
***Stachys floccosa* Benth.**[1]	Erect Ph	BP/MC/SA	2390–2710	PU/EES/KH-15223	Himalayas from Afg., Pak. to Kashmir
Stachys sericea Wall. ex Benth.[1]	Ph	SA	2920–2930	PU/EES/KH-15224	Kashmir to SE Tibet
Thymus linearis Benth.[1*]	Ah	MC/SA	2500–3000	PU/EES/KH-15250	N. Iran to Xinjiang & Himalayas
Leguminosae					
Argyrolobium flaccidum (Royle) Jaub. & Spach[1]	Prostrate Ph	MC	2400–2550	PU/EES/KH-15027	India, Nepal & Pak.
Lathyrus humilis (Ser.) Spreng.[1]	Ah or Ph	SA	3110–3120	PU/EES/KH-15130	E. Europe to temp. Asia & W. Himalayas
Lathyrus laevigatus (Waldst. & Kit.) Gren.[1]	Ph	MC/SA	2670–3060	PU/EES/KH-15131	Europe, Himalayas from Pak. to W. Nepal
Lathyrus pratensis L.[2]	Ph	SA	2830–2840	PU/EES/KH-15132	Europe to Mongolia & Himalayas, Morocco, Ethiopia & Yemen
Leonurus cardiaca L.[1]	Scrambling Ph	SA	2920–2930	PU/EES/KH-15133	Europe, Himalayas from Pak. to Nepal
Lespedeza cuneata (Dum.Cours.) G.Don[2]	Ah	BP	1980–1990	PU/EES/KH-15136	Afg. to Japan & tropical Asia, E. & SE Australia
Medicago sativa Linn.[1]	Prostrate or decumbent Ph	BP	1920–1930	PU/EES/KH-15143	Europe to Mongolia & Indian Subcontinent
Medicago lupulina L.[1*]	Erect or procumbent Ph	BP/MC	1880–2720	PU/EES/KH-15144	Asia, Africa & Europe
Medicago minima (L.) L.[1]	Ah or Ph	MC	2770–2780	PU/EES/KH-15145	Temp. Eurasia to India, tropical Africa to SW. Arabian Peninsula
***Oxytropis cachemiriana* Cambess.**[2]	Creeping annual or short-lived Ph	SA	3790–3800	PU/EES/KH-15160	N. Pak. to W. Himalayas
Oxytropis mollis Benth.[1]	Ph	SA	3790–3800	PU/EES/KH-15162	India, Pakistan & Xizang
Robinia pseudoacacia L.[2*]	DT	MC	2330–2340	PU/EES/KH-1012	Native to N. America
Trifolium pratense L.[2*]	Ph	BP/MC	1980–2710	PU/EES/KH-15234	Europe & N. Asia, Himalayas in India
Trifolium repens L.[1*]	Erect to decumbent Ph	BP/MC/SA	1920–3540	PU/EES/KH-15235	Macaronesia, NW Africa, Egypt to Zimbabwe, Europe to Mongolia & Himalayas
Trigonella emodi Benth.[1]	Ph	SA	3800–3810	PU/EES/KH-15232	Afg. to Himalayas
Vicia sativa L.[2*]	Bh	MC/SA	2780–3120	PU/EES/KH-15243	Kashmir to Eurasia
Liliaceae					
Fritillaria roylei Hook.[1]	Ph	SA	3800–3900	PU/EES/KH-15252	Pak. to C. China
Malvaceae					
Malva neglecta Wallr.[1*]	Ph	BP/MC/SA	2310–2940	PU/EES/KH-15142	Canary Islands, Morocco, Europe to C. Asia & W. Himalayas
Melanthiaceae					
Trillium govanianum Wall. ex D.Don[5]	Erect or spreading Ph	SA	3050–3310	PU/EES/KH-15233	E. Afg. to Himalayas
Oleaceae					
Syringa emodi Wall. ex Royle[1]	DT	MC	2450–2500	PU/EES/KH-1205	Pak. to Nepal & Tibet
Onagraceae					
Circaea alpina L.[1]	Rhizomatous Ph	BP/MC/SA	2380–3000	PU/EES/KH-15069	Temp. N. Hemisphere
Epilobium hirsutum L.[2*]	Ph	BP/MC/SA	2200–3150	PU/EES/KH-15097	Temp. Eurasia to Africa; W. Himalayas in India
Epilobium laxum Royle[1]	Ph	SA	2980–2990	PU/EES/KH-15098	C. Asia to W. Himalayas
Oenothera rosea L'Hér. ex Aiton[1*]	Ph	BP/MC/SA	2230–2930	PU/EES/KH-15154	Native to C. & S. America
Orchidaceae					
Cypripedium cordigerum D.Don[6]	Ph	SA	2950–2960	PU/EES/KH-15087	N. Pak. to Himalayas & S. Tibet

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
Epipactis helleborine (L.) Crantz[1]	Rhizomatous Ph	BP/MC/SA	2330–2960	PU/EES/KH-15096	NW Africa, Europe to China; Himalayas in India
Epipactis royleana Lindl.[1]	Rhizomatous Ph	MC/SA	2700–2920	PU/EES/KH-15099	E. Afg. to C. Asia & Himalayas
Orobanchaceae					
Orobanche alba Stephan[1]	Rhizomatous aromatic Ph	MC/SA	2770–3160	PU/EES/KH-15156	Europe, Afg., Pak., W. Himalayas & Tibet
***Pedicularis pectinata* Wall. ex Benn.[1]**	Ph	BP/MC/SA	2310–3810	PU/EES/KH-15163	W. Himalayas from Pak. to W. Nepal
Oxalidaceae					
Oxalis acetosella L.[1]	Tufted Ph	BP/MC/SA	1880–3120	PU/EES/KH-15158	Europe to Japan; W. Himalayas in India
Oxalis corniculata L.[1*]	Rhizomatous Ph	BP/MC/SA	1880–2950	PU/EES/KH-15159	Cosmopolitan
Papaveraceae					
***Corydalis stewartii* Fedde[1]**	Rhizomatous Ah or Bh	BP	2200–2210	PU/EES/KH-15080	Afg. to Nepal
Phytolaccaceae					
Phytolacca acinosa Roxb.[1]	Ph	BP/MC	2270–2500	PU/EES/KH-15168	Kashmir to SW China
Pinaceae					
Abies pindrow (Royle ex D.Don) Royle[2]	Coniferous ET	BP/MC/SA	2220–3300	PU/EES/KH-1001	N. Afghanistan to Nepal
Cedrus deodara (Roxb. ex D.Don) G.Don[2]	Coniferous ET	BP	1810–2200	PU/EES/KH-1005	NE Afg. to W. Nepal & NW India
Picea smithiana (Wall.) Boiss.[2]	Coniferous ET	BP/MC/SA	2000–2960	PU/EES/KH-1009	NE Afg. to C. Himalayas
***Pinus wallichiana* A.B.Jacks.[2]**	Coniferous ET	BP/MC/SA	1800–3140	PU/EES/KH-1010	Himalayas from Afg. to Tibet
Plantaginaceae					
Plantago lanceolata L.[1*]	Ph	BP/MC/SA	1920–2930	PU/EES/KH-15172	Palearctic & Nearctic regions; Himalayas in India
Plantago major L.[2*]	Ph	BP/MC/SA	2200–3160	PU/EES/KH-15173	Europe, N. & C. Asia, introduced all over the world
Veronica laxa Benth.[1]	Ph	BP/MC/SA	2120–3150	PU/EES/KH-15240	N. Pak. to Nepal, C. & S. China & Japan; W. Himalayas in India
Veronica persica Poir.[1*]	Ph	SA	2950–2960	PU/EES/KH-15241	Native to Iran, now a worldwide weed; Himalayas in India
Poaceae					
Agrostis gigantea Roth[1]	Rhizomatous Ph	BP/MC/SA	2250–2850	PU/EES/KH-15010	Palearctic region, introduced in Nearctic; Himalayas in India
Brachypodium sylvaticum (Huds.) P.Beauv.[1]	Tufted Ph	BP/MC	2250–2510	PU/EES/KH-15040	Eurasia; throughout India
Bromus inermis Leyss.[1*]	Rhizomatous Ph	BP/MC	2050–2760	PU/EES/KH-15041	Palearctic & Nearctic regions; W. Himalayas in India
Bromus japonicus Thunb.[1*]	Ah	BP/MC/SA	2250–2950	PU/EES/KH-15042	Medit. to temp. Eurasia; W. Himalayas in India
Bromus pectinatus Thunb.[1]	Ah	BP/MC/SA	2250–2300	PU/EES/KH-15043	Europe, Iran & Afg. eastwards through India to China, Pak., Sudan through Ethiopia to Egypt, Sinai & Arabia
Bromus tomentosus Trin.[1]	Rhizomatous Ph	BP/MC	2250–2800	PU/EES/KH-15044	Medit. to Xinjiang & Pak.; W. Himalayas in India
Calamagrostis pseudophragmites (Haller) Koeler[2]	Creeping rhizomatous tufted Ph	MC/SA	2450–3800	PU/EES/KH-15049	Europe to Japan & Himalaya; Himalayas in India
Cynodon dactylon (L.) Pers.[1]	Stoloniferous Ph with rhizomes	BP/MC/SA	1920–2930	PU/EES/KH-15083	Temp. & Subtropical Old World to Australia; throughout India
Elymus dahuricus Griseb.[1]	Tufted Ph	MC	2430–2780	PU/EES/KH-15094	Temp. Asia; Himalayas in India
Koeleria macrantha (Ledeb.) Schult.[1*]	Rhizomatous Ph	MC/SA	2460–3810	PU/EES/KH-15124	Temp. N. Hemisphere to Mexico; Himalayas in India
Lolium perenne L.[1*]	Ph	MC	2420–2430	PU/EES/KH-15139	N. Africa, Europe to Siberia & Himalayas
Oryzopsis gracilis (Mez) Pilg.[1]	Ah or Ph	BP/MC	1920–2630	PU/EES/KH-15157	Iran to China
Phleum alpinum L.[2]	Trailing or creeping Ph	BP/MC/SA	2250–3140	PU/EES/KH-15165	Palearctic & Nearctic regions; Himalayas in India

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
Poa alpina L.[1]	Ph	BP/MC/SA	1980–3150	PU/EES/KH-15174	Temp. N. Hemisphere to Mexico; W. Himalayas in India
Poa pratensis L.[2*]	Tufted Ph	BP/MC/SA	2070–2990	PU/EES/KH-15175	Palearctic & Nearctic region; Himalayas in India
Polypogon fugax Nees ex Steud.[1*]	Ph	BP/MC/SA	2310–3000	PU/EES/KH-15180	Iraq to Mya. mainly in Himalayas & C. Asia
Setaria viridis (L.) P.Beauv.[1*]	Bh or Ph	BP	2360–2370	PU/EES/KH-15215	Palearctic; Himalayas in India
Stipa sibirica (L.) Lam.[1]	Caespitose or tufted Ah	BP/MC	1920–2770	PU/EES/KH-15227	Temp. Asia to Himalayas
Vulpia myuros (L.) C.C.Gmel.[1*]	Prostrate Ph	BP/MC	2260–2450	PU/EES/KH-15249	Europe to Taiwan & Sri Lanka., Arabian Peninsula & Kenya; throughout India
Polemoniaceae					
Polemonium caeruleum L.[1]	Ah	MC/SA	2590–2960	PU/EES/KH-15178	Europe to C. Siberia & Caucasus, Himalayas from Pak. to W. Nepal
Polygonaceae					
Aconogonon alpinum (All.) Schur[1]	Ph	BP	2300–2400	PU/EES/KH-15003	Palearctic; W. Himalayas in India
Bistorta amplexicaulis (D.Don) Greene[1]	Erect Ph	BP/MC/SA	2300–3000	PU/EES/KH-15039	E. Afg. to C. China; Himalayas in India
Oxyria digyna (L.) Hill[1]	Ph	SA	2830–3160	PU/EES/KH-15161	Palearctic & Nearctic regions; Himalayas in India
Persicaria capitata (Buch.-Ham. ex D.Don) H.Gross[1]	Ph	BP/MC/SA	2200–3150	PU/EES/KH-15164	Indian Subcontinent to S. China & Indo-China
Polygonum aviculare L.[1*]	Ph	BP/MC/SA	2210–2950	PU/EES/KH-15177	Palearctic & Nearctic regions; Himalayas in India
Polygonum filiforme Thunb.[1]	Ph	BP	1920–1930	PU/EES/KH-15179	Japan, Korea, India, Mya., Phip. & Vietnam
***Rheum webbianum* Royle[1]**	Ph	SA	3790–3800	PU/EES/KH-15196	Himalayas from Pak. to Nepal
Rumex nepalensis Spreng.[1*]	Erect Ph	BP/MC/SA	1920–3410	PU/EES/KH-15197	Afg., India, Pak., Persia, SW China, Turkey, N. Africa & Italy
Primulaceae					
Androsace rotundifolia Sm.[1]	Rhizomatous Ph	MC	2600–2750	PU/EES/KH-15017	Afg., Tibet & W. Himalayas
Androsace sarmentosa Wall.[1]	Ph	MC	2700–2800	PU/EES/KH-15018	Indian Himalayas, Nepal & Tibet
***Primula macrophylla* D. Don[1]**	Erect Ph	MC/SA	2720–3150	PU/EES/KH-15190	Himalayas from Afg. to SE Tibet
Pteridaceae					
Adiantum capillus-veneris L.[2]	Epilithic perennial fern	BP/MC/SA	1950–3000	PU/EES/KH-15007	Nearctic, Neotropical, Afrotropical, Australasian, Indomalayan & Palearctic regions; throughout India
Pteris cretica L.[1]	Rhizomatous Ph	BP	2370–2380	PU/EES/KH-15192	S. Africa, Europe to E. Asia; throughout India
Ranunculaceae					
Aconitum chasmanthum Stapf ex Holmes[3]	Ph	SA	3200–3800	PU/EES/KH-15004	Himalayas from Pak. to Nepal & Mongolia
***Aconitum heterophyllum* Wall. ex Royle[5]**	Rhizomatous Ph	MC/SA	2700–3810	PU/EES/KH-15005	Himalayas from Pak. to C. Nepal
Actaea spicata L.[1]	Rhizomatous Ph	MC/SA	2500–2931	PU/EES/KH-15006	E. Afg. to Himalaya
Anemone obtusiloba Lindl.[1]	Ph	SA	3200–3300	PU/EES/KH-15019	Himalayas, Mongolia, NC China & Kazakhstan
Aquilegia pubiflora Wall. ex Royle[1]	Ph	MC/SA	2500–3200	PU/EES/KH-15020	Afg., Pak., & W. Himalayas
Caltha palustris L.[2]	Ph	MC/SA	2800–2950	PU/EES/KH-15048	Palearctic & Nearctic regions; Himalayas in India
Delphinium roylei Munz[1]	Ph	BP	2200–2210	PU/EES/KH-15088	Pak. & Kashmir
***Delphinium vestitum* Wall. ex Royle[1]**	Ph	MC/SA	2520–3120	PU/EES/KH-15089	Himalayas from Pak. to E. Nepal
Ranunculus hirtellus Royle[1]	Rhizomatous Eh	BP/MC	2250–2780	PU/EES/KH-15193	Himalayas from Kashmir to Sikkim, Tibet & W. China
Ranunculus laetus Wall. ex Hook. f. & J.W. Thomson[1*]	Ph	BP/MC/SA	2200–2990	PU/EES/KH-15194	Himalayas from Afg. to SW China

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
***Ranunculus palmatifidus* Riedl**[1]	Erect Ph	BP/MC/SA	2310–2930	PU/EES/KH-15195	W. Himalayas
Thalictrum minus L.[1*]	Ph	BP	2310–2340	PU/EES/KH-15231	Himalayas from Pak. to Nepal & temp. Eurasia
Rosaceae					
Agrimonia pilosa Ledeb.[1]	Rhizomatous Ph	BP/MC	2200–2600	PU/EES/KH-15011	N. & EC Europe to Japan & N. Indo-China
Alchemilla trollii Rothm[1]	Ph	MC/SA	2750–3000	PU/EES/KH-15012	W. Himalayas & Pak.
Crataegus songarica K. Koch[2*]	DS/small DT	BP	2100–2200	PU/EES/KH-1202	Iran to NW China & W. Himalayas
Filipendula vestita (Wall. ex G. Don) Maxim.[1]	Ph	MC	2420–2780	PU/EES/KH-15107	Afg., Pak., Nepal & W. Himalayas
Fragaria nubicola (Hook. f.) Lindl. ex Lacaita[1*]	Stoloniferous Ph	BP/MC/SA	1880–3540	PU/EES/KH-15108	Himalayas from Afg. to Mya.
Geum elatum Wall. ex G. Don[1]	Rhizomatous Ph	MC/SA	2720–3800	PU/EES/KH-15115	Himalayas from Pak. to SE Tibet & SC China
***Geum roylei* Wall. ex F.Bolle**[1]	Ph	BP/MC/SA	2200–3120	PU/EES/KH-15116	Himalayas from Afg. to C. Nepal
Potentilla indica (Andrews) Th.Wolf[1]	Ph	BP/MC	2120–2790	PU/EES/KH-15187	Indomalayan, E. Asia, Indian Himalayas
Potentilla anserina L.[2]	Ph	MC/SA	2790–3000	PU/EES/KH-15184	Palearctic & Nearctic regions; Indian Himalayas
Potentilla eriocarpa Wall. ex Lehm.[1]	Ph	SA	2930–2940	PU/EES/KH-15186	Pak. to SW China
Potentilla nepalensis Hook.[1]	Ph	BP/MC	2260–2790	PU/EES/KH-15188	NE Pak. to W. & C. Himalayas
Prunus cornuta (Wall. ex Royle) Steud.[1]	DT	MC	2700–2800	PU/EES/KH-1017	Himalayas from Afg. to Mya. & SW China
Rosa brunonii Lindl.[1*]	Climbing S	MC	2580–2600	PU/EES/KH-1208	NE Afg. to China & Mya., Himalayas in India
Rosa webbiana Wall. ex Royle[1]	DS	BP	2310–2400	PU/EES/KH-1207	C. Asia to W. Himalayas, Tibet & Afg.
Sibbaldia cuneata Schouw ex Kunze[1]	Ah	BP/MC/SA	2200–3810	PU/EES/KH-15216	Afg. to SW China; Himalayas in India
Sorbus lanata (D.Don) S.Schauer[1]	DT	SA	3040–3050	PU/EES/KH-1016	Afg. to W. Himalayas to Nepal
Rubiaceae					
Galium aparine L.[1*]	Bulbous Ph	BP/MC/SA	1920–3130	PU/EES/KH-15109	Europe, N. Africa, Asia minor, Siberia, Iran, Afg., Pak. & Himalayas
Galium boreale L.[1*]	Climbing Ah	BP/MC/SA	2330–3310	PU/EES/KH-15110	Subarctic & temp. N. Hemisphere; throughout India
Salicaceae					
Populus alba L.[2]	Dioecious DT	MC	2430–2440	PU/EES/KH-1014	C. & S. Europe to Xinjiang & W. Himalayas
Populus ciliata Wall. ex Royle[4]	Dioecious DT	BP	2240–2250	PU/EES/KH-1011	N. Pak. to China & Mya.; Himalayas in India
Sapindaceae					
Acer caesium Wall. ex Brandis[2]	Andromonoecious DT	MC/SA	2420–3000	PU/EES/KH-1002	E. Afg. to N. & EC China; W. Himalayas in India
Aesculus indica (Wall. ex Cambess.) Hook.[2*]	DT	MC	2750–2800	PU/EES/KH-1003	Afg., Nepal, Pak., E. & W. Himalayas
Saxifragaceae					
Bergenia ligulata Engl.[1]	Ph	MC	2750–2800	PU/EES/KH-15038	E. Afghanistan to China; Himalayas in India
Scrophulariaceae					
Scrophularia decomposita Royle ex Benth.[1]	Ph	SA	2920–3280	PU/EES/KH-15209	C. Asia; W. Himalayas from Afg. to Kumaon
Verbascum thapsus L.[1*]	Prostrate Ah	MC/SA	2620–3150	PU/EES/KH-15242	Naturalized throughout the N. Hemisphere; Indian Himalayas
Solanaceae					
Atropa acuminata Royle ex Lindl.[5]	Ph	MC	2700–2800	PU/EES/KH-15037	Afg., Iran, Pak. & W. Himalayas
Hyoscyamus niger L.[1*]	Bh or Ph	SA	3140–3150	PU/EES/KH-15120	Palearctic region; Himalayas in India

Family/Taxon	Life-form	Forest type	OER	Voucher no.	Phytogeographic distribution
Taxaceae					
Taxus wallichiana Zucc.[5]	Dioecious conical ET	MC	2560–2760	PU/EES/KH-1013	Himalayas from Afg. to SW China & Mya.
Urticaceae					
Urtica dioica L.[2*]	Rhizomatous creeping Ph	BP/MC/SA	2200–3000	PU/EES/KH-15237	Palearctic, introduced in Neotropic & Nearctic regions; throughout India
Violaceae					
Viola biflora L.[1]	Erect rhizomatous Ph	BP/MC/SA	2200–3120	PU/EES/KH-15245	Palearctic, Mya.; Indian Himalayas
Viola canescens Wall.[1]	Ph	BP/MC/SA	2250–2960	PU/EES/KH-15246	Bhutan, Nepal, India & Pak.; Temp. Himalayas & W. Ghats
Viola odorata L.[1]	Prostrate rhizomatous Ph	BP/MC/SA	1980–2960	PU/EES/KH-15247	Iran, Iraq, introduced in India & Pak. & Medit. region & Caucasia
Viola pilosa Blume[1]	Rhizomatous prostrate Ah or Ph	BP/MC/SA	1880–2940	PU/EES/KH-15248	Afg., Pak., Indomalayan; throughout India
Xanthorrhoeaceae					
Eremurus himalaicus Baker[1]	Ph	SA	3530–3550	PU/EES/KH-15102	Afg., Pak. W. Himalayas & Tajikistan

OER—Observed elevation range | 1—Not assessed (NA) | 2—Least Concern (LC) | 3—Critically Endangered (CR) | 4—Data Deficient (DD) | 5—Endangered (EN) | 6—Vulnerable (VU) | S—Shrub | Ph—Perennial herb | Ah—Annual herb | DS—Deciduous shrub | ES—Evergreen shrub | SS—Subshrub | DT—Deciduous tree | ET—Evergreen tree | Bh—Biennial herb | *—Alien species | E—Eastern | S—Southern | N—Northern | W—Western | C—Central | W—Western | SW—Southwestern | SE—Southeastern | NW—North-western | NE—Northeastern | SC—Southcentral | EC—Eastcentral | NC—Northcentral | Afg—Afghanistan | Pak—Pakistan | Thail—Thailand | Phip—Philippines | Temp—Temperate | Mya—Myanmar | Medit—Mediterranean | Species in bold are endemic to Himalaya.

effects (Qian et al. 2015). The variation in microclimate would have enabled the taxa to adjust to a wide range of niches along elevation and a variety of pre-adapted lineages to colonize in the mountain ranges. Therefore, it can be considered that climatic factors differentiate taxa as indicated by resilience developed over their evolutionary past, with these phylogenetic variations, in turn, deciding species heterogeneity (Wiens & Donoghue 2004; Rana et al. 2019).

One of the prerequisites for biodiversity conservation is to determine the areas of particular importance in the context of taxa vulnerability and characteristic habitats and critically evaluate the same, thus enabling them to prioritize these areas for further consideration (Spehn 2011). In the present study, the situation for seven (2.57%) taxa categorized under threatened, i.e., *Saussurea costus* & *Aconitum chasmanthum* (CR), *Trillium govanianum*, *Aconitum heterophyllum*, *Taxus wallichiana*, & *Atropa acuminata* (EN), and *Cypripedium cordigerum* (VU) were found occasionally in the present study and requires immediate conservational priorities across the landscape. Besides climate change and over-grazing, the species in high demand for traditional medicinal and pharmaceutics has led to their extensive collection and illegal trading, thus pushing them closer to extinction (Devi et al. 2014; Nowak et al. 2020). The sustainability of such flora is imperative across the landscape. Ecological rehabilitation, site-specific in particular should be accomplished by re-vegetating degraded sites with natural vegetation. Existing management regulations must be examined in order to adopt strict guidelines to enhance efficiency in decision-making and avoid fraud. Extensive quantitative plant diversity inventories and biogeographical explorations ought to be directed on the threatened flora to identify its abundance and frequency. Additionally, ex situ management methods must be in place in addition to the in situ conservation programmes. Overall, from our study we infer that all three types of coniferous forests are rich in flora, demonstrating their importance for conservation. We hope that our results will serve as a benchmark for potential future studies on plant ecology of the area. With notable plant diversity, Kashmir Himalaya is probably a suitable site for further investigations. Moreover, because Kashmir Himalayan forests face threats due to various anthropogenic activities, qualitative data of documented flora will help local and regional authorities to propose management and conservation priorities.

Image 1. Study area overview: A,B—Low-level blue pine forest | C,D,E—Mixed coniferous forest | F,G,H—Sub-alpine forest. © Ashaq Ahmad Dar

Image 2. Herbs: A—*Aconitum chasmanthum* | B—*Morina longifolia* | C—*Gentiana tianschanica* | D—*Sambucus wightiana* | E—*Vincetoxicum hirundinaria* | F—*Dipsacus inermis*. © Ashaq Ahmad Dar

Image 3. Herbs: A—*Swertia speciose* | B—*Iris hookeriana* | C—*Fragaria nubicola* | D—*Arisaema jacquemontii* | E—*Gentiana moorcroftiana*.
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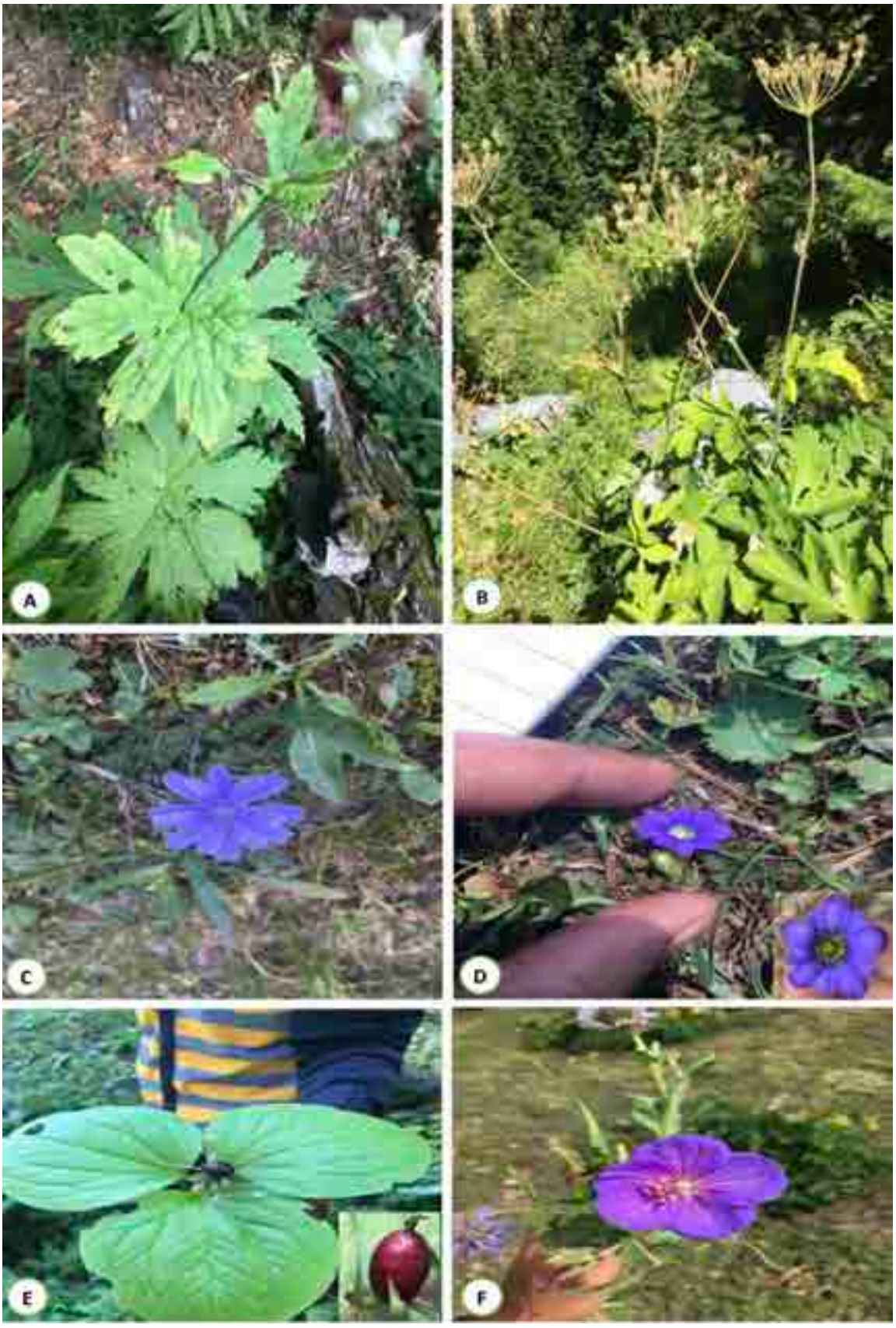

Image 4. Herbs: A—*Filipendula vestita* | B—*Heracleum candicans* | C—*Cichorium intybus* | D—*Gentiana carinata* | E—*Trillium govanianum* | E—*Geranium wallichianum*. © Ashaq Ahmad Dar

Image 5. Herbs: A—*Campanula latifolia* | B—*Senecio chrysanthemoides* | C—*Phytolacca acinosa* | D—*Euphorbia wallichii*. © Ashaq Ahmad Dar

REFERENCES

Ahmad, M., S.K. Uniyal, D.R. Batish, H.P. Singh, V. Jaryan, S. Rathee, P. Sharma & R.K. Kohli (2020). Patterns of plant communities along vertical gradient in Dhauladhar Mountains in Lesser Himalayas in North-Western India. *Science of The Total Environment* 716: 136919. https://doi.org/10.1016/j.scitotenv.2020.136919

Asif, M., Z. Iqbal, J. Alam, A. Majid, F. Ijaz, N. Ali, I.U. Rahman, S. Hussain, A. Khan & G. Qadir (2020). Floristic inventory and biological spectra of Balakot, District Mansehra, Pakistan. *Acta Ecologica Sinica* 40(3): 197–203. https://doi.org/10.1016/j.chnaes.2019.05.009

Bai, F., W. Sang, & J.C. Axmacher (2011). Forest vegetation responses to climate and environment change: a case study from Changbai Mountain, NE China. *Forest Ecology and Management* 262: 2052e2060. https://doi.org/10.1016/j.foreco.2011.08.046

Cadotte, M.W. (2006). Dispersal and species diversity: a meta-analysis. *American Naturalist* 167(6): 913–924. https://doi.org/10.1086/504850

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India* (Deli:Government of India Press), 600 pp.

Chase, M.W. & J.L. Reveal (2009). A phylogenetic classification of the land plants to accompany APG III. *Botanical Journal of the Linnean Society* 161: 122–127. https://doi.org/10.1111/j.1095-8339.2009.01002.x

Dad, J.M., M. Muslim, I. Rashid & Z.A. Reshi (2021). Time series analysis of climate variability and trends in Kashmir Himalaya. *Ecological Indicators* 126: 107690. https://doi.org/10.1016/j.ecolind.2021.107690

Dar, J.A. & S. Sundarapandian (2016). Patterns of plant diversity in seven temperate forest types of Western Himalaya, India. *Journal of Asia-Pacific Biodiversity* 9: 280–292. https://doi.org/10.1016/j.japb.2016.03.018

Devi, U., P. Sharma, J.C. Rana & A. Sharma (2014). Phytodiversity assessment in Sangla valley, Northwest Himalaya, India. *Check List* 10: 740–760. https://doi.org/10.15560/10.4.740

Gairola, S., R.S. Rawal & U. Dhar (2009). Patterns of litterfall and return of nutrients across anthropogenic disturbance gradients in three subalpine forests of west Himalaya, India. *Journal of Forest*

Image 6. Trees: A—*Juniperus squamata* | B—*Abies pindrow* | C—*Picea smithiana* | D—*Sorbus lanata*. © Ashaq Ahmad Dar

Research 14: 73–80. https://doi.org/10.1007/s10310-008-0104-6

Hajra, P.K. (1983). Western Himalayas, pp 49–61. In: Jain S.K. & A.R.K. Sastry (eds.). *Materials for a Catalogue of Threatened Plants of India*. BSI, Howrah. 69 pp.

Hooker, J.D. (1872–1897). *Flora of British India*. *Vol. 1 to 7.* L. Reeves & Company, London.

IUCN (2017). Guidelines for using the IUCN Red List categories and criteria. Version 13. Prepared by the Standards and Petitions subcommittee, http://www.iucnredlist.org.

Janssen, J.A.M., J.S. Rodwell, M. Garcia Criado, S. Gubbay, T. Haynes, A. Nieto, N. Sanders, F. Landucci, J. Loidi, A. Ssymank, T. Tahvanainen, M. Valderrabano, A. Acosta, M. Aronsson, G. Arts, F. Attorre, E. Bergmeier, R.-J. Bijlsma, F. Bioret, C. Biţă-Nicolae, I. Biurrun, M. Calix, J. Capelo, A. Čarni, M. Chytry, J. Dengler, P. Dimopoulos, F. Essl, H. Gardfjell, D. Gigante, G. Giusso del Galdo, M. Hajek, F. Jansen, J. Jansen, J. Kapfer, A. Mickolajczak, J.A. Molina, Z. Molnar, D. Paternoster, A. Piernik, B. Poulin, B. Renaux, J.H.J. Schaminee, K. Šumberova, H. Toivonen, T. Tonteri, I. Tsiripidis, R. Tzonev & M. Valachovič (2016). European Red List of Habitats. Part 2: Terrestrial and Freshwater Habitats Publications Office of the European Union, Luxembourg. 44 pp.

Javeid, G.N. (1966). Key to the families of flowering plants of Kashmir Himalaya. *Kashmir Science* 3(1–2): 101–115.

Javeid, G.N. (1978). Forest flora of Kashmir: a checklist, I. *Indian Forester* 104(11): 772–779.

Javeid, G.N. (1979). Forest flora of Kashmir: a checklist, II. *Indian Forester* 105(2): 148–170.

Kachroo, P. (1993). *Plant diversity in Northwest Himalaya* – a preliminary survey, pp 111–132. In: Dhar, U. (ed.). *Himalayan Biodiversity: Conservation Strategies*. G.B. Pant Institute of Himalayan Environment and Development, Almora. 553 pp.

Khuroo, A.A., I. Rashid, Z. Reshi, G.H. Dar & B.A. Wafai (2007). The alien flora of Kashmir Himalaya. *Biological Invasions* 9: 269–292. https://doi.org/10.1007/s10530-006-9032-6

Körner, C. (2007). The use of altitude in ecological research. *Trends in Ecology & Evolution* 22: 569–574. https://doi.org/10.1016/j.tree.2007.09.006

Krishnan, M.S. (1982). *Geology of India and Burma, 6th ed.* CBS, New

Image 7. Shrubs: A—*Syringa emodi* | B—*Parrotiopsis jacquemontiana* | C—*Rosa webbiana* | D—*Hippophae rhamnoides*. © Ashaq Ahmad Dar

Delhi, 52 pp.

Lambert, W.J. (1933). List of trees and shrubs for the Kashmir & Jammu forest circles, Jammu & Kashmir State. *Forest Bulletin* 80: 1–36.

Maes, D., N.J.B. Isaac, C.A. Harrower, B. Collen, A.J. van Strien & D.B. Roy (2015). The use of opportunistic data for IUCN Red List assessments. *Biological Journal of the Linnean Society* 115: 690–706. https://doi.org/10.1111/bij.12530

Mahapatra, S.K., C.S. Walia, G.S. Sindhu, K.P.C. Rana & T. Lal (2000). Characterization and classification of the soils of different physiographic units in the sub-humid ecosystem of Kashmir region. *Journal of the Indian Society of Soil Science* 48(3): 572–577.

Malik, A.H., A.A. Khuroo, G.H. Dar & Z.S. Khan (2010). The woody flora of Jammu & Kashmir State, India: an updated checklist. *Journal of Economic and Taxonomic Botany* 34(2): 274–294.

Malik, A.Y., D.P. Singh, M. Yunus, G.A. Bhat, G. Shukla, J. A. Bhat, M.M. Rather & S. Chakravarty (2021). Diversity and structure of plant assemblages in open scrub vegetation patches of Dachigam National Park at Kashmir Himalayas. *Trees, Forests and People* 3: 100060. https://doi.org/10.1016/j.tfp.2020.100060

Mir, N.A., T.H. Masoodi, S.M. Geelani, A.A. Wani, G.N. Parrey & J.A. Mugloo (2019). Floristic diversity along altitudinal gradient under Betula utilis in North Western Himalayas of Kashmir, India. *Acta Ecologica Sinica* 39: 362–371. https://doi.org/10.1016/j.chnaes.2019.03.001

Nayar, M.P. (1996). *Hot Spots of Endemic Plants of India, Nepal and Bhutan*. Tropical Botanic Garden and Research Institute, Thiruvananthapuram, 252 pp.

Nowak, A., S. Świerszcz, S. Nowak, H. Hisorev, E. Klichowska, A. Wróbel, A. Nobis & M. Nobis (2020). Red List of vascular plants of Tajikistan – the core area of the Mountains of Central Asia global

biodiversity hotspot. *Scientific Reports* 10: 6235. https://doi.org/10.1038/s41598-020-63333-9

Orsenigo, S., C. Montagnani, G. Fenu, D. Gargano, L. Peruzzi, T. Abeli, A. Alessandrini, G. Bacchetta, F. Bartolucci, M. Bovio, C. Brullo, S. Brullo, A. Carta, M. Castello, D. Cogoni, F. Conti, G. Domina, B. Foggi, M. Gennai, D. Gigante, M. Iberite, C. Lasen, S. Magrini, E. Perrino, F. Prosser, A. Santangelo, A. Selvaggi, A. Stinca, I. Vagge, M. Villani, R. Wagensommer, T. Wilhalm, N. Tartaglini, E. Dupre`, C. Blasi & G. Rossi (2018). Red Listing plants under full national responsibility: extinction risk and threats in the vascular flora endemic to Italy. *Biological Conservation* 224: 213–222. https://doi.org/10.1016/J.BIOCON.2018.05.030

Peel, M.C., B.L. Finlayson & T.A. Mcmahon (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences* 11: 1633–1644. https://doi.org/10.5194/hess-11-1633-2007

Polunin, O. & A. Stainton (1984). *Flowers of the Himalaya*. Oxford University Press, New Delhi. 580 pp.

Qian, H., J.J. Wiens, J. Zhang & Y. Zhang (2015). Evolutionary and ecological causes of species richness patterns in North American angiosperm trees. *Ecography* 38:241– 250. https://doi.org/10.1111/ecog.00952

Rana, S.K., T.D. Price & H. Qian (2019). Plant species richness across the Himalaya driven by evolutionary history and current climate. *Ecosphere* 10(11): e02945. https://doi.org/10.1002/ecs2.2945

Rao, R.R. & B.D. Sharma (1990). *A Manual for Herbarium Collection*. Botanical Survey of India, Calcutta, 20 pp.

Rashid, I., S.A. Romshoo, R.K. Chaturvedi, N.H. Ravindranath, R. Sukumar, M. Jayaraman, T.V. Lakshmi & J. Sharma (2015). Projected climate change impacts on vegetation distribution over Kashmir Himalayas. *Climatic Change* 132: 601–613. https://doi.org/10.1007/s10584-015-1456-5

Shaheen, H., Z. Ullah, S.M. Khan & D.M. Harper (2012). Species composition and community structure of western Himalayan moist temperate forests in Kashmir. *Forest Ecology Management* 278: 138–145. https://doi.org/10.1016/j.foreco.2012.05.009

Sidhu, G.S. & J.N. Surya (2014). Soils of North-Western Himalayan ecosystem and their land use, constraints, productivity potentials and future strategies. *Agropedology* 24: 1–19

Singh, J.B. & P. Kachroo (1994). *Forest Flora of Pir Panjal range (Northwestern Himalaya)*. Bishen Singh Mahendra Pal Singh, Dehradun. 172 pp.

Singh, P., K. Karthigeyan, P. Lakshminarasimhan & S.S. Dash (2015). *Endemic vascular plants of India*. Botanical Survey of India, Kolkata. 339 pp.

Spehn, E. (2011). Mountain Biodiversity: Effects of Climate Change and How to Manage Them; Sustainable Mountain Development 60,. ICIMOD, Kathmandu, Nepal. 40–43 pp.

The Angiosperm Phylogeny Group (2009). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society* 161: 105–121. https://doi.org/10.1111/boj.12385

The Plant List (2013). Version 1.1. Published on the Internet; http://www.theplantlist.org/ (accessed 15 January, 2021).

Tiwari, O.P., C.M. Sharma & Y.S. Rana (2020). Influence of altitude and slope-aspect on diversity, regeneration and structure of some moist temperate forests of Garhwal Himalaya. *Tropical Ecology* 61: 278–289. https://doi.org/10.1007/s42965-020-00088-4

Wester, P., A. Mishra, A. Mukherji & A.B. Shrestha (2019). The Hindu Kush Himalaya assessment— mountains, climate change, sustainability and people. Springer Nature, Cham, 627 pp.

Wiens, J.J. & M.J. Donoghue (2004). Historical biogeogra- phy, ecology, and species richness. *Trends in Ecology and Evolution* 19: 639–644. https://doi.org/10.1016/j.tree.2004.09.011

Zachos, F.E. & J.C. Habel (2011). Biodiversity hotspots: distribution and protection of conservation priority areas. Springer, Berlin/Heidelberg, 565 pp.

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ARTICLE

Associations of butterflies across different forest types in Uttarakhand, western Himalaya, India: implications for conservation planning

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Abstract: Champion & Seth classified Indian forests into different 'forest types and sub-types', based on similarity of dominant vegetation and structural arrangement of species in each. However, it is not known if the species composition and community structure of butterflies is also different in each forest sub-type. If this is the case then each forest sub-type harbouring unique species can be taken as units of conservation on a sub-regional scale. The present study assesses for the first time the species composition and community structure of butterflies across 20 different and prominent 'forest sub-types' found across the state of Uttarakhand, western Himalaya. Data collected over eight years (2006–2009; June 2012; 2017–2020) using random seasonal sampling covering 307 transects revealed 370 butterfly taxa. Hierarchical clustering of butterfly abundances revealed seven different butterfly communities spread over 19 forest subtypes. Of these four forest sub-types (3C/C2a moist Shiwalik sal forest; 12/C2c moist temperate deciduous forest; 12/C1a ban oak forest; & 3C/C2c moist Terai sal forest) were identified as most important as they hold most of the butterfly diversity of the state including 58 rare taxa identified according to 'rarity' out of the total. GIS based mapping of these 58 priority species over laid on the protected area network and forest cover distribution in the state revealed many forested sites outside the PA network supporting these rare taxa. These sites along a physio-geographical gradient with important forest sub-types and rare taxa can be recommended and listed as new sites for conservation in the state.

Keywords: Ban Oak, butterfly, protected area network, physiogeography, rarity, tropical moist deciduous forest, vegetation.

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INTRODUCTION

Butterflies, amongst invertebrates, are suitable indicators for ecological studies (Lomov et al. 2006), as the taxonomy, geographical distribution and status of many species are relatively well known (Pollard 1977; Thomas 1983; Thomas & Mallorie 1985; Murphy & Wilcox 1986). They are phytophagous, primary herbivores, good pollinators and surrogates plant diversity living close by their food plants (Ehrlich & Raven 1964; Gilbert & Smiley 1978; Pyle 1980). The precise and restricted environmental requirements of particular butterflies make them of considerable value as a group of indicator taxa that indicate the broader effects of environmental changes or reflects a particular suite of ecological conditions or habitat heterogeneity (Pyle 1980; Gilbert 1980, 1984; Brown 1982; Rosenberg et al. 1986; Murphy et al. 1990; New 1991; Kermen 1992; Pearman et al. 1995). Strong association with vegetation structure and composition makes Lepidoptera a particularly useful bioindicator for monitoring eco-restoration programs (Kremen et al. 1993; New et al. 1995).

Habitat is an important requisite for the proliferation and conservation of a butterfly species (Gilbert & Singer 1975), as species prefer particular habitats, closely related to their life history, breeding, larval and adult food resources and destruction of forest severely affects species habitats (Wells et al. 1983) and many species which were once common become rare. Thus, identification and conservation of priority landscapes, is very important. Champion & Seth (1968) classified Indian forests into different 'forest types' their sub units as 'forest sub-types', based on the similarity of dominant vegetation and structural arrangement of species within each of them, i.e., 'IV montane temperate forest' is one of VI major 'forest types" found across India (other 5 categories being "I. moist tropical forests, II. dry tropical forests; III montane subtropical forests; V sub-alpine forests, and VI alpine forests" classified by Champion & Seth (1968)), while its lowest unit in the hierarchy is a 'sub-type', e.g., "12C_1/1*a* Ban oak forest" (Here, '12' signifies "12 Himalayan moist temperate forest" in a group of three [the other two being 11 Montane wet temperate forests & 13 Himalayan dry temperate forests). Then further sub-division of this sub-group "12" into three groups: C_1–C_3 , where "C_1" signifies "C_1 lower western Himalayan temperate forest" (other 2 being "C_2 upper west Himalayan temperate forest" and "C_3 east Himalayan temperate forest") and lastly its last sub-division which is depicted as "1a", i.e., "1a Ban oak forest (*Q. incana*)" (*Quercus incana* = *Q. leucotrichophora*) amongst the set of two (the other being "1b Moru oak forest (*Q. dialata*)" (*Quercus dilatata* = *Q. floribunda*) (Champion & Seth 1968)]. In this way, different 'forest subtypes' have been classified and labelled in India.

However, it is not known if the species composition and community structure of lower groups of animals such as butterflies are also different within each 'forest-sub-type' or each have a unique community of butterflies. If this is the case then each forest sub-type harbouring unique and rare species can be taken as a unit of conservation on a sub-regional scale (western Himalaya) or state level (Uttarakhand). In this study we tried to evaluate and examine potential 'forest sub-types' or 'a group of forest sub-types' that have unique butterfly diversity which can be taken up as units of conservation of biodiversity at the state level. Besides, this can also be helpful in identification of new conservation areas with forest habitats outside the PA network and thus fill gaps in their connectivity, in the state. The rationale behind this is that many butterfly species are restricted to forested habitats in the state, have geographical distribution spread across the Himalayan region, i.e., western, central, and eastern Himalaya along a wide altitudinal gradient, e.g., Pale Green Sailer *Neptis zaida zaida* Doubleday, [1848] or Broad-banded Sailer, *N. sankara sankara* (Kollar, [1844]) (Nymphalidae) both occur in the state between 800–2,500 m, as observed in the present study. Fragmentation of their forested habitats on a larger spatial and temporal scale, may lead to isolated populations, local extinctions that can significantly affect their distribution, as they do not migrate. Thus, gaps and connectivity of the protected areas needs to be maintained for long term conservation.

STUDY AREA

The study was carried out in Uttarakhand state of India which covers an area of 53,483 km^2, which is 1.63% of the geographical area of the country, and lies between 28.716–31.466 N latitude & 77.566–81.05 E longitude. This predominantly mountainous state, shares its borders with Himachal Pradesh to the west and Uttar Pradesh to the south. It also shares international borders with Nepal in the east and China (Tibet) to the north. The state is mainly representative of the western Himalaya, the climate and vegetation vary greatly with altitude, from glaciers at the highest elevations, and temperate to subtropical at the lower elevations. Nanda Devi peak is the highest point at 7,816 m in the state while the lowest areas at ~100m lie in the Terai grasslands.

Figure 1. GPS locations of sampling sites for study on butterflies undertaken during 2006–2009, June 2012 & 2017–2020 in Uttarakhand state of India.

The average annual rainfall is 1,500 mm and the annual temperature varies from below 0° C to 43° C. Major rivers, Ganga, Yamuna, Ramganga, & Sharda, drain the state along with their tributaries. The Himalayan range in Uttarakhand is divided into the distinct non-montane and montane physiographic zones. The lower zone comprises the 'Bhabhar' region in non-montane lowland woodlands having Gangetic moist deciduous forests and the Terai region (below 500 m) running parallel to it, which comprises mainly the marshes and grasslands (Botanical Survey of India 2021). The montane region is divided into sub-Himalaya, which consists of the Shiwalik ranges, the lower Himalayan ranges, and the Doon (flat long valleys) lying north of the Shiwaliks (~ 500–1,000 m). Above this region are the lesser Himalaya (~ 1,000–3,000 m) followed mid Himalaya (~ 3,000–4,000 m) and then greater Himalaya (~ 4,000–6,000 m) (Khanduri et al. 2013) and the trans-Himalaya (above 5,000 m), also known as the Tethys Himalayas and the Indo-Tibet plateau, the region is in the rain shadow area that transforms into the cold desert.

Forests cover an area of 24,303.04 km^2 in the state, which constitutes 45.44% of the state's geographical area (FSI 2019). The state is represented by biogeographic zone 2B western Himalaya and 7B Shiwaliks of India (Rodgers & Pawar 1988). The state is rich in biodiversity having about 102 species of mammals, 692 birds (https://ebird.org/region/IN-UL), 13 amphibians & 53 reptiles (Vasudevan & Sondhi 2010), and 124 fishes (https://forest.uk.gov.in/wildlife-management). Some of the globally endangered fauna like the Asiatic Elephant *Elephas maximus*, Snow Leopard *Panthera uncia,* Tiger *Panthera tigris,* Leopard *Panthera pardus*, Musk Deer *Moschus chrysogaster*, Swamp Deer *Rucervus duvaucelii*, Cheer Pheasant *Catreus wallichii*, and the King Cobra *Ophiophagus hannah* are found in the state. Uttarakhand shelters around 4,000 species of plants, belonging to 1,198 genera, under 192 families, of which ~34 species have been listed as threatened (Nayar & Sastry 1987, 1988, 1990; https://indiabiodiversity.org/). The PA network cover 12 percent of the total geographical area of the state, which includes six national parks, seven wildlife sanctuaries, four conservation reserves, and one biosphere reserve (Appendix 1).

Previous studies on butterflies in Uttarakhand

Studies on natural history and checklists of different areas in Uttarakhand state have been carried out as early as 1886 (Doherty 1886; Mackinnon & de Nicéville 1899; Hannyngton 1910–11; Ollenbach 1930; Shull 1958, 1962; Baindur 1993; Smetacek 2002, 2004, 2012; Bhardwaj et al. 2012; Bhardwaj & Uniyal 2013; Singh &

Bhandari 2003, 2006; Singh & Sondhi 2016; Verma & Arya 2018; Sondhi & Kunte 2018; Singh & Singh 2021) and the total number of butterfly species recorded in the state so far is ~ 500 species, based on these records. However, none of these studies give an account on the association of butterfly species with different forest sub-types as classified by Champion & Seth (1968), found across the state of Uttarakhand. The author had earlier studied butterfly-forest type associations in 11 major "forest sub-types" in the state of Arunachal Pradesh (eastern Himalaya), India (Singh 2017) and identified four forest sub-types: 2B/1S1 sub-Himalayan light alluvial plains semi-evergreen forests; 2B/C1a Assam alluvial plains semi-evergreen forests; 2B/2S2 eastern alluvial secondary semi-evergreen forests, and 3/1S2 b Terminalia-Duabanga as major forest sub-types supporting 415 butterfly taxa along with many rare and endemic species in the northeastern region and eastern Himalaya, but the forest sub-types occurring in these two Himalayan states are totally different from each other.

METHODS

Random sampling surveys were carried out for eight years under two different projects (2006–2009 and 2017–2020, respectively) across 11 districts of Uttarakhand state covering all the six butterfly seasons (spring, summer, pre-monsoon, monsoon, post-monsoon, autumn, and winter; Smith 1989) of the year. Surveys were carried out using 'Pollard Walk' on the line transects (Pollard & Yates 1993). Sampling on each transect (ca. 1 km) was done and butterflies were observed up to 20 m on both the sides of the trail for 1 h in a stretch between 1000 h and 1600 h to collect data on individual butterfly species abundance. Each sampling survey was carried out by the author, while 1–2 helpers were also used for recording data, collection of insect and plant material from time to time. Coordinates of all the locations for 307 samplings carried out were recorded using a GPS (Etrex Garmin Vista) (Figure 1) covering 20 major forest sub-types (FSI 2011; Figure 2 & Appendix ii) existing across the state of Uttarakhand.

Identification and distribution range of each taxa was assessed based on published literature (Moore 1874, 1890–1992, 1893–1896, 1896–1899, 1899–1900, 1901–1903, 1903–1905; Swinhoe 1905–1910, 1910–1911, 1911–1912 & 1912–1913; Bingham 1905; Talbot 1939, 1947; Evans 1932; Wynter-Blyth 1957; D'Abrera 1982, 1985, 1986; Haribal 1992; Smith 1989, 2006; Kehimkar 2008, 2016; Singh 2011; Smetacek 2015; Gasse 2017; Sondhi & Kunte 2018) and websites (http://www.ifoundbutterflies.org/ and http://flutters.org/). Comparison of a few specimens was also done with specimens at the National Forest Insect Collection (NFIC) at Forest Research Institute, Dehradun, Uttarakhand, India, for identification.

Dominant vegetation (mainly trees & shrubs) in the respective forest sub-types were also identified and confirmed by ground truthing by laying down 10 x 10 m quadrates, collected plant material and preparing herbariums. Photographs and herbarium specimens were identified in the field and many were identified and confirmed from plant taxonomists based at Systematic Botany Branch, Botany Division, FRI, Dehradun and literature (Brandis 1906; Rai et al. 2017; http://www.gbif.org).

Evaluating species of conservation priority: rarity analysis of butterflies

The degree of "rarity' characterizing a species is usually an indicator of extinction risk (Rabnowitz et al. 1986; Pimm et al. 1988; Arita et al. 1990; Primarck 1993; Gaston 1994; Brown 1995; Gaston & Blackburn 1995) and provides a basis to identify threatened species (Rabinowitz 1981; Arita et al. 1990; Daniels et al. 1991; Berg & Tjernberg 1996). In general, species characterized by small geographic range, habitat specialization, and low abundance, are at higher risk of extinction than a widely distributed, habitat generalist and with high abundance. Rabinowitz et al. (1986) have examined types of rarity, and in what important ways rare species differ from one another. They first distinguish three traits, characteristic of all taxa recorded: (i) Geographical range - whether a species occurs over a broad area or whether it is endemic to a particular area; (ii) Habitat specificity - the degree to which a species occurs in a variety of biotopes' or 'habitats' is restricted to one or a few specialized sites versus generalists; and (iii) Local population size - whether a species occurs in large populations somewhere within range or has small populations whenever it is found.

In the present study, Rabinowitz et al. (1986) classification of rarity based on the three above traits was used. Only those species were filtered out the total as rare which had: (i) narrow geographical range, i.e., those species which had narrow distribution restricted only to western and central Himalaya as against those with wide distribution, i.e., Himalaya, northeastern India, & Peninsular India; (ii) restricted to two or less forest sub-types as against more than two forest sub-

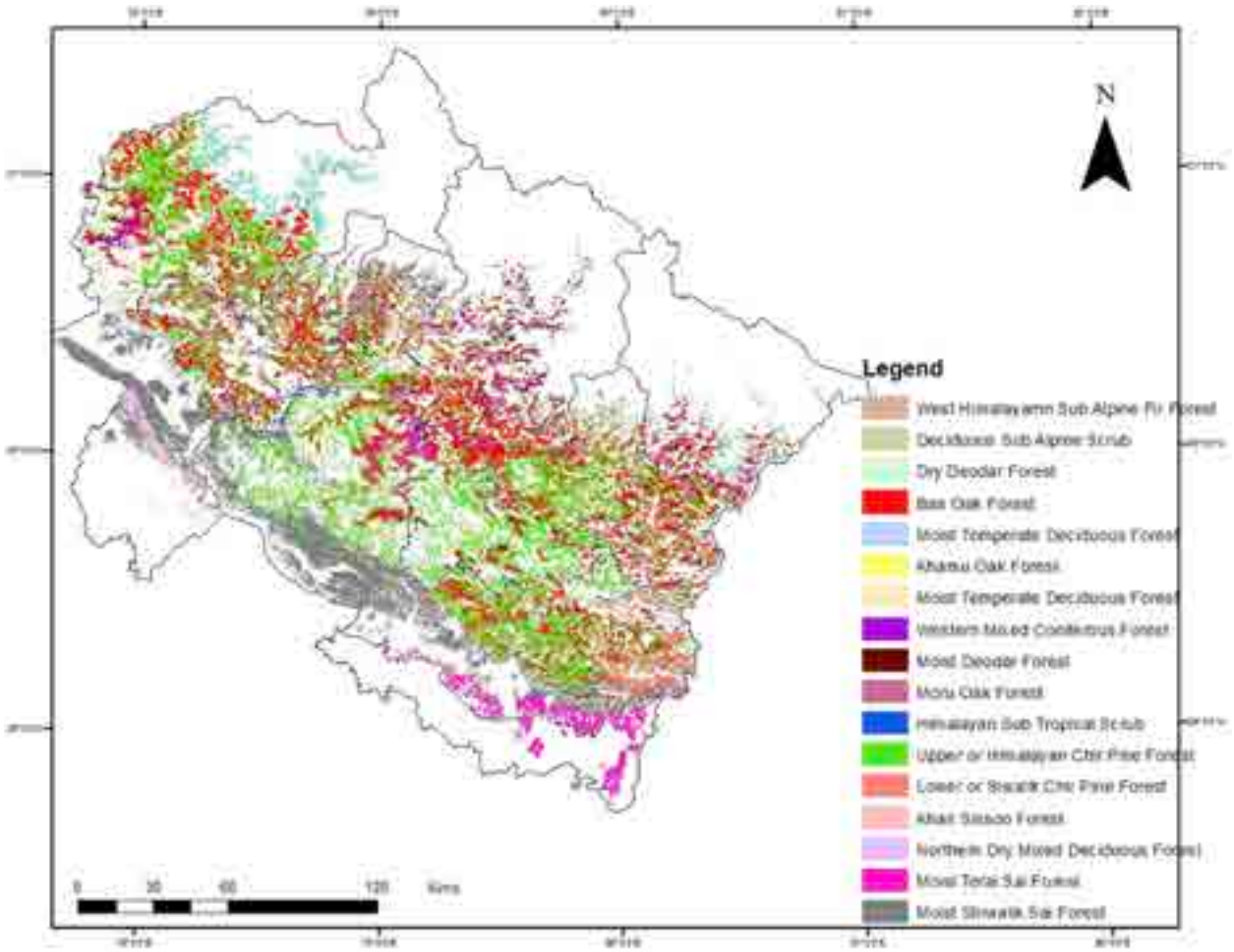


Figure 2. Distribution of major forest types surveyed in Uttarakhand.

types; and (iii) having small local population size across their distribution range, i.e., those taxa which were classified as 'very rare', 'rare', and 'not rare' by Evans (1932) and Kehimkar (2008), as against 'fairly common', 'common', and 'very common'.

Hierarchical clustering of different forest sub-types based on butterfly species distribution and relative abundance.

The data of relative abundance of all the species of butterflies sampled against 20 different forest sub-types was pooled and averaged to relative abundance per sampling in each of the forest sub-type to remove varied sampling bias and was done using statistical software "NCSS Data Analysis 2021, v21.0.2", to know the dissimilarly of forest sub-types in terms of butterfly species composition.

RESULTS AND DISCUSSION

The field surveys revealed 370 butterfly taxa (Papilionidae (31); Pieridae (32); Nymphalidae(138); Lycaenidae (97); Hesperiidae (62) and Riodinidae (7); see appendix.iii), which accounted to ca 75% of the species recorded from the state so far. If we exclude ~ 40 historic records (Singh & Sondhi 2016; Sondhi & Kunte 2018), then it totals to 80% of the total species found in the state. The study also reported new range extensions from central and eastern Himalaya, i.e., Dark Sapphire (Singh & Seal 2019); Scarce Lilacfork *Lethe dura gammiei* (Moore, [1892]) (Singh & Singh 2019), Dubious Five ring *Ypthima parasakra parasakra* Eliot, 1987 (Singh & Singh 2022) and records like White-ringed Meadowbrown, *Hyponephele davendra davendra* (Moore, 1865) (Singh & Singh 2021), Pale Jezebel *Delias sanaca sanaca* (Moore, [1858]) (Singh 2016); Mountain Tortoiseshell *Aglais rizana* (Moore, 1872) (Singh & Singh 2019); White-wedged Woodbrown *Lethe dakwania* Tytler, 1939

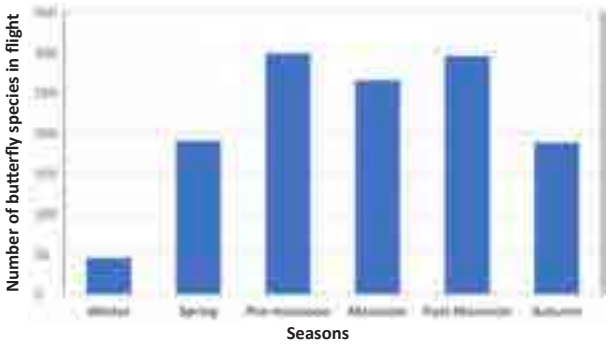


Figure 3. Seasonality of butterflies in Uttarakhand.

(Singh & Singh 2021), to the state. Some rare records like Garhwal Swordtail *Graphium garhwalica* (Katayama, 1988), Highbrown Silverspot, *Argynnis jainadeva jainadeva* Moore, 1864; Regal Apollo, *Parnassius charltonius* Gray, [1853] and new range extensions (Red-tailed Forester, *Lethe sinorix sinorix* (Hewitson, [1863]) and Nepal Comma *Polygonia c-album cognata* Moore, [1899]) are reported in this paper.

The relative abundance of species ranged 1–1,596 individuals. These species were then ranked into four abundance classes based on their quartile division, i.e.,

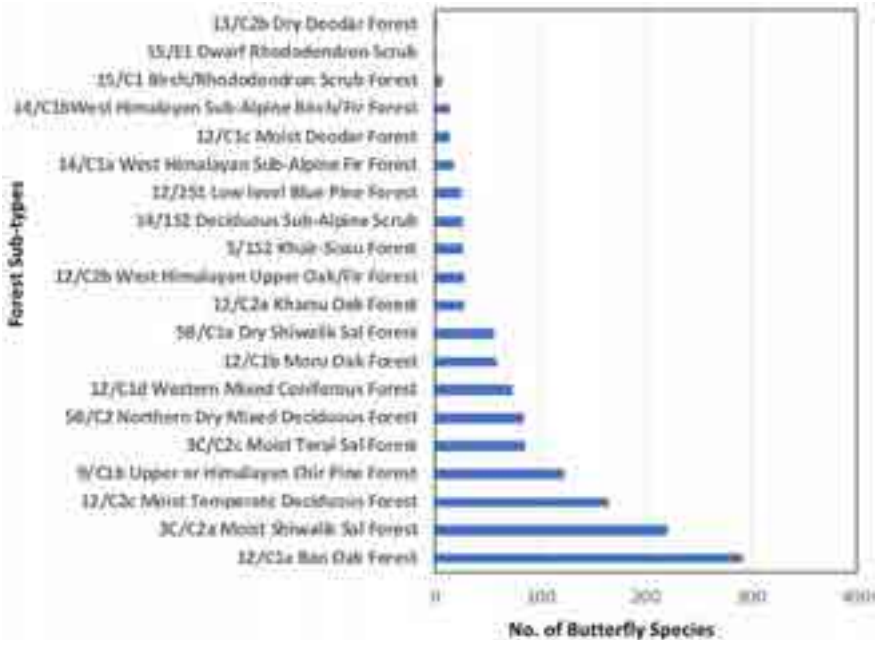


Figure 4. Relative distribution of butterfly species in different forest sub-types in Uttarakhand.

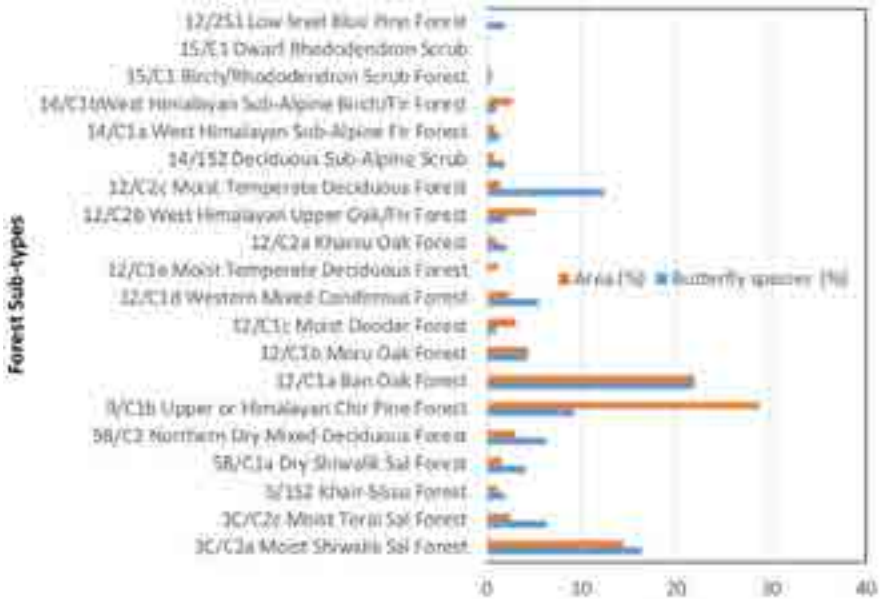


Figure 5. Percentage of butterfly species in each forest sub-type in relation to the proportional area covered by each forest sub-type in Uttarakhand.

Q1= 1–7 Uncommon (1= rare); 8–21= Fairly Common; 22–69 = Common; 70–1,596 = Very Common Median= 21 (Table 4 and an "Appendix iii" with an account of 370 taxa). Sixty-seven species sampled are listed under various schedules of the Indian Wildlife Protection Act, 1972 (appendix: Schedule I—8 species; Schedule II—51 & Schedule IV—8). The seasonality of butterflies suggests that most of the species are in flight during 'post-monsoon' and 'pre-monsoon' seasons followed by 'monsoon' season, respectively when more than 270 species are in flight (Figure 3) in the state.

The pattern of seasonality in Uttarakhand is very similar to the trend found in western and central Himalaya (Wynter-Blyth 1957) where two peaks are known to occur in a year, the bigger one during the 'post-monsoon' season and a slightly smaller one during the 'pre-monsoon' season.

Preference for Forest Sub-types

The highest number of species were recorded in 12/c1a Ban Oak Forest (292 species; Fig.4) followed by 3C/C2a Moist Shiwalik Sal Forest (220) and 12/C2c Moist Temperate Deciduous Forest (165), respectively which suggests that these forest sub-types hold the major diversity of butterflies found in the state. The number of species sampled were the least in 13/C2b Dry Deodar Forest (14), 15/C1 Birch Rhododendron Scrub (6) and 15/E1 Dwarf Rhododendron Scrub (2), respectively (Figure 4) suggesting them to be poor butterfly habitats, while the other 14 forest sub-types lay between them.

The percentage of butterfly species in each forest sub-type in relation to the proportional area covered by each in the state (Figure 5), suggests that forest sub-types: 9/C1b Upper or Himalayan Chir Pine Forest; 12/C2b West Himalayan Upper Oak/Fir Forest and 14/C1 B Western Himalayan Sub-alpine Birch/Fir Forest, support a relatively lower number of butterfly species per unit area as compared to the rest of the other forest sub-types (Figure 4). On the other hand forest sub-types: 3C/C2 Moist Shiwalik Sal Forest; 12/C1a Ban Oak Forest; 12/C2C Moist Temperate Deciduous Forest and 12/C1d Western Mixed Coniferous Forest have a relatively higher density of butterfly species per unit area amongst all the forest sub-types covered (Figure 5). The primary reason for this is that pure conifer forest stands support less diversity of butterflies as compared to the pure broad leaved or mixed conifer-broad leaved forests, as the diversity of nectar and larval food plants available are more diverse in the latter two than in the former.

Hierarchical clustering of forest sub-types

It was found that 7 forest-types butterfly clusters, 5 independent forest-subtypes and 2 clusters of 2 and 11 forest sub-types, respectively exist in the state (Fig.6). These are

1. 3C/C2a Moist Shiwalik Sal Forest.
2. 12/C2c Moist Temperate Deciduous Forest
3. 12/C1a Ban Oak Forest.
4. 3C/C2c Moist Terai Sal Forest
5. 9/C1b Upper or Himalayan Chir Pine
6. 5B/C2 Northern Dry Mixed Deciduous Forest & 5B/C1a Dry Shiwalik Sal Forest.
7. 12/C1b Moru Oak; 12/C2b Western Himalayan Upper Oak Forest/Fir; 12/C1d Western Mixed Coniferous; 12/2S1 Low Level Blue Pine; 12/C2a Kharsu Oak Forest; 14/C1a West Himalayan Sub-alpine Fir; 14/C1 Best Himalayan Sub-alpine Birch/Fir/ 14/1S2 Deciduous Sub-alpine Scrub & 15/C1 Birch/Rhododendron Scrub.

The dendrogram (Figure 6) suggests that the butterfly community of 3C/C2a Moist Shiwalik Sal Forest is totally distinct from that of 12/C2c Moist Temperate Deciduous Forest and 12/C1a Ban Oak forest. While 12/C1a Ban Oak Forest and 12/C2c Moist Temperate Deciduous Forest show greatest similarity. While diversity of 5B/C2 Northern Dry Mixed Deciduous Forest and 5B/C1a Dry Siwalik Sal is different from that of 3C/C2c Moist Terai Sal Forest or 3C/C2a Moist Shiwalik Sal Forest. Eleven forest sub-types show another cluster being distinct from other groups (Figure 6). Four forest sub-types that are most important in the state in terms of number of both butterfly species and with distinct dissimilarity of butterflies are 3C/C2a Moist Shiwalik Sal Forest; 12/C2c Moist Temperate Deciduous Forest; 12/C1a Ban Oak Forest and 3C/C2c Moist Terai Sal Forest.

Species preference of forest sub-types

Scatter plot (Figure 7) of individual butterfly species (n= 370) suggests that only one generalist species (Painted Lady *Vanessa cardui*) had preference for all 14 forest sub-types. While the number of species showing preference for more than five or more forest sub-types were fewer as compared to species showing preference for less than four forest sub-types (Figure 7 Horizontal bars) in the state. The maximum number of species showed preference for two forest sub-types (n= 90 species) followed by preference for only one forest sub-type (n= 60 species). This suggests that a large number of habitat specialist species exist in the state.

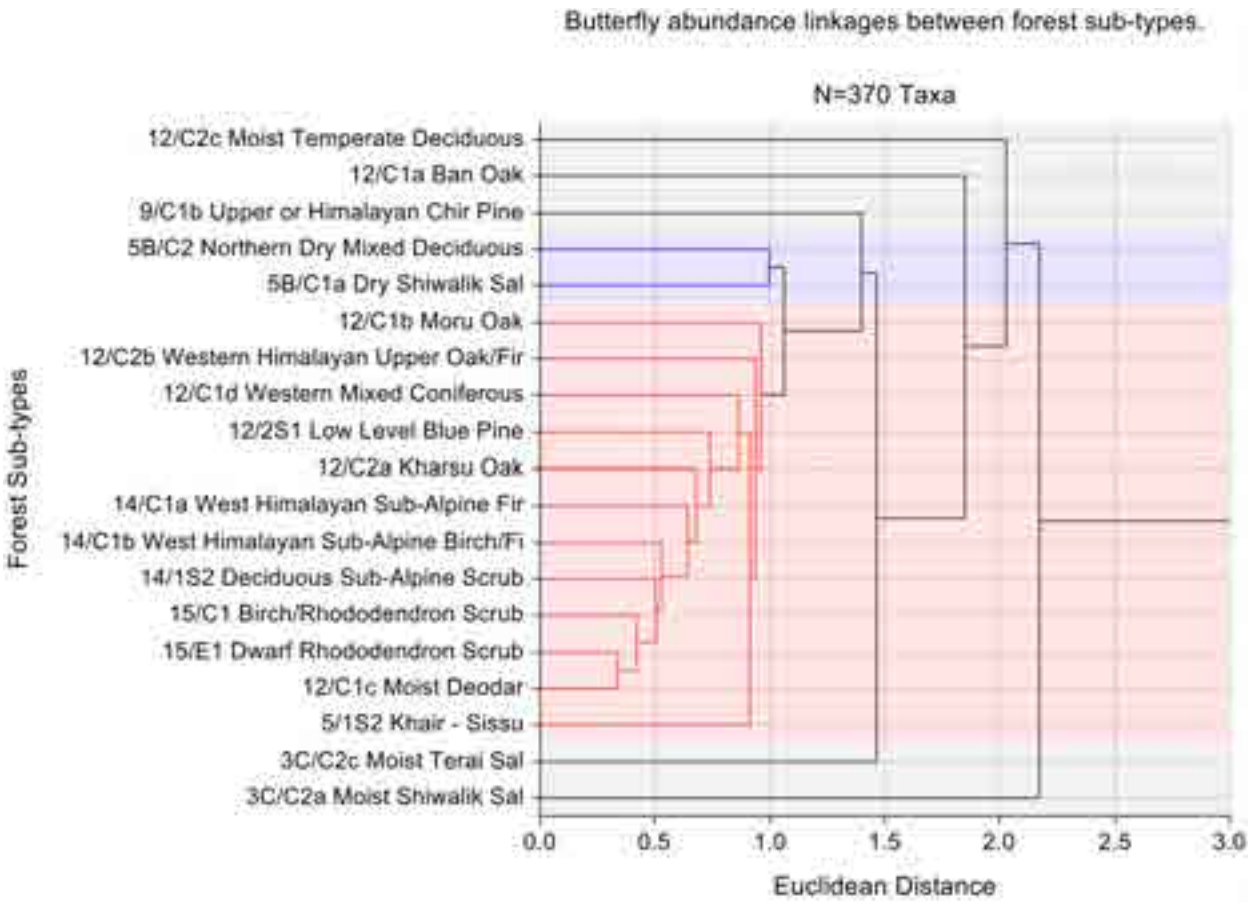


Figure 6. Dendrogram showing hierarchical clustering of forest sub-types in terms of butterfly species in each.

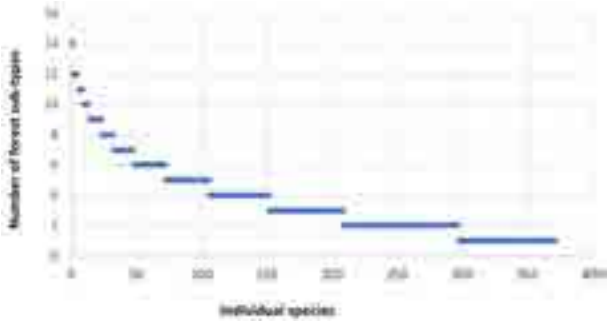


Figure 7. Preference of forest sub-type/s by individual species.

Rarity in butterflies sampled in Uttarakhand: taxa of conservation priority

Out of the 370 taxa sampled in Uttarakhand, 58 were evaluated as rare species of conservation priority /concern based on rarity analysis (Rabinowitz 1981; Rabinowitz et al. 1986) (Appendix IV).

The 58 taxa of conservation concern evaluated based on rarity are scattered all across the state in at least 12 forest sub-types (Figure 8). It was also determined that most of the butterfly taxa of conservation priority occur in 12/C1a Ban Oak Forest followed by 12/C2c Moist Temperate Deciduous forest, 3C/C2 Moist Shiwalik Sal Forest and a few taxa in 12/C2b Western Himlayan Upper Oak/Fir Forest; 12/C1d Western Mixed Coniferous Forest, repectively (Figures 8–15).

The present study proved that individual 'forest sub-types'(Champion & Seth 1968) or a group of 'forest sub-types' having high species richness, unique and rare butterfly taxa can be taken up as units of conservation at the state level in the Himalayan region as representatives of lower groups of animals, i.e., butterflies. Three most important forest sub-types: 12/C1a Ban Oak Forest followed by 12/C2c Moist Temperate Deciduous Forest and 3C/C2 Moist Shiwalik Sal Forest, respectively, hold the maximum number of butterflies, including many rare and protected taxa, in the state amongst the 20 forest sub-types evaluated, thus they form priority over the rest.

The 58 butterfly taxa conservation priority in the state lies both within and outside the PA network, but mainly in forested areas (Figure 16). Concentrations

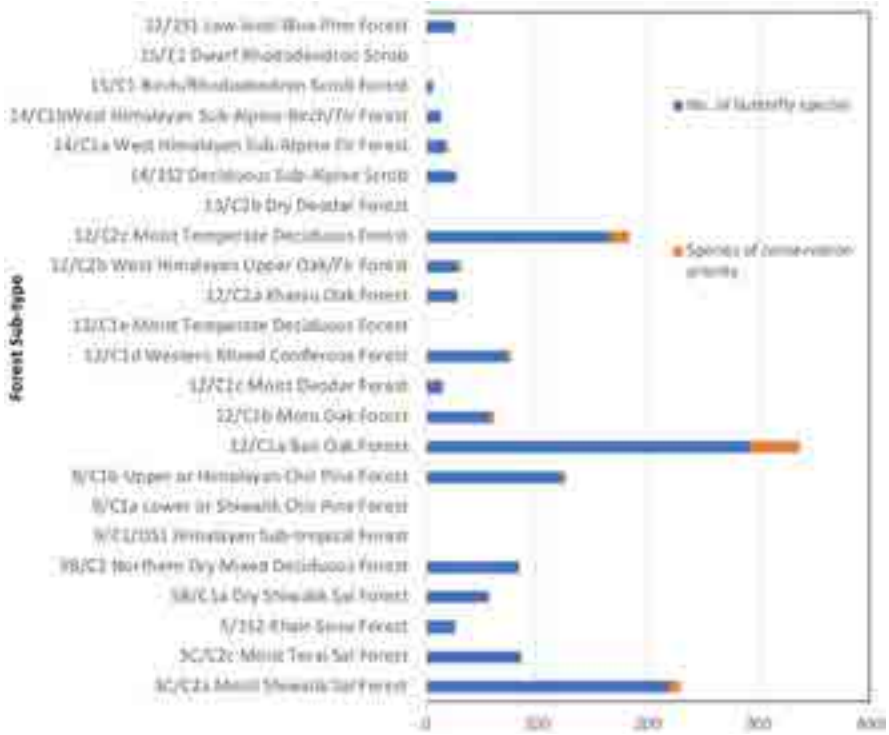


Figure 8. Spread of species of conservation priority species (orange bars) in different forest sub-types in relation to the total number of species sampled in them.

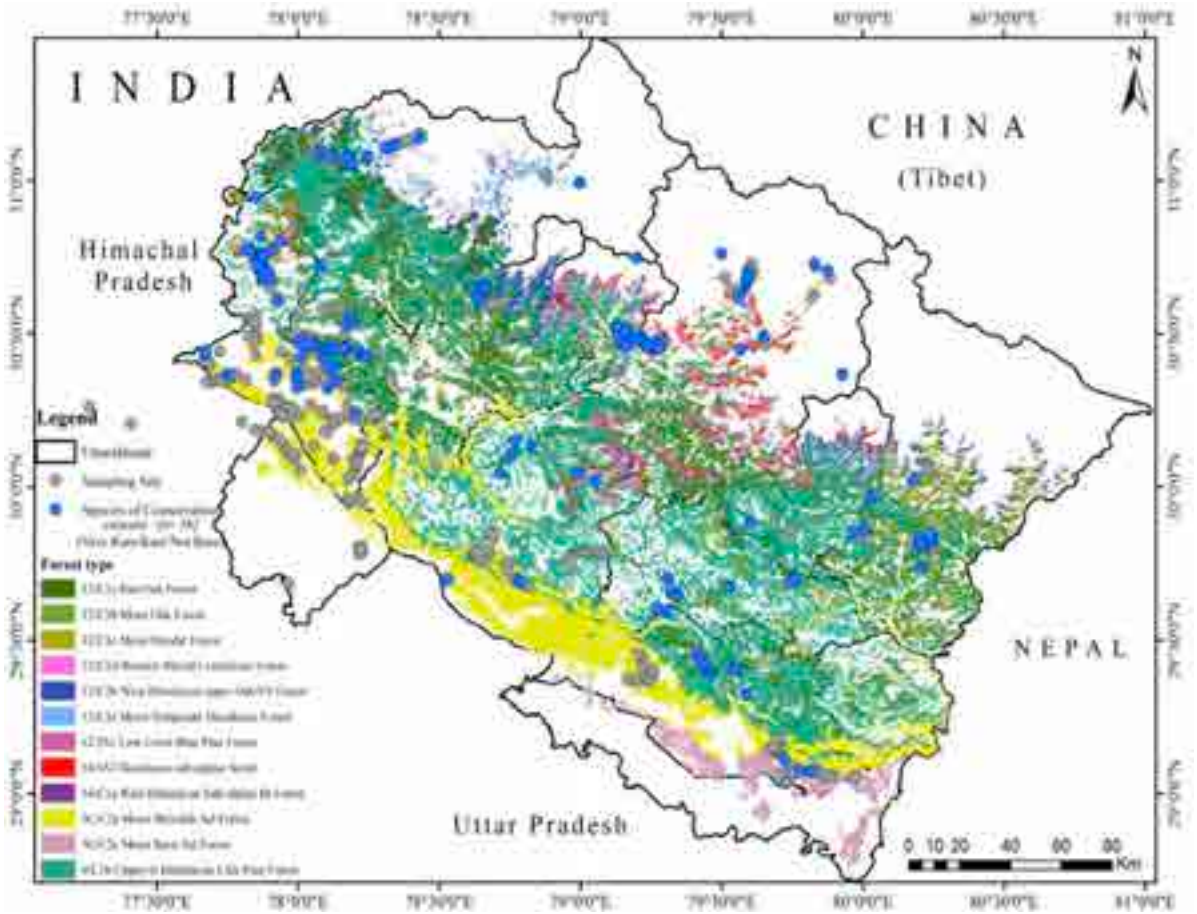


Figure 9. Map depicting the locations recorded for 58 species of conservation priority in 12 different forest sub-types across Uttarakhand.

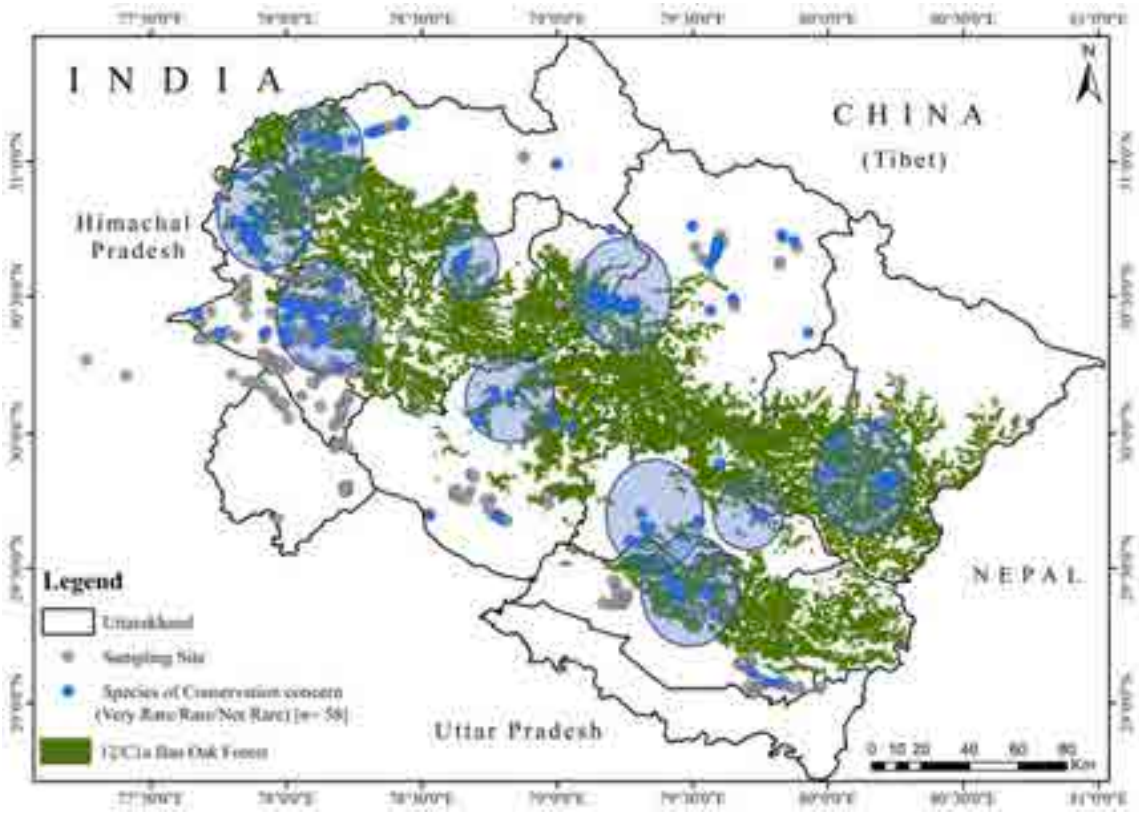


Figure 10. Important clusters of sites holding species of conservation priority in 12/C1a Ban Oak Forest in Uttarakhand.

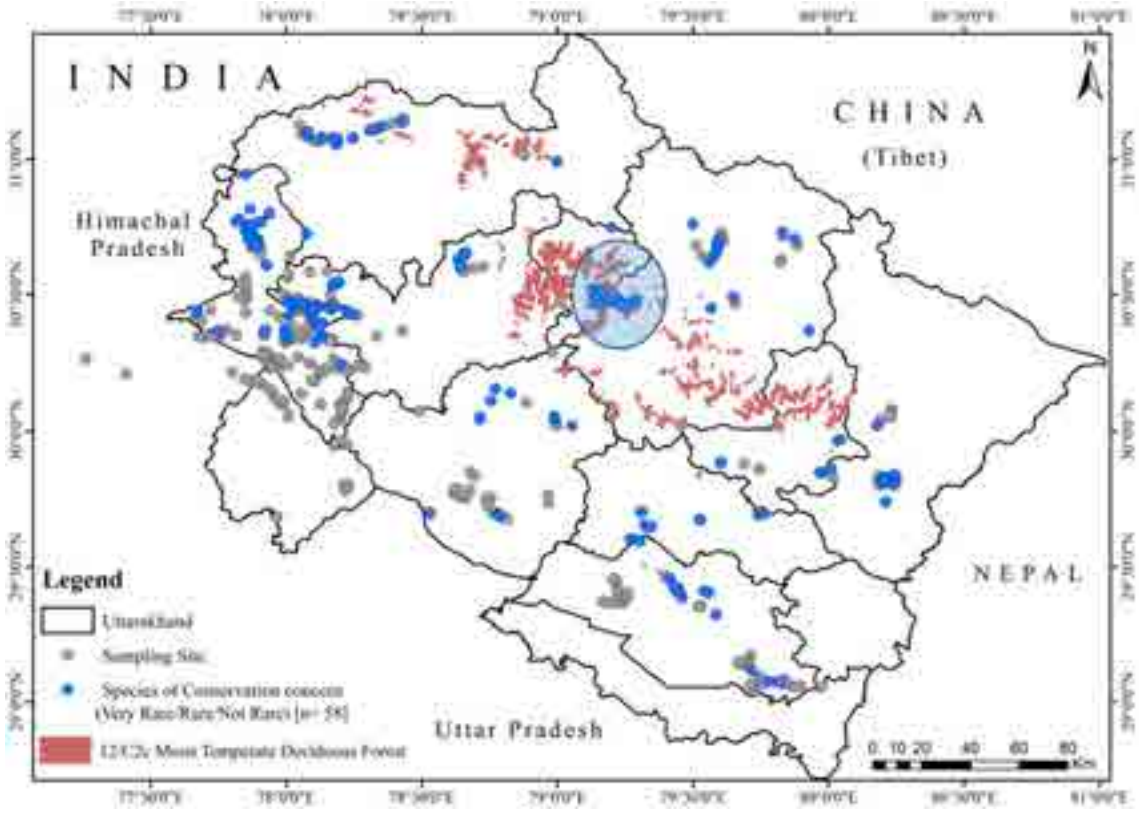


Figure 11. Important clusters of sites holding species of conservation priority in 12/C2c Moist Temperate Deciduous Forest in Uttarakhand.

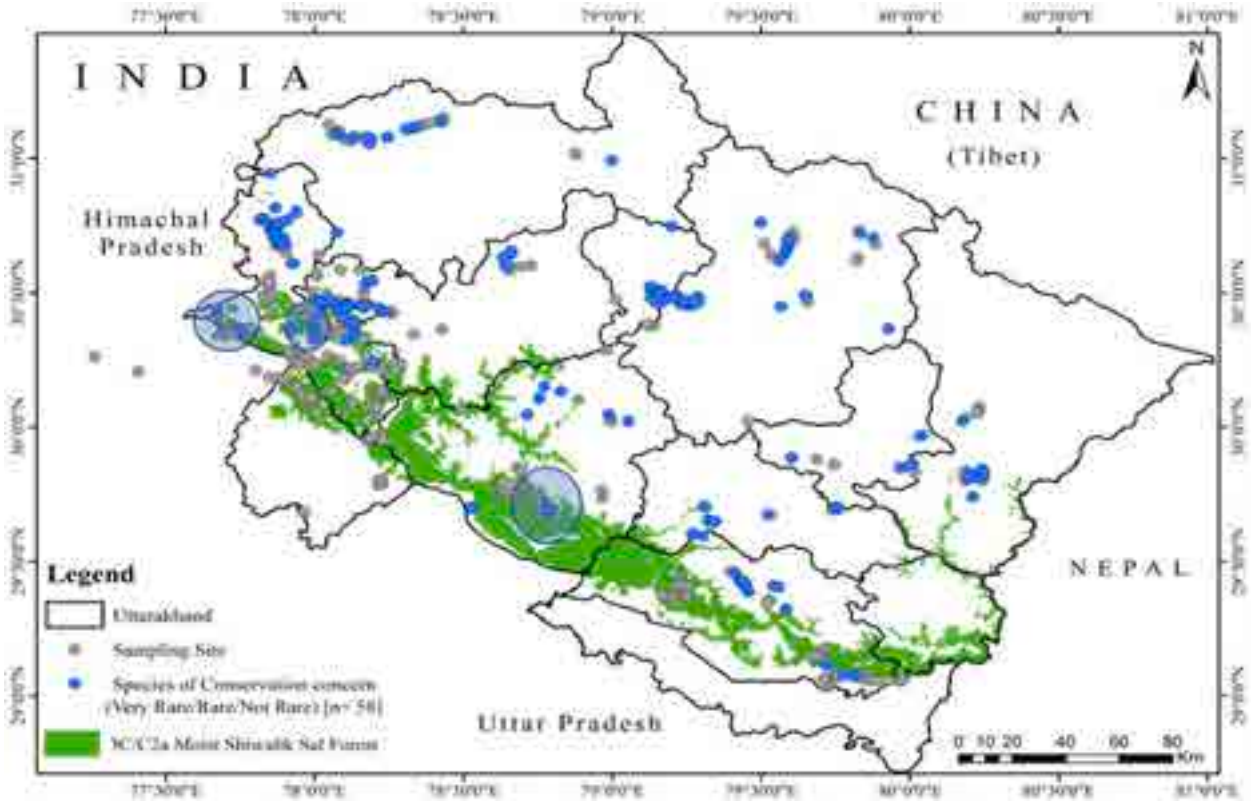


Figure 12. Important clusters of sites holding species of conservation priority in 3C/C2a Moist Shiwalik Sal Forest in Uttarakhand.

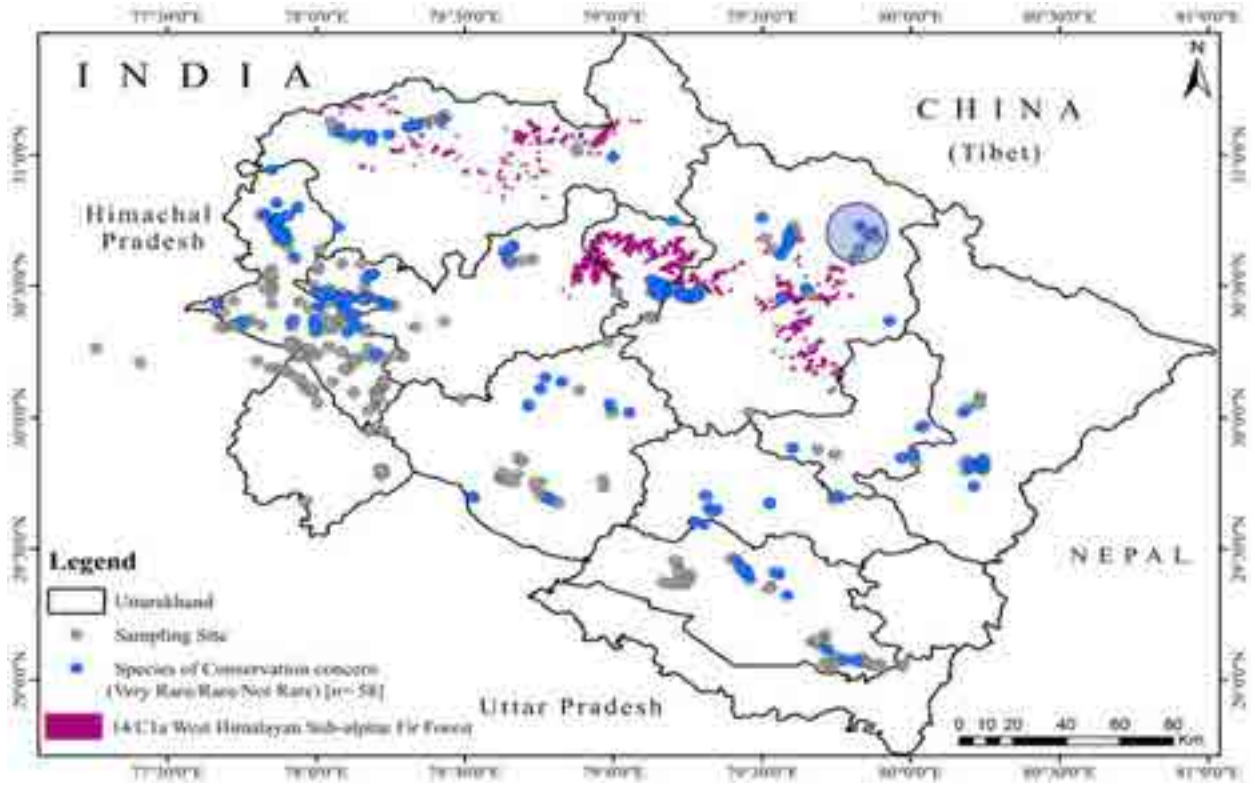


Figure 13. Important cluster of sites holding species of conservation priority in 14/C1a West Himalayan Sub-alpine Fir Forest in Uttarakhand.

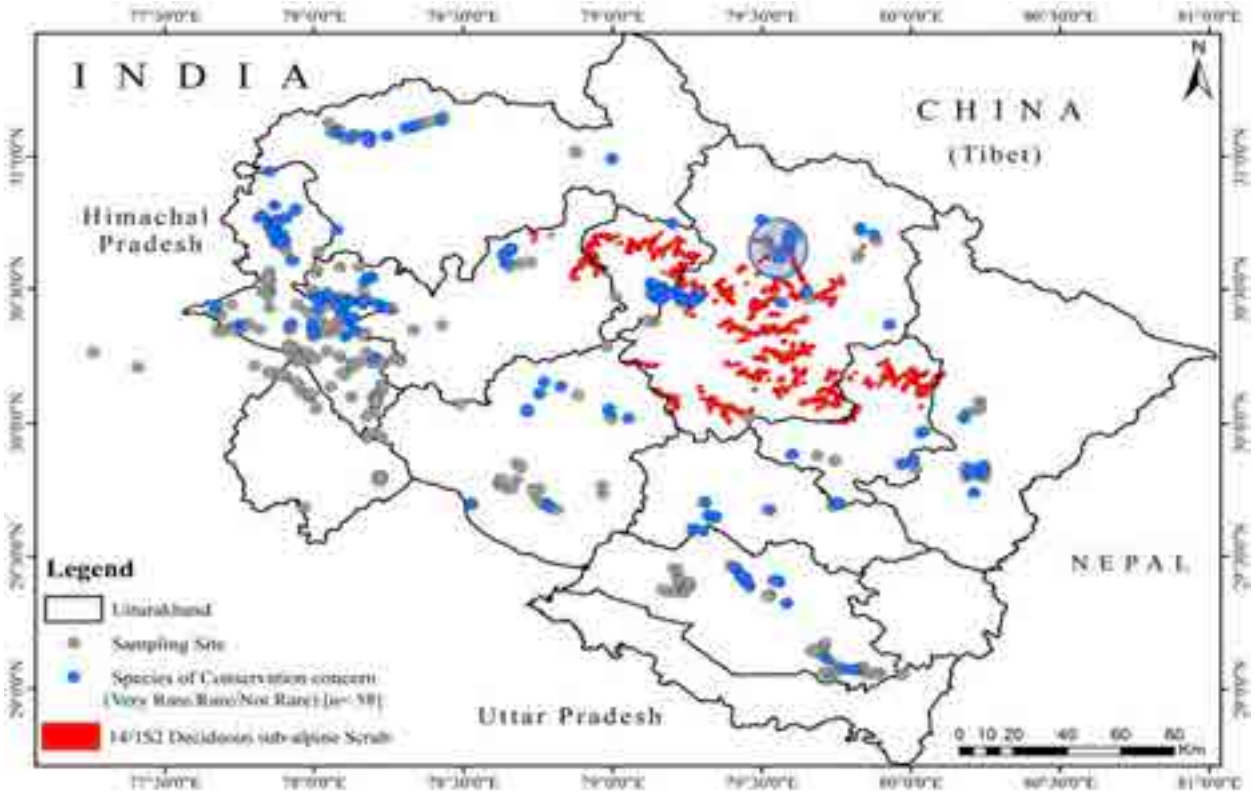


Figure 14. Important cluster of sites holding species of conservation priority in 14/1S2 Deciduous Sub-alpine Scrub in Uttarakhand.

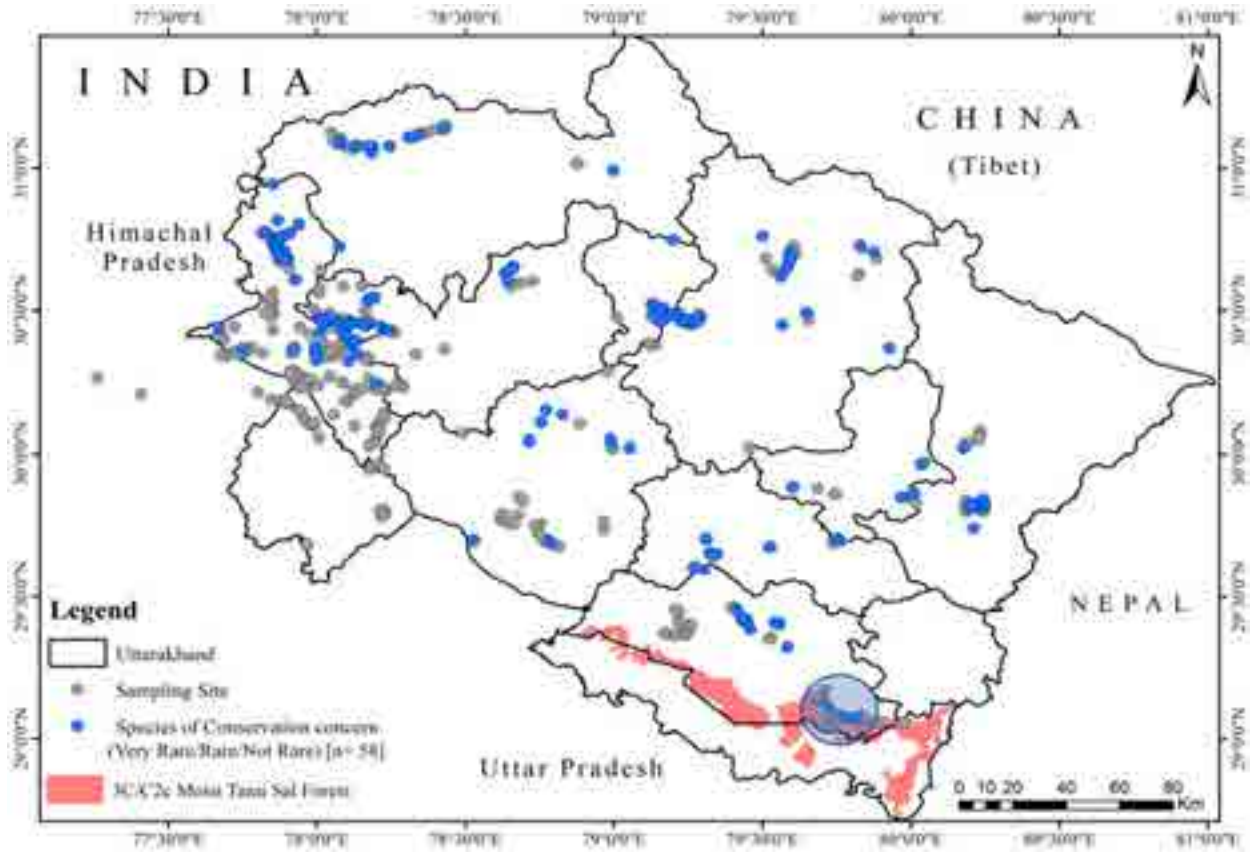


Figure 15. Important clusters of sites holding species of conservation priority in 3C/C2c Moist Terai Sal Forest in Uttarakhand.

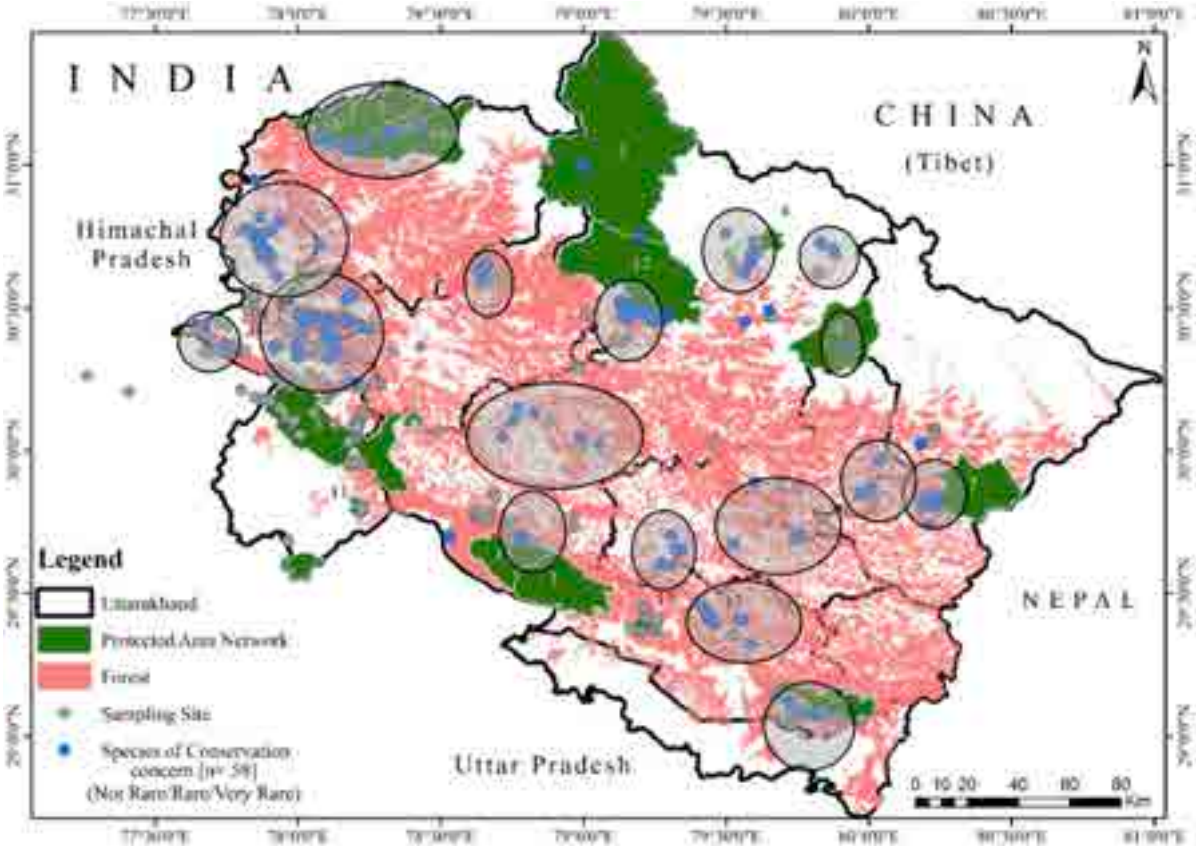


Figure 16. Locations of 58 butterfly species of conservation priority in relation to forest cover and the protected area network (16 no.), of Uttarakhand state along with 17 clusters where these species are concentrated.

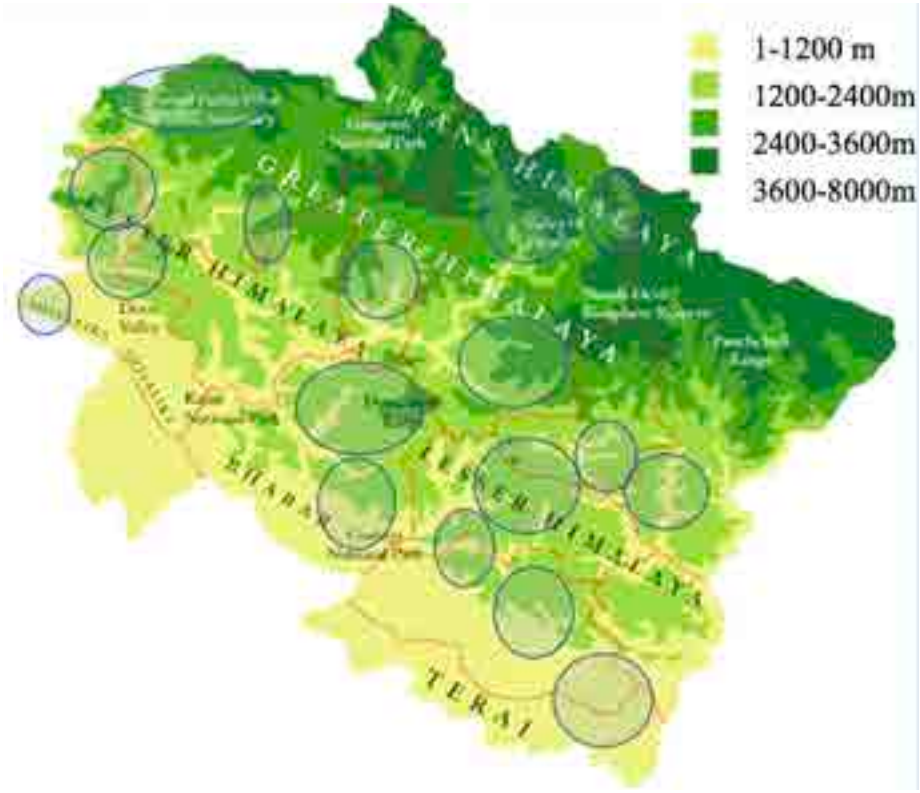


Figure 17. Locations of 17 clusters showing concentration of 58 butterfly species of conservation priority in relation to their altitudinal distribution in the state of Uttarakhand.

Sno	Name
1	Corbett National Park
2	Gangotri National Park
3	Govind National Park
4	Nanda Devi National Park
5	Rajaji National Park
6	Valley of Flowers National Park
7	Askot Wildlife Sanctuary
8	Asan Conservation Reserve
9	Binsar Wildlife Sanctuary
10	Govind Wildlife Sanctuary
11	Jhilmil Conservation Reserve
12	Kedarnath Wildlife Sanctuary
13	Benog/Mussoorie Wildlife Sanctuary
14	Nandhaur Wildlife Sanctuary
15	Pawalgarh Conservation Reserve
16	Sonanadi Wildlife Sanctuary
17	Naina Devi Bird Conservation Reserve

of 58 species of conservation priority are marked in 17 circles (Figure 16) and at least 12 of these occur outside the PA network based on the findings of the present study. Important forest sub-types identified falling in these clusters having species of conservation concern can thus be recommended for conservation or future PAs. Seventeen concentrations/clusters that are located in different physiographic zones represented in the state are, three in Trans Himalaya; three in Greater Himalaya; eight in Lesser Himalaya; one in Shiwalik/Dun; one in Bhabar; and one in Tarai area along an elevation gradient, rather than a few as currently represented in the PA network of the state (Figure 17 & Appendix V).

Also, new conservation sites can be identified from these 17 clusters/concentrations of rare buttefly taxa especially in the 'Lesser Himalaya' where the number of PAs are almost negligible. This type of approach in identifying areas of conservation priority is more inclusive and suitable at a sub-regional or state level in restoring linkages and corridors in the PA network, rather than solely based on a broader geographic scale, i.e., zoogeographic zones. Many of these sites with high butterfly richenss that lie outside the PAs and close to the villages and towns with suitable logistical support for boarding, lodging and travel can be promoted for suitainable and inclusive butterfly ecotourism activities in the state.

REFERENCES

Anonymous (2006). *The Wildlife* (*Protection*) *Act 1972*. Natraj Publishers, Dehradun, 235 pp.

Arita, H.T., J.G. Robinson & K.H. Redford (1990). Rarity in Neotropical forest mammals and its ecological correlates. *Conservation Biology* 4(2): 181–192.

Baindur, A. (1993). The butterflies of Nanda Devi. In: *Scientific and Ecological Expedition Nanda Devi, 2nd May to 22nd July 1993*. (Army Corps of Engineers; W.I.I.; Salim Ali Centre for Ornithology & Natural History, WWF-India, G.B. Pant Institute of Himalayan Environment & Development, Botanical Survey of India) Army Headquarters, New Delhi, 35–43 pp.

Bhardwaj, M., V.P. Uniyal, A.K. Sanyal & A.P. Singh (2012). Butterfly communities along an elevation gradient in the Tons valley, Western Himalayas: Implications of rapid assessment of insect conservation. *Journal of Asia-Pacific Entomology* 15(1): 207–217.

Bhardwaj, M. & V.P. Uniyal (2013). High-altitude butterfly fauna of Gangotri National Park, Uttarakhand: Patterns in species abundance, composition and similarity,pp38-48. *ENVIS Bulletin on Wildlife and Protected Areas- Arthropods and their Conservation in India* (*Insects & Spiders*), 232 pp.

Berg, A. & M. Tjernberg (1996). Common and rare Swedish vertebrates distribution and habitat preferences. *Biodiversity and Conservation* 5(1): 101–128.

Bingham, C.T. (1905). *Fauna of British India. Butterflies Vol. I*. Taylor and Francis, London, 511 pp.

Botanical Survey of India (2021). *Bibliography and Abstracts of Papers on Flora of Uttar Pradesh and Uttarakhand*. ENVIS, Government of India Ministry of Environment, Forest and Climate Change. Botanical Survey of India, Howrah, West Bengal, 616 pp.

Brandis, D. (1906). *Indian Trees* : *An Account of Trees, Shrubs, Woody Climbers, Bamboos, and Palms Indigenous or Commonly Cultivated in the British Indian Empire*. Archibald Constable and Co., Ltd. London, 767 pp.

Brown, J.H. (1995). *Macroecology*. University of Chicago Press, Chicago, IL, 284 pp.

Brown, K.S. (1982). Paleoecology and regional patterns of evolution in neotropical forest butterflies, pp. 255–308. In: Prance, G.T. (ed). *Biological Diversification in the Tropics*. Columbia University Press, New York, 714 pp.

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of The Forest Type of India*. Govt. of India Press. New Delhi, 404 pp.

D'abrera, B. (1982). *Butterflies of the Oriental Region - Part I. Papilionidae, Pieridae & Danaidae*. Hill House, Victoria, Australia, 244 pp.

D'abrera, B. (1985). *Butterflies of the Oriental Region - Part II. Nymphalidae, Satyridae & Amathusiidae.* Hill House, Victoria, Australia, 534 pp.

D'abrera, B. (1986). *Butterflies of the Oriental Region - Part III. Lycaenidae & Riodinidae*. Hill House, Victoria, Australia, 672 pp.

Daniels, R.J.R., M. Hegde, N.V. Joshi & M. Gadgil (1991). Assigning conservation value: a case study from India. *Conservation Biology* 5(4): 464–475.

Doherty, W. (1886). A list of butterflies in Kumaun. *Journal of the Asiatic Society of Bengal* 55(2): 103–140.

Ehrlich, P.R. & P.H. Raven (1964). Butterflies and plants: a study in co-evolution. *Evolution* 18: 586–608.

Evans, W.H. (1932). *The Identification of Indian Butterflies*. 2nd Edition. Bombay Natural History Society, Bombay, x+454 pp+32 pl.

Forest Survey of India (2011). *Atlas-Forest Types of India*. Forest Survey of India, Ministry of Environment and Forests, Govt. of India, Dehradun, 210 pp.

Gaston, K.J. (1994). *Rarity*. Chapman and Hall, London, 201 pp.

Gaston, K.J. & T.M. Blackburn (1995). Rarity and body size: some cautionary remarks. *Conservation Biology* 9(1): 210–213.

Gilbert, L.E. & M.C. Singer (1975). Butterfly Ecology. *Annual Review of Ecology and Systematics* 6(1): 365–397.

Gilbert, L.E. & J.T. Smiley (1978). Determinants of local diversity in

phytophagous insects: host specialists in tropical environments, pp. 89–104. In: Mound, L.A. & N. Waloff (eds.). *Diversity of Insect Faunas.* Blackwell Scientific, 204 pp.

Gilbert, L.E. (1980). Food web organization and the conservation of neotropical diversity, pp. 11–34. In: Soule, M.E. & B.A. Wilcox (eds.). *Conservation Biology: An Evolutionary-Ecological Perspective*. Sinauer Associates, Sunderland, Massachusetts, USA, 395 pp.

Gilbert, L.E. (1984). The biology of butterfly communities, pp 41–54. In: Vane-Wright, R.I. & P.R. Ackery (eds.). *The Biology of Butterflies*. Princeton University Press, Princeton, New Jersey, USA, 429 pp.

Gasse, P.V. (2017). *Annotated checklist of Butterflies of the Indo-Burmese region*. http://flutters.org/home/docs/Butterflies_of_India_Paul_Van_Gasse.pdf

Hannyngton, F. (1910–11). The butterflies of Kumaon. Parts I & Part II. *Journal of the Bombay Natural History Society* 20 (1): 130–142; (2): 361–372; (3): 871–872**.**

Haribal, M. (1992). *Butterflies of Sikkim Himalaya and their Natural History*. Sikkim Nature Conservation Foundation, Gangtok, Sikkim, India, 217 pp.

Khanduri, K., A. Singh, D. Singh, Kursotam & P. Garg (2013). Uttarakhand Himalayas: Hydropower Developments and its Impact on Environmental System. *Journal of Environment*. Volume 02. https://www.researchgate.net/publication/264673061.

Kehimkar, I. (2008). *The Book of Indian Butterflies*. Bombay Natural History Society, Oxford University, Delhi Press, 497 pp.

Kehimkar, I. (2016). *Butterflies of India*. Bombay Natural History Society, Mumbai, 505 pp.

Kremen, C. (1992). Assessing the Indicator Properties of Species Assemblages for Natural Areas Monitoring. *Ecological Applications* 2(2): 203–217.

Kremen, C., R.K. Colwell, T.L. Erwin, D.D. Murphy, R.F. Noss & M.A. Sanjayan (1993). Terrestrial arthropod assemblages: Their use in conservation planning. *Conservation Biology* 7(4): 796–808.

Lomov, B., D.A. Keith, D.R. Britton & D.F. Hochuli (2006). *Are butterflies and moths useful indicators for restoration monitoring? A pilot study in Sydney's Cumberland Plain Woodland* 7(3): 204–210. https://doi.org/10.1111/j.1442-8903.2006.00310.x

Mackinnon, P.W. & L. DeNicéville (1899). List of butterflies of Mussoorie in the Western Himalayas and neighbouring region. *Journal Bombay Natural History Society* 11(1): 205–221; (2): 368–389, 585–605.

Moore, F. (1890–1897). *Lepidoptera indica*. Parts I-VII. Lovell Reeve Co.Ltd. London.

Murphy, D.D. & B.A. Wilcox (1986). Butterfly diversity in natural habitat fragments: a test of the validity of vertebrate-based management, pp. 287–292 . In: Verner, J., M.L. Morrison & C.J. Ralph (eds.). *Wildlife 2000, Modeling Habitat Relationships of Terrestrial Vertebrates*. University of Wisconsin Press, Madison, Wisconsin, USA, 699 pp.

Murphy, D.D., K.E. Freas & S.B. Weiss (1990). An environment-metapopulation approach to population viability analysis for a threatened invertebrate. *Conservation Biology* 4(1): 41–51.

Nayar, M.P. & A.R.K. Sastry (1987, 1988, 1990). *Red Data Book of Indian Plants* Vols. I, II, III. Botanical Survey of India, Calcutta.

New, T.R. (1991). *Butterfly Conservation.* Oxford University Press, 224 pp.

New, T.R., R.M. Pyle, J. A. Thomas, C.D. Thomas & P.C. Hammond (1995). Butterfly conservation management. *Annual Review of Entomology* 40 (1): 57–83.

Ollenbach, O.C. (1930). Butterfly collection grounds at Mussoorie. *Journal of the Bombay Natural History Society* 34(3): 836–840.

Pearman, P.B., M. Guerreiro, T.D. Sisk & D. Murphy (1995). Correlation patterns among groups proposed as biological indicators :what do they indicate. *Bulletin of the Ecological Society of America* 76: 375.

Pimm, S.L., L.H. Jones & J. Diamond (1988). On the risk of extintion. *American Naturalist* 132(6): 757–785.\

Pollard, E. (1977). A method for assessing changes in the abundance of butterflies. *Biological Conservation* 12(2): 115–124.

Pollard, E. & T.J. Yates (1993). *Monitoring Butterflies for Ecology and Conservation*. Chapman and Hall, London, 287 pp.

Pyle, R.M. (1980). Butterfly eco-geography and biological conservation in Washington. *Atala* 8(1): 1–26.

Primack, R. (1993). *Essentials of Conservation Biology*. Sinauer Associates, Sunderland, MA, 585 pp.

Rabinowitz, D.S., S. Cairns & T. Dillon (1986). Seven forms of rarity and their frequency in flora of British Isles, pp. 182–204. In: Soule, M.E.(ed.). *Conservation Biology: the Science of scarcity and Diversity*. Sinuer, Sunderland, M.A, 584 pp.

Rabinowitz, D.S. (1981). Seven forms of rarity, pp. 205–217. In: Synge, H. (ed.). *The Biological Aspects of Rare Plant Conservation*. Wiley, Chichester, U.K.,558 pp.

Rai, I.D., G. Singh & G.S. Rawat (2017). *Plants of Kedarnath Wildlife Sanctuary, Western Himalaya: A Field Guide*. Bishen Singh Mahendra Pal Singh, Dehadun, 393 pp.

Rodgers, W.A. & H.S Panwar (1988). Planning a Wildlife Protected Area Network in India. 2 vol. Project FO: IND/82/003, FAO, Dehradun 339, 267 pp.

Rosenberg, D.M., H.V. Danks & D.M. Lehmkuhl(1986). Importance of insects in environmental impact assessment. Environment impact assessment. *Environment Management* 10(6): 773–783.

Samways, M.J. (1994). Individual insect species and their conservation, pp. 169–193. In: *Insect Conservation Biology.* Chapman and Hall, London, 450 pp.

Shull, E.M. (1958). My highest catch of butterfly species in a single day (4th June, 1957) Mussoorie, India. *Journal of the Lepidopterists' Society* 11(4–5): 167–168.

Shull, E.M. (1962). Over one hundred butterfly species caught in a single day (3rd June, 1961) at Mussoorie, India. *Journal of the Lepidopterists' Society* 16: 143–145.

Singh, A.P. (2017). Butterflies associated with major forest types in Arunachal Pradesh (Eastern Himalaya), India: Implications for eco-tourism and in conservation planning. *Journal of Threatened Taxa* 9(4): 10047–10075. https://doi.org/10.11609/jott.2765.9.4.10047-10075

Singh, A.P. & R.S. Bhandari (2003). Butterfly diversity in tropical moist deciduous sal (*Shorea robusta*) forests of Dehradun valley: the lower western Himalayas. *Indian Forester* 129(10): 1257–1269.

Singh, A.P. & R.S. Bhandari (2006). New Additions to the Butterflies of Dehradun valley, the lower Western Himalayas. *Indian Forester* 132(6): 767–769.

Singh, A.P. & S. Sondhi (2016). Butterflies of Garhwal, Uttarakhand, western Himalaya, India. *Journal of Threatened Taxa* 8(4): 8666–8697. https://doi.org/10.11609/jott.2254.8.4.8666-8697

Singh, A.P. (2016). Recent records of the Pale Jezebel *Delias sanaca sanaca* (Moore, 1857) (Lepidoptera: Pieridae) from Mussoorie hills, western Himalaya, India. *Journal of Threatened Taxa* 8(12): 9473–9478. https://doi.org/10.11609/jott.2834.8.12.9473–9478

Singh, A.P. & S. Seal (2019). Occurrence of Dark Sapphire *Heliophorus indicus* Fruhstorfer, 1908 (Lepidoptera: Lycaenidae) in Garhwal Himalaya, Uttarakhand, India. Bugs R All #175, In: *Zoo's Print* 34 (7): 33–34.

Singh, A.P. & T. Singh (2019). Recent records of the rare Mountain Tortoiseshell *Aglais rizana* (Moore, 1872) (Lepidoptera: Nymphalidae) in the upper Garhwal, western Himalaya, India, after 100 years. *Journal of Threatened Taxa* 11(15): 15068–15071. https://doi.org/10.11609/jott.5276.11.15.15068-15071

Si gh, A.P. & T. Singh (2020). Occurrence and association of the Scarce Lilacfork *Lethe dura gammiei* (Moore, [1892]) (Lepidoptera: Nymphalidae: Satyrinae) with Woolly-leaved Oak *Quercus lanata* Smith, 1819 (Fabaceae) forest in the Kumaon region of the Indian Himalaya. *Journal of Threatened Taxa* 12(3): 15387–15390. https://doi.org/10.11609/jot.5467.12.3.15387-15390

Singh, A.P. & T. Singh (2021). Habitat association and hybridization in woodbrowns (*Lethe nicetas*, *L. sidonis* & *L. dakwania*) (Lepidoptera: Nymphalidae: Satyrinae) in Kedarnath Musk Deer Reserve, western Himalaya. *Journal of Threatened Taxa* 13(3): 18045–18049. https://doi.org/10.11609/jott.6517.13.3.18045-18049

Singh, A.P. & T. Singh (2021). First record of White-ringed

Meadowbrown, *Hyponephele davendra davendra* (Moore, 1865) (Lepidoptera: Nymphalidae) from inner valleys of Garhwal, Uttarakhand, India. *Journal of Bombay Natural History Society* 118(2): 1–5. https://doi.org/10.17087/jbnhs/2021/v118/152490

Singh, A.P. & T. Singh (2022). Occurrence of Dubious Five-Ring, *Ypthima parasakra* Eliot in Garhwal Himalaya. *Indian Journal of Entomology* 84(1): 1–3.

Smetacek, P. (2002). The genus *Pontia* Fabricius (Lepidoptera: Pieridae) in the Kumaon Himalaya. *Journal of the Bombay Natural History Society* 99(2): 224–231.

Smetacek, P. (2004). Descriptions of new Lepidoptera from the Kumaon Himalaya. *Journal of the Bombay Natural History Society* 101(2): 269–276.

Smetacek, P. (2011). Four new Lycaenid records from the Kumaon Himalaya. *Journal of Threatened Taxa* 3(2): 1555–1558. https://doi.org/10.11609/JoTT.o2224.1555-8

Smetacek, P. (2012). A new sub-species of *Mycalesis suaveolens* Wood-Mason & de Niceville 1883 from the western Himalaya, India (Lepidoptera, Nymphalidae, Satyrinae). *Nachrichten Entomolgischen Vereins Apollo* 32: 105–108.

Smetacek, P. (2012). Butterflies (Lepidoptera: Papilionoidea and Hesperoidea) and other protected fauna of Jones Estate, a dying watershed in the Kumaon Himalaya, Uttarakhand, India. *Journal of Threatened Taxa* 4(9): 2857–2874. https://doi.org/10.11609/JoTT.o3020.2857-74

Smith, C. (1989). *Butterflies of Nepal (Central Himalaya)*. Tecpress Service L.P., Bangkok, 352 pp.

Smith, C. (2006). *Illustrated Checklist of Nepal Butterflies*. Craftman Press, Bangkok, 129 pp.

Sondhi, S. (2017). First records of butterflies *Anthene emolus emolus* (Godart, [1924]) (Lepidoptera: Lycaenidae: Polyommatinae) and *Gandaca harina assamica* Moore, [1906] (Lepidoptera: Pieridae: Coliadinae) from Kumaon, Uttarakhand, India. *Journal of Threatened Taxa* 9(6): 10355–10357. https://doi.org/10.11609/jott.3233.9.6.10355-10357

Sondhi, S. & K. Kunte (2018). *Butterflies of Uttarakhand- A Field Guide*. Bishen Singh Mahendra Pal Singh (Dehradun), Titli Trust (Dehradun) National Centre for Biological Sciences (Bengaluru).

Swinhoe, C. (1905–1910). *Lepidoptera Indica.Part VII. Rhopalocera–Papilionidae & Lycaenidae.* Lovell, Reeve & Co. Ltd, London, 286 pp +pls.551–639.

Swinhoe, C. (1910–1911). *Lepidoptera Indica. Part VIII. Rhopalocera - Lycaenidae*. Lovell, Reeve & Co. Ltd., London, 293 pp + pls. 640–705.

Swinhoe, C. (1911–1912). *Lepidoptera Indica Part IX. Rhopalocera–Lycaenidae & Hesperiidae*. Lovell, Reeve & Co. Ltd., London, 278 pp +pls. 706–756.

Swinhoe, C. (1912–1913). *Lepidoptera Indica. Part X. Rhopalocera - Hesperiidae*. Lovell, Reeve & Co. Ltd., London, 364 pp + pls. 757–835.

Talbot, G. (1939). *The Fauna of British India including Ceylon and Burma*. Butterflies. 2nd edition. Vol. I . Taylor & Francis, London, 600 pp.

Talbot, G. (1947). *The Fauna of British India including Ceylon and Burma*. Butterflies. 2nd edition. Vol. II. Taylor & Francis, London, 506 pp.

Thomas, J.A. (1983). A quick method for estimating butterfly numbers during surveys. *Biological Conservation* 27(3): 195–211.

Thomas, C.D. & H.C. Mallorie (1985). Rarity, species richness and conservation: butterflies of the Atlas mountains in Morocco. *Biological Conservation* 33(2): 95–117.

Vasudevan, K. & S. Sondhi (2010). *Amphibians and Reptiles of Uttarakhand, India*. Wildlife Institute of India, 53 pp.

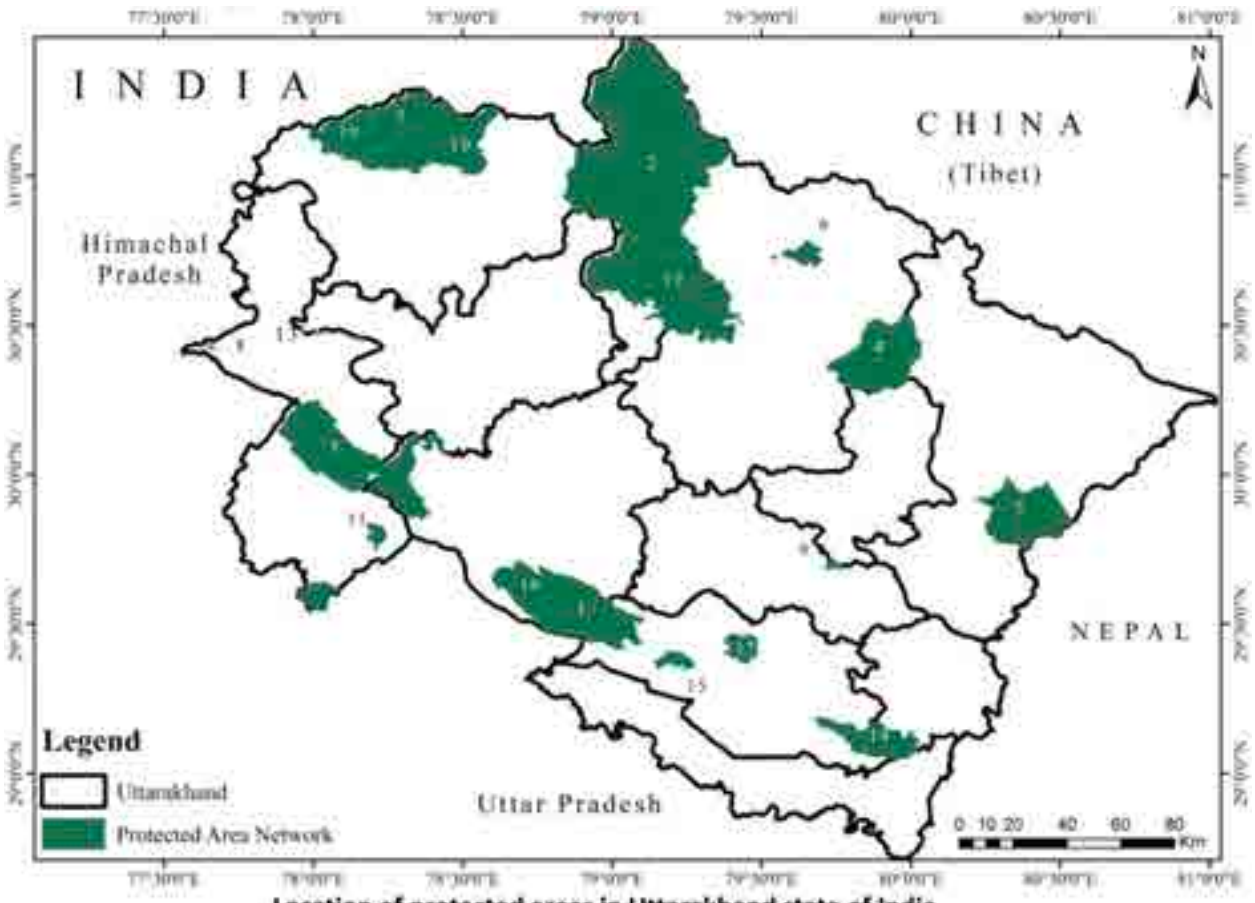
Verma, A. & M.K. Arya (2018). A preliminary study on the status and distribution of Butterfly Fauna in and around the valley of Reetha Sahib, Champawat, Kumaun Himalaya, India. *Biological Forum- An International Journal* 10(1): 43–51.

Wells, S.M., M.R. Pyle & M. Collins (1983).*The IUCN invertebrate Red Data Book*. IUCN, Switzerland, 623 pp.

Wynter-Blyth, M.A. (1957). *Butterflies of the Indian Region*. Bombay Natural History Society, Bombay, xx+523 pp+72 pls.

Appendix I. List of protected areas in Uttarakhand state, India

	Name	Area (km²)
1	Corbett National Park	520.82
2	Gangotri National Park	2390
3	Govind National Park	558.88
4	Nanda Devi National Park	624.6
5	Rajaji National Park	819.54
6	Valley of Flowers National Park	87.50
7	Askot Wildlife Sanctuary	600
8	Asan Conservation Reserve	4.44
9	Binsar Wildlife Sanctuary	45.59
10	Govind Wildlife Sanctuary	481.05
11	Jhilmil Conservation Reserve	37.84
12	Kedarnath Wildlife Sanctuary	975.20
13	Benog/Mussoorie Wildlife Sanctuary	10.82
14	Nandhaur Wildlife Sanctuary	269.96
15	Pawalgarh Conservation Reserve	58.25
16	Sonanadi Wildlife Sanctuary	301.18
17	Naina Devi Bird Conservation Reserve	111.90



Location of protected areas in Uttarakhand state of India

Appendix II. Vegetation compostion of forest sub-types sampled in the state taken up for study.

	Forest sub-type	Area (km²)	Percent of state cover	Dominant trees
1	3C/C2a Moist Shiwalik Sal Forest	3158	12.97	*Shorea robusta, Anogeissus latifolia, Terminalia tomentosa,T.bellerica, Adina cordifolia, Lannea coromandelica, Mallotus philippensis*
2	3C/C2c Moist Terai Sal Forest	542	2.19	*Shorea robusta, Adina cordifolia, T.alata, Terwia nudiflora, Syzygium cumini, Litsea glutinosa, Lagerstroemia parviflora, Cordia dichotoma, Putranjiva roxburghii,Litsea monopetla, Pogostemon benghalensis.*
3	5B/C1a Dry Shiwalik Sal Forest	236	1.5	*Shorea robusta, Anogeissus latifolia, Buchanania lanzan, Terminalia tomentosa, Bauhinia variegata, Emblica officinalis, Acacia catechu, Pinus roxburghii, Schleichera oleosa, Cassia fistula, Zizyphus xylopyrus*(*B. vahlii*-shrub)
4	5B/C2 Northern Dry Mixed Deciduous Forest	678	2.82	*Anogeissus latifolia, Boswellia serrata, Acacia catechu, Shorea robusta, Bauhinia* spp.,*Bauchanania lanzan, Diospyros tomentosa, Teminalian bellerica, Kydiacalycina, Sterculia lappeus, Miytragyna parvifolia, Aegle marmelos, Butea monsperma, Flacourtia indica, Zizyphus mauratina*
5	5/1S2 Khair-Sissu Forest	236	0.98	*Dalbergia sissoo, Acacia catechu, Zyzyphus mauratiana, Ehretia laevis, Holoptelea integrifolia.*
6	9/C1b Upper or Himalayan Chir Pine Forest	6278	26.07	*Pinus roxburghii, Quercus leucotrichophora; Lyonia ovalifolia, Rhododendron arboreum, Pyrus pashia, Myrica esculanta, Pyracantha crenulata, Symplocos crataegoides.*
7	12/C1a Ban Oak Forest	4798	20.23	*Quercus leucotrichophora, Rhododendron arboreum, Lyonia ovalifolia, Rhus semialata, Symplocos crataegoides, Benthamidia capitata, Carpinus viminea,Betula alnoides*
8	12/C1b Moru Oak Forest	9317	3.95	*Quercus floribunda, Q.leucotrichophora, Pinus wallichiana, Betula alnoides, Carpinus viminea, Acer caesium, Michilus duthei, Aesculus indica, Abies pindrow, Picea smithiana, Juglans regia.*
9	12/C1c Moist Deodar Forest	485	1.96	*Cedrus deodara, Pinus wallichiana, Quercus leucotrichophora*
10	12/C1d Western Mixed Coniferous Forest-Spruce, Blue Pine, Silver Fir	513	2.19	*Picea smithiana, Cedrus deodara, Abies pindrow, Pinus wallichiana Quercus floribunda, Q.semecarpifolia, Q.leucotrichophora, Acer caesium, A.pictum, A. acuminatum, Euonymus lacerus, Taxus baccata, Betula alnoides.*
11	12/C1e Moist Temperate Deciduous Forest	246	1.07	*Alnus nepalensis, Aesculus indica, Acer caesium, A.pictum, Carpinus viminea, Ulmus wallichiana, Betula alnoides, Juglans regia, Fraxinus micrantha, Quercus leucotrichophora, Q.floribunda, Q.semecarpifolia. Prunus cornuta, Rhododendron arboreum.*
12	12/C2a Kharsu Oak Forest (*Q. semecarpifolia*)	227	0.99	*Quercus semecarpifolia, Abiespindrow, Betula alnoides, Q. floribunda, Acer caesium, Ilex dipyrena, Taxus baccata.*
13	12/C2b West Himalayan Upper Oak/Fir Forest	1087	4.57	*Abiespindrow, Piceasmithiana, Quercus semecarpifolia, Q.floribunda, Pyrus lanata, Acer caesium, Meliosma dilleniaefolia, Eunonymus lacerus, Ilex diprena, Sorbussoliosa, Rhododendron arboreum, R. barbatum, Ulmus wallichiana, Aesc ulus indica, Corylus colurna*
14	12/2S1 Low Level Blue Pine Forest	384	1.54	*Pinus wallichiana, Quercus leucotrichophora*
15	13/C2b Dry Deodar Forest	363	1.46	*Cedrus deodara, Pinus wallichiana, Picea smithiana, Corylus colurna*
16	14/C1a West Himalayan Sub-Alpine High Level Fir Forest	195	0.78	*Abies spectalilis, Pinus wallichiana, Piceasmithiana, Rhododendron companulatum, Taxus baccata, Prunus padus*
17	14/C1b West Himalayan Sub-Alpine Birch/ Fir Forest	583	2.47	*Abies spectabilis, Acer cappadociccum, Betula utilis, Quercus semecarpifolia, Rhododendron campanulatum, R. anthopogon, Lyonia ovalifolia, Sorbusfoliolosa*
18	14/1S2 Deciduous Sub-Alpine Scrub	200	0.86	*Betula utilis*
19	15/C1 Birch/Rhododendron Scrub Forest	136	0.56	*Betula utilis, Rhododendron companulatum, Sorbus foliolosa, Quercus semecarpifolia*
20	15/E1 Dwarf Rhododendron Scrub	32	0.13	*Rhododendron anthopogon, R. lepidotum, R. companulatum, Ilex diprena*

Source: Champion & Seth (1968).

Appendix III. Complete list of butterflies sampled in 20 different forest types of Uttarakhand ranked according to their relative abundances (2006–2009 & 2017–2020).

	Butterfly species
A.	**Very Common**
1	*Eurema hecabe* (Linnaeus, 1758)
2	*Catopsilia pomona* (Fabricius, 1775)
3	*Ypthima sakra sakra* Moore, [1858]
4	*Pieris canidia indica* Evans, 1926
5	*Celastrina huegeli huegeli* (Moore, 1882)
6	*Aporia agathon* (Gray, 1831)
7	*Junonia iphita iphita* (Cramer, [1779])
8	*Callerebia nirmala* (Moore, 1865)
9	*Aglais caschmirensis aesis* (Fruhstorfer, 1912)
10	*Papilio polytes romulus* Cramer, [1775]
11	*Pseudozizeeria maha maha* (Kollar, [1844])
12	*Acytolepis puspa* (Horsfield, [1828])
13	*Aulocera swaha swaha* (Kollar, [1844])
14	*Dodona durga durga* (Kollar, [1844])
15	*Leptosia nina* (Fabricius, 1793)
16	*Neptis hylas varmona* Moore, 1872
17	*Vanessa indica indica* (Herbst, 1794)
18	*Euploea core core* (Cramer, [1780])
19	*Arhopala amantes apella* (Swinhoe, 1886)
20	*Pieris brassicae* (Linnaeus, 1758)
21	*Neptis mahendra mahendra* Moore, 1872
22	*Gonepteryx rhamni nepalensis* Doubleday, 1847
23	*Vanessa cardui* (Linnaeus, 1758)
24	*Celastrina lavendularis limbatus* (Moore, 1879)
25	*Ypthima huebneri* Kirby, 1871
26	*Junonia lemonias lemonias* (Linnaeus, 1758)
27	*Lethe sidonis* (Hewitson, 1863)
28	*Ariadne merione* tapestrina (Moore, 1884)
29	*Lasiommata schakra schakra* (Kollar, [1844])
30	*Symbrenthia lilaea khasiana* Moore, [1875]
31	*Phalanta phalantha phalantha* (Drury, [1773])
32	*Callerebia hybrida* Butler, 1880
33	*Arhopala atrax* (Hewitson, 1862)
34	*Callerebia scanda scanda* (Kollar, [1844])
35	*Parantica aglea melanoides* Moore, 1883
36	*Athyma opalina opalina* Kollar, 1844
37	*Heliophorus sena* (Kollar, [1844])
38	*Prosotas nora ardates* (Moore, [1875])
39	*Catopsilia pyranthe* (Linnaeus, 1758)
40	*Colias fieldii* Ménétriés, 1855
41	*Ypthima nikaea* Moore, [1875]
42	*Cepora nerissa phryne* (Fabricius, 1775)
43	*Danaus chrysippus chrysippus* (Linnaeus, 1758)
44	*Lethe verma verma* (Kollar, [1844])
45	*Ypthima inica* Hewitson, [1865]
46	*Ypthima baldus baldus* (Fabricius, 1775)
47	*Pareronia hippia* (Fabricius, 1787)
48	*Castalius rosimon rosimon* (Fabricius, 1775)
49	*Heliophorus tamu tamu* (Kollar, [1844])
50	*Acraea issoria issoria* (Hübner, [1819])
51	*Lampides boeticus* (Linnaeus, 1767)
52	*Cyrestis thyodamas ganescha* Kollar, 1848
53	*Jamides celeno celeno* (Cramer, [1775])
54	*Delias belladonna horsfieldi* (Gray, 1831)
55	*Neopithecops zalmora zalmora* (Butler, [1870])
56	*Euploea mulciber mulciber* (Cramer, [1777])
57	*Euaspa milionia milionia* (Hewitson, [1869])
58	*Sephisa dichroa* (Kollar, [1844])
59	*Issoria issaea* (Doherty, 1886)
60	*Prosotas dubiosa indica* (Evans, [1925])
61	*Junonia atlites atlites* (Linnaeus, 1763)
62	*Callerebia annada caeca* (Watkins, 1925)
63	*Ypthima nareda* (Kollar, [1844])
64	*Danaus genutia genutia* (Cramer, [1779])
65	*Papilio demoleus demoleus* Linnaeus, 1758
66	*Mycalesis perseus blasius* Fabricius, 1798
67	*Arhopala ganesa ganesa* (Moore, [1858])
68	*Colias erate* (Esper, 1805)
69	*Eurema blanda* (Boisduval, 1836)
70	*Junonia hierta hierta* (Fabricius, 1798)
71	*Parantica sita sita* (Kollar, [1844])
72	*Zizeeria karsandra* (Moore, 1865)
73	*Cupha erymanthis lotis* (Sulzer, 1776)
74	*Athyma perius perius* (Linnaeus, 1758)
75	*Kaniska canace canace* (Linnaeus, 1763)
76	*Ixias pyrene* (Linnaeus, 1764)
77	*Zizina otis otis* (Fabricius, 1787)
78	*Hypolimnas bolina jacintha* (Drury, 1773)
79	*Chrysozephyrus birupa* Moore, 1877
80	*Acraea terpsicore* (Linnaeus, 1758)
81	*Lycaena phlaeas baralacha* (Moore, 1884)
82	*Delias eucharis* (Drury, 1773)
83	*Celaenorrhinus leucocera* (Kollar, [1844])
84	*Junonia almana almana* (Linnaeus, 1758)
85	*Junonia orithya* (Linnaeus, 1758)

	Butterfly species
86	*Pelopidas mathias mathias* (Fabricius, 1798)
87	*Melanitis leda leda* (Linnaeus, 1758)
88	*Charaxes bharata* C. & R. Felder, [1867]
89	*Argynnis childreni sakontala* Kollar, [1848]
90	*Esakiozephyrus icana icana* (Moore, [1875])
91	*Libythea lepita lepita* Moore, [1858]
B.	**Common**
92	*Euthalia patala patala* (Kollar, [1844])
93	*Pantoporia hordonia hordonia* (Stoll, [1790])
94	*Orinoma damaris damaris* Gray, 1846
95	*Tanaecia lepidea lepidea* (Butler, 1868)
96	*Chilades pandava pandava* (Horsfield, [1829]
97	*Papilio protenor protenor* Cramer, [1775]
98	*Lycaena panava* (Westwood, 1852)
99	*Talicada nyseus nyseus* (Guérin-Méneville, 1843)
100	*Oriens gola pseudolus* (Mabille, 1883)
101	*Dodona dipoea nostia* Fruhstorfer, 1912
102	*Moduza procris* (Cramer, [1777])
103	*Rapala manea schistacea* (Moore, 1879)
104	*Pseudocoladenia fatih* (Kollar, [1844])
105	*Byasa polyeuctes letincius* (Fruhstorfer, 1908)
106	*Elymnias hypermnestra undularis* (Drury, 1773)
107	*Euthalia lubentina lubentina* (Cramer, [1777])
108	*Zemeros flegyas flegyas* (Cramer, [1780]
109	*Rhaphicera moorei moorei* (Butler, 1867)
110	*Callerebia hyagriva hyagriva* (Moore, [1858])
111	*Hypolycaena othona othona* Hewitson, [1865]
112	*Dodona eugenes* Bates, [1868]
113	*Sarangesa dasahara* (Moore, [1866])
114	*Eurema brigitta rubella* (Wallace, 1867)
115	*Mycalesis mineus mineus* (Linnaeus, 1758)
116	*Abisara bifasciata suffusa* Moore, 1882
117	*Euthalia aconthea garuda* (Moore, [1858])
118	*Rapala varuna orseis* (Hewitson, [1863])
119	*Graphium cloanthus cloanthus* (Westwood, 1841)
120	*Curetis acuta dentata* Moore, 1879
121	*Heliophorus moorei coruscans* (Moore, 1882)
122	*Notocrypta curvifascia curvifascia* (C. & R. Felder, 1862)
123	*Eurema laeta laeta* (Boisduval, 1836)
124	*Celatoxia marginata marginata* (de Nicéville, [1884])
125	*Papilio bianor polyctor* Boisduval, 1836
126	*Lethe confusa confusa* Aurivillius, [1898]
127	*Lethe dura gammiei* (Moore, [1892])
128	*Kallima inachus inachus* (Doyère, [1840])
129	*Catochrysops strabo strabo* (Fabricius, 1793)

	Butterfly species
130	*Aporia leucodice* (Eversmann, 1843)
131	*Polytremis eltola eltola* (Hewitson, 1869)
132	*Symbrenthia hypselis cotanda* Moore, [1875]
133	*Megisba malaya sikkima* Moore, 1884
134	*Neptis ananta ananta* Moore, [1858]
135	*Graphium nomius nomius* (Esper, 1799)
136	*Belenois aurota aurota* (Fabricius, 1793)
137	*Pseudergolis wedah wedah* (Kollar, [1844])
138	*Arhopala dodonaea* (Moore, [1858])
139	*Chilades lajus lajus* (Stoll, [1780])
140	*Poritia hewitsoni hewitsoni* Moore, [1866]
141	*Pieris melete ajaka* Moore, 1865
142	*Lethe isana isana* (Kollar, [1844])
143	*Leptotes plinius plinius* (Fabricius, 1793)
144	*Neptis sankara sankara* (Kollar, [1844])
145	*Rapala nissa nissa* (Kollar, [1844])
146	*Byasa latreillei latreillei* (Donovan, 1826)
147	*Lethe nicetas* (Hewitson, 1863)
148	*Tirumala septentrionis septentrionis* (Butler, 1874)
149	*Parnara guttatus mangala* (Moore, [1866])
150	*Eurema andersonii jordani* Corbet & Pendlebury, 1932
151	*Stibochiona nicea nicea* (Gray, 1846)
152	*Auzakia danava danava* (Moore, [1858])
153	*Celaenorrhinus patula* de Nicéville, 1889
154	*Pelopidas assamensis* (de Nicéville, 1882)
155	*Symphaedra nais* (Forster, 1771)
156	*Abisara fylla* (Westwood, [1851])
157	*Graphium sarpedon sarpedon* (Linnaeus, 1758)
158	*Troides aeacus* (C. & R. Felder, 1860)
159	*Hestinalis nama nama* (Doubleday, 1844)
160	*Neptis nata yerburii* Butler, 1886
161	*Vagrans egista sinha* (Kollar, [1844])
162	*Heliophorus oda* (Hewitson, 1865)
163	*Oriens goloides* (Moore, [1881])
164	*Argynnis hyperbius hyperbius* (Linnaeus, 1763)
165	*Tirumala limniace exoticus* (Gmélin, 1790)
166	*Udara albocaeruleus albocaeruleus* (Moore, 1879)
167	*Zizula hylax hylax* (Fabricius, 1775)
168	*Matapa aria* (Moore, [1866])
169	*Pachliopta aristolochiae aristolochiae* (Fabricius, 1775)
170	*Athyma selenophora selenophora* (Kollar, [1844])
171	*Lethe europa niladana* Fruhstorfer, 1911
172	*Libythea myrrha sanguinalis* Fruhstorfer, 1898
173	*Ypthima asterope mahratta* Moore, 1884
174	*Tarucus indica* Evans, 1932

	Butterfly species
175	*Udara dilectus dilectus* (Moore, 1879)
176	*Borbo cinnara* (Wallace, 1866)
177	*Pelopidas subochracea* (Moore, 1878)
178	*Ixias marianne* (Cramer, [1779])
179	*Argynnis kamala* Moore, [1858]
180	*Telinga heri* (Moore, [1858])
181	*Taractrocera danna* (Moore, 1865)
182	*Telicota bambusae bambusae* (Moore, 1878)
183	*Chrysozephyrus syla* Kollar, 1848
184	*Lobocla liliana ignatius* (Plötz, 1882)
185	*Pelopidas sinensis* (Mabille, 1877)
C.	**Fairly Common (Median)**
186	*Delias sanaca sanaca*(Moore, [1858])
187	*Pontia daplidice moorei* (Röber, [1907])
188	*Lethe rohria rohria* (Fabricius, 1787)
189	*Tagiades litigiosa litigiosa* Möschler, 1878
190	*Aulocera saraswati saraswati* (Kollar, [1844])
191	*Mycalesis visala visala* Moore, [1858]
192	*Neptis melba melba* Evans, 1912
193	*Symbrenthia brabira brabira* Moore, 1872
194	*Everes argiades diporides* Chapman, 1908
195	*Jamides bochus bochus* (Stoll, [1782])
196	*Tarucus nara* (Kollar, 1848)
197	*Papilio machaon* Linnaeus, 1758
198	*Hypolimnas misippus* (Linnaeus, 1764)
199	*Spialia galba galba* (Fabricius, 1793)
200	*Papilio clytia clytia* Linnaeus, 1758
201	*Melanitis phedima bela* Moore, [1858]
202	*Tarucus venosus* Moore, 1882
203	*Athyma cama cama* Moore, [1858]
204	*Celastrina gigas* (Hemming, 1928)
205	*Byasa dasarada ravana* (Moore, [1858])
206	*Neptis sappho astola* Moore, 1872
207	*Loxura atymnus continentalis* Fruhstorfer, [1912]
208	*Oreolyce vardhana vardhana* (Moore, [1875])
209	*Shizuyaozephyrus ziha* (Hewitson, [1865])
210	*Surendra quercetorum quercetorum* (Moore, [1858])
211	*Graphium agamemnon agamemnon* (Linnaeus, 1758)
212	*Neope yama buckleyi* Talbot, 1947
213	*Neptis clinia praedicta* Smetacek, 2011
214	*Phaedyma columella ophiana* (Moore, 1872)
215	*Everes lacturnus assamica* Tytler, 1915
216	*Horaga onyx onyx* (Moore, [1858])
217	*Atrophaneura varuna astorion* (Westwood, 1842)
218	*Euripus consimilis consimilis* (Westwood, [1851])

	Butterfly species
219	*Neope pulaha pandyia* (Talbot, 1947)
220	*Telinga lepcha lepcha* (Moore, 1880)
221	*Arhopala rama rama* (Kollar, [1844])
222	*Euchrysops cnejus cnejus* (Fabricius, 1798)
223	*Spindasis vulcanus vulcanus* (Fabricius, 1775)
224	*Notocrypta feisthamelii alysos* (Moore, [1866])
225	*Telicota colon colon* (Fabricius, 1775)
226	*Parnassius hardwickei* Gray, 1831
227	*Neptis cartica cartica* Moore, 1872
228	*Rapala iarbus sorya* (Kollar, [1844])
229	*Papilio paris paris* Linnaeus, 1758
230	*Athyma asura asura* Moore, [1858]
231	*Aricia agestis nazira* (Moore, [1866])
232	*Deudorix epijarbas epijarbas* (Moore, [1858])
233	*Rapala selira* (Moore, 1874)
234	*Burara jaina jaina* (Moore, [1866])
235	*Iambrix salsala salsala* (Moore, [1866])
236	*Meandrusa lachinus lachinus* (Fruhstorfer, 1902)
237	*Papilio agestor govindra* Moore, 1864
238	*Charaxes bernardus hierax* C. & R. Felder, [1867]
239	*Mycalesis francisca sanatana* Moore, [1858]
240	*Neptis soma butleri* Eliot, 1969
241	*Neptis zaida zaida* Doubleday, [1848]
242	*Hypolycaena kina kina* Hewitson, [1869]
243	*Borbo bevani* (Moore, 1878)
244	*Sarangesa purendra purendra* Moore, 1882
245	*Graphium eurous caschmirensis* (Rothschild, 1895)
246	*Hestina persimilis zella* Butler, 1869
247	*Paralasa kalinda kalinda* Moore, 1865
248	*Polygonia c-album cognata* Moore, [1899]
249	*Telinga nicotia* (Westwood, [1850])
250	*Freyeria trochylus orientalis* Forster, 1980
251	*Pratapa icetas icetas* (Hewitson, [1865])
252	*Caprona agama agama* (Moore, [1858])
253	*Celaenorrhinus munda* (Moore, 1884)
254	*Celaenorrhinus pulomaya pulomaya* (Moore, [1866])
255	*Suastus gremius gremius* (Fabricius, 1798)
256	*Udaspes folus* (Cramer, [1775])
257	*Ypthima kedarnathensis* Singh, 2007
258	*Heliophorus brahma brahma* (Moore, [1858])
259	*Ampittia dioscorides dioscorides* (Fabricius, 1793)
260	*Burara oedipodea belesis* (Mabille, 1876)
261	*Sovia lucasii* (Mabille, 1876)
262	*Polytremis discreta discreta* (Elwes & Edwards, 1897)
263	*Papilio arcturus arius* Rothschild, 1908

	Butterfly species
264	*Dilipa morgiana* (Westwood, [1851])
265	*Nymphalis xanthomelas fervescens* (Stichel, [1908])
266	*Celastrina argiolus kollari* (Westwood, [1852])
267	*Spindasis ictis ictis* (Hewitson, 1865)
268	*Zesius chrysomallus* Hübner, [1819]
269	*Caprona ransonnettii potiphera* (Hewitson, 1873)
270	*Potanthus dara (*Kollar, [1844])
271	*Tagiades menaka menaka* (Moore, [1866])
272	*Tarucus callinara* (Butler, 1886)
273	*Anthene emolus emolus* (Godart, [1824])
D.	**Uncommon**
274	*Aulocera brahminus* (Blanchard, 1853)
275	*Symbrenthia niphanda hysudra* Moore, 1874
276	*Freyeria putli* (Kollar, [1844])
277	*Iraota timoleon timoleon* (Stoll, [1790])
278	*Tajuria cippus cippus* (Fabricius, 1798)
279	*Tajuria diaeus diaeus* (Hewitson, [1865])
280	*Choaspes benjaminii japonica* (Murray, 1875)
281	*Hyarotis adrastus praba* (Moore, [1866])
282	*Pelopidas conjuncta conjuncta* (Herrich-Schäffer, 1869)
283	*Graphium doson axionides* (Page & Treadaway, 2014)
284	*Aporia agathon phryxe* (Boisduval, 1836)
285	*Charaxes dolon dolon* Westwood, [1848]
286	*Mimathyma ambica ambica* (Kollar, [1844])
287	*Ypthima indecora* Moore, 1882
288	*Ancema ctesia ctesia* (Hewitson, [1865])
289	*Chaetoprocta odata peilei* Forster, 1980
290	*Curetis bulis bulis* (Westwood, [1851])
291	*Thermozephyrus ataxus ataxus* (Westwood, [1851])
292	*Virachola perse perse* (Hewitson, [1863])
293	*Aeromachus stigmata stigmata* (Moore, 1878)
294	*Celaenorrhinus dhanada* (Moore, [1866])
295	*Tagiades japetus ravi* (Moore, [1866])
296	*Gandaca harina assamica* Moore, 1906
297	*Neptis narayana* Moore, 1858
298	*Ypthima hannyngtoni hannyngtoni*Eliot, 1967
299	*Arhopala paraganesa paraganesa* (de Nicéville, 1882)
300	*Azanus ubaldus* (Stoll, [1782])
301	*Aeromachus dubius* Elwes & Edwards, 1897
302	*Badamia exclamationis* (Fabricius, 1775)
303	*Argynnis jainadeva jainadeva* Moore, 1864
304	*Aulocera padma padma* (Kollar, [1844])
305	*Lethe baladeva aisa* Fruhstorfer, 1911
306	*Lethe sinorix sinorix* (Hewitson, [1863])
307	*Spindasis nipalicus* (Moore, 1884)

	Butterfly species
308	*Baoris farri* (Moore, 1878)
309	*Bibasis sena sena* (Moore, [1866])
310	*Atrophaneura aidoneus* (Doubleday, 1845)
311	*Graphium garhwalica* (Katayama, 1988)
312	*Aporia agathon caphusa* (Moore, 1872)
313	*Gonepteryx mahaguru mahaguru* Gistel, 1857
314	*Ariadne ariadne pallidior* (Fruhstorfer, 1899)
315	*Charaxes solon solon* (Fabricius, 1793)
316	*Pantoporia sandaka davidsoni* Eliot, 1969
317	*Tanaecia julii appiades* (Ménétriés, 1857)
318	*Ypthima avanta* Moore, [1875]
319	*Flos asoka* (de Nicéville, [1884])
320	*Petrelaea dana* (de Nicéville, [1884])
321	*Rapala pheretima petosiris* (Hewitson, [1863])
322	*Sinthusa chandrana chandrana* (Moore, 1882)
323	*Spalgis epius epius* (Westwood, [1851])
324	*Virachola isocrates* (Fabricius, 1793)
325	*Dodona ouida phlegra* Fruhstorfer, 1914
326	*Celaenorrhinus pero pero* de Nicéville, 1889
327	*Coladenia indrani indrani* (Moore, [1866])
328	*Ochlodes brahma* (Moore, 1878)
329	*Odontoptilum angulata angulata* (C. Felder, 1862)
330	*Seseria dohertyi dohertyi* (Watson, 1893)
331	*Taractrocera maevius* (Fabricius, 1793)
332	*Papilio alcmenor alcmenor* C. & R. Felder, [1864]
333	*Papilio memnon agenor* Linnaeus, 1758
334	*Parnassius epaphus* Oberthür, 1879
335	*Appias lalage* (Doubleday, 1842)
336	*Appias libythea* (Fabricius, 1775)
337	*Aglais rizana* (Moore, 1872)
338	*Athyma inara inara* Westwood, 1850
339	*Euploea midamus* (Linnaeus, 1758)
340	*Hyponephele pulchella* (C. & R. Felder, [1867])
341	*Lethe dakwania* Tytler, 1939
342	*Mycalesis suaveolens ranotei* Smetacek, 2012
343	*Everes hugelii hugelii* (Gistel, 1857)
344	*Heliophorus indicus* (Fruhstorfer, 1908)
345	*Horaga viola* Moore, 1882
346	*Pratapa deva lila* Moore, [1884]
347	*Spindasis elima uniformis* (Moore, 1882)
348	*Tajuria jehana jehana* Moore, [1884]
349	*Baoris pagana* (de Nicéville, 1887)
350	*Caltoris kumara* (Moore, 1878)
351	*Erionota torus* Evans, 1941
352	*Pedesta masuriensis masuriensis* (Moore, 1878)

	Butterfly species
353	*Sovia grahami grahami* (Evans, 1926)
354	*Papilio bootes janaka* Moore, 1857
355	*Papilio helenus helenus* Linnaeus, 1758
356	*Parnassius charltonius* Gray, [1853]
357	*Colotis etrida* (Boisduval, 1836)
358	*Delias acalis pyramus* (Wallace, 1867)
359	*Charaxes agrarius* Swinhoe, [1887]
360	*Hyponephele davendra davendra* (Moore, 1865)
361	*Lethe goalpara goalpara* (Moore, [1866])
362	*Polygonia c-album agnicula* (Moore, 1872)
363	*Ypthima parasakra* Eliot, 1987

	Butterfly species
364	*Heliophorus epicles latilimbata* (Fruhstorfer, 1908)
365	*Miletus chinensis assamensis* (Doherty, 1891)
366	*Spindasis lohita himalayanus* (Moore, 1884)
367	*Hasora chromus* (Cramer, [1780])
368	*Thoressa aina* (de Nicéville, 1889)
369	*Maneca bhotea bhotea* (Moore, 1884)
370	*Celaenorrhinus pyrrha* de Nicéville, 1889

The relative abundance of butterfly taxa ranging from 1–1,596 individuals. The taxa are ranked into four abundance classes based on their quartile divisions, i.e., Q1= 1–7 Uncommon; Q2= 8–21= Fairly Common; Q3= 22–69= Common; Q4= 70–1,596= Very Common; Median value= 21.

Appendix IV. Butterfly taxa of conservation priority in Uttarakhand.

	Family/Scientific name	Common name	Distribution	Associated forest sub-type*	Abundance status	WPA status	Altitudinal distribution (m)
A	**PAPILLIONIDAE**						
1	*Byasa dasara daravana* (Moore, [1858])	Great Windmill	WH; CH	12C1a; 12/C1b	NR	NA	150–2750
2	*Graphium eurous caschmirensis* (Rothschild, 1895)	Six-bar Swordtail	WH; CH	12C1a	NR	NA	1000–2800
3	*Graphium garhwalica* (Katayama, 1988)	Garhwal Swordtail	WH	12C1a	R	NA	1600–2300
4	*Parnassius charltonius* Gray, [1853]	Regal Apollo	WH; PA	12C1a	R	NA	3600–4400
B	**PIERIDAE**						
5	*Aporia agathon caphusa* (Moore, 1872)	Garhwal Great Blackvein	WH; CH	14/C1a	NR	NA	1200–3050
6	*Aporia agathon phryxe* (Boisduval, 1836)	Kashmir Great Blackvein	WH	12C1a	NR	NA	Up to 2100
7	*Delias acalis pyramus* (Wallace, 1867)	Redbreast Jezebel	WH; CH	3C/C2a	NR	NA	Up to 1500
8	*Delias sanaca sanaca* (Moore, [1858])	Pale Jezebel	WH	12/C1a; 12/C1b	NR	Sch- I	1200–3000
9	*Gonepteryx mahaguru mahaguru* Gistel, 1857	Lesser Brimstone	WH; CH	12/C1a; 12/C2c	NR	NA	Above 2100
C	**NYMPHALIDAE**						
10	*Aglais rizana* (Moore, 1872)	Mountain Tortoiseshell	WH; EH	14/1S2	R	Sch-II	2400–4500
11	*Lethe dura gammiei* (Moore, [1892])	Scarce Lilacfork	WH; EH	12/C1a; 12/C2b	VR	Sch -I	1800–2200
12	*Polygonia c-album agnicula* (Moore, 1872)	Nepalese Comma	WH; CH; EH	14/C1a	R	Sch-II	2200–4500
13	*Ypthima parasakra parasakra* Eliot, 1987	Dubious Five-ring	WH; CH; EH	12/2S1	R	NA	2000–2700
14	*Argynnis jainadeva jainadeva* Moore, 1864	HighbrownSilverspot	WH; CH	14/C1a	NR	NA	2400–4700
15	*Callerebia hyagriva hyagriva* (Moore, [1858])	Brown Argus	WH	9/C1b	R	Sch-II	1500–2400
16	*Callerebia scanda scanda* (Kollar, [1844])	Pallid Argus	WH	12/C1a; 12/C1b; 12/C1d	NR	NA	1200–2800
17	*Charaxes dolon dolon* Westwood, [1848]	Stately Nawab	WH; CH	12/C1a; 9/C1b	R	Sch -II	1430–1900
18	*Euthalia patala patala* (Kollar, [1844])	Grand Duchess	WH	12/C1a	NR	NA	400–2500
19	*Hestina persimilis zella*Butler, 1869	Siren	WH	12/C1a; 3C/C2a	R	Sch -II	750–1460

	Family/Scientific name	Common name	Distribution	Associated forest sub-type*	Abundance status	WPA status	Altitudinal distribution (m)
20	*Hyponephele davendra davendra* (Moore, 1865)	White-ringed Meadowbrown	WH; PA	12/C1c	R	Sch -II	900–2400
21	*Hyponephe lepulchella* (C. & R. Felder, [1867])	Tawny Meadowbrown	WH; PA	12/C2b	NR	NA	3000–3600
22	*Lethe baladeva aisa* Fruhstorfer, 1911	Treble Silverstripe	WH; CH	12/C1a; 12/C2c	R	Sch -II	1800–2200
23	*Lethe dakwania* Tytler, 1939	White-wedged Woodbrown	WH	12/C2c	R	NA	2300–3900
24	*Lethe goalpara goalpara* (Moore, [1866])	Large Goldenfork	WH; CH	12/C2c	R	Sch-II	1800–3000
25	*Lethe isana isana* (Kollar, [1844])	Common Forester	WH	12/C1a; 12/C1d; 9/C1b	R	NA	1500–2700
26	*Mycalesis suaveolens ranotei* Smetacek, 2012	Wood-Mason's Bushbrown	WH; CH	12/C1a	R	Sch-II	1700–2133
27	*Neope pulaha pandyia* (Talbot, 1947)	Veined Labyrinth	WH	12/C1a; 12/C2c; 12/2S1	R	Sch-II	1500–3050
28	*Neope yama buckleyi* Talbot, 1947	Dusky Labyrinth	WH; CH	12/C1a; 12/C2c	NR	Sch-II	1200–2370
29	*Neptis anantaananta* Moore, [1858]	Yellow Sailer	WH	12/C1a; 12/C2c	R	NA	400–2300
30	*Neptis clinia praedicta* Smetacek, 2011	Sullied Sailer	WH	3C/C2a; 3C/C2c; 12/C1a	NR	NA	Low
31	*Neptis sankara sankara* (Kollar, [1844])	Broad-banded Sailer	WH	3C/C2a; 5B/C2; 12/C1a	NR	NA	800–2500
32	*Neptis Zaida Zaida* Doubleday, [1848]	Pale Green Sailer	WH; CH	3C/C2a; 12/C1a	R	Sch-II	900–2500
33	*Nymphalis xanthomelas fervescens* (Stichel, [1908])	Large Tortoiseshell	WH; CH	12/C1a; 12/C2b; 14/C1a	NR	NA	900–3200
34	*Paralasa kalinda kalinda* Moore, 1865	Scarce Mountain Argus	WH	3C/C2a; 3C/C2c; 12/C1a	R	NA	2700–3900
35	*Polygonia c-album cognata*Moore, [1899]	Kumaon Comma	WH	12/C1a; 12/C2c	NR	NA	2100–4800
36	*Sephisa dichroa*(Kollar, [1844])	Western Courtier	WH; CH	12/C1a; 12/C1b; 12/C2c	NR	NA	1500–2740
37	*Symbrenthia niphanda hysudra*Moore, 1874	Bluetail Jester	WH; CH	12/C1a; 12/C2c	R	Sch-II	1000–2600
38	*Telinga Lepcha lepcha* (Moore, 1880)	West Himalayan LepchaBushbrown	WH; CH	12/C1a; 12/C2c; 3C/C2a	NR	NA	1100–2400
39	*Ypthima avanta* Moore, [1875]	Jewel Five-ring	WH; CH	12/C1a	NR	NA	600–1800
40	*Ypthima hannyngtoni hannyngtoni* Eliot, 1967	Garhwal Large Branded Five-ring	WH; CH	12/C1a; 12/C1b	NR	NA	2100–2300
41	*Ypthima indecora* Moore, 1882	Western Five-ring	WH; CH	12/C1a; 12/C2c	NR	NA	1300–1700
42	*Ypthima kedarnathensis* Singh, 2007	Garhwal Six-ring	WH; CH	12/C1a; 12/C2c	R	NA	1600–2200
D.	**LYCAENIDAE**						
43	*Aricia agestis nazira* (Moore, [1866])	Orange-bordered Argus	WH; CH	12/C1a	NR	NA	1800–2980
44	*Chrysozephyrus birupa* Moore, 1877	Fawn Hairstreak	WH; CH	12/C1a; 12/C2c	NR	NA	above 1400
45	*Esakiozephyrus icana icana* (Moore, [1875])	Dull-green Hairstreak	WH; CH	12/C1a; 12/C1d	R	Sch-II	2000–3300
46	*Euaspa milionia milionia* (Hewitson, [1869])	Water Hairstreak	WH; CH	12/C1a	NR	NA	1200–2000
47	*Heliophorus moorei coruscans* (Moore, 1882)	Azure Sapphire	WH; CH	12/C1a; 12/C2c	R	NA	1300–3000
48	*Pratapa icetas icetas* (Hewitson, [1865])	Dark Blue Royal	WH; CH	12/C1a; 12/C2b; 12/C2c	R	Sch-II	1500–2700
49	*Shizuyaozephyrus ziha* (Hewitson, [1865])	White-spotted Hairstreak	WH; CH	12/C1a	R	Sch-II	1200–2000
50	*Sinthusa chandrana chandrana* (Moore, 1882)	Broad Spark	WH; CH	12/C1a; 12/C1d; 3C/C2a	R	Sch-II	Up to 1820

	Family/Scientific name	Common name	Distribution	Associated forest sub-type*	Abundance status	WPA status	Altitudinal distribution (m)
51	*Spindasis elimauni formi s* (Moore, 1882)	Scarce Shot Silverline	WH; CH	3C/C2a	NR	Sch-II	Up to 2700
52	*Thermozephyrus ataxus ataxus* (Westwood, [1851])	Wonderful Hairstreak	WH; CH	12/C1a; 12/C2c	R	NA	1800–2400
E	**RIODINIDAE**						
53	*Dodona dipoea nostia* Fruhstorfer, 1912	Lesser Punch	WH	12/C1a; 12/C2c	R	Sch-II	1800–3000
54	*Dodona ouida phlegra* Fruhstorfer, 1914	Mixed Punch	WH; CH	12/C1a; 12/C2c	NR	NA	1200–2400
F	**HESPERIIDAE**						
55	*Celaenorrhinus peropero* deNicéville, 1889	Mussoorie Spotted Flat	WH	12/C1a	R	NA	1500–2000
56	*Potanthus dara (*Kollar, [1844])	Himalayan Dart	WH; CH	12/C1a; 3C/C2a	NR	NA	1830–2590
57	*Sovia lucasii* (Mabille, 1876)	Lucas's Ace	WH; EH	9/C1b	R	NA	1800–2000
58	*Thoressa aina* (de Nicéville, 1889)	Garhwal Ace	WH; CH	12/C1a	R	NA	1370–2800

WH–Western Himlaya | CH–Central Himalaya |* Forest Sub-type refence Table 2 | Abundance Status (Evans 1932): VR–Very Rare | R–Rare | NR–Not Rare | WPA–Wildlife (Protection) Act 1972 (Anonymous 2006) | Sch–Schedule listed in WPA1972 (Anon 2006).

Appendix V. Locations of Western Himalayan forest sub-types identified holding butterfly species of conservation priority in the state of Uttarakhand spread over different physiographic zones along the elevation gradient.

	Physiographic zone	Forest Sub-type	District	Site/village/Reserve Forest
A.	Trans Himalaya (Above 3600m)	14/C1a WestHimalayan Sub-alpine Fir Forest	Chamoli	Ghamsali-Niti Pass
		14/1S2 Deciduous Sub-alpine Scrub	Chamoli	Mana-Badrinath & Valley of Flowers NP.
B.	Greater Himalaya (2400–3600m)	12/C1a Ban Oak Forest	Chamoli & Rudraprayag	Mandal-Chopta-Duggalbitta-Makkumath-Kedarnath WS
			Uttarkashi dist	Naitwar-Sankri-Taluka-Osla (Govind WS)
			Tehri Garhwal	Buddha Kedar-Jhala
		12/C2c Moist Temperate Deciduous Forest	Chamoli & Rudra prayag	Mandal-Chopta/Makkumath-Duggalbitta
C.	Lesser Himalaya (1200-2400m)	12/C1a Ban Oak Forest	Dehradun & Tehri Garhwal	BenogWS-Mussoorie-Kotikimoi-Rotu-ki-beli
			Dehradun	Chakrata Cantt-Deoban-Mundali (Chakrata Forest Division)
			Pauri	Pauri-Talisain-Dudatoli ridge
			Pithoragarh	Didihat-Thal
			Nainital	Naina Devi Conservation reserve-Kilbury-Pangot-Vinayak Khal
			Almora	Ranikhet
				Binsar WS
D.	Shiwalik-Dun/Bhabar (Below 1200m)	3C/C2a Moist Shiwalik Sal Forest	Dehradun	Timli RF-Karvapani RF
				Jhajra RF, Chowki Dhaulas-Rikhouli RF
			Pauri	Rahuthua dhab-Mundipani-Nauri
E.	Tarai (100–350m)	3C/C2c Moist Terai Sal Forest	Nainital	Chorgalia-Jolasal-Senapani (Nandhaur WS)

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ARTICLE

Comparison of bird diversity in protected and non-protected wetlands of western lowland of Nepal

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Abstract: Protected areas are considered important for biodiversity conservation, however, studies have shown that habitats outside protected areas can also support high diversity and are important for biodiversity conservation. In this context, we compared the bird diversity between protected (Rani Taal in Shuklaphanta National Park) and non-protected (Sati Karnali Taal) wetlands in western Nepal. Bird surveys were conducted from February to August 2019, using open width point count method in 100 m intervals along transects. A total of 122 species belonging to 18 orders and 44 families were recorded from the protected wetland, and 107 species belonging to 16 orders and 41 families from the non-protected wetland area. Insectivores had high abundance in both wetlands (43% and 47% in protected and non-protected wetlands, respectively). Forest-dependent birds were more abundant in protected wetland compared to non-protected wetland. Our study showed that both protected and non-protected wetlands along with agricultural landscapes, support a richness of birds. Hence priority should be given to both wetlands for the conservation of birds.

Keywords: Aves, conservation, protected and non-protected areas, threatened birds.

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INTRODUCTION

Protected area (PA) is a key strategy for in situ conservation of biodiversity. Evidence has shown PAs that are crucial in conserving forests, natural environments, biodiversity, and ecosystem services (Rodrigues et al. 2004; Dahal et al. 2014; Watson et al. 2016). In the past, PAs surged globally, and Nepal has also made notable progress in increasing PA coverage (UNEP-WCMC et al. 2018; DNPWC 2020). By the end of 2020 over 15% of the earth's terrestrial surface was covered by PAs (Terborgh et al. 2002; UNEP-WCMC et al. 2018). In spite of increase in PAs, their efficacy in protecting overall biodiversity is contested (Rodrigues et al. 2004; Chape et al. 2005). Several important species remain outside the jurisdiction of PAs (Chakravarty et al. 2012), and some geographical areas are under-represented (Shrestha et al. 2010), incuding some global biodiversity hotspots and agro-ecosystems that support rich biodiversity (Sharma & Vetaas 2015). Researchers have argued and demonstrated that areas outside formal PAs are worth conserving, as they provide alternative habitats and refuges for maintaining viable populations of residential and migratory bird species (Shrestha et al. 2010; Cox & Underwood 2011; Dudley et al. 2014; DNPWC 2020) and thus complement PAs in achieving biodiversity goals.

Freshwater ecosystems are among the most productive ecosystems, and they provide countless services to both the human and ecological communities (Dudgeon et al. 2006). Yet they remain vulnerable to various stresses and pressures (Geist 2011). Freshwater constitutes about 2.5% of the area of all water on Earth (Ostfeld et al. 2012) and approximately 5% (743,500 ha) in Nepal (Siwakoti & Karki 2009). In the global context, wetlands support more than 40% of the birds and 12% of other animals (Kumar 2005; Paracuellos 2006). More than 20% of threatened bird species, both migratory and resident, are supported by the wetlands of Asia (Paracuellos 2006; Grimmett et al. 2016a).

Birds are important indicators of the health of freshwater ecosystems (Zakaria & Rajpar 2010; Inskipp et al. 2017; Baral & Inskipp 2020; Brotherton et al. 2020). Past studies have highlighted that Nepal's freshwater diversity has been threatened by different factors, including construction of dams, point source and non-point source pollution, habitat encroachment by invasive species, overharvesting, and recent global environmental changes (Khatiwada et al. 2021).

Many wetlands outside protected areas are important for conserving biodiversity, but are not given due attention for conservation. Past studies of bird species have been mostly concentrated in the protected areas and Ramsar sites. The difference in bird diversity between protected and non-protected areas is not well documented. In this study, we compared bird diversity between wetlands within a PA (Rani Taal in Shuklaphanta National Park) and outside it (Sati Karnali Taal), and asked following questions: (i) is there a difference in bird richness between protected and non-protected wetlands? (ii) is there a difference in conservation value for birds inside and outside protected area? (iii) do birds in protected and non-protected wetland differ in their feeding guilds? Understanding the distribution of bird diversity in and outside PAs can be useful to conservation managers and planners to formulate conservation strategies.

MATERIALS AND METHODS

Study area

This study was conducted in two wetlands, one in Shuklaphanta National Park (Rani Taal, hereafter referred to as protected and undisturbed wetland) and one in a nearby agricultural landscape (Sati Karnali Taal, hereafter non-protected and disturbed wetland), selected to compare bird diversity and distribution (Image 1). These wetlands share similar geography and climatic conditions, but differ in terms of management and disturbance (Table 1).

Bird survey

A bird survey was carried out following the "point count" method along transects near the bank of lake/wetland, following detailed instructions provided by Bibby et al. (2000) from February to September 2019 two times a day at 0600–1000 h and 1600–1800 h. A total of five transects were laid in each wetland and bird study was carried out during the winter and summer seasons. The length of the transect walks varied from 500 m to 1,000 m depending upon the shape of the wetland and forest patch. The points were fixed in every 100-m intervals along the transects, then the birds were scanned and counted with the aid of binoculars (Nikon 20 × 50 and Bushnell 10 × 40) within the 50 m circular radius.

Four observers scanned for birds in all directions for five minutes. The observed birds were counted and listed, and data from all observers were pooled for each transect. To ensure a comprehensive species list for each survey site, calls of birds were also recorded with a cell phone in MP3 format. All the observed species were

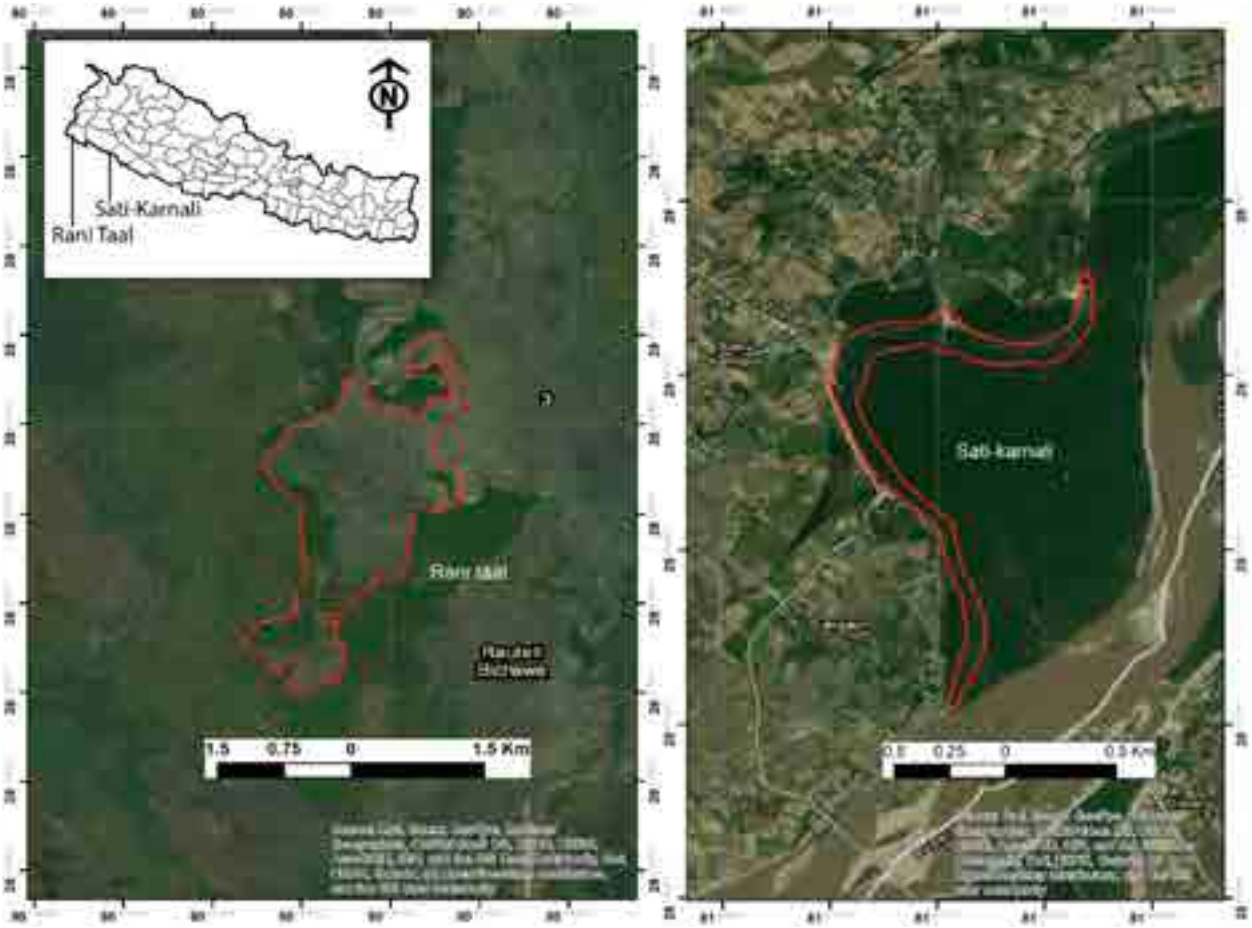

Figure 1. Map of the study area showing protected and non-protected wetlands.

recorded with abundance by visual and auditory aids, with habitat and environmental variables. Birds were identified using Grimmett et al. (2016a,b). Calls were identified using the bird song database of Xeno-Canto (https://www.xeno-canto.org/). Foraging behavior was grouped into five different trophic structures based on the feeding habit of birds and availability of food resources in the study area (Zakaria & Rajpar 2010). These trophic structures are: insectivores, omnivores, piscivores, herbivores, and carnivores. We also carried out a questionnaire survey and literature review to record migratory and other rare bird species in the area.

Data analysis

We classified birds based on their feeding guilds, habitats and migratory behavior (BCN & DNPWC 2016; Grimmett et al. 2016). We also categorized bird conservation status using IUCN Red List (https://www.iucnredlist.org). Species richness refers to the number of species, and abundance means the number of individuals of each species. We used two measures of richness, one for transects and another for sites. We also calculated the diversity indices of birds in protected and non-protected sites.

Shannon Weiner diversity index (H) was used to determine species diversity in a community (Shannon 1948).

Shannon index (H) = $\frac{1}{\sum_{i=1}^{s} p_i^2}$

Where, p_i is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

Simpson index was determined to measure community diversity in relation to habitats (Simpson 1949).

Simpson index (D) = $-\sum_{i=1}^{s} p_i \ln p_i$

Where *p* is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is the sum of the calculations, and *s* is the number of species.

Evenness (e) was used to determine distribution of

individuals of a species in a community.

Evenness = H'/Hmax

Where H' is Shannon diversity index and Hmax is the maximum possible value. E is constrained between 0 and 1.0. As with H', evenness assumes that all species are represented within the sample.

Jacob's equitability (J) was used to measure the evenness with which individuals are divided among the taxa present. Equitability (J) = H'/lnS

Where, H' = Shannon's index of diversity, S = number of taxa

Fisher's index describes mathematically the relation between the number of species and the number of individuals in those species (Fisher & Yates 1943). Fisher diversity index, defined implicitly by the formula.

$$S = a \times \ln\left(1 + \frac{n}{a}\right)$$

Where, S is number of taxa, n is number of individuals and a is the Fisher's alpha.

Differences in species richness and abundance between the protected and non-protected areas were tested using a student *t* test. Data were checked for normality before conducting the *t* test. All statistical analyses were carried out in R version. 3.6.1 (R Development Core Team 2019).

RESULTS

Diversity and distribution of birds in protected and non-protected wetlands

We recorded a total of 1,693 individuals (winter= 961; summer= 732) belonging to 122 species (winter= 118; summer= 104) from 18 orders and 44 families in the protected wetland, and 1,672 individuals (winter= 791; summer= 881) belonging to 107 species (winter= 94; summer= 86) from 16 orders and 41 families in non-protected wetland (Appendix 1). The most abundant species were from order Passeriformes (37%) followed by Coraciiformes (9.8%), Psittaciformes (7.2%), and Galliformes (6.3%) in the protected wetland whereas Passeriformes (43%) was the most abundant followed by Coraciiformes (11%), Pelecaniformes (6.9%), and Psittaciformes (6.8%) in the non-protected wetland.

In terms of cumulative abundance, Common Peafowl (4.9%) was the most abundant species in the protected wetland, followed by House Swift (4.7%), Blue-tailed Bee-eater (4.3%), and Wire-tailed Swallow (3.0%), whereas House Sparrow (4.2%) was the most abundant species followed by Cattle Egret (4.0%), Blue-tailed Bee-eater (3.5%), Lesser Whistling Duck (3.3%), and Slaty-headed Parakeet (3.2%) in non-protected wetland (Appendix 1).

Overall, there was higher richness of birds in protected wetland (n= 122 compared to non-protected wetland (n= 107, t= 8.623, p <0.004). Similarly, species richness was also higher in both summer (t= 4.01, p= 0.004) and winter (t= 4.726, p= 0.001) seasons (Figure 1) in protected wetland. However, there was no significant difference in species abundance between protected and non-protected wetlands (t= 0.140, p= 0.870). But the mean abundance of the birds was higher in summer season than winter in protected wetland (Figure 1).

The overall Shannon index of diversity (H), and Fisher alpha (α) in protected wetland was higher than from the non-protected wetland (Table 2). Similarly, the species diversity of protected wetland was more in winter season than summer. But there was no variation in species dominance index (D) during winter and summer seasons (D= 0.019, in winter and D= 0.021, in summer season) (Table 2). Similarly, the species diversity of birds in non-protected wetland was more winter (H= 4.21, α= 31.0) than in summer (H= 4.19, α= 27.43) (Table 2).

Categorization of birds according to habitat types

A total of 49 species of wetland dependent birds, followed by 43 species of forest, 17 species of open area birds, and 13 species of bush birds were recorded from protected wetland, whereas 41 species of wetland birds, 37 species of forest birds, 18 species of open area birds, and 11 species of bush dependent birds were recorded from human dominated non-protected lake (Figure 2).

Feeding guilds of birds

The proportion of insectivorous birds was higher in both wetlands (protected 43.5% and non-protected 47.41%) followed by omnivores, piscivores, herbivores, and carnivores, respectively (Figure 3).

Bird species with conservation concern

We recorded a globally Endangered species: Egyptian Vulture *Neophron percnopterus*; two Vulnerable species: Common Pochard *Aythya ferina* & Great Slaty Woodpecker *Mulleripicus pulverulentus*; and seven Near Threatened species: Grey-headed Fish Eagle *Icthyophaga ichthyaetus*, Lesser Fish Eagle *Icthyophaga humilis*, River Lapwing *Vanellus duvaucelii,* Red-headed Falcon *Falco chicquera*, Painted Stork *Mycteria leucocephala,* Asian Woollyneck *Ciconia episcopus*, & Oriental Darter *Anhinga melanogaster* in protected wetland. In non-protected wetland and its vicinity we reported three Vulnerable species: Common Pochard *Aythya ferina*, Great Slaty Woodpecker *Mulleripicus*

Table 1. Comparative information about the study area: Protected and non-protected wetlands of lowland Terai western Nepal.

Parameters	Protected wetland	Non-protected wetland
Location	Inside Shuklaphanta National Park, Kanchanpur	Inside Sati Karnali Community Forest User Group, Tikapur, Kailali
Geographic location	N28.922883/ E80.176317	N28.453533/ E81.07378
Elevation	175 m	158 m
River basin	Mahakali	Karnali
Nature of lake	Oxbow	Oxbow
Area	369 hector	25 hector
Temperature	Average temperature 25.9 °C (14.3–32 °C, warmest month May and coldest month January)	Average temperature 24.6 °C (15.6–32 °C, warmest month May and coldest month January)
Rainfall	1,579 mm	1,757 mm
Feeder	Rainwater	Rani Kulo
Vegetation	Surrounded by dense Sal (*Shorea robusta*) forest. Associated tree species are Kusum (*Scheleira oleosa*), Saaj (*Terminalia alata*), Rohini (*Mallotus phillipensis*), Jamun (*Syzygium cuminii*), Bhellar (*Trewia nudiflora*) Common shrub species: Rudilo (*Pogostemon bengalensis*), Asare (*Murraya koenighii*) and Bhati (*Clerodendrum viscosum*). The lake is surrounded by elephant grass (*Saccharum spontaneum*), Narenga (*Narenga porphyrocoma*) on south, west and east Khatiwada et al. (2019)	Surrounded by riverine type and dominated by Sissoo (*Dalbergia sissoo*), Simal (*Bombax ceiba),* Vellar *(Trewia nudiflora)* and Khayer (*Acacia catechu)*. Sindhure (*Mallotus phillipensis)* and Shirish (*Albizia chinensis)* Common shrub species: Asare (*Murraya keonighii)*, Bhati (*Clerodendron viscosum)*. This area is well known for rattan cane (*Calamus tenuis)*. Khatiwada et al. (2019)
Disturbance	No human impact, Natural eutrophication and siltation is common. More than 80% of the total area of this lake is converted into grassland and marshy land	Anthropogenic activities such as fishing, collection of snails, other aquatic products, grazing are very common.
Management authority	Shuklaphanta National Park	Sati Karnali Community Forest User Group

Table 2. The diversity and dominance indices of birds in protected and non-protected wetlands.

	Winter		Summer		Total	
	Protected	Non-protected	Protected	Non-protected	Protected	Non-protected
Species richness	118	94	104	86	122	107
Dominance_D	0.019	0.03	0.021	0.03	0.019	0.018
Shannon_H	4.512	4.21	4.29	4.19	4.47	4.38
Evenness_e^H/S	0.68	0.69	0.69	0.67	0.66	0.672
Equitability_J	0.917	0.921	0.921	0.92	0.92	0.921
Fisher_alpha	37.21	31	34.51	27.43	31.54	27.31

pulverulentus, & Lesser Adjutant *Leptoptilos javanicus*; and six Near Threatened species: Grey-headed Fish-eagle *Icthyophaga ichthyaetus*, River Lapwing *Vanellus duvaucelii,* Asian Woollyneck *Ciconia episcopus*, Painted Stork *Mycteria leucocephala*, Oriental Darter *Anhinga melanogaster*, and Alexandrine Parakeet *Psittacula eupatria* (Figure 4, Image 2).

DISCUSSION

The present study examined diversity of wetland-associated bird species from the lowlands of western Nepal. Our results indicate that bird community structure (i.e., species richness, abundance, composition) varied notably between protected and non-protected wetland and associated areas. Nevertheless, wetlands outside the protected area system also support a large number of important birds.

Bird diversity in protected and non-protected areas

The wetlands in both protected and non-protected areas support a considerable bird diversity of different feeding guilds. Overall, higher bird diversity was found in protected areas, signifying the importance of these areas for species conservation. Similar results were reported by Dahal et al. (2014) from forests of lowland Nepal. Abundance of forest specialist bird species such as Lesser Yellownape *Picus chlorolophus* and Common Peafowl *Pavo cristatus* was higher around the protected

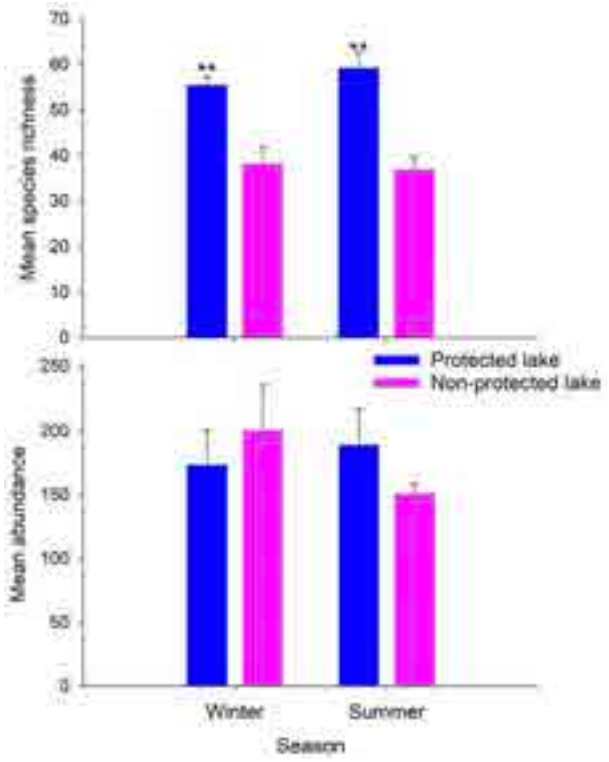

Figure 1. Mean richness and abundance of bird species on the protected and non-protected wetlands. The level of significance is from t-test (<0.01).**

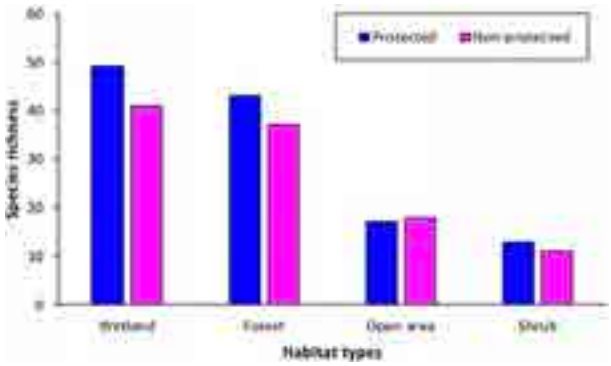

Figure 2. Habitat-wise species richness of birds.

wetland compared to non-protected wetland and surrounding areas (Appendix 1).

Our results showed an important dynamic in the wetlands in and outside the protected area. Increasing in richness in PA within the wetlands during summer, there is not distinct change in wetlands outside the PA (Figure 1). Slight increase of bird richness inside the PA might be because it provides a safe refuge for breeding birds and the disturbance is very low. Similarly, the higher abundance of the birds outside the PA during

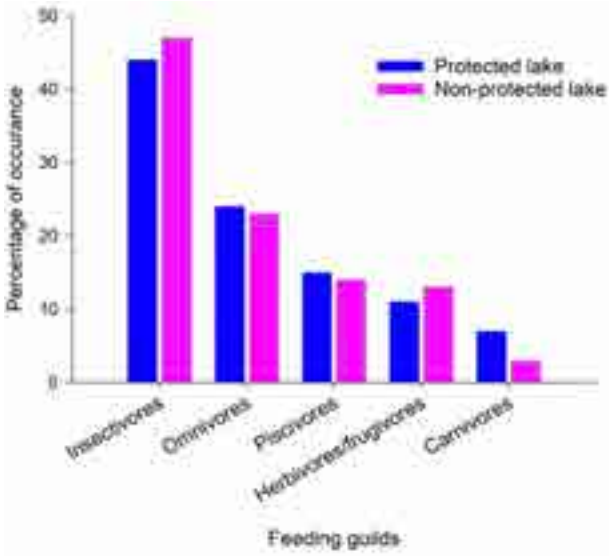

Figure 3. Percentage of bird species recorded for the different feeding guilds.

winter indicates that open and more disturbed nature of the wetlands are equally important to provide habitat for birds. Agriculture landscapes around the wetlands outside the protected area also provide bird feeding grounds. Abundance in wetlands outside PA decreases noticeably, indicating that winter migrants would have left and some resident species may also leave seeking safer habitat to breed. During March-June, water resources inside the PA become dry and the birds concentrate in this lake, hence it shows greater abundance during summer than in winter.

Our study reports higher species richness in wetland followed by forest birds (Figure 2). The species richness of birds is comparatively higher in and around the protected wetland. Lowland protected areas support old and mature forests and harbor the highest richness of forest specialist bird species (Dahal et al. 2014). Similarly, some of the wetland-dependent and associated bird species like Lesser Fish Eagle *Icthyophaga humilis*, Osprey *Pandion haliaetus*, Mallard *Anas platyrhynchos*, Ruddy Shelduck *Tadorna ferruginea*, and Gadwall *Mareca strepera* were reported only from the protected wetland and associated areas. Higher richness of birds in protected wetland areas may be attributed to lower anthropogenic disturbance (Khatri et al. 2019; Lamsal et al. 2019), supporting birds that require undisturbed forests.

National Park are surrounded by Sal forest and grassland that support many globally threatened birds. Nepal's wetlands provide an important habitat for many wetland dependent and grassland birds including 15

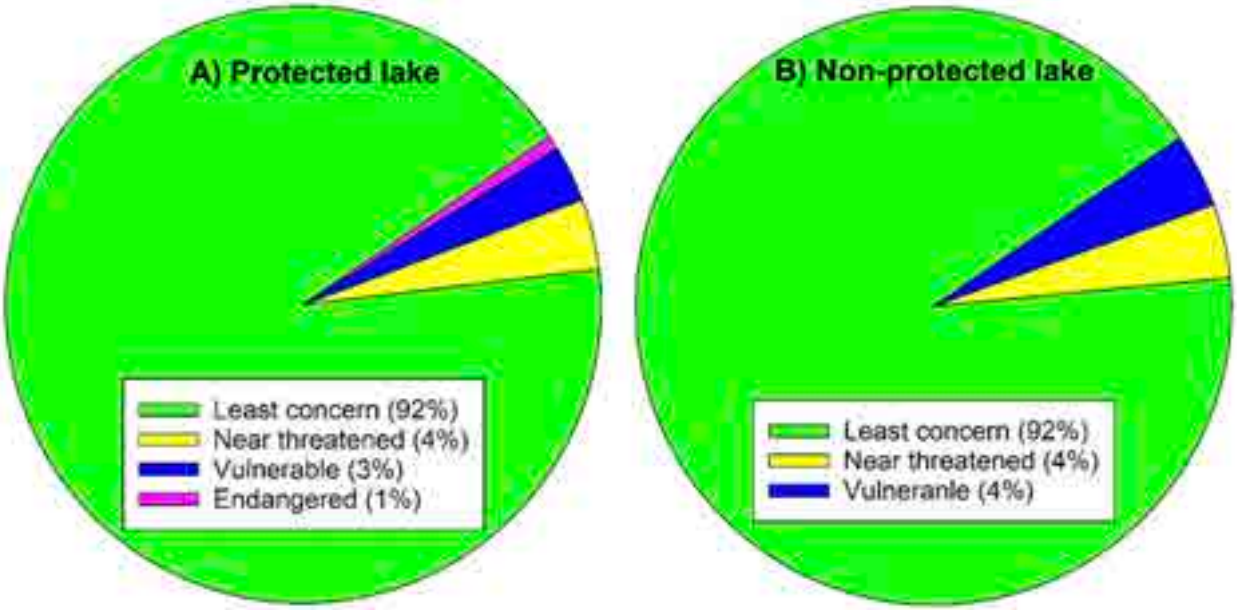

Figure 4. Pie chart showing the percentage of bird species according to IUCN Category.

globally threatened and 13 near threatened bird species (Baral & Inskipp 2009). During our study, we recorded one Endangered species of bird: Egyptian Vulture *Neophron percnopterus,* two globally Vulnerable birds: Great Slaty Woodpecker *Mulleripicus pulverulentus* Common Pochard *Aythya ferina* and five globally Near Threatened birds in and around the protected lake.

Habitat heterogeneity is greater inside the Shuklaphanta National Park in and around the protected wetland. Higher the habitat heterogeneity favours higher the species diversity (Tamme et al. 2010). Hence higher number of forest specific birds and wetland birds were recorded in the protected wetland. But the non-protected wetland is surrounded by small patch of forest and agriculture landscape. The exploitation of natural resources and impact of human pressure was more in non-protected wetland which may be a cause of lower abundance of forest and wetland specialist birds. Nevertheless, due to diverse habitats, agricultural landscape supported higher richness and abundance of open area birds. Elsen et al. (2017) reported that low intensity agriculture supports higher bird diversity during winter in Himalayan montane landscape.

The wetland outside the protected area also supported considerable bird diversity. The birds reported here included several species listed as Vulnerable (VU) in IUCN Red List. Non-protected wetland and adjoining areas provide the suitable habitats for several vulnerable and near threatened bird species. During this study, we reported three Vulnerable and six Near Threatened bird species. The adjoining area of this wetland is surrounded by paddy fields and swampy areas, which are the foraging ground to several species (de Silva et al. 2015; Adhikari et al. 2019). The tree species present in paddy field and adjoining community forest provide the nesting and foraging places for birds. The study on the responses of birds with tree species in agricultural landscape found larger population sizes of birds with low intensity farming as they share same land for foraging (Hulme et al. 2013). Hence, land sharing would result in better bird conservation outcomes (Hulme et al. 2013; Edwards et al. 2014; Schulte et al. 2016) but land sparing has greater potential biodiversity benefits for large mammals, cats and large birds than land sharing (Lamb et al. 2019; Finch et al. 2020). Several studies show that agricultural land is an important driver that effect the wild nature directly or indirectly which is very common in developing countries (Green et al. 2005; Haslem & Bennett 2008; Šálek et al. 2018; Chaudhary et al. 2020).

Difference in feeding guilds

The results showed that wetlands are suitable for avifauna as they offer shelter, food, suitable nesting, and roosting sites for different groups of birds (Giosa et al. 2018). The habitat preference of the bird could be due to the availability of food they feed on such as insects, fishes, frogs, lizards, mouse, grains, fruits, vegetable matter (Katuwal et al. 2016; Harisha & Hosetti 2018). We identified five different foraging guilds such as insectivores, omnivores, piscivores, herbivores, and

Image 2. A—protected wetland (Rani Taal) inside the Shuklaphanta National Park, western Nepal | B—non-protected wetland (Sati Karnali Taal) of Kailali district | C—Lesser Adjutant (*Leptoptilos javanicus*), globally Vulnerable, recorded from non-protected wetland | D—Asian Woolly-neck (*Ciconia episcopus*), globally Near threatened, recorded from both wetlands | E—Red-wattled Lapwing (*Vanellus indicus*), globally Least Concern, recorded from both wetlands | F—Oriental Darter (*Anhinga melanogaster*), globally near threatened recorded from both wetlands. © Jagan Nath Adhikari

carnivores of birds. Among them, insectivores were highly abundant in both wetland systems. Dahal et al. (2014) identified seven main foraging guilds of birds. Insectivores are the most dominant group of birds as compared to other birds in the globe (Zakaria & Rajpar 2010; Datta 2011; Dahal et al. 2014; Basnet et al. 2016; Adhikari et al. 2018a,b). The main reason for the selection of different habitats by birds could be the presence of different vegetation types. The vegetation surrounding the protected wetland was dense and relatively mature compared to non-protected wetland. The agricultural fields around the non-protected wetland also supported more insectivore birds. Hence, both protected and non-protected wetlands are very important from conservation aspects of birds.

CONCLUSION

This study demonstrates that both protected and non-protected wetlands have comparable richness, though the composition of birds slightly differed.

Protected areas supported some forest and wetland specialist birds. The study reported the same common bird species on both protected and non-protected wetlands, hence, wetlands outside protected areas are also important for species conservation. This result suggests that the habitats outside protected areas also play an important complementary role to conservation of bird species which are worth conserving. Mosaics of habitat patches in low-intensity agricultural landscape favored considerable bird diversity which supports the idea that food production and biodiversity conservation can be reconciled in same landscape unit. Wetlands rich in biodiversity and sources of ecosystem goods and services are dwindling faster due to increased human activities related with agriculture, land use change and infrastructure development. We underscore call for action to extend program for the protection of ecosystem outside protected areas while emphasizing the management of protected areas for enhanced in situ conservation.

REFERENCES

Adhikari, J.N., B.P. Bhattarai & D.N. Dhakal (2018a). Conservation value of Beeshhazari Lake: an insight into diversity and abundance of wetland birds. *Our Nature* 16(1): 17–26. https://doi.org/10.3126/on.v16i1.21563

Adhikari, J.N., B.P. Bhattarai & T.B. Thapa (2018b). Diversity and conservation threats of water birds in and around Barandabhar corridor forest, Chitwan, Nepal. *Journal of Natural History Mesuem* 30: 164–179. https://doi.org/10.3126/jnhm.v30i0.27553

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

Baral, H.S. & C. Inskipp (2009). The birds of Suklaphanta Wildlife Reserve, Nepal. *Our Nature* 7(1): 56–81. https://doi.org/10.3126/on.v7i1.2554

Baral, H.S. & C. Inskipp (2020). Birds of Nepal: Their Status and Conservation Especially with Regards to Watershed Perspectives, pp. 435–458. In: Regmi, G.R. & F. Huettmann (eds.). *Hindu Kush-Himalaya Watersheds Downhill: Landscape Ecology and Conservation Perspectives*. Springer. https://doi.org/10.1007/978-3-030-36275-1_22

Basnet, T.B., M.B. Rokaya, B.P. Bhattarai & Z. Munzbergova (2016). Heterogeneous Landscapes on Steep Slopes at Low Altitudes as Hotspots of Bird Diversity in a Hilly Region of Nepal in the Central Himalayas. *PLoS ONE* 11(3): e0150498. https://doi.org/10.1371/journal.pone.0150498

BCN & DNPWC (2016). *Birds of Nepal: An Official Checklist*. Bird Conservation Nepal (BCN) and Department of National Parks and Wildlife Conservation (DNPWC), Kathmandu, Nepal, 40 pp.

Bibby, C.J., N.D. Burgess, D.A. Hill & S. Mustoe (2000). *Bird census techniques*. Academic Press, Elsevier, 302 pp.

Brotherton, S., C.B. Joyce & J.P. Scharlemann (2020). Global offtake of wild animals from wetlands: critical issues for fish and birds. *Hydrobiologia* 847: 1631–1649. https://doi.org/10.1007/s10750-020-04188-z

Chakravarty, S., S. Ghosh, C. Suresh, A. Dey & G. Shukla (2012). Deforestation: causes, effects and control strategies, pp. 1–26. In: Shukla, G. (eds.). *Global perspectives on sustainable forest management*. Intech Rijeka, Croatia, 315 pp.

Chape, S., J. Harrison, M. Spalding & I. Lysenko (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Philosophical Transactions of the Royal Society B: Biological Sciences* 360(1454): 443–455. https://doi.org/10.1098/rstb.2004.1592

Chaudhary, S., Y. Wang, A.M. Dixit, N.R. Khanal, P. Xu, B. Fu, K. Yan, Q. Liu, Y. Lu & M. Li (2020). A synopsis of farmland abandonment and its driving factors in Nepal. *Land* 9(3): 1–24. https://doi.org/10.3390/land9030084

Cox, R.L. & E.C. Underwood (2011). The importance of conserving biodiversity outside of protected areas in Mediterranean ecosystems. *PLoS ONE* 6(1): e14508. https://doi.org/10.1371/journal.pone.0014508

Dahal, B.R., C.A. McAlpine & M. Maron (2014). Bird conservation values of off-reserve forests in lowland Nepal. *Forest Ecology and Management* 323: 28–38. https://doi.org/10.1016/j.foreco.2014.03.033

Dahal, B.R., C.A. McAlpine & M. Maron (2015). Impacts of extractive forest uses on bird assemblages vary with landscape context in lowland Nepal. *Biological Conservation* 186: 167–175. https://doi.org/10.1016/j.biocon.2015.03.014

Datta, T. (2011). Human interference and avifaunal diversity of two wetlands of Jalpaiguri, West Bengal, India. *Journal of Threatened Taxa* 3(12): 2253–2262. https://doi.org/10.11609/JoTT.o2739.2253-62

de Silva, T.N., S. Fernando, H.B. de Silva & P. Tennakoon (2015). Lesser Adjutant *Leptoptilos javanicus* Horsfield, 1821 (Ciconiiformes: Ciconiidae) in the dry lowlands of Sri Lanka: distribution, ecology, and threats. *Journal of Threatened Taxa* 7(14): 8089–8095. https://doi.org/10.11609/jott.2425.7.14.8089-8095

DNPWC (2020). *Protected areas of Nepal*. Department of National Parks and Wildlife Conservation (DNPWC) Nepal, Kathmandu, Nepal. Downloaded on 20 January 2020. http://www.dnpwc.gov.np

Dudgeon, D., A.H. Arthington, M.O. Gessner, Z.I. Kawabata, D.J. Knowler, C. Lévêque, R.J. Naiman, A.-H. Prieur-Richard, D. Soto & M.L. Stiassny (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews* 81(2): 163–182. https://doi.org/10.1017/S1464793105006950

Dudley, N., C. Groves, K.H. Redford & S. Stolton (2014). Where now for protected areas? Setting the stage for the 2014 World Parks Congress. *Oryx* 48(4): 496–503. https://doi.org/10.1017/S0030605314000519

Edwards, D.P., J.J. Gilroy, P. Woodcock, F.A. Edwards, T.H. Larsen, D.J. Andrews, M.A. Derhe, T.D. Docherty, W.W. Hsu, S.L. Mitchell, T. Ota, L.J. Williams, W.F. Laurance, K.C. Hamer & D.S. Wilcove (2014). Land-sharing versus land-sparing logging: reconciling timber extraction with biodiversity conservation. *Globle Change Biology* 20(1): 183–191. https://doi.org/10.1111/gcb.12353

Elsen, P.R., R. Kalyanaraman, K. Ramesh & D.S. Wilcove (2017). The importance of agricultural lands for Himalayan birds in winter. *Conservation Biology* 31(2): 416–426. https://doi.org/10.1111/cobi.12812

Finch, T., S. Gillings, D. Massimino, T. Brereton, J. Redhead, R. Pywell, R. Field, A. Balmford, R. Green & W. Peach (2020). Assessing the utility of land sharing and land sparing for birds, butterflies and ecosystem services in lowland England. Natural England Commissioned Report NECR280, 73 pp.

Fisher, R.A. & F. Yates (1943). *Statistical Tables: For Biological, Agricultural and Medical Research*. Second edition. Oliver and Boyd Ltd, London, 105 pp.

Geist, J. (2011). Integrative freshwater ecology and biodiversity conservation. *Ecological Indicators* 11(6): 1507–1516. https://doi.org/10.1016/j.ecolind.2011.04.002

Green, R.E., S.J. Cornell, J.P. Scharlemann & A. Balmford (2005). Farming and the fate of wild nature. *Science* 307(5709): 550–555. http://doi.org/10.1126/science.1106049

Grimmett, R., C. Inskipp & T. Inskipp (2016a). *Birds of the Indian Subcontinent: India, Pakistan, Sri Lanka, Nepal, Bhutan, Bangladesh and the Maldives*. Bloomsbury Publishing, 448 pp.

Grimmett, R., C. Inskipp, T. Inskipp & H.S. Baral (2016b). *Birds of Nepal: Revised Edition*. Bloomsbury Publishing, India, 386 pp.

Harisha, M.N. & B.B. Hosetti (2018). Status and conservation issues of wetland birds in Komaranahalli lake, Davanagere district, Karnataka, India. *Journal of Threatened Taxa* 10(2): 11290–11294. http://doi.org/110.11609/jott.2809.10.2.11290-11294

Haslem, A. & A.F. Bennett (2008). Birds in agricultural mosaics: the influence of landscape pattern and countryside heterogeneity. *Ecological Applications* 18(1): 185–196. https://doi.org/10.1890/07-0692.1

Hulme, M.F., J.A. Vickery, R.E. Green, B. Phalan, D.E. Chamberlain, D.E. Pomeroy, D. Nalwanga, D. Mushabe, R. Katebaka & S. Bolwig (2013). Conserving the birds of Uganda's banana-coffee arc: land sparing and land sharing compared. *PLoS ONE* 8(2): e54597. https://doi.org/10.1371/journal.pone.0054597

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

Katuwal, H.B., K. Basnet, B. Khanal, S. Devkota, S.K. Rai, J.P. Gajurel, C. Scheidegger & M.P. Nobis (2016). Seasonal Changes in Bird Species and Feeding Guilds along Elevational Gradients of the Central Himalayas, Nepal. *PLoS ONE* 11(7): e0158362. https://doi.org/10.1371/journal.pone.0158362

Khatiwada, J.R., J.N. Adhikari, D. Adhikari, S. Sapkota, S.R. Ghimire, P.B. Budha & L.N. Sharma (2019). Assessment and conservation status of aquatic biodiversity in lower Karnali and Mahakali River basin. Forest Action Nepal, USAID Pani Program, 116 pp.

Khatiwada, J. R., J.N., Adhikari, D., Rijal & L.N. Sharma (2021). Freshwater biodiversity in western Nepal: A review. *Nepalese Journal of Zoology* 5(1): 34–46. https://doi.org/10.3126/njz.v5i1.38290

Khatri, N.D., B. Neupane, Y.P. Timilsina & S. Ghimire (2019). Assessment of Avifaunal diversity and threats to them in Phewa wetland, Nepal. Forestry: *Journal of Institute of Forestry, Nepal* 16: 31–47. https://doi.org/10.3126/forestry.v16i0.28352

Kumar, A. (2005). *Handbook on Indian wetland birds and their conservation*. Zoological Survey of India, Dehradun, India, 472 pp.

Lamb, A., T. Finch, J.W. Pearce-Higgins, M. Ausden, A. Balmford, C. Feniuk, G. Hirons, D. Massimino & R.E. Green (2019). The consequences of land sparing for birds in the United Kingdom. *Journal of Applied Ecology* 56(8): 1870–1881. https://doi.org/10.1111/1365-2664.13362

Lamsal, P., K. Atreya, M.K. Ghosh & K.P. Pant (2019). Effects of population, land cover change, and climatic variability on wetland resource degradation in a Ramsar listed Ghodaghodi Lake Complex, Nepal. *Environmental Monitoring and Assessment 191*(7): 1–16. https://doi.org/10.1007/s10661-019-7514-0

Ostfeld, A., S. Barchiesi, M. Bonte, C.R. Collier, K. Cross, G. Darch, T.A. Farrell, M. Smith, A. Vicory & M. Weyand (2012). Climate change impacts on river basin and freshwater ecosystems: some observations on challenges and emerging solutions. *Journal of Water and Climate Change* 3(3): 171–184. https://doi.org/10.2166/wcc.2012.006

Paracuellos, M. (2006). Relationships of songbird occupation with habitat configuration and bird abundance in patchy reed beds. *ARDEA* 94(1): 87–98.

R Development Core Team (2019). A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Rodrigues, A.S., H.R. Akcakaya, S.J. Andelman, M.I. Bakarr, L. Boitani, T.M. Brooks, J.S. Chanson, L.D. Fishpool, G.A. Da Fonseca & K.J. Gaston (2004). Global gap analysis: priority regions for expanding the global protected-area network. *BioScience* 54(12): 1092–1100. https://doi.org/10.1641/0006-3568(2004)054[1092:GGAPRF]2.0.CO;2

Šálek, M., M. Bažant & M. Żmihorski (2018). Active farmsteads are year-round strongholds for farmland birds. *Journal of Applied Ecology* 55(4): 1908–1918. https://doi.org/10.1111/1365-2664.13093

Schulte, L.A., A.L. MacDonald, J.B. Niemi & M.J. Helmers (2016). Prairie strips as a mechanism to promote land sharing by birds in industrial agricultural landscapes. *Agriculture, Ecosystems and Environment* 220: 55–63. https://doi.org/10.1016/j.agee.2016.01.007

Shannon, C.E. (1948). Mathematical Theory of Communication. *The Bell System Technical Journal* 27(3): 379–424. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Sharma, L.N. & O.R. Vetaas (2015). Does agroforestry conserve trees? A comparison of tree species diversity between farmland and forest in mid-hills of central Himalaya. *Biodiversity Conservation* 24(8): 2047–2061. https://doi.org/10.1007/s10531-015-0927-3

Shrestha, U.B., S. Shrestha, P. Chaudhary & R.P. Chaudhary (2010). How representative is the protected areas system of Nepal? *Mountain Research and Development* 30(3): 282–294. https://doi.org/10.1659/MRD-JOURNAL-D-10-00019.1

Simpson, E.H. (1949). Measurement of diversity. *Nature* 163(4148): 688–688. https://doi.org/10.1038/163688a0

Siwakoti, M. & J.B. Karki (2009). Conservation status of Ramsar sites of Nepal Terai: an overview. *Botanica Orientalis: Journal of Plant Science* 6: 76–84. https://doi.org/10.3126/botor.v6i0.2914

Tamme, R., I. Hiiesalu, L. Laanisto, R. Szava-Kovats & M. Pärtel (2010). Environmental heterogeneity, species diversity and co-existence at different spatial scales. *Journal of Vegetation Science* 21(4): 796–801. https://doi.org/10.1111/j.1654-1103.2010.01185.x

Terborgh, J., C. van Schaik, L. Davenport & M. Rao (2002). *Making Parks Work: Strategies for Preserving Tropical Nature*. Island Press, 511 pp.

UNEP-WCMC, IUCN & NGS (2018). Protected Planet Report 2018. UNEP-WCMC, IUCN and NGS, Cambridge UK; Gland, Switzerland; and Washington, D.C., USA, 70 pp.

Watson, J.E., E.S. Darling, O. Venter, M. Maron, J. Walston, H.P. Possingham, N. Dudley, M. Hockings, M. Barnes & T.M. Brooks (2016). Bolder science needed now for protected areas. *Conservation Biology* 30(2): 243–248. https://doi.org/10.1111/cobi.12645

Zakaria, M. & M.N. Rajpar (2010). Bird species composition and feeding guilds based on point count and mist netting methods at the Paya Indah Wetland Reserve, Peninsular Malaysia. *Tropical Life Sciences Research* 21(2): 7–26.

Appendix 1. Bird species with their abundance observed in protected and non-protected wetlands in Winter and Summer. Relative abundance (RA) refers total percentage contribution of each species to the total sample. 0 indicated the species were not recorded during field study, here, EN= Endangered, VU= Vulnerable, NT= Near threatened and LC= Least Concern.

	Order/Family/ Common name	Zoological name	RA in Winter		RA in Summer		Total RA(%)		IUCN category
			Protected	Non-protected	Protected	Non-protected	Protected	Non-protected	
Order ACCIPITRIFORMES									
Family Accipitridae									
1	Black Kite	*Milvus migrans* (Boddaert, 1783)	0.004	0.5	0.007	0.554	0.524	0.53	LC
2	Crested Serpent-eagle	*Spilornis cheela* (Latham, 1790)	0.002	0.125	0.001	0.111	0.175	0.117	LC
3	Grey-headed Fish-eagle	*Icthyophaga ichthyaetus* (Horsfield, 1821)	0.002	0.503	0.001	0.443	0.175	0.47	NT
4	Lesser Fish-eagle	*Icthyophaga humilis* (Müller & Schlegel, 1841)	0.604	0	0.005	0	0.466	0	NT
5	Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)	0.001	0	0.001	0	0.117	0	EN
Family Pandionidae									
6	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	0.002	0	0.003	0	0.233	0	LC
Order ANSERIFORMES									
Family Anatidae									
7	Bar-headed Goose	*Anser indicus* (Latham, 1790)	0.005	0	0	0	0.291	0	LC
8	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	1.915	1.509	0	0	0.874	0.707	LC
9	Common Shelduck	*Tadorna tadorna (*Linnaeus, 1758)	1.017	1.509	0	0	0.932	0.7	LC
10	Common Teal	*Anas crecca* Linnaeus, 1758	0.004	0.628	0	0	0.233	0.294	LC
11	Gadwall	*Mareca strepera* (Linnaeus, 1758)	0.004	0	0	0	0.233	0	LC
12	Lesser Whistling-duck	*Dendrocygna javanica (*Horsfield, 1821)	0.91	6.92	0	0	0.583	3.241	LC
13	Mallard	*Anas platyrhynchos* Linnaeus, 1758	0.002	0	0	0	0.117	0	LC
14	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	0.002	0	0	0	0.117	0	LC
Order BUCEROTIFORMES									
Family Bucerotidae									
15	Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	0.002	0	0.003	0.111	0.233	0.05	LC
Family Upupidae									
16	Common Hoopoe	*Upupa epops* Linnaeus, 1758	0.006	0.25	0.008	0.222	0.699	0.235	LC
Order CAPRIMULGIFORMES									
Family Apodidae									
17	House Swift	*Apus nipalensis* (Hodgson, 1836)	2.052	2.77	3.04	2.328	4.662	2.533	LC
Order CHARADRIIFORMES									
Family Charadriidae									
18	Grey-headed Lapwing	*Vanellus cinereus* (Blyth, 1842)	0.004	0.251	0.005	0	0.466	0.118	LC
19	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	0.004	0.503	0.007	0.665	0.524	0.589	LC
20	River Lapwing	*Vanellus duvaucelii* (Lesson, 1826)	0.004	0.628	0.004	0.665	0.408	0.648	NT
21	Yellow-wattled Lapwing	*Vanellus malabaricus* (Boddaert, 1783)	0.004	1.006	0.005	1.219	0.466	1.119	LC
Family Jacanidae									
22	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	0.81	0.628	1.019	0.332	1.399	0.471	LC

	Order/Family/ Common name	Zoological name	RA in Winter		RA in Summer		Total RA(%)		IUCN category
			Protected	Non-protected	Protected	Non-protected	Protected	Non-protected	
Family Scolopacidae									
23	Common Sandpiper	*Actitis hypoleucos* Linnaeus, 1758	0.004	0	0.003	0	0.35	0	LC
24	Green Sandpiper	*Tringa ochropus* Linnaeus, 1758	0.012	0.503	0.007	0.554	0.991	0.53	LC
25	Marsh Sandpiper	*Tringa stagnatilis* (Bechstein, 1803)	0.004	0.503	0.003	0.443	0.35	0.471	LC
26	Wood Sandpiper	*Tringa glareola* Linnaeus, 1758	0.002	0	0	0	0.117	0	LC
Order CICONIIFORMES									
Family Ciconiidae									
27	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	0.71	1.509	0.009	1.77	0.991	1.649	LC
28	Asian Woollyneck	*Ciconia episcopus* (Boddaert, 1783)	0.002	0.125	0.003	0.886	0.233	0.53	NT
29	Black Stork	*Ciconia nigra* (Linnaeus, 1758)	0.002	0	0.003	0	0.233	0	LC
30	Lesser Adjutant	*Leptoptilos javanicus* (Horsfield, 1821)	0	0.252	0	0	0	0.117	VU
31	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	0.002	0.252	0	0	0.117	0.117	NT
Order COLUMBIFORMES									
Family Columbidae									
32	Grey-capped Emerald Dove	*Chalcophaps indica* (Linnaeus, 1758)	0.008	1.006	1.011	0.997	0.932	1.001	LC
33	Oriental Turtle-dove	*Streptopelia orientalis* (Latham, 1790)	0.004	0.503	0.005	0.443	0.466	0.47	LC
34	Red Turtle-dove	*Streptopelia tranquebarica* (Hermann, 1804)	0.004	0.503	0.005	0.554	0.466	0.53	LC
35	Rock Dove	*Columba livia* Gmelin, 1789	0.005	0	0.004	0	0.466	0	LC
36	Western Spotted Dove	*Spilopelia suratensis* (Gmelin, 1789)	0.019	0.628	0.008	4.212	1.399	2.53	LC
Order CORACIIFORMES									
Family Alcedinidae									
37	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	0.005	0.628	0.007	0.554	0.583	0.589	LC
38	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	0	0.252	0.001	0	0.058	0.117	LC
39	Stork-billed Kingfisher	*Pelargopsis capensis* (Linnaeus, 1766)	0.002	0	0	0	0.117	0	LC
40	White-breasted Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	0.07	0.88	0.012	2.1	0.932	1.532	LC
Family Coraciidae									
41	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	0.05	0.628	0.007	0.554	0.583	0.589	LC
Family Meropidae									
42	Asian Green Bee-eater	*Merops orientalis* Latham, 1802	1.018	2.138	2.013	2.106	1.573	2.121	LC
43	Blue-tailed Bee-eater	*Merops philippinus* Linnaeus, 1766	2.038	3.899	3.048	3.215	4.254	3.535	LC
44	Chestnut-headed Bee-eater	*Merops leschenaulti* Vieillot, 1817	0.004	0.503	0.005	0.222	0.466	0.353	LC
Order CUCULIFORMES									
Family Cuculidae									
45	Banded Bay Cuckoo	*Cacomantis sonneratii* (Latham, 1790)	0.002	0.252	0.003	0.222	0.233	0.23	LC
46	Common Hawk-cuckoo	*Hierococcyx varius* (Vahl, 1797)	0.002	0.252	0.003	0.222	0.233	0.23	LC
47	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	0.002	0.252	0.003	0.222	0.233	0.23	LC
48	Indian Cuckoo	*Cuculus micropterus* Gould, 1837	0.003	0.377	0.004	0	0.35	0.176	LC

	Order/Family/ Common name	Zoological name	RA in Winter		RA in Summer		Total RA(%)		IUCN category
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49	Lesser Coucal	*Centropus bengalensis* (Gmelin, 1788)	0.008	1.006	0.009	0.776	0.874	0.88	LC
50	Western Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	0.002	0	0.003	0	0.233	0	LC
Order FALCONIFORMES									
Family Falconidae									
51	Red-headed Falcon	*Falco chicquera* Daudin, 1800	0.002	0	0.003	0	0.233	0	NT
Order GALLIFORMES									
Family Phasianidae									
52	Black Francolin	*Francolinus francolinus* (Linnaeus, 1766)	0.004	0.252	0.003	0.221	0.35	0.23	LC
53	Common Peafowl	*Pavo cristatus* Linnaeus, 1758	3.052	2.767	4.047	2.328	4.953	2.53	LC
54	Common Quail	*Coturnix coturnix* (Linnaeus, 1758)	0.004	0	0.008	0	0.583	0	LC
55	Red Junglefowl	*Gallus gallus* (Linnaeus, 1758)	0.804	0.503	0.005	0.443	0.466	0.471	LC
56	Common Coot	*Fulica atra* Linnaeus, 1758	0.01	0	0	0.554	0.583	0.294	LC
Order GRUIFORMES									
Family Rallidae									
57	Ruddy-breasted Crake	*Zapornia fusca* (Linnaeus, 1766)	0.015	0	0.017	0	1.632	0	LC
58	Watercock	*Gallicrex cinerea* (Gmelin, 1789)	0.01	1.258	0.004	0	0.758	0.58	LC
59	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	0.003	0.377	0	0	0.175	0.17	LC
Order PASSERIFORMES									
Family Alaudidae									
60	Rufous-winged Lark	*Mirafra assamica* Horsfield, 1840	0.715	1.88	2.017	1.33	1.632	1.591	LC
61	Sand Lark	*Alaudala raytal* (Blyth, 1844)	0.002	0.25	0	0.221	0.117	0.23	LC
Family Campephagidae									
62	Scarlet Minivet	*Pericrocotus flammeus* (Forster, 1781)	0.006	0.754	0.009	0.665	0.758	0.7	LC
Family Cisticolidae									
63	Jungle Prinia	*Prinia sylvatica* Jerdon, 1840	0.005	0.628	0.005	0	0.524	0.294	LC
64	Zitting Cisticola	*Cisticola juncidis* (Rafinesque, 1810)	0.004	0.503	0.004	0.443	0.408	0.471	LC
Family Corvidae									
65	Grey Treepie	*Dendrocitta formosae* Swinhoe, 1863	0.002	0	0.003	0	0.233	0	LC
66	House Crow	*Corvus splendens* Vieillot, 1817	0.915	1.88	1.012	2.439	1.399	2.18	LC
67	Large-billed Crow	*Corvus macrorhynchos* Wagler, 1827	0.004	0.503	0.008	1.441	0.583	1	LC
68	Red-billed Blue Magpie	*Urocissa erythroryncha* (Boddaert, 1783)	0.002	0.25	0.003	0.221	0.233	0.235	LC
69	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	0.004	0.503	0.004	0.554	0.408	0.53	LC
Family Dicruridae									
70	Ashy Drongo	*Dicrurus leucophaeus* Vieillot, 1817	0.005	0.628	0.007	0.55	0.583	0.58	LC
71	Black Drongo	*Dicrurus macrocercus* Vieillot, 1817	1.015	1.88	2.017	1.88	1.632	1.885	LC
72	Greater Racquet-tailed Drongo	*Dicrurus paradiseus* (Linnaeus, 1766)	0.004	0.503	0.003	0.44	0.35	0.47	LC
73	Lesser Racquet-tailed Drongo	*Dicrurus remifer* (Temminck, 1823)	0.002	0.252	0.003	0.221	0.233	0.23	LC

	Order/Family/ Common name	Zoological name	RA in Winter		RA in Summer		Total RA(%)		IUCN category
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74	White-bellied Drongo	*Dicrurus caerulescens* (Linnaeus, 1758)	0	0	0	0.332	0	0.176	LC
Family Estrildidae									
75	Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	0.005	0.628	0.007	0.554	0.583	0.589	LC
Family Hirundinidae									
76	Barn Swallow	*Hirundo rustica* Linnaeus, 1758	1.023	2.642	2.028	2.771	2.506	2.71	LC
77	Wire-tailed Swallow	*Hirundo smithii* Leach, 1818	2.026	3.144	3.036	2.771	3.03	2.946	LC
Family Laniidae									
78	Grey-backed Shrike	*Lanius tephronotus* (Vigors, 1831)	0	0	0.33	0.001	0.176	0.058	LC
Family Leiotrichidae									
79	Common Babbler	*Argya caudata* (Dumont, 1823)	0.004	0.503	0.005	0.665	0.466	0.589	LC
80	Jungle Babbler	*Turdoides striata* (Dumont, 1823)	1.014	1.761	2.016	1.33	1.515	1.53	LC
81	Large Grey Babbler	*Argya malcolmi* (Sykes, 1832)	0	0	0.005	0	0.233	0	LC
Family Monarchidae									
82	Black-naped Monarch	*Hypothymis azurea* (Boddaert, 1783)	0.905	0.628	0.807	0.554	0.583	0.589	LC
83	White Wagtail	*Motacilla alba* Linnaeus, 1758	0	0	0	1.108	0	0.589	LC
84	White-browed Wagtail	*Motacilla maderaspatensis* Gmelin, 1789	0.004	0.503	0.005	0.554	0.466	0.53	LC
Family Muscicapidae									
85	Black Redstart	*Phoenicurus ochruros* (Gmelin, 1774)	0	0.629	0	0	0	0.294	LC
86	Common Stonechat	*Saxicola torquatus* (Linnaeus, 1766)	1.017	1.761	1.015	1.108	1.573	1.41	LC
87	Grey Bushchat	*Saxicola ferreus* Gray, 1846	0.002	0.251	0.003	0.221	0.233	0.23	LC
88	Indian Robin	*Saxicoloides fulicatus* (Linnaeus, 1766)	0.002	0.251	0.003	0.221	0.233	0.23	LC
89	Oriental Magpie-robin	*Copsychus saularis* (Linnaeus, 1758)	1.017	1.257	0.915	1.219	1.573	1.237	LC
90	Pied Bushchat	*Saxicola caprata* (Linnaeus, 1766)	0	0	0	0.332	0	0.176	LC
91	White-capped Water-redstart	*Phoenicurus leucocephalus* (Vigors, 1831)	0.005	0.628	0.001	0.554	0.35	0.589	LC
92	White-tailed Stonechat	*Saxicola leucurus* (Blyth, 1847)	0.004	0.503	0	0.443	0.233	0.471	LC
Family Oriolidae									
93	Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	0.004	0.503	0.004	1.33	0.408	0.942	LC
Family Passeridae									
94	Chestnut-shouldered Bush-sparrow	*Gymnoris xanthocollis* (Burton, 1838)	1.015	1.257	1.615	1.662	1.515	1.473	LC
95	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	1.026	3.144	2.028	5.21	2.681	4.242	LC
Family Ploceidae									
96	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	0.01	1.257	0.016	0.776	1.282	1	LC
Family Pycnonotidae									
97	Black Bulbul	*Hypsipetes leucocephalus* (Gmelin, 1789)	1.01	1.257	2.015	1.108	1.224	1.17	LC
98	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	0.006	0	0.008	0.665	0.699	0.35	LC
99	Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus, 1758)	1.017	2.012	1.019	1.995	1.748	2	LC

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Family Scotocercidae									
100	Pale-footed Bush-warbler	*Hemitesia pallidipes* (Blanford, 1872)	0.002	0.251	0.003	0.221	0.233	0.235	LC
Family Sturnidae									
101	Asian-pied Starling	*Gracupica contra* (Linnaeus, 1758)	0	0	0	0.886	0	0.471	LC
102	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	1.015	1.886	2.019	1.99	1.69	1.944	LC
103	Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)	1.012	1.509	1.015	2.1	1.34	1.826	LC
Family: Zosteropidae									
104	Indian White-eye	*Zosterops palpebrosus* (Temminck, 1824)	0.002	0.251	0.003	0.221	0.233	0.235	LC
Order PELECANIFORMES									
Family Ardeidae									
105	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	0.805	0.628	0.005	7.649	0.524	4.36	LC
106	Great White Egret	*Ardea alba* Linnaeus, 1758	0.006	0	0.007	0	0.641	0	LC
107	Grey Heron	*Ardea cinerea* Linnaeus, 1758	0.004	0.503	0.005	0.443	0.466	0.471	LC
108	Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	0	0	0.04	0.332	1.748	0.176	LC
109	Intermediate Egret	*Ardea intermedia* Wagler, 1829	0.003	0.628	0.004	0.554	0.35	0.589	LC
110	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	0.004	0.503	0.005	0.997	0.466	0.766	LC
111	Purple Heron	*Ardea purpurea* Linnaeus, 1766	0.004	0	0.005	0.443	0.466	0.235	LC
Family Threskiornithidae									
112	Red-naped Ibis	*Pseudibis papillosa* (Temminck, 1824)	0.004	0.503	0.005	0.11	0.466	0.294	LC
Order PICIFORMES									
Family Megalaimidae									
113	Brown-headed Barbet	*Psilopogon zeylanicus* (Gmelin, 1788)	0.002	0.251	0.003	0.221	0.233	0.235	LC
114	Coppersmith Barbet	*Psilopogon haemacephalus* (Müller, 1776)	0.005	0.628	0.005	0.55	0.524	0.589	LC
Family Picidae									
115	Brown-capped Pygmy Woodpecker	*Picoides nanus* (Vigors, 1832)	0	1.509	0	1.77	0	1.649	LC
116	Great Slaty Woodpecker	*Mulleripicus pulverulentus* (Temminck, 1826)	0.002	0.251	0.003	0	0.233	0.117	VU
117	Indian Pygmy Woodpecker	*Picoides nanus* (Vigors, 1832)	1.012	0.503	1.012	0	1.224	0.235	LC
118	Lesser Yellownape	*Picus chlorolophus* Vieillot, 1818	0.004	0	0.005	0	0.466	0	LC
119	Greater Flameback	*Chrysocolaptes guttacristatus* (Tickell, 1833)	0.808	0.503	0.78	0.44	0.816	0.471	LC
120	Yellow-crowned Woodpecker	*Leiopicus mahrattensis* (Latham, 1801)	0.005	0.628	0.004	0.554	0.466	0.589	LC
Order PSITTACIFORMES									
Family Psittacidae									
121	Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	2.021	1.257	2.025	0.997	2.273	1.119	LC
122	Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus, 1766)	2.019	1.257	0	0.886	1.049	1.06	NT
123	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	1.01	1.509	2.016	1.33	1.282	1.414	LC
124	Slaty-headed Parakeet	*Psittacula himalayana* (Lesson, 1832)	3.031	4.02	2.02	2.439	2.622	3.18	LC

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Order STRIGIFORMES									
Family Strigidae									
125	Jungle Owlet	*Glaucidium radiatum* (Tickell, 1833)	0.001	0	0.001	0	0.117	0	LC
126	Spotted Owlet	*Athene brama* (Temminck, 1821)	0.001	0	0.001	0	0.117	0	LC
Order SULIFORMES									
Family Anhingidae									
127	Oriental Darter	*Anhinga melanogaster* Pennant, 1769	0.002	0.125	0	0	0.117	0.058	NT
Family Phalacrocoracidae									
128	Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	0.01	0.503	0	0.443	0.583	0.47	LC
129	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	1.017	1.006	1.019	0.997	1.748	1	LC

Authors details: Jagan Nath Adhikari has a keen interest in the ecology, behavior and conservation of birds, large mammals and herpetofauna. Jagan has authored or co–authored more than ten peer–reviewed papers on birds, mammals, and human-wildlife interactions and three textbooks of zoology for undergraduate level. Janak Raj Khatiwada, PhD is a wildlife biologist with extensive field experience in Himalayan region. He has authored or co–authored more than 15 peer–reviewed papers on taxonomy, thermal ecology, composition, distribution, and conservation status of the herpetofauna of different parts of Nepal, India and China. To date, he has described four new species of amphibians for science from Nepal and India. Dipendra Adhikari is a wildlife biologist with field experience in lowland to highland of Nepal. His research interests include diversity and distribution patterns of small mammals, birds and photographic capture recapture of megafauna such as tigers, elephants. Suman Sapkota's research interests include ecology of frogs, bioacoustics, endemic and threatened frogs and effect of climate change on frogs. He has been involved in different researches related to herpetofauna and presented his work in different national and international conferences. He is currently working as Conservation Officer in Friends of Nature (FON), Nepal. Bishnu Prasad Bhattarai, PhD is a conservation biologist His research interests include the conservation of large carnivores, their habitats, and prey, biogeography of Himalayan flora and fauna (e.g., birds, mammals, herpetofauna, and orchids), forest and wildlife habitat management. Deepak Rijal, PhD is nationally reputed scholar of biodiversity. Over 30 years Deepak with specialist expertise in ecological adaptation has been actively involved in research and conservation of agriculture, forest, and freshwater resources. He has been a prolific writer and has been the lead and co-author for knowledge products published nationally and internationally. Deepak as a Board Chair of the nationally reputed research and development non-government organization consistently provides strategic direction that contributes to knowledge and benefit to various end-users in Nepal and abroad. Lila Nath Sharma, PhD is a researcher at ForestAction Nepal. He is an ecologist and undertakes action research related to biodiversity conservation, forest restoration, and invasive species management.

Author's contributions: JNA designed the study, carried out the fieldwork, analysed the data and prepare draft, JRK designed the study, analysed the data and revised the draft, DA carried out the fieldwork and revised the final draft, SS carried out the fieldwork and revised the final draft, BPB prepared map and revised the final draft, DR revised the final draft, LNS designed the study, helped in fieldwork, analysed and helped for the preparation of manuscript and revised the draft.

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ARTICLE

Local hunting practices and perceptions regarding the distribution and ecological role of the Large Flying Fox (Chiroptera: Pteropodidae: *Pteropus vampyrus*) in western Sarawak, Malaysian Borneo

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Abstract: Pteropodids such as flying foxes are declining rapidly across their range due to human activities, despite their benefit to humans through ecosystem services. The Large Flying Fox *Pteropus vampyrus* had a wide distribution across Borneo, but is now severely reduced in numbers, and rarely sighted. In order to develop effective conservation and management prescriptions for this species, updated information on its distribution, movement patterns, and the impact of anthropogenic pressure on its survival is crucial. As such, a questionnaire survey was conducted in western Sarawak to determine the occurrence of this species, and the conservation awareness for the species amongst local communities. The survey was conducted at nine sites during November 2018 – March 2019, involving a total of 123 respondents, including hunters (20%) and consumers (35%) of *P. vampyrus*. Respondents reported that *P. vampyrus* appears sporadically around the western tip of Borneo, and around the interior parts of western Sarawak, with more than half (51%) of the reported sightings in the interior occurring at fruit orchards during the fruiting and flowering seasons. Despite hunting and consuming this species, over 60% of the respondents felt that *P. vampyrus* could become an eco-tourism product in their area. Although many respondents viewed flying foxes as pests (47%) or food (52%), there was remarkably high awareness of the ecological roles and conservation needs of this species (76%), suggesting potentially strong support for flying fox conservation at the local level. Challenges associated with the enforcement of wildlife law in the remote parts of Sarawak need to be addressed, alongside strategic education and awareness efforts, which are all vital to achieve successful conservation and protection of this ecologically important species.

Keywords: Bats, conservation, indigenous, local communities, Malaysia, Palaeotropics, wildlife.

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INTRODUCTION

Despite providing crucial ecosystem services such as seed dispersal and pollination, populations of Old World fruit bats (Chiroptera: Pteropodidae) are rapidly decreasing across their range due to multiple anthropogenic threats (Fujita & Tuttle 1991; Kunz et al. 2011; Aziz et al. 2021). In Southeast Asia, pteropodids have been well-documented as critical pollinators of the economically important durian (*Durio zibethinus*) fruit, which is worth millions of USD to the economies of producing countries (Bumrungsri et al. 2009; Aziz et al. 2017a: Sheherazade et al. 2019). Despite these benefits, pteropodid bats, especially flying foxes (*Pteropus* spp., *Acerodon* spp., *Desmalopex* spp.), have been widely hunted for food and medicinal purposes in many Asia-Pacific cultures (Mildenstein et al. 2016; Low et al. 2021). Additionally, they are also persecuted and culled as fruit crop pests throughout their range (Aziz et al. 2016).

Pteropus vampyrus, the Large Flying Fox, is distributed throughout much of mainland and insular Southeast Asia (Bates et al. 2008). It is the largest bat found on Borneo, and is also the only known flying fox species found in Sarawak (Aziz et al. 2019). Like other pteropodids, this species plays a critical role in pollination and seed dispersal (Gould 1997; Gumal 2001; Mohd-Azlan et al. 2001; McConkey & Drake 2006; Aziz et al. 2017a). Although this species is under threat and legally protected in Sarawak under the Sarawak Wild Life Protection Ordinance 1998, it is listed as only Near Threatened on the global IUCN Red List, despite a decreasing trend noted for its global population (Bates et al. 2008) which is still being hunted/traded as a delicacy and for its perceived medicinal qualities (Fujita & Tuttle 1991; Mildenstein et al. 2016; Low et al. 2021). In general, most communities across Borneo share the belief that consumption of flying fox meat and liver is a cure for general malaise and respiratory ailments (Fujita 1988; Mohd-Azlan & Fauzi 2006; Low et al. 2021).

Like many other fruit bats in Southeast Asia, *P. vampyrus* is at high risk of becoming extinct by the end of the century, not only due to intense hunting pressure (Epstein et al. 2009) but also due to high deforestation rates across the region (Lane et al. 2006). In Sarawak, the last state-wide survey on *P. vampyrus* roosting sites was conducted during 1997–2000, and only five maternity colonies were found: in Patok Island, Sarang, Loagan Bunut, Limbang, and Sedilu (Gumal 2001). Therefore, for the conservation management of this species in Sarawak, more recent data on its distribution and status are urgently needed.

In addition to its outdated distribution and population data in Sarawak, little is known about local community perceptions, knowledge, and awareness of *P. vampyrus*, as no prior studies have been conducted on these aspects. Hence, as community-based wildlife surveys are known to be an effective tool to help elucidate the distribution of wildlife species and their interactions with humans (Fitzgibbon & Jones 2006), we employed this approach in western Sarawak to obtain information on *P. vampyrus,* namely: (i) the current distribution patterns; (ii) hunting and consumption by local communities; and (iii) their perception of the ecological role of this species.

MATERIALS AND METHODS

Study Site

Sarawak, Malaysia (1.553278°, 110.359213°; Figure 1) is located in northwestern Borneo and has a population of ~2.8 million (Department of Statistics Malaysia 2019). Sixty-two percent of the state is still forested, with peat swamp forests dominating the coastal lowlands to hill dipterocarp forests towards the interior, and montane forests in the interior highlands (Forest Department of Sarawak 2020). The climate is uniformly humid and warm throughout the year, with the north-east monsoon occurring during November–February, and the south-west monsoon occurring during June–October (Hazebroek & Abang Kashim 2000).

Approximately 29% of Sarawak's population belongs to the Iban indigenous group making up the majority, followed by 23% of ethnic Malays, Chinese (22%), Bidayuh (8%), Melanau (5%), other indigenous groups (6%), other non-indigenous groups (1%), and lastly, non-Malaysian citizens make up 6% of the population (Department of Statistics Malaysia 2019). Christianity is the most professed religion in Sarawak (43%), followed by Islam (32%), Buddhism (13%), Confucianism, Taoism, and Tribal religions (6%), Hinduism (0.2%), others (1%), no religion (3%), and unknown religion (2%) (Department of Statistics Malaysia 2010). Ethnic Malays do not hunt bats for consumption due to Islamic dietary restrictions, but may still kill fruit bats for fruit crop protection (Aziz et al. 2017b), or for sale to non-Muslims (Low et al. 2021).

Our survey was conducted at nine sites in western Sarawak: Sri Aman, Lubok Antu, Lubok Subong, Maludam, Sebuyau, Sematan, Simunjan, Serian, and Tanjung Manis (Figure 1). These locations were selected based on previous information on markets where flying foxes were sold (Gumal et al. 1997), and our own preliminary enquiries regarding popular sites for bushmeat trading.

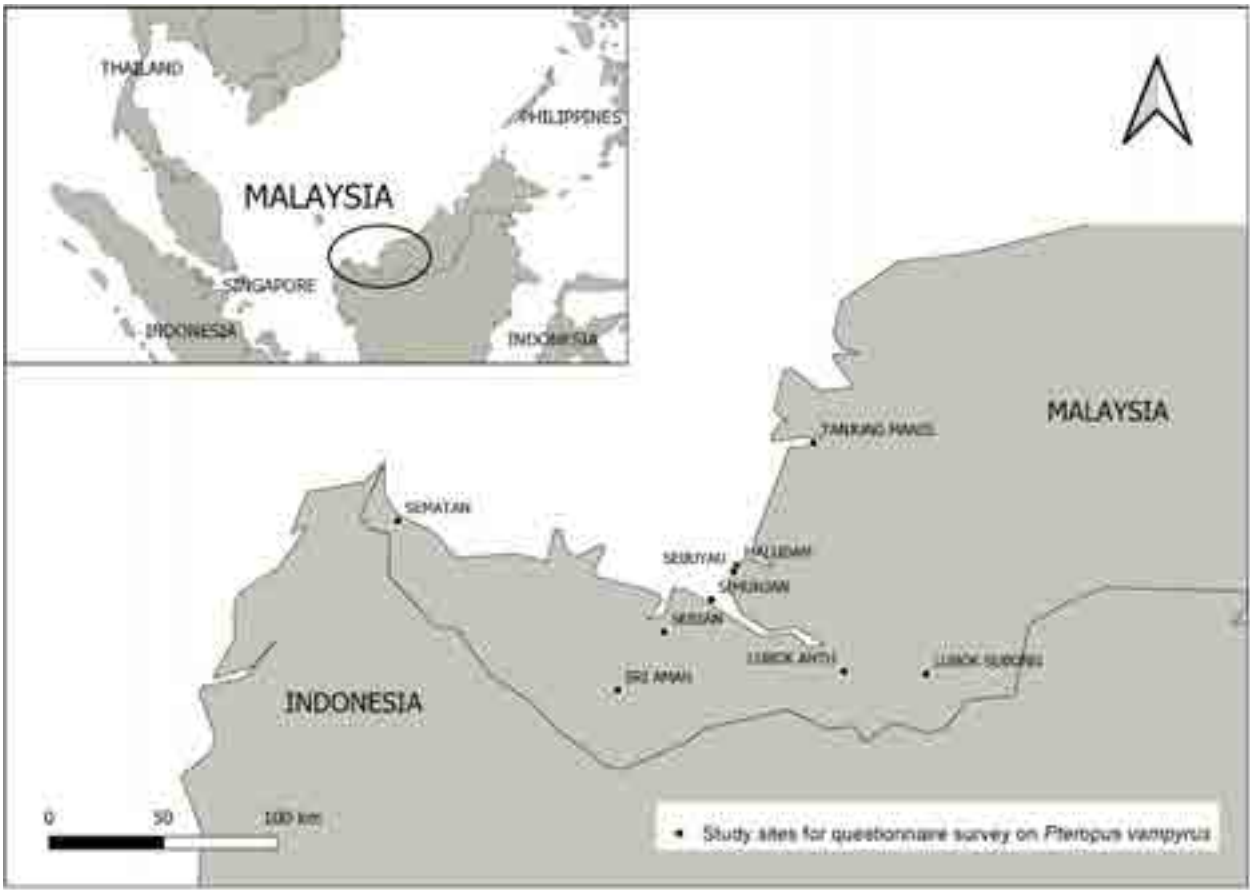

Figure 1. Study sites in western Sarawak, Malaysian Borneo (Generated by QGIS 3.6).

Study Species

Pteropus vampyrus is one of the largest bats in the world, weighing up to 1.1 kg and with a wingspan of up to 1.5 m (Image 1). It is listed as 'Near Threatened' on the IUCN Red List (Bates et al. 2008), although there appears to be a sharp population decline in Sarawak (Gumal 2001), and in Peninsular Malaysia due to over-harvesting (Epstein et al. 2009). It is listed as Endangered on the Red List of Mammals for Peninsular Malaysia (PERHILITAN 2017). In Sarawak all bat species including *P. vampyrus* are protected under the Wild Life Protection Ordinance 1998, and hunting is not allowed.

Currently**,** little is known about the population and distribution of *P. vampyrus* in Sarawak, as the last state-wide survey was conducted by Gumal (2001) around two decades ago. That survey found that all five of the reported roosts were located in remote and inaccessible areas such as peat swamps and mangroves.

Data Collection

A questionnaire survey (Table 1) consisting of open-ended and closed questions was designed to obtain data on (1) local community socio-demographics; (2) *P. vampyrus* sightings; (3) consumption and hunting of this species by local communities*;* and (4) local community perceptions of the species. A pilot survey was first conducted on 35 individuals comprising members of the general public and students from Universiti Malaysia Sarawak (UNIMAS) in Kota Samarahan.

The questionnaire survey was conducted during November 2018–March 2019, at local markets in the nine study sites. Respondents were surveyed opportunistically using snowball sampling, starting first with a durian vendor who then recommended other people known to hunt or consume flying foxes (Image 2). Respondents were then selected based on preliminary questioning to ascertain whether they were: (i) familiar with *P. vampyrus*; (ii) hunters; or (iii) consumers of the species.

Before the questionnaire commenced the respondents were first asked to identify *P. vampyrus* by displaying an image of the species with a corresponding measurement scale to convey size, and this was used to set the benchmark for the reliability of the respondents'

Table 1. Questionnaire used for survey on community knowledge, perceptions and interactions with *Pteropus vampyrus* (referred to as simply 'flying fox' in local languages during interviews) in western Sarawak.

QUESTIONNAIRE
Part 1. Flying Fox Sightings
i) Have you ever seen a flying fox? Yes No
ii) If yes, what type of habitat did you last see a flying fox in? a) Mangrove swamp forest b) Peat swamp forest c) Secondary forest d) Primary forest e) Gardens or field f) River g) Market
iii) If yes, when did the last time you saw a flying fox? a) January–March b) April–June c) July–September d) October–December
iv) Has anyone in the area you reside been hunting flying foxes? Yes No
v) If yes, how many hunters are there? a) 1–3 individuals b) 3–6 individuals c) 6–9 individuals d) 9–12 individuals e) >12 individuals
vi) If yes, how long have you been hunting? a) weeks b) months c) years
Part 2. Flying Fox Hunters and Consumers
(i) Have you ever hunted or killed flying foxes before? Yes No
(ii) If yes, for what purpose? a) Food b) Traditional medicine c) Pest control d) Source of income
(iii) If yes, where did you hunt or kill flying foxes? a) Swamp area b) Coastal area c) Forest edge d) Forest interior e) Fruit orchard f) Rubber plantation g) Oil palm plantation
(iv) If yes, how did you get to the hunting area? a) Boat b) Car c) Lorry d) Motorcycle e) On foot
(v) What method do you use to hunt flying foxes? a) Net b) Shotgun c) Traditional method (stringing up hooks on fishing line) d) Cutting down roost tree
(vi) At what time do you usually hunt flying foxes? a) 0600 hrs–0900 hrs b) 0900 hrs–1200 hrs c) 1200 hrs–1500 hrs d) 1500 hrs–1800hrs e) 1800 hrs–2100 hrs f) 2100 hrs–0000 hrs g) 0000hrs–0300 hrs h) 0300 hrs–0600 hrs
(vii) On average, how much is the total cost of a flying fox hunting trip? a) <RM50 b) RM51–RM100 c) RM101–RM300 d) RM301–RM600 e) RM601–RM1000 f) >RM1000
(viii) On average, how many flying foxes do you catch per hunting trip? a) <10 individuals b) 11–20 individuals c) 21–40 individuals d) 41–60 individuals e) 61–80 individuals f) >80 individuals
(ix) On average, what is the market price of flying fox meat? a) RM10–RM15 b) RM16–RM30 c) RM31–RM60 d) RM61–RM80 e) RM81–RM100 f) RM100–RM120
(x) What motivates you to hunt?
(xi) Do you get moral support from your local community to hunt flying foxes? Yes No
(xii) How does the local community in the area you reside feel about you hunting flying foxes?
(xiii) Have you ever consumed or cooked flying fox meat? Yes No
(xiv) If yes, how did you process the meat?
(xv) If yes, what other ingredients did you mix with the flying fox meat?
(xvi) Which parts of a flying fox are used as traditional medicine?

Part 3. Local perceptions towards flying foxes					
Statements	**Strongly Agree**	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
Occasionally consuming flying fox meat is fine.					
Consuming flying fox meat can cure respiratory ailments.					
Flying foxes can damage agricultural crops.					
Hunting & selling flying foxes can damage their populations in the long term.					
Deforestation causes more negative impacts on flying fox populations compared to hunting activities.					
Sarawak's wildlife law has been effective in protecting flying foxes.					
Flying foxes can be an important aspect in promoting tourism.					
Flying foxes play an important role in dispersing seeds.					
Awareness programs in schools will help to increase efforts to conserve flying foxes.					
Besides the Sarawak wildlife law, flying foxes also need to be protected at the village level.					
There are traditional beliefs or taboos related to flying foxes.					

Image 1. *Pteropus vampyrus* roosting in Peninsular Malaysia.

Image 2. Flying fox meat in Sarawak is considered a delicacy and perceived to have medicinal qualities.

answers. As flying foxes (*Pteropus* spp., *Acerodon* spp., *Desmalopex* spp.) often have specific local names to distinguish them from all other bats (e.g., Tanalgo et al. 2016; Low et al. 2021), wherever applicable we used the relevant local name according to a respondent's ethnicity (Supplementary Table 1).

The questionnaire was administered by three female enumerators, who were all Malaysian students at Universiti Malaysia Sarawak (UNIMAS), via face-to-face interviews conducted in Iban, Melanau, and standard colloquial Malay. Enumerators targeted respondents that were adults, i.e., aged 18 and above. Prior to commencing an interview, the student enumerators first started with an introduction of their background, i.e., UNIMAS students conducting research on flying foxes, and also showed their university student identification cards when introducing themselves. Each question was read aloud by the enumerator to the respondent, and

the respondent's answers were then recorded using the Open Data Kit Collection (ODK) version 1.18.0 application.

This study complies with the research ethics criteria designated by Universiti Malaysia Sarawak (UNIMAS), conducted under research permits NPW.907.4.4(JLD.14)-71 and WL043/2017. Before initiating any interview, the survey purpose and goals were explained first to the respondent, and free, prior, & informed consent (FPIC) was obtained. Respondent identities were kept anonymous, and they were informed of the confidentiality of their identity and information shared. The respondents were also informed in advance that they have the right to choose not to continue with the interview at any time during the process should they feel uncomfortable.

RESULTS

Out of 200 people approached, 123 (40 women and 83 men; Supplementary Table 2) responded. Most of the 38.5% of people who declined to be interviewed claimed not to have any knowledge on the topic, but some appeared to be intimidated. The biggest group (43%) of respondents was those above 55 years old (n= 53). The Iban ethnic group comprised half of all respondents, and 60% of respondents professed Christianity as their religion. A large majority (86%) resided in rural areas, with 72% having received some form of formal education (i.e., school or university), and 37% having received an education beyond primary level (i.e., >12 years old).

Sixty-one percent of respondents were self-employed, owning small businesses such as restaurants, food stalls or wet market stalls. Twenty-one percent were unemployed retirees from either the government or private sector. Sixty-nine percent had an income of less than MYR (Malaysian ringgit) 900 (~USD 213) a month, with their livelihoods dependent on the selling of forest products at markets.

Flying fox sightings

The majority (91%) of respondents were familiar with *Pteropus vampyrus*, with 51% of respondents stating that flying foxes were most commonly found during the fruiting season. Hunters reported that Engkelili, Lingga, Entumpi, Engkalong, Roban, Kampung Temiang, and Simunjan are flying fox hotspots. Seventy-nine percent of respondents stated that the highest occurrence of flying fox sightings was in July–December, with July–September being the most likely time to encounter flying foxes (Figure 2). Fifty-nine percent of respondents stated that flying foxes forage on langsat (*Lansium parasiticum*), rambutan (*Nephelium lappaceum*), and *Syzygium cephalophorum* fruits, and 51% of respondents stated that flying foxes forage on durian (*Durio* spp.) flowers.

Fifty-two percent of respondents stated that flying foxes can be seen in fruit orchards. The species was also reported as being sighted near secondary and primary forests (Figure 3). Three respondents had sighted dead flying foxes being sold at the Pasar Tamu Sri Aman, Pasar Serian, and Pasar Lubok Antu markets. An additional 10% of respondents had sighted flying fox roosting sites,

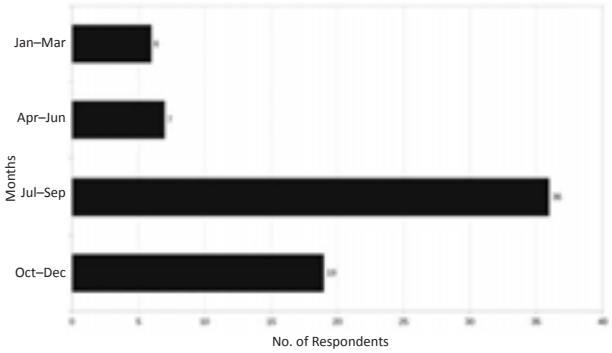

Figure 2. Time of year when *P. vampyrus* is most likely to be encountered according to respondents (n= 68) in western Sarawak, Malaysian Borneo.

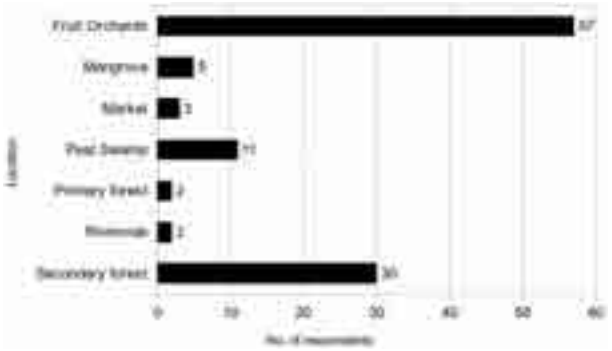

Figure 3. Habitat types where *P. vampyrus* has been sighted by respondents (n= 110) in western Sarawak, Malaysian Borneo.

Table 2. The reported price of *P. vampyrus* meat at the time of last purchase by 23 respondents in western Sarawak, Malaysian Borneo.

Price range per bat (MYR)	Number of Respondents	%
10–15	7	30
16–30	15	65
31–60	1	4

having seen the bats flying near mangrove and peat swamp forests in the Simunjan and Tanjung Manis areas around 20–30 years ago.

Hunting and consumption of flying foxes

Twenty-one percent (n= 51) of respondents were flying fox hunters, but 53% of these hunters no longer hunted due to the difficulty of locating roosting sites (Supplementary Table 3). A slight majority (58%) of hunters hunted flying foxes for food, while 35% hunted because flying foxes were viewed as pests, and the remainder hunted flying foxes for supplementary income. According to 15 respondents, price per bat ranged from MYR 16–30 (approximately USD 4–7) (Table 2), and even the lowest price of MYR 10 (approximately USD 2.50) was higher than the local price of chicken, which is MYR 8.50/kg (approximately USD 2/kg).

Forty-one percent of hunters preferred hunting in groups of 3–6 people, and 83% of hunters preferred hunting from dusk till midnight. Seventy-five percent of hunters stated that they hunted in fruit orchards. The most common hunting technique employed by the hunters was shooting the flying foxes with shotguns (46%), followed by traditional hunting techniques involving hooks and strings (29%). Many (67%) of the hunters reported that they only managed to hunt less than 10 individuals per hunting trip.

Thirty-five percent of respondents had consumed flying foxes before, while the others (65%) who had not, cited a variety of reasons including religious reasons (46%), fear (38%), and a dislike of the smell of flying foxes (16%). Those that consumed flying foxes stated that soups and stews with an assortment of herbs and spices were the main methods (86%) of cooking, whereby the fur is first removed by burning, and the animal is then skinned to eliminate its odour. The carcass (Image 2 is cleansed with either lime juice or tamarind juice to further remove any remaining odour, and the meat is then marinated with lemongrass, ginger, chilli, pepper, garlic, and onion. Some respondents claimed that the wings are a delicacy, with a chewy texture resembling the black fungus (*Auricularia polytricha*).

Our survey also revealed that people who bought flying fox meat preferred it to be as fresh as possible. To meet this demand, hunters string fine-meshed nets over waterways, or above/around fruit trees near their village. This method is the preferred method of Iban hunters, as it is an efficient and common method for capturing live bats to meet consumer demand for freshness. Live flying foxes trapped in the nets are harvested in the morning and brought to the market immediately to be sold, and only killed once a sale is made. Flying foxes caught by nets are sold at higher prices compared to those that are shot, as shot bats have wounds on their wings, and

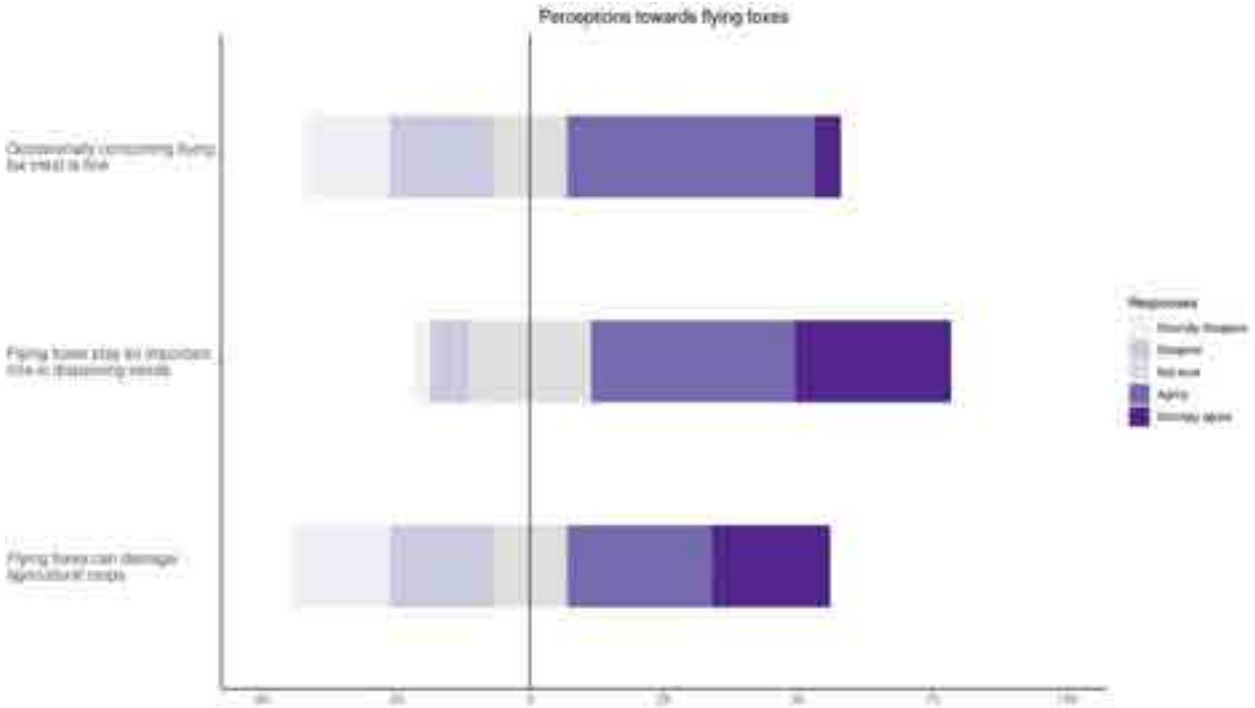

Figure 4. Perceptions of local communities towards flying foxes (*P. vampyrus*) in western Sarawak, Malaysian Borneo (n= 120).

those that survive do not stay alive for long – thereby less desirable to consumers. However, another hunting method, considered to be more traditional, involves stringing up a fishing line tied with large fishing hooks above the canopy of a fruiting or flowering tree. As the bats get caught easily on the hooks during flight, this is sometimes used due to its ffectiveness and low cost, with one hunter reporting that as many as 30 bats could be caught from just one tree in one night using this method.

Perceptions of local communities towards flying foxes

Fifty-one percent of respondents felt that the current consumption of flying fox meat does not negatively impact flying fox populations (Figure 4), although 71% of respondents conceded that hunting and selling of flying fox meat would become a threat in the long term. Sixty-nine percent of respondents believed that deforestation is a bigger threat to flying fox populations compared to hunting. Slightly more than half (55%) of the respondents were unsure of the claimed medicinal properties of flying foxes. For perceptions of flying foxes as agricultural pests, respondents were divided between those perceiving flying foxes to be pests (48%), and those who did not (38%), with the rest being unsure (14%) (Figure 4). Despite this, 66% of the respondents were aware of the role played by flying foxes in seed dispersal (Figure 4). To prevent fruit losses, growers typically set up nets around their fruit trees so that the bats are trapped before reaching the fruits. The nets are often set up in the afternoon, and taken down late at night (0000–0300 h) or the following morning.

Half of all respondents felt that flying foxes could be used to develop local eco-tourism, and 51% of respondents agreed to participate in school events such as talks or seminars conducted by the relevant conservation authorities on the importance of flying foxes. Forty-four percent of respondents believed that flying fox conservation requires management at the village or local community level in order to prevent excessive hunting. Lastly, 39% of respondents felt that the Sarawak Wild Life Ordinance 1998, which makes it illegal to hunt, capture, sell, import or export bats, is ineffective at conserving flying foxes.

DISCUSSION

Our survey has provided important and novel data on the opinion and perceptions of local communities regarding *Pteropus vampyrus* in western Sarawak. To our knowledge, this is the first attempt to collect empirical data on the knowledge and opinions of people in Malaysian Borneo regarding this species. Our study confirmed that hunting and trade of *P. vampyrus* still occurs despite the decline in sightings, and the implementation of legal protection for this species – partly due to cultural beliefs and practices, and partly due to perceptions or experiences of flying foxes as orchard pests. Indeed, the highest occurrence of *P. vampyrus* sightings now coincides with the durian flowering season in Sarawak, and the fruiting seasons of langsat, rambutan, and *Syzygium cephalophorum.* Similar trends in hunting pressure, trade and drivers were reported from Peninsular Malaysia, whereby it was predicted that legal hunting levels alone would lead to species extinction anytime between 6–81 years (Fujita 1988; Epstein et al. 2009; Cantlay et al. 2017).

Trends in hunting and trade

While the scale and intensity of flying fox hunting in western Sarawak do not seem as severe as that previously reported for Kalimantan (Indonesian Borneo; Struebig et al. 2007; Harrison et al. 2011) and Sulawesi (Sheherazade & Tsang 2015), we believe this is likely because intense hunting pressure in the past has already caused drastic population reductions in Sarawak, pushing the species to more remote/inaccessible areas, and rendering it increasingly rare. The beliefs and practices reported in our study support those of other studies across Southeast Asia (Low et al. 2021).

Concurrently, this study also yielded qualitative details that helped to supplement empirical data. For example, during this survey we found that flying fox meat was not commonly seen in markets, but respondents reported it as being easily acquired at the Serian Wet Market. We did find *P. vampyrus* being sold openly at Pasar Tamu Sri Aman, despite hunting and selling of bats being illegal. A stall owner even commented that she could sell as many as 10–15 flying foxes in one single sale. Such information corroborates earlier surveys of wildlife meat availability by TRAFFIC Southeast Asia, that found flying fox meat still available for purchase at certain markets, restaurants and roadside stalls across Sarawak (K. Krishnasamy pers. comm.; Cantlay et al. 2017). This explains why the majority of our respondents felt that legal protection of *P. vampyrus* has not deterred or reduced hunting activity, as there was perceived to be a clear lack of enforcement.

One reason *P. vampyrus* is a highly valued wild meat amongst locals is the belief that it is a remedy for a variety of ailments and diseases, such as asthma, kidney ailments, gynaecological problems, and lung ailments

(Mildenstein et al. 2016; Low et al. 2021). Flying fox liver and bile are also believed to cure asthma. One respondent even claimed that an alcoholic drink made by soaking an infant flying fox in 'langkau' (a particularly potent, locally brewed rice spirit) for a few weeks is an effective cure for asthma if consumed daily. Due to Islamic dietary restrictions, all Muslim respondents stated that it is forbidden for them to consume flying foxes. However, in Sebuyau, one Muslim respondent claimed that it is permissible to consume flying fox if this is done with the intent of curing illnesses, and not to consume it as a delicacy. This suggests that the perceived benefits of flying fox meat, which appears to be a widespread belief across their entire regional distribution (Mildenstein et al. 2016; Low et al. 2021), might be used by some as justification to override religious restrictions or aversions. Indeed, Harrison et al. (2011) reported similar attitudes in Indonesian Borneo, and cautioned that if this widely-held belief regarding health benefits is left unaddressed it would likely cause unsustainable hunting of flying foxes to continue. There is an urgent need to address this belief and practice by conducting community outreach and education for raising awareness, but also to implement targeted intervention strategies that leverage on social psychology approaches for incentivising behavioural change (Kingston 2016; St. John et al. 2018).

Worryingly, unlike in Indonesian Borneo (Harrison et al. 2011), more than half of the respondents did not feel that consumption of flying foxes had a negative impact on flying fox populations. The reason given was the belief that flying foxes breed rapidly, and therefore local hunting would not severely reduce populations, especially since hunting only occurs during the flowering and fruiting seasons. Indeed, almost 70% of the respondents stated that deforestation is a bigger threat due to it being the direct cause of flying fox habitat loss. Scientific research has shown that flying foxes actually have long lifespans and slow reproductive rates, so their populations would take a long time to recover from hunting pressure (Mildenstein et al. 2016). While *Pteropus* flying foxes are easily able to persist in human-dominated areas with sufficient food resources (e.g., Tait et al. 2014; Aziz et al. 2017b), this proximity can render them more accessible and vulnerable to hunters (Chaiyes et al. 2017; Aziz et al. 2021). Also, low abundance of flying foxes can negatively affect their ecological roles, such as seed dispersal in forest ecosystems, long before these populations actually become extinct (McConkey & Drake 2006; Luskin 2010). Therefore, we concur with Harrison et al. (2011) that overhunting remains the biggest threat to this species, and there is an urgent need to communicate such implications of intense or uncontrolled hunting pressure to local communities. Obtaining empirical long-term data on the hunting of flying foxes, and on the ecosystem services they provide, is necessary to ascertain whether current offtake levels are sustainable or not – not just in terms of population numbers, but also in terms of their ecological roles and the wider impact they have on ecosystem health.

Negative interactions due to crop-raiding

Loss (whether real or perceived) of fruits and flowers is clearly a major source of conflict between local fruit growers and flying foxes, and is also a factor driving the hunting of *P. vampyrus* in western Sarawak. Fruit growers stated that economic loss is their main motivation for killing *P. vampyrus*, as it is believed that eradication of this species can prevent such loss. Fruit growers at Pasar Tamu Sri Aman and Pasar Tani Lubok Antu even admitted to doing so despite stating that flying foxes foraging on their fruit trees would help disperse seeds to other areas. Flying foxes were still regarded as fruit pests even amongst fruit growers who acknowledged the bats' role as durian pollinators. This suggests that knowledge of flying fox ecosystem services alone is not enough to prevent killings, and therefore education and awareness-raising must be complemented by enforcement of regulations (e.g., see review by Aziz et al. 2016). Efforts are clearly needed to investigate and quantify fruit/flower losses attributed to *P. vampyrus*, and to trial non-lethal mitigation methods for protecting crops without killing or harming bats. These can be done following some of the potential methods reviewed and summarised by Aziz et al. (2016), but more recent studies have also been conducted for the Madagascan Flying Fox *P. rufus* and the Mauritian Flying Fox *P. niger*, whereby fruit loss from flying foxes was found to be minimal, and the use of organic deterrents, plastic flags, bells, and nylon net bags were found to be effective at reducing feeding in cultivated fruit trees (Raharimihaja et al. 2016; Oleksy et al. 2018; Tollington et al. 2019) .

Support for flying fox conservation

Finally, our survey uncovered some encouraging attitudes towards *P. vampyrus*: even though many respondents viewed flying foxes as pests and/or food, ecological and conservation awareness were relatively high, and there was grassroots-level support among some communities. Slightly more than half of our respondents, comprising hunters, consumers, and fruit growers, were willing to cooperate with wildlife agencies to protect *P.*

vampyrus at the village level to prevent overhunting, as they still perceived flying foxes to be important for seed dispersal or tourism. The same number also agreed to participate in school events aimed at conserving flying foxes, as they believed these events are important for educating the younger generation on the importance of biodiversity conservation, and the ecosystem services provided by flying foxes. When asked further, these respondents mentioned that they were willing to attend conservation education programmes for communities in rural areas, such as talks or seminars on flying foxes. Those that strongly disagreed to participate in awareness programs stated that they didn't see the point of such efforts due to the fact that *P. vampyrus* numbers are now too low – suggesting that further efforts are needed to convince them that appropriate conservation interventions can indeed be effective. However, those that were unsure about participating said that they felt so because they were still unsure about the importance of flying foxes. This group of people clearly needs to be targeted as a priority audience for awareness and education campaigns.

Our results suggest that there is some support for flying fox conservation amongst local communities, as almost half of the respondents felt that *P. vampyrus* can be an iconic species for ecotourism, particularly if there are protected areas to safeguard populations. Those who disagreed provided mixed reasons; some stated that population numbers are so greatly reduced that it would be difficult to view the species in the wild, whereas others feared or viewed flying foxes as gruesome, and therefore did not see any ecotourism potential. Given that this species was traditionally respected and even revered in local Malaysian cultures (Low et al. 2021), it is unclear where such negative perceptions come from. As noted from other countries, properly managed and regulated bat tourism can indeed serve as an effective strategy for bat conservation (Pennisi et al. 2004; Aziz et al. 2017b; Tanalgo & Hughes 2021). A sustained effort to revive positive local beliefs and imagery related to flying foxes, possibly in the form of Conservation Pride campaigns (Butler et al. 2013; de Pinho et al. 2014), could potentially help overcome such aversions by creating a mere-exposure effect (Zajonc 2001), hopefully predisposing both locals and tourists to start viewing bats positively.

CAVEATS AND RECOMMENDATIONS

Many of the respondents appeared to be candid in their comments, although on several occasions when they felt intimidated or suspected the enumerator to be a government official, they became very reluctant to provide details on the quantities and capture locations of flying foxes that were hunted and sold. Indeed, only 61.5% of the 200 people we approached agreed to be interviewed, and some who declined could have done so due to fear. As flying foxes are protected in Sarawak, hunting and consumption are illegal, and thus it is possible that some people did not want to participate in the survey because they feared their identity could be leaked to the authorities.

This underscores the difficulty of obtaining accurate data on flying fox hunting and trade, and highlights the need to employ more appropriate survey methods to reduce social desirability bias when asking sensitive questions that seek to understand illicit behaviour (Nuno & St. John 2015; Mildenstein et al. 2016). A more suitable approach for wildlife conservation research, such as the unmatched count technique, should be explored in future work (Hinsley et al. 2019). Additionally, the current COVID-19 situation has introduced new complexities with regards to wildlife hunting and trade, as fears of disease risk could potentially reduce such activities (Low et al. 2021), but at the same time sensationalist media reports have increased negative perceptions of bats amongst the general public (Zhao 2020; Rocha et al. 2021). Since COVID-19 could potentially erode public support for bat conservation (Rocha et al. 2020), follow-up surveys are vital.

Although our results are preliminary, the information uncovered by our exploratory survey is a useful first step to provide a better understanding of the current situation, which will be important for guiding appropriate conservation strategies for the species and its habitats. We hope that both the quantitative and qualitative data yielded by this study will prove useful in helping to direct future efforts to conserve flying foxes in Sarawak, and also provide helpful insights for flying fox conservation efforts elsewhere.

REFERENCES

Altringham, J.D. (1996). *Bats: Biology and Behaviour.* Oxford University Press, New York, 262pp.

Aziz, S.A., K.R. McConkey, K. Tanalgo K., T. Sritongchuay, M-R. Low, J.Y. Yong, T.L. Mildenstein, C.E. Nuevo-Diego, V.C. Lim & P.A. Racey (2021). The critical importance of Old World fruit bats for healthy

ecosystems and economies. *Frontiers in Ecology and Evolution* 9: 641411. https://doi.org/10.3389/fevo.2021.641411

Aziz, S.A., K.J. Olival, S. Bumrungsri, G.C. Richards & P.A. Racey (2016). The conflict between pteropodid bats and fruit growers: species, legislation and mitigation, pp. 377–426. In: Voigt, C.C. & T. Kingston (eds). *Bats in the Anthropocene: Conservation of Bats in a Changing World*. SpringerOpen. https://doi.org/10.1007/978-3-319-25220-9_13

Aziz, S.A., G.R. Clements, K.R. McConkey, T. Sritongchuay, S. Pathil, M.N.H. Abu Yazid, A. Campos-Arceiz, P-M. Forget & S. Bumrungsri (2017a). Pollination by the locally endangered island flying fox (*Pteropus hypomelanus*) enhances fruit production of the economically important durian (*Durio zibethinus*). *Ecology and Evolution* 7(21): 8670–8684. https://doi.org/10.1002/ece3.3213

Aziz, S.A., G.R. Clements, X. Giam, P-M. Forget & A. Campos-Arceiz (2017b). Coexistence and conflict between the Island Flying Fox (*Pteropus hypomelanus*) and humans on Tioman Island, Peninsular Malaysia. *Human Ecology* 45(3): 377–389. https://doig.org/10.1997/s10745-017-9905-6

Aziz, S.A., M-R. Low & G.R. Clements (2019). *A Conservation Roadmap for Flying Foxes* Pteropus *spp. in Peninsular Malaysia*. Rimba, Kuala Lumpur, 40 pp.

Bates, P., C. Francis, M. Gumal, S. Bumrungsri, J. Walston, L. Heaney & T. Mildenstein (2008). *Pteropus vampyrus*. In: IUCN 2008. IUCN Red List of Threatened Species. Accessed on 24 November 2020. https://doi.org/10.2305/IUCN.UK.2008.RLTS.T18766A8593657

Bumrungsri, S., E. Sripaoraya, T. Chongsiri, K. Sridith & P.A. Racey (2009). The pollination ecology of durian (*Durio zibethinus*, Bombacaceae) in southern Thailand. *Journal of Tropical Ecology* 25(1): 85–92. https://doi.org/10.1017/S0266467408005531

Butler, P., K. Green & D. Galvin (2013). *The Principles of Pride: The Science Behind the Mascots.* RARE, Arlington, 81 pp.

Cantlay, J.C., D.J. Ingram & A.L. Meredith (2017). A review of zoonotic infection risks associated with the wild meat trade in Malaysia. *EcoHealth* 14(2): 361–388. https://doi.org/10.1007/s10393-017-1229-x

Chaiyes, A., P. Duengkae, S. Wacharapluesadee, N. Pongpattananurak, K.J. Olival & T. Hemachudha (2017). Assessing the distribution, roosting site characteristics, and population of *Pteropus lylei* in Thailand. *Raffles Bulletin of Zoology* 65: 670–680. http://zoobank.org/References/CD1BC57B-FA8A-4E1F-9A5C-E042659CB8C6

de Pinho, J. R., C. Grilo, R.B. Boone, K.A. Galvin & J.G. Snodgrass (2014). Influence of Aesthetic Appreciation of Wildlife Species on Attitudes Towards their Conservation in Kenyan Agropastoralist Communities. *PLoS ONE* 9: e88842. https://doi.org/10.1371/journal.pone.0088842

Department of Statistics Malaysia (2010). *Population distributions and basic demographics characteristic.* Retrieved on 24 November 2020 from: https://web.archive.org/web/20140522234002/http://www.statistics.gov.my/portal/download_Population/files/census2010/Taburan_Penduduk_dan_Ciri-ciri_Asas_Demografi.pdf

Department of Statistics Malaysia (2019). *Statistics Yearbook Sarawak.* (Publication No. ISSN 0128-7613). Retrieved on 24 November 2020 from: https://newss.statistics.gov.my/newssportalx/ep/epFreeDownloadContentSearch.seam?cid=60237

Epstein, J.H., K.J. Olival, J.R.C. Pulliam, C. Smith, J. Westrum, T. Hughes, A.P. Dobson, A. Zubaid, S.A. Rahman, M.M. Basir & H.E. Field (2009). *Pteropus vampyrus*, a hunted migratory species with a multinational home-range and a need for regional management. *Journal of Applied Ecology* 46(5): 991–1002. https://doi.org/10.1111/j.1365-2664.2009.01699.x

Fitzgibbon, S.I. & D.N. Jones (2006). A community-based wildlife survey: The knowledge and attitudes of residents of suburban Brisbane, with a focus on bandicoots. *Wildlife Research* 33(3): 233. https://doi.org/1071/wr04029

Forest Department of Sarawak (2020). *Facts and Figures.* https://forestry.sarawak.gov.my/page-0-0-1170-FACTS-FIGURES.html

Fujita, M. (1988). Flying foxes and economics. *BATS* 6(1): 4–9. https://www.batcon.org/article/flying-foxes-and-economics/

Fujita, M.S. & M.D. Tuttle (1991). Flying Foxes (Chiroptera: Pteropodidae): Threatened animals of key ecological and economic importance. *Conservation Biology* 5(4): 455–463. https://doi.org/10.1111/j.1523-1739.1991.tb00352.x

Gumal, M., S. Jamahari, M.I. Abdullah, C.J. Brandah, M.K. Abdullah & A.R. Pawi (1997). The ecology and role of the large flying fox (*Pteropus vampyrus*) in Sarawakian rain forests. *Hornbill* 1: 32–47.

Gumal, M.T. (2001). Ecology and conservation of a fruit bat in Sarawak, Malaysia. PhD Thesis. Department of Anatomy, University of Cambridge, 234 pp.

Harrison, M.E., S.M. Cheyne, F. Darma, D.A. Ribowo, S.H. Limin & M.J. Struebig (2011). Hunting of flying foxes and perception of disease risk in Indonesian Borneo. *Biological Conservation* 144(10): 2441–2449. https://doi.org/10.1016/j.biocon.2011.06.021

Hazebroek, H. P. & A. M. Abang Kashim (2000). *National Park of Sarawak.* Kota Kinabalu: Natural History Publications (Borneo).

Hinsley, A., A. Keane, F.A.V. St. John, H. Ibbett & A. Nuno (2019). Asking sensitive questions using the unmatched count technique: Applications and guidelines for conservation. *Methods in Ecology and Evolution* 10(3): 308–319. https://doi.org/10.1111/2041-210X.13137

Kingston, T. (2016). Cute, creepy, or crispy – how values, attitudes, and norms shape human behavior towards bats, pp. 571–595. In: Voigt, C.C. & T. Kingston (eds). *Bats in the Anthropocene: Conservation of Bats in a Changing World*. SpringerOpen. https://doi.org/10.1007/978-3-319-25220-9_18

Kunz, T.H., E. Braun de Torrez, D. Bauer, T. Lobova T. & T.H. Fleming (2011). Ecosystem services provided by bats. *Annals of the New York Academy of Sciences* 1223(1): 1-38. https://doi.10.1111/j.1749-6632.2011.06004.x

Low, M-R., Z.H. Wong, S. Shen, B. Murugavel, N. Mariner, L.M. Paguntalan, K. Tanalgo, M.M. Aung, Sheherazade, L.A. Bansa, T. Sritongchuay, J. Preble & S.A. Aziz (2021). Bane or blessing? Reviewing cultural values of bats across the Asia-Pacific region. *Journal of Ethnobiology* 41(1): 18–34. https://doi.org/10.2993/0278-0771-41.1.18

Luskin, M.S. (2010). Flying foxes prefer to forage in farmland in a tropical dry forest landscape mosaic in Fiji. *Biotropica* 42(2) 246–250. https://doi.org/10.1111/j.1744-7429.2009.00577.x

McConkey, K.R. & D.R. Drake (2006). Flying foxes cease to function as seed dispersers long before they become rare. *Ecology* 87(2): 271–276. https://doi.org/10.1890/05-0386

Mohd-Azlan, J., A. Zubaid & T.H. Kunz (2001). Distribution, relative abundance and conservation status of large flying fox, *Pteropus vampyrus* in Peninsular Malaysia: A preliminary assessment. *Acta Chiropterologica* 3(2): 149–162.

Mohd-Azlan, J. & M.F. Fauzi (2006). Ethnozoological survey in selected areas in Sarawak. *Sarawak Museum Journal*. LXII(83): 185–200.

Mildenstein, T., I. Tanshi & P.A. Racey (2016). Exploitation of bats for bushmeat and medicine, pp. 325–375. In: Voigt, C.C. & T. Kingston (eds). *Bats in the Anthropocene: Conservation of Bats in a Changing World*. SpringerOpen. https://doi.org/10.1007/978-3-319-25220-9_12

Nuno, A. & F.A. St John (2015). How to ask sensitive questions in conservation: A review of specialized questioning techniques. *Biological Conservation* 189: 5–15. https://doi.org/10.1016/j.biocon.2014.09.047

Oleksy, R.Z., C.L. Ayady, V. Tatayah, C. Jones, J.S.P. Froidevaux, P.A. Racey & G. Jones (2018). The impact of the endangered Mauritian flying fox *Pteropus niger* on commercial fruit farms and the efficacy of mitigation. *Oryx* 55(1): 114–121. https://doi.org/10.1017/S0030605318001138

Pennisi, L.A., S.M. Holland & T.V. Stein (2004). Achieving Bat Conservation Through Tourism. *Journal of Ecotourism* 3(3): 195–207. https://doi.org/10.1080/14664200508668432

PERHILITAN (2017). *Red List of Mammals for Peninsular Malaysia. Version 2.0*. Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN), Kuala Lumpur, 206 pp.

Raharimihaja, T.E.A., J.L.M. Rakotoarison, P.A. Racey & R.A.

Andrianaivoarivelo (2016). A comparison of the effectiveness of methods of deterring pteropodid bats from feeding on commercial fruit in Madagascar. *Journal of Threatened Taxa* 8(13): 9512–9524. https://doi.org/10.11609/jott.2688.8.13.9512-9524

Rocha, R., S.A. Aziz, C.E. Brook, W.D. Carvalho,R. Cooper-Bohannon, W.F. Frick, J.C.-C. Huang, T. Kingston, A.L. López-Baucells, B. Maas, F. Mathews, R.A. Medellin, K.J. Olival, A.J. Peel, R.K. Plowright, O. Razgour, H. Rebelo, L. Rodrigues, S.J. Rossiter, D. Russo, T.M. Straka, E.C. Teeling, T. Treuer, C.C. Voigt & P. Webala (2020). Bat conservation and zoonotic disease risk: a research agenda to prevent misguided persecution in the aftermath of COVID-19. *Animal Conservation* 24(3): 303–307. https://doi.org/10.1111/acv.12636

Rocha, R., A. López-Baucells & Á. Fernández-Llamazares (2021). Ethnobiology of Bats: Exploring Human-Bat Inter-Relationships in a Rapidly Changing World. *Journal of Ethnobiology* 41(1): 3–17. https://doi.org/10.2993/0278-0771-41.1.3

Sheherazade & S.M. Tsang (2015). Quantifying the bat bushmeat trade in North Sulawesi, Indonesia, with suggestions for conservation action. *Global Ecology and Conservation* 3: 324–330. https://doi.org/10.1016/j.gecco.2015.01.003

Sheherazade, H.K. Ober & S.M. Tsang (2019). Contributions of bats to the local economy through durian pollination in Sulawesi, Indonesia. *Biotropica* 51(6): 913-922. https://doi.org/10.1111/btp.12712

St. John, F.A., M. Linkie, D.J. Martyr, B. Milliyanawati, J.E. McKay, F.M. Mangunjaya, N. Leader-Williams & M.J. Struebig (2018). Intention to kill: Tolerance and illegal persecution of Sumatran tigers and sympatric species. *Conservation Letters* 11(4): p.e12451. https://doi.org/10.1111/conl.12451

Struebig, M.J., M.E. Harrison, S.M. Cheyne & S.H. Limin (2007). Intensive hunting of large flying foxes *Pteropus vampyrus natunae* in Central Kalimantan, Indonesian Borneo. *Oryx* 41(3): 390–393. https://doi/org/10.1017/S0030605307000310

Tait, J., H.L. Perotto-Baldivieso, A. McKeown & D.A. Westcott (2014). Are flying-foxes coming to town? Urbanisation of the spectacled flying-fox (*Pteropus conspicillatus*) in Australia. *PloS One* 9: e109810. https://doi.org/10.1371/journal.pone.0109810

Tanalgo, K.C., R.D. Teves, F.R.P. Salvaña, R.E. Baleva & J.A.G. Tabora (2016). Human-bat interactions in caves of South Central Mindanao, Philippines. *Wildlife Biology in Practice* 12(1): 1–14. https://doi.org/10.2461/wbp.2016.12.2

Tanalgo, K. & A.C. Hughes (2021). The potential of bat-watching tourism in raising public awareness towards bat conservation in the Philippines. *Environmental Challenges* 4: 100140. https://doi.org/10.1016/j.envc.2021.100140

Tollington, S., Z. Kareemun, A. Augustin, K. Lallchand, V. Tatayah, V. & A. Zimmermann (2019). Quantifying the damage caused by fruit bats to backyard lychee trees in Mauritius and evaluating the benefits of protective netting. *PLOS ONE* 14: e0220955. https://doi.org/10.1371/journal.pone.0220955

Zajonc, R.B. (2001). Mere Exposure: A Gateway to the Subliminal. *Current Directions in Psychological Sciences* 10(6): 224–228. https://doi.org/10.1111/1467-8721.00154

Zhao, H. (2020). COVID-19 drives new threat to bats in China. *Science* 367(6485): 1436–1436. https://doi.org/ 10.1126/science.abb3088

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Supplementary Table 1. 'Flying Fox' in local Sarawakian languages.

Ethnic group	Local names for flying foxes
Iban	Entambah/Semawak
Malay	Keluang
Salako	Ka'uangk
Bidayuh	Jingawat
Melanau	Keluang/Nawai

Supplementary Table 2. Socio-demographic characteristics of respondents in the study area, western Sarawak, Malaysian Borneo.

Characteristics	Number of Respondents	%
Gender		
Male	83	68
Female	40	32
Age range		
<21	1	1
22-34	10	8
35-44	19	15
45-54	40	33
≥55	53	43
Religion		
Christian	74	60
Muslim	37	30
Buddhist	5	4
Atheist	4	3
Taoist	1	1
Bahai	2	2
Ethnicity		
Iban	62	50
Malay	26	21
Chinese	7	6
Bidayuh	8	7
Selako	13	11
Melanau	7	6
Others	1	1
Working Sector		
Unemployed	26	21
Self-employed	75	61
Employed in the government sector	7	6
Employed in the private sector	15	12
Income		
<RM999	85	69
RM1000-2499	32	26
RM2500-3500	4	3
>RM10000	2	2
Residency Area		
City	1	1
Town	16	13
Rural	106	86
Education		
No formal education	34	28
Primary school	33	27
Secondary school	46	37
Post-school skill certificate	5	4
Pre-university foundation course	2	2
Diploma	3	2

Supplementary Table 3. *P. vampyrus* hunting activities in the study area, western Sarawak, Malaysian Borneo.

Details	Number of Respondents	%
Hunting experience		
Have more than a year of experience	24	100
Number of hunters in a group		
1-3 person/s	10	42
3-6 people	10	42
6-9 people	2	8
9-12 people	1	4
>12	1	4
Time of the hunt		
0600hrs-0900hrs	2	8
1800hrs-2100hrs	8	34
2100hrs-0000hrs	12	50
0000hrs-0300hrs	1	4
0300hrs-0600hrs	1	4
Hunting area		
Swamp area	1	4
Forest edge	5	21
Fruit orchard	18	75
Transportation		
Car	1	4
Motorcycle	7	29
On foot	16	67
Hunting Method		
Net techniques	6	25
Shot gun	11	46
Traditional methods	7	29
Cost of hunting tools		
<MYR 50	16	67
MYR 51-100	5	21
MYR 101-300	3	12
Average number of individual bats caught		
≤10	16	67
11-20	6	25
21-40	2	8
Hunting purpose		
Food	13	54
Pest	9	38
Source of income	2	8

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COMMUNICATION

Macrolichens of Mathikettan Shola National Park, Western Ghats: a preliminary investigation with some new records

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Abstract: An extensive survey of lichens was conducted in different parts of Mathikettan Shola National Park, and analysed 55 macrolichen species under six families. Two species were found to be new to the Indian peninsula, and five species were new to the lichen flora of Kerala.

Keywords: Biodiversity, Corticolous, Foliose, Fruiticose, lichens, Kerala, Idukki, new reports, Saxicolous.

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Author contributions: AAK—conceptualization, performed field collection, formal analysis, writing original draft; SS—supervision, review, provided proper guidelines for the research; AC—review and editing draft; ASM—editing draft.

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INTRODUCTION

Mathikettan Shola National Park (MSNP, 9.950–10.010 N and 76.23–77.26 E), located in the high ranges of southern Western Ghats with an area of 1,282 ha falls under Poopara village of Ubumbanchola taluk in Idukki district, Kerala (Image 1). Altitude of the area ranges from 1,200–1,984 m in the highest peak—Kattamala—of the national park. The area represents a unique montane evergreen forest ecosystem with several endemic species—63 species of trees, 163 herbs and shrubs, and 15 species of climbers (Management Plan MSNP 2009).

The climatic conditions and the presence of forests intermingled with grasslands make MSNP suitable for the luxurious growth of lichens. However, to date no substantial work on lichens has reported on this unique area. Fragmentary lichen collections from different parts of Kerala (Kumar et al. 1999, 2000; Biju et al. 2010, 2012, 2014; Sonia et al. 2018, 2020) have not covered several interesting areas, including Wildlife Sanctuaries, national parks, mangrove forests, and cultivated areas (Sequiera 2003, 2005, 2008; Kumar et al. 2008). This report presents preliminary observations of macrolichens from a hitherto unrecorded area of MSNP, Idukki, Kerala.

MATERIALS AND METHODS

Data collection: An extensive survey of lichens was conducted in different parts of MSNP during the period of June 2019 to February 2020. Collection was made from Choondal (1,200–1,600 m), Karadippara (1,200 m), and Shivanpara (1,400 m) area of the national park. Substrate of collection, altitude and names of trees along with the lichen population was noted from each locality. The collected specimens were numbered, air dried and herbariums were prepared as per the standard method.

Identification: Collected specimens were identified based on morphological observation and comparison with published keys and descriptions (Awasthi 2007; Mishra & Upreti 2017). Species confirmation was done using various chemical colour tests such as potassium hydroxide (K), paraphenylene diamine (P), calcium hypochlorite (C), potassium iodide and thin layer chromatography (TLC) using a solvent containing toluene, dioxane, and acetic acid (TDA).

RESULTS AND DISCUSSION

More than 500 specimens were collected from the study area in MSNP. Critical analysis of the specimens revealed 55 macrolichen species under 17 genera belonging to six families; eight species were fruticose (13%) and 47 (87%) were foliose in nature. There was a maximum diversity of corticolous lichens represented by 47 species (87%), with the rest being saxicolous in nature (13%). Numerical representation of the taxa recorded is presented in Table 1. Family Parmeliaceae was predominant with 25 species from seven genera, followed by Physciaceae with 11 species from two genera, Peltigeraceae with nine species from three genera, Collemataceae with four species from two genera, Coccocarpiaceae with three species from one genus, and Ramalinaceae with one species. Among 17 genera, *Parmotrema* and *Heterodermia* were found to be dominant in the study area with nine species each followed by *Usnea* (6 species), *Sticta*, *Psuedocyphellaria* and *Hypotrachyna* with four species each, *Coccocarpia*, *Ramalina* and *Leptogium* with two species each, *Phaeophyscia*, *Xanthoparmelia* and *Canoparmelia* with two species each, *Lobaria, Collema, Physcia, Myelochroa, Parmelina* with one species each. Among the 55 species reported from the national park, two species were new to peninsular India and five species were found to be new to the lichen flora of Kerala.

New reports of lichens to Peninsular India

1. *Leptogium furfuraceum* (Harm.) Sierk.

Thallus corticolous, weekly adnate, dark brown to slate gray, lobes flabellate to orbicular, 3–5 cm wide, margins entire to lacerate; upper surface distinctly wrinkled, isidiate; isidia globular to clavate, laminal to marginal; lower surface with white tomentose on lower surface; apothecia absent (Image 2).

Specimen examined: India, Kerala, Idukki, Mathikettan Shola National Park, 10.009N to 77.239E, 1,458 m, on bark, July, Aswathi Anilkumar (2442).

The species has an earlier record from Uttarakhand state (Awasthi 2007). The present collection shows its extended distribution in peninsular India.

2. *Parmelina usambarensis* (Steiner & Zahlbr.) Hale

Thallus saxicolous, loosely attached on rock, whitish mineral grey, 3–5 cm across; lobes sublinear to rotund, 5–6 mm wide, divaricately branched, ciliate, sparsely to densely isidiate; isidia cylindrical, simple to branched; medulla white; lower surface shiny black, rhizines black, simple, 1 mm long; apothecia not present (Image 3).

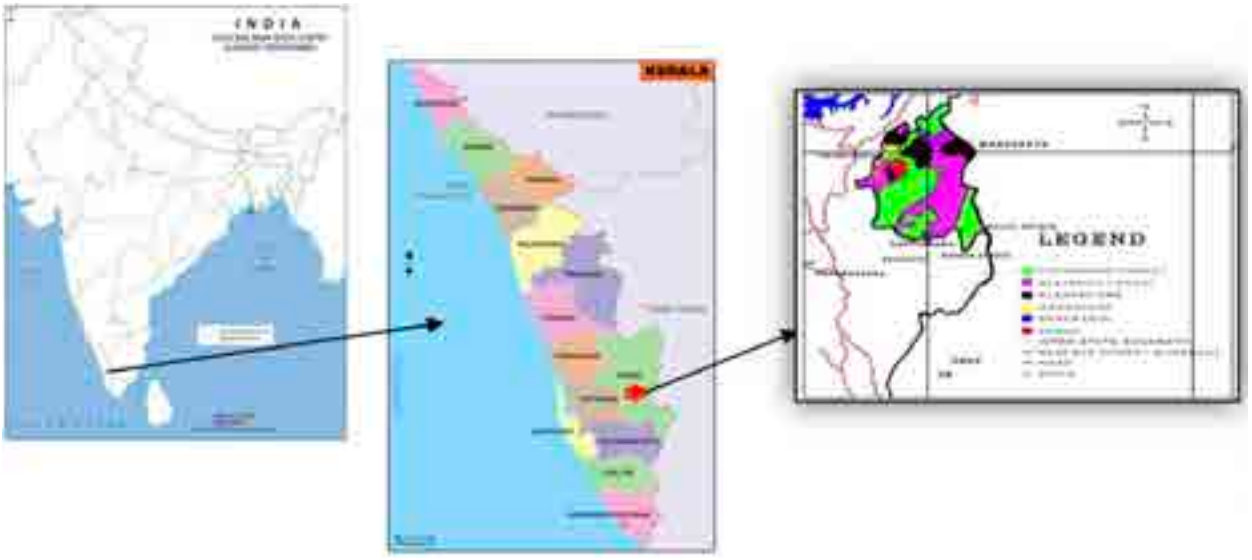

Image 1. Vegetative map of study area. Map source: www.mapsofindia.com; www.infoandopinion.com

Cortex K^+ yellow; medulla K^+ red, C^-, KC^-, P^+ red.

Specimen examined: India, Kerala, Idukki, Mathikettan Shola National Park, 10.009N to 77.245E, 1,603 m, on rock, July, Aswathi Anilkumar (2436).

This species has been reported earlier from eastern Himalaya and from Manipur state. The present collection from the study area shows its distribution in peninsular India.

New reports of lichen from Kerala

1. *Xanthoparmelia congensis* (Stein) Hale

Thallus saxicolous, very tightly adnate to the rock, foliose but centrally subcrustose, 1.5–4 cm across; lobes sub dichotomously branched, sublinear, 0.05–0.4mm wide; upper side greenish yellow, shiny at apices, dull at the center, aeriolate, isidiate; isidia pale, simple, globose often bursting open at top not forming soredia; medulla white; apothecia not seen, lower side black, shiny, rhizinate; apothecia not seen (Image 4).

Medulla K^+ yellow, C^-, KC^-, P^+ dark orange; stictic, constictic, and norstictic acid present.

Specimen examined: India, Kerala, Idukki, Mathikettan Shola National Park, 10.009N to 77.242E, 1,603 m, on rock, July, Aswathi Anilkumar (2498).

Found distributed in the state of Karnataka, Madhya Pradesh, Tamil Nadu, and Uttarakhand. The present collection confirms its extended distribution to the state of Kerala.

2. *Xanthoparmelia psuedocongensis* Hale

Thallus saxicolous, subcrustose, very tightly adnate to the substratum, 7c m across; lobes sublinear to rotund, 0.7–0.9 mm wide, black rimmed; upper surface yellowish-green, shiny in periphery, dull in center, isidiate; isidia cylindrical, simple, black tipped; medulla white; lower surface black, shiny, rhizinate, rhizines black. Apothecia absent (Image 5).

Cortex K^-; Medulla K^+ yellow, C^-, KC^-, P^+ orange; Stictic, Constictic and norstictic acid present.

Specimen examined: India, Kerala, Idukki, Mathikettan Shola National Park, 10.006N to 77.243E 1,582 m, on rock, July, Aswathi Anilkumar & Stephen Sequeira (2497).

Recorded from Madhya Pradesh and Rajasthan.

3. *Parmotrema chinense* (Osbeck) Hale & Ahti

Corticolous, less adnate, 3–5 cm across; lobes irregular, 1–4 mm wide; upper surface white grey to dark grey, margins entire, ciliate, emaculate, smooth, sorediate; Soredia marginal to submarginal; medulla white; lower surface black in centre, shiny, rhizinate, brown towards margin, erhizinate; apothecia not seen (Image 6).

Cortex K^+ yellow, medulla K^+ yellow, C^-, KC^-, P^+ pale orange; atranorin, stictic, and constictic acids present.

Specimen examined: India, Kerala, Idukki, Mathikettan Shola National Park, 10.008N to 77.245E, 1,606 m, on bark, July, Aswathi Anilkumar (2427).

Awasthi (2007) reported the occurrence of this species from Nilgiri and Palni hills of Tamil Nadu. The present collection confirms its extended distribution to the state of Kerala.

Image 2–8. New reports to lichen flora of peninsular India and Kerala: 2—*Leptogium furfuraceum* | 3—*Parmelina usambarensis* | 4—*Xanthoparmelia congensis* | 5—*Xanthoparmelia psuedocongensis* | 6—Parmotrema chinense | 7—Sticta duplolimbata | 8—*Lobaria japonica*. © Aswathi Anilkumar and Stephen Sequeira.

Table 1. Enumeration of macro lichens from Mathikettan Shola National Park.

	Species	Family	Thallus type and substratum
1	*Coccocarpia palmicola* (Spreng.) Arvidss. & D.J. Galloway	Coccocarpiaceae	Foliose Saxicolous
2	*Coccocarpia pellita* (Ach.) Mull. Arg. Em. R. Sant.	Coccocarpiaceae	Foliose Saxicolous
3	*Coccocarpia sp.*	Coccocarpiaceae	Foliose Saxicolous
4	*Collema auriforme* (With.) Coppins & J.R. Laundon	Collemataceae	Foliose Corticolous
5	*Leptogium cyanescens* (Rabenh.) Körb.	Collemataceae	Foliose Corticolous
6	*Leptogium marginella* (Sw.) Gray	Collemataceae	Foliose Corticolous
7	Lobaria japonica (Zahlbr). Asahina	Peltigeraceae	Foliose Corticolous
8	*Psuedocyphellaria argyraceae* (Bory ex Delise) Vain.	Peltigeraceae	Foliose Corticolous
9	*Psuedocyphellaria aurata* (Sm. Ex Ach.) Vain	Peltigeraceae	Foliose Corticolous
10	*Psuedocyphellaria* ceylonensis H. Magn.	Peltigeraceae	Foliose Corticolous
11	*Psuedocyphellaria crocata* (L.) Vain	Peltigeraceae	Foliose Corticolous
12	*Psuedocyphellaria intricata* (Delise) Vain	Peltigeraceae	Foliose Corticolous
13	*Sticta duplolimbata* (Hue) Vain.	Peltigeraceae	Foliose Corticolous
14	*Sticta limbata* (Sm.) Ach	Peltigeraceae	Foliose Corticolous
15	*Sticta orbicularis* (R. Br.) Hue	Peltigeraceae	Foliose Corticolous
16	*Sticta weigelii* (Ach.) Vain.	Peltigeraceae	Foliose Corticolous
17	*Canoparmelia pustulescence* (Kurok.) Elix	Parmeliaceae	Foliose Corticolous
18	*Canoparmelia texana* (Tuck.) Elix & Hale	Parmeliaceae	Foliose Corticolous
19	*Hypotrachyna cirrhata* (Fr.) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Parmeliaceae	Foliose Corticolous
20	*Hypotrachyna dactylifera* (Vain.) Hale	Parmeliaceae	Foliose Corticolous
21	*Hypotrachyna infirma* (Kurok.) Hale	Parmeliaceae	Foliose Corticolous
22	*Hypotrachyna nepalense* (Taylor) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Parmeliaceae	Foliose Corticolous
23	*Myelochroa xantholepis* (Mont. & Bosch) Elix & Hale	Parmeliaceae	Foliose Corticolous
24	*Parmelina usambarensis* (Steiner & Zahlbr.) Hale	Parmeliaceae	Foliose Saxicolous
25	*Parmotrema chinense* (Osbeck) Hale & Ahti	Parmeliaceae	Foliose Corticolous
26	*Parmotrema indicum* Hale	Parmeliaceae	Foliose Corticolous
27	*Parmotrema tinctorum* (Despr. ex Nyl) Hale	Parmeliaceae	Foliose Corticolous
28	*Parmotrema reticulatum* (Taylor) Choisy	Parmeliaceae	Foliose Corticolous
29	*Parmotrema crinitum* (Ach.) Choisy	Parmeliaceae	Foliose Corticolous
30	*Parmotrema praesorediosum* (Nyl.) Hale	Parmeliaceae	Foliose Corticolous
31	*Parmotrema hababianum* (Gyeln.) Hale	Parmeliaceae	Foliose Corticolous
32	*Parmotrema cristiferum* (Taylor) Hale	Parmeliaceae	Foliose Corticolous
33	*Parmotrema stuppeum* (Taylor) Hale	Parmeliaceae	Foliose Corticolous
34	*Usnea baileyi* (Stirt.) Zahlbr.	Parmeliaceae	Fruticose Corticolous
35	*Usnea rigidula* (Stirt.) G. Awasthi	Parmeliaceae	Fruticose Corticolous
36	*Usnea thomsonii* Stirt.	Parmeliaceae	Fruticose Corticolous
37	*Usnea pectinate* Taylor	Parmeliaceae	Fruticose Corticolous
38	*Usnea picta* (J. Steiner) Mot.	Parmeliaceae	Fruticose Corticolous
39	*Usnea subflorida* (Zahlbr.) Mot.	Parmeliaceae	Fruticose Corticolous
40	*Xanthoparmelia congensis* (B. Stein) Hale	Parmeliaceae	Foliose Saxicolous
41	*Xanthoparmelia psuedocongensis* Hale	Parmeliaceae	Foliose Saxicolous
42	*Heterodermia boryi* (Fée) Kr.P. Singh & S.R. Singh	Physciaceae	Foliose Corticolous
43	*Heterodermia comosa* (Eschw.) Follman & Redon	Physciaceae	Foliose Corticolous
44	*Heterodermia hypocaesia* (Yasuda) D.D. Awasthi	Physciaceae	Foliose Corticolous
45	*Heterodermia incana* (Stirton) D. D. Awasthi	Physciaceae	Foliose Corticolous
46	*Heterodermia isidiophora* (Vain.) D.D. Awasthi	Physciaceae	Foliose Corticolous
47	*Heterodermia japonica* (Sato) Swinsc. & Krog	Physciaceae	Foliose Corticolous
48	*Heterodermia obscurata* (Nyl.) Trevis.	Physciaceae	Foliose Corticolous
49	*Heterodermia speciosa* (Wulf.) Trevis.	Physciaceae	Foliose Corticolous
50	*Heterodermia togashii* (Kurok.) D.D. Awasthi	Physciaceae	Foliose Corticolous
51	*Pheophyscia hispidula* (Ach.) Moberg	Physciaceae	Foliose Corticolous
52	*Pheophyscia orbicularis* (Neck.) Moberg	Physciaceae	Foliose Corticolous
53	*Physcia tribacoides* Nyl.	Physciaceae	Foliose Saxicolous
54	*Ramalina conduplicans* Vain.	Ramalinaceae	Fruticose Corticolous
55	*Ramalina pacifica* Asahina	Ramalinaceae	Fruticose Corticolous

4. *Sticta duplolimbata* (Hue) Vain.

Corticolous thallus, photobiont cyanobacterium, holdfast seen, foliose, 4–5 cm wide; upper surface yellowish-brown, glossy, ciliate, cilia black, isidiate; Isidia black, marginal; medulla off white; lower surface brown, tomentose, cyphellae yellow; apothecia not known (Image 7).

Specimen examined: India, Kerala, Idukki, Mathikettan Shola National Park, 10.007N to 77.246E, 1,591 m, on rock, July, Aswathi Anilkumar (2480).

Recently collected from Nilgris hills of Tamil Nadu (Pandit & Sharma 2012). The present collection confirms its extended distribution to the state of Kerala.

5. *Lobaria japonica* (Zahlbr). Asahina

Thallus corticolous, loosely adnate, 5–9 cm across, yellow brown, dull, photobiont green algae; Upper surface smooth without recticulate ridges, minor wrinkles; no isidia and soredia; lower surface pale brown, tomentose, rhizinate, rhizines black; apothecia immature (Image 8).

Cortex K^-; medulla K^-, C^-, KC^-, P^-. No lichen materials

Specimen examined: India, Kerala, Idukki, Mathikettan Shola National Park, 10.006N to 77.243E, 1,582 m, on rock, July, Aswathi Anilkumar (2380).

Collected from Nilgris hills of Tamil Nadu and Nagaland.

CONCLUSION

It is estimated that India supports about 2,532 lichen species under 324 genera and 78 families, including 541 endemic species (Singh & Sinha 2010). Only about 691 species are so far reported from Kerala since only fragmentary studies have been done on lichen taxonomy from the state. This study mainly focused on survey of macro lichen species from Mathikettan Shola National Park, and the results revealed that further extensive exploratory studies may end up with new additions to lichen biota of the state, and also to the country.

REFERENCES

Awasthi, D.D. (2007). *A Compendium of the Macrolichens from India, Nepal and Sri Lanka*. Bishen Singh Mahendra Pal Singh, Dehra Dun, India, 580 pp.

Biju, H., R.G. Bagool & S. Nayaka (2010). Additions to the lichen flora of Kerala state 2; Parmeloid macro lichens. Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Kerala, India.

Biju, H., R.G. Bagool & S. Nayaka (2012). Additions to the lichen flora of Kerala state 2; Graphidaceae. Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Kerala, India.

Biju, H., R.G. Bagool & S. Nayaka (2014). New records of Graphidaceous lichens form Western Ghats, India. *Indian Journal of Forestry* 37(4): 477–481.

Management Plan Mathikettan Shola National Park (2009). First Management Plan, Mathikettan Shola National Park 2009–2018. Department of Forests and Wildlife, Govt. of Kerala**.**

Kumar, M. (2000). *Lichen (Macrolichen) flora of Kerala part of Western Ghats*. KFRI Research Report No. 194. Kerala Forest Research Institute, Peechi, Thrissur, Kerala, 212 pp.

Kumar, M. & S. Sequiera (1999). Lichens of Western Ghats: An overview, pp. 297–331. In: Mukerji, K.G., B.P. Chamola, D.K. Upreti & R.K. Upadhyay (eds.). *Biology of Lichens*. Aravali Books International, New Delhi, 419 pp.

Kumar, M. & S. Sequiera (2008). Preliminary survey on the lower groups of plants of Neyyar Wildlife Sanctuary, Thiruvananthapuram, Kerala (India). *Indian Journal of Forestry* 31(2): 261–268.

Mishra, G. & D. Upreti (2017). The lichen genus *Parmotrema* A. Massal. (Lecanorales, Ascomycota) from India with addition distributional records. *Cryptogam Biodiversity and Assessment* 2(02): 18–40.

Pandit, G. & B. Sharma (2012). New records in the lichen family Lobariaceae from the Western Ghats of India. *Mycosphere* 3(4): 430–435. https://doi.org/10.5943 /mycosphere/3/4/6

Sequiera, S. (2003). Taxonomy *and Ecology of lichens of Silent Valley National Park, southern Western Ghats, India*. PhD. Thesis, FRI, Dehra Dun.

Sequiera, S., M. Remesh & M. Kumar (2005). Lichens: the unsung members of Kerala forests, pp. 181–182. In: Muthunayagam, A.E. (ed.). *Proceedings of 17th Kerala Science Congress 2005*. Kerala State Council for Science, Technology & Environment.

Sequiera, S. & M. Kumar (2008). Epiphyte host relationship of Macrolichens in the tropical wet evergreen forest of Silent Valley National Park, Western Ghats of India. *Tropical Ecology* 49(2): 211–224.

Singh, K.P. & G.P. Sinha (2010). *Indian Lichens: An Annotated Checklist*. Botanical Survey of India, Kolkata, 571 pp.

Zachariah, S.A., S. Nayaka, S. Joseph, P. Gupta, S. Thomas & S.K. Varghese (2018). New and noteworthy records of lichens from Pathanamthitta district, Kerala, India. *Studies in Fungi* 3(1): 349–356.

Zachariah, S.A., S. Nayaka, S. Joseph, P. Gupta, S. Thomas & S.K. Varghese (2018). Eleven new records of lichens to the state of Kerala, India**.** *Journal of Threatened Taxa* 12(10): 16402–16406. https://doi.org/10.11609/jott.5475.12.10.16402-16406

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COMMUNICATION

New distribution record of globally threatened Ocean Turf Grass *Halophila beccarii* Ascherson, 1871 from the North Andaman Islands highlights the importance of seagrass exploratory surveys

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Abstract: *Halophila beccarii*, listed as 'Vulnerable' on the IUCN Red List, aids in seagrass and mangrove succession, acts as a substrate stabilizer and provides feeding grounds for mega-herbivores like dugongs. This species was first recorded from the Andaman & Nicobar Islands in 2015, and its distribution status within the archipelago remains under-investigated. We report a new distribution record of *H. beccarii* from the North Andamans and shed light on its inter-island distribution. *H. beccarii* was recorded from a mixed meadow comprising of *Cymodocea rotundata* (20.5 ± 28.8%, mean seagrass cover), *Thalassia hemprichii* (16.3 ± 23.3%, mean seagrass cover), and *Halodule pinifolia* (6.3 ± 12.1%, mean seagrass cover) at Pokkadera, North and Middle Andaman district. *H. beccarii* had the highest mean seagrass cover (30 ± 34.7%) and shoot density (103.5 ± 68.3 shoots/ m^2) among sympatric seagrass species. We also recorded eight seagrass-associated macrofaunal groups (gastropods, bivalves, polychaetes, foraminiferans, nematodes, brachyurans, decapods and asteroids) from the infaunal and epibenthic micro-habitats within the meadow. Infaunal macrobenthos had a much higher density (73.5 ± 129.7 individuals/m^2) than the epibenthic macrofauna (0.4 ± 1.5 individuals/m^2), possibly influenced by the seagrass canopy structure and biomass. Overall, gastropods were the most dominant macrobenthic faunal group (overall mean 95.0 ± 106.1 individuals/m^2). The present findings emphasize the need for more exploratory surveys to understand *H. beccarii* distribution in the Andaman & Nicobar archipelago to identify priority conservation areas.

Keywords: Andaman & Nicobar Islands, Dugongs, epifauna, habitat conservation, macrobenthos, seagrass associated.

Abbreviations: ANI—Andaman & Nicobar Islands | LIT—Line Intercept Transect.

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INTRODUCTION

Seagrasses are ecosystem engineers (Hoegh-Guldberg & Bruno 2010) that stabilize sediments (Ondiviela et al. 2014), modify habitats they colonize (Koch 2001) and contribute to coastal protection (Ondiviela et al. 2014). Seagrass meadows contribute to local carbon sinks (Suchanek et al. 1985), trophic transfer within habitats (Costanza et al. 1997), and primary production (Waycott et al. 2009), and they support a diversity of associated invertebrate fauna (Orth et al. 1984; Lee et al. 2001; Leopardas et al. 2014; Su et al. 2020).

In India, seagrasses are distributed along the coastlines of Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, and Odisha states, and the Lakshadweep and Andaman & Nicobar archipelagos (Thangaradjou et al. 2018). These ecologically valuable and fragile coastal habitats are threatened in Indian waters by high anthropogenic dependency, destructive practices like boat anchorage, extractive fishing, and nutrient enrichment through agricultural run-offs or domestic sewage disposal (Thangaradjou et al. 2008; Sridhar et al. 2010; Nobi & Thangaradjou 2012). Despite being protected under the 'Coastal Regulation Zone Act' (Dhiman et al. 2019), seagrasses have received less attention than other marine ecosystems (Jagtap et al. 2003).

Seagrass research in the Andaman & Nicobar Islands (ANI) has been sporadic. Pioneering work by Jagtap (1991, 1992) and Das (1996) collectively reported nine species. *Halodule uninervis, Thalassia hemprichii*, and *Halophila ovata* were the first seagrass records from ANI (Jagtap 1991), followed by new regional records of *Halophila ovalis, Cymodocea rotundata, Enhalus acoroides*, and *Syringodium isoetifolium* (Jagtap 1992). Pan-Island seagrass exploratory surveys by Das (1996) reported *Cymodocea serrulata* and *Halodule pinifolia*, followed by a two decadal gap in investigating species distribution status in ANI. Later, *Halophila minor* and *Halophila decipiens* were reported from the island waters (D'Souza et al. 2015).

The most recent addition to the species checklist from Andaman waters is *Halophila beccarii* reported from the Haddo Bay of South Andaman (Savurirajan et al. 2015). Globally, *H. beccarii* has a fragmented distribution range in the Indo-Pacific region which extends from the eastern coast of Africa up to southeastern Asia (Green & Short 2003). Although the species was first reported from Indian waters in 1991 (Jagtap 1991), its distribution was not known from the Andaman Islands till 2015. Furthermore, little is known about its inter-island distribution, as records post the first report (Savurirajan et al. 2015) are restricted to South Andaman (Ragavan et al. 2016).

In this study, we report a new distribution site for *Halophila beccarii* in the Andaman Islands and update its current distribution status for the Andaman group. Our study provides detailed meadow characteristics and associated macrofaunal assemblages, and highlights the habitat importance of seagrass meadows.

STUDY AREA

The Andaman and Nicobar archipelago is situated in the Bay of Bengal (6.750–13.683 ^{0}N and 92.2–93.95 ^{0}E) and encompasses 836 islands, islets, and rocky outcrops with a total geographical area of 8,249 km^{2} (http://andaman.gov.in) and a 1,962 km long coastline (Census Directorate 2011). The shallow waters of the archipelago support 830 hectares of seagrass cover (Ragavan et al. 2016).

The present study was carried out in May 2019 as a part of a pan-island seagrass mapping survey at Pokkadera (12.902^{0}N & 92.910^{0}E). Pokkadera is situated on the East coast of Mayabunder (North & Middle Andaman district) in the Andaman archipelago. It's a large intertidal unprotected area, with a vertical zonation expanse (distance between high to low tide when exposed) in low tide, up to ~ 400 m. The benthic substrate profile is characterized by mixed muddy-sandy sediment in the upper and lower intertidal zones and exposed sand bars in the mid-intertidal area (Figure 1). Pokkadera is an ecologically diverse site, which supports critical coastal ecosystems like seagrass meadows, mangroves, sandy, and rocky intertidal habitats, along with tropical littoral vegetation.

METHODS

Field sampling

We carried out on-foot exploration during low tide in the upper intertidal zone of Pokkadera. After locating a seagrass meadow we walked the perimeter and GPS marked the points at the edges (transition of seagrass habitat and adjacent unvegetated sediments). Later, we plotted the coordinates on Google Earth Pro version 7.3 to calculate the total area of the sampled study site. We used systematic line intercept transects (LIT) to assess seagrass meadow characteristics such as species composition, seagrass cover, shoot density, shoot length,

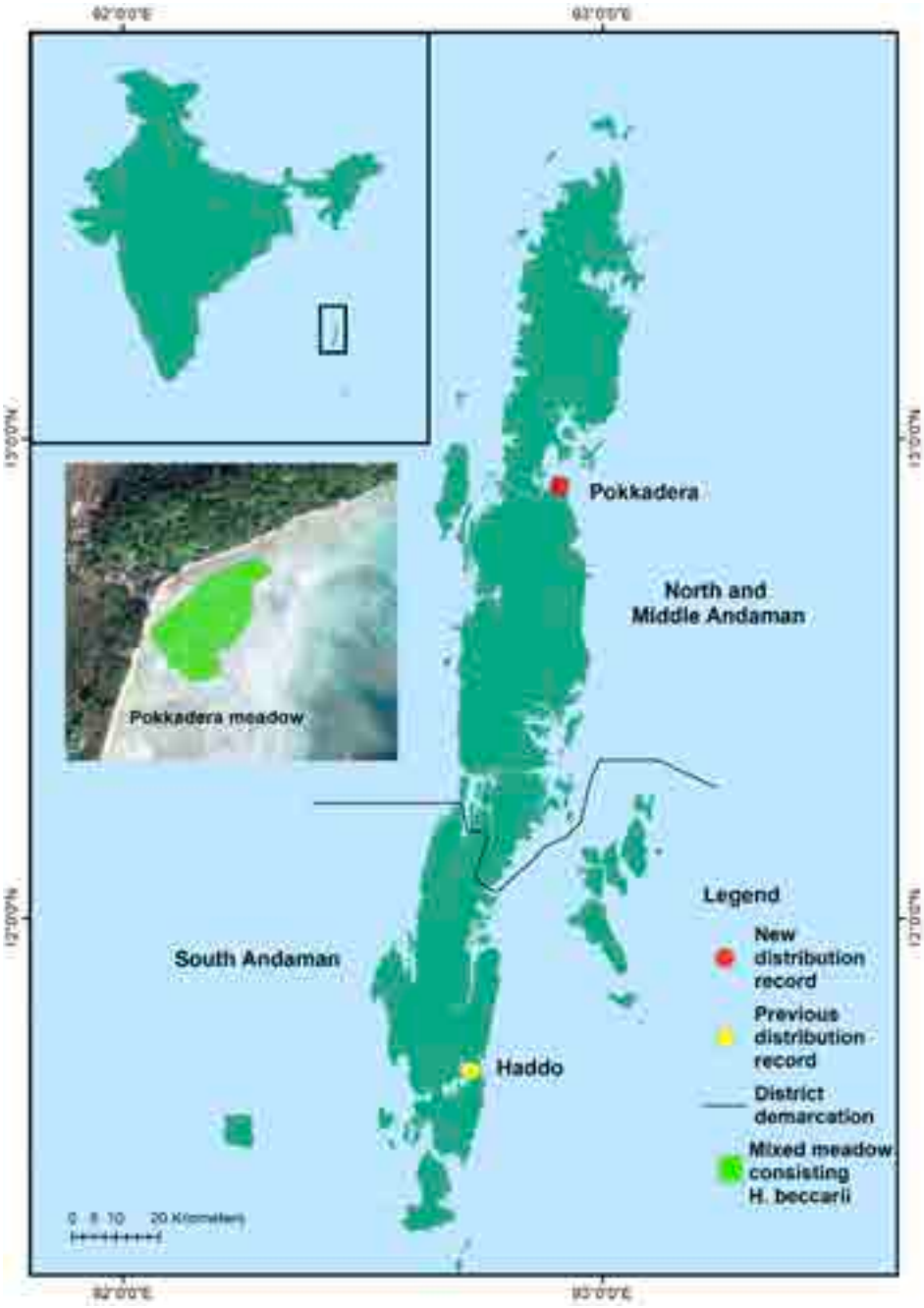

Figure 1. ***Halophila beccarii*** **distribution records from Pokkadera seagrass meadow, Mayabunder, North and Middle Andaman district and Haddo seagrass meadow, South Andaman district at Andaman & Nicobar Islands.**

total biomass (above and below ground; dry weight), and non-epiphytic algal cover (English et al. 1997). We deployed four 50 m long LITs inside the meadow, spaced apart at a distance of 150–200m. A 50 x 50 cm quadrat was placed after every 5 m interval on the LIT to record meadow characteristics (percentage seagrass cover, species composition, non-epiphytic algal cover). Algal shoots, independent of seagrass blades with distinct substratum penetration, were quantified to estimate non-epiphytic algal cover within the quadrat. We recorded seagrass-associated epibenthic macrofaunal groups within the quadrat to estimate group densities (ind. /m^2).

We collected seagrass samples from a 20 X 20 cm quadrat within the larger (50 x 50 cm) quadrat in each transect (n= 3/ transect) to estimate seagrass shoot density, shoot length, and total biomass (above and below ground; dry weight) in the laboratory. To assess

the seagrass-associated infaunal (within the sediments) macrobenthic communities, we hand-scooped (up to 10 cm) sediment samples in triplicates from 20 X 20 cm area, randomly from each transect (n= 3/ transect). Seagrass and macrobenthic sediment samples were stored in ziplock bags on the field and transported to the laboratory for further analysis.

We also recorded environmental parameters on the field, like pH and sea surface temperature using a hand-held multi-parameter tester (Eutech Oaklon- PCS Testr 35) and salinity with a handheld refractometer (LABART).

Laboratory analysis

In the laboratory, we rinsed seagrass samples with fresh water to remove sediment particles from the shoots and roots. We discarded any algal shoots within the samples and thoroughly rinsed them again. Later, we counted seagrass shoots (species-specific) present in the samples to estimate shoot density (shoots/ m^2). Further, using a measuring scale (cm), we recorded the length of randomly picked ten shoots to give species-specific shoot length. For *Halophila beccarii*, we noted additional measurements (shoot width, n=9, and internodal length, n=6), species characteristics, and natural history observations. Lastly, we sun-dried the seagrass samples (whole plant, shoots, and roots) and calculated total biomass above and below ground by dry weight (g/m^2) on a micro-scale weighing balance (WENSAR PGB-220/ 0.001 to 200 g).

Infaunal macrobenthic analysis

We immediately preserved the macrobenthic sediments in 4% (buffered) formalin-Rose Bengal solution and later sieved them on a 500 micron mesh to retain macrobenthic fauna (0.5mm and above; Ingole et al. 2009). We identified the seagrass associated macrofauna up to group level under a stereoscope (Zeiss discovery V.8) and, groups were validated using standard identification manuals (Fauchald 1977; Keppner & Tarjan 1989; Sturm et al. 2006; Sasaki 2008). Lastly, we counted individuals of each group to estimate their abundances.

RESULTS

We recorded four seagrass species and eight macrobenthic groups associated with seagrass habitats from the present study. We report a new distribution record of globally threatened seagrass species, *Halophila beccarii*, from the North Andaman region. Pokkadera seagrass meadow spreads across ~8.2 hectares (Figure 1), comprising early-successional species like *H. beccarii, Halodule pinifolia,* and *Cymodocea rotundata;* and late-successional species like *Thalassia hemprichii* (Vonk et al. 2015; Nowicki et al. 2017).

The mean seagrass cover in the meadow was 18.3 ± 24.7 %, with a non-epiphytic algal cover of 18.3 ± 35 %. *H. beccarii* (30 ± 34.7 %) and *H. pinifolia* (6.3 ± 12.1 %) contributed to the highest and lowest seagrass cover. *H. beccarii* had the highest shoot density (103.5 ± 68.3 shoots/ m^2), whereas *C. rotundata* added to maximum total biomass (44.0 ± 56.1 g/ m^2; Table 1).

Halophila beccarii

Halophila beccarii belongs to the family Hydrocharitaceae in the order Alismatales. The specimen recorded at the Pokkadera meadow had 4–8 lanceolate leaves with no cross venation (Image 1B & C). The mean shoot length was 1.3 ± 0.4 cm (n= 10), mean shoot width was 1.3 ± 0.5 mm (n= 9) with a mean internodal length of 1.7 ± 0.3 cm (n= 6). Rhizomes were smooth as observed for the species (Image 1B).

Habitat

Halophila beccarii was distributed in the upper intertidal zone, either as monospecific strands on sand flats or was found associated with *T. hemprichii*, *C. rotundata*, and *H. pinifolia* in a mixed species meadow (Image 1A). The species was present in intertidal puddles or exposed on sand bars in line with previous observations (Waycott et al. 2004) and here was dominantly distributed at the fringes of the intertidal zone, adjacent to littoral vegetation.

Associated macrobenthic fauna

We recorded a total of eight macrofaunal groups, both epibenthic (n= 5 groups; number of quadrats= 44) and infaunal (n= 5 groups; number of sediment samples = 12) belonging to six phyla, associated with the seagrass beds at Pokkadera viz; gastropods, bivalves, polychaetes, nematodes, brachyuran, decapods, asteroids, and foraminiferans. Gastropods and bivalves were common groups found in both the micro-habitats.

In order of abundance, gastropods (51.4%) dominated the infaunal assemblages, followed by bivalves (35.2%) and polychaetes (7.4%), while the least dominant groups were nematodes (3%) and foraminifera (3%). Gastropods were dominant in epibenthic assemblages (50%), followed by brachyurans (31.3%; Table 2). The total mean density of epibenthic groups (0.4 ± 1.5 ind. / m^2) was much lower than infaunal assemblages (73.5 ± 129.7 ind. /m^2; Table 2).

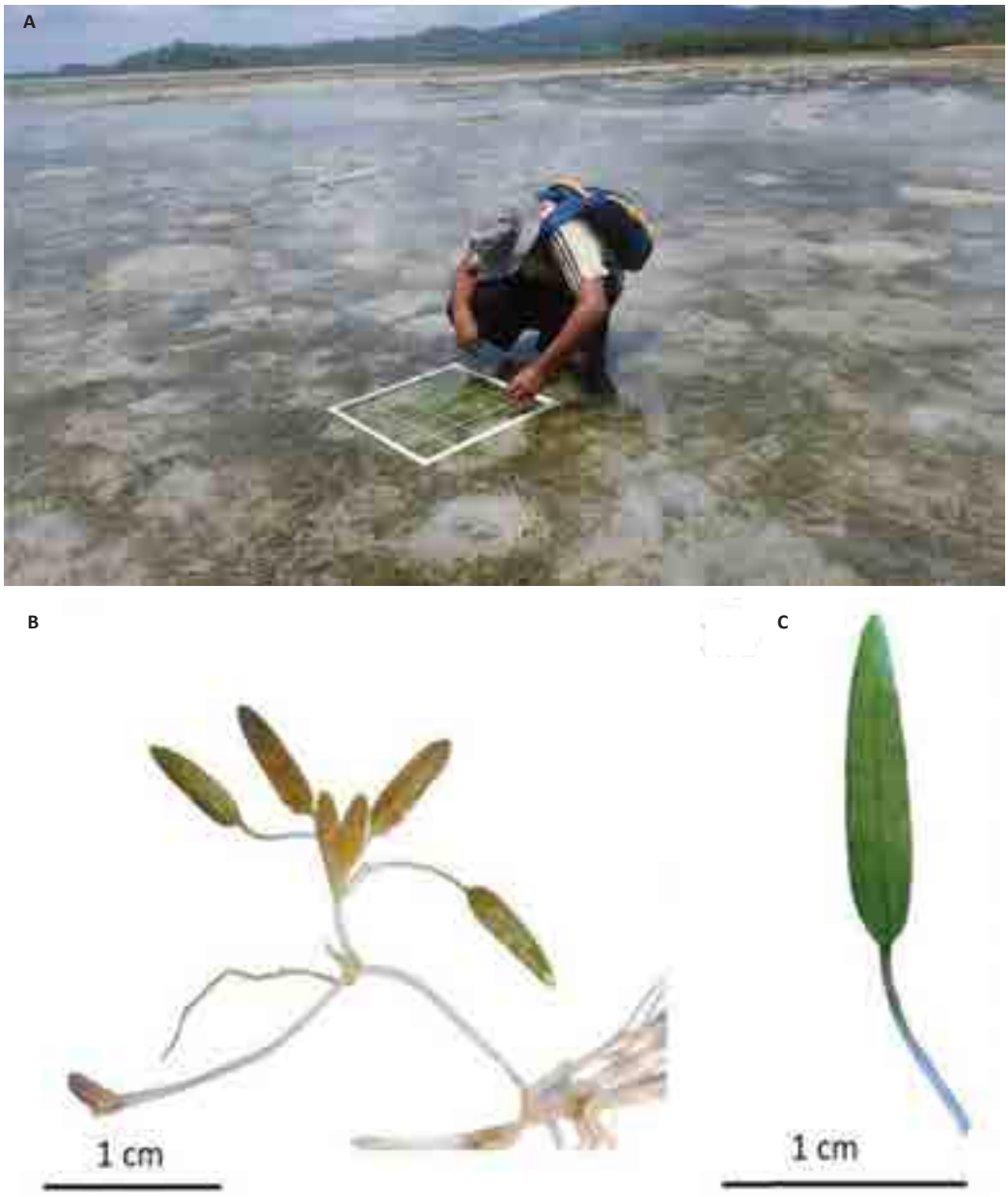

Image 1. A—Habitat characterization of seagrass meadow at Pokkadera, Mayabunder coast, North and Middle Andaman | B—*Halophila beccarii* species specimen | C—*H. beccarii* leaf structure. © Swapnali Gole.

Table 1. Seagrass meadow characteristics of Pokkadera seagrass meadow, Mayabunder, North and Middle Andaman district of Andaman & Nicobar Islands.

Meadow characteristics	Seagrass species			
	Halophila beccarii	*Cymodocea rotundata*	*Thalassia hemprichii*	*Halodule pinifolia*
Mean seagrass cover (%)	30 ± 34.7	20.5 ± 28.8	16.3 ± 23.3	6.3 ± 12.1
Shoot density (shoots/ m^2)	103.5 ± 68.3	45.5 ± 24.4	40.6 ± 30	42.5 ± 12
Shoot length (cm; n= 10)	3.2 ± 2.8	6.9 ± 1.7	5.1 ± 3.5	4.3 ± 1.4
Total Biomass (above and below; dry weight) (g/ m^2)	1.3 ± 2.2	44.0 ± 56.1	14.1 ± 25.1	0.6 ± 1.8
Sea surface temperature- (°C) 37.3 ± 0.7		Salinity- (ppt) 29.0 ± 1.0	pH- 8.8 ± 0.1	

(Values expressed as mean ± standard deviation).

Table 2. Mean densities of major seagrass-associated macrobenthic taxonomic groups recorded at Pokkadera seagrass meadow.

Faunal groups	Infaunal (ind. / m²)	Epifaunal (ind. / m²)
Gastropods	188.9 ± 151.8	1 ± 1.7
Bivalves	129.2 ± 391	0.1 ± 0.7
Polychaetes	27.1 ± 52.2	not recorded
Nematodes	11.1 ± 26	not recorded
Foraminiferans	11.1 ± 27.4	not recorded
Asteroids	not recorded	0.1 ± 0.7
Brachyurans	not recorded	0.6 ± 3.5
Decapods	not recorded	0.1 ± 0.7

DISCUSSION

Halophila beccarii is a euryhaline species found associated with mangrove vegetation (Jagtap 1991) that provides numerous ecosystem services. Studies have highlighted the role of *H. beccarii* meadows as sediment stabilizers, refugia to macrobenthic and fish diversity (Mathews et al. 2010), and pioneers for seagrass succession (Aye et al. 2014). The species is presently listed as 'Vulnerable' in the IUCN Red List (Short et al. 2010) and some of the major threats are coastal infrastructure development, marine pollution, and exploitative fishing practices, leading to modifications of its natural habitat (Short et al. 2010).

In addition to reporting a new distribution record, our study emphasizes the importance of mixed seagrass beds for associated species thus, highlights the value of these coastal ecosystems. Studies have highlighted habitat importance of *H. beccarii* meadows in supporting macrobenthic diversity (Su et al. 2020). Our findings suggest high numerical dominance of infaunal assemblages which needs further investigation, as epifaunal and infaunal abundance in seagrass meadows is influenced by meadow characteristics like structural complexity, canopy height, leaf morphology, shoot density, and above and below ground biomass (Orth et al. 1984; Lee et al. 2001; Leopardas et al. 2014).

The intertidal region at Pokkadera is an unprotected area, and the seagrass habitats are open ground for shoreline fishing activities and cattle trampling during ebb tide, posing a threat to the existing seagrass beds, and in turn associated fauna. Based on few anecdotal reports by local fishers, Pokkadera is a dugong feeding habitat, which signifies the importance of the site and adds to the necessity for habitat and species conservation.

Scientists have emphasized the need for integrating research with policy-making to conserve *H. beccarii* habitats (Ramesh et al. 2018). Our work highlights *H. beccarii* distribution for prioritizing its conservation in the Andaman and Nicobar Islands, in line with recommendations to aid ecological assessments globally (Short et al. 2010). Lastly, we strongly recommend the need for more seagrass exploratory surveys and long-term monitoring of critical meadows to form a robust baseline for seagrass management in the Andaman Islands.

REFERENCES

Aye, A., A. Hsan & U. Soe-Htun (2014). The Morphotaxonomy and Phytosociology of *Halophila beccarii* (Family: Hydrocharitaceae) in Kalegauk Island, Mon State. *Mawlamyine University Research Journal* 5(1): 1–15.

Census Directorate (2011). Provisional population total: rural-urban distribution, Andaman and Nicobar Islands, 18 pp.

Das, H. (1996). Status of Seagrass habitats of Andaman and Nicobar Coast. SACON, Coimbatore, India, Technical Report No. 4, 32 pp.

Dhiman, R., P. Kalbar & A.B. Inamdar (2019). Spatial planning of coastal urban areas in India: current practice versus quantitative approach. *Ocean & Coastal Management* 182: 104929. https://doi.org/10.1016/j.ocecoaman.2019.104929

D'Souza, E., V. Patankar, R. Arthur, N. Marbà & T. Alcoverro (2015). Seagrass Herbivory Levels Sustain Site-Fidelity in a Remnant Dugong Population. *PLoS ONE* (10): 1–18. https://doi.org/10.1371/journal.pone.0141224.t001

English S., C. Wilkinson, & V. Baker (1997). *Survey manual of Tropical Marine Resources*: *2nd Edition*. Australian Institute Resources, Townsville, 385 pp.

Fauchald, K. (1977). *The Polychaete worms. Definitions and keys to the orders, families and genera*. Natural History Museum of Los Angeles County, Science Series, 28: 188.

Green, E.P. & F. T. Short (2003). *World Atlas of Seagrasses*. University of California Press, Berkeley, USA, 324 pp.

Ingole B., S. Sivadas, M. Nanajkar, S. Sautya, & A. Nag (2009). A comparative study of macrobenthic community from harbours along the central west coast of India. *Environmental Monitoring and Assessment* 154(1–4): 135–146. https://doi.org/10.1007/s10661-008-0384-5

Jagtap, T. (1991). Distribution of seagrass along the Indian coast. *Aquatic Botany* 40: 379–386.

Jagtap, T. (1992). Marine flora of Nicobar group of Islands, Andaman Sea. *Indian Journal of Marine Sciences* 22: 56–58.

Jagtap, T., D. Komarpant & R. Rodrigues (2003). Status of a seagrass ecosystem: An ecologically sensitive wetland habitat from India. *Wetlands* 23(1): 161–170. https://doi.org/10.1672/0277-5212(2003)023[0161:SOASEA]2.0.CO;2

Kaladharan, P., P.U. Zacharia & K.V. Kumaran (2011). Coastal and marine floral biodiversity along the Karnataka coast. *Journal of Marine Biological Association of India* 53(1): 121–129.

Keppner, E. & A. Tarjan (1989). Illustrated Key to the Genera of Free-Living Marine Nematodes of the Order Enoplida. NOAA Technical Report NMFS 77, 26 pp.

Lee, S., C. Fong & R. Wu (2001). The effects of seagrass (Zostera japonica) canopy structure on associated fauna: a study using artificial seagrass units and sampling of natural beds. *Journal of Experimental Marine Biology and Ecology* 259(1): 23–50. https://doi.org/10.1016/s0022-0981(01)00221-0

Leopardas, V., W. Uy & M. Nakaoka (2014). Benthic macrofaunal assemblages in multispecific seagrass meadows of the southern Philippines: Variation among vegetation dominated by different

seagrass species. *Journal of Experimental Marine Biology and Ecology* 457: 71–80. https://doi.org/10.1016/j.jembe.2014.04.006

Mathews, G., D. Raj, T. Thinesh, J. Patterson, J.K. Edward & D. Wilhelmsson (2010). Status of seagrass diversity, distribution and abundance in Gulf of Mannar Marine National Park and Palk Bay (Pamban to Thondi) south eastern India. *South Indian Coastal and Marine Bulletin* 2: 1–21.

Nobi, E. & T. Thangaradjou (2012). Evaluation of the spatial changes in seagrass cover in the lagoons of Lakshadweep Islands, India, using IRS LISS III satellite images. *Geocarto International* 27(8): 647–660. https://doi.org/10.1080/10106049.2012.665501

Nowicki, R., J. Thomson., D. Burkholder, J. Fourqurean & M. Heithaus (2017). Predicting seagrass recovery times and their implications following an extreme climate event. *Marine Ecology Progress Series* 567: 79–93. https://doi.org/10.3354/meps12029

Orth, R., K. Heck & J. Montfrans (1984). Faunal Communities in Seagrass Beds: A Review of the Influence of Plant Structure and Prey Characteristics on Predator-Prey Relationships. *Estuaries* 7(4A): 339–350.

Ragavan, R., R. Jayaraj, M. Muruganantham, C. Jeeva, V. Ubare, A. Saxena & P. Mohan (2016). Species Composition and Distribution of Sea grasses of the Andaman and Nicobar Islands. *Vegetos* 29: 78–87.

Ramesh, R., K. Banerjee, A. Paneerselvam, A. Lakshmi, P. Krishnan & R. Purvaja (2018). Legislation and policy options for conservation and management of seagrass ecosystems in India. *Ocean and Coastal Management* 159: 46–50. https://doi.org/10.1016/j.ocecoaman.2017.12.025

Sasaki, T. (2008). Micromolluscs in Japan: Taxonomic composition, habitats, and future topics. *Zoosymposia* 1: 147–232. https://doi.org/10.11646/zoosymposia.1.1.12

Savurirajan, M., R.K. Lakra & T. Ganesh (2015). A new record of the seagrass *Halophila beccarii* Ascherson from the Port Blair coast, Andaman and Nicobar Islands, India. *Botanica Marina* 58: 409–413. https://doi.org/10.1515/bot-2014-0076

Short, F.T., R. Coles, M. Waycott, J.S. Bujang, M. Fortes, A. Prathep, A.H.M. Kamal, T. Jagtap, S. Bandeira, A. Freeman, P. Erftemeijer, Y. La Nafie, S. Vergara, H.P. Calumpong & I. Makm (2010). *Halophila beccarii*. *The IUCN Red List of Threatened Species*. https://doi.org/10.2305/IUCN.UK.2010-3.RLTS.T173342A6995080.en

Sridhar, R., T. Thangaradjou, L. Kannan & S. Astalakshmi (2010). Assessment of coastal bio resources of the Palk Bay, India, using IRS LISS-III data. *Journal of the Indian Society of Remote Sensing* 38: 565–575. https://doi.org/10.1007/s12524-010-0040-8

Sturm, C.F., T.A. Pearce & A. Valdés (eds.) (2006). *The Mollusks: A Guide to Their Study, Collection, and Preservation, Vol. 2*. American Malacological Society, Pittsburgh and Universal Publishers, U.S.A, xii+445 pp.

Su, Z., G. Qiu, H. Fan & C. Fang (2020). Seagrass beds store less carbon but support more macrobenthos than mangrove forests. *Marine Environmental Research* 162: 105162. https://doi.org/10.1016/j.marenvres.2020.105162

Thangaradjou, T., R. Sridhar, S.S. Kumar & S. Kannan (2008). Seagrass resource assessment in the Mandapam coast of the Gulf of Mannar Biosphere reserve, India. *Applied Ecology and Environmental Research* 6(1): 139–146. https://doi.org/10.15666/aeer/0601_139146

Thangaradjou, T. & J. Bhatt (2018). Status of seagrass ecosystems in India. *Ocean & Coastal Management* 159: 7–15. https://doi.org/10.1016/j.ocecoaman.2017.11.025

Vonk, J., J. A. Christianen, J. Stapel & K. O'Brien (2015). What lies beneath: Why knowledge of belowground biomass dynamics is crucial to effective seagrass management. *Ecological Indicators* 57: 259–267. https://doi.org/10.1016/j.ecolind.2015.05.008

Waycott, M., K. Mc Mahon, J. Mellors, A. Calladine & D. Kleine (2004). *A guide to tropical seagrasses of the Indo-West Pacific.* James Cook University Townsville, Queensland, Australia, 72 pp.

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Author contributions: SG—conceptualisation and drafting of manuscript, field work, sample collection and post processing, data entry and analysis. PDF—field work, sample collection and post processing. SB—laboratory work of infaunal macrobenthic samples. AP—supervision of the field work, conceptualisation and reviewing the manuscript. JAJ—supervision of the field work, reviewing the manuscript. SK—study design, supervision of the field work and data analysis, reviewing the manuscript

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COMMUNICATION

An inventory of new orchid (Orchidaceae) records from Kozhikode, Kerala, India

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Abstract: Orchidaceae is one of the largest families in the plant kingdom. It has high diversity within the tropical and subtropical parts of the world, and is considered as a characteristic feature to measure forest richness. This study explores the orchid diversity in Kozhikode District, Kerala, India. A total of 57 species belonging to 28 genera were identified within the study region. Among the total, 42 were epiphytic species and 15 species were terrestrial. Additionally, 16 species were identified as endemic to India, of which, 10 species were exclusive to the Western Ghats, four species to the Western and Eastern Ghats, and two species to peninsular India. Previous studies conducted within this region, only recorded 10 species. The present study, however, adds new records of 47 species to the orchid diversity of Kozhikode.

Keywords: Conservation, diversity, epiphytes, new distribution, Western Ghats.

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Author contributions: The first author surveyed, collected specimens for identification and prepared the manuscript; while the second and third authors validated the manuscript.

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INTRODUCTION

Orchids are abundant in the humid tropics and subtropics of the world. They are known for their attractive colour, beautiful structure, and long vase life of the flowers. Orchids play an important role in horticulture trade due to their aesthetic appeal. Horticulturalists show a huge interest in orchid hybrids, which are among the most highly valued horticultural plants in mass-market trade (USDA 2019). Besides the floriculture importance, the orchids face over-exploitation for medicinal practices and are included in the threatened categories (Jalal et al. 2014). Due to the threatened status of orchids, different frameworks and acts are established by international agencies and the Indian Government with the aim to provide legal protection to conserve native orchid diversity. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has included native orchids in Appendix I & II to prevent the illegal trade. Similarly, orchids are placed under Schedule VI of Wildlife Protection Act, 1972 amended in 1992 to regulate the trade activities of orchids within India (Wildlife Protection Act 1972; Nagrare 2006).

India is widespread with biogeographic regions with varied topography, climate and habitat providing the floristic wealth of country with 21,730 taxa under 2,774 genera and 268 families (Mao & Dash 2020). Within India, orchids are documented with 1,256 taxa belonging to 155 genera and 305 endemic species (Singh et al. 2019). Latest records from the Western Ghats indicated the presence of 305 orchid species under 77 genera. Additionally, just in the state of Kerala, 265 orchid species belonging to 77 genera have been listed so far (Nayar et al. 2014). Moreover, the Western Ghats and the state of Kerala have been reported to host a high level of orchid endemism with 111 endemic species in the Western Ghats, and 22 species that are exclusively endemic to Kerala (Singh et al. 2015).

Kerala is known to be rich in orchid diversity. The first research study that aimed to create an inventory of orchid species in Kozhikode District, Kerala was 32 years ago. The study resulted in recording only 10 species (Manilal & Sivarajan 1982). Ever since, most researchers have mainly focused on identifying new species. Thus the present work aims to build upon the study that was conducted by Manilal & Sivarajan (1982) and bring out a more comprehensive inventory of orchid species in Kozhikode District, Kerala.

As the natural ecosystem is highly threatened by multiple anthropogenic stressors, it is imperative to periodically estimate the floral wealth in a region. The orchids are adapted to live in a specialized environment because of their specialized requirement and many species are very restricted in distribution and endemism is very high (Nagrare 2006). Any destruction or degradation of natural habitat beyond a tolerable limit cause threat for their survival. Hence the present study also necessitates to survey and study the orchid diversity and distribution of an area in regular period.

Study Area

Kozhikode is one of the coastal districts in Kerala. It is bound by Kannur district in the north, Wayanad district in the east, Malappuram district in the south, and the Lakshadweep Sea in the west. It lies between north latitudes 11.140–11.835 and east longitudes 75.508–76.137. It has a forest cover of 1,493 km^2 (Economic Review 2019). The study areas, viz., Kakkad, Kakkayam, Kuttiyadi, Malabar Wildlife Sanctuary, Puduppadi, Peruvannamuzhy, and Thamarassery were selected as they are composed of different forest types such as: tropical semi-evergreen forest, tropical evergreen forest, and grasslands (Table 1). In the year 2019, Kozhikode recorded an annual rainfall of 3,205 mm. The minimum temperature in this region ranges between 22 and 25.8^{0}C and the maximum between 28.2 and 32.9^{0}C. The temperature reaches its peak in the month of April. The zonal relative humidity ranges 74–92 % during the morning hours and 64–89 % in the evening hours (Figure 1).

METHODS

Field survey

Explorations on orchids at Kozhikode were carried out from January 2018 to December 2019. The random survey succeeded through frequent visits in all seasons

Table 1. Geographic location of orchid diversity, Kozhikode District.

	Location	Altitude (m)	Latitude	Longitude
1	Kakkad	10	11.036082	75.940545
2	Kakkayam	772	11.550156	75.928466
3	Kuttiyadi	81	11.659060	75.749145
4	Malabar Wildlife Sanctuary	1,176	11.558230	75.958238
5	Puduppadi	82	10.789007	76.230478
6	Peruvannamuzhy	60	11.583010	75.818076
7	Thamarassery	55	11.423630	75.946984

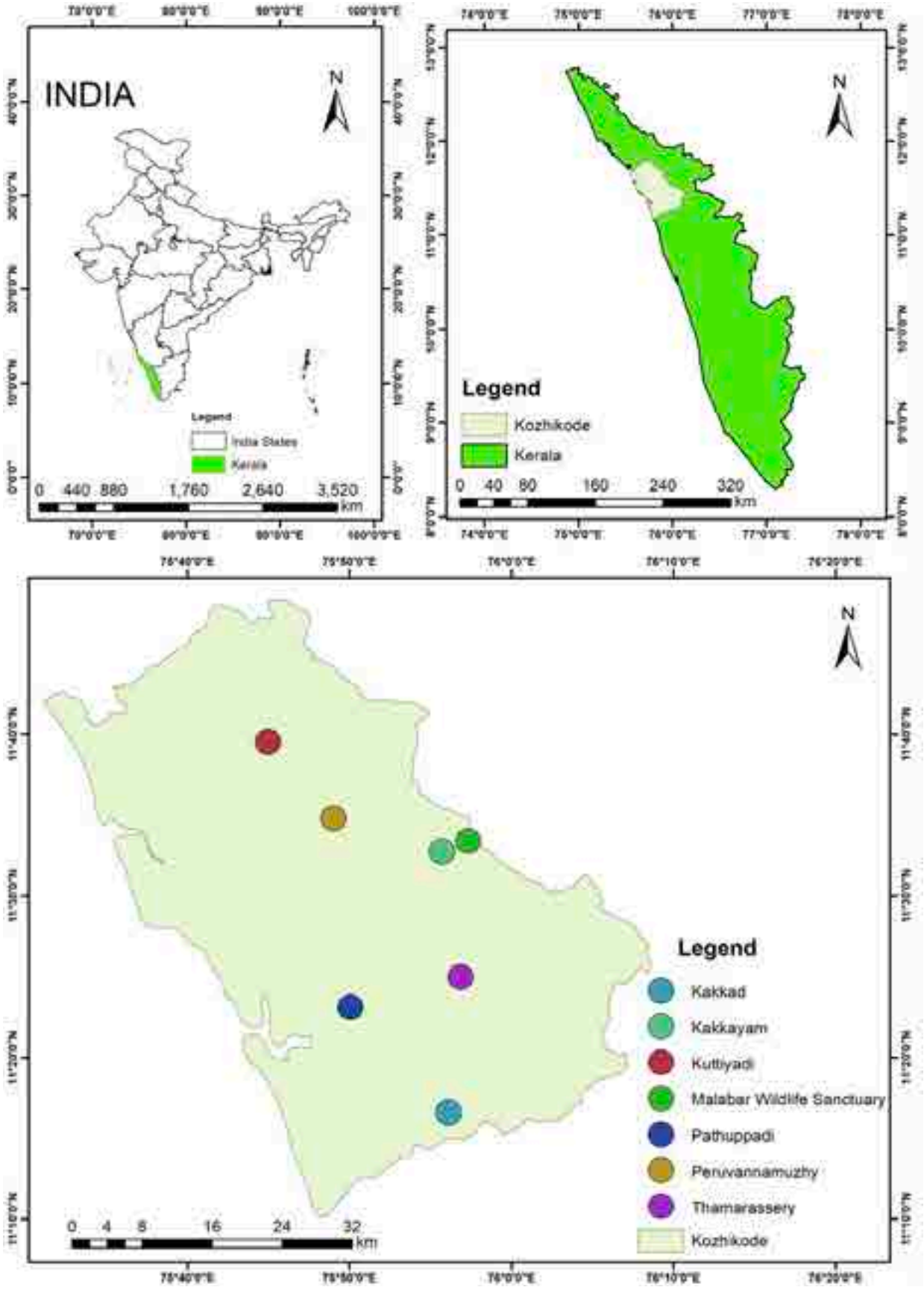

Figure 1. Study area.

and locating the orchids in tropical semi-evergreen forest, tropical evergreen forest, and grasslands of Kozhikode, Kerala. Normally about three specimens were collected with reproductive structures while single specimen was collected for the orchids with least population or an uncommon species. The terrestrial or ground orchids were collected leaving the tuber or rhizome for regeneration and epiphytes were collected using sticks without disturbing its population. The non-flowered orchids were collected and planted in the botanical garden of the Botanical Survey of India, Coimbatore and upon flowering of the species the identification was carried out.

The field notes included names of the flora, habit, habitats, species name, family, flowering, fruiting, date of collection, collection number, collectors, and remarks. In addition, the geo-coordinates and elevation of the orchids were recorded using GPS-Garmin and digital photos were taken using a Nikon D300s Camera for future reference.

After gathering the plant materials, herbarium was prepared using standard herbarium techniques such as poisoning, drying, mounting, and labelling (Jain & Rao 1976). The specimens were identified using relevant literature, regional and national floras (Abraham & Vatsala 1981; Ansari & Balakrishnan 1990; Gamble 1928; Kumar & Manilal 2004; Misra 2007; Sasidharan 2013; Singh et al. 2015, 2019), as well as specimens examined at regional and national herbaria, namely, Madras Herbarium (MH), Tropical Botanic Garden and Research Institute (TBGT), Kerala Forest Research Institute (KFRI), and University of Calicut (CALI). The mounted specimens were labelled with accessed number and deposited in the Madras Herbarium (MH), Botanical Survey of India, Southern Regional Centre, Coimbatore, Tamil Nadu.

RESULTS

Floristic diversity

This study was conducted as an attempt to create an inventory of orchid species from Kozhikode. A total of 57 species of orchids, belonging to 28 genera were identified as a part of this study (Table 2). The orchids were categorized based on habitat type, and it is noted that, among the total, 42 species are observed to be epiphytic and 15 species are terrestrial. The above collection also included 16 orchid species which are endemic to India. Of these 16 endemic species, 10 species are exclusively found in Western Ghats, viz.: *Bulbophyllum aureum, B. rheedei, Dendrobium heyneanum, D. nodosum,*

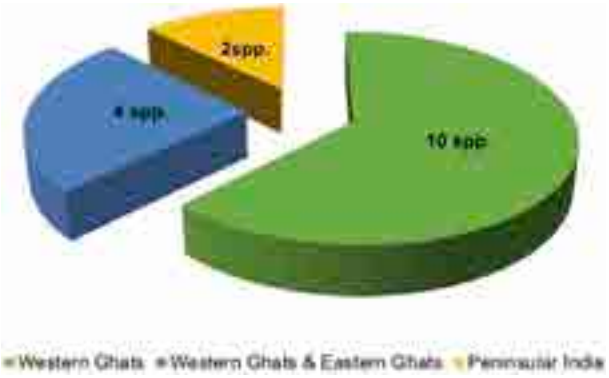

Figure 2. Distribution of endemic orchids from Kozhikode.

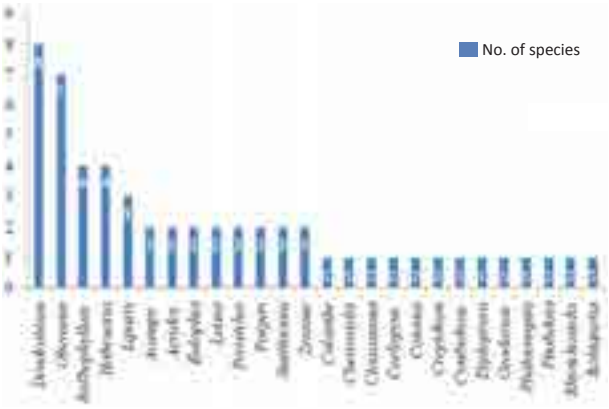

Figure 3. Distribution of dominant orchid genera from Kozhikode.

Luisia macrantha, Oberonia josephi, O. sebastiana, O. verticillata, Robiquetia josephiana, and *Smithsonia maculata*; four species are endemic to the Eastern and Western Ghats, viz.: *Dendrobium nanum, D. ovatum, Habenaria heyneana*, and *Porpax exilis*; and two species are endemic to peninsular India, viz.: *Oberonia brunoniana* and *O. proudlockii* (Figure 2).

The most dominant orchid genera in Kozhikode are *Dendrobium* (8 spp.), *Oberonia* (7 spp.), *Bulbophyllum* and *Habenaria* each (4 spp.), and *Liparis* (3 spp.). Eight genera are represented by two species each, while the 13 genera have one species each. (Figure 3).

DISCUSSION

The land of Kozhikode is endowed with forests, wetlands and beaches. In the past, many academics, botanists, and scientists have conducted expeditions to explore the floristic diversity of this region (Ellis et al. 1967; Manilal & Sivarajan 1982; Chandra & Azeez 2010). The results of those expeditions include, discoveries of

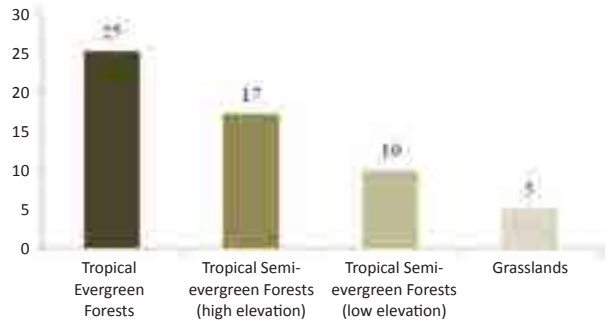

Figure 4. Distribution of Orchids in Forest Types from Kozhikode.

new species, new distribution records, rediscoveries of species, checklist of endemic species, medicinal plants, and lower plants (Nair & Madhusoodanan 2006; Udayan et al. 2008; Ambily et al. 2010).

The present study confirmed the new distribution of 57 orchid species including 10 species that were earlier documented in the region by Manilal & Sivarajan (1982), viz: *Acampe ochracea*, *Bulbophyllum sterile*, *Crepidium versicolor, Dendrobium macrostachyum, Geodorum densiflorum, Habenaria diphylla, H. viridiflora, Luisia tristis, Rhynchostylis retusa*, and *Zeuxine longilabris*. On comparison of orchid diversity in neighboring districts of Kannur and Wayanad resulted in high number of orchids with 46 and 165, respectively (Ramachandran & Nair 1998; Ratheesh 2009); while Kozhikode was documented with less number (Manilal & Sivarajan 1982). Upon analyzing the study area, same level of plant richness was observed. Besides, it is also noted that previous researchers has focused more on floristic aspects rather than concentrating on specific groups like Orchidaceae.

The new distributional findings of the 48 orchid species were mainly found in Kakkayam (tropical evergreen forests), Malabar Wildlife Sanctuary (tropical semi-evergreen forests, tropical evergreen forests, and grasslands), Kakkad & Pathuppadi (tropical semi-evergreen forests), and Kuttiyadi, Peruvannamuzhy, & Thamarassery (tropical semi-evergreen forests and tropical evergreen forests) (Image 1–4). A majority of the species from the survey was found in tropical evergreen forests (25 species). At high elevations the tropical semi-evergreen forests hosted the second highest diversity of 17 species, while in comparison, at lower elevation the diversity of orchids was relatively less, i.e., 10 species. Orchid diversity within grasslands was the lowest with five species (Figure 4).

The high number of orchid flowerings are observed between the months of August to December and others between the months of January to June. The endemic genus for the Western Ghats of *Smithsonia maculata* and *S. straminea* are excellent collections from the study area. *Oberonia josephii*, previously known only from Wayanad, is now included in this collection as a secondary addition. An interesting species, *Eulophia zollingiri* known for its rare blooming was recorded and conserved with other orchids as ex situ conservation at the botanical garden, Botanical Survey of India, Coimbatore. Hence, this work also highlights the presence and distribution of species is the first step in determining areas of conservation and conservation strategies.

CONCLUSION

The present findings resulted in recording the new distributions for 47 species of orchids in Kozhikode; as the earlier records has indicated only 10 species. This study also confirms the importance of conducting repeated field surveys in the study area to bring out a comprehensive inventory of orchid species. In addition, it also helps in documenting the changes happening in forest cover and land use finally identifying the threat factors of the vegetation. Thus it is concluded that inventory of any floristic elements is quite essential to assess the diversity of a given area and it act as a baseline data to suggest the appropriate conservation measures in the future timescale.

REFERENCES

Abraham, A. & P. Vatsala (1981). *Introduction to Orchids with Illustrations and Descriptions of 150 South Indian Orchids.* Tropical Botanical Garden and Research Institute, Trivandrum, 533 pp.

Ambily, D.V., N.P. Rajith, V. George & P. Pushpangadan (2010). Utilization of medicinal plants by the Paniyan tribe of Kozhikode district, Kerala. *Ethnobotany* 22: 14–24.

Ansari, R. & N.P. Balakrishnan (1990). A revision of the Indian species of Oberonia (Orchidaceae). *Orchid Monographs* 4: i–iv, 1–82.

Chandra, R. & P.A. Azeez (2010). Flora Diversity of Kottuli: a wetland of national importance, Kozhikode, Kerala. *Journal of Economic and Taxonomic Botany* 34: 440–450. https://www.scientificpubonline.com//journalarticledetails/floral-diversity-kottuli-wetland-national-imortance-kozhikode-kerala/1677

Economic Review (2019). State Planning Board, Thiruvananthapuram, Kerala, India. https://spb.kerala.gov.in/economic-review/ER2019/index.php

Ellis, J.L., M.S. Swaminathan & M. Chandrabose (1967). Studies on the vascular flora of sultan battery and chedaleth forest ranges, Kozhikode, Kerala. *Bulletin of the Botanical Survey of India* 9: 1–16.

Gamble, J.S. (1928). *The Flora of Madras Presidency*. Adlard & Son, Limited, London, 1416 pp.

Jain, S.K. & R.R. Rao (1976). A Hand Book of Field and Herbarium Methods. Today and Tomorrow's Printers and Publishers, New

Table 2. Orchid enumeration of Kozikode district, Kerala.

	Name of the species	Life form	Flowering & fruiting	Voucher No. (MH)	Locality	Distribution
1	*Acampe ochracea* (Lindl.) Hochr.	E	Nov–May	145445	Anjulimukku (Peruvannamuzhy)	India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Arunachal Pradesh, Sikkim, Karnataka, Kerala, and Tamil Nadu), Sri Lanka, Bhutan, Bangladesh, Myanmar, China, Thailand, Laos, Cambodia, and Vietnam.
2	*Acampe praemorsa* (Roxb.) Blatt. & McCann	E	Feb–Nov	145444	Kuttiyadi	India (Andhra Pradesh, Odisha, Goa, Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Daman & Diu, Dadara & Nagar Haveli, Jharkhand, Chhattishgarh, Madhya Pradesh, and Rajasthan), Sri Lanka, Nepal, Myanmar, and Seychelles.
3	*Aerides crispa* Lindl.	E	May–Aug	145414	Ambalappara (Kakkayam)	India (Goa, Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, and Dadara & Nagar Haveli), Sri Lanka, Myanmar, and Bangladesh.
4	*Aerides ringens* (Lindl.) C.E.C.Fisch.	E	Feb–Nov	145446	Kuttiyadi	India (Andhra Pradesh, Odisha, Goa, Gujarat, Karnataka, Kerala, and Tamil Nadu) and Sri Lanka.
5	*Bulbophyllum aureum (*Hook.f.) J.J.Sm.	E	Jan–Feb	145449	Athozhi (Kuttiyadi)	India (Kerala and Tamil Nadu) Endemic to Western Ghats.
6	*Bulbophyllum rheedei* Manilal & C.S.Kumar	E	May–Aug	145411	Ambalappara (Kakkayam)	India (Kerala) Endemic to Western Ghats.
7	*Bulbophyllum sterile* (Lam.) Suresh	E	Apr–Nov	14541	Sankaranpuzha camp (Kakkayam)	India (Andhra Pradesh, Goa, Maharashtra, Karnataka, Kerala and Tamil Nadu), Nepal, Bangladesh and Myanmar.
8	*Bulbophyllum stocksii* (Benth. ex Hook.f.) J.J.Verm., Schuit. & de Vogel	E	Sep–Nov	145412	Ambalappara (Kakkayam)	India (Maharashtra, Karnataka, Kerala and Tamil Nadu), Myanmar and Bangladesh.
9	*Calanthe sylvatica* (Thouars) Lindl.	T	Sep–Nov	145438	Sothupara (Kakkayam)	India (Assam, Mizoram, West Bengal, Karnataka, Kerala, and Tamil Nadu), Bhutan, Nepal, Sri Lanka, China, Myanmar, Indonesia, Japan, Malaysia, Thailand, Indo-China, Madagascar, and Africa
10	*Cheirostylis parvifolia* Lindl.	T	Jun–Sep	145431	Ambalappara Grass land (Kakkayam)	India (Maharashtra, Karnataka, Kerala, Tamil Nadu, and Odisha) and Sri Lanka.
11	*Cleisostoma tenuifolium* (L.) Garay	E	Jan–Dec	145447	Pathuppadi	India (Goa, Maharashtra, Karnataka, Kerala, and Tamil Nadu), Sri Lanka, and Thailand.
12	*Coelogyne breviscapa* Lindl.	E	Jan–Apr	145403	Ambalappara (Kakkayam)	India (Karnataka, Kerala, and Tamil Nadu) and Sri Lanka.
13	*Cottonia peduncularis* (Lindl.) Rchb.f.	E	Jan–Apr	145415	Kakkayam	India (Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, and Odisha) and Sri Lanka.
14	*Crepidium versicolor* (Lindl.) Sushil K.Singh, Agrawala & Jalal	T	Sep–Nov	145426	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Andhra Pradesh, Odisha, Goa, Maharashtra, Karnataka, Kerala, and Tamil Nadu) and Sri Lanka.
15	*Cymbidium aloifolium* (L.) Sw.	E	Mar–Jun	145439	Kakkad	India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Uttarakhand, Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, Bihar, Chhattishgarh, Jharkhand, Madhya Pradesh, and Andaman & Nicobar Islands), Sri Lanka, China, Myanmar, Bangladesh, Laos, Cambodia, Vietnam, Malaysia, and Indonesia.
16	*Dendrobium herbaceum* Lindl.	E	Oct–Nov	145415	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Mizoram, West Bengal, Andhra Pradesh, Odisha, Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, Bihar, Chhattishgarh, Jharkhand, and Madhya Pradesh) and Bangladesh.
17	*Dendrobium heterocarpum* Wall. ex Lindl.	E	Feb–Apr	145410	Ambalappara (Kakkayam)	India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Arunachal Pradesh, Sikkim, West Bengal, Uttarakhand, Karnataka, Kerala and Tamil Nadu), Sri Lanka, Nepal, Myanmar, Thailand, Malaysia, Philippines, and Indonesia.
18	*Dendrobium heyneanum* Lindl.	E	Sep–Nov	145430	Ambalappara (Kakkayam)	India (Karnataka, Kerala, and Tamil Nadu). Endemic to Western Ghats.

	Name of the species	Life form	Flowering & fruiting	Voucher No. (MH)	Locality	Distribution
19	*Dendrobium macrostachyum* Lindl.	E	Mar–Jun	145427	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Arunachal Pradesh, West Bengal, Uttarakhand, Odisha, Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, and Jharkhand), Sri Lanka, Nepal, Bangladesh, Indonesia, Thailand, and Vietnam.
20	*Dendrobium nanum* Hook.f.	E	Sep–Nov	145419	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Goa, Maharashtra, Karnataka, Kerala, and Tamil Nadu). Endemic to Eastern and Western Ghats.
21	*Dendrobium nodosum* Dalzell	E	Mar–Jun	145403	Ambalappara (Kakkayam)	India (Goa, Maharashtra, Karnataka, Tamil Nadu, and Kerala). Endemic to Western Ghats.
22	*Dendrobium ovatum* (L.) Kraenzl.	E	Jan–Dec	145448	Thamarassery	India (Andhra Pradesh, Gujarat, Goa, Maharashtra, Karnataka, Kerala, and Tamil Nadu). Endemic to Eastern and Western Ghats.
23	*Dendrobium salaccense* (Blume) Lindl.	E	Sep–Nov	145409	Ambalappara (Kakkayam)	India (Assam, Meghalaya, Mizoram, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Odiaha, Karnataka, Kerala, Tamil Nadu, and Andaman & Nicobar Islands), Sri Lanka, Bhutan, China, Indonesia, Laos, Malaysia, Myanmar, Thailand, and Vietnam.
24	*Diploprora championii* (Lindl.) Hook.f.	E	Aug–Sep	145421	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Meghalaya, Arunachal Pradesh, Sikkim, West Bengal, Odisha, Karnataka, Kerala, and Andaman & Nicobar Islands), Sri Lanka, China, Bangladesh, Myanmar, Thailand, and Vietnam.
25	*Eulophia nuda* Lindl.	T	Sep–Oct	145435	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Uttarakhand, Uttar Pradesh, Jharkhand, Bihar, Madhya Pradesh, Chhattishgarah, Punjab, Odisha, Andhra Pradesh, Maharashtra, Karnataka, Kerala, Tamil Nadu, and Andaman & Nicobar Islands), Sri Lanka, Nepal, China, Myanmar, Bangladesh, Thailand, Malaysia, Philippines, and Pacific Island.
26	*Eulophia zollingeri* (Rchb.f.) J.J.Sm.	T	Jan–Feb	145435	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Assam, Meghalaya, Nagaland, Arunachal Pradesh, Sikkim, West Bengal, Karnataka, Kerala, and Andaman & Nicobar Islands), Bhutan, Nepal, Sri Lanka, China, Japan, Malaysia, Philippines, Thailand, Papua New Guinea, Australia, and Vietnam.
27	*Geodorum densiflorum* (Lamk.) Schlech.	T	Apr–Nov	145440	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Uttarakhand, Andhra Pradesh, Odisha, Goa, Karnataka, Maharashtra, Kerala, Tamil Nadu, Bihar, Chhattishgarh, Jharkhand, and Madhya Pradesh) New Guinea, Thailand, Indo-China, southeastern Asia, Pacific Islands, Australia, and Fiji.
28	*Habenaria diphylla* Dalz.	T	Aug–Sep	145451	Atthikode grass land (Malabar Wildlife Sanctuary)	India (Meghalaya, Sikkim, West Bengal, Himachal Pradesh, Uttarakhand, Odisha, Andhra Pradesh, Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu, Bihar, Jharkhand, and Chhattishgarh), Bangladesh, Bhutan, Nepal, Myanmar, Thailand, China, and Philippines.
29	*Habenaria heyneana* Lindl.	T	Aug–Sep	145433	Ambalappara grass land (Kakkayam)	India (Andhra Pradesh, Goa, Karnataka, Kerala, Maharashtra, and Tamil Nadu). Endemic to Eastern and Western Ghats.
30	*Habenaria longicorniculata* J.Graham	T	Aug–Sep	145423	Athikode grass land (Malabar Wildlife Sanctuary)	India (Andhra Pradesh, Odisha, Gujarat, Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, Jharkhand, Chhattishgarh, Madhya Pradesh, and Rajasthan) and Sri Lanka.
31	*Habenaria viridiflora* (Sw.) R. Br.	T	Aug–Dec	145451	Atthikode grass land (Malabar Wildlife Sanctuary)	India (Assam, Karnataka, Kerala, Maharashtra, and Tamil Nadu), Sri Lanka, Thailand, Bangladesh, Indo-China, Thailand, and Vietnam.

	Name of the species	Life form	Flowering & fruiting	Voucher No. (MH)	Locality	Distribution
32	*Liparis deflexa* Hook.f.	T	Oct–Nov	145440	Kuttiyadi R.F.	India (Assam, Sikkim, West Bengal, Uttarakhand, Andhra Pradesh, Goa, Karnataka, Kerala, Tamil Nadu, and Chhattishgarh), Myanmar, Nepal, Laos, Cambodia, Indo-China, and Vietnam.
33	*Liparis elliptica* Wight	E	Sep–Oct	145427	Kakkayam R.F.	India (Manipur, Meghalaya, Arunachal Pradesh, Sikkim, Odisha, Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu), Sri Lanka, Nepal, Myanmar, China, Thailand, Taiwan, Indonesia, Philippines, Vietnam, and Pacific Islands.
34	*Liparis viridiflora* (Blume) Lindl.	E	Aug–Dec	145428	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Assam, Meghalaya, Manipur, Mizoram, Nagaland, Tripura, Sikkim, West Bengal, Uttarakhand, Andhra Pradesh, Odisha, Karnataka, Kerala, and Tamil Nadu), Sri Lanka, China, Nepal, Bhutan, Taiwan, Myanmar, Bangladesh, Malaysia, Philippines, Indonesia, Thailand, and Pacific Islands.
35	*Luisia macrantha* Blatt. & McCann	E	Feb–Nov	145408	Ambalappara (Kakkayam)	India (Karnataka and Kerala). Endemic to Western Ghats.
36	*Luisia tristis* (G.Forst.) Hook.f.	E	Mar–Jun	145441	Athozhi (Kuttiyadi)	India (Assam, Meghalaya, Manipur, Nagaland, Arunachal Pradesh Maharashtra, Karnataka, Tamil Nadu, Kerala, and Andaman & Nicobar Islands), Sri Lanka, Nepal, China, Bangladesh, Myanmar, Bhutan, Malaysia, and southeastern Asia.
37	*Oberonia bicornis* Lindl.	E	Aug–Nov	145420	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Manipur, Mizoram, Meghalaya, Maharashtra, Karnataka, Kerala, and Tamil Nadu), Sri Lanka, and Bangladesh.
38	*Oberonia brunoniana* Wight	E	Aug–Dec	145419	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Andhra Pradesh, Goa, Maharashtra, Karnataka, Kerala, and Tamil Nadu). Endemic to peninsular India.
39	*Oberonia ensiformis* (Sm.) Lindl.	E	Aug–Dec	145402	Sankaranpuzha (Kakkayam)	India (Manipur, Meghalaya, Mizoram, Nagaland, Arunachal Pradesh, Sikkim West Bengal, Uttarakhand, Andhra Pradesh, Odisha, Maharashtra, Karnataka, Kerala, Tamil Nadu, and Andaman & Nicobar Islands), Nepal, China, Myanmar, Thailand, Laos, and Vietnam.
40	*Oberonia josephi* C.J.Saldanha	E	Aug–Dec	145424	Kakkayam R.F.	India (Karnataka and Kerala) Endemic to Western Ghats.
41	*Oberonia proudlockii* King & Pantl.	E	Aug–Dec	145402	Sankaranpuzha (Kakkayam)	India (Odisha, Maharashtra, Karnataka, Kerala and Tamil Nadu) Endemic to Peninsular India.
42	*Oberonia sebastiana* B.V.Shetty & Vivek.	E	Aug–Nov	145442	Anjulimukku (Kuttiadi)	India (Kerala and Tamil Nadu). Endemic to Western Ghats.
43	*Oberonia verticillata* Wight	E	Aug–Nov	145418	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Goa, Maharashtra, Karnataka, Tamil Nadu, and Kerala). Endemic to the Western Ghats.
44	*Peristylus aristatus* Lindl.	T	Aug–Sep	145434	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Goa, Karnataka, Kerala, Maharashtra, and Tamil Nadu), Nepal, Pakistan, Myanmar, Malaysia, and Indonesia.
45	*Peristylus spiralis* A.Rich.	T	Aug–Sep	145432	Ambalappara Grass land (Kakkayam)	India (Maharashtra, Karnataka, Tamil Nadu, and Kerala) and Sri Lanka
46	*Phalaenopsis mysorensis* C.J.Saldanha	E	Feb–Apr	145407	Ambalappara (Kakkayam)	India (Karnataka and Kerala) and Sri Lanka.
47	*Pholidota imbricata* Hook.f.	E	Jan–Mar	145428	Thamarassery	India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Uttarakhand, Andhra Pradesh, Odisha, Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, Jharkhand, Chhattishgarh, Madhya Pradesh, and Andaman & Nicobar Islands), Sri Lanka, tropical & subtropical Asia, and Pacific Islands.
48	*Porpax exilis* (Hook.f.) Schuit., Y.P.Ng & H.A.Pedersen	E	Feb–Apr	145404	Ambalappara (Kakkayam)	India (Goa, Karnataka, Kerala, Maharashtra, and Tamil Nadu). Endemic to Eastern and Western Ghats

	Name of the species	Life form	Flowering & fruiting	Voucher No. (MH)	Locality	Distribution
49	*Porpax reticulata* Lindl.	E	Jan–Mar	145413	Ambalappara (Kakkayam)	India (Goa, Maharashtra, Karnataka, Kerala, and Tamil Nadu), Laos, Thailand, and Vietnam.
50	*Rhynchostylis retusa* (L.) Blume	E	Apr–Nov	145443	Kakkad	India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Himachal Pradesh, Jammu & Kashmir, Uttarakhand, Andhra Pradesh, Odisha, Gujarat, Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, Jharkhand, Chhattishgarh, Haryana, Madhya Pradesh, and Andaman & Nicobar Islands), Sri Lanka, Bhutan, Myanmar, Nepal, Bangladesh, china, Thailand, Laos, Cambodia, Vietnam, Malaysia, Philippines, and Java.
51	*Robiquetia josephiana* Manilal & C.S.Kumar	E	Sep–Oct	145422	Soothuppara (Kakkayam)	India (Kerala and Tamil Nadu). Endemic to Western Ghats.
52	*Sirhookera lanceolata* (Wight) Kuntze	E	Aug–Nov	145405	Ambalappara (Kakkayam)	India (Karnataka, Kerala and Tamil Nadu) and Sri Lanka.
53	*Smithsonia maculata* (Dalzell) C.J.Saldanha	E	Jun–Sep	145429	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Goa, Karnataka, Kerala, Maharashtra, and Tamil Nadu). Endemic to Western Ghats.
54	*Smithsonia straminea* C.J.Saldanha	E	Feb–Apr	145406	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Goa, Karnataka, Kerala, and Maharashtra) and Sri Lanka.
55	*Taeniophyllum alwisii* Lindl.	E	Sep–Mar	145422	Atthikode R.F. (Malabar Wildlife Sanctuary)	India (Karnataka, Kerala, and Tamil Nadu) and Sri Lanka.
56	*Zeuxine gracilis* (Breda) Blume	T	Sep–Dec	145431	Kuttiyadi	India (Meghalaya, Nagaland, Arunachal Pradesh, Odisha, Karnataka, Kerala, Maharashtra, and Tamil Nadu), Borneo, Indonesia, Myanmar, Malaysia, Thailand, Vietnam
57	*Zeuxine longilabris* (Lindl.) Trimen	T	Aug–Dec	145430	Ambalappara (Kakkayam)	India (Assam, Tripura, Arunachal Pradesh, West Bengal, Odisha, Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu, and Bihar), Sri Lanka, Bangladesh, Myanmar, Thailand, and Cambodia.

Delhi, 157 pp.

Jalal, J.S., J. Jayanthi & P. Kumar (2014). *Eulophia spectabilis*: A high value medicinal orchid under immense threat due to overexploitation for medicinal uses in Western Ghats, Maharashtra, India. *The MIOS Journal* 15(10): 9–15.

Kumar, C.S. & K.S. Manilal (eds.) (2004). *Orchids Memories; A Tribute to Gunnar Seidenfaden.* Mentor books, Calicut, 265 pp.

Manilal, K.S. & V.V. Sivarajan (1982). *Flora of Calicut.* Bishen Singh Mahendra Pal Singh, Dehra Dun, 357 pp.

Mao, A.A. & S.S. Dash (2020). *The Flora of India: An Annotated Checklist*. Botanical Survey of India, Kolkata, West Bengal, 970 pp.

Misra, S. (2007). *Orchids of India - A Glimpse.* Bishen Singh Mahendra Pal Singh, Dehra Dun, 402 pp.

Nagrare, V. (2006). Orchid Diversity of India: Its Conservation and sustainable utilization. National Research Centre of Orchids, Pakvone, Sikkim, 19 pp.

Nair, M.C. & P.V. Madhusoodanan (2006). "A preliminary checklist of bryophytes of Vellarimala in the Western Ghats of Kerala". *Indian Journal of Forestry* 29: 191–196.

Narayanan, M.K.R. & M. Sivadasan (2009). Floristic study of Wayanad district with special emphasis on conservation of rare and threatened flowering plants. (Ph.D. thesis). Department of Botany, University of Calicut, Kerala, 1076pp. http://hdl.handle.net/10603/4046

Nayar, T.S., A.S. Beegam, N. Mohanan & G. Rajkumar (2014). *Flowering Plants of Western Ghats*. Tropical Botanic Garden and Research Institute, Thiruvananthapuram, Kerala, India.

Ramachandran, V.S. & V.J. Nair (1988). Flora of Cannanore district. Botanical Survey of India, Calcutta, 599 pp.

Ratheesh Narayanan, M.K. & M. Sivadasan (2009). Floristic study of Wayanad district with special emphasis on conservation of rare and threatened flowering plants. PhD thesis. Department of Botany, University of Calicut, Kerala, 1076pp. http://hdl.handle.net/10603/4046

Sasidharan, N. (2013). *Flowering Plants of Kerala:* CD-ROM ver 2.0. Kerala Forest Research Institute, Peechi, Kerala.

Singh, P., K. Karthigeyan, P. Lakshminarasimhan & S.S. Dash (2015). *Endemic Vascular Plants of India.* Botanical Survey of India, Kolkata, India, 339 pp.

Singh, S.K., A.D. Kumar, J.J. Singh, S.S. Dash & A. Mao (2019). *Orchids of India - Pictorial Guide.* Botanical Survey of India, Kolkata, 546 pp.

Udayan, P.S., K.V. Tushar, S. George & I. Balachandran (2008). Notes on some endemic, medicinal, rare and red listed plants from the Western Ghats of Kakkayam forest, Kozhikode (Calicut) district, Kerala, India. *Journal of Economic and Taxonomic Botany* 32: 581–594.

USDA (2019). Summary (December 2020). **U.S. Department of Agriculture.** National Agricultural Statistics Service, Washington, 66 pp.

Wildlife Protection Act, 1972 (Amended 1993). Government of India. (Accessed 05 December, 2021) https://moef.gov.in/en/wildlife-wl/wildlife

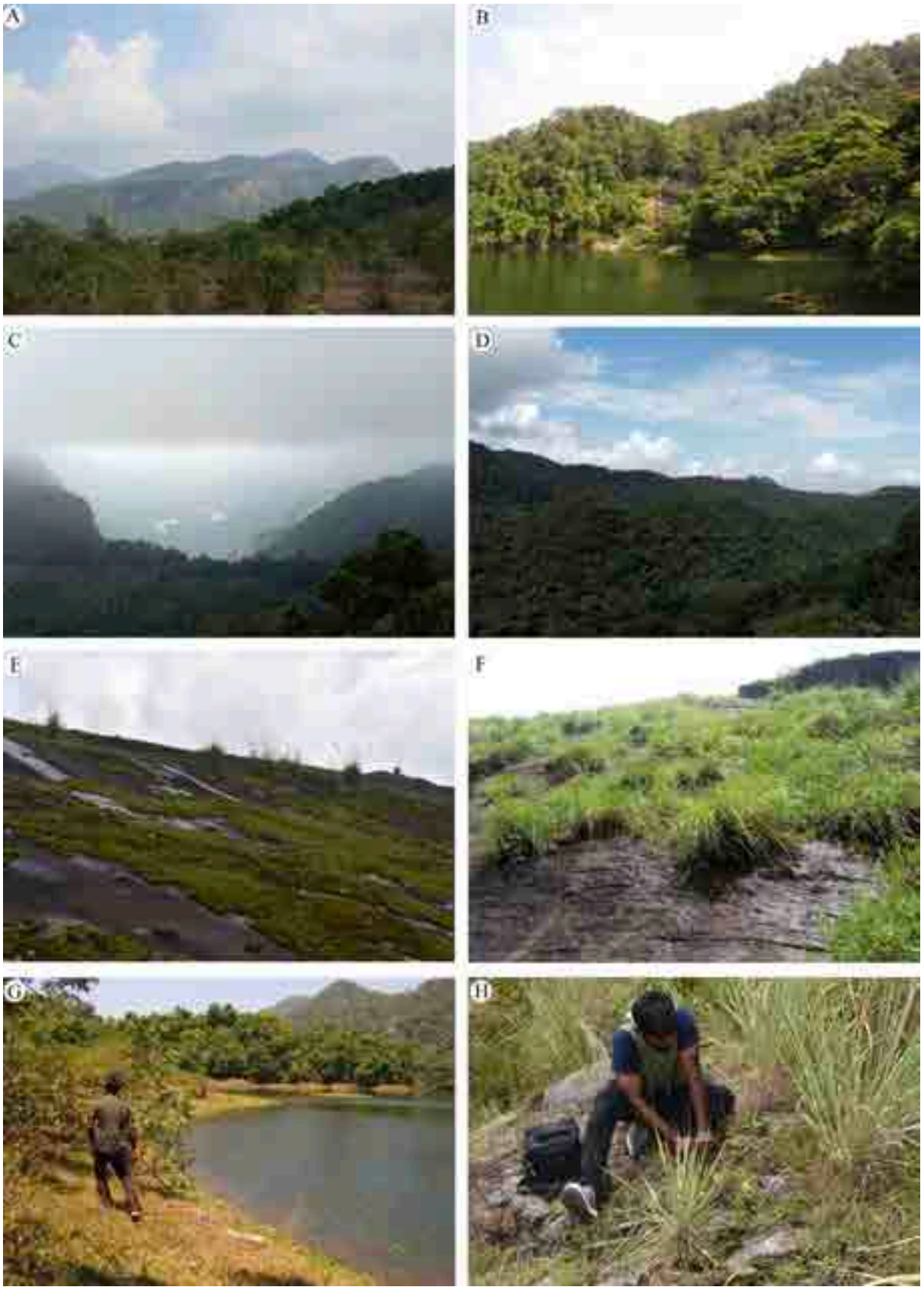

Image 1. Forest vegetations, survey and collection: A—Tropical Semi-evergreen forests | B—Tropical Wet evergreen forests | C & D—Southern hill top evergreen forests | E & F—Grass lands | G—Survey | H—Collection. © M. Sulaiman

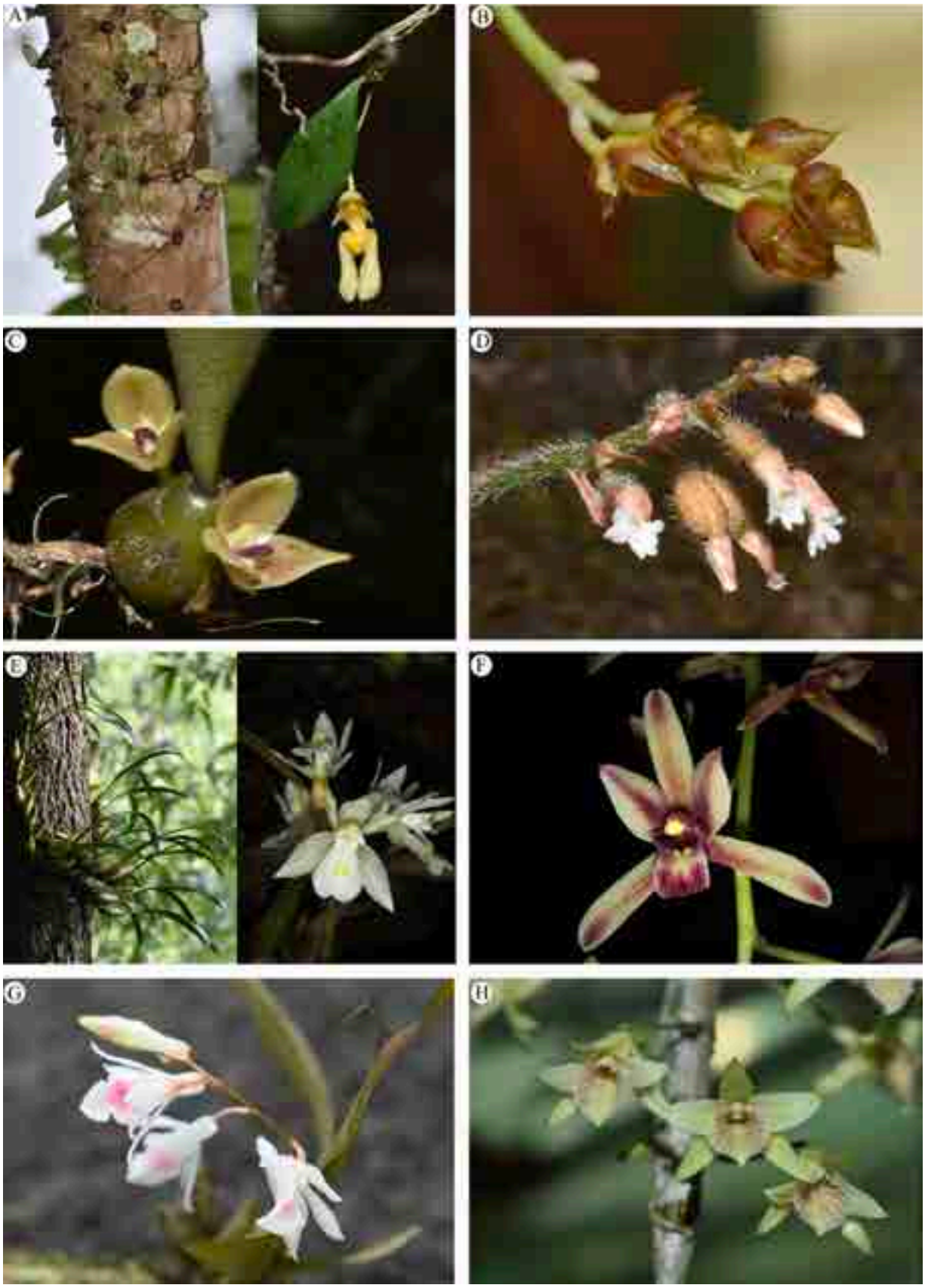

Image 2. A—*Bulbophyllum aureum* | B—*Bulbophyllum sterile* | C—*Bulbophyllum stocksii* | D—*Cheirostylis parvifolia* | E—*Coelogyne breviscapa* | F—*Cymbidium aloifolium* | G—*Dendrobium heyneanum* | H—*Dendrobium macrostachym.* © M. Sulaiman

Image 3. A—*Dendrobium nanum* | B—*Dendrobium nodosum* | C—*Dendrobium ovatum* | D—*Dendrobium salaccense* | E—*Diploprora championii* | F—*Eulophia nuda* | G—*Eulophia zollingeri* | H—*Habenaria heyneanum*. © M. Sulaiman

Image 4. A—*Luisia macrantha* | B—*Oberonia josephi* | C—*Oberonia proudlockii* | D—*Peristylus aristatus* | E—*Peristylus spiralis* | F—*Phalaenopsis mysorensis* | G—*Zeuxine gracilis* | H—*Zeuxine longilabris.* © M. Sulaiman

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COMMUNICATION

Abundance and spatial distribution analyses of *Stemonoporus moonii* Thwaites (Dipterocarpaceae) - a critically endangered species endemic to Sri Lanka

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Abstract: Hora Wel *Stemonoporus moonii* Thwaites, a plant species endemic to Sri Lanka, is the central focus of this study. Because of its strictly narrow distribution area of fewer than 100 km^2 and declining habitat, coupled with a high risk of extinction, it is placed under the 'Critically Endangered' category in International Union for the Conservation of Nature Red List category. A field survey was conducted during February–March 2020 in Walawwe-Watta Wathurana freshwater swamp forest to assess the population status of this species. Global positioning system (GPS) coordinates of individuals were documented. The root collar diameter of plants was measured to differentiate adults. Population size analysis was performed using GeoCAT online software, and a distribution map was prepared using Quantum GIS (QGIS 3). A total of 600 plants were recorded, with 50% each adult (root collar diameter more than 2.0 cm) and young individuals (root collar diameter equal to or less than 2.0 cm). The extent of occurrence (EOO) and area of occupancy (AOO) of *S. moonii* were calculated as 0.06 km^2 and 4.000 km^2, respectively. Two subpopulations of *S. moonii* can be seen within the Walawwe-Watta Wathurana Environmental Protection Area. The findings of the present study support the current IUCN Red List status of *S. moonii* as Critically Endangered. Even though the existing populations of this species located within a protected area and not presently exposed to major threats, the location is easily accessible and can potentially be affected by anthropogenic pressures and habitat loss. Therefore, this species and the habitat warrant suitable in situ conservation measures. .

Keywords: AOO (Area of occupancy), Critically Endangered, EOO (Extent of occurrence), GeoCAT, Hora Wel, IUCN Red List, narrow endemic, QGIS, threat of extinction, Wathurana swamp forest.

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Author contributions: K.A.M.R.P. Atapattu, H.D.D.C.K. Perera—manuscript writing, field data gathering. H.S.Kathriarachchi—supervising, proof reading A.R.Gunawardena—map preparation.

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INTRODUCTION

Sri Lanka is a tropical island with a total land area of 65,610 km^2 situated in the Indian Ocean. Despite its small size, it has rich ecosystem diversity due to its topography, climatic heterogeneity, and coastal influence (Gunatilleke et al. 2008). It harbors more than 4,100 species of flowering plants, with one-fourth being endemic to the island (Gunatilleke et al. 2008). The southwestern region is the only seasonal ever-wet region in southern Asia, harboring particularly high biodiversity with a high concentration of endemic species. Along with the Western Ghats of India, Sri Lanka is one of the 36 global biodiversity hotspots, and was identified among the eight most significant areas ("hottest hotspots") with a high endemic/area ratio for both vertebrates and plants (Myers et al. 2000).

Walawwe-Watta Wathurana Swamp Forest (WWWSF) is the only freshwater swamp forest in Sri Lanka (CEA 1994; Jayasuriya et al. 2006). Freshwater swamps are described as "nature's kidneys" because they have been found to protect shorelines, prevent floods, clean polluted water and recharge groundwater (CEA 1994). The WWWSF harbors an endemic plant species *Stemonoporus moonii* Thwaites (Kostermans 1992; CEA 1994; Jayasuriya et al. 2006) that was believed to be extinct in the wild until it was rediscovered in 1979 after a lapse of 160 years (Kostermans 1992; CEA 1994). *Stemonoporus moonii* is a small, slender tree with a similar appearance to a climber (Image 1A), hence it is locally known as 'Hora Wel' or 'Berumandoru'. It can be distinguished by the long, slender, persistent stipules on the apical branches, crowded leaves, prominent secondary veins and distinct leaf scars (Image 1B) (Rubasingha et al. 2008). The flowers appear singly or in clusters; the corolla is white, with red longitudinal bands on the abaxial side (Image 1C) (Kostermans 1992).

Stemonoporus Thwaites is the most species-rich (27 species) endemic genus of the family Dipterocarpaceae in Sri Lanka. Almost all species of *Stemonoporus* are categorized as either Endangered or Critically Endangered in the IUCN Red Data Book (Rubasinghe et al. 2008). They are mainly confined to the wet zone and have a well-defined habitat and geographical and ecological range (Dassanayake & Fosberg 1980). The degradation and fragmentation of natural habitats have had adverse effects on the regeneration and distribution of these threatened species (Ediriweera 2004). *Stemonoporus moonii* is confined to WWWSF in Sri Lanka. Many studies suggest that narrow endemic species are susceptible to extinction and that these extinction-prone species grow naturally in a narrow geographical area (Kani 2011). For this reason, narrow endemic species are the first to experience the adverse effects of habitat destruction, fragmentation or alteration.

Stemonoporus moonii was assessed as 'Critically Endangered' in the 1998 IUCN Red List of Threatened Species (Ashton 1998). According to the IUCN (2012), the purpose of categorization of species is to create a relative estimate of the likelihood of extinction of the taxon, where the Red List Criteria should be applied to a taxon based on the available evidence such as several individuals, trends, and distribution (Haciogullari et al. 2019). A taxon is categorized as Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E and therefore it is considered to be facing an extremely high risk of extinction (IUCN 2019). The Red List current assessment lists *S. moonii* as Critically Endangered B1ab(i,ii,iii)+2ab(i,ii,iii). The justification for this categorization is related to its extremely restricted distribution. Both the Extent of occurrence (EOO) and Area of occupancy (AOO) of *S. moonii* estimated to be less than 10 km^2 (MOE 2012).

As per IUCN rules, if an assessment is more than 10 years old, it has to be reassessed. The IUCN category of particular taxa can be changed due to 'genuine' or 'non-genuine' reasons (IUCN 2019). Therefore to assess the status of biodiversity, it is vital to reassess the species periodically. However, no recent published data regarding the current distribution, population size, and threats of *S. moonii* exist. In this study, the current distribution area and population size of *S. moonii* were determined based on comprehensive and up-to-date assessments.

METHODS

Study site

The Walawwe-Watta Wathurana Freshwater Swamp Forest is located in the Kalu Ganga river basin and spread over to 12 ha in the southwestern part of Sri Lanka. It is located on the private land in Bulathsinhala of Damparadugoda, 25 km inland from Kaluthara District in Western Province, and presently managed by the Walawwe-Watta Plantation Company (Image 2). This forest patch is surrounded by Bulathsinhala and Atura in the north-west, Galketiya in the east, and Pahalawelgama in the west. This land is accessible from the Horana-Kalawellawa road through Pahalawelgama and from the Bulathsinhala-Paragoda road. This site is situated along a stream locally known as 'Batapotte ela', which originates

Image 1. Exomorphic features of *Stemonoporus moonii*: A—Mature plants | B—New foliage | C—Flower | D—New branchlet. © H.D.D.C.K. Perera.

Image 2. The study site in Walawwe-Watta Wathurana Swamp Forest.

at Yatagampitiya and feeds a tributary of the Kalu Ganga. This forest area experiences seasonal flooding twice a year, generally from July to September, and is inundated with up to 3–4 m of water for 1–2 months. The mean annual rainfall of the area lies between 4,000–5,000 mm, and the annual temperature is recorded as 27°C. This area receives rainfall mainly from the south-west monsoon from May to July and the north-east monsoon from October to December (Ashton et al. 2001).

Field surveys

Field surveys were conducted during February–March 2020, and distance sampling methods were used during field surveys. Distance sampling is a widely used technique for estimating the size of a population. For this study the point transect method was used, as it is most appropriate to the rugged and difficult terrain of the site (Haciogullari et al. 2019). In the point transect method, an observer visits randomly-selected points and surveys the species present within a predetermined zone (5 m radius in this study). GPS locations of all individuals in the point

transects were recorded, and root collar diameter was measured. Mature (root collar diameter more than 2.0 cm) and immature (root collar diameter equal to or less than 2.0 cm) individuals were counted to determine the population size. Additionally, special features such as the presence of flowers, buds, or fruits, whether the plant is dead or dead branches are present, and potential threats were recorded.

Abundance and Spatial Distribution Analyses

The distribution of *S. moonii* was analyzed using QGIS 3 (Quantum GIS) software from the obtained locality data. QGIS is an open-source geographic information system. Google satellite image of the study area was overlaid with available locality data of *S. moonii*. GeoCAT online software was used to calculate the AOO and the EOO; this open-source application can perform rapid geospatial analysis for the Red List assessment. EOO was measured using the quickhull method. AOO was calculated by summation of the area of square grids the species occupies (Bachman et al. 2011). For calculating AOO, a 2 km^2 cell size was used, as recommended in the IUCN guidelines (IUCN 2019).

RESULTS

Abundance and Spatial Distribution

Walawwe-Watta Wathurana swamp forest was surveyed for the occurrence and abundance of *S. moonii*. Ten years ago, a few individuals of the species were recorded from the area known as Honaka mountain (H.D.D.C.K. Perera, pers. comm., 22 March 2020). However, in the present study, individuals were recorded only from the WWWSF. Individuals were recorded from the seasonally inundated lands in the forest. In total, 600 individual plants were recorded, including 297 (49.5%) mature and 303 (50.5%) immature individuals (Figure 1). Observations were made at the end of the flowering season (January–March), and only one plant was recorded with flowers and eight plants with flower buds. In the study area, *S. moonii* was commonly associated with the other dominant species, including *Garcinia hermonii* Kosterm., *Dipterocarpus hispidus* Thwaites, *Cullenia rosayroana* Kosterm., *Durio zeylanicus* Auct., *Humboldtia laurifolia* Vahl, *Quassia indica* (Gaertn.) Noot., *Macaranga digyna* (Wight) Müll.Arg., *Ochlandra stridula* Thwaites, and *Calamus* species. No seedlings of *S. moonii* were observed during the study. Of the 600 individuals, six plants were found dead, one dying, and seven others had dried branches. The individuals were mainly found in two major clusters (1 and 2); 169 in cluster-1 and 431 in cluster-2. Some of the individuals in cluster-2 were located at the riverbank of Kudu Ganga (Image 3). The EOO and AOO of *S. moonii* were calculated at 0.057 km^2 and AOO 4.000 km^2, respectively.

Potential threats

Although the population is presently not exposed to threats and is still balanced under natural conditions, it could be threatened by various anthropogenic activities. Possible threats are listed below.

- Wetlands help maintain freshwater flows within river systems and act as a sponge. The changing land-use patterns and illegal tree felling can lead to flooding in the area and could cause significant detrimental effects on the survival of this species.
- Even though Wathurana swamp forest is a protected area, it is easily accessible to nearby villagers who can potentially extract plant parts, collect fuel woods, edible fruits, medicinal plants, poles for agricultural purposes, and timber. The villagers use poles of *S. moonii* to make trellises for beetle vines.
- Due to the modern agricultural practices carried out in the nearby area, the use of chemical fertilizers has increased drastically. Illegal fishing using dynamites is practiced in Batapotte ela stream. Most of these chemicals flow along the water streams of the area, and excess of them tend to deposit in the soil. This may alter the soil composition of the area, which could further impact *S. moonii* population.
- People in the vicinity have already altered parts of Wathurana Wetlands to construct new buildings and establish rubber plantations. Such clearing of Wathurana swamp forest areas for agricultural and developmental purposes may directly affect biodiversity.
- The soil in this forest area contains high proportions of clay, and mining clay deposits in the area may drastically alter the forest's ecological functions.
- The forest clearing and changing land-use patterns in the study area could potentially affect the groundwater table and eventually threaten the existence of the habitat and survival of its flora.

Reassessment of conservation status

As per the National Red List 2012 of Sri Lanka (MOE 2012), *S. moonii* was assessed as Critically Endangered based on the criteria B1ab(i,ii,iii)+2ab(i,ii,iii). Based on the newly-available locality data, an up-to-date conservation status can be assessed to determine whether the current conservation status is still valid or if some degree of modification is required. The AOO and EOO calculated in this study confirm the Critically Endangered status of

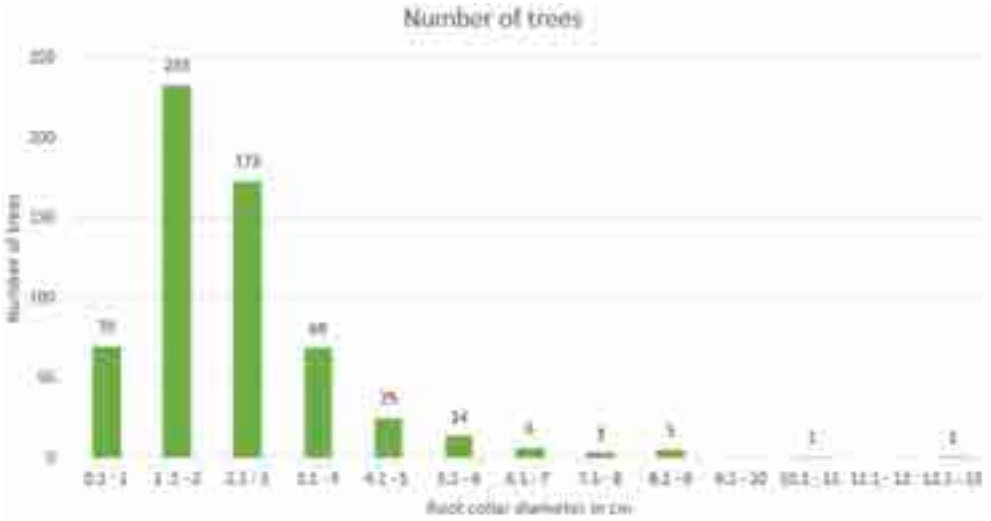

Figure 1. Root Collar Diameter class distribution of individuals of *Stemonoporus moonii* in the Wathurana swamp forest.

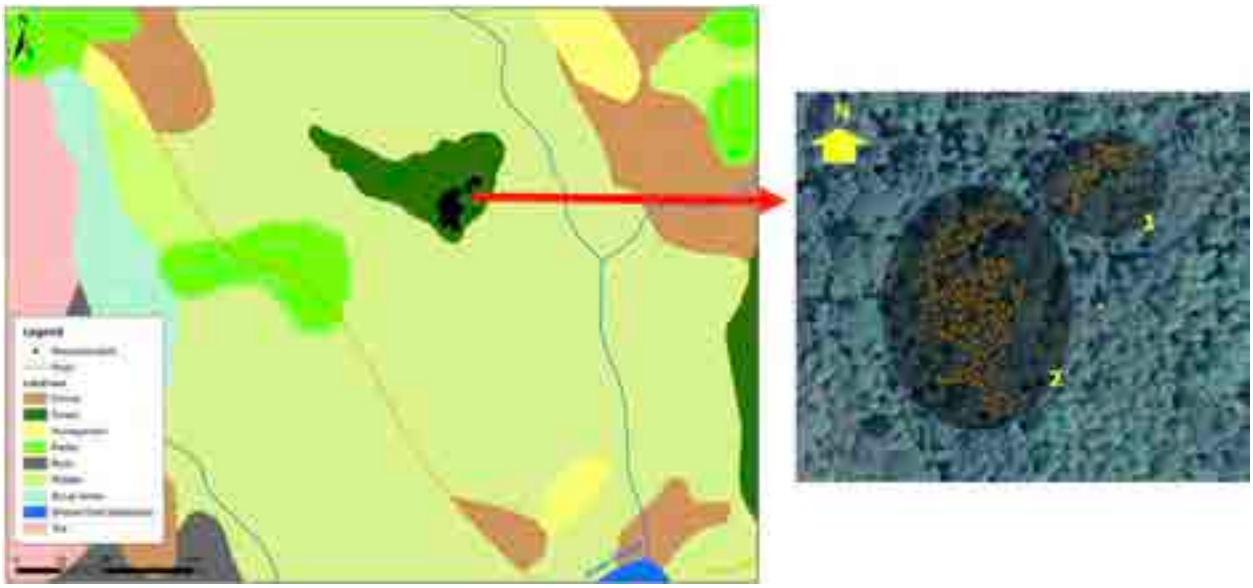

Image 3. Distribution map of *Stemonoporus moonii*

S. moonii due to its restricted distribution and habitat loss. As a narrow endemic species, *S. moonii* is strictly confined to the study area, therefore, has a great chance of being extinct in the wild. Currently, it is assessed as B1, which means its EOO is less than 100 km^2. The calculated EOO value is 0.057 km^2. Therefore, it can be placed in the same category as the current assessment but could also fall under criteria B2 as the AOO is 4 km^2, below the 10 km^2 threshold. Moving to the next step of the assessment, at least two of the three listed sub-criteria, a, b and c, are to be met. According to the current assessment, it is assessed as ab(i, ii, iii), which means (a) severely fragmented or present in only one location and (b) continuous decline observed, estimated, inferred or projected in (i) extent of occurrence (ii) area of occupancy (iii) area, extent and/or quality of habitat. The survey results suggest that criterion (a) could still be relevant, because it is located in only one location.

In this study, two subpopulations of the species were observed within the protected area with a population density of 9,670 plants/km^2 (600 plants/0.062045 km^2). The distance between the two subpopulations was approximately 15 m. The soil types observed in the study area are bog and half bog exhibiting poor drainage compared to the small hillocks. This soil is oxygen and nutrient-poor, and acidic. The seedlings of *S. moonii* have

to thrive in such environmental conditions, and these plants prefer seasonally inundated lands in the forest. Also, a strong case could be argued for the inclusion under the b(i,ii,iii) category, where declines can be seen in EOO, AOO, and habitat quality. However, the category c(i,ii,iii,iv) could not be included due to the absence of historical data. Moreover, based on the obtained results, the ratio between immature and mature individuals remains nearly 1:1. Therefore the decline in the number of mature individuals could not be observed. With this new information, the present reassessment supports retaining the current Critically Endangered status of *S. moonii*.

DISCUSSION

One of the main objectives for this study was to assess the population status of *S. moonii*. Due to its small population size and narrow distribution in Sri Lanka, this has become a threatened species. However, no study has so far been carried out to assess the population size of *S. moonii*, except for the IUCN Red List evaluation (Ashton 1998). The results of the present study reiterate the Critically Endangered status of this species. Due to the absence of historical records, it is impossible to assess if the population experienced any extreme fluctuations. In this study, the root collar diameter of each individual was measured to find out the proportion of mature and immature individuals. Root collar diameter was the only attainable data from the species because even though it is a tree, it grows like a liana in natural conditions. Hence it is not feasible to measure DBH (Diameter at breast height). Population count proves that the species has no issues with reproduction. The presence of young individuals indicates that seed germination is not an issue, and because of that already balanced population size could be maintained. The equal percentage of mature and young individuals shows that species fecundity is not an issue.

During the survey, no extension or alteration in the flowering period was observed. Usually, plants tend to match their developmental transitions with the best time of year for growth and reproduction to maintain high fitness (Blackman 2017). Flowering time is associated with processes that play a key role in eco-evolutionary dynamics (Franks 2015).

In the study area, *S. moonii* is commonly associated with other species, including *Garcinia hermonii* Kosterm., *Dipterocarpus hispidus* Thwaites, *Cullenia rosayroana* Kosterm., *Durio zeylanicus* Auct., *Humboldtia laurifolia* Vahl, *Quassia indica* (Gaertn.) Noot., *Macaranga digyna* (Wight) Müll.Arg., *Ochlandra stridula* Thwaites, and *Calamus* species. In long-lived mixed-species perennial communities, inter-species interactions are more complex. All species share a common environment that interacts with each other, thereby resource competition is high. However, *S. moonii* was distributed well throughout their habitat. Resource allocation strategies prioritize the persistence of a species, allowing them to persist for a long period in their habitat below their maximum size (Dillon et al. 2019).

The present study reveals that *S. moonii* is still strictly confined to WWWSF probably due to the unique environmental conditions of the area. Freshwater swamps particularly grow on fertile alluvial soils, open to river flooding, and generally have intercommunicating streams with well-mineralized water (Penfound 1952; Aselmann & Crutzen 1989; CEA 1994; Mitsch & Gosselink 2000; Gupta et al. 2006). Almost all the individuals of *S. moonii* were recorded from WWWSF and none of them were recorded from any nearby area. Based on these observations it is clear that *S. moonii* has not extended its geographical region and that it prefers a unique habitat.

Although the different natural and anthropogenic circumstances and processes that promote the loss of species in the area do not cause direct pressure on *S. moonii* it has a great chance of being extinct from the wild due to its extremely restricted distribution range. People who are involved in cultivating betel (*Piper betel*), extract these plants as poles to provide the support needed by the betel. Expansion of the agricultural lands and rubber plantations in the nearby area may severely affect their population size. Other than that, a great effect can be caused by the use of chemical fertilizers. Out of the total count, chemical fertilizers are used by 86.67% of farmers in the area and they have been using them for more than ten years (Siriwardana & Sangasuman 2018). These chemicals easily wash out and get into water streams in the area. During the flooding season, these chemicals can be deposited on forest lands. *S. moonii* shows unique features in their distribution only by preferring inundated but most upper margins of the area. Without any doubt, by studying their distribution pattern, it could be said that soil composition and the soil structure cause a great influence on their distribution. If people in the vicinity use these kinds of harmful fertilizers regularly, there is a great chance of altering their distribution, population size, and germination patterns. Many parts of Asia tend to change flow regimes in running waters and consequently impact habitats and species that are sensitive to floods and droughts due to climate change (IPCC 2014). Moreover, the same report on climate change prepared by the Intergovernmental Panel on climate change reveals that

habitats that depend on seasonal inundation, such as flood plain grasslands and freshwater swamp forests, will be particularly vulnerable (IPCC 2014). Many freshwater habitats are similarly isolated and their restricted-range species may be equally vulnerable.

Due to the impending threats, highly restricted distribution and poor awareness among the local public, urgent measures are required to protect this species. Further studies involving ecological assessment of *S. moonii* covering its population trends, demography, reproductive biology, and population genetics are needed to be carried out. Even though this species is distributed inside the protected area, it is necessary to establish focused in situ and ex situ conservation and management programs. Creating awareness among the general public and the relevant authorities is crucial to curtail unintentional damage to the species and its fragile habitat, and to ensure effective and successful conservation of this unique and highly threatened species.

CONCLUSION

Analysis of population data collected during the present study supports the existing 'Critically Endangered' status of *S. moonii*. Maintaining a proper ratio between mature and immature individuals under natural conditions reveals that species fecundity is not an issue. Distribution patterns of *S. moonii* show that they prefer seasonally inundating but most upper margins of the forest. Even though *S. moonii* does not suffer directly from the threats in its natural habitat, it has a great chance of being extinct from the wild because of its narrow distribution. Therefore, suitable conservation measures are urgently needed to protect the populations and habitats of *Stemonoporus moonii*.

REFERENCES

Aselmann, I & P.J. Crutzen (1989). Global distribution of natural freshwater wetlands and rice paddies, their net primary productivity, seasonality and possible methane emissions. *Journal of Atmospheric Chemistry* 8: 307–358.

Ashton, M.S., C S.V. Gunatilleke, B.M.P. Singhakumara & I.A.U.N. Gunatilleke (2001). Restoration pathway for rain forest in Southwest Sri Lanka: a review of concepts and models. *Forest Ecology and Management* 154: 409–412.

Ashton, P. (1998). *Stemonoporus moonii*. The IUCN Red List of Threatened Species. Downloaded on 02 March 2020. https://doi.org/10.2305/IUCN.UK.1998.RLTS.T33439A9784484.en

Bachman, S., J. Moat, A. W. Hill, J. Torre & B. Scott (2011). Supporting Red List threat assessments with GeoCAT: geospatial conservation assessment tool. *Zookeys* 150: 117–126.

Blackman, B.K. (2017). Changing Responses to Changing Seasons: Natural Variation in the Plasticity of Flowering Time. *Plant Physiology* 173 (1): 16–26.

CEA (1994). Walawwe-Watta Waturana Swamp Forest. Wetland site report. Central Environmental Authority, Colombo 10, Sri Lanka, 54pp.

Dassanayake, M.D. & F.R. Fosberg (eds.) (1980). A revised handbook to the flora of Ceylon. Amerind Publishing Company, New Delhi.

Dillon, K. T., A. N. Henderson, A. G. Lodge, N. I. Hamilton, L. L. Sloat, B. J. Enquist, C. A. Price, and A. J. Kerkhoff (2019). On the relationships between size and abundance in plants: beyond forest communities. *Ecosphere* 10(9):e02856. 10.1002/ecs2.2856.

Ediriweera, S. (2004). Conservation Leadership Programme, Preparation of conservation profiles for *Stemonoporus* species in Sri Lanka. Downloaded on 02 March 2020. http://www.conservationleadershipprogramme.org/project/preparation-conservation-profiles-stemonoporus-species-sri-lanka/

Franks, S.J. (2015). The unique and multifaceted importance of the timing of flowering, *American Journal of Botany* 102(9): 1401–1402.

Gunatilleke, N., R. Pethiyagoda & S. Gunatilleke (2008). Biodiversity of Sri Lanka. *Journal of National Science Foundation Sri Lanka*. 36(Special Issue): 25–62.

Gupta, N., A. Anthwal & A. Bahuguna (2006). Biodiversity of Mothronwala swamp. Doon Valley. Uttaranchal. *The Journal of American Science* 2: 33–40.

Haciogullari, I., S. Gucel, J. Wayne, O. Ozden (2019). Abundance and spatial distribution analysis of *Salvia Veneris*: a critically endangered plant species endemic to Cyprus, *Biodiversity* 20: 98–105.

IPCC (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, & L.L. White (eds.). New York, USA, 688 pp.

IUCN (2019). Guidelines for Using the IUCN Red List Categories and Criteria. Version 14. Prepared by the Standards and Petitions Committee. Downloaded on 04 March 2020. http://www.iucnredlist.org/documents/RedListGuidelines.pdf

Jayasuriya, A.H.M., D. Kitchner & C.M. Biradar (2006). Portfolia of strategic conservation site/ protected area gap analysis in Sri Lanka. Ministry of Environment and Natural resources, Davidson road, Colombo 4, 207 pp.

Kani, I.S I.K. (2011). Rare and endemic species: why are they prone to extinction? *Turkey Journal of Botany* 35: 411–417.

Kostermans, A.J.G.H. (1992). *A hand book of the Dipterocarpaceae of Sri Lanka*. The wildlife heritage trust of Sri Lanka.

Mitsch, W.J. & J.G. Gosselink (2000). *Wetlands, 3rd edition*. John Wiley & Sons, Inc., New York.

MOE (2012). The National Red List 2012 of Sri Lanka, Conservation Status of the Fauna and Flora. Ministry of Environment, Colombo, Sri Lanka, viii+476 pp.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Penfound, W.T. (1952). Southern swamp and marshes. *Botanical review*. 18: 413–466.

Rubasinghe, S.C.K, D.M.D. Yakandawala & D.S.A. Wijesundara (2008). Phylogenetics of the endemic genus *Stemonoporus* Thw(Dipterocarpaceae). *Journal of National Science Foundation Sri Lanka* 36(4): 281–297.

Siriwardana, S.H.S.M. & V.P. Sangasumana (2018). The Impact of Anthropogenic Intervention on the Walawwe-Watta Wathurana Fresh Water Swamp Forest in Sri Lanka. *International Journal of Multidisciplinary Studies* 5(2): 130–138.

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COMMUNICATION

Plant diversity of Point Calimere Wildlife Sanctuary and fodder species grazed by the Blackbuck *Antilope cervicapra* L.

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Abstract: A rapid but intense survey was conducted using visual landmarks in the Point Calimere Wildlife Sanctuary to enumerate the flora and foraging habits of the Blackbuck *Antelope cervicapra*. The area was divided into various segments such as the sanctuary entrance, Maattu muni kovil, Savukku plot or Casuarina plantation, S-Bend road and the old light house for precise enumeration. A total of 111 plant species that include 50 herbs, 16 climbers/lianas, 30 shrubs and sub-shrubs, and 15 trees belonging to 39 plant families were recorded in this study. Visual observations showed that Blackbucks grazed on grasses such as the Mangrove Grass *Aeluropus lagopoides* (L.) Thwaites, Dog's Tooth Grass *Cynodon barberi* Rang. & Tadul., Indian Durva Grass *Cynodon dactylon* (L.) Pers., Feather Finger Grass *Chloris virgata* Sw., and a sedge, the pointed fimbristylis *Fimbristylis acuminata* Vahl during the day time. They were also observed browsing on the leaves and pods of Algaroba *Prosopis juliflora* (Sw.) DC. in the evenings. Our observation on the presence of feral horses and stray cattle in the Point Calimere Wildlife Sanctuary shows that they compete for food and water with the Blackbuck. The spread of invasive alien plant species competes with and reduces the space for native species.

Keywords: Feral, foraging habits, Nagapattinam District, tropical dry evergreen forests, Fodder species, alien species, habitat, survey, Bishnoi community.

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Author contributions: AKU, AAE and ASV were involved in the field survey, identification of plants and preparation of the manuscript. DN supervised the work and gave important inputs for the study. All authors contributed towards writing the manuscript.

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INTRODUCTION

Point Calimere Wildlife Sanctuary harbours a rich diversity of animals, among them is the Blackbuck which is the most exquisite animal in the sanctuary. The name Blackbuck is in reference to the dark-coloured coat of the adult male which varies from dark brown to black. The belly and hind side of the legs are white. The horns of the males are ridged and twisted. Blackbuck *Antilope cervicapra* L. is listed under Schedule I, Part I of the Indian Wildlife Protection Act, 1972. Habitats of the Blackbuck have been declared as protected areas in several parts of India, with the support of the local people. Punjab and Haryana have honoured the animal as their state animal (Hundal 2004) and the Bishnoi community of Rajasthan considers the blackbuck as a sacred animal. There are six protected areas in Tamil Nadu where Blackbucks occur in considerable numbers. They include: (a) the Guindy National Park and its contiguous campuses such as Raj Bhavan and the Indian Institute of Technology, Madras (IIT-M), though these campuses do not fall under the protected category; (b) Vallanadu Sanctuary, Tuticorin; (c) Point Calimere Wildlife Sanctuary, Kodiakkarai; (d) Sathyamangalam Wildlife Sanctuary and Tiger Reserve, Erode; (e) Kanyakumari Wildlife Sanctuary, Kanyakumari; and (f) Mudumalai Wildlife Sanctuary and National Park, Nilgiris.

Blackbucks are sensitive and get disturbed by human presence. They prefer open grasslands and like to graze during early mornings and late afternoons. There are no direct predators for the Blackbucks in the Point Calimere Wildlife Sanctuary (PCWS). A census conducted in 2015 by the forest department, Tamil Nadu in coalition with the A.V.C Engineering College, Mayiladuthurai and Government Arts and Science College, Poompuhar recorded 948 Blackbucks, 172 feral horses, 82 Wild Boars, 12 Black-naped Hares, and 20 Jackals in the sanctuary (Suresh 2015). The objectives of this study were (a) to survey the plant diversity and highlight the species of herbs, shrubs, and trees seen in PCWS and (b) to document the grasses and other plant species grazed by the Blackbucks.

MATERIALS AND METHODS

Study area

PCWS is one of the largest tropical dry evergreen forests (TDEF) in India located between 10.2878°N & 79.8651°E with an expanse of 1,729 ha located in the Nagapattinam district of Tamil Nadu (Figure 1) (Ali 2005; Parthasarthy et al. 2015). TDEF are the areas of vegetation without a distinct differentiation between the small and canopy forming trees, having coriaceous leaves with an average height of less than 12 m, having a luxuriant growth of lianas and climbers along with an inconspicuous presence of grasses (Champion & Seth 1968; Parthasarthy et al. 2015). This vegetation receives both summer and winter monsoons due to depressions and cyclones in the Bay of Bengal (Meher-Homji 1974). It forms an interface between the coastal and the deciduous vegetation, having varied ecosystems with a visible change in the soil type from sandy, saline to alluvial.

Point Calimere was declared a wildlife sanctuary in 1967 for conserving the Blackbuck population that was dwindling due to intensive poaching and hunting (Baruah 2005). PCWS is bordered by Vedaraniyam salt pans in the north, Palk Strait in the south, Bay of Bengal in the east, and Kodiakadu in the west. It gets its name from the point at which both the Bay of Bengal and the Palk Strait meet. The human habitations around the forest are found mainly in two villages namely, Kodiakkarai and Kodiakadu. The sanctuary is an island which is connected to the mainland by the Vedaraniyam-Kodiakkarai road.

Data collection and analyses

The methods of assessment used were very simple and based on visual observations in the field, i.e., observing Blackbucks while they grazed, followed by visiting the grazing sites to identify the plant species (Altman 1974). Since, this was a rapid survey, methods such as quadrates and other indices were not planned for in the study. However, the sanctuary was divided into the following segments using visual landmarks for effective and efficient data collection: (a) sanctuary entrance, (b) Maattu muni kovil - a temple visited by local cowherds, (c) Savukku plot or Casuarina plantation, (d) S-Bend road, and (e) the old light house. Rapid survey was conducted within the sanctuary for almost a month and a total of about 120 hours were spent exclusively for observing foraging and resting habits of Blackbucks in the PCWS. During the study period, field binoculars were used to observe the grazing activities. The segments were explored to interpret the foraging pattern of Blackbucks and to make a list of plants available in the sanctuary, which was further used to understand the components of the vegetation. Most of the plant species were identified on the site and undesignated plant specimens especially the grasses were taken to the laboratory for identification. All the identified plant species were classified based on their

Figure 1. Study area

habitats. The botanical names of the plant species were updated using online databases such as POWO (2020), The Plant list (2013) and The International Plant Name Index (IPNI 2018). Specimens were also photographed and kept for reference.

RESULTS

A total of 111 plant species that included 50 herbs (12 grasses, five sedges and four creepers), 16 climbers/ lianas, 30 shrubs & subshrubs, and 15 trees belonging to 39 plant families were recorded in this study (Figure 2). Of the plant families recorded Fabaceae, Poaceae, Amaranthaceae, Lamiaceae, Cyperaceae, Rubiaceae, Convolvulaceae, and Asteraceae were the most species-rich families having four or more species each (Figure 3). The habitats of different plant species observed were divided into five major types, namely, (a) Inundated plains—areas getting seasonally flooded, dominated by *Chloris virgata* Sw., *Cynodon barberi* Rang. & Tadul., *C. dactylon* (L.) Pers., *Perotis indica* (L.) Kuntze, *Fimbristylis acuminata* Vahl, *F. argentea* (Rottb.) Vahl, *Epaltes pygmaea* DC., and *Platostoma menthoides* (L.) A.J.Paton; (b) Low mounds—an elevated land c. a meter high, dominated by *Eragrostis viscosa* (Retz.) Trin.; (c) High mounds—an elevated land c. 1.5–2 m high, having *Cyanthillium cinereum* (L.) H.Rob., (d) Sand dunes—small hills of loose sand, with species such as *Calotropis gigantea* (L.) W.T.Aiton. and *Ipomoea pes-caprae* (L.) R.Br.; and (e) Mangrove—tropical coastal vegetation comprising of salt tolerant species such as *Avicennia marina* (Forssk.) Vierh. and *Excoecaria agallocha* L. The term 'mound' used here is to distinguish elevated patches of land from the rest of the study area. Many plant species (except mangroves) were not rigidly habitat specific and were observed occurring in different habitats. A checklist of plants with their local Tamil names and habitats within the sanctuary was also prepared (cf. Appendix I).

Visual observations from a distance followed by instantaneous site visits in the field showed that the Blackbucks preferred to graze on selected grasses such as *Aeluropus lagopoides* (L.) Thwaites, *Cynodon barberi* Rang. & Tadul., *C. dactylon* (L.) Pers., *Chloris virgata* Sw.,

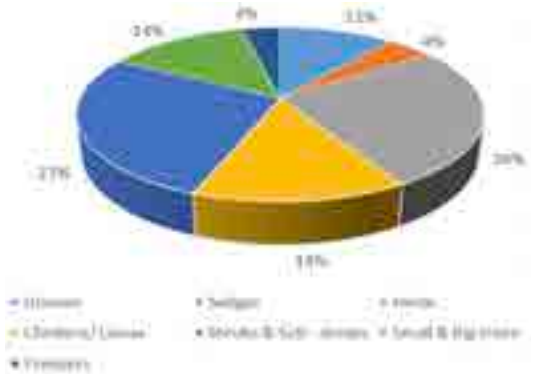

Figure 2. Habit types observed at Point Calimere Wildlife Sanctuary.

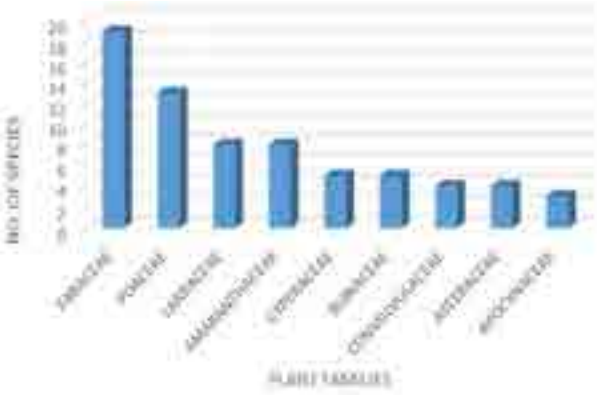

Figure 3. Dominant Plant families.

Table 1. Suggested fodder species for introduction in Point Calimere Wildlife Sanctuary.

1.	Grass species for Blackbucks	*Cynodon radiatus* Roth, Blue panic grass *Panicum coloratum* L., *Panicum curviflorum* Hornem., Torpedo grass *Panicum repens* L., *Setaria flavida* (Retz.) Veldkamp
2.	Grasses to be introduced in saline areas	Sprangle top *Leptochloa obtusiflora* Hochst., *Sporobolus maderaspatanus* Bor, Coastal rat tail grass *Sporobolus virginicus* (L.) Kunth
3.	Grasses to be introduced in sandy areas	Daabh *Desmostachya bipinnata* (L.) Stapf, *Dimeria avenacea* (Retz.) C.E.C.Fisch., *Manisuris myurus* L., Indian comet grass *Perotis indica* (L.) Kuntze, *Trachys muricata* (L.) Pers. ex Trin
4.	Tree species to be introduced within the sanctuary	Babul *Vachellia nilotica* (L.) P.J.H.Hurter&Mabb., Reonja *Vachellia leucophloea* (Roxb.) Maslin, Seigler & Ebinger, Bidi leaf tree*Bauhinia racemosa* Lam., Flame of the forest *Butea monosperma* (Lam.) Kuntze, Siris tree *Albizia lebbeck* (L.) Benth., Krishna Siris *Albizia amara* (Roxb.) B.Boivin, Black Siris *Albizia odoratissima* (L.f.) Benth., Indian Coral tree *Erythrina variegata* L.

a sedge *Fimbristylis acuminata* Vahl during the day time and they were seen browsing on the leaves and pods of *Prosopis juliflora* (Sw.) DC. in the evenings usually before sunset. They preferred grazing in open areas and around mounds. They were usually observed grazing in herds and rarely in solitude.

DISCUSSION

Conservation of the whole habitat of blackbucks in the sanctuary initially resulted in multiplication of their numbers but that was impeded due to the increase in the number of feral horses and stray cattle over the years. Entry of feral horses and stray cattle into the sanctuary poses two main problems: (a) competition for food and water and (b) spread of invasive alien plant species. Pods of *Prosopis juliflora* (Sw.) DC., one of the most aggressive invasive alien species is preferred by these cattle and the seeds were dispersed through their faeces into the sanctuary area, leading to the spread and increase in its population. By trampling the vegetation, altering the soil texture and overgrazing, these animals have a penetrating effect on the ecosystem. Feral horses build up to high numbers during good years, and many starve during drought (Wilson et al. 1992). Quality and nutritional value of plants available for grazing influences the diet and habitat relationship in large herbivores (Ahrestani et al. 2012). The distribution pattern of plant species and their dominance in an area plays an important role in their preference by these herbivores (Chamaille-Jammes & Bond 2010). Blackbucks, cattle from nearby villages, and feral horses, all compete for the same forage stock and there are not many differences between their foraging habits.

To control the competition faced by Blackbucks in PCWS by feral horses and stray cattle a few steps may be implemented.

1. Native fodder species can be introduced into the sanctuary on an experimental basis to provide more fodder to herbivores and to enhance local biodiversity (Dayanandan 1994). A few fodder species including grasses and leguminous trees have been listed for this purpose. (Table 1).

2. Stray cattle from the nearby villages can be stopped by fencing at strategic places where they are most probable to enter inside, and awareness programs can be conducted to educate the nearby villagers about the ecological and cultural significance of Blackbucks and the ill-effects of stray cattle grazing in the sanctuary premises. The population of feral horses can be controlled by methods such as relocation and sterilization (Khan et al. 2019).

CONCLUSION

This study has employed a very simple direct observational methodology for collection of data sets from PCWS. In spite of the seasonal limitations experienced, it provides a base for possible furthering of full-fledged ecological, floristic, and conservation studies in the area. Field surveys in different seasons need to be undertaken for a holistic understanding of the ecology of Blackbuck in Point Calimere with emphasis on the fodder species, especially the grasses. This study is expected to help prepare policies for plantation of fodder species in the sanctuary, and help in conservation of Blackbuck population with their long-term survival. The suggested mitigation measures are expected to help in controlling the spread of invasive alien plant species too, thereby, enriching the local flora.

Image 1. 1—A view of the tropical dry evergreen forest (TDEF) in Blackbuck habitat of Point Calimere Wildlife Sanctuary | 2—Vegetation on sand dunes | 3—The sanctuary entrance and beginning of study segment at Maattu-muni kovil | 4—Constructed water pool by used spotted deers and feral horses during dry seasons | 5—Blackbucks in the Sanctuary | 6—Local cattle grazing in the sanctuary, a competition for Blackbucks for fodder and water | 7—Feral horses spotted in the sanctuary | 8—Blackbucks grazing in slightly inundated plains. © Ashutosh Kumar Upadhyay

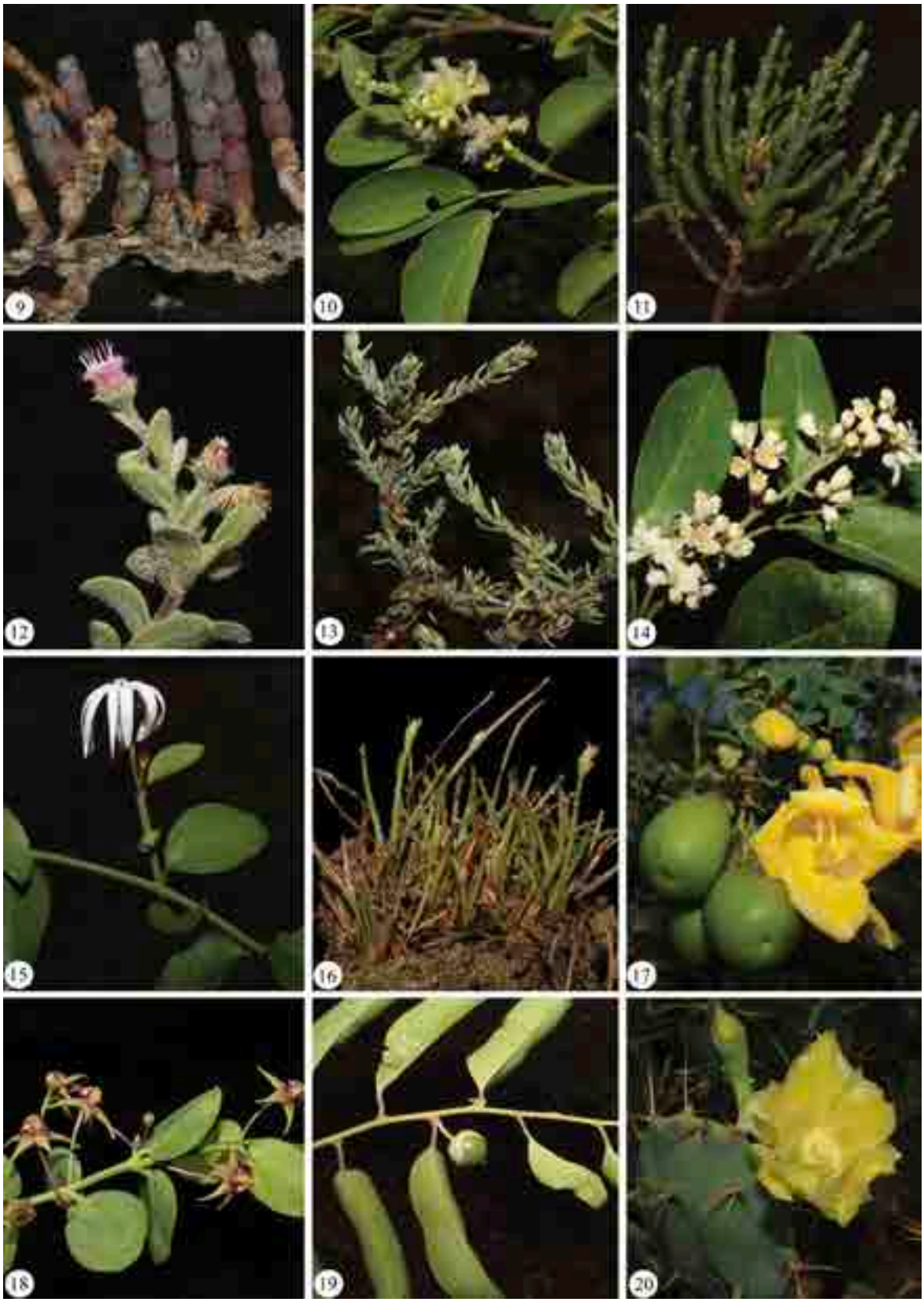

Image 2. Flora of Point Calimere Wildlife Sanctuary: 9—*Salicornia brachiata* Roxb. | 10—*Pithecellobium dulce* (Roxb.) Benth. | 11—*Tecticornia indica* (Willd.) K.A. Sheph. & Paul | 12—*Epaltes divaricata* Cass. | 13—*Cressa cretica* L. | 14—*Glycosmis mauritiana* (Lam.) Tanaka | 15—*Jasminum angustifolium* (L.) Willd. | 16—*Fimbristylis acuminata* Vahl | 17—*Gmelina asiatica* L. | 18—*Pentatropis capensis* (L.f.) Bullock | 19—*Olax scandens* Roxb. | 20—*Opuntia dillenii* (Ker Gawl.) Haw. © Ashutosh Kumar Upadhyay

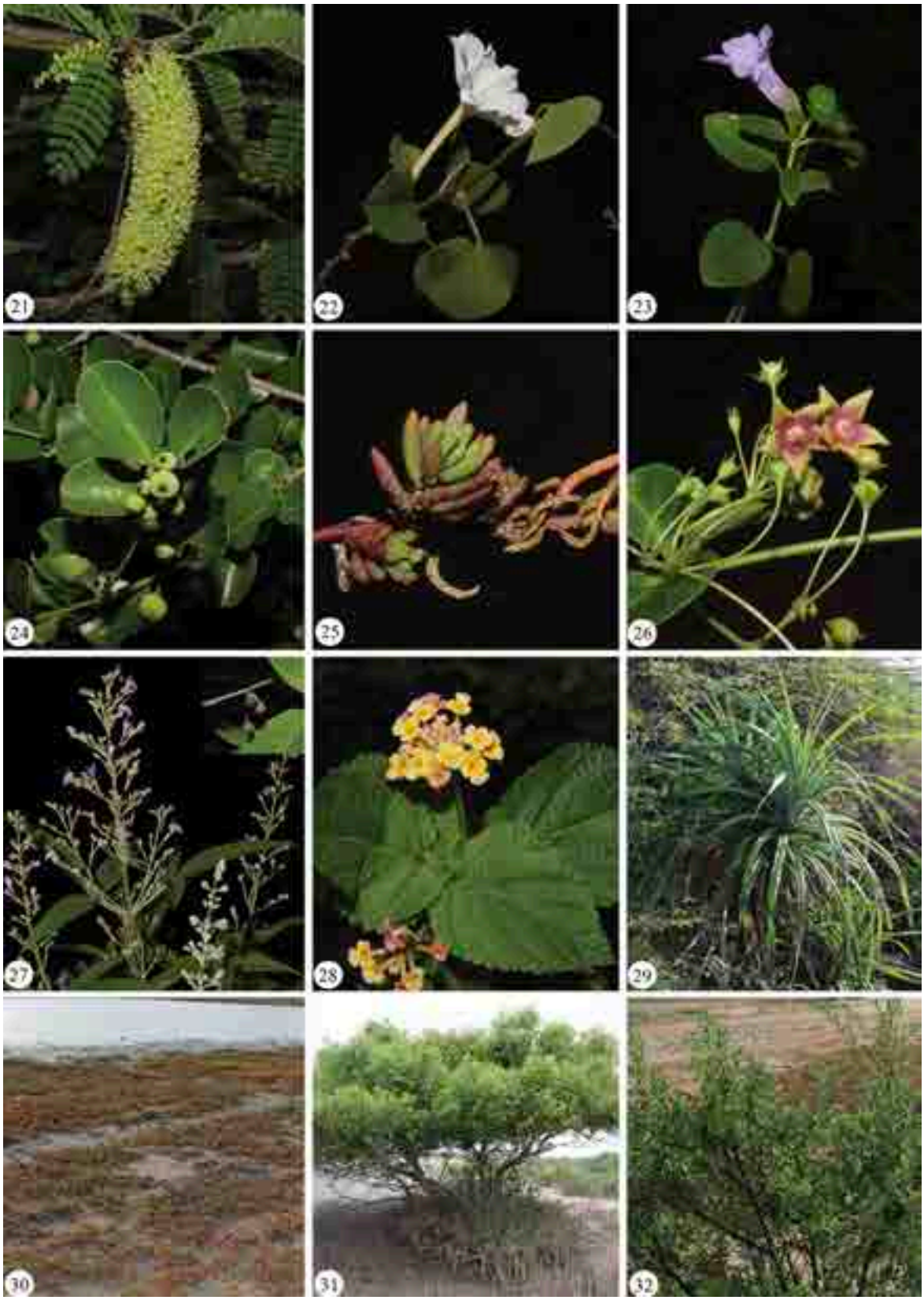

Image 3. Flora of Point Calimere Wildlife Sanctuary: 21—*Prosopis juliflora* (Sw.) DC. | 22—*Rivea hypocrateriformis* (Desr.) Choisy | 23—*Ruellia patula* Jacq. | 24—*Scutia myrtina* (Burm.f.) Kurz | 25—*Suaeda maritima* (L.) Dumort. | 26—*Vincetoxicum indicum* (Burm.f.) Mabb. | 27—*Vitex negundo* L. (inset- fruits) | 28—*Lantana camara* L. | 29—*Pandanus odorifer* (Forssk.) Kuntze | 30—*Sesuvium portulacastrum* (L.) L. | 31—*Avicennia marina* (Forssk.) Vierh. | 32—*Suaeda monoica* Forssk. ex J.F. Gmel. © Ashutosh Kumar Upadhyay

REFERENCES

Ahrestani, F.S., I.M.A. Heitkonig & H.H.T Prins (2012). Diet and habitat-niche relationships within an assemblage of large herbivores in a seasonal tropical forest. *Journal of Tropical Ecologyl* 28: 385–394.

Ali, R. (2005). Field studies for the conservation and management of point Calimere Complex. Foundation for Ecological Research, Advocacy and Learning. A Report for the Tamil Nadu Forest Department, 40 pp.

Altman, J. (1974). Observational study of behaviour: Sampling methods. *Behaviour* 49: 227–267.

Baruah, A.D. (2005). *Point Calimere Wildlife & Bird Sanctuary–A Ramsar Site*. Tamil Nadu Forest Department, 180 pp.

Chamaille-Jammes, S. & W.J. Bond (2010). Will global change improve grazing quality of grasslands? A call for a deeper understanding of the effects of shifts from C-4 to C-3 grasses for large herbivores. *Oikos* 119: 1857–1861.

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India*. Manager of Publications, Delhi, xxvii+404 pp.

Dayanandan, P. (1994). *Maximization of the Value of Native fodder grasses and grazing lands*. Society for Social Forestry Research and Development, Tamil Nadu, 52 pp.

Hundal, S.S. (2004). Wildlife Conservation Strategies and Management in India: An Overview. *Proceedings Species at Risk 2004 Pathways to Recovery Conference,* Victoria B.C., Canada, 2: 2–6.

IPNI (2018). International Plant Names Index. Published on the Internet (http://www.ipni.org), The Royal Botanic Gardens, Kew, Harvard University Herbaria & Libraries and Australian National Botanic Gardens. [Retrieved 03 June 2018].

Khan, K.A., S. Savan, B. Singh, R. De, V.B. Mathur, A. Rajvashi, B. Habib, S.P. Goyal & A.K. Bhardwaj (2019). Abohar-Sito Gunno-Dabwali road (NH-354E) section passing through Abohar Wildlife Sanctuary, Punjab, India. Technical Report. Wildlife Institute of India, Dehradun, 57 pp.

Meher-Homji, V.M. (1974). On the origin of the tropical dry evergreen forest of south India. *International Journal of Ecology and Environmental Sciences* 1: 19–39.

Parthasarthy, N., P. Vivek & K. Anil (2015). Liana diversity and their Ecosystem Services in Tropical Dry Evergreen Forest on the Coromandel Coast of India, pp. 161–178. In: Parthasarthy, N. (ed.). *Biodiversity of Lianas, Sustainable Development and Biodiversity. Vol.5.* https://doi.org/10.1007/978-3-319-14592-1_10.

POWO (2020). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. http://www.plantsoftheworldonline.org/. Retrieved 21 February 2020.

The Plant List (2013). Version 1.1. Published on the Internet. Accessed 3 June 2015; http://www.theplantlist.org/

The Wildlife Protection Act (1972). http://nbaindia.org/uploaded/Biodiversityindia/Legal/15.%20Wildlife%20(Protection)%20Act,%201972.pdf

USDA Agricultural Research Service (2015). Germplasm Resources Information Network (GRIN). Ag Data Commons. https://doi.org/10.15482/USDA.ADC/1212393. Accessed 2018-03-03.

Wilson, G., A. McNee & P. Platts (1992). *Wild animal resources: their use by aboriginal communities*. Australian Government Publishing Service, Canberra, x+122 pp.

Appendix I. List of plants observed at Point Calimere Wildlife Sanctuary

Sno	Binomial & Common names	Family	Habitat
	GRASSES		
1	*Aeluropus lagopoides* (L.) Thwaites	Poaceae	Inundated plains
2	*Stapfochloa elata* (Desv.) P.M.Peterson Tamil name: Kodai pullu, Sevarug pullu	Poaceae	Inundated plains
3	*Chloris virgata* Sw.	Poaceae	Inundated plains
4	*Cynodon barberi* Rang. & Tadul.	Poaceae	Inundated plains
5	*Cynodon dactylon* (L.) Pers. Tamil name: Arugam pullu	Poaceae	Inundated plains
6	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae	Inundated plains
7	*Eragrostis sp*.	Poaceae	Inundated plains with sparse trees
8	*Eragrostis tenella* (L.) P.Beauv. ex Roem. & Schult Tamil name: Poom Pullu	Poaceae	Low mounds
9	*Eragrostis viscosa* (Retz.) Trin.	Poaceae	Low mounds
10	*Panicum sp.*	Poaceae	High mounds and Inundated plains
11	*Perotis indica* (L.) Kuntze Tamil name: Narival, Kudiraival pullu, Thopparai pullu	Poaceae	Inundated plains
12	*Spinifex littoreus* (Burm.f.) Merr. Tamil name: Elikunjai pullu, Ravanan meesai	Poaceae	Sand dunes
	SEDGES		
1	*Cyperus dubius* Rottb.	Cyperaceae	Inundated plains
2	*Fimbristylis acuminata* Vahl	Cyperaceae	Inundated plains
3	*Fimbristylis argentea* (Rottb.) Vahl	Cyperaceae	Inundated plains
4	*Fimbristylis falcata* (Vahl) Kunth	Cyperaceae	Inundated plains
5	*Fimbristylis sp.*	Cyperaceae	Inundated plains
	HERBS		
1	*Achyranthes aspera* L. Tamil name: Nayurivi	Amaranthaceae	Inundated plains with sparse trees

Sno	Binomial & Common names	Family	Habitat
2	*Ouret lanata* (L.) Kuntze Tamil name: Peelai, Sirupeelai	Amaranthaceae	Inundated plains with sparse trees
3	*Salicornia brachiata* Roxb. Tamil name: Kolliam, Pavalappundu	Amaranthaceae	Halophytic
4	*Asystasia gangetica* (L.) T. Anderson	Acanthaceae	Inundated plains with sparse trees and low mounds
5	*Boerhavia diffusa* L. Tamil name: Mookarattai	Nyctaginaceae	Inundated plains with sparse trees
6	*Cressa cretica* L. Tamil name: Vuppu marikkozhundhu	Convolvulaceae	Inundated plains
7	*Croton bonplandianus* Baill. Tamil name: Rail poondu	Euphorbiaceae	Inundated plains with sparse trees and low mounds
8	*Cyanthillium cinereum* (L.) H. Rob. Tamil name: Mookutthipoondu, Sahadevi	Asteraceae	Low mounds with sparse trees
9	*Epaltes divaricata* (L.) Cass.	Asteraceae	Inundated plains
10	*Epaltes sp.*	Asteraceae	Inundated plains
11	*Geniosporum sp.*	Lamiaceae	Inundated plains
12	*Tecticornia indica* (Willd.) K.A.Sheph. & Paul G.Wilson Tamil name: Pavazhappundu, Sitrumari	Amaranthaceae	Halophytic
13	*Leucas diffusa* Benth.	Lamiaceae	Inundated plains with sparse trees
14	*Ocimum americanum* L. Tamil name: Ganjaankorai, Nai thulasi	Lamiaceae	Inundated plains with sparse trees
15	*Ocimum tenuiflorum* L. Tamil name: Thulasi, Rama thulasi	Lamiaceae	Inundated plains with sparse trees
16	*Oldenlandia herbacea* (L.) Roxb.	Rubiaceae	Inundated plains with sparse trees
17	*Oldenlandia umbellata* L.	Rubiaceae	Inundated plains with sparse trees
18	*Vicoa indica* (L.) DC. Tamil name: Jimikipoo, Mookutthipoondu	Asteraceae	Inundated plains with sparse trees
19	*Platostoma menthoides* (L.) A.J.Paton Tamil name: Ganjaankorai	Lamiaceae	Inundated plains
20	*Ruellia patula* Jacq.	Acanthaceae	Inundated plains with sparse trees
21	*Synostemon bacciformis* (L.) G.L.Webster	Phyllanthaceae	Inundated plains with sparse trees and low mounds
22	*Sesuvium portulacastrum* (L.) L.	Aizoaceae	Halophytic
23	*Spermacoce hispida* L. Tamil name: Nathaichoori	Rubiaceae	Sand dunes
24	*Suaeda maritima* (L.) Dumort. Tamil name: Nari vumari, Uppukkeerai	Amaranthaceae	Halophytic
25	*Suaeda vermiculata* Forssk.ex J.F. Gmel.	Amaranthaceae	Halophytic
26	*Tephrosia maxima* (L.) Pers. Tamil name: Kollukaai vaelai, Periya kozhinji	Fabaceae	Inundated plains with sparse trees
27	*Tephrosia purpurea* (L.) Pers. Tamil name: Kozhinji, Kollukaai vaelai	Leguminosae	Inundated plains with sparse trees
28	*Vahlia dichotoma* (Murray) Kuntze	Vahliaceae	Inundated plains
29	*Vigna trilobata* (L.) Verdc. Tamil name: Pani payaru	Fabaceae	Inundated plains with sparse trees
CLIMBER / LIANA			
1	*Abrus precatorius* L. Tamil name: Kundumani	Fabaceae	Inundated plains with sparse trees
2	*Asparagus racemosus* Willd. Tamil name: Thaneer vitaan kizhangu, Sadhavaeri	Asparagaceae	Inundated plains with sparse trees
3	*Capparis brevispina* DC.	Capparaceae	High mound with sparse trees
4	*Capparis zeylanica* L. Tamil name: Athondai	Capparaceae	Inundated plains with sparse trees
5	*Cissus quadrangularis* L. Tamil name: Pirandai	Vitaceae	Inundated plains and low mounds
6	*Cissus vitiginea* L. Tamil name: Chembirandai, Mudai naari	Vitaceae	Inundated plains with sparse trees
7	*Coccinia grandis* (L.) Voigt Tamil name: Kovai	Cucurbitaceae	Inundated plains with sparse trees

Sno	Binomial & Common names	Family	Habitat
8	*Gmelina asiatica* L. Tamil name: Nilakkumizh, Mulkumizh	Lamiaceae	Inundated plains
9	*Jasminum angustifolium* (L.) Willd. Tamil name: Kaattu malli, Paambu kala	Oleaceae	Inundated plains with sparse trees
10	*Jasminum cuspidatum* Rottler Tamil name: Oosi malli	Oleaceae	Inundated plains with sparse trees
11	*Olax scandens* Roxb. Tamil name: Kadal azhinji, Malli vaeppam	Olacaceae	Low mound with sparse trees
12	*Pentatropis capensis* (L. f.) Bullock Tamil name: Uppili, Uppilankodi	Apocynaceae	Halophytic
13	*Rivea hypocrateriformis* (Desr.)Choisy Tamil name: Boodhikeerai	Convolvulaceae	Low mound with sparse trees
14	*Scutia myrtina* (Burm. f.) Kurz Tamil name: Indu, Kokku mullu	Rhamnaceae	Inundated plains
15	*Solanum trilobatum* L. Tamil name: Thoodhuvalai	Solanaceae	Inundated plains with sparse trees
16	*Vincetoxicum indicum* (Burm.f.) Mabb. Tamil name: Naippalai, Nanjaruppaan	Apocynaceae	Inundated plains with sparse trees
	SHRUBS & SUB-SHRUBS		
1	*Azima tetracantha* Lam. Tamil name: Pee changam, Mulsangam	Salvadoraceae	Inundated plains
2	*Acacia sp.*	Fabaceae	Inundated plains
3	*Guilandina bonduc* L. Tamil name: Kazharchikaai, Gajjakkaai	Fabaceae	Inundated plains and sand dunes
4	*Calotropis gigantea* (L.) W.T.Aiton Tamil name: Erukku, Arkkam	Apocynaceae	Sand dunes
5	*Canthium parviflorum* Roxb.	Rubiaceae	Inundated plains with sparse trees
6	*Catunaregam spinosa* (Thunb.) Tirveng. Tamil name: Kaalagam, Madukaarai	Rubiaceae	Inundated plains with sparse trees
7	*Chamaerops humilis* L.	Arecaeae	Inundated plains with sparse trees
8	*Crotalaria laburnifolia* L. Tamil name: Kilukiluppai, Narimiratti	Fabaceae	Inundated plains with sparse trees
9	*Crotalaria pallida* Aiton	Fabaceae	Inundated plains with sparse trees
10	*Dichrostachys cinerea* (L.) White & Arn. Tamil name: Vidathalam thazhai	Fabaceae	Inundated plains
11	*Diospyros ferrea* (Willd.) Bakh. Tamil name: Irumbuli	Ebenaceae	Inundated plains with sparse trees
12	*Ehretia microphylla* Lam.	Boraginaceae	Inundated plains
13	*Flueggea leucopyrus* Willd. Tamil name: Pulanji	Phyllanthaceae	Inundated plains
14	*Glycosmis mauritiana* (Lam.) Tanaka Tamil name: Konji	Rutaceae	Inundated plains with sparse trees
15	*Grewia carpinifolia* Juss.	Malvaceae	Inundated plains with sparse trees
16	*Gymnosporia emarginata* (Willd.) Thwaites Tamil name: Kattanji	Celastraceae	Inundated plains
17	*Hygrophila auriculata* (Schumach.) Heine Tamil name: Neermulli	Acanthaceae	Inundated plains
18	*Lantana camara* L. Tamil name: Unnichedi, Jimiki malli	Verbenaceae	Inundated plains
19	*Opuntia dillenii* (Ker Gawl.) Haw. Tamil name: Chappathikkalli	Cactaceae	Inundated plains and low mounds
20	*Pandanus odorifer* (Forssk.) Kuntze Tamil name: Thazhai, Kaidha	Pandanaceae	Inundated plains
21	*Prosopis juliflora* (Sw.) DC. Tamil name: Velikkaathaan, Seemai mullu	Fabaceae	Inundated plains
22	*Psilotrichum elliotii* Baker	Amaranthaceae	Inundated plains and low mounds
23	*Senna auriculata* (L.) Roxb. Tamil name: Avaram, Avaarai	Fabaceae	Inundated plains and low mounds
24	*Senna occidentalis* (L.) Link Tamil name: Peiyavarai, Thagarai	Fabaceae	Inundated plains and low mounds
25	*Senna timoriensis* (D.C.) H.S. Irwin & Barneby	Fabaceae	Inundated plains

Sno	Binomial & Common names	Family	Habitat
26	*Suaeda monoica* Forssk. ex J.F. Gmel. Tamil name: Karuvumari, Umarinandi	Amaranthaceae	Halophytic
27	*Vitex negundo* L. Tamil name: Nochi, Vennochi	Lamiaceae	High mound with sparse trees
28	*Volkameria inermis* L. Tamil name: Pinchil, Pinarichanganguppu	Lamiaceae	Inundated plains
29	*Ziziphus jujuba* Mill. Tamil name: Illandhai	Rhamnaceae	Inundated plains
30	*Ziziphus oenopolia* (L.) Mill. Tamil name: Soorai pazham, Soorai mullu	Rhamnaceae	Inundated plains with sparse trees
SMALL AND BIG TREES			
1	*Albizia lebbeck* (L.) Benth. Tamil name: Vaagai	Fabaceae	Inundated plains with sparse trees
2	*Avicennia marina* (Forssk.) Vierh. Tamil name: Venkandal, Vellaikkandal	Avicenniaceae	Mangrove
3	*Azadirachta indica* A. Juss. Tamil name: Vaembu, Vaeppam	Meliaceae	Inundated plains
4	*Cassia fistula* L. Tamil name: Kondrai, Sarakkondrai	Fabaceae	Inundated plains
5	*Casuarina equisetifolia* L. Tamil name: Savukku	Casuarinaceae	Inundated plains
6	*Excoecaria agallocha* L. Tamil name: Thillai	Euphorbiaceae	Mangrove
7	*Ficus benghalensis* L. Tamil name: Aal, Ichi	Moraceae	Sand dunes
8	*Lannea coromandelica* (Houtt.) Merr. Tamil name: Odhiya maram, Odhi	Anacardiaceae	Inundated plains
9	*Manilkara hexandra* (Roxb.) Dubard Tamil name: Kannupalai, Paala maram	Sapotaceae	Inundated plains with sparse trees
10	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne Tamil name: Iyalvaagai, Perugondrai	Fabaceae	Inundated plains with sparse trees
11	*Pithecellobium dulce* (Roxb.) Benth. Tamil name: Kodukkaai puli	Fabaceae	Inundated plains and high mounds
12	*Pongamia pinnata* (L.) Pierre Tamil name: Punga maram	Fabaceae	Inundated plains
13	*Premna serratifolia* L. Tamil name: Munnai	Lamiaceae	Inundated plains with sparse trees
14	*Salvadora persica* L. Tamil name: Chitthu vila, Kalarva	Salvadoraceae	Inundated plains
15	*Thespesia populnea* (L.) Sol. ex Correa Tamil name: Poovarasu	Malvaceae	Inundated plains
CREEPERS			
1	*Grona triflora* (L.) H.Ohashi & K.Ohashi Tamil name: Sirupulladi	Fabaceae	Inundated plains
2	*Euphorbia thymifolia* L. Tamil name: Sittrapaladai	Euphorbiaceae	Low level shady moist area
3	*Evolvulus alsinoides* (L.) L. Tamil name: Vishnukarandi	Convolvulaceae	Inundated plains with sparse trees
4	*Ipomoea pes-caprae* (L.) R. Br. Tamil name: Attukkal, Kudhirai kulambu	Convolvulaceae	Sand dunes

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COMMUNICATION

Raptors observed (1983–2016) in National Chambal Gharial Sanctuary: semi-arid biogeographic region suggestions for parametric studies on ecological continuity in Khathiar-Gir Ecoregion, India

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Abstract: The birds of prey or raptors in the National Chambal Sanctuary (NCS) assume importance as they are among the top predators of the region, predating on small crocodilians, turtles, and birds. Our checklist of 30 species of raptors is developed from observations made during winter surveys conducted between 1983 and 2016. The study area covered the course of river Chambal including its confluence with river Kuno that leads from Palpur-Kuno Sanctuary in Madhya Pradesh. The raptors which use the steep and inaccessible mud cliffs of the Chambal landscape include Bonelli's Eagle *Aquila fasciata*, Laggar Falcon *Falco jugger*, Egyptian Vulture *Neophron percnopterus*, White-rumped Vulture *Gyps bengalensis*, Spotted Owlet *Athene brama*, and the Indian Eagle-Owl or Rock Eagle Owl *Bubo bengalensis*. Most of the other raptors noted in NCS appear to visit from and around the adjoining wildlife areas of Rajasthan and Madhya Pradesh. According to two methods of classification the study comes in the semi-arid biogeographic zone or Khathiar-Gir dry deciduous forest ecoregion. The list of raptors from NCS-Kuno has been compared with previous reports and the list available for Sariska Tiger Reserve and Ranthambhore Tiger Reserve in Rajasthan. The present work is the outcome of a long-term ecological monitoring that primarily focused on the Gharial *Gavialis gangeticus* and its ecological associates in water and the riverine shores. The birds of prey demanded time and attention for looking above and away from the water surface or the shorelines. Yet, our meticulous records maintained over 34 years have generated a basal profile that is expected to inspire focused studies on parameters that sustain ecological association of raptors of NCS adjoining forest habitats and wildlife sanctuaries in the ecoregion.

Keywords: Chambal, crocodile predator, ecological continuity, Khathiar-Gir Ecoregion, National Chambal Sanctuary, Palpur-Kuno Sanctuary, Ranthambhore Tiger Reserve, Raptor checklist, Sariska Tiger Reserve, semi-arid biogeographic region.

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Author contributions: RKS contributed the primary checklist and the photographs with URP. LAKS developed the analytical text with illustrations.

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INTRODUCTION

Background to the study

The UNDP/FAO/Government of India Project for Conservation of Crocodiles which was initiated in 1974–75 (Bustard 1999) concluded in 1982 (de Vos 1984) with several significant contributions to a scenario in Indian wildlife conservation (Singh 1999). The next year, at the behest of the Government of India, LAKS from the erstwhile Central Crocodile Breeding and Management Training Institute (CCBMTI), Hyderabad, established and pursued teamed-up research goals in National Chambal Sanctuary (NCS), with headquarters at Deori Village Gharial Rearing Centre in Morena district, Madhya Pradesh. Since then, annual monitoring of Gharials and incidental collection of ecological and biological data of prominent wetland fauna has been carried out with simple protocols, for highlighting the results of wildlife management in NCS.

Much of the research work from NCS in this context is focused on Gharial, Mugger crocodile, Gangetic Dolphins, turtles, and non-raptor birds (Singh & Rao 1984, 1985; Singh 1985; Singh & Sharma 1985, 2015, 2018; Rao & Singh 1987a,b,c; Sharma & Singh 1986, 2014, 2015, 2018; Sharma et al. 1995). Until superannuation in 2016, fieldwork continued with RKS, a key member of the NCS team. The records on the birds of prey during the river surveys were occasional as they demanded attention for looking above and away from the water surface or the shorelines. However, because of meticulous records maintained over a long time, attention was reverted to raptors which are among the biological predators of crocodiles and large birds.

The raptors or birds of prey, while predating upon fish and bird fledglings, also predate through creche of crocodilian hatchlings and small juveniles of Gharial and Mugger. Although cursory remarks on predation aspects have been made in our previous publications, a separate treatment for raptors was not attempted. Sharma & Singh (1986) who covered field studies during 1983–1985, observed 10 species of raptors, namely, Western Osprey *Pandion haliaetus*, Black Kite *Milvus migrans*, Black-shouldered Kite *Elanus axillaris*, Egyptian Vulture *Neophron percnopterus*, White-rumped Vulture *Gyps bengalensis*, Red-headed Vulture *Sarcogyps calvus*, Pallas's Fish Eagle *Haliaeetus leucoryphus*, Tawny Eagle *Aquila rapax*, Western Barn Owl *Tyto alba*, and Spotted Owlet *Athene brama*.

Raptors among crocodile predators

Elsewhere, Vyas (2019) provided a list of predators which affect nests or young ones of different crocodilian species. In this list, the species of birds that are known to predate on crocodilians are the Crow, Black or Pariah Kite, egrets, Purple Heron, Black-necked Stork, Painted Stork, Sarus Crane, and the White-bellied Sea Eagle. The presence of all species except the White-bellied Sea Eagle, is recorded for NCS (Sharma & Singh 1986). Gopi & Pandav (2006) and Palei et al. (2019) have reported or photographed the White-bellied Sea Eagle *Haliaeetus leucogaster* preying on Saltwater Crocodile *Crocodylus porosus*. The role of raptors in decimating populations of Mugger Crocodile *Crocodylus palustris* by 1975 (Singh 1979) in Similipal Tiger Reserve, Odisha cannot be ruled out, but Singh (1993) gave a list of 25 raptors seen here.

The raptors are among the world's most graceful and spectacular birds for their characteristic display of wings in flight, their body colour, and the size and shape of the tail. The high visual acuity of eagles in bright daylight and the highly sensitive vision of owls with adaptations to dim-light vision has fascinated mankind (Potier et al. 2020). Being predators at the top, the birds of prey live in low numbers. The threats to tropical raptors include habitat destruction, environmental contamination, and persecution or shooting (Bildstein et al. 1998; Prakash et al. 2003; Green et al. 2004; Meteyer et al. 2004; Shultz et al. 2004; Swan et al. 2006a,b; Hernández & Margalida 2009; Zabala et al. 2020).

Out of 292 species of tropical raptors, 76% (222) are completely in the tropics; and most of the forest dwelling tropical raptors are secretive and difficult to study (Bildstein et al. 1998). The Chambal region supports a significant number of raptors and this is evident from numerous casual sightings and anecdotal references, as well as incidental observations. Based on our notes from the riverine landscape, and the taxonomic status given in the IOC World Bird List (Gill et al. 2021), the diurnal birds of prey that include hawks, eagles, and vultures are in the order Accipitriformes, and falcons in the order Falconiformes. Owls, which are nocturnal birds of prey are in order Strigiformes. A few of these species breed in the Chambal landscape. The steep and inaccessible mud cliffs appear to be preferred sites of Bonelli's Eagle, Laggar Falcon, Egyptian Vulture, White-rumped Vulture, Spotted Owlet, and Indian Eagle Owl.

In this note, we present a list of raptors that were incidentally sighted during our annual river surveys in the National Chambal Sanctuary and the Kuno confluence leading to Palpur-Kuno Sanctuary in Madhya Pradesh. Since the presence of some raptors does not get the support of breeding evidence along the Chambal, the raptor lists from Ranthambhore and Sariska have

been compared for possible insight into their presence resulting from local flights and extended home range. We expect our study may stimulate more conclusive knowledge on these aspects from systematic raptor-specific studies in the future in the Chambal landscape within the semi-arid biogeographic zone (Rodgers & Panwar 1988) and the Khathiar-Gir dry deciduous forest ecoregion (WWF 2021).

Study Area

Chambal in northwest India is a clear and fast-flowing river that originates from the Vindhya Range in central India. A stretch of about 572 km of the river Chambal, bordering the states of Madhya Pradesh, Rajasthan, and Uttar Pradesh, constitutes the National Chambal Sanctuary (NCS) (Figure 1). The NCS is protected for conservation and management of the endangered Gharial *Gavialis gangeticus* since 1979.

The biodiversity components of the river under NCS holds a number of indicator fauna which include the crocodilians, chelonians, and avian species. Besides, there are the Gangetic Dolphins and otters. Within the sanctuary limits, the river banks have ravines with sparse ground cover. The natural vegetation comprises of thorn forests, forming most of the boundary for Madhya Pradesh. The nearest forested habitat is in the Kuno-Palpur Wildlife Sanctuary in Madhya Pradesh (Figure 2). However, close to NCS, there are a few forest-based well-known wildlife sanctuaries (WS) in Rajasthan. These include the Jawahar Sagar Wildlife Sanctuary and Ranthambhore Tiger Reserve in Rajasthan.

The habitat from Pali to Chakarnagar in Chambal (Figure 2) comprises the most significant area for the conservation of Gharial. Keeping in mind the conservation significance of the critically endangered gharial and its habitat, the population trends and

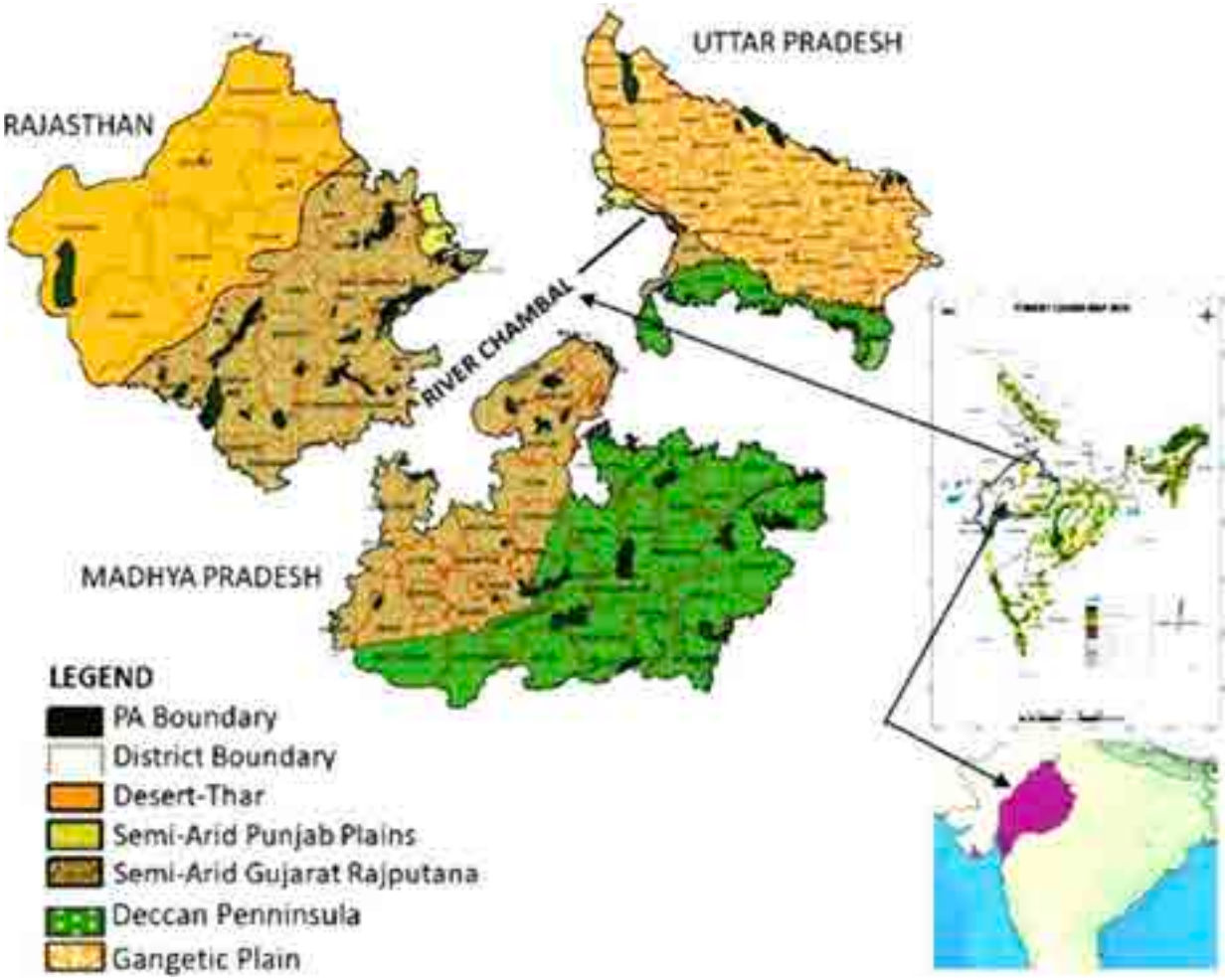

Figure 1. Locations of Wildlife Sanctuaries (PA, protected area boundary) with respect to River Chambal, National Chambal Sanctuary bordering the states of Rajasthan, Madhya Pradesh, and Uttar Pradesh within Khathiar-Gir dry deciduous forest ecoregion (inset, right bottom) in northwestern India. Source maps from ENVIS 2020, FSI 2019, Wikipedia 2021.

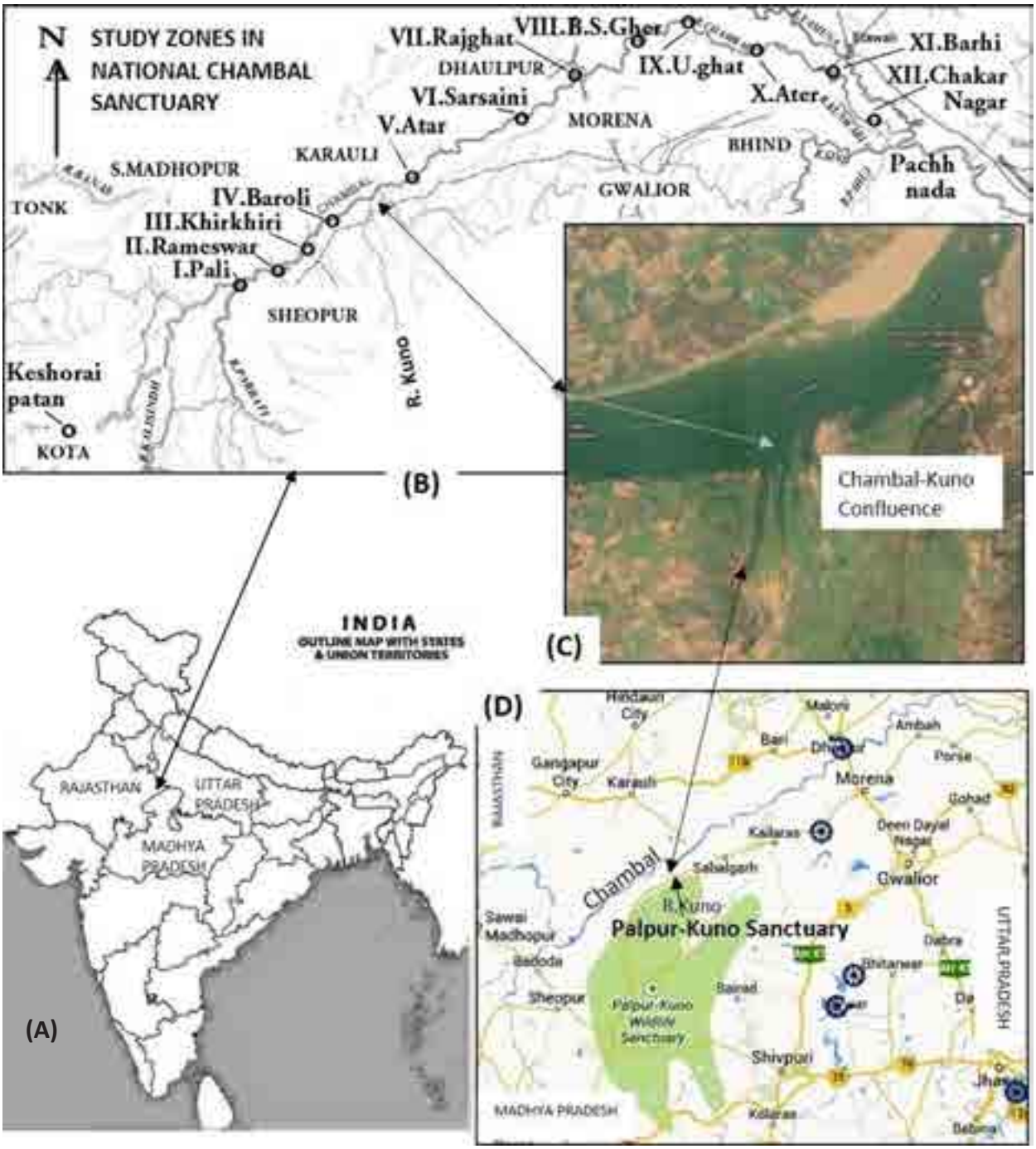

Figure 2. Map of India (A) showing study zones in National Chambal Sanctuary (B), the confluence with river Kuno (C) that originates from Palpur-Kuno Sanctuary (D).

probable threats are among the parameters that have been assessed regularly with defined gaps. Every year, Madhya Pradesh Forest Department takes a systematic initiative to carry out a comprehensive survey to find out the status and distribution of Gharial and its ecological associates in NCS. Sometimes, survey cruises by boat and foot are also extended into the tributaries like, Parbati, Kali Sindh, Banas, and Kuno.

The Kuno-Chambal confluence is downstream of Nadigaon village which is a nesting site of Gharial and Mugger (Singh 1985; Sharma & Singh 2015). Upstream of Nadigaon, the Baroli sandbank, and Baroli island are considered among the best nesting sites of gharial and offer scope to observe all the sequences of breeding

behaviour by adults and creche formation by hatchlings. The hatchlings congregate around the confluence of the Kuno river, because of the availability of smaller fishes, and for retreat into the tributary during the flood. About 30 km upstream of the Kuno-confluence, the Palpur-Kuno WS was established in 1981 in the state of Madhya Pradesh with an initial area of about 344.68 km^2. It is a dry deciduous forest forming a part of the Vindhyan hill range.

MATERIALS AND METHODS

The NCS was marked into twelve stretches of smaller study zones (Figure 2 based on Singh 1985) and the area was surveyed by travelling on a motor boat as well as by walking on foot. The surveyors were equipped with 1:50,000 toposheets from Survey of India, A4-size bits of field map sheets, binoculars, and a camera. The team along with the support staff normally moved between 0900 h and 1700 h. during the winter. When moving by motorboat, the transect speeds ranged within 15 km per hour, depending on the demands of the situation and navigability of the stream. Birds were sighted with the help of binoculars (Olympus 10 × 50 mm), occasionally aided with a spotting scope. Field notes were made directly on the field map sheets or notebooks. The bird species were identified using standard field guides, such as Ali (1979, 2002), Naoroji (2011), and Grimmett et al. (2011). Observed species of raptors were recorded along with sighting time and nearest village name and other ancillary information on datasheets. A list of all the raptor species observed in the Chambal and Kuno region is given in Table 1. The recent names and synonyms are according to the International Ornithological Congress-IOC World Bird List (Gill et al. 2021).

RESULTS AND DISCUSSION

1. The Checklist of raptor birds in NCS-Kuno

a) The list of raptors based on our observations comprises a total of 30 species (Table 1 and Supplement Table A). It includes six species of vultures, one osprey, two kites, one shikra, one harrier, three buzzards, five eagles, one kestrel, one hobby, two falcons, and seven owlet/owls. The family-wise list incorporates Falconidae four species, Accipitridae 18 species, Tytonidae one species, Strigidae six species, and Pandionidae one species.

b) In our list, a total of nine species falls under the IUCN threatened categories of Critically Endangered (CR) (3), Endangered (EN) (2), Vulnerable (VU) (1), and Near Threatened (NT) (3) of which six are residents and three are winter visitors. Other 21 species, which includes six winter-visiting species, are with status of Least Concern (LC) (Table 1 and Supplement Table B).

c) Nine of the 30 species listed are winter visitors. These are Cinereous Vulture, Griffon Vulture, Western Osprey (seen through early summer till May), Western Marsh Harrier, Common Buzzard, Pallas's Fish Eagle, Tawny Eagle, Common Kestrel, and Eurasian Hobby (Table 1 and Supplement Table B). A detailed study on their migration pattern to the wetlands of river Chambal may indicate if NCS deserves to be considered as a Ramsar site.

d) Our preliminary observations indicate that the raptors received protection that is available as incidental to Gharial conservation in NCS.

e) In Wildlife (Protection) Act, India the Schedule-IV status is given to Cinereous Vulture, Egyptian Vulture and Red-headed Vulture. This, however, does not match the grave status given to these species under the IUCN as NT, EN, and CR, respectively (Table B). We agree that the Egyptian Vulture or Pharaoh's Chicken appear to be in relatively good numbers but because of their size they might be more prone to killing. The suggestions made here on the possible lift or upgradation of Scheduled status of these three raptors merits the attention of the Ministry of Environment, Forests and Climate Change (MOEFCC) and requires further consultation with established ornithologists of India.

2. Species-wise total sightings

a) The total number of birds counted during the survey period 2003–2016 was 2070, with a range of 85–188, and an average of 148 birds per year (Table 2). The moving average of the number of birds per year appears to indicate that NCS continues to be a good habitat for raptor sighting (Figure 3).

b) In the entire list (Table 1) there are seven species whose total count in 14 annual surveys has been less than five. These are, one bird per one survey for Cinereous Vulture (4 sightings), Griffon Vulture (4 sightings), Common Buzzard (4 sightings), White-eyed Buzzard (2 sightings), Crested Honey Buzzard (4 sightings), Pallas's Fish Eagle (1 sighting), and Dusky Eagle Owl (4 sightings).

c) Pallas Fish Eagle was last seen in 1986 (Supplement Table A) and has not been recorded since then. There has been an increase in the number of sightings of Western Osprey over the years. Although the Western Osprey is considered to be a winter visitor, it is seen in Chambal in

Table 1. Species of raptors observed in National Chambal Sanctuary over 14 surveys during 2003–2016 of Gharial monitoring. Where synonyms exist, the first mentioned name is according to the nomenclature in IOC World Bird List (v11.1) (Gill et al. 2021). Key to IUCN status: CR—Critically Endangered | EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concern. 'Winter' in migratory status refers to months November to February.

	English name	Scientific name	Location	Total raptor counts (max 14 surveys	Total years when seen (max 14)	IUCN Red List status	Migratory status
1	Cinereous Vulture	*Aegypius monachus*	Chambal, Kuno	4	3	NT	Winter visitor
2	Egyptian Vulture	*Neophron percnopterus*	Chambal, Kuno	999	14	EN	Resident
3	White-rumped Vulture (Indian White-backed Vulture)	*Gyps bengalensis*	Kuno, Chambal	80	14	CR	Resident
4	Indian Vulture (Longbilled Vulture)	*Gyps indicus*	Chambal, Kuno	12	6	CR	Resident
5	Red-headed Vulture	*Sarcogyps calvus*	Chambal, Kuno	30	13	CR	Resident
6	Griffon Vulture (Eurasian Griffon)	*Gyps fulvus*	Kuno	4	4	LC	Winter visitor
7	Western Osprey (Osprey)	*Pandion haliaetus*	Chambal	562	14	LC	Winter visitor, seen till May
8	Black-shouldered Kite	*Elanus axillaris*	Chambal, Kuno	39	9	LC	Resident
9	Black Kite (Common Pariah Kite)	*Milvus migrans*	Chambal, Kuno	62	8	LC	Resident
10	Shikra	*Accipiter badius*	Chambal	74	14	LC	Resident
11	Western Marsh Harrier (Eurasian Marsh Harrier)	*Circus aeruginosus*	Chambal	38	13	LC	Winter visitor
12	Common Buzzard	*Buteo buteo*	Chambal	4	3	LC	Winter visitor
13	White-eyed Buzzard	*Butastur teesa*	Chambal, Kuno	2	2	LC	Resident
14	Crested Honey Buzzard (Oriental Honey Buzzard)	*Pernis ptilorhynchus*	Chambal, Kuno	4	4	LC	Resident
15	Bonelli's Eagle	*Aquila fasciata*	Chambal, Kuno	29	10	LC	Resident
16	Pallas's Fish Eagle	*Haliaeetus leucoryphus*	Chambal	0	0	EN	Winter visitor
17	Tawny Eagle	*Aquila rapax*	Chambal	11	5	VU	Winter visitor
18	Crested Serpent Eagle	*Spilornis cheela*	Chambal	5	4	LC	Resident
19	Changeable Hawk Eagle	*Nisaetus cirrhatus (Spizaetus cirrhatus)*	Kuno	5	4	LC	Resident
20	Common Kestrel	*Falco tinnunculus*	Chambal	29	10	LC	Winter visitor
21	Eurasian Hobby	*Falco subbuteo*	Kuno	6	6	LC	Winter visitor
22	Laggar Falcon	*Falco jugger*	Chambal	27	13	NT	Resident
23	Red-necked Falcon	*Falco chicquera*	Chambal	9	7	NT	Resident
24	Spotted Owlet	*Athene brama*	Chambal	4	4	LC	Resident
25	Western Barn Owl (Barn Owl)	Tyto alba	Chambal, Kuno	5	4	LC	Resident
26	Dusky Eagle Owl	*Bubo coromandus*	Chambal	4	4	LC	Resident
27	Brown Fish Owl	*Ketupa zeylonensis*	Kuno	5	4	LC	Resident
28	Indian Scops Owl	*Otus bakkamoena*	Kuno	7	5	LC	Resident
29	Mottled Wood Owl	*Strix ocellata*	Kuno	5	4	LC	Resident
30	Indian Eagle-Owl (Rock Eagle Owl)	*Bubo bengalensis*	Kuno	5	4	LC	Resident

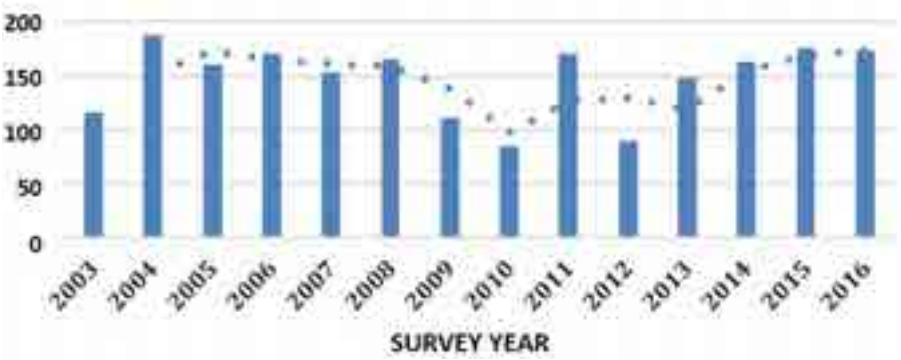

Figure 3. Number of raptor birds counted in different survey years 2003–2016, with moving average of the counts (dotted line) in National Chambal Sanctuary.

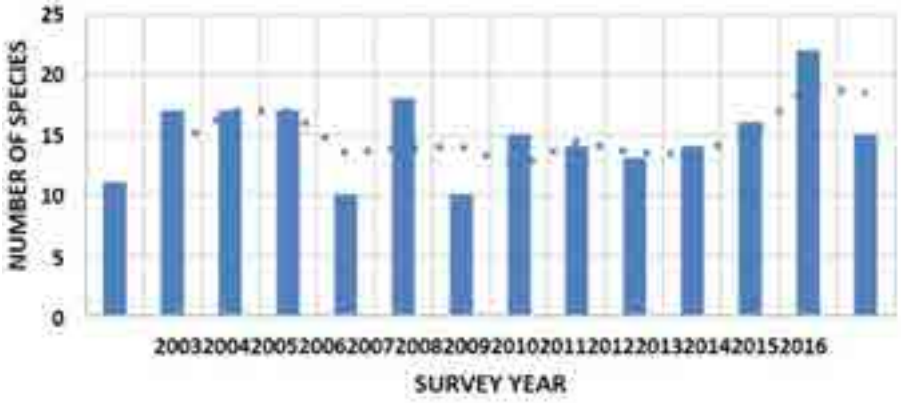

Figure 4. Number of raptor species noted in different survey years 2003–2016 with moving average (dotted line) in National Chambal Sanctuary.

fair numbers until late summer.

d) Indian White-rumped Vultures were found in fair numbers in Chambal Sanctuary and large flocks could be seen until 1990, when a maximum of 304 vultures were recorded (Supplement Table A). Following this, there has been a steady decline. Only a total of four vultures were recorded in 2016

3. Survey-year-wise species sightings (Table 2)

a) Ten species of raptors appear to have NCS in their preferred home range. Seven species were observed for 11 or more of the total 14 continuous annual surveys. These are the Egyptian Vulture (14 years), White-rumped Vulture (all 14 years), Red-headed Vulture (13 years), Western Osprey (all 14 years), Shikra (14 years), Western Marsh Harrier (13 years), and Laggar Falcon (13 years). There were two species that were seen in 10 out of 14 surveys. These species are the Bonelli's Eagle and Common Kestrel (Table 1).

b) During our survey years, 2003 to 2016, the number of species observed per year varied between 10 and 22 species (Table 2, Figure 4). In 1990, only three species of raptors were noted namely, the White-rumped Vulture with 304 counts, Indian Vulture four birds counted and 28 bird counts of Western Osprey (Supplement Table A).

c) Very low sightings or no sighting of a species during any survey indicates the basic territorial characteristics of raptors, the possibility of their long home range, their seasonal and migratory habits, and our winter-season linear survey along the 572 km long Chambal River. Moreover, the survey objectives were targeted at the species seen in the water or on the river banks.

d) The index describing year-wise raptor counts and raptor species is an average of 9.9. This demonstrates a fairly favourable relationship between the habitat of NCS and the appearance of raptors within its landscape. In the beginning, i.e., in 2003 it was 10.5 and in 2016 it was 11.5 with fluctuations between values 5.7 and 15.3 (Table 2; Figure 5).

e) It is expected that the index values may enable to construe conclusion on conservation impacts from NCS with details of ecological parameters influencing the survival and behaviour of raptors through decades since the 1980s.

4. NCS-Kuno raptor names by other authors

a) Lists of NCS raptors that were possible to access for comparison are in Mitra (1979), the management

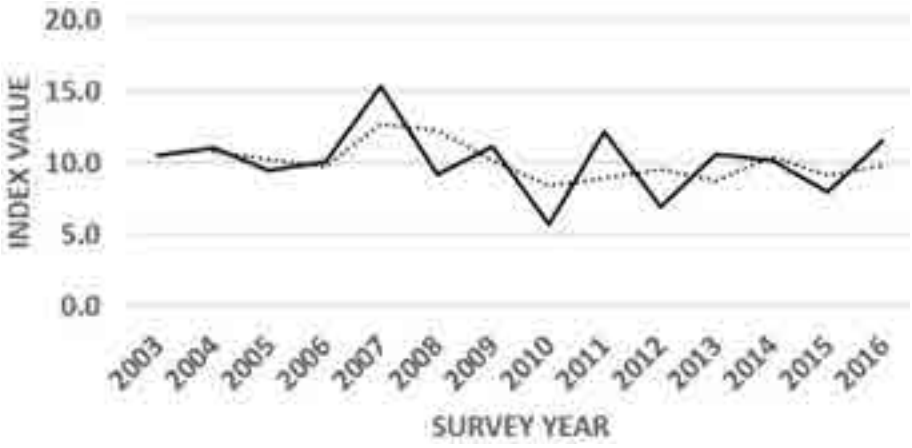

Figure 5. Trend in index value of 'Number of raptor species' and 'Number of raptor birds counted' in different survey years 2003–2016 with moving average (dotted line) in National Chambal Sanctuary.

Table 2. Year-wise survey with record of total numbers of species, raptor birds, and the trend of their index ratio.

Year	Species no.	Raptor count	Bird count / Species count index
2003	11	116	10.5
2004	17	188	11.1
2005	17	160	9.4
2006	17	171	10.1
2007	10	153	15.3
2008	18	166	9.2
2009	10	111	11.1
2010	15	85	5.7
2011	14	170	12.1
2012	13	90	6.9
2013	14	148	10.6
2014	16	163	10.2
2015	22	176	8.0
2016	15	173	11.5
Total	209	2070	-
Average	14.9	147.9	9.9

plan by Sale (1982), a Technical Report by Sharma & Singh 1986, the management plan by Murthy (2004), the consolidated list in Nair & Krishna (2013) and the proposed tri-state management plan by Choudhury et al. 2014. The list by Mitra (1979) was an original survey before our work commenced.

b) Mitra (1979) reported the presence of six raptor species. These were the Laggar Falcon, Pale Harrier, White-eyed Buzzard, Short-toed Eagle, Common Kestrel, and Crested Hawk Eagle (Changeable Hawk Eagle). Out of these, our observations till 2016 confirm the continued sighting of four species. These are the Laggar Falcon, Kestrel, White-eyed Buzzard, and the Changeable Hawk Eagle.

c) In the consolidated list of the vertebrate fauna of the Chambal basin, Nair & Krishna (2013) furnished a list of 308 bird species under 64 families. This list includes 45 species of raptors. These belong to Falconidae six species, Accipitridae 29 species, Tytonidae one species, and Strigidae nine species.

d) Given the gharial-oriented primary objectives, the season, and nature of our annual river surveys, we agree that our observations will not tally with other lists available for comparison.

NCS-Kuno raptor list compared with Ranthambhore and Sariska (Table 3)

a) Bildstein et al. (1998) mentioned 63 diurnal raptor species in India. Naoroji (2011) mentioned the occurrence of a total of 44 raptor species in the semi-arid biogeographic zone, of which 26 are migrants and 18 are residents.

b) Since Chambal banks offer only the cliffs for limited perch or nest, we have attempted to compare our observed list with sanctuaries of Rajasthan that may be within the active home range of the raptors.

c) Eleven raptor species observed in NCS are also reported from Ranthambhore Tiger Reserve **(**RTR) (Anonymous 2021) and Sariska Tiger Reserve **(**STR) (Sultana 2013). These are the Black-shouldered Kite, Western Barn Owl, Common Kestrel, Crested Serpent Eagle, Indian Vulture, Crested Honey Buzzard, Red-headed Vulture, Shikra, Spotted Owlet, Brown Fish Owl, and Indian Scops Owl.

d) Six species are not reported either from RTR or STR. These are the Cinereous Vulture, Common Buzzard, Pallas's Fish Eagle, Changeable Hawk Eagle, Eurasian Hobby, and Indian Eagle Owl. Future studies will confirm

Table-3. Comparison of raptors observed in National Chambal Sanctuary with reports from Ranthambhore Tiger Reserve (RTR) and Sariska Tiger Reserve (STR). Tharmalingam et al 2011 refers to report from Kuno-Palpur Sanctuary. P—Presence mentioned | N—Not mentioned. Ten of these species at serial numbers 2,3,5,7,8,9,16,17,24 and 25 were observed in 1983–85 and reported earlier in Sharma & Singh 1986 (Supplement Table A).

	Common name	Scientific name	Anonymous 2021 (RTR)	Sultana 2013 (STR)	Kuno – Palpur (Thermalingam et al 2011)
1	Cinereous Vulture	*Aegypius monachus*	N	N	N
2	Egyptian Vulture	*Neophron percnopterus*	N	P	P
3	White-rumped Vulture	*Gyps bengalensis*	N	P	P
4	Indian Vulture	*Gyps indicus*	P	P	P
5	Red-headed Vulture	*Sarcogyps calvus*	P	P	P
6	Griffon Vulture	*Gyps fulvus*	N	P	N
7	Western Osprey	*Pandion haliaetus*	N	P	P
8	Black-shouldered Kite	*Elanus axillaris*	P	P	N
9	Black Kite	*Milvus migrans*	P	N	N
10	Shikra	*Accipiter badius*	P	P	P
11	Western Marsh Harrier	*Circus aeruginosus*	N	P	P
12	Common Buzzard	*Buteo buteo*	N	N	N
13	White-eyed Buzzard	*Butastur teesa*	N	P	P
14	Crested Honey Buzzard	*Pernis ptilorhynchus*	P	P	N
15	Bonelli's Eagle	*Aquila fasciata*	N	P	P
16	Pallas's Fish Eagle	*Haliaeetus leucoryphus*	N	N	N
17	Tawny Eagle	*Aquila rapax*	N	P	N
18	Crested Serpent Eagle	*Spilornis cheela*	P	P	P
19	Changeable Hawk Eagle	*Nisaetus cirrhatus*	N	N	P
20	Common Kestrel	*Falco tinnunculus*	P	P	P
21	Eurasian Hobby	*Falco subbuteo*	N	N	N
22	Laggar Falcon	*Falco jugger*	N	P	N
23	Red-necked Falcon	*Falco chicquera*	N	P	N
24	Spotted Owlet	*Athene brama*	P	P	P
25	Western Barn Owl	*Tyto alba*	P	P	N
26	Dusky Eagle Owl	*Bubo coromandus*	P	N	N
27	Brown Fish Owl	Ketupa zeylonensis	P	P	P
28	Indian Scops Owl	*Otus bakkamoena*	P	P	N
29	Mottled Wood Owl	*Strix ocellata*	N	P	N
30	Indian Eagle-Owl	*Bubo bengalensis*	N	N	N

if these are migrants from other parts of the semi-arid biogeographic zone or the adjoining geographic regions.

e) Out of the 30 raptor species presented in this work from NCS-Kuno, we didn't find reports of 11 species in RTR and two species in STR. The species not reported from STR are the Black Kite and Dusky Eagle Owl. The species not reported from RTR are the Bonelli's Eagle, Western Marsh Harrier, Egyptian Vulture, White-rumped Vulture, Laggar Falcon, Western Osprey, Red-necked Falcon, Tawny Eagle, White-eyed Buzzard, Griffon Vulture, and Mottled Wood Owl.

f) Raptors are known to have long home ranges, and they may be flying to NCS-Kuno for food. Besides, Chambal forms confluences with other perennial tributaries like Kali-Sindh, Parbati, and Banas upstream, and the confluence of five rivers around Pachhnada in the downstream. Future studies may further reveal the relationship between the home range of different raptor species and the riverine habitat.

RECOMMENDATIONS

The National Chambal Sanctuary, which constitutes a part of river Chambal, is included under wetland types 11 (rivers, streams – slow-flowing, lower perennial) & 12 (rivers, streams – fast-flowing, upper perennial) (Scott 1989). As a protected area of national stature, river Chambal is provided with incidental conservation benefits for avian diversity. The river plays a crucial role in supporting local stork populations as well as giving alternate refuge for local migrants during the years with extreme ecological conditions (Sharma & Singh 2018). Similarly, continuous monitoring of wetland habitats in and outside Chambal may highlight the kind of ecological attraction Chambal holds for the skimmer populations of other wetlands in the region (Singh & Sharma 2018).

1. Consideration for the tri-state Chambal Ramsar site

Based on field surveys we have reported in the past on the status and population trends of large shorebirds and Raptor species of NCS (Sharma & Singh 1986; Sharma et al. 1995, 2013). The wetland and the adjoining area of the National Chambal Sanctuary form the habitat for many resident and migratory bird species, of which some are globally threatened. Our study on raptors identifies nine of the thirty raptors under the migratory category, attracted to the wetland landscape of NCS. A detailed study on the migration pattern of raptors and large shorebirds to River Chambal may further highlight the need for improved attention to river Chambal as a tri-state Ramsar site of India. Madhya Pradesh has already initiated the proposal some years back and deserves coordination at the national level.

2. Review of Scheduled status for three species of raptors

As predators, the raptors form one of the top links in the ecological chain and are, therefore, indicators of the health of the environment (Naoroji 2011). Among the most effective predators, the birds of prey keep a constant check on the population of amphibians, reptiles, mammals, and birds, and even on themselves. Found in diverse habitats, they are among the first that are affected by chemical pollution, adverse exploitation, and an overall decline of the habitat. The results from the present study on raptors propose that the MoEFCC consider reviewing the status given under the Wildlife (Protection) Act to Cinereous Vulture *Aegypius monachus*, Egyptian Vulture *Neophron percnopterus*, and Red-headed Vulture *Sarcogyps calvus*.

3. A comprehensive study on raptors of Arid Biogeographic Region / Khathiar-Gir Eco Region

Studies on tiger by Reddy et al. (2012) have already suggested on-ground gene-pool continuity over RTR and Sawai Madhopur National Park (MNP), which are in Rajasthan on the northern side of NCS and the Kuno-Palpur Wildlife Sanctuary (KPWS) of Madhya Pradesh on the southern side of NCS. Only a future study on raptors would further confirm the nature of ecological connectivity of habitats on either side of the National Chambal Sanctuary through the air.

We expect some of the raptors in NCS are visitors from the adjoining habitats of Rajasthan and Madhya Pradesh, within the dry deciduous forest ecoregion. Tharmalingam et al. (2011) reported the presence of 19 raptor species in Kuno-Palpur of Madhya Pradesh, and the list doesn't show the presence of 16 raptors observed in our present list (Table 3). However, out of these 16 species, six are reported from Ranthambhore Tiger Reserve (RTR) and nine from Sariska Tiger Reserve (STR). The observations suggest some continuity in the distribution of raptors in the north and south of river Chambal.

The list of raptor birds given in the present study forms a base for time-related comparison of species-availability and for an impact assessment. It is urged, that detailed studies may be promoted on raptors seen in National Chambal Sanctuary and their possible home ranges extending through other perennial tributaries and forest habitats like those of Kuno and Shivpuri in Madhya Pradesh, and Ranthambhore and Sariska in Rajasthan.

REFERENCES

Anonymous (2021). Birds of Ranthambhore: http//www.ranthambhoreguides.com/birds/checklist, Download 22nd March 2021.

Ali, S. (1979). *The Book of Indian Birds. Eleventh Edition*. Bombay Natural History Society, Bombay. Pp xlvii + 187.

Ali, S. (2002). *The Book of Indian Birds. Thirteenth Edition Revised*. Bombay Natural History Society, Oxford University Press. Pp lvii + 326.

Bildstein, K.L., W. Schelsky, J. Zalles & S. Ellis (1998). Conservation status of tropical raptors. *Journal of Raptor Research* 32(1): 3–18.

Bustard, H. R. (1999). Indian Crocodile Conservation Project. Pages 5-9. Envis (Wildlife and Protected Areas) 2(1): . Wildlife Institute of India, Dehradun. Pp 1-155.

Choudhary B. C. Gautam, P. & Nair. T. (2014). Generic tri-state management plan. National Chambal sanctuary, National tri-state Chambal sanctuary management and co-ordination committee (NTRIS - CASMACC) Ministry of environment and Forests, Government of India.

de Vos, A. (1984). Crocodile Conservation in India. *Biological Conservation* 29 (1984): 183–189.

Image 1. Top. Laggar Falcon *Falco jugger* at Jetpur, river Chambal (3 km upstream from study zone-VII Rajghat). Above. Ravine cliff facing river Chambal, used by Laggar Falcon pair at Jetpur. © Udayan

Image 2. Changeable Hawk Eagle *Nisaetus cirrhatus* at Ker Kho in Palpur Kuno WS. © Udayan

Image 3. Osprey *Pandion haliaetus* while lifting a fish out of water at Daljit Singh ka Pura, river Chambal, seen with a Gharial *Gavialis gangeticus* in the background returning to water after nesting. The location is in study zone-VIII, 45 km downstream Rajghat. © Udayan

Image 4. Bonelli's Eagle eating a bird, at Barsala (48 km downstream from Rajghat, study zone- VIII). © R.K. Sharma

Image 5. Bonelli's Eagle adult with chick at nest built on the ravine facing river Chambal, Chakarnagar in study zone-XII. © R.K. Sharma

Image 6. Dusky Eagle Owl *Bubo coromandus* at Baroli (study zone-III) on Rajasthan bank of Chambal close to Ranthambhore Tiger Reserve and Kaila Devi Wildlife Sanctuary. © Udayan

Image 7. Vultures at nest along Kuno. © R.K. Sharma

Image 8. Egyptian Vulture at Tigri Rithaura in study zone-VII while feeding on carcass of Emydid Turtle in National Chambal Sanctuary. © R.K. Sharma

Image 9. Egyptian Vultures downstream Rajghat at Daljit ka Pura (Study zone-VIII). Immature Egyptian Vultures are distinguishable from their darker body. © R.K. Sharma

ENVIS (2020). Protected Areas of India www.wiienvis.nic.in/ updated 03 August 2020. Downloaded 20 March 2021.

FSI (2019). The State of Forest Report 2019. Forest Survey of India, Ministry of Environment and Forest, Dehra Dun. Pp 1-167.

Gill F., D. Donsker & P. Rasmussen (Eds). (2021). IOC World Bird List (v11.1). Accessed 28 Feb 2021. https://doi.org/10.14344/IOC.ML.11.1

Gopi, G. V. & B. Pandav (2006). White bellied sea-eagle *Haliaeetus leucogaster* preying on salt-water crocodile *Crocodylus porosus*. Indian Birds 2(6): 171.

Grimmett, R., C. Inskipp, & T. Inskipp (2011). Birds of the Indian subcontinent. India: Oxford, 528pp.

Hernández, Mauro & Antoni Margalida (2009). Poison-related mortality effects in the endangered Egyptian vulture (Neophron percnopterus) population in Spain. August 2009, European Journal of Wildlife Research 55(4):415–423. https://doi.org/10.14344/IOC.ML.11.110.1007/s10344-009-0255-6

Meteyer, C.U., B. A. Rideout, H. L. Shivasprasad, S. **Ahmed, M. J. I. Chaudry, M. Arshad, S. Mahmood,** A. **Ali, & A. A. Khan (2004).** Diclofenac residues as the cause of vulture population declines in Pakistan. *Nature* 427: 630–633.

Mitra (1979). Checklist of Birds in National Chambal Sanctuary. Unpublished official report.

Murthy, R. S. (2004). Management Plan of National Chambal Sanctuary, Morena (M.P.) 2003–2004 to 2013–2014. Forest Department, Government of Madhya Pradesh, Bhopal, India, 148pp.

Nair, T. & Y. C. Krishna (2013). Vertebrate fauna of the Chambal River Basin, with emphasis on the National Chambal Sanctuary, India. *Journal of Threatened Taxa* 5(2): 3620–3641. https://doi.org/10.11609/JoTT.o3238.3620-41

Naoroji Rishad (2011). Birds of prey of the Indian subcontinent. Om books international corporate & editorial. www.ombooks.com, 692pp.

Palei, N. C., B. P. Rath & B. P. Acharya (2019). An observation of the White-Bellied Sea Eagle *Haliaeetus leucogaster* preying on Saltwater Crocodile *Crocodylus porosus* in Bhitarkanika Wildlife Sanctuary, India. Journal of Threatened Taxa, Vol.11, Number 13: 14767–14769. https://doi.org/10.11609/jott.4916.11.13.14767-14769

Potier, S., M. Mitkus & A. Kelber (2020). Visual adaptations of diurnal and nocturnal raptors. Seminars in Cell and Developmental Biology, https://doi.org/10.1016/j.semcdb.2020.05.004

Prakash, V., D. J. Pain, A. A. Cunningham, P. F. Donald, N. Prakash, A. Verma, R. Gargi, S. Sivakumar & A. R. Rahmani (2003). Catastrophic collapse of Indian white-backed *Gyps bengalensis* and long-billed *Gyps indicus* vulture populations. *Biological Conservation* 109: 381–390.

Rao, R.J. & L.A.K. Singh (1987a). Notes on comparative body size, reproductive effort and species of *Kachuga* (Reptilia, Chelonia) in the National Chambal Sanctuary. *Journal of the Bombay Natural History Society* 84(1): 55–65.

Rao, R.J. & L.A.K. Singh (1987b). Notes on ecological relationship in basking and nesting site utilisation among *Kachuga* spp. (Reptilia, Chelonia) and *Gavialis gangeticus* (Reptilia, Crocodilia) in National Chambal Sanctuary. *Journal of the Bombay Natural History Society* 84(3): 599–604.

Rao, R.J. & L.A.K. Singh (1987c). *Kachuga* (Reptilia, Emydidae) in National Chambal Sanctuary: Observations on diurnal nesting emergences and unsuccessful nesting crawl. *Journal of the Bombay Natural History Society* 84(3): 688–691.

Reddy P. A., D. S. Gour, M. Bhavanishankar, K. Jaggi, S.M. Hussain, K. Harika & S. Shivaji (2012). Genetic Evidence of Tiger Population Structure and Migration within an isolated and fragmented landscape in Northwest India. *PLoS ONE* 7(1): e29827. https://doi.org/10.1371/journal.pone.0029827

Rodgers, W.A. & H.S. Panwar (1988). Planning a Wildlife Protected Area Network in India. A report prepared for the Ministry of Environment and Forests and Wildlife, Government of India, volumes 1 and 2. 339, 267.

Sale, J. B. (1982). 2nd Draft. Management Plan for the National Chambal Sanctuary. First Five-Year Period 1982/83 – 1986/87. Central Crocodile Breeding and Management Institute, Hyderabad, iii+82pp.

Scott, D.A. [ed.] (1989). *A Directory of Asian Wetlands*. IUCN, Gland, Switzerland, and Cambridge, UK, xiv+1181pp, 33 maps.

Sharma, R.K. & L.A.K. Singh (1986). Wetland Birds in National Chambal Sanctuary. Preliminary Report from field camp. Crocodile Research Centre of Wildlife Institute of India, Hyderabad, 36pp+7table.

Sharma, R.K. & L.A.K. Singh (2014). Status of Gangetic Dolphin (*Platanista gangetica*) in National Chambal Sanctuary after thirty years. *Zoos' Print Magazine* XXIX (7): 22–27.

Sharma, R.K. & L.A.K. Singh (2015). Status of Mugger Crocodile (*Crocodylus Palustris*) in National Chambal Sanctuary after thirty years and its implications on conservation of Gharial (*Gavialis Gangeticus*). *Zoos' Print Magazine* XXX (5): 9–16.

Sharma, R. K. & L.A.K. Singh (2018). Spatial and temporal patterns of stork sightings (Aves: Ciconiidae) in National Chambal Sanctuary of Gangetic River system. *Journal of Threatened Taxa* 10(3): 11410–11415. http://doi.org/10.11609/jott.3817.10.3.11410-11415

Sharma, R.K., R. Mathur & S. Sharma (1995). Status and Distribution of fauna in National Chambal Sanctuary, Madhya Pradesh. The Indian Forester, Dehradun, 121(10): 912–916.

Sharma, R. K., S. C. Bhadoria, B. S. Rathore & N. Dasgupta (2013). Diversity of aquatic animals in National Chambal Sanctuary, Madhya Pradesh, pp. 246–261. In: Rathore, B.S. & V.S. Rathore

(eds.) *Management Resource for Sustainable Development*. Divya Publishing House, Astral International Pvt. Ltd, New Delhi, 306pp.

Shultz, S., Baral, H.S., Charman, S., Cunningham, A.A., Das, D., Ghalsasi, G.R., Goudar, M.S., Green, R.E., Jones, A., Nighot, P., Pain, D.J. & Prakash, V. (2004). Diclofenac poisoning is widespread in declining vulture populations across the Indian subcontinent. *Proceedings of the Royal Society of London B*, (Supplement) 271: S458–S460. https://doi.org/10.1098/Rsbl.2004.0223

Singh, L.A.K. & R. J. Rao (1984). Ecological relationship among Turtles in National Chambal Sanctuary. Interim Study Report-1 CRC/NCS/21-a.Crocodile Research Centre. Wildlife Institute of India. Morena, 45pp.

Singh, L.A.K. & R. J. Rao (1985). Ecological Relationship among Turtles in National Chambal Sanctuary, Interim Study Report-2. National Chambal Sanctuary, Deori, Morena, Madhya Pradesh, 27pp.

Singh, L.A.K. & R. K. Sharma (1985). Gangetic Dolphin (*Platanista gangetica*) observations on habits and distribution pattern in National Chambal Sanctuary. *Journal of the Bombay Natural History Society* 82(3): 648–653.

Singh, L.A.K. & R. K. Sharma (2015). Climate-related warnings viewed through population trend of crocodiles and dolphin in National Chambal Sanctuary. Presentation made at and Abstract in: UGC-SAP Sponsored National Seminar on Challenges and practices in biodiversity conservation with special reference to herpetofauna, 20–21 November 2015, Department of Zoology, North Orissa University.

Singh, L.A.K. & R. K. Sharma (2018). Sighting trend of the Indian Skimmer (Charidiformes: Laridae: *Rynchops albicollis* Swainson, 1838) in National Chambal Gharial Sanctuary (1984–2016) reflecting on the feasibility of long-term ecological monitoring. *Journal of Threatened Taxa* 10(5): 11574–11582. http://doi.org/10.11609/jott.3732.10.5.11574-11582

Singh, L.A.K. (1979). Results of survey on the status of mugger crocodile (*Crocodylus palustris* Lesson) in rivers Budhabalanga West Deo in Similipal Tiger reserve, Orissa. Typed Report, Dec. 1979. Similipal Tiger Reserve, Jashipur.

Singh, L.A.K. (1985). Gharial Population Trend in National Chambal Sanctuary with notes on radio- tracking. Study Report December 1985. Crocodile Research Centre, Wildlife Institute of India, Hyderabad, 167pp+vii.

Singh, L.A.K. (1999). Status of Gharial and Mugger in Orissa, pp. 17–23. In: *Indian Crocodiles*. Envis (Wildlife and Protected Areas). Vol.2, No.1, Wildlife Institute of India, Dehra Dun, June 1999, 155pp.

Singh, L.A.K. (1993). Survey of Raptors seen in Simlipal Tiger Reserve, Orissa. Bihang newsletter, Vol. 1 (2), January – February 1993: 5–6.

Sultana, A. (2013). An updated checklist of birds of Sariska Tiger Reserve, Rajasthan, India. *Journal of Threatened Taxa* 5(13): 4791–4804. http://doi.org/10.11609/JoTT.o3215.4791-804

Swan, G.E., Cuthbert, R., Quevedo, M., Green, R.E., Pain, D.J., Bartels, P., Cunningham, A.A., Duncan, N., Meharg, A.A., Oaks, J.L., Parry-Jones, J., Shultz, S., Taggart, M.A., Verdoorn, G. & Wolter, K. (2006a). Toxicity of diclofenac to *Gyps* vultures. *Biology Letters* 2:279–282.

Swan, G., Naidoo, V., Cuthbert, R., Green, R.E., Pain, D.J., Swarup, D., Prakash, V., Taggart, M., Bekker, L., Das, D., Diekmann, J., Diekmann, M., Killian, E., Meharg, A., Patra, R.C., Saini, M. & Wolter, K. (2006b). Removing the threat of diclofenac to critically endangered Asian vultures 2006. *Public Library of Science Biology* 4: 396–402.

Tharmalingam, R., N. Shridharan & R. Kalle (2011). Birds of Kuno Wildlife Sanctuary, Central India, Zoos' Print, vol. XXVI, Issue-12 Dec.2011.

Vyas, R.V. (2019). Note on interactions between predators and prey: Indian crocs and birds. *Crocodile Specialist Group, Newsletter* 38(2): 4–7.

Wikipedia 2021. Khathiar-Gir dry deciduous forests. Last edited on 26 January 2021. Accessed 19 March 2021. https://en.wikipedia.org/wiki/Khathiar-Gir_dry_deciduous_forests

WWF (2021). Southern Asia: Northwestern India, Ecoregions. Downloaded on 19 April 2021 from https://www.worldwildlife.org/ecoregions/im0206

Zabala-Albizua, Jabi, Joel C. Trexler, Nilmini Jayasena & Peter Frederick (2020). Early Breeding Failure in Birds Due to Environmental Toxins: A Potentially Powerful but Hidden Effect of Contamination. October 2020, Environmental Science and Technology 54(21): 13786–13796. https://doi.org/10.1021/acs.est.0c04098

सारांश

राष्ट्रीय चंबल अभ्यारण्य (NCS) में शिकारी पक्षी (रैपटर्स) महत्व रखते हैं क्योंकि वे इस क्षेत्र के शीर्ष शिकारी पक्षियों में से हैं, जो छोटे मगरमच्छों, कछुओं और अन्य पक्षियों का शिकार करते हैं। राप्टर्स की 30 प्रजातियों की हमारी चेकलिस्ट 1983 और 2016 के बीच शीतकालीन सर्वेक्षणों के दौरान किए गए अवलोकनों से विकसित की गई है। इस अवधि में हमने जिस क्षेत्र में सर्वेक्षण किया उसके अंतर्गत राष्ट्रीय चंबल अभ्यारण्य और चंबल कूनो नदी के संगम के क्षेत्र मध्य प्रदेश सीमा में आते हैं। चंबल परिदृश्य के बीहड़ की खड़ी और दुर्गम मिट्टी चट्टानों का उपयोग करने हेतु जो शिकारी पक्षी पहचाने गए हैं उनमें बॉनलीज ईगल, लागर फाल्कन, इजिप्शियन वल्चर, व्हाइट रैम्पड वल्चर, स्पॉटेड आउलेट, इंडियन ईगल आउल आदि अन्तर्भुक्त हैं । राष्ट्रीय चंबल अभ्यारण्य में वर्णित अधिकांश अन्य रैपटर्स क्रमशः राजस्थान एवं मध्य प्रदेश के आसपास के वन्यजीव क्षेत्रों से तथा समीपवर्ती क्षेत्रों के आगंतुक माने जाते हैं । वर्गीकरण के दो तरीकों के अनुसार यह इलाका अर्ध शुष्क जैव भौगोलिक क्षेत्र या खाटिहार गिर शुष्क पर्णपाती वन क्षेत्र में आता है । एनसीएस-कूनो की सूची की तुलना पिछली रिपोर्ट्स एवं राजस्थान की सरिस्का टाइगर रिजर्व और रणथंबोर टाइगर रिजर्व के लिए उपलब्ध सूची से की गई है। वर्तमान कार्य एनसीएस में वर्ष 1983 से प्रारंभ किए गए घड़ियाल (गेवियलिस गैंजेटिकस) एवं अन्य जलीय जीवो की दीर्घकालीन परिस्थिति की निगरानी का परिणाम है। शिकारी पक्षियों को देखने के लिए पानी की सतह एवं तटरेखा से और दूर तक देखने के लिए समय और ध्यान देने की जरुरत मांग की है। फिर भी, 34 वर्षों में बनाए गए हमारे सावधानीपूर्वक रिकॉर्ड ने एक बुनियादी रूपरेखा तैयार की है, जो उन मापदंडों पर केंद्रित अध्ययनों को क्रियान्वित करने के लिए प्रेरित करती है जो एनसीएस के आसपास के वन आवासों और वन्यजीव अभ्यारण्य के पारिस्थितिक तंत्र को बनाए रखते हैं।

Supplement Table A. Year-wise presence and count record of different raptor species in National Chambal Sanctuary (NCS). Data for 1983-85 contained information for a checklist and published with other details in Sharma and Singh 1986. Surveys during 1987-1989 and 1991-2002 were limited to certain stretches of NCS and for raptors are treated as 'No data'. N–No data or Not observed, O–Observed. CR—Critically Endangered | VU—Vulnerable | EN—Endangered | NT—Near Threatened | LC—Least Concern.

Sno	Common name	Scientific name	1983-85	1986	1987-1989	1990	1991-2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	TOTAL raptor number	Seen in how many years	SUM for raptor groups (row)	Remarks
1	Cinereous Vulture	*Aegypius monachus*	N	N	N	N	N	N	N	2	N	N	N	N	1	N	N	N	1	N	N	4	3		NT, rare, winter visitor
2	Egyptian Vulture	*Neophron percnopterus*	O	11	N	N	N	62	116	102	98	72	60	41	22	88	36	61	94	67	80	999	14		EN, common
3	White rumped Vulture	*Gyps bengalensis*	O	32	N	304	N	8	7	9	8	6	5	4	2	3	4	5	6	9	4	80	14		CR, rare, resident
4	Indian Vulture	*Gyps indicus*	N	N	N	4	N	3	N	2	N	2	N	N	1	2	N	N	N	2	N	12	6		CR, rare, resident
5	Red headed Vulture	*Sarcogyps calvus*	O	2	N	N	N	2	1	2	4	2	4	2	1	2	N	3	1	4	2	30	13		CR, rare, resident
6	Griffon Vulture	*Gyps fulvus*	N	N	N	N	N	N	N	N	1	N	1	N	N	N	1	N	N	1	N	4	4		LC, rare, winter visitor
			Listed 3	3	N	2	N	4	3	5	4	4	4	3	5	4	3	3	4	5	3			54	
7	Western Osprey	*Pandion haliaetus*	O	4	N	28	N	27	35	21	30	50	51	40	29	59	25	57	32	52	54	562	14		LC, winter visitor, upto summer
8	Black-shouldered Kite	*Elanus axillaris*	O	3	N	N	N	N	3	2	N	N	5	6	4	N	N	3	5	7	4	39	9		LC, common, resident
9	Black Kite	*Milvus migrans*	O	2	N	N	N	8	11	N	12	N	10	N	9	N	6	N	2	4	N	62	8		LC, common, resident
10	Shikra	*Accipiter badius*	N	N	N	N	N	1	2	3	5	9	7	6	5	4	5	6	7	8	6	74	14		LC, common, resident
11	Western Marsh Harrier	*Circus aeruginosus*	N	N	N	N	N	N	2	3	1	4	6	5	2	2	1	2	1	3	6	38	13		LC, occasional, winter visior
12	Common Buzzard	*Buteo buteo*	N	N	N	N	N	N	1	N	2	N	N	N	N	N	N	N	1	N	N	4	3		LC, rare, winter visitor
13	White eyed Buzzard	*Butastur teesa*	N	N	N	N	N	N	N	1	N	N	N	N	N	N	N	1	N	N	N	2	2		LC, rare, resident
14	Crested Honey Buzzard	*Pernis ptilorhynchus*	N	N	N	N	N	N	1	N	1	N	N	N	N	N	N	N	1	N	1	4	4		LC, occasional, resident
15	Bonelli's Eagle	*Aquila fasciata*	N	N	N	N	N	2	N	N	N	N	4	2	1	2	4	2	4	3	5	29	10		LC, occasional, resident
			Listed 3	3	N	1	N	4	7	5	6	3	6	5	6	4	5	6	8	6	6			77	
16	Pallas's Fish Eagle	*Haliaeetus leucoryphus*	O	1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	0	0		EN, rare, winter visitor
17	Tawny Eagle	*Aquila rapax*	O	1	N	N	N	N	N	4	N	N	2	N	1	N	2	N	N	N	2	11	5		VU, rare, winter visitor

Sno	Common name	Scientific name	1983-85	1986	1987-1989	1990	1991-2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	TOTAL raptor number	Seen in how many years	SUM for raptor groups (row)	Remarks
18	Crested Serpent Eagle	*Spilornis cheela*	N	N	N	N	N	N	N	N	2	N	N	1	N	N	N	1	N	1	N	5	4		LC, occasional, resident
19	Changeable Hawk Eagle	*Spizaetus cirrahatus*	N	N	N	N	N	1	N	N	1	N	N	N	N	N	N	2	N	1	N	5	4		LC, occasional, resident
			Listed 2	2	N	N	N	1	N	1	2	N	1	1	1	N	1	2	N	2	1			13	
20	Common Kestrel	*Falco tinnunculus*	N	N	N	N	N	N	2	3	N	4	N	N	2	1	1	2	4	6	4	29	10		LC, Ccommon, winter visitor
21	Eurasian Hobby	*Falco subbuteo*	N	N	N	N	N	1	1	N	1	N	1	N	N	1	N	N	N	1	N	6	6		LC, rare, winter visitor
22	Laggar Falcon	*Falco jugger*	N	N	N	N	N	N	2	2	1	2	2	4	4	2	2	2	1	1	2	27	13		NT, rare,resident
23	Red-necked Falcon	*Falco chicquera*	O	N	N	N	N	N	N	1	2	N	2	N	1	1	N	N	N	1	1	9	7		NT, rare, resident
			Listed 1	N	N	N	N	1	3	3	3	2	3	1	3	4	2	2	2	4	3			36	
24	Spotted Owlet	*Athene brama*	O	1	N	N	N	N	N	1	1	N	N	N	N	N	N	N	1	1	N	4	4		LC, rare, resident
25	Western Barn Owl	Tyto alba	N	1	N	N	N	N	N	1	N	N	1	N	N	N	N	N	2	N	1	5	4		LC, rare, resident
26	Dusky Eagle Owl	*Bubo coromandus*	N	N	N	N	N	N	1	N	1	N	N	N	N	1	N	N	N	1	N	4	4		LC, rare, resident
27	Brown Fish Owl	Ketupa zeylonensis	N	N	N	N	N	1	1	N	N	2	N	N	N	N	N	1	N	N	N	5	4		LC, rare, resident
28	Indian Scops Owl	*Otus bakkamoena*	N	N	N	N	N	N	1	N	N	N	2	N	N	N	2	N	N	1	1	7	5		LC, occasional, resident
29	Mottled Wood Owl	*Strix ocellata*	N	N	N	N	N	N	N	1	N	N	1	N	N	2	N	N	N	1	N	5	4		LC, occasional, resident
30	Indian Eagle Owl	*Bubo bengalensis*	N	N	N	N	N	N	1	N	N	N	2	N	N	N	1	N	N	1	N	5	4		LC, occasional, resident
			Listed 1	2	N	N	N	1	4	3	2	1	4	N	N	2	2	1	2	5	2			29	
	TOTAL raptor species seen during concerned survey		Listed 10	10	No data	3	No data	11	17	17	17	10	18	10	15	14	13	14	16	22	15	2070	209		
	TOTAL no of raptor birds counted in the year		Noted presence, good localities, and total number (Sharma and Singh 1986)	66	No data	339	No data	116	188	160	171	153	166	111	85	170	90	148	163	176	173	2070	209	209	
	Index: Ratio Bird / Spp numbers			6.6		113.0		10.5	11.1	9.4	10.1	15.3	9.2	11.1	5.7	12.1	6.9	10.6	10.2	8.0	11.5	Average Index 2003-2016=	9.9		

Supplement Table B. Raptors of National Chambal Sanctuary and their international and national status of protection with recommendation. CR—Critically Endangered | VU—Vulnerable | EN—Endangered | NT—Near Threatened | LC—Least Concern.

Species Sl. No.	English name	Scientific name	IUCN Status	Status in Wildlife Act, 1972	Cites Appendix	Migratory status
1	Cinereous Vulture	*Aegypius monachus*	NT	Schedule-IV Cannot hunt without permission	II	Winter visitor
2	Egyptian Vulture	*Neophron percnopterus*	EN	Schedule-IV	II	Resident
3	White-rumped Vulture (Synonym: Indian White-backed Vulture)	*Gyps bengalensis*	CR	Schedule-I	II	Resident
4	Indian Vulture (Synonym: Long-billed Vulture)	*Gyps indicus*	CR	Schedule-I	II	Resident
5	Red-headed Vulture	*Sarcogyps calvus*	CR	Schedule-IV	II	Resident
6	Griffon Vulture (Synonym: Eurasian Griffon)	*Gyps fulvus*	LC	Schedule-IV	II	Winter visitor
7	Western Osprey (Synonym: Osprey)	*Pandion haliaetus*	LC	Schedule-I Fully protected	II	Winter visitor, seen till May
8	Black-shouldered Kite	*Elanus axillaris (Syn: E. caeruleus)*	LC	Schedule-IV	II	Resident
9	Black Kite (Syn: Common Pariah Kite)	*Milvus migrans*	LC	Schedule-IV	II	Resident
10	Shikra	*Accipiter badius*	LC	Schedule-IV	II	Resident
11	Western Marsh Harrier (Synonym: Eurasian Marsh Harrier)	*Circus aeruginosus*	LC	Schedule-IV	II	Winter visitor
12	Common Buzzard	*Buteo buteo*	LC	Schedule-IV	II	Winter visitor
13	White-eyed Buzzard	*Butastur teesa*	LC	Schedule-IV	II	Resident
14	Crested Honey Buzzard (Synonym: Oriental Honey Buzzard)	*Pernis ptilorhynchus*	LC	Schedule-IV	II	Resident
15	Bonelli's Eagle	*Aquila fasciata* (Syn: *Hieraaetus fasciatus*)	LC	Schedule-IV	II	Resident
16	Pallas's Fish Eagle	*Haliaeetus leucoryphus*	EN	No mention	II	Winter visitor
17	Tawny Eagle	*Aquila rapax*	VU	Schedule-IV	II	Winter visitor
18	Crested Serpent Eagle	*Spilornis cheela*	LC	Schedule-IV	II	Resident
19	Changeable Hawk Eagle	*Nisaetus cirrhatus, Syn. Spizaetus cirrhatus*	LC	Schedule-IV	II	Resident
20	Common Kestrel	*Falco tinnunculus*	LC	Schedule-IV	II	Winter visitor
21	Eurasian Hobby	*Falco subbuteo*	LC	Schedule-IV	II	Winter visitor
22	Laggar Falcon	*Falco jugger*	NT	Schedule-I	I (One)	Resident
23	Red-necked Falcon	*Falco chicquera*	NT	Schedule-I	II	Resident
24	Spotted Owlet	*Athene brama*	LC	Schedule-IV	II	Resident
25	Western Barn Owl (Synonym: Barn Owl)	Tyto alba	LC	Schedule-IV	II	Resident
26	Dusky Eagle Owl	*Bubo coromandus*	LC	Schedule-IV	II	Resident
27	Brown Fish Owl	*Ketupa zeylonensis* (Synonym: *Bubo zeylonensis*)	LC	Schedule-IV	II	Resident
28	Indian Scops Owl	*Otus bakkamoena*	LC	Schedule-IV	II	Resident
29	Mottled Wood Owl	*Strix ocellata*	LC	Schedule-IV	II	Resident
30	Indian Eagle-Owl (Synonym: Rock Eagle Owl)	*Bubo bengalensis*	LC	Schedule-IV	II	Resident

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OPEN ACCESS

COMMUNICATION

Nesting success of Sharpe's Longclaw (*Macronyx sharpei* Jackson, 1904) around the grasslands of lake Ol'bolossat Nyandarua, Kenya

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Abstract: Sharpe's Longclaw *Macronyx sharpei* is an endangered Kenyan endemic bird restricted to high-altitude grasslands with long tussocks. The species occurs on the grasslands surrounding Lake Ol'Bolossat in Nyandarua, Kenya, an area that is globally recognized as an Important Bird and Biodiversity Area. The grasslands receive little conservation measures, which have led to the decline in the population density of Sharpe's Longclaw. Nesting success in birds is crucial for their population growth. The daily survival rate for natural nests of Sharpe's Longclaw in the grasslands of Lake Ol'Bolossat had not been systematically assessed prior to this study. Natural nests were actively searched during the breeding seasons of March–May 2016, while artificial nests were constructed using dry grass containing artificial eggs made of cream modeling clay. Natural nests had a higher daily nest survival percentage than artificial nests. The highest daily nest survival rate was 40% and the lowest 0.01%. Predators, livestock grazing and fires greatly reduced the survival of nestlings. We recommend intensive ecological management of the high-altitude grasslands of Lake Ol'Bolossat.

Keywords: Daily survival rate, Endangered, endemic, Lake Ol'Bolossat, nest, nestling, Sharpe's Longclaw.

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Author contributions: HAR—conceived and designed experiment of the study, collected field data, analyzed data, interpreted data, discussed data, wrote the manuscript. CMW—designed study, analyzed, interpreted and discussed data, wrote the manuscript. PN—designed study, analyzed and interpreted data, wrote the manuscript.

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INTRODUCTION

Approximately, 350 bird species are grassland dwellers in Kenya (Morris et al. 2009). Sharpe's Longclaw *Macronyx sharpei* (Jackson 1904) is among these grassland birds. It is 16 to 17 cm long, with upper parts heavily marked with buff and rufous streaks, yellow underparts, and white outer tail feathers in flight (BirdLife International 2016). Sharpe's Longclaw is endemic to Kenya and it is listed as globally endangered in the International Union for Conservation of Nature (IUCN) Red List of threatened species (BirdLife International 2016). The preferred habitat for Sharpe's Longclaw is the high-altitude grasslands of the central Kenyan highlands. The population of Sharpe's Longclaw in the grasslands of Ol'Bolossat has been on the decline due to the loss of feeding and nesting habitats caused by the conversion of grasslands into crop fields, afforestation, uncontrolled bird shooting, mining activities and constant use of insecticides (Monadjem & Virani 2016).

For birds that lay eggs in nests and incubate them until they hatch, many eggs are lost due to predation, which varies with the quality and site of nests (Martin & Clobert 1996). Nests located in hidden places (for example, cavities) have a higher probability of survival than those located in open ground (Walk et al. 2010). During the breeding season, the selection of good nest sites is important because it affects nesting success and the survival of the nestlings (Lima 2009). Other factors that affect nesting success of grassland birds include wind and sunlight direction, which influence the microclimate of the nest (Wiebe et al. 2001; Tieleman et al. 2008).

Sharpe's Longclaw constructs its nest in long grass tussocks (Dominic et al. 2020), which provide both nest material (Collias & Collias 2014) and cover from predators (Muchai & Plessis 2005). However, tussocks can be destroyed by various human activities such as farming, fires and overgrazing (Wamiti et al. 2008) which alter the quality of bird nesting habitats and reduce nesting areas. Nests in inferior quality habitats will expose eggs and nestlings to predators such as snakes, predatory birds and moles, leading to decreased nest success (Pace et al. 1999; Polis et al. 2000). Adverse weather conditions have also contributed to the decline in nesting success of Sharpe's Longclaw (Stephenson et al. 2011; Shiao et al. 2015). During heavy rains, runoff water destroys nests reducing nesting success and survival rates (Rodriguez & Barba 2016).

Nesting success is mainly influenced by changes in habitat structures through management practices. These changes reduce nesting substrates which hide the nest from their predators (Ammon & Stacey 1997). Nesting success is also related to the structure of the habitat (Bowman & Harris 1980), nest site features (Norment 1993), nesting bird behavior (Cresswell 1997) and parental activity (Martin et al. 2000). The nests located in hidden places such as cavities, shrubs, and tussocks have a higher probability of survival than nests located in open spaces (Walk et al. 2010). Food availability is also an important factor determining nestlings' growth and survival (Roff 1992).

Increased parental activity escalates the risk of nest predation (Martin et al. 2000). The birds with minimal parental activities, therefore, reduce nest predation. Habitats may indirectly influence predation risks, food availability for nesting birds, and time and energy available for nest defense (Martin 1995). When a predator visits a particular nest and takes some of its contents but not all (i.e., partial depredation), the behavior may lead to selective pressure, which is not enforced by complete nest predation (Lariviere & Messier 1997; Amundsen 2000).

To properly manage the declining populations of grassland dwelling birds, habitat protection is important because it directly influences their nesting success (Winter & Faaborg 1999). Determining the nesting success of Sharpe's Longclaw is therefore, important when developing species-specific conservation measures. This study was designed to determine the nest success of Sharpe's Longclaw in the grasslands around Lake Ol'Bolossat in Nyandarua , Kenya.

STUDY AREA AND RESEARCH METHODS

Study area

Lake Ol'Bolossat is located in Kenya, Nyandarua County, Ol-joro-orok Sub-County. It lies between latitudes 0.1640 90' 00" South and longitudes 36.4450 26' 00" East (Figure 1). It is positioned in Ongata Pusi valley and is adjacent to the Rift valley with an elevation of 2,340 m above sea level. It is a natural wetland covering an area of approximately 43.3 km^2 and its open waters cover 4 km^2. It has a rich biodiversity zone with many species of water birds and other threatened species. The riparian land around Lake Ol'Bolossat is covered by grasslands inhabited by birds (Wamiti et al. 2008). It was internationally recognized as the sixty-first Important Bird and Biodiversity Area (IBA) in Kenya in March 2008 by BirdLife International (Mwangi et al. 2010) and protected officially from February 2018

Figure 1. Lake Ol'Bolossat basin showing the main geographical features in the study area (Google 2018).

(Nature Kenya 2018).

The climate is sub-humid throughout the year and is mainly influenced by the surrounding highlands. Lake Ol'Bolossat has a rainfall pattern between 700 and 1,000 ml with long rains from April to July, and short rains in November (Wamiti et al. 2008). Temperatures are cold because of the wind blowing from the Aberdare ranges, which can bring frost that can destroy grass, including the tussocks favored by Sharpe's Longclaw (Wamiti et al. 2008).

Methods

Determination of natural nest success

Nests were searched during the breeding seasons of March to May (2016) by fortuitous encounters, or by following adults carrying nesting material during incubation and feeding of the young, or by dragging a 50m rope between two people and flushing birds from nests (Bibby et al. 2000). Once the nests were located, global positioning system (GPS) coordinates were taken for future geo-location. They were checked after three days to determine their status.

Care was taken during nest searches to avoid disturbance to the nests and surrounding vegetation. A stick was used to hold the vegetation aside to prevent contact with human clothing/skin that would leave behind scents that attract predators. Mayfield nesting success formula was used to estimate the probability of successful nesting (Mayfield 1975).

$$\text{Daily survival probability} = \frac{\text{Exposure days - Failed nests}}{\text{Exposure days}}$$

Daily survival probability refers to the probability of the nestling to survive from one day to the next in the nest. In contrast, exposure days refer to the total number of days a nest will be observed active and susceptible to failure.

Nest survival refers to the probability that a nest fledges at least one chick using a nesting period of 26 days (4 laying, 12 incubating, and 10 nestling).

Nest survival= daily survival probability $^{\text{nesting period}}$

Predation rate for artificial nets

Artificial nests were used to assess the effect of different variables on the rate and trend of nest predation (Major & Kendall 1996). They allow researchers to manipulate the number of nests in the study area, and take less time to place and locate than natural nests (Yahner & Delong 1992). However, the lack of an incubating adult may affect the ability of predators to locate them (Martin 1987).

The artificial nest experiment in the grasslands of Lake Ol'Bolossat was conducted between March and July 2016. Experimental nests were constructed 10 cm wide and 5 cm deep using dry grass interwoven to mirror Sharpe's Longclaw nests as much as possible. Cream non-toxic modeling clay was used to make artificial eggs. The plasticine eggs were similar in size, shape and color to Sharpe's Longclaw eggs. After shaping the egg, a marker was used to make irregular spots. Edge effects were considered near forests, roads, and hedgerows (Keyel et al. 2013) and extended between 50–100 m into the nesting habitat (Bollinger & Gavin 2004).

The grassland habitat was divided into several portions measuring 1,000 x 850 m. Three line transects were laid in each habitat 200 m apart. Samples of 30 nests were laid out. These included three nests in two transects and four in one transect, repeated two more times in habitats with tussocks. Each nest had three white plasticine eggs, which were left for a minimum of 21 days, a duration that resembles Sharpe's Longclaw incubation period.

The average distance between nests was 250 m. Artificial nests were randomly placed together with Sharpe's Longclaw nests but at a specified distance of 250 m away. GPS coordinates were taken for the future location. The eggs were examined for bites or teeth impressions and the appropriate records made, ensuring a proper differentiation between avian and rodent predators (Dion et al. 2000). Nests were considered depredated when the plasticine eggs were destroyed or showed bite marks.

Data analysis

Raw data were recorded and then tabulated in Microsoft Excel for cleaning and storage. Quantitative data was exported to SPSS (Statistical Package for Social Sciences) software version 25.0 (IBM corporation, Armonk, New York, United States of America) for analysis. An unpaired t-test was used to test for the statistical difference between the daily survival percentage of natural and artificial nests. The null hypothesis was rejected when $p \leq 0.05$.

RESULTS

Sharpe's Longclaw nesting success

A total of seven natural nests were identified in seven locations between April and July 2016, and observed during the nesting period. Nests were discovered on 12 May, 26 May, 10 June, 02 July, and 06 July around the grasslands of Lake Ol'Bolossat. At the beginning of the study, nests were in various stages of development: two nests had eggs, two nests had nestlings, and three nests were in the construction stage. One of the seven natural nests located in Nduthi was abandoned during the construction stage, possibly due to flooding caused by heavy rains. Three eggs were recorded in each nest, although nests located in Rurii and Nduthi had none (Table 1). All eggs hatched to chicks in Mukindu, Kirima, Munyeki, and Makereka nest locations, indicating a 100% hatching rate. However, the eggs in Kanguo did not hatch (Table 1). Tussock height ranged between 25.0 m in Makindu to 21.5 m in Rurii (Table 1).

Daily survival of natural and plasticine eggs

The highest daily nesting survival among the natural nests of 96% was recorded in Kirima, while the least daily survival of 75% was recorded in Rurii, as shown in Table 2. The least daily survival rate of natural nests of 0.01% was observed in Rurii, while the highest daily survival rate of natural nests of 40% was reported in Kirima (Table 2; Figure 2). The survival of chicks in some of the nests was greatly reduced. For example, one of the nests was found with healthy chicks during the interval check, but a chunk of round feaces was found in the nest on the next checking date. This was an indication that the chicks had been predated by an unknown animal (Image 1).

The artificial nests recorded the highest nest daily survival of 90% in Rurii, Nduthi and Kanguo, while the least daily survival of 67% was recorded in Munyeki and Makereka (Table 2). The least daily survival rate for plasticine egg of 0.003% was recorded in Munyeki and Makereka, while the highest daily survival rate of 6.0% was reported in Rurii, Nduthi, and Kanguo (Table 2; Figure 2). A large portion of the tussocks that contained a total of 10 artificial nests was consumed by fire. Of the remaining ten nests, two experimental nests were attacked by unknown predators, leaving bite marks on the eggs (Image 2). Other factors that strongly

Table 1. Sharpe's Longclaw nesting success.

No. of nest	Nest Location	Status at Discovery	Tussock size	No. of nest	No. of eggs	No. of chicks	Status
1	Makindu	Construction	25.0	1	3	3	Chick fledged
2	Rurii	Laying	21.5	1	0	0	Faeces found
3	Nduthi	Construction	24	1	0	0	Nest abandoned
4	Kirima	Fledging	23	1	3	3	
5	Kanguo	Laying	27	1	3	0	
6	Munyeki	Laying	25	1	3	3	
7	Makereka	Fledging	24	1	3	3	

Image 1. Picture showing fresh faeces from unknown predictor (sourced from this study).

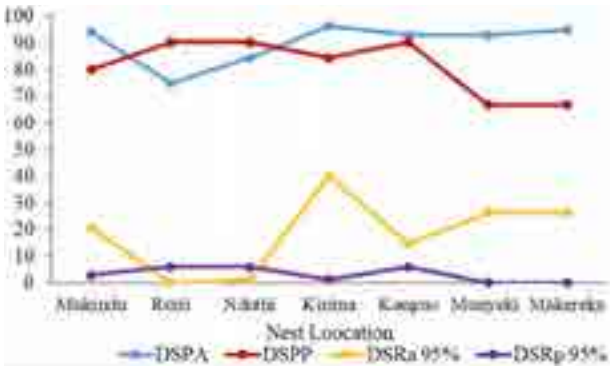

Figure 2. Daily survival percentage and daily survival rate for both natural and artificial nests. DSPA—Daily survival percentage for natural nest | DSPP—Daily survival percentage for artificial nest | DSRa—Daily survival rate for natural nest | DSRp—Daily survival rate for artificial nest.

contributed to the low survival of plasticine eggs were human disturbance, livestock grazing, and trampling on the eggs.

In comparison, there was no significant difference between daily survival of natural (90.14±2.19) and artificial (81.35±4.06) nests (unpaired t-test; df= 12; t= 1.29; p= 0.11).

Table 2. Daily nest survival for natural and artificial nests.

Study site	DSP_A	DSP_p	DSR_a 95%	DSRp 95%
Mukindu	94.12	80.00	20.67	3.00
Rurii	75.00	90.47	0.01	6.0
Nduthi	84.61	90.47	1.30	6.0
Kirima	96.50	84.61	40.14	1.30
Kanguo	92.86	90.47	14.56	6.0
Munyeki	92.86	66.70	26.35	0.003
Makereka	95.00	66.70	26.35	0.003

Key: DSP_A—Daily survival percentage for natural nest | DSP_p—Daily survival percentage for artificial nest | DSRa—Daily survival rate for natural nest | DSRp—Daily survival rate for artificial nest.

DISCUSSION

Sharpe's Longclaw is a threatened bird due to the rapid encroachment of its habitat. This endemic and endangered species is restricted to highland grasslands in Kenya (Dominic et al. 2020). This study has revealed a higher hatching success of Sharpe's Longclaw in some areas around the grasslands of Lake Ol'Bolossat, such as Makindu, Kirima, Munyeki, and Makereka. The higher nesting hatching success could be attributed to dense, long tussocks, which helped conceal the nests from predation. However, in some nests, the hatching success of chicks was greatly reduced due to predation. This was revealed by the presence of a chunk of round faeces in the nest. Predation is the main cause of nest failure in grassland nesting birds and many populations living in fragmented habitats experience low reproductive success worldwide (Chalfoun et al. 2002; Klug & Jackrel 2010). Human disturbance, fires, and livestock grazing leading to trampling on the eggs are other factors that strongly contributed to reduced hatching success.

Image 2. Photos of some damaged experimental eggs (sourced from this study).

The study has also found that daily natural nest survival of Sharpe's Longclaw is higher in grasslands around Lake Ol'Bolossat, especially in areas such as Kirima, Makereka, Mukindu, Munyekia, and Kanguo. The higher daily survival can be attributed to dense, tussocks, which help protect the nests from predators. The nests located in dense long tussocks have a higher probability of survival than those located in open fields (Walk et al. 2010). Also, the lowest and highest daily survival rate of the natural nests were observed in Rurii and Kirima, respectively. It was noted that the survival of the chicks was greatly reduced in some of the nests due to predation. This is consistent with a study carried out by (Leonard et al. 2017), which has reported that the predators significantly reduce the nest survival rate. Besides, flooding also destroyed the nests resulting in reduced nest success and survival rates. This finding is also reported by Rodriguez & Barba (2016) on the growth and survival of Great Tit *Parus major* nestlings.

Parental activity and nest-site characteristics strongly impact the predation of eggs and nestlings (Martin et al. 2000). Parental activity such as loud calls and beggings can act as a signal for the nestlings and attract predators (Martin et al. 2000; Muchai & Plessis 2005), hence increasing the probability of predation. This is because parents always visit nests more frequently to feed the young. Birds with low predation rates have developed short to long on and off bouts to reduce activities that would attract predators (Conway & Martin 2000). Nests likely to be attacked by predators are always located early in their nestling cycle (Skutch 1985). Nests that are not well concealed have a high predation rate in the incubation stage than during the nestling stage (Liebezeit & George 2002).

It is also observed that the daily survival of natural and artificial nests is not significantly different in the grasslands of Lake Ol'Bolossat. This can be attributed to the fact that the plasticine eggs resembled almost natural eggs and the predators could not differentiate them (Estrada et al. 2002).

Approaches to conserve threatened birds

Increased agricultural activities diminish and fragment suitable breeding habitats for Sharpe`s Longclaw (Wamiti et al. 2008). This reduces the habitat for breeding birds leading to the formation of patches. Therefore, the predators may specialize on the patches in search of rewarding prey, decreasing Sharpe`s Longclaw population. Increased vegetation heterogeneity would significantly reduce the risk of nest predation (Davis 2015). This is because shrubs would grow together with grassland, reducing the nest's visibility to their potential predators.

Mowing of the vegetation should not occur frequently, and if it does it should only happen after nestlings have left their nests around mid-July. When delayed nesting occurs, mowing should be delayed to guard the nests together with their fledglings (Gruebler et al. 2012). In addition, dry vegetation should be left on the habitat because it will provide cover and offer the birds with nest construction materials in the next breeding season (Shaffer et al. 2019).

Overgrazing should be discouraged, but instead, moderate grazing should be enhanced because it is beneficial. This is because moderate grazing prevents the growth of foreign grass and improves the nesting habitat for Sharpe`s Longclaw (Bock et al. 1993; Sutter 2006; Wersher et al. 2011). Large grassland fields should be identified, preserved and protected as they reduce the rate of nest destruction and brood parasitism (Davis & Sealy 2000). Burning of the grasslands should also be discouraged since it destroys the eggs leading to reduced population growth of Sharpe's Longclaw during its breeding time.

The recovery of grassland can be achieved through the seeding of native grasses in both private and public lands through Conservation Reserve Program (CRP); (Best et al. 1998; Riffell et al. 2008); and the formation

of buffers around agricultural fields (Adams et al. 2013). This aids in designing a suitable habitat for the birds during nesting.

In conclusion, some areas of Lake Ol'Bolossat had higher survival rates of the eggs and nestling. In contrast, others had low survival rates due to predators, human activities, livestock grazing and fire. This is due to the low survival rate caused by increased habitat loss through human activities, thereby exposing eggs and nestlings to predictors. Therefore, measures to protect and conserve grasslands inhabited by Sharpe's Longclaw around Lake Ol'Bolossat should be enforced to prevent their extinction in the near future.

REFERENCES

Adams, H.L., L.W. Burger Jr. & S. Riffell (2013). Disturbance and landscape effects on avian nests in agricultural conservation buffers. *The Journal of Wildlife Management* 77: 1213–1220. https://doi.org/10.1002/jwmg.568

Ammon, E.M. & P.B. Stacey (1997). Avian nest success in relation to past grazing regimes in a montane riparian system. *Condor* 99: 7–13. https://doi.org/10.2307/1370219

Amundsen, T. (2000). Why are female birds ornamented?. *Trends in Ecology and Evolution* 15: 149–155. https://doi.org/10.1016/S0169-5347(99)01800-5

Best, L.B., H. Campa, M.R. Ryan & J.A. Savinge (1998). Avian abundance in CRP and crop fields during winter in the Midwest. *Journal of Nature Science* 139: 311–324. https://doi.org/10.1674/0003-0031(1998)139[0311:AAICAC]2.0.CO;2

Bibby, C.J., N.D. Burgess, D.A. Hill & S. Mustoe (2000). *Bird Census Techniques, 2nd Edition*. Academic Press, San Diego, Califonia.

BirdLife International (2016). *Macronyx sharpei*. *The IUCN Red List of Threatened Species* 2016: e.T22718436A94580467. Downloaded on 25 January 2019. http://doi.org/10.2305/IUCN.UK.2016-.RLTS.T227184

Bock, C.E., V.A. Saab, T.D. Rich & D.S. Dobkin (1993). Effects of livestock grazing on neotropical migratory landbirds in western North America, pp. 296–309, 229: 296–309 In: Finch, D.M. & P.W. Stangel (eds.). Status and management of neotropical migratory birds: September 21–25, 1992, Estes Park, Colorado. Genaral Technical Report. RM-229. Rocky Mountain Forest and Range Experiment Station, US Department of Agriculture, Forest Service, Fort Collins, Colorado.

Bollinger, E.K. & T.A. Gavin (2004). Responses of nesting Bobolinks (*Dolichonyx oryzivorus*) to habitat edges. *The Auk* 121: 767–776. https://doi.org/10.1093/auk/121.3.767

Bowman, G.B. & L.D. Harris (1980). Effect of spatial heterogeneity on ground-nest depredation. *The Journal of Wildlife Management* 44: 806–813. https://www.jstor.org/stable/3808308

Chalfoun, A.D., F.R. Thompson III & M.J. Ratnaswamy (2002). Nest predators and fragmentation: a review and meta-analysis. *Conservation Biology* 16: 306–318. https://doi.org/10.1046/j.1523-1739.2002.00308.x

Collias, N.E. & E.C Collias (2014). *Nest Building and Bird Behavior* (Vol. 857). Princeton University Press.

Conway, C.J., & T.E. Martin (2000). Evolution of passerine incubation behavior: influence of food, temperature, and nest predation. *Evolution* 54: 670–685. https://doi.org/10.1111/j.0014-3820.2000.tb00068.x

Cresswell, W. (1997). Nest predation: the relative effects of nest characteristics, clutch size and parental behaviour. *Animal Behaviour* 53: 93–103. https://doi.org/10.1006/anbe.1996.0281

Davis, S.K., & S.C.G. Sealy (2000). Cowbird Parasitism and Nest Predation in Fragmented Grasslands. Ecology and management of cowbirds and their hosts: studies in the conservation of North American passerine birds, 220–237.

Davis, S.K. (2005). Nest–site selection patterns and the influence of vegetation on nest survival of mixed–grass prairie passerines. *The Condor* 107(3): 605–616. https://doi.org/10.1093/condor/107.3.605

Dion, N., K.A. Hobson & S. Larivière (2000). Interactive effects of vegetation and predators on the success of natural and simulated nests of grassland songbirds. *The Condor* 102: 629–634. https://doi.org/10.1093/condor/102.3.629

Dominic, K., M. Muchai, J. Kimanzi, J. Mwangi, W. Wamiti, S. Bakari, B. Walter & P. Njoroge (2020). Habitat structure determines the abundance of the Endangered Sharpe's Longclaw *Macronyx sharpei* (Aves: Passeriformes: Motacillidae) at Timau montane grasslands in central Kenya. *Journal of Threatened Taxa* 12(5): 15565–15571. https://doi.org/10.11609/jott.5366.12.5.15565-15571

Estrada, A., A. Rivera & R. Coates-Estrada (2002). Predation of artificial nests in fragmented Landscape in the tropical region of Los Tuxtlas, Mexico*, Biological Conservation Journal* 106: 199–209. https://doi.org/10.1016/S0006-3207(01)00246-4

Google (2018). Map of Lake Olbolosat. Retrieved September 12 2018 from https://www.google.com/maps/place/Lake+Olbolosat/@-0.1316589,36.3568995

Gruebler, M.U., H. Schuler, P. Horch & R. Spaar (2012). The effectiveness of conservation measures to enhance nest survival in a meadow bird suffering from anthropogenic nest loss. *Biological Conservation 146*: 197–203. https://doi.org/10.1016/j.biocon.2011.12.019

Keyel, A.C., A.M. Strong, N.G. Perlut & J.M. Reed (2013). Evaluating the roles of visual openness and edge effects on nest-site selection and reproductive success in grassland birds. *The Auk* 130: 161–170. https://doi.org/10.1525/auk.2012.12039

Klug, P.E. & S.L. Jackrel (2010). Linking snake habitat use to nest predation risk in grassland birds: the dangers of shrub cover. *Oecologia* 162: 803–813. https://doi.org/10.1007%2Fs00442-009-1549-9

Lariviere, S. & F. Messier (1997). Seasonal and daily activity patterns of striped skunks (Mephitis mephitis) in the Canadian prairies. *Journal of Zoology* 243: 255–262. https://doi.org/10.1111/j.1469-7998.1997.tb02780.x

Liebezeit, J.R. & T.L. George (2002). Nest predators, nest-site selection, and nesting success of the Dusky Flycatcher in a managed ponderosa pine forest. *The Condor* 104(3): 507–517. https://doi.org/10.1093/condor/104.3.507

Lima, S.L. (2009). Predators and the breeding bird: behavioral and reproductive flexibility under the risk of predation. *Biological Reviews 84*: 485–513. https://doi.org/10.1111/j.1469-185X.2009.00085.x

Leonard, P.J., D.R. Wood & W.E. Meyer (2017). Avian Diversity, Abundance, and Nest Success among Managed Prairies and Agricultural Plots in Oklahoma and Texas. *The Prairie Naturalist* 49(2): 48–56.

Major, R.E. & C.E. Kendal (1996). The contribution of artificial nest experiments to understanding avian reproductive success: a review of methods and conclusions. *Ibis* 138: 298–307.

Martin, T.E. (1987). Artificial nest experiments: effects of nest appearance and type of predator. *The Condor* 89: 925–928.

Martin, T.E. (1995). Avian life history evolution in relation to nest sites, nest predation, and food. *Ecological Monographs* 65: 101–127. https://doi.org/10.2307/2937160

Martin, T.E. & J. Clobert (1996). Nest predation and avian life-history evolution in Europe versus North America: a possible role of humans? *The American Naturalist* 147: 1028–1046.

Martin, T.E., J. Scott & C. Menge (2000). Nest predation increases with parental activity: separating nest site and parental activity effects. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 267: 2287–2293. https://doi.org/10.1098/rspb.2000.1281

Mayfield, H.F. (1975). Suggestions for calculating nest success. *The Wilson Bulletin* 87: 456–466. https://www.jstor.org/stable/4160682

Monadjem, A. & M.Z. Virani (2016). Habitat associations of birds at

Mara Naboisho Conservancy, Kenya. *Ostrich* 87: 225–230. https://www.jstor.org/stable/4160682

Morris, D.L., D. Western & D. Maitumo (2009). Pastoralist's livestock and settlements influence game bird diversity and abundance in a savanna ecosystem of southern Kenya. *African Journal of Ecology* 47: 48–55. https://doi.org/10.1111/j.1365-2028.2007.00914.x

Muchai, M. & M.A.D. Plessis (2005). Nest predation of grassland bird species increases with parental activity at the nest. *Journal of Avian Biology 36(2)*: 110–116. https://doi.org/10.1111/j.0908-8857.2005.03312.x

Mwangi, M.K., S.H.M. Butchart, F.B. Munyekenye, L.A. Bennun, M.I. Evans, L.D. Fishpool & R. Mulwa (2010). Tracking trends in key sites for biodiversity: a case study using Important Bird Areas in Kenya. *Bird Conservation International* 20(3): 215–230. https://doi.org/10.1017/S0959270910000456

Nature (2018). Lake Ol' Bolossat now protected! https://naturekenya.org/2018/02/28/lake-ol-bolossat-now-protected/. Retrieved September 2021

Norment, C.J. (1993). Nest–site characteristics and nest predation in Harris' Sparrows and White-crowned Sparrows in the Northwest Territories, Canada. *The Auk* 110: 769–777. https://doi.org/10.2307/4088632

Pace, M.L., J.J. Cole, S.R. Carpenter & J.F. Kitchell (1999). Trophic cascades revealed in diverse ecosystems. *Trends in Ecology and Evolution 14*: 483–488. https://doi.org/10.1016/S0169–5347(99)01723-1

Polis, G.A., A.L.W Sears, G.R. Haxel and J. Maroon (2000). When is a trophic cascade? *Trends in Ecology and Evolution 15*: 473–475. https://doi.org/10.1016/S0169-5347(00)01971-6

Riffell, S., D. Scognamillo & L.W. Burger (2008). Effects of the Conservation Reserve Program on northern bobwhite and grassland birds. *Environmental Monitoring and Assessment 146*: 309–323. https://doi.org/10.1016/S0169-5347(00)01971-6

Rodriguez, S. & E. Barba (2016). Nestling growth is impaired by heat stress: an experimental study in a Mediterranean Great Tit population. *Zoology Study* 55: 40–53. https://doi.org/10.6620%2FZS.2016.55–40

Roff, D.A. (1992). *The evolution of life histories: theory and analysis.* New York: Ghapman and Hall.

Shaffer, J.A., L.D. Igl, D.H. Johnson, M.L. Sondreal, C.M. Goldade, J.P. Thiele & B.R. Euliss (2019). *The effects of management practices on grassland birds-Northern Harrier (Circus hudsonius)* (No. 1842-L). US Geological Survey.

Shiao, M.T., M.C. Chuang, H.W. Yuan & Y. Wang (2015). Effects of weather variation on the timing and success of breeding in two cavity–nesting species in a subtropical montane forest in Taiwan. *The Auk* 132: 671–684. https://doi.org/10.1642/AUK-15-10.1

Skutch, A.F. (1985). Clutch size, nesting success, and predation on nests of Neotropical birds, reviewed. *Ornithological Monographs* 36: 575–594. https://www.jstor.org/stable/40168306

Stephenson, J.A., K.P. Reese, P. Zager, P.E Heekin, P.J. Nelle & A. Martens (2011). Factors influencing survival of native and translocated mountain quail in Idaho and Washington. *The Journal of Wildlife Management* 75: 1315–1323. https://doi.org/10.1002/jwmg.189

Sutter, G.C. (2006). *Habitat Selection and prairie drought in relation to grassland birds community structure and nesting ecology of Spragues pipit, Anthus spragueii.* Doctor of Philosophy Thesis, University of Regina, 144 pp.

Tieleman, B.I., H.J. Van Noordwijk & J.B. Williams (2008). Nest site selection in a hot desert: trade-off between microclimate and predation risk. *The Condor* 110: 116–124. https://doi.org/10.1525/cond.2008.110.1.116

Walk, J.W., E.L. Kershner, T.L. Benson & R.E Warner (2010). Nesting success of grassland birds in small patches in an agricultural landscape. *The Auk* 127: 328–334. https://doi.org/10.1525/auk.2009.09180

Wamiti, W. & P. Malaki (2008). Survey of Globally threatened birds of the Lake Ol'Bolossat Grassland, central Kenya. *Ibis* 150: 439–445.

Wamiti, W., P. Malaki & A. Mwangi (2008). Birds of Conservation Concern Upgrades Lake Ol'Bolossat Status to Kenya's 61st Important Bird Area. In *12th Pan-African Ornithological Congress, Goudin Spa Conference Centre, Cape Town, South Africa*.

Wiebe, K.L. (2001). Microclimate of tree cavity nests: is it important for reproductive success in Northern Flickers?. *The Auk* 118: 412–421. https://doi.org/10.1093/auk/118.2.412

Winter, M. & J. Faaborg (1999). Patterns of area sensitivity in grassland-nesting birds. *Conservation Biology* 13: 1424–1436. https://doi.org/10.1046/j.1523-1739.1999.98430.x

Yahner, R.H. & C.A. DeLong (1992). Avian predation and parasitism on artificial nests and eggs in two fragmented landscapes. *The Wilson Bulletin* 104: 162–168.

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COMMUNICATION

Population, distribution and diet composition of Smooth-coated Otter *Lutrogale perspicillata* Geoffroy, 1826 in Hosur and Dharmapuri Forest Divisions, India

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Abstract: Living in different aquatic ecosystems, otters play a vital role in maintaining aquatic species assemblages, particularly fish communities. Thus their wellbeing indicates the health of wetland ecosystems. Smooth-coated Otter *Lutrogale perspicillata*, a piscivorous mustelid, is widely distributed across Asia. Its population is declining due to habitat transformation, pollution and hunting. This study aimed to understand the ecological requirements of the species by assessing its distribution and its determinants, population and diet composition along the Cauvery River in Hosur and Dharmapuri Forest Divisions. Through monthly extensive surveys between December 2010 and February 2011, covering 62.5 km of Cauvery from the Karnataka border to Palar River junction, this study identified and mapped a 31 km stretch from Dubguli (Yellolapatti) to Biligundlu (Musulumaduvu) as an otter distribution area. Comparison of ecological parameters including bank type, water depth, river width, human disturbance, vegetation cover and water current with the distribution pattern of otters across 125 blocks revealed that water depth and vegetation cover influenced otter distribution positively, while human disturbance had negative influence (these three variables explained 54% of variation in otter distribution). Based on direct sightings, seven different groups consisting of 36 individuals were estimated as the minimum population. The mean group size was 3.8 ± 0.16 (range: 2–7) individuals. Twenty-one otter spraints were analyzed to determine diet composition, revealing that otters feed on insects, molluscs, crabs, fish, frogs, reptiles and birds. Fish constituted the bulk of otter diets. Conservation measures like reducing anthropogenic pressures (e.g., fishing, cattle pens, tourism), increasing awareness of sustainable fishing to stakeholders, and instituting long-term monitoring programs are suggested for the long-term conservation of otters in the study area.

Keywords: Carnivora, Cauvery River, determinants, diet, group size, Hosur and Dharmapuri Forest Divisions, Mustelidae, population, water depth influence.

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Author contributions: NB—conceiving the concept, planning & execution, data analysis & writing. RSS—data collection, entry & preliminary analysis. RS—helping in data analysis & writing.

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INTRODUCTION

Otters are piscivorous mustelids belonging to the family Mustelidae and subfamily Lutrinae. Of the five species of otters found in Asia, three occur in India: the Smooth-coated Otter *Lutrogale perspicillata* (Image 1), the Eurasian Otter *Lutra lutra*, and the Oriental Small-clawed Otter *Aonyx cinerea* (Hussain 1993; Prater 1998; Reuther 1999; Menon 2003; Raha & Hussain 2016). The Smooth-coated Otter is distributed widely throughout India south of the Himalaya (Pocock 1949; Prater 1971; Hussain 1993) and also in Myanmar, Indonesia, Kampuchea, Laos, Malaysia, Vietnam, southwestern China, and Brunei, with an isolated subspecies, *L. perspicillata maxwelli,* found in the marshes of southern Iraq (Mason & Macdonald 1986).

Living in different aquatic ecosystems (Pardini 1998), otters play a major role in maintaining aquatic species communities, particularly fish communities (Sivasothi 1995; Anoop & Hussain 2005). They are health indicators of wetland ecosystems, being sensitive to degradation of habitat and the food chain (Erlinge 1972). Loss of wetlands habitat, reduction in prey species, disturbances from developmental projects and poaching are the major threats to otter survival in India (Nagulu et al. 1999a,b; Meena 2002). The Smooth-coated Otter is presently listed as a 'Vulnerable' species on the IUCN Red List (de Silva et al. 2015), Appendix I in CITES (CoP 2019) and is protected under Schedule II in Indian Wildlife (Protection) Act (1972). Despite their wide distribution and vital role in the wetland ecosystem, not much attention has been paid to understand their ecology. The existing populations of the species and their habitat have never been systematically surveyed throughout India (Hussain & Choudhury 1997). Systematic data on their habitat, distribution, population, and feeding ecology are essential for conservation planning and management of the species in India.

In southern India, the species has been studied in Periyar Tiger Reserve, Kerala (Anoop 2001; Anoop & Hussain 2005) and in the Cauvery River in Karnataka (Shenoy 2005; Shenoy et al. 2006), in particular the Cauvery Wildlife Sanctuary. This study aimed to cover the entire range of the species in Cauvery River to evaluate the current distribution, population, group size, and diet.

Study Area

The study was carried out along the Cauvery River within Hosur and Dharmapuri Forest Divisions, stretching from Ichiebara (12.198 N, 77.593 E) to the junction of Palar (11.953 N, 77.676 E), a tributary of the Cauvery (Image 2) between December 2010 and August 2011. The river stretches over 62 km and varies in altitude from 307 m upstream to 236 m downstream. Cauvery is a major perennial river, the eighth largest river of the subcontinent and ranks as a medium river on the global scale (Jayaram 2000). It provides water to most areas in Karnataka and Tamil Nadu states. The Cauvery originates at Talakaveri (12.198 N, 77.593 E) in Kodagu district of Karnataka in the Western Ghats at an altitude of 1,341 m. From the edge of the Western Ghats, within sight of the Arabian Sea, to the Bay of Bengal, the river traverses through nearly 770 km in a roughly north-west to south-east direction. It passes through the Western Ghats, the Deccan Plateau and the Eastern Ghats, crossing diverse habitats ranging from high altitude shola forests to the dry scrub jungles of the plains (Jayaram 2000). It has 29 major tributaries and its basin receives rainfall from the south-west and north-east monsoons with a major share from south-west monsoon. The river basin in the study area provides natural habitat to a diverse highly threatened mammalian species. The riparian habitat offers an important habitat to the Smooth-coated Otter (Baskaran et al. 2010). The river basin and its adjoining areas in Hosur-Dharmapuri Forest Divisions are subject to severe anthropogenic pressure in terms of cattle grazing, MFP collection, fishing, tourism, and pilgrimage.

Image 1. Smooth Coated Otter *Lutrogale perspicillata*

MATERIALS AND METHODS

Mapping of otter habitats

To map the distribution of otter and its habitats, the 62.5 km of the Cauvery River falling within the study area was marked into 125 survey blocks of 500 m and surveyed by foot on a monthly basis from

Image 2. Map showing the study area Cauvery River along Hosur-Dharmapuri Forest Divisions in Tamil Nadu with adjoining forest division the Cauvery Wildlife Sanctuary in Karnataka.

December 2010 to February 2011. During each survey, the presence or absence of otters based on direct sightings and indirect evidence was recorded in each block. All approachable islands within the river were also surveyed. The indirect evidences considered for their presence include spraints (fecal matter), tracks, holts, food remains, and scrapes (Ottino & Giller 2004). Spraints were categorized according to consistency and degree of bleaching, they were considered fresh when found with moisture and strong odour, old when intact but without moisture and odour, and very old if disintegrated without moisture and odour. The tracks, holts and food remains were divided into three different categories based on moisture, appearance (disturbed/undisturbed), condition in case of food remains (fresh/old/very old) and when found with spraints their status was taken into account for categorization. At every sighting of otters and their evidence, the geographical location (latitude and longitude) and the survey block number were noted down using a global positioning system (GPS). Superimposing the otter location geocoordinate into Google Earth map, we established the otter distribution map.

Assessment of factors influencing distribution

Studies on otters (Hussain & Chodhury 1997; Ottino & Giller 2004; Anoop & Hussain 2005; Shenoy et al. 2006) show that variables such as river bank type (earthen, sandy, and rocky) river width, water depth, water current (low and high), vegetation density and human disturbance influence the distribution pattern of otters. The human disturbance was rated as low for areas with infrequent disturbance by local people due to fuel wood and MFP collection, bathing and cattle grazing, medium for areas with frequent disturbance by local people due to fuel wood, MFP collection, self-fishing, fire for cooking, bathing, cattle grazing and eco-tourism, and high for areas with regular disturbance by local people due to fuel wood collection, self/commercial fishing, MFP collection, bathing, cattle grazing and cattle pen, tourism including seasonal pilgrimage, fire for cooking, and discarded food. These variables were evaluated at each 500-m interval in the survey blocks. At each survey block, the river width, water depth and water current were evaluated at three to five locations and averaged for each block. Within each survey block, vegetation density was assessed at 100-m intervals, placing a 20 m^2 quadrat for trees, 5 m^2 quadrat shrubs, and 1 m^2 quadrat for grass species and averaged for each block.

The difference in otter abundance observed among (like river bank type: earthen, sandy, rocky) and between categories in different variables (like water current: low and high) were tested for statistical significance, respectively, employing, Kruskal-Wallis H test and Mann-Whitney U-test in SPSS Version 16.0.

The influence of ecological factors on the distribution of otters was explored using multiple regression analysis after testing for normality. In the multiple regression framework, the dependent variable was the otter abundance, arrived based on both direct sighting of otter and their indirect evidences, while the independent variables were the river bank type (earthen, sandy, and rocky), river width, water depth, water current, vegetation density and human disturbance. At first the relationship between the dependent variable and independent variables were tested using scatter plots. Based on the relationship of independent variables, the variable was entered either in linear form or non-linear form with quadratic term. When the relationship was quadratic, both independent variable and its square term were entered into the multiple regression models. If the quadratic term turned out to be insignificant, it was dropped. At the end, only significant independent variables were retained in the equation.

Evaluation of population and group size

Although the presence or absence of otters could be assessed through direct sighting of otters and their evidence, no simple foolproof method is available for censusing river otters (Melquist & Dronkert 1987). A number of factors influence marking intensity and hence this measure cannot be used as a direct indicator of population size (Jefferies 1966; Krqsuuk & Conroy 1987). The Smooth-coated Otter lives in social groups that vary in size and change with seasons (Hussain 1996; Anoop & Hussain 2005). The population size was estimated based on the spatial distribution of various groups, differentiated based on group size and their movement pattern observed during the study period. In total, seven different groups were differentiated based on group size and movement pattern and the total number of individuals recorded within each group was taken into account to estimate the population size in the study area. Data on group size were recorded on each sighting of the identified groups. Mean group size was estimated for the seven groups we identified by averaging the groups size recorded in the multiple sightings of the respective groups. Similarly, the mean group size for overall population was arrived averaging the group size of all the seven groups.

Diet composition

Spraint collection: To study the diet composition of Smooth-coater Otters, spraint analysis was used following Anoop & Hussain (2005), as direct observation was not possible due to anthropogenic disturbance. Spraints of the otter were collected visiting the riparian habitat on fortnight interval. Spraints were collected in self-lock polythene covers and labeled with different variables such as status of the spraint, microhabitat, date, and location. The collected samples were air-dried at room temperature and stored separately for laboratory analysis.

Reference sample of fish collection: To identify the fish species from the spraint, a checklist of fish presents in the Cauvery River was prepared. Different fish species were caught from each survey block-using a gas net. The fish species were identified using standard reference books (Jayaram 1994) with the help of experts from the Indian Institute of Science, Bengaluru. From each species, a set of scales were collected and permanent reference slides prepared by mounting with a drop of glycerin and seal with adhesive.

Spraint analysis: The air-dried spraints were weighed to nearest 0.01 g using a physical balance. From each spraint, mucus was removed soaking it in a solution of oxidizing agent (Webb 1976). The spraint was washed with a sieve of 0.5 mm mesh and dried again. All prey remains were segregated under a binocular microscope, assigned to food categories and weighed. Species level identification of the fish were done using reference slides. Other species like insects, mussels, crabs, amphibians, reptiles, and birds were broadly segregated into order level using feathers, teeth and other bones, insect remains, shells, etc. The buff white colour of the bone was used to identify the frogs eaten by otters, while in the case of crab and mussel, general shape, colour and shape exoskeleton were used as key (Anoop & Hussain 2005). The segregated food categories were air-dried and weighed using a physical balance.

Data are presented for each food category using three different methods: (i) Percent frequency F= number of spraints containing a given prey category divided by total number of spraints × 100 (Jenkins et al. 1979), (ii) Relative percentage frequency R= number of occurrences of a food category divided by total number of occurrences of all prey categories × 100 (Rowe-Rowe 1977), and (iii) Dry weight Dw= dry weight of a given food category divided by total dry weight of all prey categories × 100.

RESULTS

Distribution

58 direct sightings and 31 indirect indications were recorded across 125 survey blocks in the Cauvery River. Direct sightings and indirect evidence showed that otter distribution was restricted to the stretch from Dubguli (Yellolapatti) to Biligundlu (Musulumaduvu) downstream (Image 3). The total length of this stretch is 31 km within this study area, no sighting or evidence of otters was found between Anchetty stream to Uganium (around 6 km). Further, there was no direct sighting or indirect evidence of otters in the rest of 31.5 km from Musulumaduvu to Palar indicating restricted distribution of otter in the Hosur and Dharmapuri Forest Divisions.

Factors influencing distribution

Otter were observed to be significantly concentrated in river stretches with higher water depth (K-W χ^2= 11.358, *df*= 2, *P* <0.01), in islands with shrub/grass cover (K-W χ^2= 40.595, *df*= 2, *P* <0.001), and in areas with lower water current (M–W U=1098, *P* <0.05) and human disturbance (K-W χ^2- 33.379, *df*= 2, *P* <0.001) (Table 1). Further comparison of otter abundance recorded in the five blocks with the ecological factors prevailed in the respective block revealed that water depth (Coefficient±SE= 0.133 ± 0.034, *P* <0.001) and vegetation cover (Coefficient±SE= 0.031 ± 0.005, *P* <0.001) influenced the otter abundance positively, while the human disturbance influenced negatively (Coefficient±SE= -0.664 ± 0.190, *P* <0.01) and these three variables explained 54% otter of the variations in distribution (Table 2).

Population and group size

The study, based on the group size and spatial locations recorded from the 47 direct sightings, differentiated seven different groups of otters. From these seven groups, the study recorded a minimum of 36 individuals during the survey (Table 3). Out of 47 direct sightings of otters, the study estimated the mean group size of 3.8 ± 0.16. The minimum and maximum group size recorded was two and seven individuals, respectively.

Diet composition

The analysis of 21 otter spraints revealed that otters feed on prey items which include insects, molluscs, crabs, fish, frogs, reptiles, and birds. Fish appeared most frequently in the diet of otters (Table 4). The fish species *Labeo callbasu* occurred in 15 out of 21 scats, and also contributed 90% of dry weight of all the food

Image 3. Map of study area showing seven otter groups' distribution area along Cauvery River.

Table 1. Distribution pattern of smooth-coated otter in relation to ecological factors along Cauvery River in Hosur and Dharmapuri Forest Divisions, Eastern Ghats.

Factor	Category (n)	Otter abundance mean ± se	Kruskal–Wallis (χ^2) / *Mann–Whitney U	*df*	*P*
Bank type	Earthen (37)	0.41 ± 0.180	1.36	2	0.507
	Sandy (45)	0.84 ± 0.270			
	Stony (43)	0.51 ± 0.271			
Water depth	Low (26)	0.12 ± 0.085	11.358	2	0.003
	Medium (58)	0.40 ± 0.165			
	High (41)	1.20 ± 0.355			
River width	Low (30)	0.93 ± 0.437	0.715	2	0.699
	Medium (65)	0.58 ± 0.178			
	High (30)	0.30 ± 0.153			
Vegetation	Low (17)	0.0	40.595	2	0.000
	Medium (59)	0.0			
	High (49)	1.53 ± 0.329			
Water current	Low (29)	1.10 ± 0.410	*10.98		0.01
	High (96)	0.45 ± 0140			
Human disturbance	Low (28)	2.32 ± 0.520	33.379	2	0.000
	Medium (57)	0.18 ± 0.062			
	High (40)	0.0			

Table 2. Regression equation model to explore the influence of ecological factors on the distribution pattern of Smooth-coated Otter along Cauvery River in Hosur and Dharmapuri Forest Divisions, Eastern Ghats.

Variable	Coefficient ± Std. error	*P*	model (R^2)	*F*	model *(p)*
Constant	0.348 ± 0.523	0.507	0.545	33.616	0.000
Water depth	0.133 ± 0.034	0.000			
Human disturbance	-0.664 ± 0.190	0.001			
Vegetation cover	0.031 ± 0.005	0.000			

items, indicating importance of *Labeo* in the otter diet in the study area. It is interesting to note that higher vertebrates such as reptiles and birds seldom feature in the otter diet. In terms of dry weight, fish accounted for 90% of otter diets (Table 4), followed by birds (5%), frogs (2%), molluscs (1%), and crabs (1%). Prey items such as insect and reptiles formed less than one percent of the overall diet of otters.

DISCUSSION

Distribution of otter

This study identified 31 km of otter habitat in the study area. The distribution of otter habitat was mapped during the dry season, and it is likely that during the wet season otters may expand their distribution area. Also, absence of otter signs in a particular place does not necessarily mean otters are absent from the area, as occasionally they may inhabit an area without depositing spraints (Jenkins & Burrows 1980; Melquist & Hornocker 1983; Kruuk et al. 1987), although this is infrequent (Chehebar 1985). Nevertheless, the findings on the otter distribution area, mapped by the present study, based on dry season observations, have vital management implications, as it is a pinch period in which animals restrict themselves to smaller areas due to resource limitations, which need to be protected from human disturbance for the long-term conservation of the species.

Factors influencing distribution

The multiple regression analysis revealed among the five ecological correlates tested, water depth, vegetation

Table 3. Population size and group size of Smooth-coated Otter estimated based on seven different groups occupying the study area during December 2009–March 2010.

Group ID	Survey blocks used	Total number of individuals	Group size mean ± SE
1	12 to 15	5	4.0 ± 0.45
2	18 to 25	4	3.3 ±0.18
3	33 to 37	5	4.2 ± 0.37
4	45 to 49	5	3.7 ± 0.67
5	52 to 57	7	5.5 ± 0.96
6	62 to 68	5	3.5 ± 0.21
7	71 to 74	5	3.7 ± 0.33
Total	12 to 74	36	3.8 ± 0.16

Table 4. Frequency of occurrence of various prey items identified from Smooth-coated Otter spraints in the study area December 2009–March 2010.

Prey items	Occurrence		Dry weight (%)
	Percent frequency	Relative percent frequency	
Insects	9.5	4.5	0.10
Molluscs	9.5	4.5	1.12
Crab	4.8	2.3	1.40
Pisces			
Labeo callbasu	71.4	34.1	89.80
Channa argus	9.5	4.5	
Masatcembalus sp.	14.3	6.8	
Tor khudree	9.5	4.5	
Notopterus notopterus	4.8	2.3	
Unidentified fish	33.3	15.9	
Frog	28.6	13.6	2.20
Reptile	9.5	4.5	0.40
Birds	4.8	2.3	4.70

cover influenced otter distribution positively, on the other hand, human disturbance influenced negatively. The positive influence of vegetation cover in the form of dense shrub/grass cover along river banks and islands on otter distribution is likely due to the preference of such areas by otters for excavating their holts, most of which were recorded in river stretches associated with dense undergrowth. This has also been reported in earlier findings (Shenoy 2002, 2005; Annob & Hussain 2005; Shenoy et al. 2006). Similarly, water depth also showed a positive influence on otter distribution. Since the study period (December 2009–February 2010) was largely confined to the dry season, it is likely that during that season otters in the study area preferred stretches with deep water to avoid high temperatures. Also, Paterson & Whitfield (2000) reported that fish distribution is closely correlated to water depth. It is important to note the decrease in otter abundance with human disturbance through fishing, bathing, cattle grazing, and forest product collection, which could affect the otter distribution adversely. Direct observations of otters suggest bank edges with sandy soil and islands of rocky outcrops and boulders provide ideal microhabitats for feeding (Burton 1968; Channin 1985), sleeping (Channin 1985; Nolet et al. 1993), grooming (Nolet et al. 1993), playing (Shariff 1984), and territory marking (Green et al. 1984; Kruuk 1992). Islands and rocky outcrops in the middle of the river are safer for aquatic species like otter to escape from threats as compared to river banks, where anthropogenic disturbances are more and such islands are ideal if they contain vegetation undergrowth to provide cover (Shenoy 2002). Prey availability is probably a crucial factor influencing the distribution of the otters follow their food abundance gradient and alter their home ranges accordingly (Mason & Macdonald 1986). Our attempt to estimate the prey abundance did not yield adequate data due to the reason that much of the river stretches in the study area are with low water depth, which could not be sampled using gill net. However, fish being the major prey of the Smooth-coated Otters, fish must be available all the year round, if otters are to remain as permanent residents in an area (Melquist & Hornocker 1983). Although, water depth, ground vegetation and human disturbance explained 54% of the otter distribution in the study area, the rest 46% could be a function of fish abundance, which is not addressed adequately in this study.

Population and group size

Although no data is available from southern region for comparison, a detailed survey on population conducted along a 425-km stretch of the Chambal River in a sanctuary reports 29 otters during 1988 and 14 in 1992 (Hussain & Choudhury 1997). The present report of 36 otters for the entire stretch of 62 km surveyed (from Ichiebara on the upstream of Cauvery River to the junction of Palar in the downstream) represents a healthy population. Since the study covered the Cauvery River stretch in the upstream only from Tamil Nadu boundary, it is likely the same river further up in Karnataka region could also be supporting Smooth-coated Otters and thus actual population may be larger than reported here. Overall, the study estimates a mean group size of 3.9 individuals based on 47 sightings. The mean group size was marginally higher during February

(4.3 individuals) compared to January (3.4 individuals). In National Chambal Sanctuary, India, Hussain (1996) estimated a mean group size of 4.6 individuals based on larger sample size (*n*= 422). The present finding of 3.9 individuals per group is comparable to those from Hussain (1996). The smaller group size in the present study could be attributed to the short-term nature representing only the dry season and the absence of wet season data in which the group size reported to be larger (Hussain 1993).

Diet composition

Fish constituted the major prey items during the study, both in terms of frequency of occurrence and dry weight. When occurrence of a food item is high, that food is important for the dependent species (Knudsen & Hale 1968). Similar to the present study, fish were identified as the stable food of Smooth-coated Otters elsewhere in southern India (Balasubramanian 1989; Anoop & Hussain 2005). Although the otters are mainly piscivorous animals, in the present study area they also feed on a variety of other prey items like insects, molluscans, crabs, reptiles, frogs, and birds as reported elsewhere (Anoop & Hussain 2005). Similar to the present study, Norris (1974) found the occurrence of freshwater mussels as part of the otter diet. Otters rarely preyed on birds, although reported elsewhere from other parts of India (Anoop & Hussain 2005). A similar trend in diet composition has been reported for the Eurasian Otter *Lutra lutra* L. (Ottino & Giller 2004).

CONCLUSIONS AND RECOMMENDATIONS

The study shows that Smooth-coated Otters are distributed along the Cauvery River from Dubguli (Yellolapatti) upstream, to Biligundlu (Musulumaduvu) downstream. While water depth and vegetation cover influenced the otter distribution positively, human disturbance influenced it negatively. The study estimated 36 individuals as the minimum population of otter in the area and showed that otters feed on insects, molluscs, crabs, fishes, frogs, reptiles, and birds with fish as the principal component. As the survival of otters depend on the fish population in the area, protection of fish fauna of Cauvery River and the riverine system are essential for the long-term conservation of the otters. Unfortunately, there is tremendous pressure on fish fauna in the study area from local people due to commercial fishing, which needs to be reduced to a sustainable level as the first step for conservation of otters. Apart from fishing, the riparian habitats also experience other kinds of anthropogenic pressure, including over grazing by scrub cattle, cattle-pen and non-timber forest produce collections and disturbances. Pollution from seasonal pilgrimage and regular tourism as reported in Baskaran et al. (2010), which should be regulated/ stopped for the conservation of riparian habitats of the Cauvery River and its dependent species like smooth-coated otters. Increased awareness of sustainable fishing by the community and long-term monitoring will also benefit the otters' survival.

REFERENCES

Anoop, K.R. & S.A. Hussain (2005). Food and feeding habits of smooth-coated otters (*Lutra perspicillata*) and their significance to the fish population of Kerala, India. *Journal of Zoology (London).* 266: 15–23. https://doi.org/10.1017/S0952836905006540

Anoop, K.R. (2001). Factors affecting habitat selection and feeding habits of Smooth-coated Otter (*Lutra perspicillata*) in Periyar Tiger Reserve, Kerala. M.Sc. Thesis. Wildlife Institute of India, Dehra Dun, India, 62 pp.

Balasubramanian, M. (1989). Food habits of Smooth-coated Otters *Lutra perspicillata* in Mudumalai Wildlife Sanctuary, Tamil Nadu. Unpublished M.Sc. Dissertation. A.V.C. College, Mannampandal, Mayiladuthurai, Tamil Nadu, 20 pp.

Baskaran, N., G. Nayak, M. Saravanan, K. Senthilkumar, S.R. Chandramouli & K.G. Avinash (2010). Vertebrate faunal diversity in Hosur Forest Division and its contiguous habitats in Dharmapuri Forest Division of Tamil Nadu. Summary Report Tamil Nadu Forest Department, May 2010, 31 pp.

Burton, M. (1968). Wild Animals of the British Isles, pp. 131–136. In: The Otter. Warne, F. and Co Ltd, London.

Channin, P. (1985). *The Natural History of Otters*. Christopher Helm, London, 179 pp.

Chehebar, C. (1985). A survey of the Southern River Otter *Lutra provocax* Thomas in Nahuel Huapi National Park, Argentina. *Biological Conservation* 32: 299–307. https://doi.org/10.1016/0006-3207(86)90056-X

CITES (2019). CITES 18th Conference of Parties (CoP) held in Geneva on 26 August 2019.

de Silva, P., W.A. Khan, B. Kanchanasaka, L.I. Reza, M.M. Feeroz & O.F. Al-Sheikhly (2015). *Lutrogale perspicillata*. The IUCN Red List of Threatened Species 2015: e.T12427A21934884. Downloaded on 19 November 2021. https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T12427A21934884.en

Erlinge, S. (1972). The situation of the otter population in Sweden. *Viltrevy* 8: 379–397.

Green, J., R. Green & D.J. Jefferies (1984). A radio-tracking survey of otter (*Lutra lutra)* on a Perthshire river system. *Lutra* 27: 85–145. https://www.iucnosgbull.org/Volume14/Volume14 Issue2.pdf

Hussain, S.A. (1993). Aspects of the ecology of Smooth-coated Indian Otter (*Lutra perspicillata*) in National Chambal Sanctuary. PhD Thesis, Aligarh Muslim University, xxiii+206 pp.

Hussain, S.A. (1996). Group size, group structure and breeding in Smooth-coated Otter (*Lutra perspicillata)* Geoffroy in National Chambal Sanctuary. *Mammalia* 60(2): 289–297.

Hussain, S.A. & B.C. Choudhury (1997). Distribution and status of the Smooth-coated Otter (*Lutra perspicillata*) in National Chambal Sanctuary, India. *Biological Conservation* 80: 199–206.

Jayaram, K.C. (2000). Kaveri Riverine System: An Environmental Study, Madras Science Foundation, Chennai.

Jayaram, K.C. (1994). The freshwater fishes of India, Pakistan,

Bangladesh, Burma and Sri lank — A Handbook. Zoological Survey India, Calcutta, xxii+475 pp.

Jefferies, D.J. (1966). The value of otter (*Lutra lutra*) surveying using spraints: an analysis of its success and problems in Britain. *Journal of the Otter Trust* 1(9): 25–32.

Jenkins, D. & G.O. Burrows (1980). Ecology of otters in northern Scotland. III. The use of faeces as indicators of otter (*Lutra lutra*) density and distribution. *Journal of Animal Ecology* 49: 755–774. https://doi.org/10.2307/4225

Jenkins, D., J.G.K. Walker & D. McGowan (1979). Analysis of the otter (*Lutra lutra*) faeces from Deeside, N.E. Scotland. *Journal of Zoology, London* 187: 235–144. https://doi.org/10.1111/j.1469-7998.1979.tb03946.x

Knudsen, G.J. & J.B. Hale (1968). Food habits of otters in Great Lakes Region. Journal of Wildlife Management 32(10): 89–93. https://doi.org/10.2307/3798240

Kruuk, H. & J.W.H. Conroy (1987). Surveying the otter (*Lutra lutra*) populations: a discussion of problems with spraints. *Biological. Conservation* 41(3): 179–183. https://doi.org/10.1016/0006-3207(87)90101-7

Kruuk, H. 1992. Scent marking by otters (*Lutra lutra*): Signaling the use of resources. *Behavioural Ecology* 3: 33–140.

Mason, C.F. & S.M. Macdonald (1986). Otters – ecology and conservation. *Cambridge University Press,* 248 pp.

Mason, C.F. & S.M. Macdonald (1987). The use of spraints to survey populations of otters (*Lutra lutra*). *Biological Conservation* 41(3): 167–177.

Meena, V. (2002). Otter poaching in Palni Hills. *Zoos Print Journal.* 17: 696–698.

Melquist W.E. & A.E. Dronkert (1987). River otter North Bay, Ontario, Canada, pp. 625–641. In: Novak, M.J., A. Baker & M.E. Obbard (eds.). Wild Furbearer Management and Conservation in North America.

Melquist, W.E. & M.G. Hornocker (1983). Ecology of river otters in west central Idaho. *Wildlife Monograph* 83: 1–60.

Menon, V. (2003). *A Field Guide to Indian Mammals*. Penguin India and Dorling Kindersley, India, 164 pages.

Nagulu, V., C. Srinivasulu & R. V. Vasudeva (1999a). Status of otter in southern Indian states: an updated report 1999. *In*: *Envis Bulletin: Wildlife and Protected Areas* 2(2): 71–73.

Nagulu, V., R.V. Vasudeva & C. Srinivasulu (1999b). Curative property of otter blood - a belief. *IUCN Otter Specialist. Group Bulletin* 16(1): 44.

Nolet, B.A., D.E.H. Wansink & H. Kruuk (1993). Diving of otters (*Lutra lutra*) in a marine habitat: use of depths by a single-prey loader. *Journal of Animal Ecology* 62: 22–32. https://doi.org/10.2307/5479

Norris, D. (1974). A study of the otter (*L. lutra*) on the R. Fergus from July to September 1974. *Unpublished Wildlife Service Report.*

Ottino, P. & P. Giller (2004). Distribution, density, diet and habitat use of the otter in relation to land use in the Argali valley, Southern Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy* 104(1): 1–17

Pardini, R. (1998). Feeding ecology of the Neotropical River Otter (*Lontra longicaudis*) in an Atlantic Forest Stream, south-eastern Brazil. *Journal of Zoology (London.)* 245: 385–391. https://doi.org/10.1111/j.1469-7998.1998.tb00113.x

Paterson, A.W. & A.K. Whitfield (**2000).** Do shallow-water habitats function as refugia for juvenile fishes? *Estuarine and Coastal Shelf Science* 74: 263–273. https://doi.org/10.1006/ecss.2000.0640

Pocock, R.I. (1949). *The Fauna of British India, including Ceylon and Burma, Vol. 2, Mammals.* Taylor and Francis, London, xxxi+459 pp.

Prater, S.H. **(1971).** The Book of Indian Animals, 11th impression, pp. 146–154. Bombay Natural History Society and Oxford University Press, Calcutta.

Raha, A. & S.A. Hussain (2016). Factors affecting habitat selection by three sympatric otter species in the southern Western Ghats, India. *Acta Ecologica Sinica* 36: 45–49. https://doi.org/10.1016/j.chnaes.2015.12.002

Reuther, C. (1999). From the Chairman's desk. *IUCN Otter Spec. Group Bulletin* 16: 3–6.

Rowe-Rowe, D.T. (1977). Food ecology of otters in Natal, South Africa. Oikos 28: 210–219.

Shariff, S.M. (1984). Some observations on otters at Kuala Gula, Perak and National Park, Pahang. *Journal of Wildlife Parks* 43: 2075–2488.

Shenoy, K. (2002). Habitat selection and diet composition of Smooth-coated Otters (*Lutra perspicillata*) in the Cauvery Wildlife Sanctuary, Karnataka, India. M.Sc. Dissertation. Pondicherry University, Pondicherry, India.

Shenoy, K. (2005). Otters in the River Cauvery, Karnataka. Occasional report no. 11. Wildlife Trust of India, 42 pp.

Shenoy, K., S. Varama & K.V.D. Prasad (2006). Factors determining habitat choice of the smooth-coated otter, *Lutra perspicillata* in a south Indian river system. *Current Science* 91(5): 637–643.

Sivasothi, N. (1995). The status of otters (Carnivora: Mustelidae: Lutrinae) in Singapore and Malaysia, and the diet of smooth-coated otter (*Lutrogale perspicillata*) in Penang, West Malaysia. M.Sc. Thesis National University of Singapore, 86 pp.

Webb, J.B. (1976). *Otter spraint analysis - Vol. 15*. Mammal Society Publication, London, 52pp.

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COMMUNICATION

Utilization of home garden crops by primates and current status of human-primate interface at Galigamuwa Divisional Secretariat Division in Kegalle District, Sri Lanka

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Abstract: Many humans coexist with non-human primates (NHP), and as human populations have increased so have the pressures on natural habitats. For example, deforestation results in habitat loss and food scarcity for NHPs. In response, NHPs sometimes enter human habitats in search of food, which can result in negative interactions between humans and NHPs. This study focused on human-NHP interactions in three Grama Niladhari divisions in Kegalle District, Sri Lanka. We used interviewer-administered structured questionnaires to collect data from 500 randomly selected informants. The majority stated that they could not obtain sufficient harvests from home gardens for their own consumption owing to crop damage and losses caused largely by NHPs and other wild animals. This has led many people to abandon home gardening. Toque Macaques caused the most damage to crops, followed by Wild Boars, porcupines, and Purple-faced Leaf Langurs. Damage was caused to coconuts, vegetables, bananas, and yams. NHPs also caused property damage, with Toque Macaques causing more damage than langurs. People commonly used firecrackers, catapults and air rifles, and wore wooden or plastic face masks, in attempts to control crop damage by NHPs, with little success. People are of the opinion that the NHPs should be relocated to other forested areas or sterilized to control their numbers. In conclusion, to address the issues pertaining to human-primate interactions in terms of conflict due to crop utilization of primates, an integrated management plan should be developed in cooperation with the relevant stakeholders.

Keywords: Crop raiding, deforestation and habitat loss, economic loss, forest edge home gardens, human-primate conflict, integrated management plan, *Macaca sinica*, *Semnopithecus vetulus*.

Abbreviations: DSD—Divisional Secretariat Division | GN divisions—Grama Niladhari divisions | NHP—Non-human primate.

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INTRODUCTION

Humans, macaques, and langurs are members of the sub-order Anthropoidea in the Order Primates. The three species share many physiological, anatomical, and behavioral characteristics and thus have similar requirements to sustain themselves. As a result, when they share the same environment a variety of interactions between them become inevitable. Sometimes these interactions have negative impacts on species when they share similar food resources (Houle 1997; Peiman & Robinson 2010). The intensity of the interactions increases with the similarity of shared resources, creating competition within or between species, which at times can be detrimental to one or both.

Non-human primates and humans maintain both positive and negative interactions. The positive interactions include deploying primates for economically beneficial activities such as harvesting coconuts, as can be seen in Thailand and also as performers to entertain humans (Nahallage & Huffman 2013; Nahallage 2019). In both instances, humans gain economic benefit by employing primates in various activities, which in turn creates a positive attitude towards them. Most crucial for the survival of the primates and their conservation is mitigating adverse interactions that create negative attitudes toward primates, primarily in the form of human and non-human primate competitions over common resources.

One of the main reasons for escalating human-primate negative interactions in Sri Lanka is the loss of natural primate habitat due to various development projects (Nahallage et al. 2008; Cabral et al. 2018; Dittus et al. 2019). Primates become isolated in small forest patches because of the fragmentation of forests they inhabit, which leads to an increase in competition for food and space. When resources become depleted in the natural habitat, primates frequent villages in search of food, which intensifies human-primate interactions (Dela 2007; Rudran 2007; Nahallage et al. 2008; Dittus 2012; Rudran & Kotagama 2016, Dittus et al. 2019; Nahallage 2019). Other reasons monkeys are attracted to nearby settlements include improper garbage disposal, feeding by humans, cultivation of large-scale cash crops, and scarcity of food & water in the natural habitats during the dry season (Dittus et al. 2019).

In Sri Lanka, the three diurnal primate species are mainly involved in human-primate interactions: Toque Macaquea *Macaca sinica*, Purple–faced Leaf Langurs *Semnopithecus vetulus* and Gray Langurs *Semnopithecus priam* (Nahallage & Huffman 2013; Dittus et al. 2019). No conflicts have been reported with two resident nocturnal *Loris* spp., which have little interaction with humans. Macaques are sociable animals that interact frequently with humans and prefer to stay close to human settlements, while langurs prefer more natural habitats and foods (Nahallage & Huffman 2013; Dittus et al. 2019; Nahallage 2019). Purple-faced Leaf Langurs are strictly arboreal folivores and have the least interaction with humans in many places. This relationship, however, varies in different parts of the country (Rudran 1973, 2007; Dela 2007; Dittus 2012; Dittus et al. 2019; Nahallage 2019), with Purple-faced Leaf Langurs in the Western Province considered the most prominent species living close to humans causing crop and property damage. Food selection by Gray Langurs depends on their habitat; in natural environments they depend mainly on plant material, while those in urban environments and temple areas tend to consume food given to them by pilgrims, such as leftover offerings (Nahallage et al. 2008; Nahallage & Huffman 2013; Dittus et al. 2019). During periods of food scarcity, both Gray Langurs and Toque Macaques obtain food forcibly from people or directly from houses or shops, leading to intense human-primate negative interactions.

Human-primate interactions is not a recent occurrence in the country. Robert Knox, an English traveler who was imprisoned on the island by the Kandyan King but allowed to live in various places freely for about 20 years, described how macaques invaded corn fields and home gardens despite their being heavily guarded (Knox 1681). There were even folk poems written regarding the crop raiding of primates (Ananda 2000). At present, crop raiding occurs in all 25 districts of the country. Crop raiding by primates generally depends on the types of crops grown, seasonality, distance to the village from the forest, availability of natural foods, and the methods of crop guarding (Hill 2000; Marchal & Hill 2009; Fungo 2011). In Sri Lanka, macaques inflict more damage to crops than langurs, but all are considered pests to varying degrees in the provinces where they are found (Nahallage at al. 2008; Nahallage & Huffman 2013; Prasad et al. 2016; Nahallage 2019; Dittus et al. 2019). In places where all three diurnal primates exist, Toque Macaques damage crops the most, followed by Gray Langurs (Nahallage et al. 2008), however, in some parts of the North Central Province, Gray Langurs cause more damage than Toque Macaques (Perera & Vandercone 2016).

The main objective of this study was to determine the present status of human-primate interactions in relation to home garden crop damage in selected

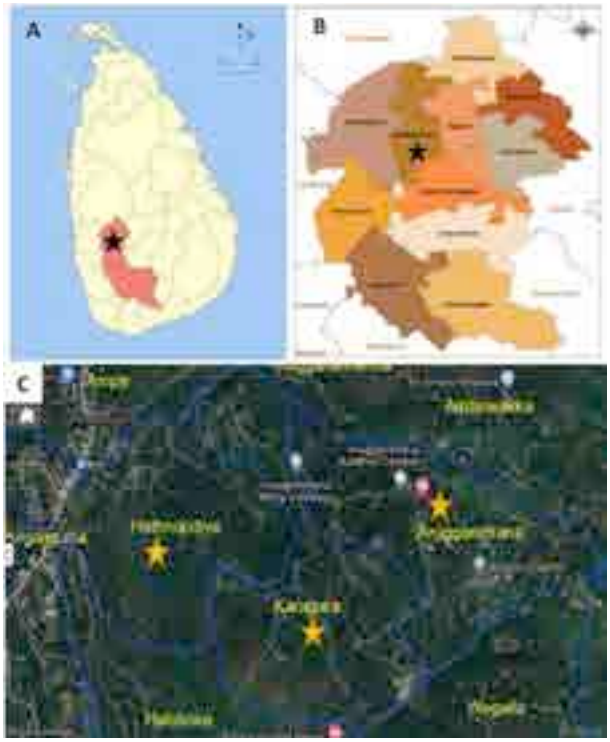

Image 1. Study area: A—Kegalle District | B—Galigamuwa Divisional Secretariat Division | C—Three GN divisions (Hathnapitiya, Karagala, and Aruggammana).

areas in Kegalle District. This study looks into the wild animals in the selected study area and their impact on home garden crops. Home garden cultivations are very important to these low-income rural villagers, as they supply food to meet their daily needs and allow them to earn additional income by selling the excess harvest. The specific objectives were to find out the extent of crop damage by non-human primates and other wild animals, the types of crops that are mostly affected by crop raiding primates, the types of property damage they do, the control measures used by humans to prevent or reduce crop damage and the people's perception of the type of mitigative actions that should be taken to control conflicts.

METHODS

The selected study area was in the Galigamuwa Divisional Secretariat Division (DSD) in the Kegalle district, Sabaragamuwa Province. Out of the 51 Grama Niladhari Divisions (GN divisions), three GN divisions namely Aruggammana, Hathnapitiya, and Karagala were purposely selected as they recorded higher incidents of human primate interactions according to the Galigamuwa DSD office (Image 1). This was a descriptive cross-sectional study.

Galigamuwa DSD is located in the wet zone, and receives more than 2,500 mm annual average rainfall, and has a mean temperature of 22–27 ^{0}C. Agriculture is the main economic sector in the area. The land extent is 127 km^2. Hapudeniya is the highest parish in the division at 366 m above sea level and the lowest is Helamada at 27m. The two primate sub-species present in the area are *Macaca sinica aurifrons* and *Semnopithecus vetulus nestor.*

Location of the home gardens

Of the home gardens, 48% in Hathnapitiya, 32% in Aruggammana, and 80% in Karagala are located less than 50 m from the forest. Most of the home gardens in Karagala are located at the edge of the forest. Compared to Karagala GN divisions, most home gardens in Hathnapitiya and Aruggammana are located more than 100 m away from the forest edge (52% in Hathnapitiya and 68% in Aruggammana).

A total of 500 households were surveyed (Table 1). The electoral registers lists were obtained from Grama Niladhari officers in the respective GN Divisions to randomly select the houses for the survey. In instances where the people were not willing to participate in the survey or had vacated these houses, the next address was selected. The study was conducted between October and December 2018.

We used an interviewer-administered questionnaire method to collect data from each household for the survey. We obtained the required information from the head of the house or an adult (wife, parents or in-laws of the head of the house) present in each house at the time the data collectors visited the house. The structured questionnaire included 19 closed and open-ended questions on such topics as: occupation of the informant; the size of the home garden; types of crops cultivated; average monthly income; types of wild animals frequenting the home garden; the types of crops consumed or damaged by the animals; the extent of property damage; the measures taken to control the damage, and the peoples' perceptions on

Table 1. Selected sample sizes in each GN Division.

GN Division	Total No. of houses in each GN Division	Number of houses surveyed
Aruggammana	368	214
Hathnapitiya	303	136
Karagala	232	150

how to control the damage caused by primates. Before collecting these data, we explained the purpose of the survey to the participants. Those who were willing to provide information were then given enough time to ask questions regarding the survey, and their written consent was obtained with a signature at the bottom of each questionnaire. On average, it took about 20 minutes to fill the questionnaire. In addition, we conducted field observations as well.

The collected data were entered into a Microsoft Excel sheet and analyzed using SPSS package (version 16).

RESULTS

Occupation of the informants

Except for Aruggammana GN Division, the majority of the informants were housewives (Table 2). Aruggammana and Karagala have more self–employed informants than Hathnapitiya.

Size of the Home Garden

All three GN divisions had many home gardens of less than 1.0 acre (4047 m^2) in size, representing 93% of home gardens in Hathnapitiya, 66% in Aruggammana and 82% in Karagala (Table 3). When compared with the other two GN divisions, 33% of the home gardens in Aruggammana were larger, ranging from 1 to 5 acres.

Types of crops cultivated in the home gardens

The most common home gardening crops grown in all three GN divisions were coconuts (15%), Jack fruits (13%), areca nuts (13%), pepper (10%), and bananas (9%). More people grow coconuts in Hathnapitiya than Aruggammana and Karagala, while tea was cultivated more in Aruggammana and Karagala areas (Table 4).

Economic loss due to crop damage

During the time of data collection, the informants of Hathnapitiya (50%), Aruggammana (23%), and Karagala (21%) stated that they could not get sufficient harvest from home gardens for their consumption. All of the Hathnapitiya, 94% of Aruggammana, and 62% of Karagala respondents informed us that at present they cannot get sufficient additional income from home garden crops. Of the informants, 4% from Aruggammana and 33% from Karagala said that they get less than SLR 10,000 income per month and only 1% of Aruggammana and 6% of Karagala informants said they receive more than SLR 10,000 income per month (Table 05).

Reasons for not engaging in cultivation

In all three GN divisions people gave various reasons for not cultivating crops in home gardens, however, the majority of the informants stated the main reason was crop damage caused by wild animals, mainly primates (Hathnapitiya 87%, Aruggammana 92%, Karagala 94%). The other reasons were not enough manpower (Hathnapitiya 5%, Aruggammana 4%, Karagala 6%), inadequate land area (Hathnapitiya 5%, Aruggammana 2%), inadequate water (Hathnapitiya 2%, Aruggammana 2%), and infertility of the soil (Hathnapitiya 1%).

Animals responsible for crop damage

In all three respective GN divisions, the main species identified as responsible for crop damage were Toque Macaques, Wild Boars, porcupines, and Purple-faced Leaf Langurs (Table 6).

According to informants the NHPs frequent home gardens irrespective of the time of the day (Table 7).

The crops utilized by animals

The three main crops that the NHP utilized most were coconuts, bananas, and different types of yams. In addition, they consumed garden vegetables including brinjal *Solanum melongina*, winged beans *Psophocarpus tetragonolobus*, snake gourds *Trichosanthes cucumerina*, long beans *Vigna unguiculata,* lady's-fingers *Abelmoschus esculentus* (Table 08).

Consequences of crop damage by animals

Decreases in harvests (Hathnapitiya 59%, Aruggammana 51%, Karagala 43%) and income (Hathnapitiya 16%, Aruggammana 22%, Karagala 28%) were the main effects of crop damage by animals. As a result, people have discontinued home garden cultivation (Hathnapitiya 25%, Aruggammana 26%, Karagala 27%), and some have abandoned all or parts of their lands as they cannot control animal visits (Aruggammana 1%, Karagala 2%).

Property damage caused by Toque Macaques and langurs

In addition to crop damage, Toque Macaques and langurs also damage property. Toque Macaques caused the most property damage by entering houses and damaging household furniture and utensils (Table 9).

Langurs were not reported to cause much property damage, which was only reported in 2 GN divisions where langurs caused damage to roofs (Table 9). There were no reports of other wild animals causing property damage.

Table 2. Occupation of the informants in each GN divisions.

Occupation	Hathnapitiya		Aruggammana		Karagala	
	Frequency	%	Frequency	%	Frequency	%
No occupation (housewives)	67	49	54	25	72	48
Government sector	27	20	60	28	21	14
Private sector	24	18	33	15	21	14
Commercial farming	3	2	1	0.5	2	1
Self-employment	13	10	66	31	31	21
Security service	2	2	0	0	3	2
Total	136	100	214	100	150	100

Table 3. Size of the Home garden.

GN Division	Hathnapitiya		Aruggammana		Karagala	
Size of home garden	N	Valid Percent	N	Valid Percent	N	Valid Percent
Less than 1 acre (less than 4,047 m^2)	103	93	126	66	116	82
Between 1.1 to 5 acres (4,047–20,234 m^2)	5	5	63	33	22	15
More than 5 acres (more than 20,234 m^2)	3	3	3	2	4	3
Total	111	100	192	100	143	100
Not responded	25		22		8	
Total	136		214		150	

Methods used by people to control crop damage by primates

Methods used to prevent primates from entering gardens are described in Table 10. The most common methods used to chase away monkeys were firecrackers, catapults, and wooden or plastic face masks. During the study period some people had been using air rifles to chase monkeys from their gardens, a new addition to control methods.

Recommendations to control crop damage by primates.

Suggestions by informants to reduce primate crop damage were: 46% wanted monkeys relocated into other areas; 30% suggested sterilizing them to control population growth; 9% think government authorities should provide mitigative strategies; 10% wanted permission to use guns; and 5% suggested killing monkeys (5%).

DISCUSSION

Crop damage by primates and other wild animals

Although most studies on human-primate negative interactions were concentrated on commercial farming, the present study mainly focused on the human-primate interactions occurring due to crop raiding of primates on home gardens. In the semi urban and rural areas in Sri Lanka, local people grow crops such as coconuts, banana, jack fruits, areca nuts, vegetables, and different kinds of spices in their home gardens to meet their daily food needs. Before the intensification of crop raiding, people have been able to obtain their daily food needs and an additional income from their home gardens. This way, they do not have to spend much money to buy food items. Home gardening has been a very important means of maintaining their economic status for generations.

However, at present, people are facing many problems as wild animals have started to frequently raid home gardens to take food (Nahallage & Huffman 2013; Cabral et al. 2016; Dela et al. 2016; Perera & Vandercone 2016; Prasad et al. 2016; Rudran & Kotagama 2016; Cabral et al. 2018; Dittus et al. 2019). The majority of home gardens in the study area are comparatively small (less than 1 acre) and primates cause extensive damage to these small-scale garden cultivations. The majority of the informants of all three GN divisions complained that they cannot get adequate harvest for their daily needs and that they had to buy coconuts and vegetables from the market. This is creating a new economic burden

Table 4. Types of home garden crops cultivated in the respective GN divisions.

Types of crops	Hathanapitiya (%)	Aruggammana (%)	Karagala (%)
Coconut	18	14	13
Banana	12	9	7
Jack Fruit	11	14	13
Areca nut	11	13	13
Pepper	8	11	10
Avocado	5	6	4
Vegetables	5	1	3
Tea	4	8	11
Clove	3	8	6
Rubber	2	3	3
Yams	2	2	3
Pineapple	1	1	1
Durian	1	2	1
Breadfruit	1	1	1
Magnus	1	0	2
Betel	1	1	2
Nutmeg	0	0	1
Cardamon	0	0	0
Other	12	7	7

Table 5. Monthly income obtained from home gardening.

GN Division	Hathnapitiya		Aruggammana		Karagala	
Income	Present		Present		Present	
	N	%	N	%	N	%
No income	136	100	202	94	92	62
Less than SLR 10,000	0	0	9	4	49	32
More than SLR 10,000	0	0	3	2	9	6
Total	136	100	214	100	150	100

Table 6. Animals that are responsible for crop damage.

GN Division	Hathnapitiya (%)	Aruggammana (%)	Karagala (%)
Toque Macaque	40	34	29
Wild Boar	25	30	25
Porcupine	14	23	21
Purple-faced Leaf Langur	18	7	16
Giant Squirrel	1	2	3
Rat	0	1	1
Snail	0	1	1
Coconut Beetle	1	0	0
Peacock	1	1	1
Parrot	0	0	1
Grey Hornbill	0	0	1
Other	0	1	1

Table 7. The time of animal visits to home gardens.

GN Division	Hathnapitiya (%)	Aruggammana (%)	Karagala (%)
Moring only	6	1	3
Evening only	6	1	3
Night only	15	0	5
Anytime of the day	67	96	82
Cannot say	6	2	7

as these people are in the low-income group and face economic hardships because of the crop damage. The crops that are mainly affected by primates and other wildlife were coconuts, bananas, and vegetables, the key food varieties of these communities. The animals that are causing considerable damage to coconuts were Toque Macaques in all three study areas. According to informants, macaques visit the gardens daily and drop the young coconuts to the ground and also peel off the mature coconuts and eat the soft flesh inside. This way, many immature nuts get destroyed resulting in a decrease in the total harvest. During the field visits the authors were able to observe these young coconuts piled up by the side of the garden. Furthermore, the macaque visits were not limited to a particular time of the day, and they stayed for a long time which escalated the scale of damage. This situation has led some people to abandon growing and tending coconut trees, as they believe that it was a waste of time and money. At present, people are buying coconuts from the nearby markets for their own consumption. Coconuts have been one of their main additional income generating crops. Therefore, currently the people not only have to spend money to buy coconuts but have lost their additional income as well. However, Purple-faced Leaf Langurs were not reported to damage coconut trees in the study area.

The other home garden crop that was mostly affected by the primates was banana. Both Toque Macaques and Purple-faced Leaf Langurs raid banana trees. They not only eat the banana fruits but damage the trees which reduces future harvests as well. Of the two primates, langurs consume the banana most. Informants stated that langurs mostly consume the unripe fruit while the macaques eat the ripe yellow fruit. However, in a separate study, Purple-faced Leaf Langurs were reported to eat ripe fruits in some districts of the country (Dela 2012). Other than bananas, both primate species

Table 8. The crops utilized by animals.

GN Division	Hathnapitiya (%)	Aruggammana (%)	Karagala (%)
Coconut	22	29	21
Vegetables	19	4	9
Banana	15	12	12
Yams (kiri ala, casava)	12	16	15
Pepper	4	9	10
Areca nut	3	6	8
Jack Fruit	4	6	5
Pineapple	2	1	1
Tea	1	4	5
Avocado	1	1	1
Rubber	1	2	1
Bread Fruit	1	1	1
Betel	1	2	3
Durian	1	1	0
Nutmeg	1	0	1
Cardamom	1	0	0
Clove	0	0	1
Other	11	6	6

were reported to consume jack fruit, pineapple, other available fruits, vegetables, and yams, depending on the season. In general, macaques cause more damage to crops than langurs in all the districts in the country. The omnivorous macaques consume a diverse range of food items including fruits, leaves, bark, flowers, seeds, roots, cereals, insects, other invertebrates, eggs, small mammals, birds, and food prepared by humans. Owing to these diverse food habits and larger group sizes, macaques can adapt to any environmental condition and hence cause more damage than the two langur species. According to the study conducted by Prasad et al. (2016), of the complaints received by the Wildlife Department, 54% were against macaques and 29% against Purple-faced Leaf Langurs. Out of these, 70% were related to crop damages; however, the primate species responsible for crop damage was different in different parts of the country. According to the study of Perera & Vandercone (2016), in Mihintale Kaludiyapokuna forest edge farms, Gray Langurs and Toque Macaques were responsible for 78% and 22% of the reported crop damages, respectively. Purple-faced Leaf Langurs were not recorded to damage crops in that area. A study carried out by Dittus et al. (2019) in Polonnaruwa reported similar results indicating that macaques and Gray Langurs were responsible for human-primate interactions rather than the Purple-

Table 9. Types of property damage caused by Toque Macaques and Purple-faced Leaf Langur.

Type of Damage	Hathnapitiya (%)	Aruggammana (%)	Karagala (%)
Macaques			
Damage household goods	15	25	27
Consume foods that are inside the house	35	31	37
Defecate inside the house	25	22	23
Damage roofs	24	17	10
Other types of damages	1	5	3
Purple-faced Leaf Langur			
Damage roof	15	1	0
No damage	85	99	100

Table 10. Methods used to reduce the crop damage by Toque Macaques.

GN Division	Hathnapitiya (%)	Aruggammana (%)	Karagala (%)
Catapult	21	33	30
Firecrackers	42	36	30
Masks	10	7	10
Hanging tin cans	1	0	0
Nets to cover crops	2	3	6
Boards	1	1	6
Shouting	11	4	4
Black cloth	1	1	1
Air rifles	0	1	1
Use of dogs	0	1	1
Clapper board	0	1	1
Others	11	12	10

faced Leaf Langurs. In Western province, it is the Purple-faced Leaf Langurs that cause the most damage to home garden crops (Dela 2007; Rudran 2007; Nahallage et al. 2008; Cabral et al. 2016; Prasad et al. 2016; Nahallage 2019). The other factors that are responsible for crop damage are the availability of natural foods, the variety of crops grown, seasonality, distance from the forest and the people's perceptions (Hill 2005). According to some informants in Hathnapitiya GN division, the frequency of primate visits was less during the months of January to July as it was the fruiting season and monkeys could find food in the forests where they live.

In addition to primates, the other wild animal species that are responsible for crop damage in the study area are the two nocturnal mammals: the Wild

Boars and porcupines. These animals mainly damage the vegetables and the yams that people grow. Next to macaques, Wild Boars caused the most damage to cultivations followed by porcupines. Most of the people in the three GN divisions have stopped cultivating home garden crops due to the crop damage caused by wildlife resulting in the decrease of the harvest and income as well.

In addition to crop damage, primates were the only wildlife species reported to damage property. Macaques were reported to have damaged the household goods such as pots, pans, plates, rice cookers, and furniture. When they are able to enter into a house in an unguarded moment, they consume the foods stored inside cupboards and racks, runaway with the cooked and other types of dry foods, defecate inside the house and damage roofs as well. Similar incidence was reported in Kandy district where macaques were responsible for taking food by force, damaged the roof, and damaged the infrastructure (Cabral et al. 2016). Compared to macaques, langurs cause less property damage and the only reported damage by the langurs (PFL – present study and Gray Langur – Dittus et al. 2019) was to roofs due to their large body size. In the study area, people used wire meshes and wood planks to cover their windows and spaces between the roof and the walls. This successfully cut down the multiple entry points of the monkeys to one's house (CN personal observation). This leaves the monkeys to come into the house either from the back or front door, which only the boldest ones would try.

Methods used by people to reduce crop damage

People believe that over the years the primate populations have increased and many now consider them as pests due to crop damage. The methods used by people in the study area to reduce primate crop damage were similar within the country as well as in other countries. The most common methods were the use of stones, firecrackers, shouting, and catapults to chase the primates away from their properties with very little success (Nahallage et al. 2008; Hill & Webber 2010; Dittus et al. 2019). The monkeys get used to or learn to avoid these methods and with time the methods become less effective. People abstain from hunting, killing or poisoning monkeys due to their religious beliefs and most of the time are tolerant of their behaviors (Nahallage & Huffman 2013), or they employ methods just to chase the monkeys from their home gardens. The people in the study area wear long black cloths with a wooden or plastic face mask and carry a stick to scare the monkeys, or point a gun shaped wooden stick at them. This seems to work better compared to other methods. In the study area, the most effective technique was air rifles. The monkeys were afraid of them. However, since the air rifles were expensive most people cannot afford to buy them. In addition, people wrap thorny branches of jackal jujube *Ziziphus oenoplia* and lime *Citrus aurantifolia* around banana bunches or on the fronds to prevent monkeys from getting to the fruits or they cover the banana bunches with nylon nets or bags. To protect coconuts, they wrap aluminium sheets around coconut trees to prevent macaques climbing the trees. Further they sprinkle cow dung mixed with water on coconuts and the informants believed that macaques dislike the smell of cow dung. During a survey in the Northwestern province CN observed that in some coconut plantations, people covered the young coconut bunch with iron mesh so macaques could not reach the coconuts. However, the owner of the plantation informed this was both time consuming as well as costly and that they must increase the mesh size when the coconuts increase in size (CN personal observation). This is not practical to implement in large coconut estates. The use of dogs to chase the monkeys has not been much in practice in the present study areas. The most effective method the informants used to protect crop damage by wild boar was to cover the vegetable beds with sarees to keep the wild boars away. To protect the vegetables from porcupines, people sprinkled human hair around the vegetable beds. They reported that the porcupines dislike this and try to evade such vegetable beds. This method too was not practical in the long run because the hairs get blown away with the wind and the rain dampens it reducing its effectiveness.

Mitigative actions to control the damage caused by monkeys

To reduce the damage caused by primates to home garden crops, the majority of people wanted the monkeys to be relocated to another area or sterilized them to control population growth. Relocation of monkeys has detrimental effects to the monkeys if not managed properly. For the relocation to be effective, the monkeys have to be transported to a similar environment or ecological zone that they were used to. Otherwise, it will not be possible for them to adapt to the new environment successfully and will have trouble finding necessary food sources and might die of starvation. Therefore, effective post translocation monitoring mechanisms should be implemented. Further, translocation of monkeys who were used to living close to human settlements (and utilize human grown crops) to remote areas also will not

be effective as the monkeys will go in search of nearby human habitats. Thus, relocation might temporarily solve the problem in one location but will spread the problem to other parts of the country (Nahallage 2019; Dittus et al. 2019).

Sterilization of the monkeys will be effective to some extent. Though sterilization requires manpower, veterinary expertise, and money, it is a permanent solution for population control (Jayalath & Dangolla 2011). In addition, some countries use birth control as an effective strategy of fertility control (Shimizu 2012). This is most applicable to monkeys that are seasonal breeders, making the process reversible, allowing them to resume their normal cycles and normal pregnancies later. With further studies and investigations there is a high possibility to apply this method successfully in Sri Lanka as well.

Further, the informants want the government to take some initiatives for control and advise them on how they could best control the situation. So far, the authorities have not conducted awareness programs for the villagers. According to the discussions the authors had with the villagers during data collection and field visits, it was obvious that they do not know much about the primates in their area or even that the primate species are endemic to the country. Thus, it is important that the villagers understand the behaviors, life histories and the factors that drive these primates to the villages. This awareness would give them an insight into the issue and help them to act accordingly. During the field visits, intentional provision of food to primates and keeping primates as pets were not observed in the study area. However, garbage dumping sites and macaques feeding on garbage dumping sites were observed in all three divisions

Therefore, the authors recommend the following mitigative actions to control the situation; conduct awareness programs, introduce proper garbage disposal mechanisms, enrichment of the natural habitats of the primates and to facilitate long term research to gather more information.

CONCLUSION

For decades, scientists and primatologists across the world have been conducting research studies related to human primate interactions to find ways to minimize damage to both parties concerned, such as damage to crops and properties of humans and killing and wounding of primates. Though these studies provide many useful recommendations, none of them were able to provide plausible long-term solutions to mitigate this problem. Nahallage et al. (2018), proposed to use an integrated management plan (IMP) to minimize the damage to the conflicted parties. The integrated management plan is mainly based on the: a) biology and the behavior of the primate; b) occurrence and the level of damage; c) habitats; and d) interaction between the primates and the humans. With this method, the local authorities, with the help of the experts have to decide the control strategies for each of the above-mentioned components and select control methods that are suitable to local conditions and implement them with the cooperation of relevant stakeholders. However, future research is needed to test this plan with different primate species and under different environmental conditions.

REFERENCES

Ananda, P.A.S. (2000). *Sinhala Janashruthiya saha sathwa lokaya*. Godage Publishers, Colombo, 152 pp.

Cabral, S.J., T. Prasad, T.P. Deeyagoda, S.N. Weerakkody, A. Nadarajah & R. Rudran (2018). Investigating Sri Lanka's human-monkey conflict and developing a strategy to mitigate the problem. *Journal of Threatened Taxa* 10(3): 11391–11398. https://doi.org/10.11609/jott.3657.10.3.11391-11398

Cabral, S.J., A.P. Sumanapala, R. Ratnayake, H.D. Jayasinghe, D.K. Weerakoon, S.W. Kotagama & R. Rudran (2016). Distribution of Toque Macaques (*Macaca sinica*) and their impact on human lives in Kandy district of Sri Lanka. In: Proceedings of the 5th Asian Primate Symposium, University of Sri Jayewardenepura, Sri Lanka, 46pp.

Dela, J.D.S. (2007). Seasonal food use strategies of *Semnopithecus vetulus nestor*, at Panadura and Piliyandala, Sri Lanka. *International Journal of Primatology* 28: 607–626. https://doi.org/10.1007/s10764-007-9150-8

Dela, J.D.S. (2012). Western Purple-faced Langurs (*Semnopithecus vetulus nestor*) feed on ripe and ripening fruits in human-modified environments in Sri Lanka. *International Journal of Primatology* 33: 40–72. https://doi.org/10.1007/s10764-011-9538-8

Dela, J.D.S., U.K.G.K. Padmalal, A. Sathurusinghe & A.S.S. Silva (2016). Bringing back *Semnopithecus vetulus nestor* from the living dead to the visibly thriving: Identification of threats and prescriptions. In: Proceedings of the 5th Asian Primate Symposium, University of Sri Jayewardenepura, Sri Lanka, p. 51.

Dittus, W. (2012). Problems with pest monkeys: myths and solutions. *Loris* 26(3/4): 18–23.

Dittus, W.P.J., S. Gunathilake & M. Felder (2019). Assessing public perceptions and solutions to human-monkey conflict from 50 years in Sri Lanka. *Folia Primatologica* 90: 89–108. https://doi.org/10.1159/000496025

Fungo, B. (2011). A review of crop raiding around protected areas: Nature, control and research gaps). *Environmental Research Journal* 5(2): 87–92.

Hill, C.M. (2000). A conflict of interest between people and baboons: crop raiding in Uganda. *International Journal of Primatology* 21: 299–315. https://doi.org/10.1023/A:1005481605637

Hill, C.M. (2005). People, crop and primates: A conflict of interest., pp. 40–59. In: Peterson, J.D. & J. Wallis (eds.). *Commensalism and Conflict: The Human–Primate Interface. Norman, Oklahoma*: American Society of Primatologists, 483 pp.

Hill, C.M. & A. Webber (2010). Perceptions of nonhuman primates

in human-wildlife conflict scenarios. *American Journal of Primatology* 72(10): 919–924. https://doi.org/10.1002/ajp_20845

Houle, A. (1997). The role and phylogeography and behavioral competition in the evolution of coexistence among primates. *Canadian Journal of Zoology* 75: 827–846. https://doi.org/10.1139/z97-106

Jayalath, P.P. & A. Dangolla (2011). Capture and translocation of trouble making Toque Monkeys (*Macaca sinica*) in Mahakanda: Lessons learnt. In: Proceedings of the Annual Scientific sessions of the Sri Lanka Veterinary Association, Institute of Continuing Association, Education in Animal Production and Health, Gannoruwa, 35 pp.

Knox, R. (1681). *An Historical Relation of the Island Ceylon in East-Indies*. Richard Chefwell Publishers, London, 189 pp.

Marchal, V. & C. Hill (2009). Primate crop-raiding: A study of local perceptions in four villages in North Sumathra, Indonesia. *Primates* 24(1): 107–116. http://doi.org/10.1896/052.024.0109

Nahallage, C.A.D. & M.A. Huffman, N. Kuruppu & T. Weerasingha (2008). Diurnal primates in Sri Lanka and people's perception of them. *Primate Conservation* 23: 81–88. https://doi.org/10.1896/052.023.0109

Nahallage, C.A.D. & M.A. Huffman (2013). Macaque - Human interactions in past and present day in Sri Lanka, pp. 135–148. In: Radhakrishna, A., M.A. Huffman & A. Singha (eds.). *Macaque Connections: Corporation and Conflict between Humans and Macaques*. Springer Publication, London, 255 pp.

Nahallage, C.A.D., N. Kumarasinghe & A. Dangolla (2018). Integrated management of Toque Macaque in affected areas of Kandy, Matale and Nuwaraeliya districts. A concept paper submitted to Statutory Board for Preservation of Kandyan Heritage, pp 1–5.

Nahallage, C.A.D. (2019). An ethnological perspective of Sri Lankan primates. *Vidyodaya Current Research* 1: 27–37.

Peiman K.S. & B.W. Robinson (2010). Ecology and evolution of resource-related heterospecific aggression. *The Quarterly Review of Biology* 85: 133–158. https://doi.org/10.1086/652374

Perera, M. & R. Vandercone (2016). Temporal patterns of crop raiding by diurnal primates in and around the Kaludiyapokuna Forest Reserve in the dry zone of Sri Lanka. In: Proceedings of the 5th Asian Primate Symposium. University of Sri Jayewardenepura, Sri Lanka, 48 pp.

Prasad, T., S.J. Cabral, S.N. Weerakkody & R. Rudran (2016). Human monkey conflict in Sri Lanka and mitigation efforts. In: Proceedings of the 5th Asian Primate Symposium, University of Sri Jayewardenepura, Sri Lanka, 45pp.

Rudran, R. (1973). Adult male replacement in one-male troops of Purple-faced Langurs (*Presbytis senex senex*) and its effect on population structure. *Folia Primatologica* 19: 166–192.

Rudran, R. (2007). A survey of Sri Lanka's endangered and endemic Western Purple-faced Langur (*Trachipithecus vetulus nestor*). *Primate Conservation* 22: 139–144. https://doi.org/10.1896/052.022.0115

Rudran, R. & S. Kotagama (2016). Strategy to conserve and coexist with Sri Lanka's monkeys. In: Proceedings of the 5th Asian Primate Symposium, University of Sri Jayewardenepura, Sri Lanka, p. 17.

Shimizu, K. (2012). Birth control in female Japanese macaques at Iwatayama Monkey Park, Arashiyama, pp. 435–452. In: Leca, J., M.A. Huffman & P. Vasey (eds.). *The monkeys of Stromy mountain: 60 years of Primatological research on Japanese macaques of Arashiyama*, Cambridge University Press, Cambridge, 517 pp.

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COMMUNICATION

Revival of Eastern Swamp Deer *Rucervus duvaucelii ranjitsinhi* (Groves, 1982) in Manas National Park of Assam, India

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Abstract: A healthy population of the threatened Eastern Swamp Deer *Rucervus duvaucelii ranjitsinhi* in Manas National Park was almost exterminated due to politico-ethnic disturbances in the late 1980s that culminated with the formation of Bodoland Territorial Council in 2003. The Swamp Deer population in Manas began to revive with augmentation starting in 2014, in keeping with a UNESCO World Heritage Site Committee mandate. The Eastern Swamp Deer population in Kaziranga was threatened by the annual flood of the Brahmaputra River, and to secure the future of this threatened species, 36 deer were relocated in two batches in 2014 and 2017 from Kaziranga to Manas. The population of Manas had grown to an estimated 121 individuals by March 2021. Swamp deer is considered an important prey species for Swamp Deer population top predators, especially tigers, which have also increased in number in Manas over the last decade. Thus the revival of Eastern Swamp Deer has contributed to the rewilding programme of the Manas landscape.

Keywords: Conservation, Manas landscape, population, rewildling, Swamp Deer, Tiger prey, translocation.

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INTRODUCTION

Swamp Deer *Rucervus duvaucelii* (Cuvier, 1823), also called Barasingha, is an ungulate endemic to the region of Indian sub-continent. On the basis of morphological and geographical variations, three subspecies have been described: Western Swamp Deer *Rucervus duvaucelii duvaucelii* (Cuvier, 1823) confined to the terai grasslands in northern India and southwestern Nepal; Hard-ground Barasingha *R. d. branderi* (Pocock, 1943) restricted to Madhya Pradesh, and Eastern Swamp Deer *R. d. ranjitsinhi* (Groves, 1982) found in the Brahmaputra valley of Assam (Schaller 1967; Groves 1982; Gopal 1992; WII 2017). Swamp Deer underwent a considerable decline in the closing decades of the 20th century, due to large scale poaching and alteration of preferred habitats (Singh 1970; Sankaran 1990; Qureshi et al. 2004; Ahmed & Khan 2008; Saikia et al. 2012; Goswami & Ganesh 2014). The species is assessed as 'Vulnerable' in the IUCN Red List of Threatened Species, and listed in the Schedule-I of the Indian Wildlife (Protection) Act, 1972 (Duckworth et al. 2015).

Eastern Swamp Deer (ESD) in Assam

Historically, Eastern Swamp Deer were abundant in Assam, inhabiting the river islands or 'char' areas of the Brahmaputra floodplains and extending down to the eastern Sundarbans (Jerdon 1867). A large number of individuals resided in the undivided Goalpara, Kamrup, Nagaon, Sibsagar, and Darrang districts of Assam (Bhadian 1934). The ESD were found in the flat alluvial plains covered with tall grasses in the Brahmaputra valley, and in the terai grasslands of flat to moderately hilly terrain, especially in the Manas landscape in the southern foothills of Bhutan (Schaller 1967). The only known concentrated population of this subspecies was located in Kaziranga National Park (Lahan & Sonowal 1973), and by the 1980s there were only two known populations remaining in Assam, in Kaziranga and Manas.

The Kaziranga population was affected by the annual floods of the Brahmaputra. This was amply demonstrated during two major floods during 2012, when the ESD population showed a sharp decline with the loss of about 23% of the total population. The total population of ESD in Kaziranga has been hovering around 1,000 individuals. On the other hand, a healthy population of ESD with more than 500 individuals occurred in the terai grassland of Manas National Park in 1987 prior to the civil unrest (DebRoy 1991; Choudhury 1997). During the unrest period, this threatened species was almost exterminated from the landscape (Saikia et al. 2012; Borah et al. 2013; Goswami & Ganesh 2014).

Manas National Park

Manas National Park is administratively located in the Baksa and Chirang districts of Bodoland Territorial Area Districts (BTAD) in western Assam. It spans a region from latitude 26.623–26.822 N to longitude 90.808–91.251 E in the southern foothills of the eastern Himalaya (Figure 1). This area falls within the Burma monsoon forests on the borders between the Indo-Gangetic, Indo-Malayan, and Indo-Chinese bio-geographical realms, and is part of Brahmaputra Valley Bio-geographic Province with Assam valley semi-evergreen forests and terai-duar wet alluvial savanna grasslands (Champion & Seth 1968). Manas is recognized for its spectacular scenic beauty with a variety of habitat types in the Bhabar-Terai belt that support diverse wildlife including rare and globally threatened species, making it one of the richest of Indian wildlife areas.

The diverse habitats of Manas National Park harbour the largest number (n= 22) of threatened mammalian fauna which are listed in the Schedule-I of the Wildlife (Protection) Act, 1972 (Lahkar 2008). Apart from being a national park, a part of Manas (Wildlife Sanctuary) was listed as a World Natural Heritage Site in 1985. It is also a tiger reserve, an elephant reserve, and a biosphere reserve.

Conservation of ESD in Manas

The politico-ethnic disturbances in the 1990s decimated most animal populations in Manas, including the ESD. After the return of normalcy, indirect evidence including irregular sightings of ESD occurred in Manas National Park, but photographic evidence could be obtained only during the tiger estimation (Das et al. 2009; Sharma et al. 2012). This photographic evidence proved the continued existence of a small population (estimated <20 individuals) of this threatened species in Manas National Park.

After the Bodo strife, the only viable population of eastern swamp deer existed in Kaziranga National Park. Hence, there was an urgent need to build up a second home for this species. Manas was the natural choice because of its history of having the species, and because protection mechanisms had improved. A translocation programme was developed at the recommendation of the UNESCO World Heritage Site Committee by Assam Forest Department in collaboration with Wildlife Trust of India-WTI and other partner organizations as a part of the recovery of this threatened species

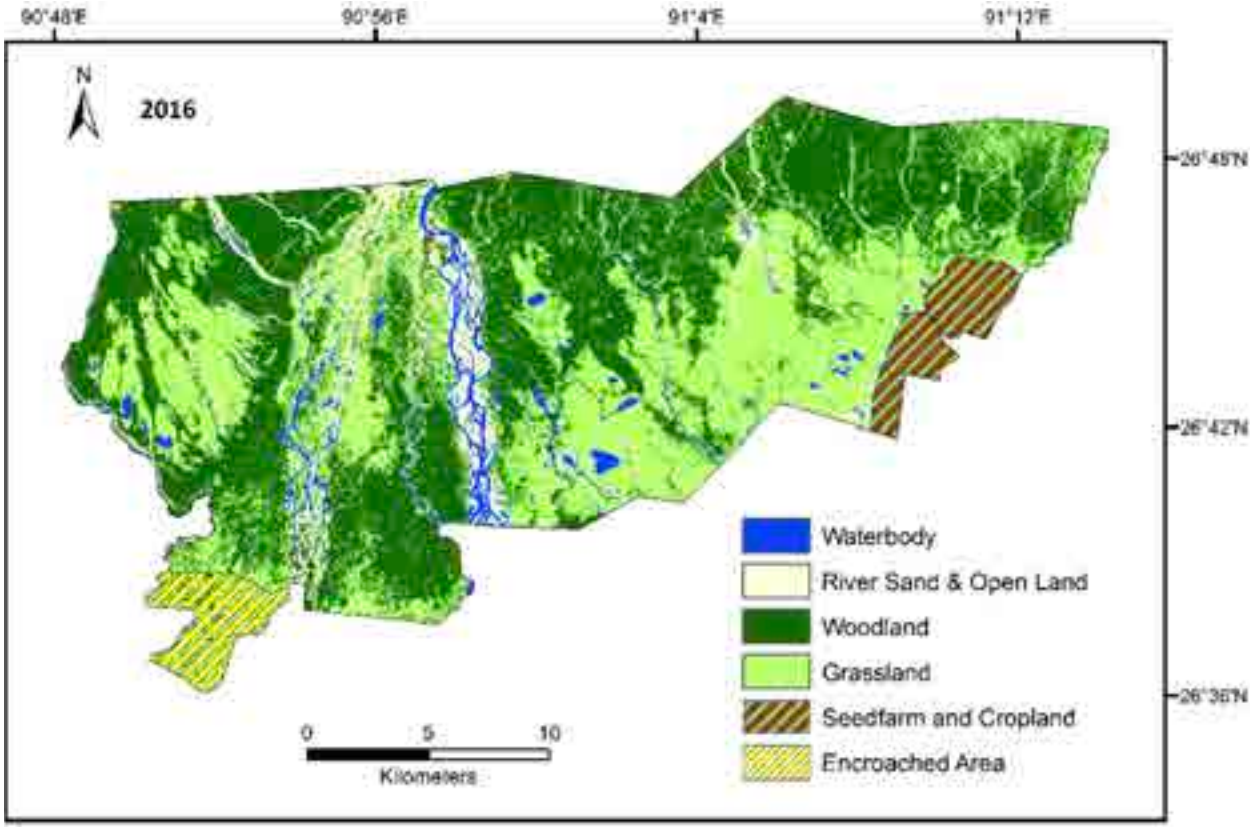

Figure 1. LULC Map of Manas National Park, Assam. © Dr. Dhritiman Das.

in Manas National Park (UNESCO 2016). Under this programme, 36 individuals of ESD in two batches of 19 and 17 individuals were captured from Kaziranga and translocated to Manas in December 2014 and February 2017 respectively (Ahmed et al. 2016; WTI 2018). The translocated ESD were kept in a predator proof enclosure within the Manas National Park for a few months before their release into the wild.

CONSERVATION RESULTS

Monitoring trends in distribution and abundance is vital to evaluate the success of any conservation objective. We monitored the ESD populations regularly post release in Manas. This activity was conducted once in a year after grasses had been burnt to aid sighting and after the calves had been dropped, usually in March or April. We used a block count method (Maruyama & Nakama 1983; Herrero et al. 2011), where counts were repeated over three mornings consecutively to obtain a mean value that was taken as the absolute number of estimation.

Between release and March 2021, the number of

Figure 2. Population growth trend of Eastern Swamp Deer in Manas National Park.

ESD estimated in Manas National Park has more than doubled, with increases in all age and sex classes (Figure 2). A total of 121 individuals, consisting of 24 adult males (20%), 67 adult females (55%), 17 subadults (14%), and 13 fawns (11%) were recorded. The presence of five ESD individuals (2 males & 3 females) were also confirmed through direct sighting in the Sidajhar grassland under the Kahitama Beat, on the west of Beki of Manas National

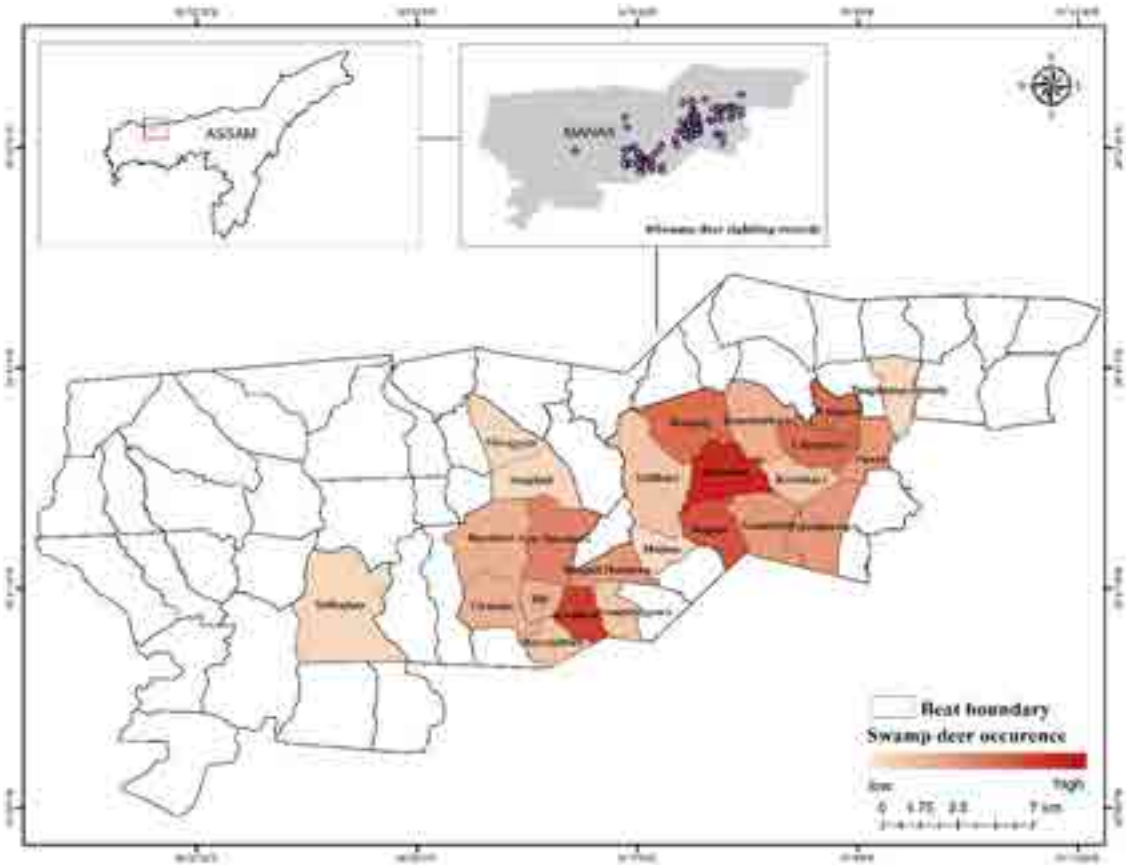

Figure 3. Occurrence of Eastern Swamp Deer in different blocks of Manas National Park.

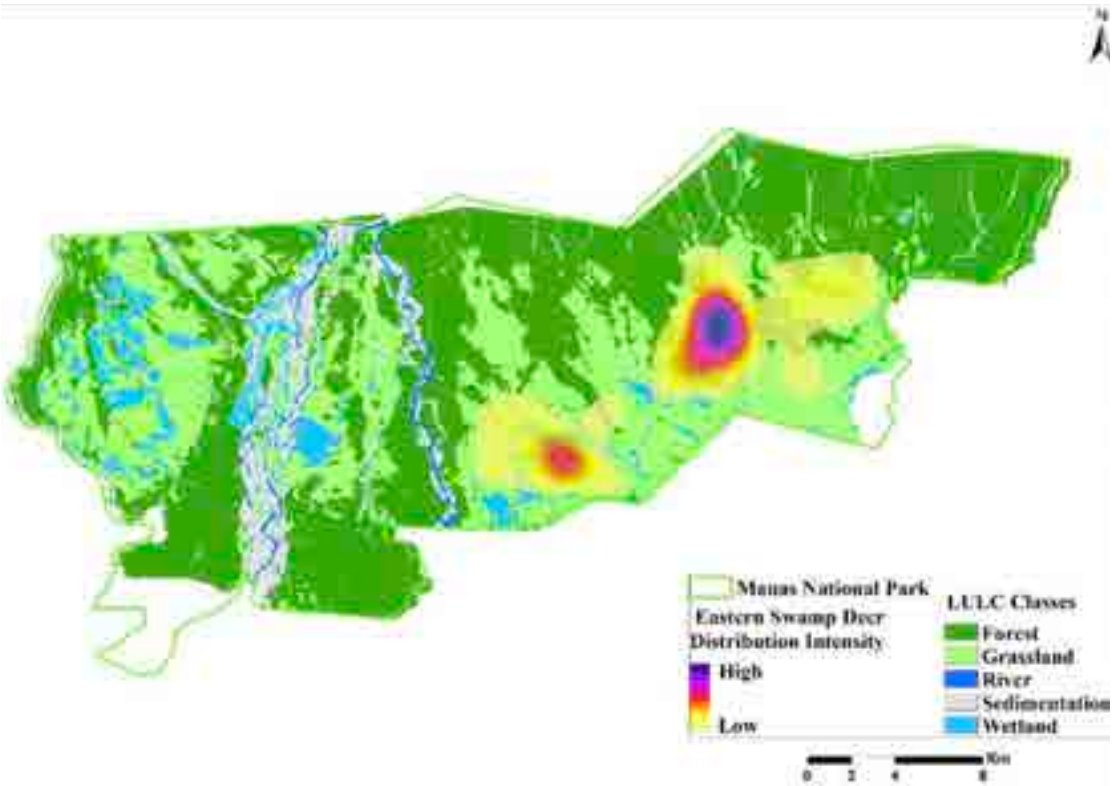

Figure 4. Distribution Intensity of Eastern Swamp Deer in Manas National Park.

Park (Figure 3). Being a grassland dwelling species, major herds were found mostly in the wet alluvial grassland habitats in Kuribeel and its surrounding areas under Bansbari range and Rupohi-Kanchanbari-Abwidara area under Bhuyanpara range of Manas (Figure 4).

DISCUSSION

The annual population estimation has revealed that the ESD population is increasing in Manas National Park. Deer have been recorded from different wet-alluvial grassland patches and swampy habitats of the park, indicating that translocated groups have suitably adapted in the wild, dispersed and occupied different grassland habitats. Remnant populations of eastern swamp deer also appear to have revived with strengthening of their protection. Translocation of animals to recover populations and reduce the risk of extinction has made significant differences to the conservation status of many species worldwide (Berger-Tal et al. 2019). Supplementation of the eastern swamp deer population with individuals from Kaziranga has had a positive effect on the recovery of the resident population, helping to rescue it from the brink of extinction (Ahmed et al. 2016). Further relocations from Kaziranga to Manas may also be effective.

Eastern Swamp Deer is considered an important prey species for top predators, especially tigers, which have also flourished recently in Manas. The 12th annual camera trap assessment by the National Tiger Conservation Authority-NTCA revealed a total of 48 individuals, with 38 adults, three subadults, and seven cubs. This represents a three-fold rise in adult tigers over a decade in Manas, a record for tiger conservation in India.

CONCLUSION

The Eastern Swamp Deer has recovered from near-extinction in Manas National Park, where populations have dispersed to several different areas. There is potential for further growth with the aid of scientific and managerial inputs to strict protection and restoration of suitable habitats. The recovery of this population of a major tiger prey species has vindicated the holistic ecological approach of Project Tiger in India.

REFERENCES

Ahmed, A., R. Barman, B. Choudhury, R. Sarma, N.V.K. Ashraf, R. Kaul & V. Menon (2016). Supplementation of eastern swamp deer in Manas National Park, Assam, India, pp. 178–181. In: Soorae, P.S. (ed.). *Global Re-Introduction Perspectives: Case-studies from Around the Globe*. Gland, Switzerland: IUCN/SSC Reintroduction Specialist

Image 1. Eastern Swamp Deer in Manas National Park. © Nazrul Islam/IFAW-WTI

Group and Abu Dhabi, UAE: Environment Agency, Abu Dhabi.

Ahmed, K. & J.A. Khan (2008). Status, population structure and conservation of swamp deer (*Cervus duvauceli duvauceli*) in Dudhwa Tiger Reserve, Uttar Pradesh, India. *International Journal of Ecology and Environmental Sciences* 34(2): 75–82.

Berger-Tal, O., D.T. Blumstein & R.R. Swaisgood (2019). Conservation translocations: a review of common difficulties and promising directions. Animal Conservation. The Zoological Society of London, 11pp.

Bhadian, C. (1934). Notes on the Swamp Deer (*Rucervus duvauceli*) in Assam. *Journal of the Bombay Natural History Society* 37(2): 485–486.

Blanford, W.T. (ed.) (1898). The Fauna of British India: Including Ceylon and Burma. Taylor & Francis, London, 617pp. https://doi.org/10.5962/bhl.title.48423

Borah, J., T. Sharma, K. Azad, P. Chakraborty & A. Swargowari (2013). Photographic evidence of the swamp deer in Manas National Park. *Oryx* 47(4): 481–481.

Brander, A.A.D. (1923). The Swamp Deer or Barasingha, pp. 192–208. In: *Wild Animals in Central India* (Second Impression). Lowe & Brydone (Printers) Limited, London.

Champion, S.H. & S.K. Seth (1968). *A Revised Survey of The Forest Types Of India*. Natraj Publishers, Dehradun.

Choudhury, A. (1997). Checklist of the Mammals of Assam. Gibbon Books with ASTEC, Guwahati, Assam.

Cuvier, G. (1823). Recherches sur les ossemens fossiles de quadrupèdes. Nouvelle édition, Tome Quatrième. Dufour & d'Ocagne, Paris, Amsterdam.

Das, J.P., A. Sinha & B.K. Talukdar (2009). Swamp deer in Manas: Present status and feasibility of restocking. Preliminary Report submitted to Manas Project Tiger Directorate, Assam Forest Department. Retrieved from https://www.rufford.org/files/61.07.08%20Preliminary%20Report.pdf

Duckworth, J.W., N.S. Kumar, C.P. Pokharel, H.S. Baral & R. Timmins (2015). *Rucervus duvaucelii*. *The IUCN Red List of Threatened Species* 2015:e.T4257A22167675. Downloaded on 17 March 2021. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T4257A22167675.en

Ellerman, J.R & T.C.S. Morrison-Scott (1951). *Checklist of Palaearctic and Indian Mammals*. Trustees of the British Museum, 810pp.

Gopal, R. (1992). Resurrection of the Branderi Barasingha. *Cheetal. Journal of the Wildlife Preservation Society of India* 31(1&2): 1–5.

Goswami, R. & T. Ganesh (2011). Conservation amidst political unrest: the case of Manas National Park, India. *Current Science* 100(4): 445–446.

Goswami, R. & T. Ganesh (2014). Carnivore and herbivore densities in the immediate aftermath of ethno-political conflict: the case of Manas National Park, India. *Tropical Conservation Science* 7(3): 475–487.

Groves, C. (1982). Geographic variation in the Barasingha or Swamp Deer (*Cervus duvaucelii*). *Journal of the Bombay Natural History Society* 79: 620–629.

Herrero, J., A. García-Serrano, C. Prada & O. Fernández-Arberas (2011). Using block counts and distance sampling to estimate populations of chamois. *Pirineos* 166: 123–133.

Jerdon, T.C. (1867). *The mammals of India: a natural history of all the animals known to inhabit continental India*. Roorkee: Printed for the author by the Thomason College Press, 254–256pp.

Jhala, Y.V., Q. Qureshi & A.K. Nayak (eds.) (2020). Status of tigers, copredators and prey in India, 2018. National Tiger Conservation Authority, Government of India, New Delhi, and Wildlife Institute of India, Dehradun.

Lahan, P. & R. Sonowal (1973). Kaziranga wildlife sanctuary, Assam. *Journal of the Bombay Natural History Society* 70(2): 245–278.

Lahkar, B.P. (2008). Ecology and management of grassland with special reference to grass and bird communities in Manas national park, Assam. PhD Thesis. Department of Zoology, Gauhati University, xii+187pp. http://hdl.handle.net/10603/68038

Lahkar, D., M.F. Ahmed, R.H. Begum, S.K. Das & A. Harihar (2020). Responses of a wild ungulate assemblage to anthropogenic influences in Manas National Park, India. *Biological Conservation* 243(March): 108425. https://doi.org/10.1016/j.biocon.2020.108425

Martin, C. (1977). Status and ecology of the Barasingha (*Cervus duvaucelii branderi*) in Kanha National Park (India) (Doctoral dissertation, Organisation KOLB). *Journal of the Bombay Natural History Society* 74: 60–126.

Maruyama, N. & S. Nakama (1983). Block count method for estimating serow populations. *Japanese Journal of Ecology* 33(3): 243–251.

Pocock R. (1943). The larger deer of British India. *Journal of the Bombay Natural History Society*. 43: 553–572.

Qureshi, Q., V.B. Sawarkar, A.R. Rahmani & P.K. Mathur (2004). Swamp Deer or barasingha (*Cervus duvauceli* Cuvier, 1823). *Ungulates of India* 7: 181–192.

Saikia, B.P., A. Rabha & P.K. Saikia (2012). 'Manas: Last Destination of Swamp Deer (*Rucervus duvauceli*) after Kaziranga in North East India', pp. 78–84. In: Rabha, A. & B.P. Saikia (eds.). *Manas: Our Good Ol' Darling*. 1st Edition. Bookland Publishers, Guwahati.

Sankaran, R. (1990). Status of the Swamp Deer (Cervus duvauceli duvauceli) in the Dudwa National Park, Uttar Pradesh, India. *Journal of the Bombay Natural History Society* 87(2): 250–259.

Schaaf, D. & A. Singh (1977). Barasingha in the Dudhwa sanctuary. *Oryx* 13(5): 495–498.

Schaller, G.B. (1967). The Deer and the Tiger. A Study of Wildlife in India. The University of Chicago Press, 370pp.

Sharma, A., D.K. Dutta & A. Swargowary (2012). Elusive Beauties of Manas National Park-The Swamp Deer. *Tigerpaper* 39(3): 21–25.

Singh, A. (1970). The Swamp Deer of North Kheri. *IUCN 11th Tech. Meeting*. Vol. 2. Problems of Threatened Species. IUCN Pub. new series 18: 52–54.

UNESCO (2016). Eastern Swamp Deer Conservation in Manas National Park 2015-16. In: *State of Conservation Report of Manas Wildlife Sanctuary (India) (N338)*. Response To the World Heritage Committee Decision 38 Com 7B.11: 20–24.

Wildlife Institute of India (2017). National Studbook of Swamp Deer (*Rucervus duvaucelii*). Wildlife Institute of India, Dehradun and Central Zoo Authority, New Delhi. TR No 2017/011, 41pp.

Wildlife Trust of India (2018). Project Dol Horina. https://www.wti.org.in/resource_centre/project-dol-horina/ (downloaded on 17 March 2021)

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COMMUNICATION

Trypanosoma evansi infection in a captive Indian Wolf *Canis lupus pallipes* – molecular diagnosis and therapy

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Abstract: A five-year old, apparently healthy male Indian Wolf *Canis lupus pallipes* of Nandankanan Zoological Park, Odisha became ill with acute signs of anorexia, lethargy, staggering gait, and was non-responsive to external stimuli. Microscopic examination of Giemsa stained blood smear revealed presence of extracellular flagellates having morphological similarity to *Trypanosoma* spp. Haematological parameters showed anaemia (Hb 6.0 g%), mild leucopenia (total leukocyte count 5 × 10^3 / mm^3) and thrombocytopenia (180 x 10^3 / µl). Serum biochemistry revealed high aspartate aminotransferase (AST) (830 IU/L), blood urea nitrogen (BUN) (178.2 mg/dl), creatinine (4.44 mg/dl), and low glucose (25.7 mg/dl) levels. Polymerase chain reaction (PCR) analysis targeting internal transcribed spacer (ITS1) region followed by National Centre for Biotechnology Information blast confirmed *Trypanosoma evansi* infection in the captive Indian Wolf. The animal showed clinical recovery with the administration of single dose of quinapyramine sulphate and quinapyramine chloride @ 4.0 mg/kg b wt subcutaneously. The wolf started taking meat from the very next day with improved activity. No trypanosomes could be detected in the stained blood smears as well as through PCR carried 25 days post treatment. The occurrence became an eye opener for the zoo and henceforth, all canids were included under chemoprophylaxis protocol against trypanosomosis.

Keywords: Anemia, Canids, captivity stress, Chemoprophylaxis, PCR, Quinapyramine salts.

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Competing interests: The authors declare no competing interests.

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Author contributions: SKS, SKG and DM have executed the treatment, collected samples and documented the clinical findings. MD and NS have carried out molecular screening, interpreted the results and guided the treatment. All authors formulated and revised the manuscript, and approved the final version.

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INTRODUCTION

Trypanosomosis, caused by an unicellular, eukaryotic haemoprotozoan of different *Trypanosoma* spp., is an important disease of domestic and wild animals (Aulakh et al. 2005; Gupta et al. 2009). A number of trypanosomes exist worldwide; however, *Trypanosoma evansi* is the only pathogenic species prevalent in India (Desquesnes et al. 2001; Kumar et al. 2021). Sengupta (1974), Ziauddin et al. (1992), and Shukla (2002) reported trypanosomosis in Indian Wolves in Indian zoos at Kolkata, Mysore, and Lucknow, respectively. This extra-cellular haemoparasite is transmitted by biting flies of genera *Tabanus*, *Stomoxys*, and *Haematobia* (Parashar et al. 2006, 2018). The disease is characterized by anaemia, anorexia, intermittent fever, generalised weakness, conjunctivitis, corneal opacity, oedema of head and throat, difficulty in swallowing, hoarse voice, and staggering gait (Chaudhuri et al. 2009). The disease can be diagnosed by direct demonstration of trypomastigote forms of the parasite in the stained blood smears, but the polymerase chain reaction (PCR) has an increased diagnostic potential with high sensitivity and specificity to detect parasite DNA (Eloy & Lucheis 2009). Trypanosomosis has been successfully treated with a single dose of diminazine aceturate @ 3.5 mg/kg body weight intramuscular (Rani & Suresh 2007) or sulphate and chloride salts of quinapyramine @ 4.0 mg/ kg bw subcutaneous (Singh et al. 1993).The present case study documents molecular diagnosis through PCR and successful therapy of *Trypanosoma evansi* infection in a captive Indian Wolf at Nandankanan Zoological Park (NKZP), India.

CASE HISTORY AND OBSERVATION

The NKZP received a pair of wolves during September 2018 from Sri Chamarajendra Zoological Gardens, Mysuru under an animal exchange program. Both were housed in an open air enclosure of 28 sq meters attached to a feeding cell of 15 sq meters. Regular prophylactic measures included annual vaccination against rabies, parvo, distemper, parainfluenza, adenovirus type I and II, hepatitis and *Leptospira* spp., fecal sample examination followed by deworming with albendazole/ fenbendazole at three month intervals and ground spray of enclosure with ectoparasiticides deltamethrine/cypermethrine in alternate months. The female partner died on 07 March 2019 due to cardiac dysfunction leaving the male wolf alone.

On 24 September 2019, the 5-year old apparently healthy male partner (approximate body weight 20.0 kg) was noticed anorectic, debilitated, non-responsive to external stimuli, reduced activity levels with staggering gait. Close examination inside a squeeze cage revealed shallow breathing and pale conjunctiva. Body temperature was 103.2°F. Peripheral blood samples were collected on the same day from the left saphenous vein in ethylene diamine tetraacetic acid @ 1.5 mg/ml (EDTA) and clot activator vials for haemato-biochemical and parasitological examination. Faecal samples were collected for detection of gastrointestinal infection.

DIAGNOSIS AND TREATMENT

Coprological examination did not reveal the presence of any endoparasite ova or cyst. Blood smear stained with Giemsa stain and examined under oil immersion showed the presence of extracellular flagellated Trypanosomes (Image 1). Molecular test was performed for confirmation of the species. DNA was extracted from the EDTA blood sample using Qiamp DNA blood Mini kit (M/S Qiagen, Germany) according to the manufacturer's instructions. PCR was carried out in 50 µl reaction volumes containing 10X reaction buffer with KCl, 25 mM $MgCl_2$, 2 mM dNTPs, 3 units of Taq DNA polymerase, 2 µM of each primer (Njiru et al. 2005), nuclease free water and 2 µl of template DNA. PCR was programmed to perform a denaturation step at 95^0 C for 10 mins followed by 35 cycles consisting of 30 secs at 94^0C, 30 secs at 55^0 C, and 30 secs at 72^0 C. The last extension step was 10 mins at 72^0 C. The PCR product was run in 2% agarose gel with ethidium bromide-stain using an electrophoresis system (M/S BIO-RAD, USA) along with one positive (1 µg of DNA) and one negative control (Image 2). After getting the desired band at 480 bp, the PCR product was sequenced and the data was compared in National Centre for Biotechnology Information (NCBI) database. The sequenced data matched with *T. evansi* with 93.6% identity and 97.0% query cover. The consensus sequence (generated in BIOEDIT software) was submitted in genbank (NCBI) and the assigned accession number was MZ321577.

Analysis results depicted in Table 1 revealed decrease in certain haemato–biochemical values like haemoglobin (6.0 g%), total leukocyte count (5.0 $10^3/mm^3$) neutrophil (56%), platelets count (180 × 10^3/µl) and glucose (25.7 mg/dl). Increased values in both haematological and biochemical parameters included lymphocyte (41%), AST (830.4 IU/l), total protein (7.63 g/dl), urea (178.2

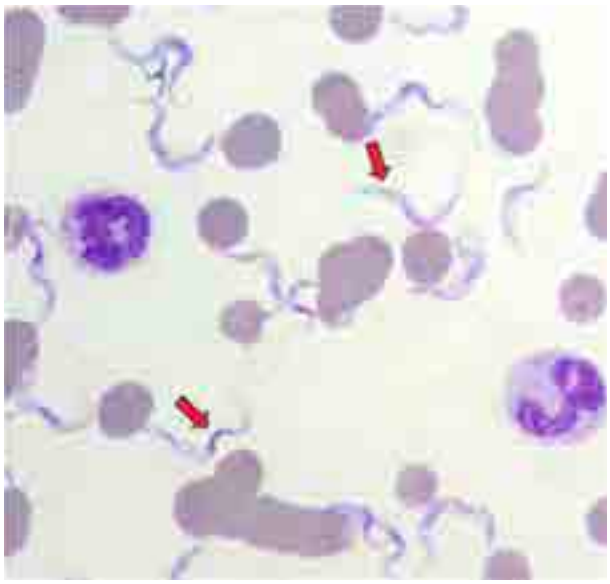

Image 1. Giemsa stained blood smear showing *Trypanosoma evansi* marked in red arrow (X1000).

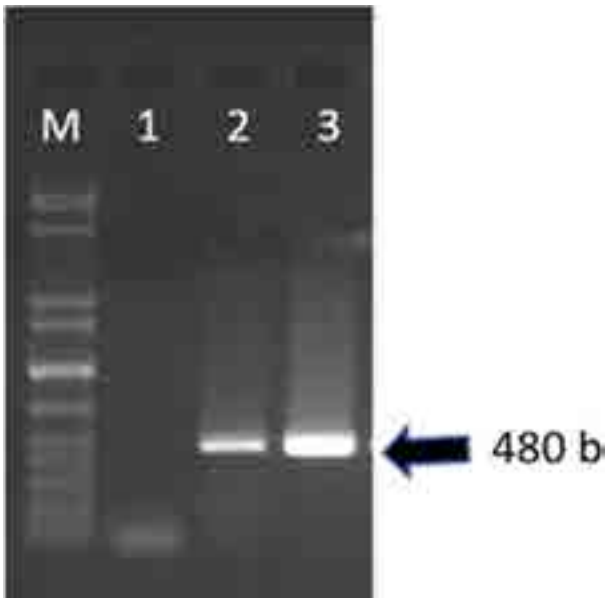

Image 2. Gel electrophoresis of PCR products (480bp). Lane M: 100 bp marker, lane 1: Negative Control, Lane 2: sample of interest, Lane 3: Positive Control.

mg/dl), creatinine (4.44 mg/dl), cholesterol 272.7 mg/dl), triglyceride (418.8 mg/dl), calcium (11.1 mg/dl), phosphorous (11.4 mg/dl), magnesium (2.7 mg/dl), and total billirubin (0.80 mg/dl)

Quinapyramine sulphate and chloride @ 4.0mg/ kg b wt (Injection Triquin of M/S Vetoquinol India Animal Health Pvt Ltd., Thane) was administered subcutaneously. As supportive therapy, the Indian Wolf was administered with paracetamol inj (Injection Fevastin of M/S Tablets India Limited, Chennai) @ 2.0 ml intramuscular and electrolytes with 20% dextrose infusion @ 300 ml (Rintose of M/S Vetoquinol India Animal Health Pvt Ltd.). The Indian Wolf started responding to treatment from the very next day itself. Body temperature dropped to 101.4°F with signs of improvement in the activity and appetite.

DISCUSSION

NZKP had the earlier records of trypanosomosis among white Tigers *Panthera tigris*, Bengal Tigers *Panthera tigris tigris*, and Jungle Cat *Felis chaus* (Parija & Bhattacharya 2001; Sahoo et al. 2009). Hence, the NKZP is following a chemoprohylaxis protocol against trypanosomosis for all large felids (N= 46) and calculated doses of quinapyramine salts (Injection Triquin of M/S Vetoquinol India Animal Health Pvt Ltd, Maharashtra) are being administered subcutaneously at every four month intervals. But the canids were not included in this chemoprophylaxis protocol, as there was no incidence of the said disease amongst canids at NKZP.

It is quite challenging to ascertain the species of *Trypanosoma* spp. from the blood smear. PCR is the ultimate diagnostic protocol to reveal the fact. PCR targeting internal transcribed spacer (ITS1) region is highly sensitive and reliable for the diagnosis of pathogenic *Trypanosoma* spp. such as *T. evansi, T. brucei brucei*, *T. b. rhodesiense, T. b. gambiense, T. congolense, T. savannah, T. congolense kilifi, T. congolense forest, T. simiae, T. simiae tsavo, T. godfreyi*, and *T. vivax* (Njiru et al. 2005). Successful detection of *Trypanosoma* spp. has been reported using ITS1 CF and BR PCR primers in cattle, tsetse fly, sand fly, dogs, equids, monkeys, and camels (Thumbi et al. 2008; Alanazi et al. 2018; Gaithuma et al. 2019; Medkour et al. 2020). The current study unveiled incidence of *T. evansi* in a captive Indian Wolf at NKZP.

Wild animals often exhibit moderate levels of trypano-tolerance with their innate ability to co-exist with trypanosomes without showing overt disease (Sudan et al. 2017). The disease flares up when the animal gets exposed to physiological and somatic stress following concurrent infection, capture, translocation and captivity that often compromises their innate resistance (Fowler 1986; Singh et al. 2003).

The clinical signs in the present case were high rise of temperature (103.2^{0}F), pale mucous membrane, bilateral lacrimation, and generalised debility. These observations were in agreement with the findings of Rani

Table 1. Pre- and post-treatment haemato-biochemical values of an Indian Wolf with *Trypanosoma evansi* infection.

Parameter	Days of blood collection		
	24.ix.2019 (Pre-treatment)	18.x.2019 (Post-treatment)	Reference range
Hematology			
Haemoglobin (g %)	6.0	13.0	10.5-15[a]
Total leucocyte count (10^3/mm^3)	5.0	5.6	5-14.1 [b]
Neutrophil (%)	56.0	70.0	58-71[a]
Eosinophil (%)	3.0	3.0	0-4[a]
Lymphocyte (%)	41.0	26.0	28-39[a]
Monocyte (%)	-	1.0	0-2[a]
Basophil (%)	-	0	0[a]
Platelet (×10^3/µl)	180.0	226.0	211-621[b]
Biochemistry			
ALT(IU/L)	10.3	331.1	24-64[a]
AST(IU/L)	830.4	159.8	23-66[b]
ALP(IU/L)	96.1	26.3	20-156[b]
BUN (mg/dl)	178.2	63.8	16-41[a]
Creatinine (mg/dl)	4.4	2.18	0.5-1.5[b]
Glucose (mg/dl)	25.7	117.2	58.2 - 91[a]
Total protein(g/dl)	7.63	6.4	5.07- 6.49[a]
Albumin (g/dl)	1.5	2.7	2.92-3.53[a]
Globulin (g/dl)	5.0	3.6	2.03- 3.16[a]
Cholesterol (mg/dl)	272.7	178.5	138-198[a]
Triglyceride(mg/dl)	418.7	39.7	20-112[b]
Calcium (mg/dl)	11.1	10.9	5.58-7.94[a]
Phosphorous (mg/dl)	11.4	2.6	4 – 5.32[a]
Magnesium (mg/dl)	2.7	2.4	1.8-2.4 [b]
Total Billirubin (mg/dl)	0.8	0.8	0.10-0.50 [b]

[a] Sabapara & Vadalia(1999) | [b] Kaneko et al.(2008)

& Suresh (2007). The fever might be due to the effects of toxic metabolites produced by dying trypanosomes (Tizard et al. 1978).

Anemia was a consistent finding as reported earlier in different hosts including dogs infected with Trypanosomosis (Moreira et al. 1985; Monzon et al. 1991; Silva et al. 1995; Gurtler et al. 2007). The anaemia is attributable to extravascular destruction of RBC which may be through the process of erythrophagocytosis or metabolic product and toxins liberated from the parasites. Blood cellular changes revealed leucopenia along with reduced neutrophil count. Similar findings were recorded by Barr et al. (1991).

Increase in AST, ALT, ALP, urea, creatinine level as compared to reference level corroborated with findings of Barr et al. (1991) who reported a similar pattern of changes in a dog during the acute phase. Marked elevation in the level of total protein values were recorded as compared to reference level. Hyperproteinemia found in this study could be associated with hypergammaglobulinemia due to antigenic stimulation provoked by the parasite, as seen in canines (Aquino et al. 2002). There was a decrease in the albumin and globulin ratio. The fall in albumin levels was secondary to hyperglobulinemia as a compensatory mechanism for maintenance of normal blood viscosity increased by globulin levels (Aquino et al. 2002). Hyperbilirubinemia has been reported in naturally infected dogs as a consequence of an increase in unconjugated bilirubin (Sandoval et al. 1994) and conjugated bilirubin. There was decrease in serum glucose (25.7 mg/dl) level. Hypoglycemia has been shown to be an important

clinical laboratory finding in naturally infected animals, and it is inversely proportional to blood trypanosome count.

Diminazine aceturate is a commonly used drug in the treatment of trypanosomosis (Rani & Suresh 2007). However, a combination of quinapyramine sulphate and quinapyramine chloride (3:2 w/w) at dose rate 4.0 mg/kg b wt is also effective in achieving complete recovery (Singh et al 1993). Shukla (2002) did not get a complete cure with diminazine@ 0.8g/ 100 kg b. wt in case of an Indian Wolf, rather, quinapyramine sulphate @ 5.0mg/ kg b wt resulted in complete recovery. In a similar line, combination of quinapyramine sulphate and quinapyramine chloride @ 4.0mg/kg b wt administered subcutaneously as a single dose showed uneventful recovery in the present case.

The incidence of trypanosomosis in an Indian Wolf became an eye opener for the zoo to extend the chemoprophylaxis to other hosts. As per the recommendation, the susceptible species, viz., Indian Wolf, Jackal, Dhole, and hyenids of NKZP are being included in the preventive protocol against trypanosomosis now.

CONCLUSION

Molecular diagnosis of *Trypanosoma evansi* infection in an Indian Wolf followed by successful treatment with a single injection of quinapyramine sulphate and quinapyramine chloride @ 4.0 mg/kg b wt subcutaneously was recorded at Nandankanan Zoological Park.

REFERENCES

Alanazi, A.D., R. Puschendorf, B. Salim, M.S. Alyousif, I.O. Alanazi & H.R. Al-shehri (2018). Molecular detection of equine trypanosomiasis in the Riyadh Province of Saudi Arabia. *Journal of Veterinary Diagnostic Investigation* 30(6): 942–945. https://doi.org/10.1177/1040638718798688

Aquino, L.P.C.T., R.Z. Machado, A.C. Alessi, A.E. Santana, M.B. Castro & L.C. Marques (2002). Hematological, biochemical and anatomopathological aspects of experimental infection with *Trypanosoma evansi* in dogs. *Arquivo Brasileiro de Medicina Veterinária e* Zootecnia 54: 8–18. https://doi.org/10.1590/S0102-09352002000100002

Aulakh, G.S., L.D. Singla & J. Singh (2005). Bovine trypanosomosis due to *Trypanosoma evansi*: Clinical, haematobiochemical and therapeutic studies, pp 137–144. In: Sobti, R.C. & V.L. Sharma (Eds.). *New Horizons in Animal Sciences*. Vishal Publishing and Co., Jalandhar.

Barr, S.C., K.A. Gossett & T.R. Klei (1991). Clinical, clinicopathologic, and parasitologic observation of trypanosomiasis in dog infected with North American *Trypanosoma cruzi* isolates. *American Journal of Veterinary Research* 52: 954–960.

Chaudhuri, S., B. Changkija & J.P. Varshney (2009). Concurrent infection of *Trypanosoma evansi* and *Dirofilaria immitis* in a non-descript bitch. *Journal of Veterinary Parasitology* 23: 167–169.

Desquenes, M., Z. Bengaly, L. Millogo, Y. Meme & H. Sakande (2001). The analysis of the cross-reactions occurring in antibody-ELISA for detection of trypanosomes can improve identification of the species involved. *Annals of Tropical Medicine and Parasitology* 95(2): 141–155. https://doi.org/10.1080/00034980120050251

Eloy, L.J. & S.B. Lucheis (2009). Canine trypanosomiasis: Etiology of infection and implications for public health. *Journal of Venomous Animals and Toxins including Tropical Diseases* 15(4): 589–611. https://doi.org/10.1590/S1678-91992009000400002

Fowler, M.E. (1986). *Zoo and Wild Animal Medicine, 2nd edition.* W.B. Saunders company.

Gaithuma, A.K., J. Yamagishi, A. Martinelli, K. Hayashida, N. Kawai & M. Marsela (2019). A single test approach for accurate and sensitive detection and taxonomic characterization of trypanosomes by comprehensive analysis of internal transcribed spacer 1 amplicons *PLoS Neglected Tropical Diseases* 13(2): e0006842. https://doi.org/10.1371/journal.pntd.0006842

Gupta, M.P., H. Kumar & L.D. Singla (2009). Trypanosomosis concurrent to tuberculosis in black bucks. *The Indian Veterinary Journal* 86: 727–728.

Gurtler, R.E., M.C. Cecere, M. A. Lauricella, M.V. Cardinal, U. Kitron & J.E. Cohen (2007). Domestic dogs and cats as source of *Trypanosoma cruzi* infection in rural northwestern Argentina. *Parasitology* 134: 69–82. https://doi.org/10.1017/S0031182006001259

Kaneko, J.J., J. Harvey & M.L. Bruss (2008). *Clinical Biochemistry of Domestic Animals - 6th Edition*. Academic Press, San Diego, pp. 873-904. https://doi.org/10.1016/B978-0-12-370491-7.00033-7

Kumar, H., M.P. Gupta, P.K. Sidhu, V. Mahajan, M.S. Bal, K. Kaur, Ashuma, S. Verma & L.D. Singla (2012). An outbreak of acute *Trypanosoma evansi* infection in crossbred cattle in Punjab, India. *Journal of Applied Animal Research* 40(03): 256–259. https://doi.org/10.1080/09712119.2012.667651

Medkour, H., M. Varloud, B. Davoust & O. Mediannikov (2020). New molecular approach for the detection of kinetoplastida parasites of medical and veterinary interest. *Microorganisms* 8: 356. https://doi.org/10.3390/microorganisms8030356

Monzon, C.M., V.I. Villavicencio & J.P. Roux (1991). Estudioshematológicosencobaios y equinosinfectados Con el *Trypanosoma evansi*. *Veterinary Argent* 8: 668–676.

Moreira, R.D. & R.Z. Machado (1985). Identificaçãoeisolamento do *Trypanosoma equinum*em um cãodomunicípio De Camapuã-MS, pp. 66. In: Encontro de pesquisasveterinárias, jaboticabal. *resumo...* jaboticabal: UNESP/Faculdade de Ciências Agrárias.

Njiru, Z.K., C.C. Constantine, S. Guya, J. Crowther, J.M. Kiragu, R.C.A. Thompson & A.M.R. Dávila (2005). The use of ITS1 rDNA PCR in detecting pathogenic African trypanosomes. *Parasitology Research* 95: 186–192.

Parashar, B.S., V. Singh, S. Prakash & V. Kumar (2006). Prevalence of blood sucking flies, vector of trypanosomiasis in the Nandankanan Zoological Park, Bhubaneswar (Orissa) and their control by integrated pest management. In: *Indian Zoo Year Book* 4: 112–125.

Parashar, R., L.D. Singla, K. Batra, R. Kumar, N. Kashyap, P. Kaur & M.S. Bal (2018). Unraveling cryptic epizootiology of equid trypanosomosis in Punjab state of India by parasitological and sero-molecular techniques. *Acta Tropica* 185: 18–26.

Parija, S.C. & S. Bhattacharya (2001). Tragedy of tigers: Lessons to learn from Nandankanan episode. *Indian Journal of Medical Microbiology* 19: 116–118.

Rani, N.L. & K. Suresh (2007). Canine trypanosomiasis. *Indian Veterinary Journal* 84: 186–187.

Sabapara, R.H. & D.M. Vadalia (1999). Haematology and serum chemistry of Indian Wolf (*Canis lupus pallipes*). *Zoos' Print Journal* 14: 92–93. https://doi.org/10.11609/JoTT.ZPJ.14.8.92-3

Sahoo, N., P.K. Roy, R.K. Samantaray & A. Das (2009). Treatment of trypanosomiasis in a Jungle Cat. *Indian Veterinary Journal* 86(8):

844–845.

Sandoval, G.L., N.B. Coppo & M.S. Negrette (1994). Alteraçõesbioquímicas e histopatológicas de um cãoeratosinfectados com Trypanosoma evansi. *Hora Vet* 81: 53–55.

Sengupta, M.R. (1974). A preliminary report on diseases and parasites of zoo animals, birds and reptiles. *Indian Journal of Animal Health* 13: 15–24.

Silva, R.A.M.S., A.T.M. Barros & H.M. Herrera (1995). Trypanosomosis outbreaks due to *Trypanosoma evansi* in the Pantanal, Brazil. A preliminary approachon risk factors. ***Revue d'élevage et de médecinevétérinaire des pays tropicaux*** 48: 315–319.

Singh, R., L.D. Singla & P.S. Dhaliwal (2003). Dexamethasone flared up trypanosomosis in a dog. *Indian Veterinary Medical Journal* 27: 93–94

Shukla, U. (2002). Trypanosomiasis in wolf (*Canis lupus*)- a case study for Lucknow Zoo. *Zoos' Print Journal* 17: 862. https://doi.org/10.11609/JoTT.ZPJ.17.8.862

Sudan, V., A.K. Verma & A.K. Jaiswal (2017). Trypanosomiasis of wild animals with emphasis on Indian scenario. *Veterinary Parasitology Regional Studies and Reports* 10: 25–28. https://doi.org/10.1016/j.vprsr.2017.07.003

Singh, B., I.S. Kalra, M.P. Gupta & D.C. Nauriyal (1993). *Trypanosoma evansi* in dogs: seasonal prevalence and chemotherapy. *Veterinary Parasitology* 50: 137–141.

Thumbi, S.M., F.A. McOdimba & R.O. Mosi (2008). Comparative evaluation of three PCR base diagnostic assays for the detection of pathogenic trypanosomes in cattle blood. *Parasites Vectors* 1**:** 46 https://doi.org/10.1186/1756-3305-1-46

Tizard, I.R., K.H. Nielsen, J.R. Seed & J.E. Hall (1978). Biologically active products from African trypanosomes. *Microbiological Reviews* 42: 661–681. https://doi.org/10.1128/mr.42.4.664-681.1978

Ziauddin, K.S., K. Muralidharan & S.J. Seshadri (1992). Trypanosomiasis in a wolf at Mysore Aoo- a case report. *Indian Journal of Wildlife Health Management* 1: 47.

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VIEWPOINT

COVID-19 and civil unrest undoing steady gains in karst conservation and herpetological research in Myanmar, and an impediment to progress

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Abstract: The COVID-19 pandemic and political turmoil in Myanmar has dealt a severe blow to the country's progress in herpetological research and the protection of limestone habitats. Both afflictions have reversed much of the scientific and conservation gains made in the past decade, and continue to hinder exploratory surveys and continued monitoring of threatened karst ecosystems. There is an urgent need to resume field studies and conservation effort as soon as possible and continue enhancing the capacity of local scientific and technical staff in Myanmar.

Keywords: Biodiversity, *Cyrtodactylus*, endemism, geckos, limestone.

In the last decade, Myanmar was riding the crest of a wave of renewed interest in herpetological research, particularly in karst ecosystems (Grismer et al. 2020c). Karst habitats are generators and refugia for biodiversity but are unfortunately also amongst the most threatened ecosystems in the world (Grismer et al. 2020a,c, 2021; Quah et al. 2021). Despite there being a great concentration of karst in Myanmar, many locations are already being quarried to produce cement (Grismer et al. 2018a).

The resurgence in herpetological research in Myanmar resulted in the staggering discovery of nearly 50 new species of reptiles and amphibians, especially geckos of the genus *Cyrtodactylus*, of which most species are micro-endemics (Figure 1; Grismer et al. 2018a, 2020b). Among the discoveries was a new species of slender gecko, *Hemiphyllodactylus tonywhitteni*, named in honour of the late Dr. Tony Whitten of Fauna and Flora International, who championed karst conservation throughout southeastern Asia (Grismer et al. 2018b). The results of these discoveries in turn have aided in the formal protection of some karst landscapes in Myanmar, that not just benefit the endemic geckos but all other flora and fauna that inhabit them (Komerički et al. 2020).

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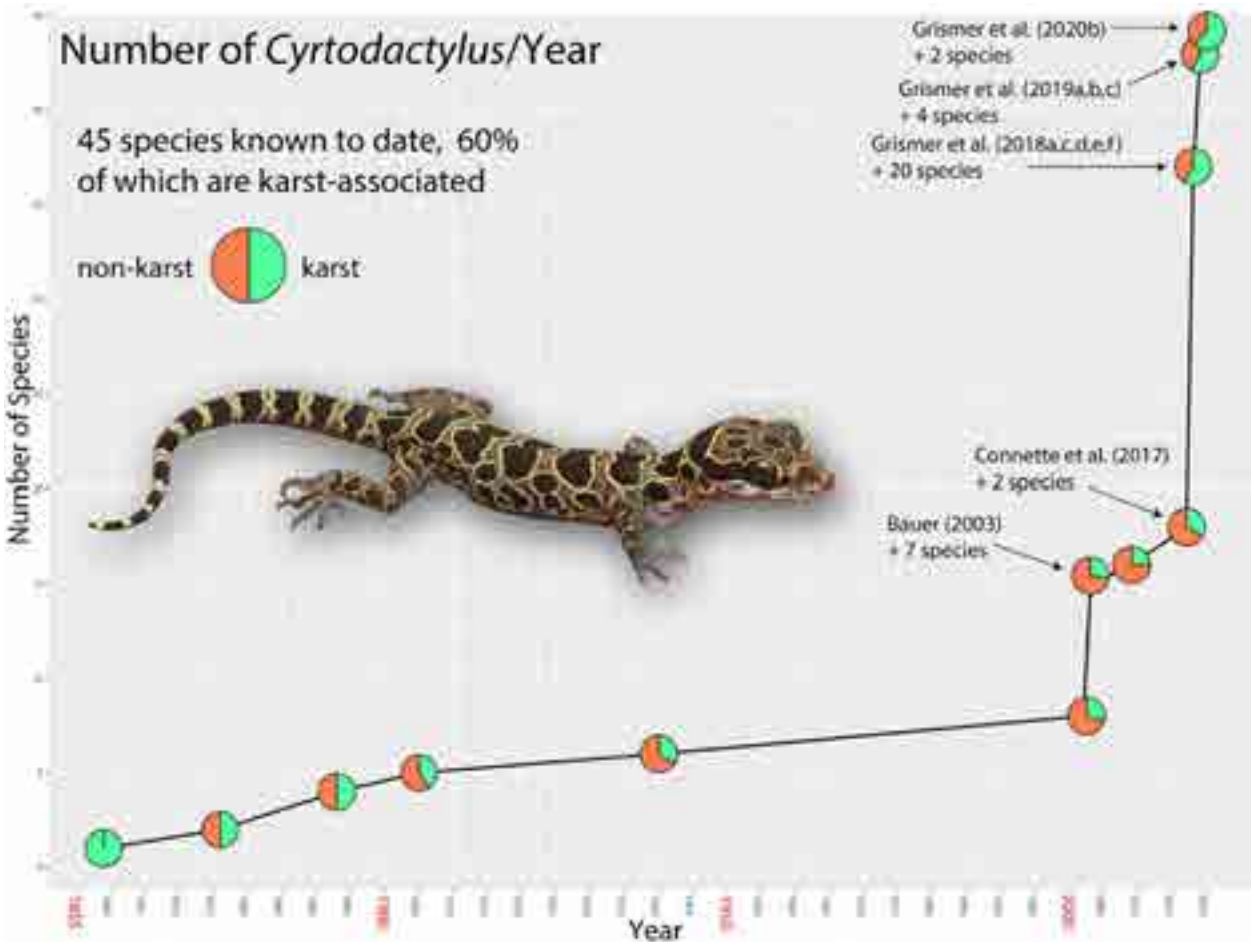

Figure 1. Numbers of *Cyrtodactylus* gecko species known from Myanmar at time intervals of the descriptions of new species (i.e., at the pie charts) and the percentage of those species at those time intervals that are karst-associated (adapted from Grismer et al. 2020c)

Unfortunately, this progress came to a sudden halt in 2020 due to the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2 or COVID-19) pandemic which prevented travel for field work as nations around the globe went into lockdown in an effort to curb the spread of the virus (Corlett et al. 2020; Zahawi et al. 2020). Matters were compounded by the civil unrest which erupted in Myanmar beginning early 2021 which has once again caused great discord in the country. Apart from having cost numerous lives and crippled the economy, both these afflictions have reversed much of the gains that have been made in the past few years in terms of cataloguing the biological diversity of Myanmar, conserving critical habitats, and the enhancement of local capacity of scientific and technical staff in Myanmar.

With the COVID-19 pandemic continuing to rage on around the world and political instability in the country, it may be many more years before research efforts can resume safely in the country. By which time, some of the karst outcrops may have already been completely destroyed and along with it the many countless species found on them, similar to what has happened in Brazil due to weakened environmental protection (Schwartz et al. 2020; Vale et al. 2021). The undoing of a decade of progress in research and conservation is a woeful reminder of the urgency to lay the foundations for on the ground conservation efforts by local stakeholders through knowledge transfer and training. Nevertheless, we remain hopeful that the in-country situation will improve, and researchers will be able to continue the much-needed exploration and discovery phase of the conservation process in the Indo-Burmese biodiversity hotspot.

References

Bauer, A.M. (2003). Descriptions of seven new *Cyrtodactylus* (Squamata: Gekkonidae) with a key to the species of Myanmar (Burma). *Proceedings of the California Academy of Sciences* 54: 463–498.

Connette, G.M., P. Oswald, M.K. Thura, K.J.L. Connette, M.E.

Grindley, M. Songer, G.R. Zug & D.G. Mulcahy (2017). Rapid forest clearing in a Myanmar proposed national park threatens two newly discovered species of geckos (Gekkonidae: *Cyrtodactylus*). *PloS ONE* 12: e0174432. https://doi.org/10.1371/journal.pone.0174432

Corlett, R.T., R.B. Primack, V. Devictor, B. Maas, V.R. Goswami, A.E. Bates, L.P. Koh, T.J. Regan, R. Loyola, R.J. Pakeman, G.S. Cumming, A. Pidgeon, D. Johns & R. Roth (2020). Impacts of the coronavirus pandemic on biodiversity conservation. *Biological Conservation* 246: 108571. https://doi.org/10.1016/j.biocon.2020.108571

Grismer, L.L., P.L. Wood Jr., M.K. Thura, T. Zin, E.S.H. Quah, M.L. Murdoch, M.S. Grismer, A. Lin, H. Kyaw & N. Lwin (2018a). Twelve new species of *Cyrtodactylus* Gray (Squamata: Gekkonidae) from limestone habitats in east-central and southern Myanmar demonstrate high localized diversity and unprecedented microendemism. *Zoological Journal of the Linnean Society* 182: 862–959. https://doi.org/10.1093/zoolinnean/zlx057

Grismer, L.L., P.L. Wood Jr., M.K. Thura, T. Zin, E.S.H. Quah, M.L. Murdoch, M.S. Grismer, A. Lin, H. Kyaw & N. Lwin (2018b). Phylogenetic taxonomy of *Hemiphyllodactylus* Bleeker, 1860 (Squamata: Gekkonidae) with descriptions of three new species from Myanmar. *Journal of Natural History* 52: 881–915. https://doi.org/10.1080/00222933.2017.1367045

Grismer, L.L., P.L. Wood Jr., M.K. Thura, N.M. Win, M.S. Grismer, L.A. Trueblood & E.S.H. Quah (2018c). A redescription of *Cyrtodactylus chrysopylos* Bauer (Squamata: Gekkonidae) with comments on the adaptive significance of bright orange coloration in hatchlings and descriptions of two new species from eastern Myanmar (Burma). *Zootaxa* 4527: 151–185. https://doi.org/10.11646/zootaxa.4527.2.1

Grismer, L.L., P.L. Wood Jr., M.K. Thura, E.S.H. Quah, M.S. Grismer, M.L. Murdoch, R.E. Espinoza & A. Lin (2018d). A new *Cyrtodactylus* Gray (Squamata, Gekkonidae) from the Shan Hills and the biogeography of Bent-toed Geckos from eastern Myanmar. *Zootaxa* 4446: 477–500. https://doi.org/10.11646/zootaxa.4446.4.4

Grismer, L.L., P.L. Wood Jr., M.K. Thura, E.S.H. Quah, M.L. Murdoch, M.S. Grismer, M.W. Herr, A. Lin & H. Kyaw (2018e). Three more new species of *Cyrtodactylus* (Squamata: Gekkonidae) from the Salween Basin of eastern Myanmar underscore the urgent need for the conservation of karst habitats. *Journal of Natural History* 52: 1243–1294; https://doi.org/10.1080/00222933.2018.1449911

Grismer, L.L., P.L. Wood Jr., E.S.H. Quah, M.L. Murdoch, M.S. Grismer, M.W. Herr, R.E. Espinoza, R.M. Brown & A. Lin (2018f). A phylogenetic taxonomy of the *Cyrtodactylus peguensis* group (Reptilia: Squamata: Gekkonidae) with descriptions of two new species from Myanmar. *PeerJ* 6: e5575. https://doi.org/10.7717/peerj.5575

Grismer, L.L., P.L. Wood Jr., M.K. Thura, E.S.H. Quah, J.R. Oaks & A. Lin (2019a). A new species of Bent-toed Gecko (Squamata, Gekkonidae, *Cyrtodactylus*) from the Shan Plateau in eastern Myanmar (Burma). *Zootaxa* 4624: 301–321. https://doi.org/10.11646/zootaxa.4624.3.1

Grismer, L.L., P.L. Wood Jr., E.S.H. Quah, M.K. Thura, M.W. Herr & A.K. Lin (2019b). A new species of forest-dwelling *Cyrtodactylus* Gray (Squamata: Gekkonidae) from the Indawgyi Wildlife Sanctuary, Kachin State, Myanmar. *Zootaxa* 4623: 1–25. https://doi.org/10.11646/zootaxa.4623.1.1

Grismer, L.L., P.L. Wood Jr., M.K. Thura, N.M. Win & E.S.H. Quah (2019c). Two more new species of the *Cyrtodactylus peguensis* group (Squamata: Gekkonidae) from the fringes of the Ayeyarwady Basin, Myanmar. Zootaxa 4577: 274–294. https://doi.org/10.11646/zootaxa.4577.2.3

Grismer, L.L., P.L. Wood Jr., M.D. Le, E.S.H. Quah & J.L. Grismer (2020a). Evolution of habitat preference in 243 species of Bent-toed geckos (Genus *Cyrtodactylus* Gray, 1827) with a discussion of karst habitat conservation. *Ecology and Evolution* 10: 13717–13730. https://doi.org/10.1002/ece3.6961

Grismer, L.L., P.L. Wood Jr., E.S.H. Quah, M.S. Grismer, M.K. Thura, J.R. Oaks & A. Lin (2020b). Two new species of *Cyrtodactylus* Gray, 1827 (Squamata: Gekkonidae) from a karstic archipelago in the Salween Basin of southern Myanmar (Burma). *Zootaxa* 4718: 151–183. https://doi.org/10.11646/zootaxa.4718.2.1

Grismer, L.L., P.L. Wood Jr., E.S.H. Quah & M.K. Thura (2020c). Origin, diversity, and conservation of karst-associated Bent-toed Geckos (Genus *Cyrtodactylus*) in Myanmar (Burma). *Israel Journal of Ecology & Evolution* 2020: 202–208. https://doi.org/10.1163/22244662-20191094

Grismer, L.L., P.L. Wood Jr., N.A. Poyarkov, M.D. Le, S. Karunarathna, S. Chomdej, C. Suwannapoom, S. Qi, S. Liu, J. Che, E.S.H. Quah, F. Kraus, P.M. Oliver, A. Riyanto, O.S.H. Pauwels & J.L. Grismer (2021). Karstic Landscapes are Foci of Species Diversity in the World's Third Largest Vertebrate Genus *Cyrtodactylus* Gray, 1827 (Reptilia: Squamata; Gekkonidae). *Diversity* 13: 183. https://doi.org/10.3390/d13050183

Komerički, A., A. Lin, L. Ngwe & F. Momberg (2020). Myanmar karst key biodiversity areas. Fauna and Flora International Special Report, 104 pp.

Quah, E.S.H., L.L. Grismer & A.M.S. Shahrul (2021). Conservation of Peninsular Malaysia's Karst Herpetofauna: A review of herpetological discoveries, research trends, and challenges. *Raffles Bulletin of Zoology* 69: 235–252.

Schwartz, M.W., J.A. Glikman & C.N. Cook (2020). The COVID-19 pandemic: A learnable moment for conservation. *Conservation Science and Practice* 2: e255. https://doi.org/10.1111/csp2.255

Vale, M.M., E. Berenguer, M.A. de Menezes, E.B.V. de Castro, L.P. de Siqueira & R.d.C.Q Portella (2021). The COVID-19 pandemic as an opportunity to weaken environmental protection in Brazil. *Biological Conservation* 255: 108994. https://doi.org/10.1016/j.biocon.2021.108994

Zahawi, R.A., J.L. Reid & M.E. Fagan (2020). Potential impacts of COVID-19 on tropical forest recovery. *Biotropica* 52: 803–807. https://doi.org/10.1111/btp.12851

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SHORT COMMUNICATION

Morphological characterization and mt DNA barcode of a tiger moth species, *Asota ficus* (Fabricius, 1775) (Lepidoptera: Noctuoidea: Erebidae: Aganainae) from India

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Abstract: The members of the genus *Asota* are widely distributed from Africa, India, Sri Lanka, Myanmar, and Malayan regions to the Australian region containing 55 described species. *Asota ficus* (Fabricius, 1775) is one among the nine species of the genus described from India having a wide range of distribution. The present study includes the first mitochondrial DNA barcode generated from India for *A. ficus* with a valid voucher describing external morphological characters together with the male and female genitalia. Discussions pertain to the utility of DNA barcodes for studies on moths in India with a comment on the identity of other sequences showing shallow genetic divergence with our sequences.

Keywords: Arctiinae, Ficus, genitalia study, Hypsa, Lepidopterism, Maharashtra, Mitragyna, molecular study, mt COI, Ricinus.

The subfamily Aganainae Boisduval, 1833 was earlier considered as family Aganaidae or Hypsidae (Inoue et al 1982). Later studies considered it as subfamily Hypsinae of Arctiidae (Seitz 1914; Daniel 1943) or subfamily Aganainae of Noctuidae (Holloway 1988; Scoble 1992; Kitching & Rawlins 1998). Until molecular studies, the familial position was unstable, later on phylogenetic studies placed the subfamily Aganainae under the family Erebidae (Fibiger & Lafontaine 2005; Zahiri et al. 2012). Aganainae includes 109 species of 11 genera worldwide (Zahiri et al. 2012; Bayarsaikhan et al. 2016).

Many Aganainae moths are large, brightly coloured, aposematic, with bare lower frons and long upturned labial palps having long and slender third segment; vein M2 in forewing arises closer to the origin of M3 than M1, in the lower part of the discal cell; Cu appearing four-branched; vein M2 in the hindwing is present so Cu appears four-branched (Holloway 1988; Zahiri et al. 2012). The larvae have single subventral seta on the mesothoracic and metathoracic segments. The subfamily exhibits a sister relationship with Arctiinae with a strongly supported pairing (Zahiri et al 2011).

Moths from this subfamily are pests on plant species of Apocynaceae, Asclepiadaceae, Moraceae (Holloway 1988; Common 1990; Bayarsaikhan et al. 2016), and lactiferous families that contain cardenolides (Bayarsaikhan et al. 2016). They feed on poisonous plants, and hence are often aposematic day flyers (Kitching & Rawlins 1998; Bayarsaikhan et al. 2016).

The genus *Asota* Hübner, [1819] was erected by Jacob

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Hubner in 1819 considering *Phalaena javana* (Cramer, [1780]) from Java as type species. So far, 55 species are known from this genus including nine from India. The *Asota* species reported from India are: *caricae* (Fabricius, 1775); *plana* (Walker, 1854); *canaraica* (Moore, 1878); *egens* (Walker, 1854); *ficus* (Fabricius, 1775); *heliconia* (Linnaeus, 1758); *paphos* (Fabricius, 1787); *producta* (Butler, 1875); *sericea* (Moore, 1878). *A. ficus* was placed under the genus *Hypsa* as *Hypsa ficus* by Hampson (1892) under the family Hypsidae: section-II. Hampson (1892) divided the genus *Hypsa* under two sections on the basis of structure of antennae. In Section-I the antennae of males are fasciculated with short cilia. The fasciculated male antennae, long cilia and the long 3rd segment of palpi forms the section-II. Caterpillar of *A. ficus* is recorded feeding mainly on castor and ficus.

The genus *Asota* is responsible for Lepidopterism, a disease caused by the adult or the caterpillar of moths or butterflies (Wills et al. 2016). In Kerala India, it was reportedly caused by the tiger moth *A. caricae* (Anonymous 2016). The fever caused by Lepidopterism mimics the symptoms of the mosquito borne infectious diseases like chikungunya and dengue. The adult moths, while emerging from the pupae, extricate the scales on their body and secretes fluids (Anonymous 2016) which lead to the high fever either when in contact with the human skin or due to inhalation. As per Wills et al. (2016), allergic reactions are due to the presence of poisonous chemicals like histamines, imidazole and peptides.

DNA barcoding is a quick and reliable nucleotide-based identification technique across the animal kingdom, founded on the mitochondrial Cytochrome oxidase I gene (mt COI) by Hebert's group in 2003. The ability of COI sequences to discriminate closely allied species based on restricted intraspecific mitochondrial DNA divergence and utilizing it as an aid to resolve the alpha diversity of species in diverse taxonomic groups including Lepidoptera has been validated (Hebert et al. 2003b). These species-specific signatures, identified as DNA barcodes help to delimit the problematic taxa (Hebert et al. 2003a) also in cases where identification is not possible with the traditional taxonomic techniques alone. DNA barcode not only provides a boon to taxonomic research but also serves as a form of comprehensive, widely accessible system for identification and validation of species. Hence, in the present study an attempt has been made to develop a DNA barcode for the species *A. ficus* from Maharashtra along with its morphological description (adult together with external genitalia); the utility of mt DNA barcodes in the Indian moth studies are discussed.

Materials and Methods

Moth specimens were collected using a light trap having mercury vapour lamp as a light source of 160 W. It was hung in the middle of the white sheet installed in the field during the night. Moth specimens that were captured were euthanized by ethyl acetate vapours. Then they were transported to the laboratory in insect packets (made of butter paper) for further analysis.

In the laboratory, the specimens were stretched, pinned and stored in entomological boxes filled with preservatives. For morphological studies the specimens were studied under Leica EZ4E stereomicroscope. The map of the collection locality was prepared using open free QGIS software. The details of the collection locality are given under the material examined and is also shown in Figure 1. Identification of the specimens was done as per Hampson (1892). Male and female genitalia were studied following Robinson (1976). The identified specimens are deposited at the National Zoological Collections of the Zoological Survey of India, Western Regional Centre, Pune, Maharashtra, India (ZSI/WRC).

DNA extraction was performed using DNeasy blood and tissue kit (Qiagen) using leg and abdomen of a dried specimen. DNA quantitation was performed by HS dsDNA assay kit on Qubit 2.0 fluorometer. Mitochondrial COI (mt COI) gene was amplified using universal primer pair, LCO1490 and HCO2198 (Folmer et al. 1994) in 25 µL reaction volume constituted by 12.5 µL of Master Mix (Promega), 10 pmol of each forward and reverse primer, 50 ng of template DNA along with Nuclease free water up to Q.S. Thermal cycling profile performed as per Kalawate et al. (2020a). Amplification of the desired gene was confirmed by gel electrophoresis stained by SYBR safe DNA gel stain (Invitrogen), visualized under UV by gel documentation system. Purification of the amplified product was done by Invitrogen's Pure Link PCR Purification Kit. The purified PCR product was sequenced bi-directionally by Sanger's method on ABI 377 (Applied Biosciences) sequencer.

Both the forward and reverse sequences generated in the current studies were verified manually for corrections. Initially 838 mt COI gene sequences available for the genus *Asota* were downloaded from the GenBank and were aligned using MEGA 5.2 software (Tamura et al 2011). MEGA 5.2 (Tamura et al. 2013) was used for calculating uncorrected pairwise genetic distances. Initial tree was built (using MEGA 5.2) including all reported species with molecular data for the genus *Asota*, comprising 235 sequences excluding identical sequences from the same locality for a single species/subspecies. Since mt COI is not a good candidate

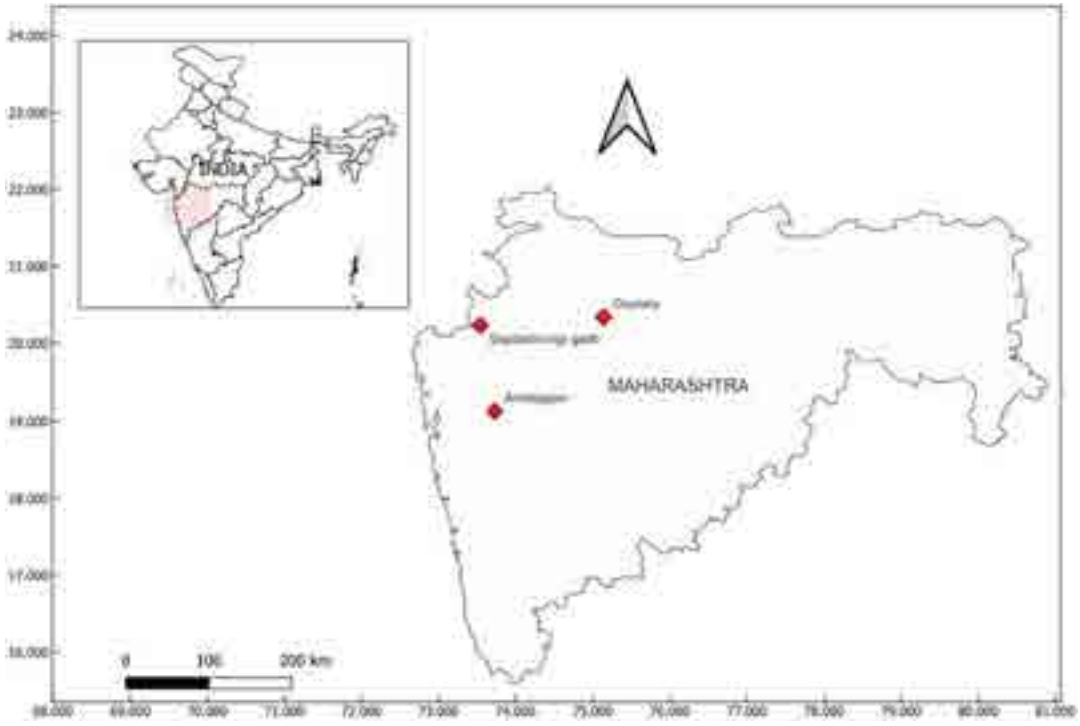

Figure 1. Collection localities of *Asota ficus* from Maharashtra, India.

gene for phylogenetic studies (Cameron et al. 2004; Lafontaine & Schmidt 2010) and our initial single gene phylogenetic tree ended up in polytomies without proper phylogenetic relationships, we considered presenting the phylogenetic tree comprising all the sequences of *A. ficus* available on the GenBank with the sequences generated by us and the probable sister species *A. speciosa* treating species *Neochera inops* as an outgroup. The phylogenetic inferences drawn are only to show the monophyly of all the sequences of *A. ficus*. Maximum likelihood tree was generated using RaxML (Silvestro & Michalak 2012) with thorough bootstrap of 1,000 replicates under the GTR+GAMMA+I model and the final consensus tree was visualized by Fig Tree v1.4.0. Sequences generated in the studies are submitted to the GenBank (OL630456.1 & OL630457.1).

Result and Discussions

Taxonomic account

Superfamily Noctuoidea Latreille, 1809
Family Erebidae Leach, [1815]
Subfamily Aganainae Boisduval, 1833
Genus *Asota* Hübner, [1819]
Asota Hübner, [1819], *Verz. bek. Schmett*. (11): 164.
Type Species: *Phalaena javana* (Cramer, [1780])

***Asota ficus* (Fabricius, 1775)**

Noctua ficus Fabricius,1775*, Syst. Ent*.: 595.
Lacides ficus, Moore,188, *Lep. Ceylon,* 2(1): 53, pl. 100, f. 2.
Hypsa ficus, Hampson,1892*, Fauna Brit. India, Moths*, 1: 504.
Type Locality. India.

Material examined/source: 01 male, Saptashringigadh, Nashik, Maharashtra, India (20.23N, 73.54E; 1,000 m), 06 November 2016, coll. A.S. Kalawate (ZSI/WRC/L-1482); 01 female, Ambegaon, Pune, Maharashtra, India (19.13N, 73.73E; 730 m), 23 June 2017, coll. A.S. Kalawate & party (ZSI/WRC/L-1780); 02 male, Bhaskaracharya Forest Rest house, Gautala, Jalgaon, Maharashtra, India (20.34N, 75.14E; 711 m), 27 September 2019, coll. P.S. Bhatnagar & party (ZSI/WRC/L-2069).

Morphological description: Adult (Image 1A,B). Wing expanse: 55 mm in male and 63 mm in female. Antennae of male fasciculated, cilia long; 3rd joint of palpi long, grey in colour, tipped with black. Head, thorax and abdomen orange-yellow; tegulae with yellow base and a black spot. Abdomen with series of black spots. Orange basal patch on forewing extending along costa and in cell to two-third length of cell, an orange spot encircled with black on the costa, and streaks in cell and on inner margin, two black spots on costa and in

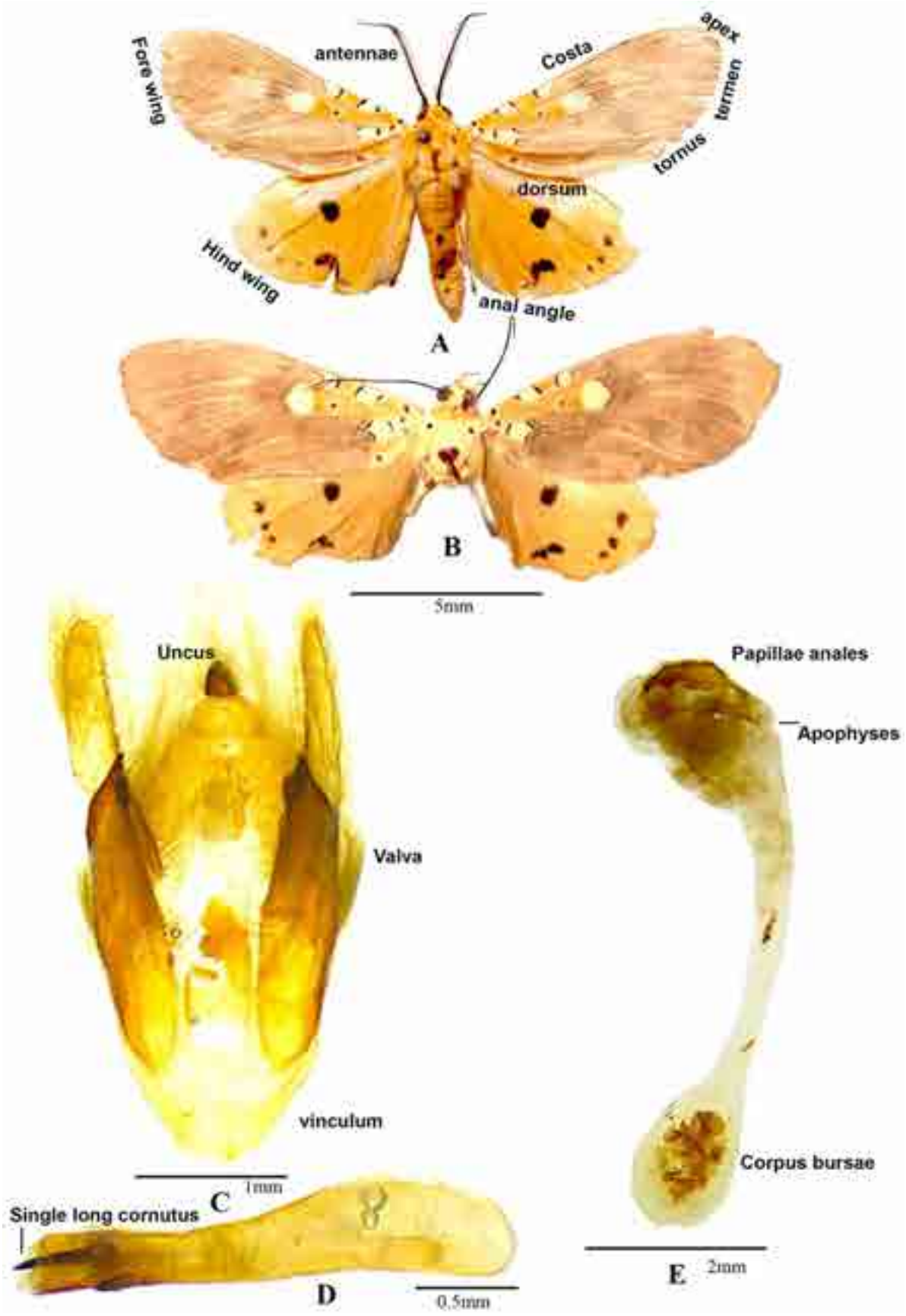

Image 1. *Asota ficus*: A—Male | B—Female | C—Genitalia | D—Aedeagus | E—Female genitalia.

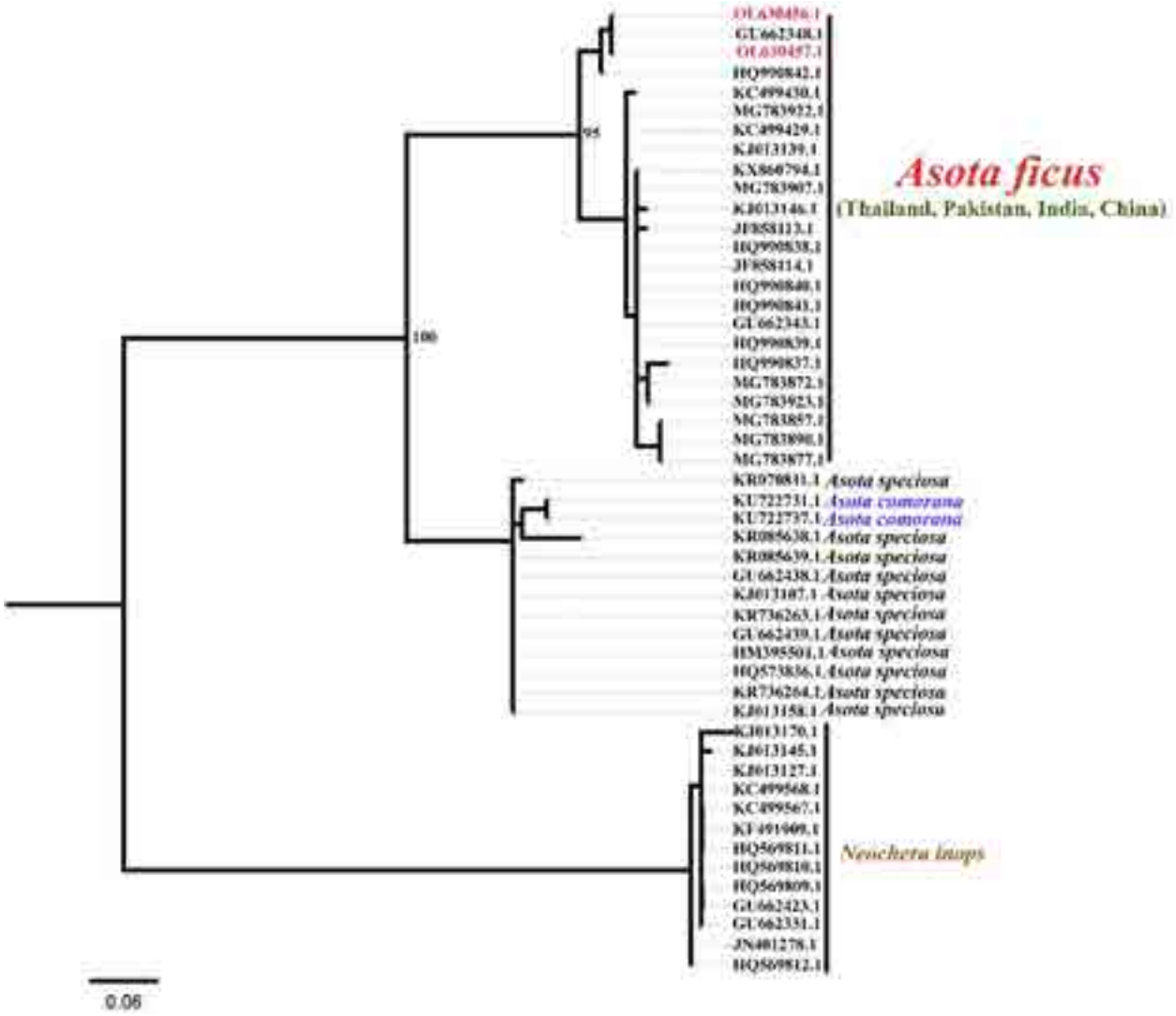

Figure 2. Maximum likelihood (ML) tree for the species of Asota based on the 578 bp of mitochondrial COI DNA gene sequences.

cell, one on inner margin, and two lines across interno-median interspace; rest of the wing olive-brown, the veins are striped with yellow. Hind wing bright orange-yellow; black spot at end of cell and series of irregular sized and placed black spots at submarginal area. Male and female are similar in external morphology except antennae. In male they are, fasciculated with long cilia and very short cilia in female.

Male genitalia (Image 1C). Uncus long, highly sclerotised broad till middle and then narrowing down, apex pointed recurved. Tegumen longer than the uncus, moderately sclerotised with broad arms, inverted v-shaped; valvae symmetrical, weakly sclerotised, setosed, costa strongly produced into a long process, harpe with a pointed process; vinculum longer than tegumen, u-shaped; juxta elongated; Aedeagus (Image 1D) long, relatively thin, apical portion dentate ventrally. Vesica membranous with single, long cornutus.

Female genitala (Image 1E). Corpus bursae oblong, membranous; ductus bursae long, membranous; ostium bursae simple, sclerotized; posterior and anterior apophyses are of equal length, sclerotized; papilla analis oval, heavily sclerotized with setae.

Distribution: India (throughout including Maharashtra), China, Japan, Malaysia, Myanmar, Nepal, Sri Lanka, Taiwan, and Thailand.

Host plants. *Ricinus communis*, *Ficus carica, F. hispida, F. racemosa, F. pumila, F. infectoria, F. religiosa,* and *Mitragyna diversifolia* (ICAR-NBAIR 2020).

DNA barcode studies: In the GenBank a total of 22 sequences of mt COI are available for *A. ficus* (Table 1), of which nine sequences are from India. Within India, these sequences are from the states of Assam, Maharashtra and Tamil Nadu (all are unpublished data

Table 1. Details of the mt COI GenBank accession numbers of *Asota* utilised in the construction of ML phylogenetic tree.

	GenBank Accession No.	Locality	Species name as per NCBI	Publication details as per NCBI
1	GU662348.1	Thailand: Chiang Mai	*Asota ficus*	Unpublished
2	OL630456.1	India: Maharashtra, Nasik, Saptashrungigadh.	*Asota ficus*	Current study
3	OL630457.1	India: Maharashtra , Jalgaon	*Asota ficus*	Current study
4	HQ990842.1	Pakistan	*Asota ficus*	Unpublished
5	KC499430.1	India: Tamil Nadu, Kalkad	*Asota ficus*	Unpublished
6	MG783922.1	India: Maharashtra	*Asota ficus*	Unpublished
7	KC499429.1	China: Yunnan	*Asota ficus*	Unpublished
8	KJ013139.1	India: Assam,	*Asota ficus*	Unpublished
9	KX860794.1	Pakistan: Punjab	*Asota ficus*	Ashfaq et al. (2017)
10	MG783907.1	India: Maharashtra	*Asota ficus*	Unpublished
11	KJ013146.1	India: Nameri NP	*Asota ficus*	Unpublished
12	JF858113.1	Pakistan	*Asota ficus*	Unpublished
13	HQ990838.1	Pakistan	*Asota ficus*	Unpublished
14	JF858114.1	Pakistan	*Asota ficus*	Unpublished
15	HQ990840.1	Pakistan	*Asota ficus*	Unpublished
16	HQ990841.1	Pakistan	*Asota ficus*	Unpublished
17	GU662343.1	Thailand: Chiang Mai	*Asota ficus*	Unpublished
18	HQ990839.1	Pakistan	*Asotaficus*	Unpublished
19	HQ990837.1	Pakistan	*Asota ficus*	Unpublished
20	MG783872.1	India: Maharashtra	*Asota ficus*	Unpublished
21	MG783923.1	India: Maharashtra	*Asota ficus*	Unpublished
22	MG783857.1	India: Maharashtra	*Asota ficus*	Unpublished
23	MG783890.1	India: Maharashtra	*Asota ficus*	Unpublished
24	MG783877.1	India: Maharashtra	*Asota ficus*	Unpublished
25	KR070811.1	Kenya: Kajiado North	*Asota speciosa*	Unpublished
26	KU722731.1	Comoros: Grande Comore	*Asota comorana*	Unpublished
27	KU722737.1	Comoros: Grande Comore	*Asota comorana*	Unpublished
28	KR085638.1	Zambia: Victoria Falls	*Asota speciosa*	Unpublished
29	KR085639.1	Zambia: Lusaka Ridgeway	*Asota speciosa*	Unpublished
30	GU662438.1	Nigeria: Laeinde	*Asota speciosa*	Unpublished
31	KJ013107.1	Tanzania: Mbizi forest	*Asota speciosa*	Unpublished
32	KR736263.1	Nigeria:Oyo	*Asota speciosa*	Unpublished
33	GU662439.1	Cameroon: North Province	*Asota speciosa*	Unpublished
34	HM395501.1	Gabon: WoleuNamiTchimble	*Asota speciosa*	Unpublished
35	HQ573836.1	Gabon: Ogooue-Ivindo	*Asota speciosa*	Unpublished
36	KR736264.1	Nigeria:Oyo	*Asota speciosa*	Unpublished
37	KJ013158.1	Ethiopia: Arba Minch	*Asota speciosa*	Unpublished
38	KJ013170.1	Laos: Nang Phoa	*Neochera inops*	Unpublished
39	KJ013145.1	Laos: Nang Phoa	*Neochera inops*	Unpublished
40	KJ013127.1	Laos: Namha protected area,	*Neochera inops*	Unpublished
41	KC499568.1	Indonesia: Kalimantan Barat	*Neochera inops*	Unpublished
42	KC499567.1	China: Hainan	*Neochera inops*	Unpublished
43	KF491909.1	Malaysia	*Neochera inops*	Unpublished
44	HQ569811.1	Thailand: Nan	*Neochera inops*	Unpublished
45	HQ569810.1	India: Meghalaya	*Neochera inops*	Unpublished
46	HQ569809.1	VietNam: Tam Dao	*Neochera inops*	Unpublished
47	GU662423.1	Thailand: Chiang Mai	*Neochera inops*	Unpublished
48	GU662331.1	Thailand: Chiang Mai	*Neochera inops*	Unpublished
49	JN401278.1	Japan	*Neochera inops*	Zahiri et al. (2012)
50	HQ569812.1	Malaysia: Sarawak	*Neochera inops*	Unpublished

as per GenBank). The current study forms the first published record of DNA barcode for the species *A. ficus* from India with assigned voucher numbers.

In the preliminary phylogenetic tree generated for the studies, all the mt DNA barcodes formed a monophyletic clade for the species *A. ficus* (Figure 2) showing genetic distance variance from 0.6% to 1.3%. The clade comprising *A. speciosa* and *A. comorana* showed sister relationship with the clade of *A. ficus*, wherein genetic distance between the species *A. ficus* and *A. comorana* was 2.9% and *A. ficus* and *A. speciose* was 3.4%. In the present study *A. comorana* is nested within *A. speciosa* which suggests either one of the species was wrongly identified ending up in mislabelled sequences or synonymy of these two taxa. Further studies are necessary to resolve the identity and validity of the species *A. comorana* as the genetic distance between the species *A. speciosa* and *A. comorana* is too shallow (0.6–1.7 %).

Evolutionary distances are fundamental in molecular reconstructions including phylogenetic analysis (Nei & Kumar 2000). The nucleotide substitution method is widely used to calculate a reliable genetic difference between pairs of sequences (Nei & Kumar 2000). Since there are limitations with the mt COI gene (Cameron et al. 2004; Hebert & Gregory 2005; Lafontaine & Schmidt 2010), we suggest further studies to comment on the phylogenetic relationships among the species of the genus *Asota*. Nuclear DNA (n DNA) studies are advocated (Zahiri et al. 2012) to study ancient evolutionary divergence for resolving deeper nodes above species level, having slower mutation rate than mt DNA.

In India, generation of mt COI DNA barcodes for moths is still in a stage of infancy. Recently, Kalawate et al (2020a) have reported the palearctic moth species *Olepa schleini* Witt et al. 2005 from India with a description of subspecies based on the DNA barcode studies and morphological variations. Additionally, Kalawate et al. (2020b) described three new species along with a subspecies and provided the description of multiple morphotypes of *Olepa* from India. These studies clearly endorse the utility of DNA barcodes in identification of palearctic species from India (Kalawate et al. 2020a). This technique further avoids taxonomic inflation by describing morphologically different looking morphotypes as a new species (Kalawate et al. 2020b). Further, DNA barcode studies are expected to alleviate identification of morphologically variant species and uncover the cryptic diversity prevailing within the taxonomic groups. Multigene phylogenetic analysis is warranted to decipher the phylogenetic relationships across the members of the family which are wide spread in distribution range.

References

Anonymous (2016). Alert issued for fever caused by tiger moth. http://timesofindia.indiatimes.com/articleshow/51869389.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst assessed 01.12.2020.

Ashfaq, M., S. Akhtar, M.A. Rafi, S. Mansoor & P.D. Hebert (2017). Mapping global biodiversity connections with DNA barcodes: Lepidoptera of Pakistan. *PLoS ONE* 12(3): e0174749. https://doi.org/10.1371/journal.pone.0174749

Bayarsaikhan, U., N. Sol-Moon & B. Yang-Seop (2016). Review of the subfamily Aganainae (Lepidoptera, Erebidae) from Cambodia. *Journal of Asia-Pacific Biodiversity* 9(2): 219–229. https://doi.org/10.1016/j.japb.2016.02.010

Cameron, S.L., K.B. Miller, C.A. D'Haese, M.F. Whiting & S.C. Barker (2004). Mitochondrial genome data alone are not enough to unambiguously resolve the relationships of Entognatha, Insecta and Crustacea sensu lato (Arthropoda). *Cladistics* 20(6): 534–557. https://doi.org/10.1111/j.1096-0031.2004.00040.x

Common, I.F.B. (1990). Moths of Australia. E.J. Brill and Melbourne University Press, New York.128 pp.

Daniel, F. (1943). Beiträge zur Kenntnis der Arctiidae Ostasiens unter besonderer Berücksichtigung der Ausbeuten H. Höne's aus diesem Gebiet (Lep. Het.). II Teil. Hypsinae, Micrarctiinae, Spilosominae, Arctiinae. Mitteilungen der München Entomologischen Gesellschft 33: 673–759.

Fibiger, M. & J.D. Lafontaine (2005). A review of the higher classification of the Noctuoidea (Lepidoptera) with special reference to the Holarctic fauna. *Esperiana* 11: 7–92.

Folmer, O., W.R. Hoeh, M.B. Black & R.C. Vrijenhoek (1994). Conserved primers for PCR amplification of mitochondrial DNA from different invertebrate phyla. *Molecular Marine Biology and Biotechnology* 3(5): 294–299.

Hampson, G.F. (1892). *The fauna of British India including Ceylon and Burma, Moths - Volume* 1. Taylor and Francis, London, 504 pp.

Hebert, P.D., S. Ratnasingham & J.R. deWaard (2003a). Barcoding animal life: cytochrome c oxidase subunit 1 divergences among closely related species. *Proceedings Biological sciences* 270 (Suppl. 1): S96–S99. https://doi.org/10.1098/rsbl.2003.0025

Hebert, P.D., A. Cywinska, S.L. Ball & J.R. deWaard (2003b). Biological identifications through DNA barcodes. *Proceedings Biological Sciences* 270(1512): 313–21. https://doi.org/10.1098/rspb.2002.2218

Hebert, P.D.N. & T.R. Gregory (2005). The promise of DNA barcoding for taxonomy. *Systematic Biology* 54 (5): 852–859. https://doi.org/10.1080/10635150500354886

Holloway, J.D. (1988). The Moths of Borneo, part. 6: family Arctiidae, subfamilies Syntominae, Euchromiinae, Arctiinae; Noctuidae misplaced in Arctiidae (Camptoloma, Aganaidae). SouthdeneSdnBhd, Kuala Lumpur.

ICAR-NBAIR (2020). *Asota ficus*. https://www.nbair.res.in/Databases/Databases/insectpests/Asota-caricae php+&cd=12&hl=en&ct=clnk&gl=in accessed 08.xii.2020.

Inoue, H., S. Sugi, H. Kuroko, A. Kawabe & M. Owada (1982). Moths of Japan. Kodansha, Tokyo, 344–405 pp.

Kalawate, A.S., S. Pawara, A. Shabnam & K.P. Dinesh (2020a). DNA barcode reveals the occurrence of Palearctic *Olepas chleini* Witt et al., 2005 (Lepidoptera: Erebidae: Arctiinae) from peninsular India with morphological variations and a new subspecies. *Journal of Threatened Taxa* 12(9): 16143–16152. https://doi.org/10.11609/jot.5596.12.9.16143-16152

Kalawate, A.S., K.P. Dinesh & A. Shabnam (2020b). DNA barcoding unravels three new species and a subspecies of *Olepa* Watson, 1980 (Lepidoptera, Erebidae, Arctiinae) from India, with

morphotypes. *Journal of Insect Biodiversity* 19(2): 44–60. https://doi.org/10.12976/jib/2020.19.2.2

Kitching, I.J. & J. Rawlins (1998). The Noctuoidea, pp. 355–401. Kristensen, N.P. (ed.). *Handbook of Zoology, Lepidoptera, Moths and Butterflies, Vol. 1. Evolution, Systematics, and Biogeography*. W. de Gruyter, Berlin.

Lafontaine, J.D. & B.C. Schmidt (2010). Annotated check list of the Noctuoidea (Insecta, Lepidoptera) of North America north of Mexico. *ZooKeys* 40: 1–239. https://doi.org/10.3897/zookeys.40.414

Nei, M. & S. Kumar (2000). *Molecular Evolution and Phylogenetics*. Oxford University Press, 333 pp.

Robinson, G.S. (1976). The preparation of slides of Lepidoptera genitalia with special reference to the Microlepidoptera. *Entomologist's Gazette* 27(2): 127–132.

Scoble, M.J. (1992). *The Lepidoptera. Form, Function and Diversity*. Oxford University Press, Oxford, 404 pp.

Seitz, A. (1914). The Macrolepidoptera of the world. II. Division: Fauna Exotica, A. Kernen, Stuttgart, 10: 105–290 (Bombyces and Sphinges of the Indo-Australian Region). https://doi.org/10.5962/bhl.title.9400

Silvestro, D. & I. Michalak (2012). raxmlGUI: a graphical front-end for RAxML. *Organisms Diversity & Evolution* 12(4): 335–337.

Tamura, K., D. Peterson, N. Peterson, G. Stecher, M. Nei & S. Kumar (2011). MEGA5: Molecular Evolutionary Genetics Analysis using Maximum Likelihood, Evolutionary Distance and Maximum Parsimony Methods. *Molecular Biology and Evolution* 28(10): 2731–2739. https://doi.org/10.1093/molbev/msr121

Wills, P.J., M. Anjana, M. Nitin, R. Varun, P. Sachidanandan, T.M. Jacob, L. Madhavan, R.V. Thampah & K.K. Varma (2016). Population explosions of Tiger Moth lead to Lepidopterism mimicking infectious fever outbreaks. *PLoS ONE* 11(4): e0152787. https://doi.org/10.1371/journal.pone.0152787

Zahiri, R., I.J. Kitching, J.D. Lafontaine, M. Mutanen, L. Kaila, J.D. Holloway & N. Wahlberg (2011). A new molecular phylogeny offers hope for a stable family level classification of the Noctuoidea (Lepidoptera). *Zoologica Scripta* 40(2): 158–173.

Zahiri, R., J.D. Holloway, I.J. Kitching, J.D. Lafontaine, M. Mutanen, & N. Wahlberg (2012). Molecular phylogenetics of Erebidae (Lepidoptera, Noctuoidea). *Systematic Entomology* 37(1): 102–124. https://doi.org/doi:10.1111/j.1365-3113.2011.00607.x

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SHORT COMMUNICATION

Distribution of Smooth-coated Otters *Lutrogale perspicillata* (Mammalia: Carnivora: Mustelidae): in Ratnagiri, Maharashtra, India

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Abstract: This report describes the distribution of Smooth-coated otters in Ratnagiri, Maharashtra, and investigates the utility of scat counts for quantifying otter occurrence. The study duration was from February to June 2020. Surveys were conducted along the Jog River in Anjarle and Aade River in Aadekond using camera traps. The results subjected to principal component analysis indicated that the occurrence of Smooth-coated Otters at Anjarle is 76% and at Aadekond 48%. We also mapped the distribution and threats associated with Smooth-coated Otters. This study serves as a baseline for efforts to support long-term otter research and conservation.

Keywords: Anjarle, conservation, distribution, Otter, scat counts, status, threats.

Otters are prime indicators of the status of wetland ecosystems, where they are often the key predators. According to the IUCN Red List, the conservation status of the Smooth-Coated Otter *Lutrogale perspicillata* is 'Vulnerable' (Image 1). It is listed in the CITES under Appendix I, and in India, it is a Scheduled II species under the Wildlife (Protection) Act, 1972, which prevents/ prohibits any person from hunting, trapping, trade of its products and killing of the species.

In Maharashtra, otters have been largely overlooked, and with growing concerns over deforestation, the shrinking of wetlands, and the constant conversion of wetlands for development, the focus needs to be shifted to small carnivores like otters. This paper aims to provide scientific data on the distribution and status of otters in Anjarle, Ratnagiri. Spraint/ scat surveys have been widely used and provide a reliable picture to assess the distribution of otters (Mason & Macdonald 1987). However, direct observations and counting individuals are difficult especially since the Smooth-coated Otter is both elusive and has a large home range. For such species, indirect field census methods (Tracks, scat, territory marking sites, dens) have been developed to estimate their distribution, and their population trends (Wilson & Delahay 2001; Sittenthaler et al. 2020).

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Methods

Study area

Ratnagiri is a district situated on the western coast of Maharashtra, having nine talukas (townships). Being open to the sea, it has a large population dependent on fishing for their livelihood. Our selected field site for research on otters is Anjarle (17.846N & 73.087E) (Image 2), a small village situated in Dapoli Taluka. It is more significant for wildlife than other talukas, as the Anjarle beach is a nesting site for Olive Ridley Sea Turtles *Lepidochelys olivacea* (Image 3). Every year, tourists flock to see the hatchlings going into the sea.

Part of the local population is aware of the otters and their whereabouts; however, knowledge of otters is scarce amongst the general population in India, and the villagers and tourists coming to Anjarle are no different.

Scat surveys have become the method of choice to monitor species distribution, population trends, and habitat use (Sittenthaler et al. 2020). The total length of the Jog River, about 33.3 km, and the Aade River, about 10.62 km, was digitized using Google Earth and QGis; 2.5 km survey grids were placed on the river.

In each grid, a transect was done; in each transect was of 50 × 250 m (left and right bank of the river) was used. Six survey replicates were conducted in each grid (Mason & Macdonald 2009; Borker 2014).

Surveys were carried out from February to June 2020, as the summer season is the best time to survey otters, as sightings and otter signs are easier to detect. During transects surveys, otter signs (pugmarks, grooming sites, holts/dens) were recorded. GPS essentials were used to mark the latitude and longitude of any otter sign. Plots with otter signs were considered as 'used plot' and plots adjacent to that (upstream and downstream) were termed 'available plot' (this is done to reduce the dependency of plot use).

A plot was only considered a 'new plot' if otter signs are present, and there was a 5 m or more distance between the new and old otter signs. Camera trapping was used to record species identification (Image 5, 7; Video 1), but mostly focused on otter activity and group size (Mudappa et al. 2012; Khan et al. 2014; Prakash et al. 2014).

Identifying the current status of otters

Threats faced by otters were visually identified and recorded during the surveys. These threats were taken into account during the analysis, which acted as covariates to measure impact on distribution.

Image 1. Aerial photograph of a Smooth-Coated Otter in Anjarle

Image 2. Field shot of Anjarle.

Image 3. Female Olive Ridley Sea Turtle *Lepidochelys olivacea* returning to sea after laying eggs at the field site in Anjarle.

Data analysis

It was assumed (Foster-Turley 1992; Barrios 2020) that otters in human-modified areas would be nocturnal or crepuscular, and that this would create difficulty in using direct observation to estimate occupancy. As a

Image 4. Smooth-coated Otter feasting on a mud crab (Kirva).

result, distribution and frequency of spraint and tracks (indirect signs) were used. To estimate the percentage of area occupied by otters, we used principal component analysis (PCA) coupled with logistic regression with forward stepwise analysis. Scores of those were considered as the percentage of occurrence of otters.

Results

The estimated length of the Jog River surveyed is about 33.3 km starting from Sondeghar, flowing to Matwan to Sakurde to Bandhativare to Sarang to Tadil to Kongale to Murdi, and ending into Anjarle (Arabian Sea) on the western Coast of Maharashtra, India. The estimated proportion of the length of Jog River occupied by Smooth-coated Otters was 76.2% based on our sign survey as shown in Figure 1.

The estimated length of the Aade River surveyed is about 10.6 km starting from Aade to Adekond to Lonvadi to Borthal dam. The estimated proportion of the length of Aade River occupied by Smooth-coated Otters was 47.6% based on our sign survey as shown in Figure 2.

Threats to the Otter population

Habitat loss: For otters, the requirement to breed, rest, and defecate is vital. In our study area, these roles are carried out within the mangrove forests. Places like sandbanks, soil, or even leaf litter act as grooming and defecation areas for otters along the river banks. Such areas are in decline owing to illegal sand mining and increasing conversion of wetlands into agricultural areas (Image 6).

Sand mining poses a direct threat to habitat of many species, as uncontrolled extraction of benthic sand from rivers (Image 6) and from riverbanks leads to an increase in water depth, loss of prey base, and habitat degradation and loss. Some stretches of the rivers are completely degraded because of sand mining.

Otter-fisherman competition

In certain areas with high fish resources, high fishing activity and high otter activity have been observed, showing a positive correlation of 0.663 with otter presence (Table 1).

These are potential otter conservation zones, but measures need to be taken to ensure fishermen who are dependent on the particular zone are provided with some alternative, or that sustainable methods that allow otters to coexist are adopted

Discussion

Otters are widely distributed in Anjarle and Aadekond, and a survey of spraints using standard methodology gives a reliable picture of otter distributions. According to informal interviews, food-rich zones are prime areas for

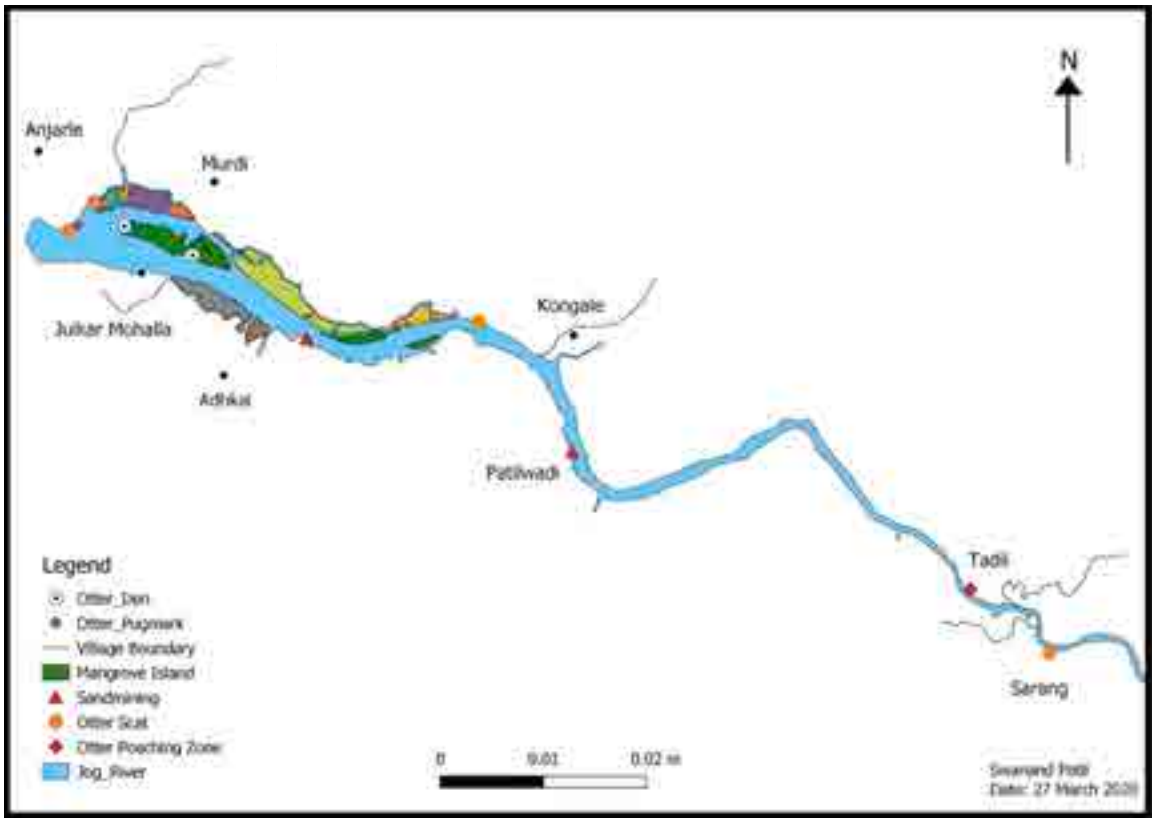

Figure 1. Map showing Smooth-coated Otter distribution in Jog River, Anjarle.

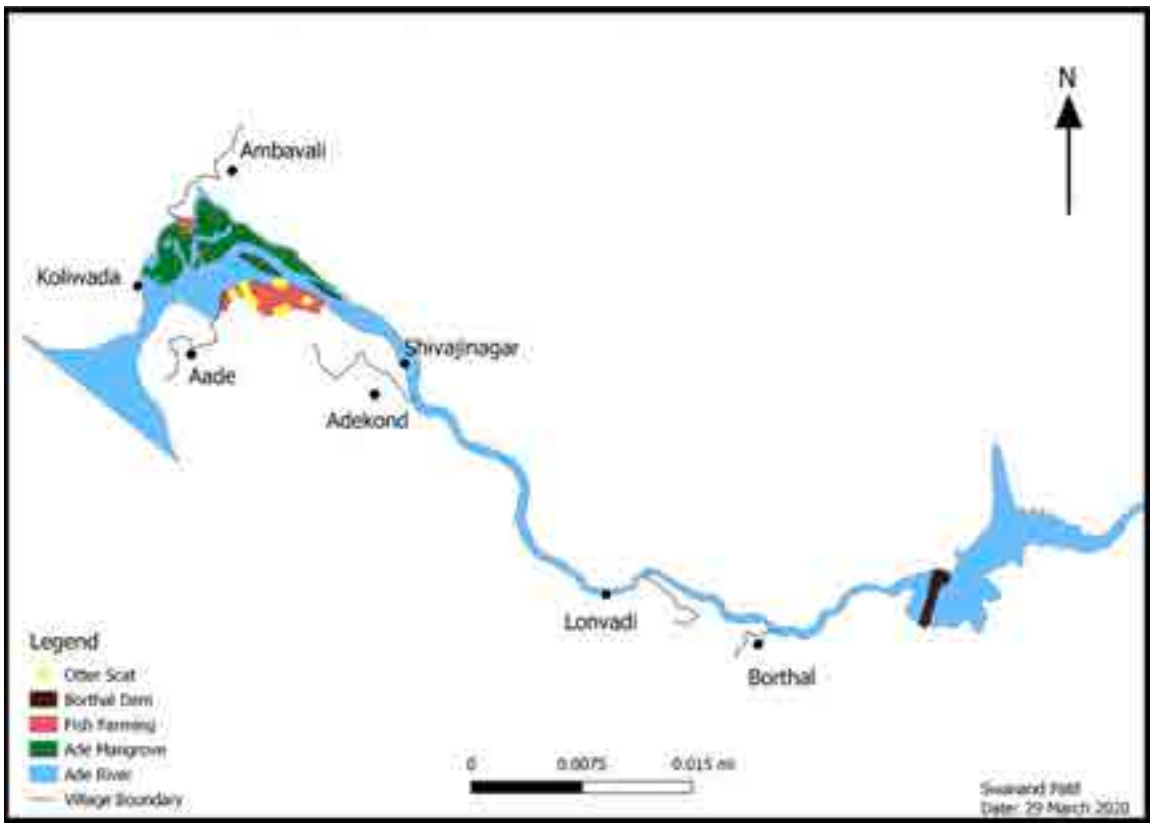

Figure 2. Map showing Smooth-coated Otter distribution in Aade River, Aade.

Image 5. Camera trap image showing otters in Anjarle.

Image 6. Extensive sand mining at the field site.

Image 7. Video snapshot of romp of Smooth-coated Otters.

Table 1. Table showing positive correlation of 0.663 between otter and fishing activity,

Correlations			
		Fishing activity	Otter sign
Fishing_ Activity	Pearson Correlation	1	.663**
	Sig. (2-tailed)		.000
	N	54	54
Otter_Sign	Pearson Correlation	.663**	1
	Sig. (2-tailed)	.000	
	N	54	54
**. Correlation is significant at the 0.01 level (2-tailed).			

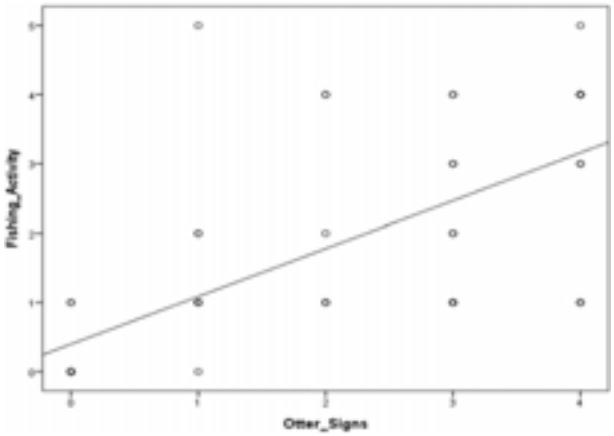

Figure 3. Plot of fishing intensity v/s otter signs.

Image 8. Fresh otter scat/ defecation area.

Image 9. Kataris from local community showing otter dens.

otter-fisherman interactions (Figure 3). During informal interviews within the village community, a person had killed an otter using stones and wooden logs, as his only source of income was harvesting mud crabs and fishing. Such instances are rare, but help us understand the attitude of small-scale fishermen towards otters. Due to habitat fragmentation and degradation, unsustainable fishing practices and lack of awareness are such parameters responsible for the decline in the population of Smooth-coated Otters. There is limited or no data on otter research and conservation within the forest department.

According to otter surveys conducted, a considerable amount of otter distribution lies outside the protected area, which emphasizes the need for integrating the management of human-modified land with the management of protected areas (DeFries et al. 2010).

Conclusion

Though this is a preliminary study, baseline data was created to guide future otter conservation efforts in Ratnagiri, facilitated by Arcane Conservancy, an NGO for long-term research and conservation to improve the protection of otters.

References

Barrios, O. (2020). Approach to a qualitative methodology for the search and direct detection of the Neotropical Otter (*Lontra longicaudis* Olfers, 1818). *IUCN Otter Specialist Group Bulletin* 37: 140–146.

Borker, A. (2014). Conservation of otter habitats through stakeholder participation [WWW Document]. Conservation Leadership Programme. http://www.conservationleadershipprogramme.org/project/otters-goa-india/ (accessed 8.20.19).

DeFries, R., K.K. Karanth & S. Pareeth (2010). Interactions between protected areas and their surroundings in human-dominated tropical landscapes. *Biological Conservation* 143: 2870–2880. https://doi.org/10.1016/j.biocon.2010.02.010

Foster-Turley, P. (1992). Conservation Aspects of the Ecology of Asian Small-Clawed and Smooth Otters on the Malay Peninsulas [WWW Document]. URL https://www.iucnosgbull.org/Volume7/Foster_Turley_1992.html (accessed 8.20.19).

Khan, M.S., N.K. Dimri, A. Nawab, O. Ilyas & P. Gautam (2014). Habitat use pattern and conservation status of smooth–coated otters Lutrogale perspicillata in the Upper Ganges Basin, India. *Animal Biodiversity and Conservation* 31(1): 69–76. https://doi.org/10.32800/abc.2014.37.0069

Mason, C.F. & S.M. Macdonald (1987). The use of spraints for surveying Otter *Lutra lutra* populations: an evaluation. *Biological Conservation* 41: 167–177. https://doi.org/10.1016/0006-3207(87)90100-5

Mason, C.F. & S.M. Macdonald (2009). *Otters: Ecology and Conservation*. Cambridge University Press, 248 pp.

Mudappa, D., A. Kumar & N. Prakash (2012). Conservation of the Asian Small-Clawed Otter (*Aonyx cinereus*) in human-modified landscapes, Western Ghats, India. *Tropical Conservation Science* 5: 67–78. https://doi.org/10.1177/194008291200500107

Prakash, N., A. Perinchery & R.R. Nayak (2014). Monitoring Otter Populations and Combating Poaching Through Stakeholder Participation in India (Final Report). Conservation Leadership Programme, 31 pp.

Sittenthaler, M., E.M. Schöll, C. Leeb, E. Haring, R. Parz-Gollner & K. Hackländer (2020). Marking behaviour and census of Eurasian Otters (*Lutra lutra*) in riverine habitats: what can scat abundances and non-invasive genetic sampling tell us about Otter numbers? *Mammal Research* 65: 191–202. https://doi.org/10.1007/s13364-020-00486-y

Wilson, G.J. & R.J. Delahay (2001). A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. *Wildlife Research* 28(2): 151–164. https://doi.org/10.1071/WR00033

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SHORT COMMUNICATION

Wildlife at the crossroads: wild animal road kills due to vehicular collision on a mountainous highway in northwestern Himalayan region

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Abstract: Wildlife mortality due to vehicular collision is well known across the world and the number of such incidences is steadily rising in Himalaya as well. To assess the quantum of wildlife road kills, we conducted an intensive survey spanning 33 months along a mountainous National Highway 244 in the Union Territory of Jammu & Kashmir. Forty-nine wild animal carcasses of 13 species of higher vertebrates were observed lying on the road, shoulders, edges, and valley slopes. These included seven mammals, four birds, and two reptiles. This survey, first of its kind in this part of the Himalaya would be helpful in understanding the underlying reasons of the rising wildlife fatalities on the hill roads, identifying susceptible hotspots, and developing measures to address this new threat to Himalayan wildlife. We recommend creating wildlife passages, raising speed halters, and placing warning signages in vulnerable sections to reduce the road-related wildlife mortality in such mountainous highways.

Keywords: Carcasses, dumping sites, mammals, mortality, National Highway, non-protected areas, road kills, speed halters, wildlife fatalities, wildlife passages.

Roads are the leading cause of anthropogenic mortality after legal harvesting for many vertebrates world over (Hill et al. 2019). The effect of roads on wildlife is multidimensional, from habitat loss and fragmentation (Burnett 1992; Richardson et al. 1997; Carr & Fahring 2001), altering movement and distribution patterns (Newmark et al. 1996; Desai & Baskaran 1998), affecting breeding (Reijnen et al. 1995), and causing injury and mortality by vehicular collisions (Das et al. 2007; Seshadri et al. 2009; Baskaran & Boominathan 2010; Hill et al. 2019; Schwartz et al. 2020). This barrier effect and wildlife-vehicular collisions are predicted to worsen as road network and traffic intensity rise internationally. The incidents of mammal-vehicle collisions have increased dramatically since the early 1970s (Hill et al. 2019).

India has the world's second largest road network, with a total road length of 6.2 million km (Ministry of Road Transport and Highways 2021). A country with such a massive road system puts animals that scurry or move across the highways in grave danger. The Union Territory (UT) of Jammu & Kashmir has seen a massive rise in national highway expansion, up about 194 percent from 823 km in 2003, to 2,433 km now, accounting for 1.8 percent of India's entire national highway network (Ministry of Road Transport and Highways 2021).

Indian Himalayan region with a wide range of habitats support unique arrays of biodiversity and ecosystem services both within and outside of the protected areas. The non-protected areas (Non-PAs) in the Indian Himalaya house a good number of wildlife species (Thapa et al. 2021) which are ecological generalists and

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possess good amount of behavioural plasticity (Buchi & Vuilleumier 2014; Gaynor et al. 2018). These non-PAs lack scientific monitoring and management strategies to conserve wildlife species which increases the risk of them coming in close proximity to human-dominated areas and thus becoming vulnerable to several fatalities including vehicular collisions. Apart from a few short-term studies on wildlife road kills (Gokula 1997; Sunder 2004; Das et al. 2007; Seshadri et al. 2009; Baskaran & Boominathan 2010; Bhupathy et al. 2011; Kumar & Srinivasulu 2015; Samson et al. 2016; Santhoshkumar et al. 2017; Hatti & Mubeen 2019), no major study has been conducted in India or in the western Himalaya, emphasizing the fact that very little attention is being paid to the impacts of roads and highways on wildlife. In order to assess the quantum of road kills in the region, we monitored wildlife road kills on National Highway 244 (NH-244), which connects Batote (Jammu) to Kashmir Valley, in the UT of Jammu & Kashmir. The highway creates a dangerous terrain for wildlife that live besides it, as evident by the number of road kill reports that have piled up over the years.

Material and Methods

To understand the frequency of road kills, their likely causes and the wild animal species exposed to the accidents, we carried out surveys on NH-244, connecting Batote (Jammu) to Kashmir Valley. Upgraded to a national highway in 2016, the road is currently undergoing upgrades, including widening of the lanes and construction of extensive tunnels. The highway, which is built into the mountainside, criss-crosses multiple perennial streams and runs the substantial length of the Chenab gorge. Located between 823 and 1,638 m, the corridor is characterized with a broad range of habitats, including sub-temperate broad-leaved mixed forests interspersed with pure conifer patches, dry open scrub, rocky slopes, villages and urban areas, supporting a rich biodiversity. Our study was limited to 120 km stretch on NH-244, from Batote, a sub-urban township to Kishtwar town (Figure 1). The highway was surveyed by car twice a month for a period of two years and nine months, from January 2018 to December 2019 and from December 2020 to August 2021. No surveys could be conducted during 2020 due to COVID-19 restrictions. The road kills sighted during the whole effort were identified up to the

Figure 1. Location of NH-244 in the UT of Jammu & Kashmir, India.

species level (except for reptiles). The spatial attributes of the accident site were recorded and the carcasses were removed from the road to avoid repetitive counts. No specimens were collected during the survey.

Results and Discussion

During the surveys, we recorded 49 road kills involving 13 species of higher vertebrates (Table 1; Image 1a-g), including seven species of mammals, four species of birds, and two species of reptiles. Golden Jackal *Canis aureus,* Rhesus Macaque *Macaca mulatta*, and Red Fox *Vulpes vulpes* suffered the most fatalities among the mammals (Table 1). Two carcasses each of globally threatened Common Leopard *Panthera pardus* and Himalayan Vulture *Gyps himalayensis* were also observed during the surveys. The data analysis revealed an encounter rate of 0.40 road kills/km and most of the road kill aggregations were found near Batote, a vital junction intersecting the Jammu-Srinagar National Highway (NH-44). The location of carcasses found during the surveys is shown in Figure 2.

The animal carcasses so observed indicated that these species were struck or overrun by speeding vehicles especially during night as most of victims were nocturnal. During the night, animals can be seen roaming around the marketplaces and rubbish dumps in search of food. Predators also make their way down the mountainside in search of water and food sources. As a result, these animals are subjected to rash and reckless driving and end up in road mishaps. Our study found that mammals are affected more than other taxa, mostly including nocturnal animals. In many instances, the authors observed that species like Red Fox and Golden Jackal get traumatized in front of the high beam lights of vehicles and get transfixed on the road and ultimately fall victim to speeding vehicles. Another vulnerable group is the scavengers that are drawn to the roadside dead animal carcasses and eventually get killed. Although the numbers of these taxa seem to be very small, such loss is insufferable considering their slow life histories and low population densities (Baskaran & Boominathan 2010). The secondary information obtained as a result of casual conversation with regularly plying drivers substantiates an increase in wild animal sightings, notably vultures,

Figure 2. Image showing the location of road kills observed on NH 244.

Table 1. Road kills recorded on NH-244 during the sampling period.

Species	Common name	IUCN status	Number	Habitat type	Altitude (in m)
Mammals					
1. *Panthera pardus*	Common Leopard	VU	2	PF, BD	1000–1415
2. *Vulpes vulpes*	Red Fox	LC	3	PF, BD, OS	1224–1580
3. *Canis aureus*	Golden Jackal	LC	12	PF, BD, OS, UR	990–1332
4. *Paguma larvata*	Himalayan Palm Civet	LC	2	PF, BD	890–940
5. *Viverricula indica*	Small Indian Civet	LC	2	OF, UR	934–1244
6. *Macaca mulatta*	Rhesus Macaque	LC	7	PF, BD, OS, UR	910–1310
7. *Eoglaucomys fimbriatus*	Kashmir Flying Squirrel	LC	2	PF	1100–1246
Birds					
8. *Gyps himalayensis*	Himalayan Vulture	NT	2	PF	1250
9. *Milvus migrans*	Black Kite	LC	3	OS, UR	1140–1402
10. *Pycnonotus cafer*	Red-vented Bulbul	LC	2	OS	1016–1456
11. *Acredotheres tristis*	Common Myna	LC	3	OS, UR	944–1113
Reptiles					
12. Snake sp.	-	-	2	UR	943–1105
13. Calotes sp.	-	-	7	OS, UR	946–1510

VU—Vulnerable | NT—Near Threatened | LC—Least Concern | PF—Pine forests | OS—Open Scrub | BD—Broadleaved mixed | UR—Urban areas.

kites, civets, jackals and common leopards in recent years.

The wildlife in the Himalaya is subjected to many threats including the one under discussion that needs to be seriously addressed and appropriately dealt with. Assessment of wildlife vehicular mortality is important to understand road impacts, effects on local population of wildlife, to decipher the accident-prone hotspots, and identify the factors underlying the animal road fatalities (Carvalho & Mira 2010; Taylor & Goldingay 2010). Our survey may not have reported all the road kills as many of the carcasses remain hidden beneath structures or foliage, or are removed by other motorists, authorities, or scavenger animals before being discovered (Dickerson 1939; Vestjens 1973; Coulson 1982; Taylor & Goldingay 2003), like an incident of setting afire a leopard carcass near Batote. The study revealed a major road kill cluster around Batote township, which may be because of the presence of open waste dumping site located by the side of the road as well as a water channel fulfilling feeding and water demands of wild animals. Given the current grim situation and foreseeing the highway expansion that would exacerbate already existing threats, necessitates call for scientifically-based mitigation measures. These include construction of wildlife passages at vulnerable sections especially the below-road crossing structures like culverts for larger species and drainage pipes for small size species (Chen et al. 2021), maintaining a wide field of view for drivers and wildlife, widening shoulders to facilitate wait and go calls, planting caution boards and laying speed breakers near water bodies and dumping sites, sensitizing the drivers and organising citizens to build a reliable dataset for better analysis.

References

Baskaran, N. & D. Boominathan (2010). Road kills of animals by highway traffic in the tropical forest of Mudumalai Tiger Reserve, southern India. *Journal of Threatened Taxa* 2(3): 753–759. https://doi.org/10.11609/JoTT.o2101.753-9

Bhupathy, S., G. Srinivas, N. Sathish, T. Karthik & A. Madhivanan (2011). Herpetofaunal mortality due to vehicular traffic in the Western Ghats, India: a case study. *Herpetotropicos* 5: 119–126.

Buchi, L. & S. Vuilleumier (2014). Coexistence of specialist and generalist species is shaped by dispersal and environmental factors. *American Naturalist* 183: 612–624. https://doi.org/10.1086/675756

Burnett, S. (1992). Effects of a rainforest road on movements of small mammals: mechanisms and implications. *Wildlife Research* 19: 95–104. https://doi.org/10.1071/WR9920095

Carr, L.W. & L. Fahrig (2001). Impact of road traffic on two amphibian species of differing vagility. *Conservation Biology* 15: 1071–1078. https://doi.org/10.1046/j.1523-1739.2001.0150041071.x

Carvalho, F. & A. Mira (2010). Comparing annual vertebrate road kills over two time periods, 9 years apart: a case study in Mediterranean farmland. *European Journal of Wildlife Research* 57: 157–174. https://doi.org/10.1007/s10344-010-0410-0

Chen, H.-L., E.E. Posthumus & J.L. Koprowski (2021). Potential of small culverts as wildlife passages on forest roads. *Sustainability* 13: 7224. https://doi.org/10.3390/su13137224

Coulson, G. (1982). Road kills of macropods on a section of highway in central Victoria. *Australian Wildlife Research* 9: 21– 26. https://doi.org/10.1071/WR9820021

Das, A., M.F. Ahmed, B.P. Lahkar & P. Sharma (2007). A preliminary report of reptilian mortality on road due to vehicular movements near Kaziranga National Park, Assam, India. *Zoos' Print Journal* 22(7): 2742–2744. https://doi.org/10.11609/JoTT.ZPJ.1541.2742-4

Image 1a. Common Leopard © Muzaffar A Kichloo

Image 1b. Golden Jackal © Asha Sohil

Image 1c. Red Fox © Muzaffar A Kichloo

Image 1d. Himalayan Palm Civet © Neeraj Sharma

Image 1e. Rhesus Macaque © Asha Sohil

Image 1f. Black Kite © Muzaffar A Kichloo

Image 1g. Snake sp. © Muzaffar A Kichloo

Desai, A.A. & N. Baskaran (1998). Ecology of Malabar Giant Squirrel (*Ratufa indica*) in Mudumalai Wildlife Sanctuary, South India. Technical Report Bombay Natural History Society, Bombay.

Dickerson, L.M. (1939). The problem of wildlife destruction by automobile traffic. *Journal of Wildlife Management* 3: 104–116. https://doi.org/10.2307/3796352

Gaynor, K.M., C.E. Hojnowski, N.H. Carter & J.S. Brashares (2018). The influence of human disturbance on wildlife nocturnality. *Science* 360: 1232–1235. https://doi.org/10.1126/science.aar7121

Gokula, V. (1997). Impact of vehicular traffic on snakes in Mudumalai Wildlife Sanctuary. *Cobra* 27: 26

Sunder, K.S.G. (2004). Mortality of herpetofauna, birds and mammals due to vehicular traffic in Etawah district, Uttar Pradesh. India. *Journal of the Bombay Natural History Society* 103(3): 392–398.

Hatti, S.S. & H. Mubeen (2019). Roadkill of animals on the road passing from Kalaburagi to Chincholi, Karnataka, India. *Journal of Threatened Taxa* 11(7): 13868–13874. https://doi.org/10.11609/jott.4292.11.7.13868-13874

Hill, J.E., T.L. DeVault & J.L. Belant (2019). Cause-specific mortality of the world's terrestrial vertebrates. *Global Ecology and Biogeography* 28: 680–689. https://doi.org/10.1111/geb.12881

Kumar, G.C. & C. Srinivasulu (2015). Impact of vehicular traffic on Kashmir Rock Agama *Laudakia tuberculata* (Gary, 1827) near Kalatop-Khajjiar Wildlife Sanctuary, Chamba, Himachal Pradesh, India. *Reptile Rap* 17: 44–47.

Ministry of Road Transport & Highways (2021). https://morth.nic.in/ (accessed on 07-11-2021)

Newmark, W.D., J.I. Boshe, H.I. Sariko & G.K. Makumbule (1996). Effects of highway on large mammals in Mikumi National Park, Tanzania. *African Journal of Ecology* 34: 15–31. https://doi.org/10.1111/j.1365-2028.1996.tb00590.x

Reijnen, R., R. Foppen, C.T. Braak & J. Thissen (1995). The effects of car traffic on breeding bird populations in woodland III: Reduction of density in relation to the proximity of main roads. *Journal of Applied Ecology* 32: 187–202. https://doi.org/10.2307/2404428

Richardson, J.H., R.F. Shore, J.R. Treweek & S.B.C. Larkin (1997). Are

major roads a barrier to small mammals? *Journal of Zoology* 243: 840–846. https://doi.org/10.1111/j.1469-7998.1997.tb01982.x

Samson, A., B. Ramakrishnan, A. Veeramani, P. Santhoshkumar, S. Karthick, G. Sivasubramanian, M. Ilakkia, A. Chitheena, J.L. Princy & P. Ravi (2016). Effect of vehicular traffic on wild animals in Sigur Plateau, Tamil Nadu, India. *Journal of Threatened Taxa* 8(9): 9182–9189. https://doi.org/10.11609/jott.1962.8.9.9182-9189

Santhoshkumar, S., P. Kannan, A. Veeramani, A. Samson, S. Karthick & J. Leonaprincy (2017). A preliminary report on the impact of road kills on the herpetofauna species in Nilgiris, Tamil Nadu, India. *Journal of Threatened Taxa* 9(3): 10004–10010. http://doi.org/10.11609/jott.3001.9.3.10004-10010

Schwartz, A.L.W., F.M. Shilling & S.E. Perkins (2020). The value of monitoring wildlife roadkill. *European Journal of Wildlife Research* 66: 18. https://doi.org/10.1007/s10344-019-1357-4

Seshadri, K.S., A. Yadav & K.V. Gururaja (2009). Road kills of amphibians in different land use areas from Sharavathi river basin, central Western Ghats, India. *Journal of Threatened Taxa* 1(11): 549–552. https://doi.org/10.11609/JoTT.o2148.549-52

Taylor, B.D. & R.L. Goldingay (2003). Cutting the carnage: wildlife usage of road culverts in north-eastern New South Wales. *Wildlife Research* 30: 529–537. https://doi.org/10.1071/WR01062

Taylor, B.D. & R.L. Goldingay (2010). Roads and wildlife: impacts, mitigation and implications for wildlife management in Australia. *Wildlife Research* 37: 320–331. https://doi.org/10.1071/WR09171

Thapa, A., P.K. Pradhan, B.D. Joshi, T. Mukherjee, M. Thakur, K. Chandra & L.K. Sharma (2021). Non-protected areas demanding equitable conservation strategies as of protected areas in the Central Himalayan region. *PLoS ONE* 16(8): e0255082. https://doi.org/10.1371/journal.pone.0255082

Vestjens, W.J.M. (1973). Wildlife mortalities on a road in New South Wales. *Emu - Austral Ornithology* 73: 107–112. https://doi.org/10.1071/MU973107

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NOTE

Robiquetia gracilis (Lindl.) Garay—a new record to the flora of Anamalai Hills, Tamil Nadu, India

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Robiquetia, an indispensable genus of the family Orchidaceae, was first described by Gaudichaud-Beaupréin, 1829 in his work "Voyage autour du monde"; it belongs to the tribe Vandeae. It encompasses about 70 species which are distributed from India and Sri Lanka to Samoa (Cootes 2011; Ormerod 2017). In India, the genus is represented by four species (*Robiquetia gracilis*, *R. jossephiana*, *R. spathulata*, and *R. succisa*), of which *Robiquetia jossephiana* is known to be endemic to Kerala (Kumar & Manilal 1992, 1994; Jalal & Jayanthi 2012).

Anamalai Tiger Reserve (ATR) is carved out of the Tamil Nadu portion of the Anamalais. It lies south of the Palakkad gap in the southern Western Ghats mountain chain. Geographically, it is located between the longitudes 76.821–77.356E and latitudes 10.220–10.555N. The two important UNESCO World Heritage Sites of Western Ghats such as the Karian Shola and the Grass hills are located within the ATR.

Frequent field surveys by the authors (2017–2019) in Anamalai hills has resulted in locating a number of rare and unknown species of plants which included a specimen of an interesting orchid species of the genus *Robiquetia*. Specimens were collected from two localities in Valparai plateau and were kept at Anamalai orchidarium for monitoring, on initiation of the inflorescence, the authors visited the site and observed the flowering and fruiting and recorded the same. A detailed taxonomic study with perusal of relevant literature (Kumar & Manilal 1994; Sasidharan 2013) and consultation with experts confirmed its identity as *Robiquetia gracilis,* a rare species, till now not reported from the Anamalai hills. In Tamil Nadu this species was reported in Kakachi-Kodayar, Kalakkad-Mundathurai Tiger Reserve (KMTR; Ganesan & Livingstone 2001) and Athirumala and Agasthymala of Kerala (Sasidharan 2013). Based on scrutiny of the specimen, it was confirmed that the species exists in the Anamalais ranging 1,100–1,400 m altitude. It is a new record to the flora of Anamalai hills. *Robiquetia gracilis* can be distinguished from other species by the zig-zag and sheathed stem character. Meanwhile, tiny white flowers with red dots confirm its identification in the wild. Ganesan & Livingston (2001) reported the habitat of *Robiquetia gracilis* as mid-elevation evergreen forest (1,200–1,550 m) areas of KMTR.

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***Robiquetia gracilis* (Lindl.) Garay**

Bot. Mus. Leafl. Harvard Univ. 23: 197. 1972

Saccolabium gracile Lindl., Gen. Sp. Orchid. Pl. 225. 1833. (Image 1)

Monopodial, pendulous, epiphyte. Roots: branched, terete, elongate, emerging from nodes up to 25 cm long. Stems 10–15 cm long, semi hard, zigzag, green sheathed. Leaves alternate 6–12 x 0.5–0.7 cm, linear-lanceolate, acuminate at apex, sheathed at base. Inflorescence leaf opposed, drooping raceme, 8–12 cm long. Peduncles filiform, 12–16 flowered. Flowers, white, 0.4–0.5 cm across. Sepals and petals 0.15–0.2 cm long, linear,

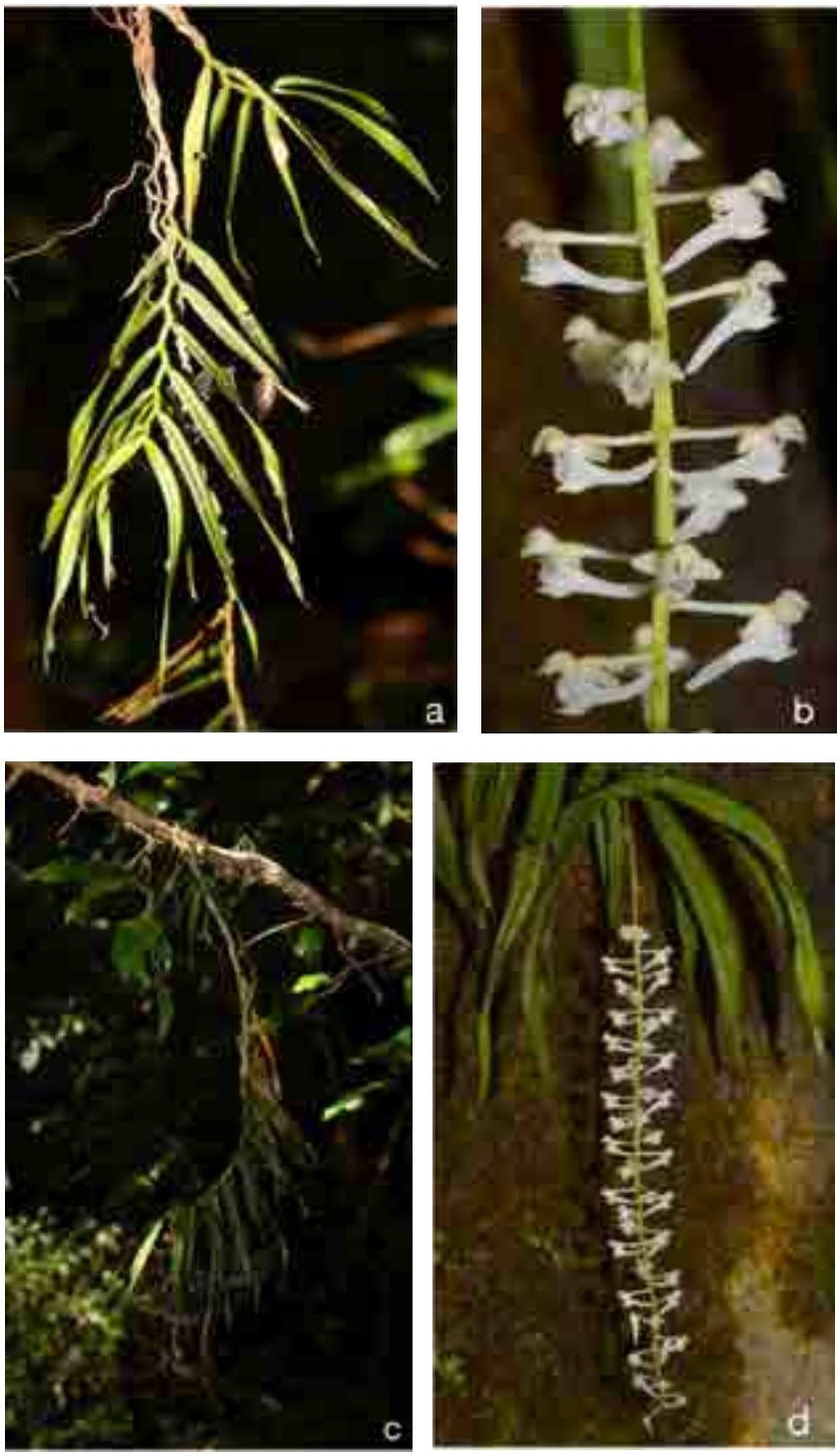

Image 1. *Robiquetia gracilis* (Lindl.) Garay: a—habit | b—closeup of flower | c—habitat | d—inflorescence. © B. Subbaiyan & P.R. Nimal Kumar.

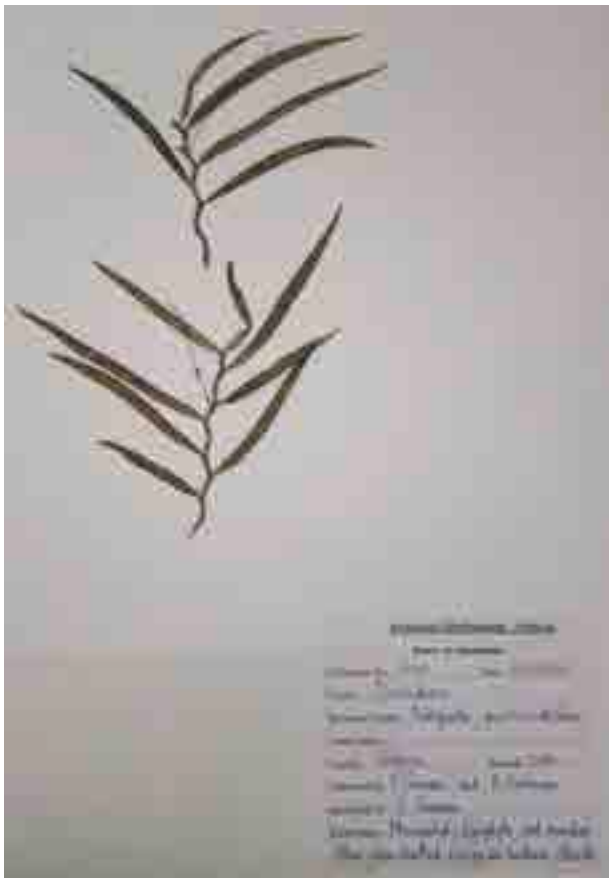

Image 2. Herbarium sheet of *Robiquetia gracilis* (Lindl.) Garay.

subulate. Lip 0.3–0.4 cm long, spurred, lateral lobes; mid-lobe small. Column 0.1–0.15 cm long; foot 0. Pollinia 2, globose, attached to long slender caudicle. Pedicels and ovary 0.3–0.35 cm long. Capsules subglobose, 0.5 × 0.4 cm.

Habit: Grows as epiphytic herbs in association with *Garcinia morella* (Gaertn.) Desr.

Habitat: Evergreen forests between 1,100–1,400 m.

Specimens examined: India, Tamil Nadu, Coimbatore district, Anamalai Tiger Reserve, 2018, Ganesan & Subbaiyan (0055; Image 2) Anamalai Herbarium, Pollachi.

Distribution: Southern India (Kerala, Tamil Nadu) and Sri Lanka.

Flowering & Fruiting: August–January.

Notes: A very few individuals of this species were identified in the collection locality. The species has not been recorded earlier in any localities of the reserve so far. Therefore, it is suggested that an exploration in other possible localities is essential to assess its exact conservation status. Two live specimens are deposited in Anamalai Orchidarium at Attakatti for conservation purpose.

References

Cootes, J.E. (2011). *Philippine Native Orchid Species*. Katha Publishing Co., Inc., Quezon City, 289pp.

Ganesan, R. & C. Livingstone (2001). Checklist of orchids from a mid elevation evergreen forest at Kakachi-Kodayar, Kalakkad-Mundanthurai Tiger Reserve, Agasthyamalai, southern Western Ghats. *Zoos' Print Journal* 16(3): 445–446. https://doi.org/10.11609/JoTT.ZPJ.16.3.445-6

Jalal, J.S. & J. Jayanthi (2012). Endemic orchids of peninsular India: a review. *Journal of Threatened Taxa* 4(15): 3415–3425. https://doi.org/10.11609/JoTT.o3091.3415-25

Kumar, C.S. & K.S. Manilal (1992). Epiphytes orchids of India. *Rheedea* 2(2): 80–100.

Kumar, C.S. & K.S. Manilal (1994). *A Catalogue of India Orchids*. Bishen Singh Mahendra Pal Singh, Dehradun, 84pp.

Ormerod, P. (2017). *Checklist of Papuasian Orchids*. Nature & Travel Books, Lismore (Australia), 496pp.

Sasidharan, N. (2013). Flowering Plants of Kerala: CD-ROM ver. 2.0. Kerala Forest Research Institute, Peechi, Kerala.

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NOTE

Ipomoea laxiflora H.J. Chowdhery & Debta (Convolvulaceae): new records for the Western Ghats and semiarid regions

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Ipomoea L. is one of the largest genera of the family Convolvulaceae Juss., growing naturally in tropical, subtropical, and temperate regions (Kattee et al. 2019). Members of the family are characterised by their twining and trailing herbaceous or perennial habit, whereas shrubs or trees are rare. About 650 species are reported worldwide in Convolvulaceae (Mabberley 2017); of which 64 species are reported from different biogeographical regions of India (Shimpale et al. 2014; Kattee et al. 2019). Many of them have been used as ornamental plants with a popular English name 'morning glory', in foods, medicines, and in religious rituals (Meira et al. 2012). During field trips to different regions of Gujarat state for collection of *Ipomoea* and other species of the Convolvulaceae for histological studies, the authors collected a few specimens of *Ipomoea* (looking similar to *I. triloba*) with glabrous fruits. After studying the literature (Chowdhery & Debta 2009; Singh et al. 2011; Kattee et al. 2019) and comparing with the herbarium specimens deposited in The New College Herbarium & Shivaji University Kolhapur (SUK) Herbarium, the collected specimens were identified as *I. laxiflora* H.J.Chowdhery & Debta. *I. laxiflora* is known from northern India (Uttarakhand) and recently reported from Deccan peninsula (eastern region of Kolhapur district) by Kattee et al. (2019). It has not been reported from the Western Ghats (including the Kolhapur district), however, now it is collected from the Dangs (Western Ghats region of Gujarat) and semiarid regions of Gujarat. Herewith, the species is reported as a new distribution record for the Western Ghats and semiarid region of India. The presence of this species in these regions will help researchers working in the area to understand the distribution pattern of this endemic species. This discovery also hints towards its possible wider distribution range. A detailed description, distribution conservation status, and photographs (Image 1) of *I. laxiflora* are provided herewith.

Ipomoea laxiflora H.J.Chowdhery & Debta**,**
Indian J. Forest. 2009, 32(1): 120–121 (Image 1)

Plants 4–5 m (6 m) long, annual climber; stems purple-green, soft, herbaceous, quadrangular, sparsely hairy at nodes; leaves 5–10 × 4–9 cm, simple, showing great variations in shape, cordate or trilobed, acuminate, entire, base cordate; petioles 7–12 cm, purple-green, long, glabrous; flowers 3–7 in lax cymes, monoecious, clumped; peduncles 5–8 cm long, purple-green, slightly verrucose, glabrous, swollen at apex; pedicels 2.5–3 mm long, quadrangular, glabrous, elongated in fruits; bracts

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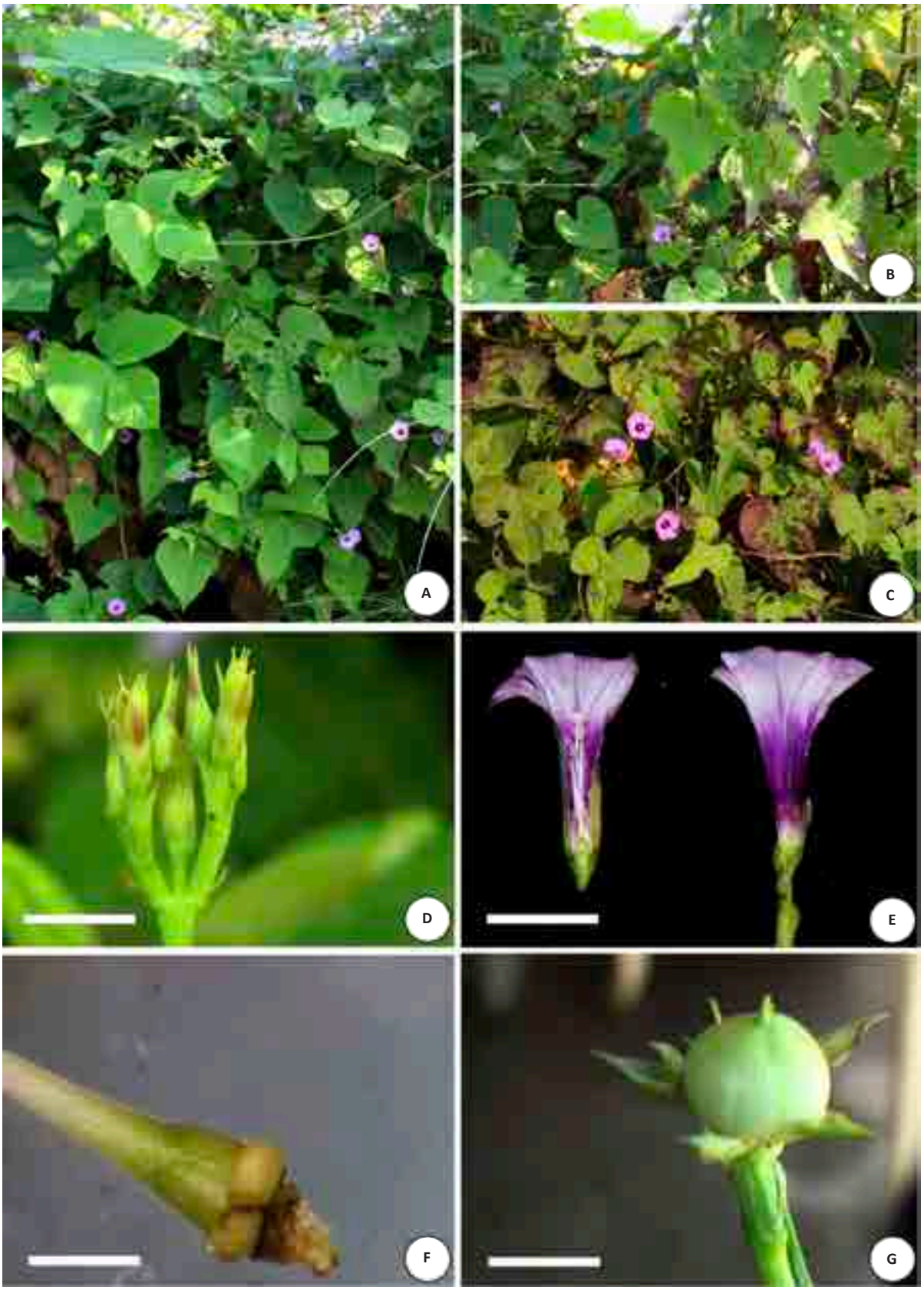

Image 1. *Ipomoea laxiflora*: A–C—Habit | D—Young floral buds | E—Flowers (longitudinal section of flower on the left and complete flower on the right) | F—Gynoecium, | G—Fruits (note the absence of hairs on gynoecium and capsule). Scale: D & E = 1cm | F = 2cm | G = 5mm. © K.S. Rajput and S.M. Patil

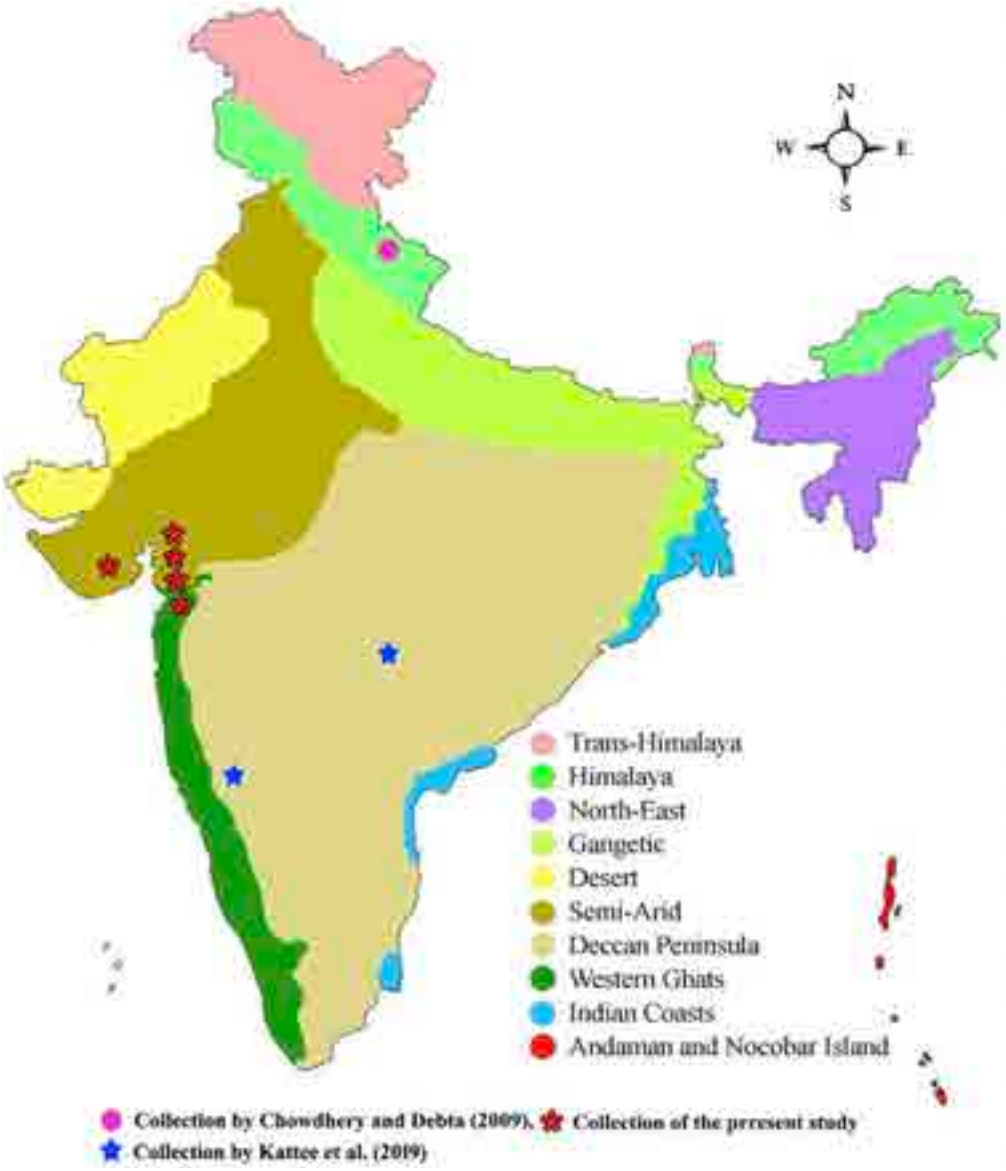

Figure 1. Point locations of *Ipomoea laxiflora* (marked with dots) in different biogeographic zones of India (map not to scale).

2–4 mm long, linear, caducous; calyx 5, fused, green with purple tinged at tip; lobes 0.7–0.9 × 0.2–0.3 cm, ovate-lanceolata, sub-equal, feebly veined, glabrous; corolla c. 1.5 × 1.2 cm, funnel-shaped; limb 5-lobed; lobes apiculate; stamens 5; filaments 0.7–0.8 cm long, unequal, included, hairy at base; ovary c. 1 × 1.5 mm, glabrous; style c. 0.6–1 cm long; stigma unlobed or bilobed; capsules ovoid, 5 × 6 mm, 4-valved, with purple tinge at young, glabrous; seeds 4 per capsule, ovoid to deltoid, brownish-black, c. 4 × 4 mm, glabrous.

Flowering period: September–October

Distribution: India

Note: In India this was reported from Uttarakhand and Maharashtra. However, now it is collected from the Western Ghats (The Dangs) and semi-arid regions (Vadodara, Panchmahal, and Rajkot) of Gujarat state (Figure 1).

Conservation status: *Ipomoea laxiflora* is an endemic species collected from different regions of India (Singh et al. 2015). In the present work it has been collected from the Western Ghats and semiarid regions of India. About 30–80 individuals were found per locality and the area of occupancy (AOO) is 150–250 km^2 by using the Geo-CAT software. However, other forest regions are yet to be explored completely and the species may be distributed under similar ecological conditions. Hence, more floristic surveys are needed to determine and document the full range of distribution of *Ipomoea*

laxiflora.

Ecology: The species grows from high rainfall regions (>1,300 mm) to low rainfall (<400 mm) regions. It grows on sandy gravelly or sandy alluvial soil on hilly terrain, foot hills and hill slopes. It also occurs in human habitats particularly on farm or home fencing and compound walls of industries, along road sides and in open areas. The phyto-associates observed in various areas are *Capparis decidua* (Forssk.) Edgew., *Euphorbia* sp., *Ficus hispida* L.f., *Pongamia pinnata* (L.) Pierre, *Prosopis juliflora* (Sw.) DC., *P. cineraria* (L.) Druce, and *Ziziphus* sp.

Specimens examined: 1001 (BARO!) 2019, Gujarat, Dangs forest (20°45'38"N & 73°41'54"E), coll. Patil, Vasava & Rajput; 105 (BARO!), 2015, Rajkot (22°17'06"N & 70°44'35"E), coll Rajput; 1541, 1542, 1543 (The New College Herbarium! & SUK!) 2016, Maharashtra-Kolhapur district, Ichalkaranji, coll. Kattee & Shimpale; 1544, 1545 (The New College Herbarium! & SUK!) 2016, Gadchiroli coll. Kattee & Shimpale

References

Chowdhery, H.J. & M.R. Debta (2009). A new species of *Ipomoea* L. (Convolvulaceae) from India. *Indian Journal of Forestry* 32(1): 119–121.

Kattee, A.V., C.R. Patil, S.L. Patel, V.I. Kahalkar & V.B. Shimpale (2019). Notes on the occurrence of *Ipomoea acanthocarpa* and *Ipomoea laxiflora* (Convolvulaceae) in India. *Rheedea* 29(3): 209–214.

Mabberley, D.J. (2017). *The Plant-Book: A portable dictionary of plants, their classification and uses.* Fourth edition. Cambridge University Press, Cambridge, 466–467 pp.

Meira, M., da E.P. Silva, J.P. David & J.M. David (2012). Review of Genus *Ipomoea*: Traditional uses, chemistry and biological activities. *Revista Brasileira de Farmacognosia* 22(3): 682–713.

Shimpale, V.B., M.A. Kare, D.K. Londhe & A.S. Bhuktar (2014). On the occurrence of *Ipomoea tenuipes* (Convolvulaceae) in India. *Rheedea* 24(2): 117–119.

Singh, A.K., R.K. Sahu & M. Srivastava (2011). On the occurrence of *Ipomoea laxiflora* in Uttar Pradesh. *Indian Journal of Forestry* 34(3): 335–338.

Singh, P., K. Karthigeyan, P. Lakshminarasimhan & S.S. Dash (2015). Endemic Vascular Plants of India. Botanical Survey of India, Kolkata.

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NOTE

Counting the cost: high demand puts *Bunium persicum* (Boiss.) B.Fedtsch. in jeopardy

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The mighty Himalaya has been identified as one of the 36 biodiversity hotspots due to its immense hoard of endemic species as well as the ever-increasing threats looming upon this region (Mittermier et al. 2004). The highly adapted and fragile ecosystems are rich in biodiversity, of which vegetation forms an important component. The stretch of Himalaya that constitutes the Indian Himalayan region (IHR) harbours ca. 11,157 species of flowering plants belonging to 2,359 genera under 241 families (Singh et al. 2019). IHR, an abode to various medicinal and aromatic plants (MAPs) accounts for >1,748 species of medicinal plants (23.4% of India) comprising 1,685 species of angiosperms, 12 gymnosperms, and 51 pteridophytes that have traditional and modern therapeutic uses (Samant et al. 1998). Owing to their high medicinal value, most of MAPs are at high demand and hence face immense pressure that has led to a decline in their wild populations, for instance Goraya & Ved (2017) enlisted 36 Himalayan medicinal plant taxa that are in high commercial demand by the herbal industries.

In the western Himalaya, the relative isolation and remoteness of high-altitude regions have made the ethnic communities the last bastions of traditional medicinal knowledge. MAPs serve as one of the major sources of subsistence and income generation for local communities and have found use in many culinary and medicinal practices since time immemorial. These ethnic communities inhabiting harsh environmental conditions practice unique traditions and customs including ethno-botanical dependence, thus, hold substantial ethno-botanical knowledge due to the regular use of medicinal plants for treatment of diseases, wounds, fractures, and other ailments (Samant et al. 1998; Samant & Palni 2000). The local traditional healers known as 'Larjee' or 'Amchi' practice traditional health care systems such as the Tibetan system of medicine (Sowa-Rigpa) for the treatment of various ailments based on their traditional knowledge.

With the rising growth in the demand and market of herbal medicines, the herbs-based healthcare wellness sector across the world including India is booming. This in turn has resulted in higher demand and thus puts higher pressure on the medicinal plant resources, both

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wild and cultivated (Goraya & Ved 2017). Unfortunately, due to the absence of sustainable harvesting and collection protocols, and cultivation tools and techniques, the MAPs are harvested indiscriminately (Kumar et al. 2021). In some cases, though there are no locally known uses of the MAPs, they are harvested unsustainably, solely to be sold in the market, the trade of which serves as a lucrative source of income for the plant collectors (Dorji 2016; Mathela et al. 2020). Hence, the heavy and increased demand on high value MAPs in the wild, coupled with destructive harvesting and competitive wild collection has resulted in the rapid decline of the wild populations (Goraya & Ved 2017). The market prices at which these MAPs are sold can easily paint a picture of the demand, for instance, *Fritillaria cirrhosa* D.Don (Jangli lehsun) sells at 12,000–15,000 INR kg^{-1}, *Aconitum heterophyllum* Wall. ex Royle (Kaur) 3,000–4,000 INR kg^{-1}, *Pichrorhiza kurroa* Royle ex. Benth (Kadu) 900–1,500 INR kg^{-1}, and *Dactylorhiza hatagirea* (D.Don) Soó (Hathajadi) 2,200–6,000 INR kg^{-1} (Mathela et al. 2020; Mathela et al. 2021; Kumar et al. 2021). Due to the extremely high demand, increased illegal trade, destructive wild collection and dwindling populations, these MAPs are threatened and many are on the brink of extinction from the wild (Goraya & Ved 2017; Mathela et al. 2020). The unorganized and illegal trade is increasing day by day in the western Himalayan region in spite of strict government instructions on the trade and transportation.

Noticeably, in the recent decade, there have been several reports of medicinal species being reported in peril in the western Himalaya, such as well-known insect fungus *Ophiocordyceps sinensis* (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora commonly called 'Keerajadi' and 'Yartsagunba' with multiple medicinal uses, which received high attention in terms of increased trade, excessive harvesting, and dependency of local communities, especially in Uttarakhand (India), Nepal, and China. The increasing exploitation has led to rising pressure on the species leading to decrease in the wild population (Yadav et al. 2019). Similarly, the population of *Nardostachys jatamansi* (D.Don) DC. has declined by 60–80% in the wild from IHR, hence categorized as endangered in Arunachal Pradesh, Sikkim, & Himachal Pradesh and critically endangered in Uttarakhand as per CITES. Another species with high market demand and dwindling wild population is *Trillium govanianum* Wall. ex D.Don (Nagchatri) native to the western Himalaya. Another species worth mentioning is *Dactylorhiza hatagirea* commonly known as 'Salampanja' or 'Hathajadi', which is in high medicinal demand in national and international markets. The annual demand of Salampanja has been recorded at ca. 5,000 tons (Bhatt et al. 2005). The regeneration capacity of this orchid is rather poor due to pollinator specificity and requirement of mycorrhizal association, therefore, over-extraction from the wild poses a serious threat (Pant et al. 2012).

Image 1. *Bunium persicum* flowers. © G.S. Goraya.

Image 2. *Bunium persicum* seeds. © Sipu Kumar.

Keeping the sudden spurt in price and high demand of yet another highly threatened MAP *Bunium persicum* (Boiss.) B.Fedtsch. commonly known as 'Kalazeera' or black cumin of Himachal Pradesh in view, the current communication attempts to raise high conservation concern to preserve the species in the wild (Images 1–4). Based on intensive market surveys and individual interactions with the local populace and traders comprising 255 respondents in the Lahaul and Pangi landscape of Himachal Pradesh covering 12 villages, namely, Sural Bhatori, Hundan Bhatori, Chasak Bhatori, Killar, Punto, Mindhal, Sechu, Ghisal, Kuthal, Sach, Dharwas & Karyas of Pangi and five villages, namely, Khanjar, Udaipur, Urgos, Tindi, & Thanpattan of Lahaul; the predominant factors that pose a major threat to

Image 3 & 4. *Bunium persicum* in trade. © Himanshu Bargali.

the wild populations of the species include high market demand, increased illegal trade, destructive harvesting, relentless collection of seeds, competitive wild collection and its restricted population. Due to high medicinal and aromatic properties, the species is facing tremendous population decline from the wild and has been reported to sell like hot cakes in the markets. The species also faces identity crisis as it is often mistaken with *Carum bulbocastanum* (L.) W.D.J.Koch or *Carum carvi* L. Also, it is often adulterated with *Cuminum cyminum* L. (Bansal et al. 2018). Additionally, according to Sofi et al. (2009), low productivity mainly due to the poor crop management practices, inadequate planting density, high weed incidence, diseases, insect damage, low germination percentage of seeds, uncertain quality and lack of trade standards are the other issues responsible for its vulnerability in the Himalayan region.

Globally, Kalazeera is distributed in Baluchistan, Afghanistan, and India. In India, it is distributed in Kashmir and the high-altitude regions of Himachal Pradesh including the Padder valley, Chamba, Kinnaur, Lahaul, Pangi, and Spiti at elevations ranging between 1,500–3,500 m (Chauhan 1999; Gupta et al. 2012; Ravikumar et al. 2018). It grows mainly in grassy slopes and low alpine pastoral lands (Sofi et al. 2009). As a whole plant, it is an economically important culinary crop that is cultivated for its seed which matures in the months of late July to August (Chauhan 1999). The seeds are darkish-brown, ribbed with pointed ends and have a deep aroma (Image 2). *B. persicum* has been kept under red-listed Himalayan forest species and is listed amongst the 100 species of conservation concern in commercial demand for use as a herbal raw drug in India (Goraya & Ved 2017). Interestingly, it is also among the few wild species in the western Himalaya which has been recommended for commercial cultivation (Singh et al. 2009). This species with considerable knowledge and literature on its usage, is harvested and traded extensively in Himachal Pradesh. Owing to low volume, high value, and as a non-perishable commodity, it is one the most preferred species for indigenous use and trade in Lahaul and Pangi valley (Singh et al. 2009). The species has diuretic, digestive, anticonvulsive, and anthelmintic effects (Stappen et al. 2017). Owing to these properties, the plant finds use in several medicinal, culinary, and aromatic practices (Sofi et al. 2009), the seeds are widely used as a food additive, tea making condiment and a popular spice and flavoring agent. Due to its therapeutic effect on digestive and urinary tract disorders, it is used for chronic cholangitis and kidney stone, and is useful in treating diabetes (Hassanzadazar et al. 2018), diarrhea, dyspepsia, curing fever, flatulence, stomach-ache, haemorrhoids, and obstinate hiccups (Chauhan 1999). *B. persicum* has been traditionally used as an appetizer, to reduce cholesterol, anxiety, depression, to alleviate indigestion, bronchitis, diseases of blood & ear, leprosy, convulsions, foul breath, joint pain, lumbago, and weak memory (Singh et al. 2009).

Kalazeera is facing enormous threats not only due to the illegal trade and unscientific harvesting it is subjected to, but also due to loss of its habitats, featuring unique topography and climatic conditions, due to development and degradation resulting in drastic decline in the wild populations (Kala 2000; Goraya & Ved 2017). According to Chauhan (1999), the market price of Kalazeera was 300–400 INR kg^{-1} in the state of Himachal Pradesh, whereas the report of 2,200–4,200 INR kg^{-1} as per Kumar et al. (2021) indicates that the price has increased 10 fold in the last 20 years. According to Goraya & Ved (2017), the estimated annual trade of Kalazeera in

Himachal Pradesh was <10 metric tonne (MT). The Himachal Pradesh State forest department issues permits for regulating the collection of medicinal plants, however, the illegal trade in terms of hidden markets is posing a threat to the species. Therefore, it is submitted that competitive collection, increased illegal trade may inevitably lead to the decline in wild populations of *B. persicum* in the near future if appropriate conservation and mitigation measures are not taken. The species, therefore, requires urgent management interventions for its conservation, sustainable availability to the herbal sector, and continuous cash income to thousands of wild gatherers. Further, the species can be put in 'Action Lists' for proactive action towards its conservation, building of their wild population and developing sustainable harvesting practices as envisaged by Goraya & Ved (2017). The first step towards its conservation is identifying the existing population base, species distribution and abundance, therefore it becomes important to conduct such studies on an urgent basis. Identification of best cultivation practices, research, and development to reduce long-gestation periods, cost effective technology, organic-farming, buy-back mechanisms, policy-revision in the interest of stakeholders, protocols for post-cultivation management, quality-control and awareness training would be the practical solution in this direction. Recently, the species has been granted the Geographical Indication (GI) tag by the Government of Himachal Pradesh. This is an important step towards conserving this plant and plant-based products and can further improve its market potential, boosting the region's economy by giving better returns at the grassroot levels. Additionally, a major step towards species conservation can be the strengthening of the Biodiversity Management Committee and spreading awareness on the dwindling populations among the various stakeholders. Identifying and building the capacities of stakeholders including respective forest department, locals, traditional healers, and local plant traders can help in community based natural resource management.

References

Bansal, S., S. Thakur, M. Mangal, A.K. Mangal & R.K. Gupta (2018). DNA barcoding for specific and sensitive detection of *Cuminum cyminum* adulteration in *Bunium persicum*, *Phytomedicine* 50: 178–183. https://doi.org/10.1016/j.phymed.2018.04.023

Bhatt, A., S.K. Joshi & S. Gairola (2005). *Dactylorhiza hatagirea* (D.Don) Soo–a west Himalayan orchid in peril. *Current Science* 89(4): 610–612.

Chauhan, N.S. (1999). *Medicinal and aromatic plants of Himachal Pradesh*. Indus Publishing, 632 pp.

Dorji, K. (2016). Ecological status of high-altitude medicinal plants and their sustainability: Lingshi, Bhutan. *BioMed Central Ecology* 16(1): 45. https://doi.org/10.1186/s12898-016-0100-1

Goraya, G.S. & D.K. Ved (2017). Medicinal plants in India: An assessment of their demand and supply. National Medicinal Plants Board, Ministry of AYUSH, Government of India, New Delhi and Indian Council of Forestry Research and Education, Dehradun, 430pp.

Gupta, V., D. John, V.K. Razdan & S.K. Gupta (2012). First report of tuber rot disease of Kalazeera caused by a member of the *Fusarium solani* species complex in India. *Plant Disease* 96(7): 1067–1067.

Hassanzadazar, H., B. Taami, M. Aminzare & S. Daneshamooz (2018). *Bunium persicum* (Boiss.) B.Fedtsch: An overview on phytochemistry, therapeutic uses and its application in the food industry. *Journal of Applied Pharmaceutical Science* 8(10): 150–158. https://doi.org/10.1094/PDIS-02-12-0148-PDN

Kala, C.P. (2000). Status and conservation of rare and endangered medicinal plants in the Indian trans-Himalaya. *Biological Conservation* 93(3): 371–379. https://doi.org/10.1016/S0006-3207(99)00128-7

Mathela, M., H. Bargali, M. Sharma, R. Sharma & A. Kumar (2020). Brainstorming on the future of the highly threatened medicinal plants of the Western Himalaya, India. *Current Science* 118(10): 1885–1865.

Mathela, M., A. Kumar, M. Sharma, & G.S. Goraya (2021). Hue and cry for *Fritillaria cirrhosa* D.Don, a threatened medicinal plant in the Western Himalaya. *Discover Sustainability* 2(38). https://doi.org/10.1007/s43621-021-00048-5

Mittermier, R.A., P.R. Gils, M. Hoffmann, J. Pilgrim, T. Brooks, C.G. Mittermeier, J. Lamoreaux & G.A.B. da Fonseca (2004). *Hotspots Revisited. Earth's Biologically Richest and Most Endangered Terrestrial Ecosystems*. CEMEX, USA.

Pant, S. & T. Rinchen (2012). *Dactylorhiza hatagirea*: A high value medicinal orchid. *Journal of Medicinal Plants Research* 6(19): 3522–3524. https://doi.org/10.5897/JMPR12.097

Ravikumar, K., S.N. Begum, D.K. Ved, J.R. Bhatt & G.S. Goraya (2018). *Compendium of Traded Indian Medicinal Plants*. Foundation for Revitalization of Local Health Traditional, Bengaluru, India.

Samant, S.S., U. Dhar & L.M.S. Palni (1998). *Medicinal plants of Indian Himalaya: diversity distribution potential values*. Nainital, India, Gyanodaya Prakashan, 161 pp.

Samant, S.S. & L.M.S. Palni (2000). Diversity, distribution and indigenous uses of essential oil yielding plants of Indian Himalayan Region. *Journal of Medicinal and Aromatic Plant Sciences* 22(1B): 671–684.

Singh, A., M. Lal & S.S. Samant (2009). Diversity, indigenous uses and conservation prioritization of medicinal plants in Lahaul valley, proposed Cold Desert Biosphere Reserve, India. *International Journal of Biodiversity Science & Management* 5(3): 132–154.

Singh, P., S.S. Dash & B.K. Sinha (2019). *Plant of Indian Himalayan region (an annotated checklist and pictorial guide)*. Botanical Survey of India, Kolkata, 650 pp.

Sofi, P.A., N.A. Zeerak & P. Singh (2009). Kala zeera (*Bunium persicum* Bioss.): a Kashmirian high value crop. *Turkish Journal of Biology* 33(3): 249–258.

Stappen, I., N. Tabanca, A. Ali, D.E. Wedge, J. Wanner, V. Gochev, V. Jaitak, B. Lal, V.K. Kaul, E. Schmidt & L. Jirovetz (2017). Biological activity of *Bunium persicum* essential oil from Western Himalaya. *Planta Medica International Open* 4(2): 52–58. https://doi.org/10.1055/s-0043-106857

Kumar, A., S. Sathyakumar, G.S. Goraya, A.K. Gupta, B.S. Adhikari & G.S. Rawat (2021). Assessment of medicinal and aromatic plant species on their collection, usage, demand, markets, price trends and life cycle in Lahaul and Pangi landscape, Himachal Pradesh. A report submitted to Himachal Pradesh Forest Department and United Nations Development Programme, 141 pp.

Yadav, P.K., S. Saha, A.K. Mishra, M. Kapoor, M. Kaneria, M. Kaneria, S. Dasgupta & U.B. Shrestha (2019). *Yartsagunbu*: transforming people's livelihoods in the Western Himalaya. *Oryx* 53(2): 247–255. https://doi.org/10.1017/S0030605318000674

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NOTE

First record of Parasitic Jaeger *Stercorarius parasiticus* (Aves: Charadriiformes: Stercorariidae) from inland freshwater Inle Lake, Myanmar

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The Parasitic Jaeger, also known as Arctic Skua *Stercorarius parasiticus*, breeds in the arctic tundra in northern Eurasia and North America and is a common breeding bird in the arctic. The species overwinters in the southern hemisphere, mainly in the southern tropical to temperate seas and oceans around Australia, southern Africa, and southern South America (BirdLife International 2018). They move to the southern Hemisphere during October to November and return in February to March (Harrisson & Smythies 1960; GBIF 2021). The main migration routes of this marine species are predominately coastal and offshore, but it has been observed migrating over land. The species is uncommon offshores of Thailand, Peninsular Malaysia, and a vagrant to Singapore (Robson 2011; Poole et al. 2014; GBIF 2021), but is relatively rare inland southeastern Asia compared to coastal and offshore. Another rare encounter of the species inland of southeastern Asia was an adult female specimen from Borneo on 5 November 1960, likely an individual blown off course by the typhoons (Harrisson & Smythies 1960). Based on these records from elsewhere in Southeast Asia, the Parasitic Jaeger was postulated to occur in Myanmar (Holmes et al. 2014), but so far, the species was not recorded from terrestrial Myanmar. Since Inle Lake is a birding hotspot in Myanmar it is regularly visited by a large number of potential observers of the species. Our team surveyed the Inle Lake regularly from 2018 to late 2020 for all water birds.

Observations and identification: In November 2018, we recorded a single individual of a distinct looking bird with blackish-brown plumage at Inle Lake. On 24 October 2019, we observed the same species again, chasing Brown-headed Gulls, *Larus brunnicephalus* and Black-headed Gulls, *L. ridibundus* for several minutes in the afternoon in Inle Lake, Shan State, Myanmar. The bird was distinctive in plumage form the gulls and the behaviour was strikingly. We observed the individual chasing and in flight; it was gliding for a considerable time after the gulls disappeared. Afterwards the jaeger stayed still while floating on the water (Image 1). Based

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Image 1. Parasitic Jaeger *Stercorarius parasiticus* observed perched in Inle Lake, Shan State, Myanmar on 24 October 2019. © Myint Kyaw.

Image 2. Parasitic Jaeger *Stercorarius parasiticus* observed in flight over Inle Lake, Shan State, Myanmar on 24 October 2019. © Soe Naing Aye.

on its plumage characters, we identified it as a pale morph of Parasitic Jaeger *Stercorarius parasiticus*. The plumage of the observed individual was mostly blackish-brown and the body shape appeared lighter built than other *Stercorarius* and resembled in size more to the observed gulls. *S. parasiticus* distinguishes from other similar species, Pomarine Jaeger *Stercorarius pomarinus* and Long-tailed Jaeger *Stercorarius longicaudus* by showing pointed central tail feathers while the Pomarine Jaeger has spoon-shaped tail projection – the tail projection confirms species status for our individual (Image 1, 2) and from observations in the field by us. The breast band is less contrasting when compared with Pomarine Jaeger. The cap is black, the throat, nape and belly are white, while the underwing has pale tips – the tail projections and wing pattern indicate parasitic jaeger (Image 2; cf. Olsen & Larsson 1997). The bird has a small area of white in the primary bases on underwing and it forms white flashes during flight. The front is black and the bill is of dark colour. We compared the photo with plates in Olsen & Larsson (1997) visually and asked three colleagues for independent identification (listed in acknowledgments). While we have a photograph (Image 1, 2) of the 2019 bird, we have no photographic proof of the earlier record from 2018.

Discussion: The record is important for two reasons: This is the first record of the species from an inland freshwater lake in southeastern Asia, which is approximately 380 km off the coast. In addition, the species is recorded the first time in freshwater habitat in Myanmar, unusual for the species. Similarly, Pfister (2004) also reported that *S. parasiticus* was seen chasing a Brown-headed Gull *L. brunnicephalus* over the Tsomoriri Lake, India. While this species is marine and coastal, it may be observed during migration inland (BirdLife International 2018). Our Parasitic Jaeger record is the first observation of the species in Myanmar, but also highlights the potential role of Inle Lake as a large natural inland stopover site in Myanmar (Naing et al. 2020; BirdLife International 2021). Inle Lake was also designated as Ramsar Site in 2018 and important bird area (IBA) in 2004.

The Parasitic Jaeger is the first and second record for Myanmar and we assume that it is a stray individual for Myanmar. We have observed it during the migration period to the southern hemisphere, where the Parasitic Jaeger is wintering in tropical regions. In theory, Inle Lake could be a stopover for migration as has been identified for many wader and gull species, e.g., Brown-headed Gulls have a significant wintering population in Inle Lake. However, while for waders and gulls, stopover and wintering have been observed at Inle Lake and other Myanmar freshwater sites, pelagic species such as the jaeger, have been more observed along the southern shores of Myanmar (Li et al. 2020). Therefore, the observed jaeger might be a bird on migration, but with the two records of the jaeger at Inle Lake in two different years it remains arguable whether or not the jaeger is a stray bird or uses Inle Lake as a stopover on migration, but it is most likely a vagrant species to Myanmar.

Similar looking species, such as the Pomarine Jaeger, *Stercorarius pomarinus*, have been recorded at Mawlamyine (Smythies 1953) and in the Gulf of Martaban in December 1941 (Wood 1949). Although Robson (2011) stated that Pomarine Jaeger are found in Myanmar it has been observed as vagrant in Tanintharyi. However, all Jaeger species are rare and uncommon records for Myanmar.

References

BirdLife International (2018). *Stercorarius parasiticus*. The IUCN Red List of Threatened Species 2018: e. T22694245A132535550. Downloaded on 19 January 2022. https://doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22694245A132535550.en

BirdLife International (2021). Important Bird Areas factsheet: Inle Lake. http://www.birdlife.org on 31.viii.2021

GBIF (2021). *Stercorarius parasiticus* (Linnaeus, 1758) in GBIF Secretariat (2021). GBIF Backbone Taxonomy. https://doi.org/10.15468/39omei

Harrisson, T. & B.E. Smythies (1960). Artic Skua *Stercorarius parasiticus* in Borneo. *IBIS* 103a(2): 293–294.

Holmes, K.E., T. Tun, K.T. Latt, M. Subedee, S.V. Khadke & A.E. Hostetler (2014). Marine Conservation in Myanmar - The current knowledge of marine systems and recommendations for research and conservation. WCS and MSAM, Yangon, 198 pp.

Li, D., G. Davison, S. Lisovski, P.F. Battley, Z. Ma, S. Yang, C.B. How, D. Watkins, P. Round, A. Yee, V. Srinivasan, C. Teo, R. Teo, A. Loo, C.C. Leong & K. Er (2020). Shorebirds wintering in Southeast Asia demonstrate trans-Himalayan flights. *Scientific Reports* 10: 21232. https://doi.org/10.1038/s41598-020-77897-z

Naing, T.Z., C. Zöckler, K.Z. Tun, L. Win, M. Kyaw, N. Lin & N. Lwin (2020). New and interesting avifaunal records for Myanmar, 2005–2019. *BirdingAsia* 33: 118–127.

Olsen, K. & H. Larsson (1997). *A guide to the skuas and jaegers of the world*. Pica Press, The Banks, Mountfield, Sussex.

Pfister, O. (2004). Birding Hotspot: Ladakh-a high-altitude melting pot. http://orientalbirdclub.org/ladakh

Poole, C.M., W.H. Davison & S. Rajathurai (2014). Marine surveys to study the movement of seabirds through the Singapore Strait 2010–2014. *Forktail* 30: 5–9.

Robson, C. (2011). *A field guide to the birds of South-East Asia*. New Holland Publishers, London.

Smythies, B.E. (1953). *The Birds of Burma*. Oliver and Boyd, Edinburg.

Wood, J.D. (1949). Probable pomatorhine skua off Burma. *Ibis* 91: 690

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BOOK REVIEW

Capparis of India

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The Genus *Capparis* Tourn. ex L. is distributed almost throughout the old world especially in tropical and subtropical regions with about 140 species. In this book, Maurya et al. concisely presented the *Capparis* account in India by recognizing 34 species and one subspecies. However, Mastakar et al. (2020), listed 37 taxa (31 species, 5 subspecies and 1 variety) under *Capparis* in "Flowering Plants of India, An Annotated Checklist (Dicotyledons)", which is mainly based on the work of R.S. Raghavan (1993) in "Flora of India", who recognised only 29 species. The major difference among these works are, Maurya et al. considered the three subspecies of *C. acutifolia* Sweet as separate species.

The book is handy with 92 pages and easy to use, starts with a very brief introduction, which includes review of literature, the genus distribution in the world and in the Indian subcontinent, table showing its food and medicinal uses of *Capparis* species and finally materials and methods as well as data presentation in the book. The taxonomic account begins with the key to the sections in the genus and to the species represented in India. Keys to all the four sections are well illustrated with the photographs of the live plants showing diagnostic characters, by which one can easily identify their specimens instantly to the sectional level. The species are arranged section wise, the section *Monostichocalyx* is represented in India by 30 species out of 34 recognised in this work and the section *Capparis* by two species and one subspecies, indeed the section *Sodada* is a monotypic and the remaining one section *Busbeckea* is represented in India by only one species.

Under each species basionym if present and selected synonyms only are cited, but the descriptions are well written. The diagnostic characters, type, etymology, phenology, common English/vernacular names, distribution, specimens examined and uses if any were given for each taxon. In fact, in the Tabular form, the Food and Medicinal uses of the 23 taxa (22 species and

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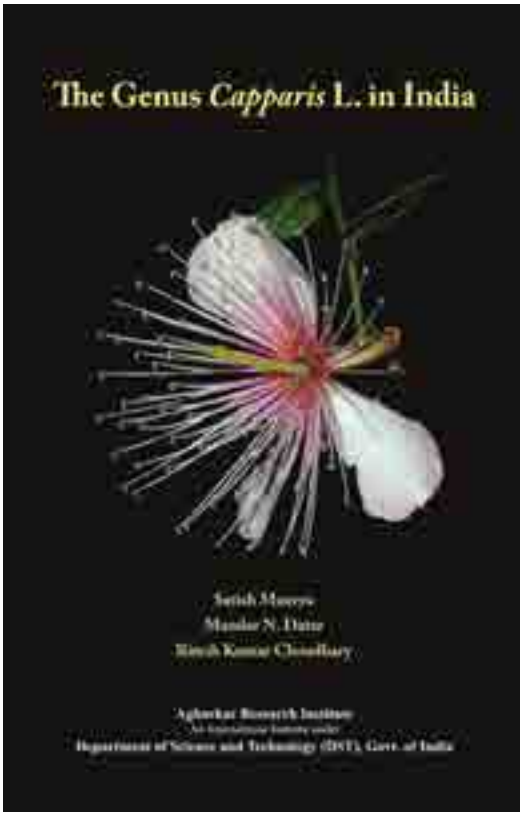

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one subspecies) are well presented in 'Introduction' chapter itself. For most of the species ideally illustrated photo-plates are presented and for some the herbarium specimen's images are reproduced for easy identification. Apart, in each species, a good distribution map is also provided to get a glimpse of the particular species distribution in Indian political boundary.

The key to the species is well prepared with good opposite characters, in which the only one subspecies also added by which the 35 taxa are keyed out in 34 couplets. Since the species are arranged section wise, it would have been better if they would have mentioned species number against each species in the key. For making the book compact, under each species, important synonyms are only cited, which made two-third of them are only with accepted name citations! Actually, the authors should have included more synonyms especially of the names published from the Indian subcontinent. For example, the species *Capparis wallichiana* Wight & Arn. and *C. heyneana* Wall. ex Wight & Arn. described in the "Prodromus Florae Peninsulae Indiae Orientalis" (1834) should have been included.

Although the descriptions are written somewhat in detail, the authors should have maintained the uniformity as far as possible since the number of species represented in India are very less. A glaring mistake to be pointed out here is, in some descriptions the colour of the petal is given under "Flower" while in some in "petal". Similarly, the usage of singular and plural also should have been taken care, e.g. described 'blades', 'petioles' in most species while in some 'blade', 'petiole' are used.

It seems the authors have made good effort in galley proof reading, the book is almost devoid of any spelling errors. However, they should have noticed *Capparis bodinieri* H.Lév. and *C. acutifolia* ssp. *bodinieri* (A.Lév.) M. Jacobs, and should have used either one of the author standard form for Augustin Abel Hector Léveillé. In the subtitle of '*Capparis* in the Indian Subcontinent' under the "Introduction" chapter, the authors forgot to mention the name Myanmar (Burma), although in the map (Fig. 2) they provided the location of different *Capparis* species distributed in Myanmar. Similarly, they should have detected the error of mentioning 'Endemic' in the distribution of *Capparis brevispina* DC., where it is mentioned as "INDIA: Endemic to Peninsular India … and SRI LANKA". Further, placing of *Capparis versicolor* Griff. under 'Excluded species' is not properly justified.

At the end, Bibliography and Index are provided. Indeed, it is the shortest and one page index ever produced in a taxonomic account comprising only just more than a 50 names for 35 accepted taxa. Although good number of references are provided in the Bibliography, standard procedure to cite the references are not followed and in some, citations are also wrong. The main purpose of giving reference is to enable the readers to find those literature, but citing them in short form, may not help in anyway.

In overall aspect, the book on *Capparis* in India is a good work, it is an updated version for the work done by the Late R.S. Raghavan, who published this genus account in "Flora of India, volume 2" in 1993. This book should be purchased and kept in the libraries of colleges, universities and research organizations dealing with the Life Science. Hope the authors will take care some of the demerits pointed out above while publishing the revised edition or the molecular phylogenetics of the *Capparis* in India.

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