Building evidence for conservation globally

Journal of Threatened Taxa

Open Access

www.threatenedtaxa.org

26 January 2022 (Online & Print)
14(1): 20311-20538
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)
Estimating the completeness of orchid checklists and atlases: a case study from southern Italy

Antonio Croce

GIROS (Gruppo Italiano per la ricerca sulle Orchidee Spontanee - Italian Group for the Research on Wild Orchids)
Via Chiesa - Tuoro, 44 - 81057 Teano, Caserta, Italy.
antocrx@gmail.com

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. È 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’esauritività 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.
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; Rocchi 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?
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 km² 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 km² 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 km² 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.

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

To compare the three datasets in terms of sampling effort and observed specific richness (\(S_{\text{obs}}\)), 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 (\(S_{\text{obs}}\)) and the number of estimated species (\(S_{\text{est}}\)).

\[
C = \frac{S_{\text{obs}}}{S_{\text{est}}}
\]

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 (\(S_{\text{est}}\)) the maximum value between Chao2 (\(S_{\text{Chao2}}\)) and Jackknife1 (\(S_{\text{jack1}}\)) 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 x 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 Roccamongina area has the highest species richness, average number of records/plot and plot/km². Vairanese and W-Matese show comparable values of the number of records/plot (higher values for W-Matese) and number of plots/km² (higher values for Vairanese). Nevertheless, the distribution of the number of plots (Figure 2a) and observed species richness (Figure 2b) in the 1 km² cells is extremely heterogeneous with a very high standard deviation of the plots/cells ratio (6.9 for Roccamongina, 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 km² 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 Roccamongina 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 km² cells as sampling units (Table 3), we get identical values for Roccamongina area, a slightly higher value for Vairanese area and slightly lower for W-Matese area.

The completeness of the 1 km² cells in the three areas (Figure 2c) is distributed in a similar way in the Roccamongina and Vairanese areas (Table 4): the 35.6% and 33.3% of the 1 km² 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 km² 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 Roccamongina 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 Roccamongina 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 km² cells and 80% of the 36 km² 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 Roccamongina 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 Roccamongina 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.

<table>
<thead>
<tr>
<th></th>
<th>Roccamontfina</th>
<th>Vairanese</th>
<th>W-Matese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sobs</td>
<td>46</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>210</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>1 km² cells</td>
<td>163</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>altitude (min-max)</td>
<td>150–1005</td>
<td>125–588</td>
<td>150–811</td>
</tr>
<tr>
<td>Number of Plots</td>
<td>1184</td>
<td>121</td>
<td>124</td>
</tr>
<tr>
<td>Database-records</td>
<td>3046</td>
<td>263</td>
<td>296</td>
</tr>
<tr>
<td>records/plot</td>
<td>2.57</td>
<td>2.17</td>
<td>2.39</td>
</tr>
<tr>
<td>Plot/km²</td>
<td>7.26</td>
<td>6.72</td>
<td>6.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Roccamontfina</th>
<th>Vairanese</th>
<th>W-Matese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anacamptis coriophora (L.) R.M.Bateman, Pridgeon &amp; M.W.Chase</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Anacamptis morio (L.) R.M.Bateman, Pridgeon &amp; M.W.Chase</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Anacamptis papilionacea (L.) R.M.Bateman, Pridgeon &amp; M.W.Chase</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Anacamptis pyramidalis (L.) Rich.</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cephalanthera damasonium (Mill.) Druce</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cephalanthera longifolia (L.) Fritsch</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cephalanthera rubra (L.) Rich.</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dactylorhiza maculata (L.) Soó subsp. saccifera (Brongn.) Diklić</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dactylorhiza romana (Sebast.) Soó subsp. romana</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dactylorhiza sambucina (L.) Soó</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epipactis exilis P.Delforge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epipactis helloborine (L.) Crantz subsp. helloborine</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epipactis microphylla (Ehrh.) Sw.</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Epipactis muelleri Godfery</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epipactis mariae (Croce, Bongiorni, De Vivo &amp; Fori) Presser &amp; S.Hertel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epipactis placentina Bongiorni &amp; Grünanger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gymnadenia conopsea (L.) R.Br.</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Himantoglossum adriaticum H.Baumann</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limodorum abortivum (L.) Sw.</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Neotinea maculata (Desf.) Stearn</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Neotinea tridentata (Scop.) R.M.Bateman, Pridgeon &amp; M.W.Chase</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Neottia nius-avis (L.) Rich.</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neottia ovata (L.) Bluff &amp; Fingerh.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophrys apiifera Hud.</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ophrys argonica H.Fleischm. ex Vierh. subsp. crabronifera (Mauri) Faurh.</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ophrys bertolonii Moretti subsp. bertolonii</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ophrys bombyliflora Link</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophrys exaltata Ten. subsp. monts-leonis (O.Danesch &amp; E.Danesch) Soca</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophrys holosericea (Burm.f.) Greuter subsp. gracilis (Büel, O.Danesch &amp; E.Danesch) O.Danesch &amp; E.Danesch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophrys holosericea (Burm.f.) Greuter subsp. holosericea</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ophrys incubacea Bianca</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophrys insectifera L.</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ophrys lutea Cav.</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ophrys promontorii O.Danesch &amp; E.Danesch</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ophrys sphegodes Mill. subsp. sphegodes</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ophrys sphegodes Mill. subsp. minipassionis (Romolini &amp; Soca) Biagioli &amp; Grünanger</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>
J. TT

(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

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

<table>
<thead>
<tr>
<th></th>
<th>Roccamonfina</th>
<th>Vairanese</th>
<th>W-Matese</th>
</tr>
</thead>
<tbody>
<tr>
<td>n. Plots (100 x 100 m)</td>
<td>1184</td>
<td>121</td>
<td>124</td>
</tr>
<tr>
<td>Sobs</td>
<td>46</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>$S_{berv}$</td>
<td>49</td>
<td>35.72</td>
<td>37.9</td>
</tr>
<tr>
<td>$S_{jack}$</td>
<td>51.99</td>
<td>40.93</td>
<td>39.94</td>
</tr>
<tr>
<td>Completeness %</td>
<td>88.5</td>
<td>78.2</td>
<td>82.6</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Roccamonfina</th>
<th>Vairanese</th>
<th>W-Matese</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of 1 km² cells</td>
<td>163</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Sobs</td>
<td>46</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>$S_{berv}$</td>
<td>48.98</td>
<td>40.5</td>
<td>36.33</td>
</tr>
<tr>
<td>$S_{jack}$</td>
<td>51.96</td>
<td>40.5</td>
<td>40.3</td>
</tr>
<tr>
<td>Completeness %</td>
<td>88.5</td>
<td>79.0</td>
<td>81.9</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Completeness level %</th>
<th>Roccamonfina</th>
<th>Vairanese</th>
<th>W-Matese</th>
</tr>
</thead>
<tbody>
<tr>
<td>n. cells</td>
<td>%</td>
<td>n. cells</td>
<td>%</td>
</tr>
<tr>
<td>n.e.</td>
<td>84</td>
<td>51.5</td>
<td>7</td>
</tr>
<tr>
<td>0–25</td>
<td>3</td>
<td>1.8</td>
<td>2</td>
</tr>
<tr>
<td>25–50</td>
<td>5</td>
<td>3.1</td>
<td>1</td>
</tr>
<tr>
<td>50–75</td>
<td>35</td>
<td>21.5</td>
<td>4</td>
</tr>
<tr>
<td>75–100</td>
<td>36</td>
<td>22.1</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>163</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>555</td>
<td>58</td>
<td>35.6</td>
<td>6</td>
</tr>
</tbody>
</table>
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 km\(^2\) cells, a half of them are classified as SSS. The distribution of the completeness for a grid of 1 km\(^2\) 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

Figure 3. Correlation between number of plots and number of observed species for each of the 1 km\(^2\) 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 and Jackknife1 estimators, using cells of different size (100 x 100 m, 1 km\(^2\), 4 km\(^2\), 9 km\(^2\), 16 km\(^2\), 25 km\(^2\), and 36 km\(^2\)) as sampling units for the Roccamonfina area.
Orchid checklists and atlases: a case study from southern Italy

Croce

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.

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

<table>
<thead>
<tr>
<th></th>
<th>1 km²</th>
<th>4 km²</th>
<th>9 km²</th>
<th>16 km²</th>
<th>25 km²</th>
<th>36 km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n.e.</td>
<td>84</td>
<td>51.5</td>
<td>23</td>
<td>37.7</td>
<td>10</td>
<td>16.4</td>
</tr>
<tr>
<td>0–25</td>
<td>3</td>
<td>1.8</td>
<td>1</td>
<td>1.6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25–50</td>
<td>5</td>
<td>3.1</td>
<td>4</td>
<td>6.6</td>
<td>5</td>
<td>8.2</td>
</tr>
<tr>
<td>50–75</td>
<td>35</td>
<td>21.5</td>
<td>14</td>
<td>23</td>
<td>6</td>
<td>9.8</td>
</tr>
<tr>
<td>75–100</td>
<td>36</td>
<td>22.1</td>
<td>19</td>
<td>31.1</td>
<td>12</td>
<td>19.7</td>
</tr>
<tr>
<td>tot</td>
<td>163</td>
<td>61</td>
<td>33</td>
<td>22</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>SSS</td>
<td>58</td>
<td>35.6</td>
<td>28</td>
<td>45.9</td>
<td>17</td>
<td>51.5</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Roccamomfina</th>
<th>Sobs</th>
<th>Plots</th>
<th>S_chao2</th>
<th>S_Jack1</th>
<th>C %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial (incl. Road verges)</td>
<td>25</td>
<td>50</td>
<td>28.9</td>
<td>33.8</td>
<td>73.9</td>
</tr>
<tr>
<td>Agriculture</td>
<td>11</td>
<td>18</td>
<td>20.0</td>
<td>16.7</td>
<td>55.0</td>
</tr>
<tr>
<td>Open habitats</td>
<td>33</td>
<td>158</td>
<td>36.5</td>
<td>40.9</td>
<td>80.6</td>
</tr>
<tr>
<td>Broadleaved woodlands (excl. Chestnut woods)</td>
<td>25</td>
<td>82</td>
<td>27.1</td>
<td>30.9</td>
<td>80.9</td>
</tr>
<tr>
<td>Chestnut coppices</td>
<td>18</td>
<td>62</td>
<td>19.0</td>
<td>21.0</td>
<td>85.9</td>
</tr>
<tr>
<td>Chestnut orchards</td>
<td>38</td>
<td>839</td>
<td>44.0</td>
<td>44.0</td>
<td>86.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vairanese</th>
<th>Sobs</th>
<th>Plots</th>
<th>S_chao2</th>
<th>S_Jack1</th>
<th>C %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open habitats</td>
<td>26</td>
<td>89</td>
<td>26.5</td>
<td>29.0</td>
<td>89.8</td>
</tr>
<tr>
<td>Broadleaved woodlands</td>
<td>24</td>
<td>33</td>
<td>42.0</td>
<td>35.6</td>
<td>57.1</td>
</tr>
<tr>
<td>Evergreen woodlands</td>
<td>6</td>
<td>8</td>
<td>6.7</td>
<td>8.6</td>
<td>69.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>W-Matese</th>
<th>Sobs</th>
<th>Plots</th>
<th>S_chao2</th>
<th>S_Jack1</th>
<th>C %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open habitats</td>
<td>28</td>
<td>60</td>
<td>100.0</td>
<td>39.8</td>
<td>28.0</td>
</tr>
<tr>
<td>Broadleaved woodlands</td>
<td>27</td>
<td>57</td>
<td>28.6</td>
<td>32.0</td>
<td>84.4</td>
</tr>
</tbody>
</table>

Figure 6. Rarefaction curves for the different habitats of the Roccamonfina area.
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 km² for small islands and reserves to cells of 100 km² 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


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

Ashaq Ahmad Dar 1,2, Akhtar Hussain Malik 2 & Narayanaswamy Parthasarathy 3,4

1,2 Department of Ecology and Environmental Sciences, School of Life Sciences, Pondicherry University, Puducherry 605014, India
3 Centre for Biodiversity and Taxonomy, Department of Botany, University of Kashmir, Jammu & Kashmir 190006, India
4 bcsahaq@gmail.com, ecoakhtar@gmail.com, nparthasarathypu@gmail.com (corresponding author)

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 Piceae 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.


Editor: Anonymity requested. Date of publication: 26 January 2022 (online & print)


Copyright: © Dar et al. 2022. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use, reproduction, and distribution of this article in any medium by providing adequate credit to the author(s) and the source of publication.

Funding: University Grant Commission (UGC) by means of Junior Research Fellowship (UGC-JRF) UGC-Ref. No.: 3796/[NET-JULY-2018].

Competing interests: The authors declare no competing interests.

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.

Acknowledgements: Authors are indebted to the Jammu & Kashmir Forest Department for kindly providing permission to carry out research fieldwork. We express gratitude to the Centre for Biodiversity and Taxonomy, Department of Botany, University of Kashmir for their paid assistance in identifying plant specimens. Field excursions would not have been conceivable without the enthusiastic assistance of Mudasir Ahmad Wani, Bilal Ahmad Dar, Basharat Ahmad Wani, Mushtaq Ahmad Dar, and many others especially guard officer Tariq Ahmad. Special thanks to Ayushi Kurian, Institut Français de Pondichéry, for GIS (map) related assistance.
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 harboung 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 °N & 74.497–75.019 °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%). Disurbances 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 conescens* 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...
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 identified in the region. Botanical explorations were undertaken during 2019 (March–July) and 2020 (May–August) by employing a random sampling approach considering the accessibility 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 are distributed 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 Camb.) 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 shrubs (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 Lamiales, 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>
<thead>
<tr>
<th>Phylum</th>
<th>Taxon</th>
<th>Genera</th>
<th>Family</th>
<th>Trees</th>
<th>Shrubs</th>
<th>Subshrub</th>
<th>Herbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnoliophyta</td>
<td>262</td>
<td>187</td>
<td>59</td>
<td>10</td>
<td>10</td>
<td>3</td>
<td>239</td>
</tr>
<tr>
<td>Pinophyta</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>–</td>
<td>–</td>
<td>2</td>
</tr>
<tr>
<td>Pteridophyta</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>272</td>
<td>196</td>
<td>64</td>
<td>17</td>
<td>10</td>
<td>3</td>
<td>242</td>
</tr>
</tbody>
</table>
& 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.

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acanthaceae</td>
<td>Erect</td>
<td>BP</td>
<td>2200–2300</td>
<td>PU/EES/KH-1210</td>
<td>E. Afg. to S. China, N. Indo-China &amp; Taiwan</td>
</tr>
<tr>
<td>Adoxaceae</td>
<td>Erect Ph</td>
<td>BP/MC/SA</td>
<td>2200–3310</td>
<td>PU/EES/KH-15201</td>
<td>India, Pak., W. Himalayas</td>
</tr>
<tr>
<td>Viburnum</td>
<td>DS</td>
<td>BP/MC/SA</td>
<td>1890–3000</td>
<td>PU/EES/KH-1206</td>
<td>Himalayas from Kashmir to SE Tibet</td>
</tr>
<tr>
<td>Acanthaceae</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2600–3000</td>
<td>PU/EES/KH-15001</td>
<td>Tropical &amp; Subtropical Old World; throughout India</td>
</tr>
<tr>
<td>Adoxaceae</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2650–2990</td>
<td>PU/EES/KH-15065</td>
<td>Temp. Eurasia to Indian Subcontinent</td>
</tr>
<tr>
<td>Viburnum</td>
<td>Ah</td>
<td>MC/SA</td>
<td>2910–3160</td>
<td>PU/EES/KH-15066</td>
<td>C. &amp; S. Europe to Nepal; W. Himalayas in India</td>
</tr>
<tr>
<td>Apocynaceae</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2500–2600</td>
<td>PU/EES/KH-15008</td>
<td>Temp. Asia; W. Himalayas in India</td>
</tr>
<tr>
<td>Acanthaceae</td>
<td>Ph</td>
<td>SA</td>
<td>3100–3150</td>
<td>PU/EES/KH-15045</td>
<td>Turkey to C. Asia &amp; Pak. to W. Himalayas</td>
</tr>
<tr>
<td>Bupleurum</td>
<td>Ph</td>
<td>BP</td>
<td>2200–2300</td>
<td>PU/EES/KH-15046</td>
<td>Europe to Himalayas</td>
</tr>
<tr>
<td>Bupleurum</td>
<td>Ph</td>
<td>SA</td>
<td>3750–3800</td>
<td>PU/EES/KH-15047</td>
<td>Himalayas from Pak. to Bhutan</td>
</tr>
<tr>
<td>Corus</td>
<td>Ph</td>
<td>BP</td>
<td>2350–2400</td>
<td>PU/EES/KH-15054</td>
<td>Paleartic region; throughout India</td>
</tr>
<tr>
<td>Chaerophyllum</td>
<td>Ph</td>
<td>MC/SA</td>
<td>1927–2450</td>
<td>PU/EES/KH-15063</td>
<td>Himalayas from Pak. to SW China</td>
</tr>
<tr>
<td>Chaerophyllum</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2050–2920</td>
<td>PU/EES/KH-15064</td>
<td>N. Pak. to China; Himalayas in India</td>
</tr>
<tr>
<td>Eryngium</td>
<td>Ph</td>
<td>BP</td>
<td>2120–2130</td>
<td>PU/EES/KH-15103</td>
<td>EC Turkey to Lebanon &amp; W. Pak., W. Himalayas in India</td>
</tr>
<tr>
<td>Heracleum</td>
<td>Climbing</td>
<td>MC/SA</td>
<td>2400–3810</td>
<td>PU/EES/KH-15119</td>
<td>Himalayas from Pak. to SW China</td>
</tr>
<tr>
<td>Pimpinella</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2200–3120</td>
<td>PU/EES/KH-15170</td>
<td>N. Pak. to China; Himalayas in India</td>
</tr>
<tr>
<td>Pimpinella</td>
<td>Ph</td>
<td>MC</td>
<td>2460–2770</td>
<td>PU/EES/KH-15171</td>
<td>E. Afg. to China &amp; Indo-China; Himalayas in India</td>
</tr>
<tr>
<td>Prangos</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2720–3140</td>
<td>PU/EES/KH-15189</td>
<td>Turkey to C. Asia &amp; W. Himalayas</td>
</tr>
<tr>
<td>Sanicula</td>
<td>Ph</td>
<td>SA</td>
<td>2910–2930</td>
<td>PU/EES/KH-15202</td>
<td>SE Asia from Pak. to W. China &amp; S. Japan to SE Africa</td>
</tr>
<tr>
<td>Scandix</td>
<td>Tall robust Ph</td>
<td>3300–3310</td>
<td>PU/EES/KH-15207</td>
<td>Europe to NW India</td>
<td></td>
</tr>
<tr>
<td>Selinum</td>
<td>Ph</td>
<td>SA</td>
<td>3790–3800</td>
<td>PU/EES/KH-15211</td>
<td>NE Pak. to W. Himalayas</td>
</tr>
<tr>
<td>Seseli</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2740–2920</td>
<td>PU/EES/KH-15214</td>
<td>Europe, Turkey, Iran, W. Pak. &amp; India</td>
</tr>
<tr>
<td>Apocynaceae</td>
<td>Prostrate erect or climbing Ah</td>
<td>BP/MC</td>
<td>1980–2760</td>
<td>PU/EES/KH-15244</td>
<td>Europe to W. Siberia &amp; N. Turkey, NW Africa, Himalayas</td>
</tr>
<tr>
<td>Araceae</td>
<td>Rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>2250–2950</td>
<td>PU/EES/KH-15028</td>
<td>Afg. to Mya.</td>
</tr>
<tr>
<td>Araceae</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2450–2950</td>
<td>PU/EES/KH-15029</td>
<td>Pak. to Himalayas &amp; Tibet</td>
</tr>
<tr>
<td>Araliaceae</td>
<td>Ph</td>
<td>BP/MC</td>
<td>1980–2610</td>
<td>PU/EES/KH-15118</td>
<td>Afg. to Thail., Himalayas in India</td>
</tr>
<tr>
<td>Family/Taxon</td>
<td>Life-form</td>
<td>Forest type</td>
<td>OER</td>
<td>Voucher no.</td>
<td>Phytogeographic distribution</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-----</td>
<td>------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Asparagaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asparagus filicinus Buch.-Ham. ex D.Don¹</td>
<td>Erect or twining Ph</td>
<td>BP</td>
<td>1800–1900</td>
<td>PU/EES/KH-15036</td>
<td>Himalayas to C. China</td>
</tr>
<tr>
<td>Polygonatum multiflorum (L.) All.¹</td>
<td>Tufted Ah</td>
<td>BP/MC</td>
<td>2270–2440</td>
<td>PU/EES/KH-15181</td>
<td>Eurasia; W. Himalayas in India</td>
</tr>
<tr>
<td>Polygonatum verticillatum (L.) All.¹</td>
<td>Rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>1980–3120</td>
<td>PU/EES/KH-15183</td>
<td>Europe to China; Himalayas in India</td>
</tr>
<tr>
<td>Balsaminaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impatiens brochycantha Kar. &amp; Kir.¹</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2120–3310</td>
<td>PU/EES/KH-15122</td>
<td>Afg. to C. Asia &amp; W. Himalayas</td>
</tr>
<tr>
<td>Berberidaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berberis lycium Royle¹</td>
<td>Semi-DS</td>
<td>BP</td>
<td>2100–2150</td>
<td>PU/EES/KH-1203</td>
<td>W. Himalayas from Pak. to Nepal</td>
</tr>
<tr>
<td>Epimedium elatum C.Morren &amp; Decne.¹</td>
<td>Rhizomatous Ph</td>
<td>MC/SA</td>
<td>2520–3020</td>
<td>PU/EES/KH-15095</td>
<td>N. Pak. to W. Himalayas</td>
</tr>
<tr>
<td>Podophyllum hexandrum Royle¹</td>
<td>Rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>2370–3310</td>
<td>PU/EES/KH-15176</td>
<td>NE Afg. to C. China; Himalayas in India</td>
</tr>
<tr>
<td>Betulaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betula utilis D.Don²</td>
<td>DT</td>
<td>SA</td>
<td>2910–3300</td>
<td>PU/EES/KH-1004</td>
<td>Afg. to N. &amp; C. China; Himalayas in India</td>
</tr>
<tr>
<td>Corylus jacquemontii Decne.⁶</td>
<td>DT</td>
<td>MC</td>
<td>2560–2790</td>
<td>PU/EES/KH-1006</td>
<td>Europe, Himalayas from Afg. to W. Nepal</td>
</tr>
<tr>
<td>Boraginaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arnebia benthamii (Wall. ex G. Don) I.M. Johnst.¹</td>
<td>Rhizomatous Ph</td>
<td>SA</td>
<td>3800–3900</td>
<td>PU/EES/KH-15024</td>
<td>NE Pakistan to W. &amp; C. Himalaya</td>
</tr>
<tr>
<td>Cynoglossum ovatum Forsk.¹</td>
<td>Bh or Ph</td>
<td>BP/SA</td>
<td>2230–3800</td>
<td>PU/EES/KH-15085</td>
<td>Tropical &amp; S. Africa to Subtropical Asia; throughout India</td>
</tr>
<tr>
<td>Myosotis alpestris F.W. Schmidt¹</td>
<td>Ph</td>
<td>SA</td>
<td>2910–3120</td>
<td>PU/EES/KH-15117</td>
<td>Himalayas from Pak. to SW China</td>
</tr>
<tr>
<td>Myosotis sylvatica Ehrh. ex Hoffm.¹</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2260–3150</td>
<td>PU/EES/KH-15149</td>
<td>Europe, Himalayas from Pak. to Bhutan</td>
</tr>
<tr>
<td>Brassicaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arabis amplexicaulis Edgew.¹</td>
<td>Ph</td>
<td>BP/MC</td>
<td>2200–2410</td>
<td>PU/EES/KH-15021</td>
<td>Afg. to Mongolia &amp; Himalayas</td>
</tr>
<tr>
<td>Arabis petersperma Edgew.¹</td>
<td>Ph</td>
<td>MC</td>
<td>2700–2800</td>
<td>PU/EES/KH-15023</td>
<td>Kashmir to China</td>
</tr>
<tr>
<td>Capsella bursa-pastoris (L.) Medik.¹</td>
<td>Erect Ah or Bh</td>
<td>MC/SA</td>
<td>2420–2950</td>
<td>PU/EES/KH-15053</td>
<td>Temp. Eurasia, N. Africa; throughout India</td>
</tr>
<tr>
<td>Chorispora tenella (Pall.) DC.¹</td>
<td>Ah</td>
<td>MC</td>
<td>2750–2770</td>
<td>PU/EES/KH-15067</td>
<td>SE &amp; E. Europe to China; W. Himalayas in India</td>
</tr>
<tr>
<td>Lepidium oettingeri F.W. Schmidt¹</td>
<td>Rhizomatous Ph</td>
<td>BP</td>
<td>2120–2130</td>
<td>PU/EES/KH-15134</td>
<td>E. Europe to temp. Asia; Himalayas in India</td>
</tr>
<tr>
<td>Turritis glabra L.⁷</td>
<td>Ah or Bh</td>
<td>BP/SA</td>
<td>2300–2650</td>
<td>PU/EES/KH-15022</td>
<td>Temp. N. Hemisphere; W. Himalayas in India</td>
</tr>
<tr>
<td>Campanulaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Campanula lasiocarpa Royle¹</td>
<td>Ph</td>
<td>SA</td>
<td>3150–3200</td>
<td>PU/EES/KH-15050</td>
<td>Afg. to W. Himalayas to Nepal</td>
</tr>
<tr>
<td>Campanula latifolia L.¹</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2525–2920</td>
<td>PU/EES/KH-15051</td>
<td>SW Siberia, W. Asia to C. Himalayas</td>
</tr>
<tr>
<td>Codonopsis ovata Benth.²</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2720–3800</td>
<td>PU/EES/KH-15076</td>
<td>C. Asia, Himalayas from Pak. to Kashmir</td>
</tr>
<tr>
<td>Codonopsis rotundifolia Benth.¹</td>
<td>Twining Ph</td>
<td>BP</td>
<td>2200–2340</td>
<td>PU/EES/KH-15077</td>
<td>Pak. to Himalayas &amp; S. Tibet</td>
</tr>
<tr>
<td>Cannabaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannabis sativa L.²</td>
<td>Ah</td>
<td>BP/MC</td>
<td>1920–2650</td>
<td>PU/EES/KH-15052</td>
<td>Native to C. Asia now cosmopolitan</td>
</tr>
<tr>
<td>Caprifoliaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dipsacus inermis Wall.³</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2700–3810</td>
<td>PU/EES/KH-15092</td>
<td>Himalayas from Afg. to SW China &amp; Mya.</td>
</tr>
<tr>
<td>Lonicera quinquefolialis Hard.¹</td>
<td>ES</td>
<td>MC</td>
<td>2500–2700</td>
<td>PU/EES/KH-1209</td>
<td>E. Afg. to Himalayas</td>
</tr>
<tr>
<td>Morina longifolia Wall.¹</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2700–2920</td>
<td>PU/EES/KH-15147</td>
<td>N. Pakistan to Himalaya &amp; S. Tibet</td>
</tr>
</tbody>
</table>
### Floristic survey across three coniferous forests of Kashmir Himalaya

**Dar et al.**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scabiosa speciosa Royle</td>
<td>Ah</td>
<td>MC</td>
<td>2720–2730</td>
<td>PU/EES/KH-15208</td>
<td>Himalayas from Pak. to Uttarakhand</td>
</tr>
<tr>
<td>Valeriana hardwickii Wall.</td>
<td>Dioecious Ph</td>
<td>MC/SA</td>
<td>2570–3140</td>
<td>PU/EES/KH-15238</td>
<td>N. Pak. to S. China &amp; W. Malesia, Himalayas in India</td>
</tr>
<tr>
<td>Valeriana jatamansi Jones</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2700–3150</td>
<td>PU/EES/KH-15239</td>
<td>Himalayas from Afg. to SW China</td>
</tr>
</tbody>
</table>

**Caryophyllaceae**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arenaria arboiculata Royle ex Edgew. &amp; Hook.</td>
<td>Ah</td>
<td>MC</td>
<td>2500–2600</td>
<td>PU/EES/KH-15026</td>
<td>Afg. to China; Himalayas in India</td>
</tr>
<tr>
<td>Cerasium cerastoides (L.) Britton</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>1920–3160</td>
<td>PU/EES/KH-15060</td>
<td>Temp. Eurasia, E. Canada to Greenland; W. Himalayas in India</td>
</tr>
<tr>
<td>Lepyrodiclis holosteoides (C.A. Mey.) Fenzl ex Fisch. &amp; C.A. Mey.</td>
<td>Ah or Bh</td>
<td>MC/SA</td>
<td>2630–3120</td>
<td>PU/EES/KH-15135</td>
<td>Turkey to Mongolia &amp; Himalayas</td>
</tr>
<tr>
<td>Lychnis coronaria Desr.</td>
<td>Ph</td>
<td>BP/MC</td>
<td>2070–2780</td>
<td>PU/EES/KH-15141</td>
<td>EC &amp; SE Europe to N. Iran &amp; C. Asia to W. Himalayas</td>
</tr>
<tr>
<td>Silene himalayensis (Rohrb.) Majumdar</td>
<td>Ah</td>
<td>SA</td>
<td>2810–2820</td>
<td>PU/EES/KH-15218</td>
<td>NE Afg. to C. China; Himalayas in India</td>
</tr>
<tr>
<td>Silene vulgaris (Moench) Garcke</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2200–2920</td>
<td>PU/EES/KH-15219</td>
<td>Paleartic; W. Himalayas in India</td>
</tr>
<tr>
<td>Sparganium diandra (Guss.) Heldr.</td>
<td>Ph</td>
<td>MC</td>
<td>2700–2710</td>
<td>PU/EES/KH-15221</td>
<td>Canaries Islands, Medit. to SW Siberia &amp; N. China; W. Himalayas in SW Himalayas</td>
</tr>
<tr>
<td>Stellaria decumbens Edgew.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2200–3150</td>
<td>PU/EES/KH-15225</td>
<td>E. &amp; NE Afg. to China; Himalayas in India</td>
</tr>
<tr>
<td>Stellaria media (L.) Vill.</td>
<td>Densely or laxly caespitose Ph</td>
<td>BP/MC</td>
<td>2250–2780</td>
<td>PU/EES/KH-15226</td>
<td>Temp. Eurasia, N. &amp; NE Tropical Africa; throughout India</td>
</tr>
</tbody>
</table>

**Compositae**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achillea millefolium L.</td>
<td>Rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>2200–3800</td>
<td>PU/EES/KH-15002</td>
<td>SubArctic &amp; temp. N. Hemisphere to Guatemala; W. Himalayas in India</td>
</tr>
<tr>
<td>Anaphalis staiononi Georgiadou</td>
<td>Ph</td>
<td>MC</td>
<td>2700–2800</td>
<td>PU/EES/KH-15015</td>
<td>N. Pak. to W. Himalayas</td>
</tr>
<tr>
<td>Anaphalis virgata Thomson</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2200–3200</td>
<td>PU/EES/KH-15016</td>
<td>Afg. to Xinjiang &amp; Himalayas</td>
</tr>
<tr>
<td>Arctium lappa L.</td>
<td>Bh</td>
<td>BP/SA</td>
<td>2300–2950</td>
<td>PU/EES/KH-15025</td>
<td>Temp. Eurasia; Himalayas in India</td>
</tr>
<tr>
<td>Artemisia absinthium L.</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2750–2920</td>
<td>PU/EES/KH-15030</td>
<td>Europe to Siberia &amp; W. Himalayas</td>
</tr>
<tr>
<td>Artemisia brevifolia Wall. ex DC.</td>
<td>SS</td>
<td>MC</td>
<td>2450–2720</td>
<td>PU/EES/KH-15031</td>
<td>Afg. to W. Tibet &amp; W. Himalayas</td>
</tr>
<tr>
<td>Artemisia dubia Wall.</td>
<td>SS</td>
<td>BP</td>
<td>2300–2400</td>
<td>PU/EES/KH-15032</td>
<td>Himalayas from Pak. to C. Nepal &amp; China</td>
</tr>
<tr>
<td>Artemisia scoparia Waldst. &amp; Kitam.</td>
<td>Bh or Ph</td>
<td>MC/SA</td>
<td>2450–3300</td>
<td>PU/EES/KH-15033</td>
<td>Paleartic region; throughout India</td>
</tr>
<tr>
<td>Artemisia vestita Wall. ex Besser</td>
<td>SS</td>
<td>SA</td>
<td>3200–3400</td>
<td>PU/EES/KH-15034</td>
<td>Pak. to Mongolia &amp; China, W. Himalayas in India</td>
</tr>
<tr>
<td>Artemisia vulgaris L.</td>
<td>Ph</td>
<td>SA</td>
<td>2830–2916</td>
<td>PU/EES/KH-15035</td>
<td>Temp. Eurasia to Indo-China &amp; N. Africa</td>
</tr>
<tr>
<td>Caresium abrotanoides L.</td>
<td>Ph</td>
<td>BP/MC</td>
<td>2200–2570</td>
<td>PU/EES/KH-15057</td>
<td>S. &amp; C. Europe to Japan &amp; Himalayas</td>
</tr>
<tr>
<td>Caresium cernuum L.</td>
<td>Ah</td>
<td>MC/SA</td>
<td>2750–2930</td>
<td>PU/EES/KH-15055</td>
<td>Eurasia; W. Himalayas in India</td>
</tr>
<tr>
<td>Centaurea iberica Trevir.</td>
<td>Ph</td>
<td>BP</td>
<td>2250–2300</td>
<td>PU/EES/KH-15059</td>
<td>SE &amp; E. Europe to Xinjiang &amp; W. Himalayas</td>
</tr>
<tr>
<td>Cichorium intybus L.</td>
<td>Ph</td>
<td>BP/MC</td>
<td>2050–2490</td>
<td>PU/EES/KH-15068</td>
<td>N. Africa, C &amp; SW Asia &amp; Europe</td>
</tr>
<tr>
<td>Cirsium arvense (L.) Scop.</td>
<td>Dioecious Ph</td>
<td>BP</td>
<td>2200–2210</td>
<td>PU/EES/KH-15070</td>
<td>Temp. Eurasia, NW Africa; Himalayas in India</td>
</tr>
<tr>
<td>Cirsium falconeri (Hook.f.) Petr.</td>
<td>Ph</td>
<td>SA</td>
<td>2840–2990</td>
<td>PU/EES/KH-15071</td>
<td>N. Pak. to S. Tibet &amp; N. Mya.</td>
</tr>
<tr>
<td>Family/Taxon</td>
<td>Life-form</td>
<td>Forest type</td>
<td>OER</td>
<td>Voucher no.</td>
<td>Phytogeographic distribution</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-------</td>
<td>-------------</td>
<td>--------------------------------------------------------------------</td>
</tr>
<tr>
<td>Cirsium vulgare (Savi) Ten.(^1)</td>
<td>Bh</td>
<td>SA</td>
<td>2940–2950</td>
<td>PU/EES/KH-15072</td>
<td>Europe to Siberia &amp; Arabian Peninsula; W. Himalayas in India</td>
</tr>
<tr>
<td>Cirsium walcotti DC.(^1)</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>1920–3210</td>
<td>PU/EES/KH-15073</td>
<td>Afg. to Indian Subcontinent</td>
</tr>
<tr>
<td>Conyza canadensis (L.) Cronquist(^1)</td>
<td>Ah</td>
<td>BP</td>
<td>2010–2210</td>
<td>PU/EES/KH-15079</td>
<td>Native to Neotropic &amp; Neartic regions</td>
</tr>
<tr>
<td>Crepis sancta (L.) Bomm.(^1)</td>
<td>Ah</td>
<td>SA</td>
<td>2910–2920</td>
<td>PU/EES/KH-15081</td>
<td>E. Europe, W. Asia eastwards in Himalayas up to Nepal</td>
</tr>
<tr>
<td>Doronicum roylei DC.(^1)</td>
<td>Ph</td>
<td>SA</td>
<td>3800–3810</td>
<td>PU/EES/KH-15093</td>
<td>NE Pak. to Himalayas &amp; S. Tibet</td>
</tr>
<tr>
<td>Erigeron multiradiatus (Lindl. ex DC.) Benth. ex C. B. Clarke(^1)</td>
<td>Rhizomatous Ph</td>
<td>MC/SA</td>
<td>2530–3800</td>
<td>PU/EES/KH-15101</td>
<td>Afg. to China</td>
</tr>
<tr>
<td>Lactuca macrorhiza (Royle) Hook. (^{1})</td>
<td>Ph</td>
<td>MC</td>
<td>2530–2540</td>
<td>PU/EES/KH-15126</td>
<td>Himalayas from Afg. to SW China</td>
</tr>
<tr>
<td>Lactuca dolichophylla Kitam.(^1)</td>
<td>Ah</td>
<td>BP/MC/SA</td>
<td>2315–2710</td>
<td>PU/EES/KH-15129</td>
<td>Europe to Siberia &amp; Iran; W. Himalayas in India</td>
</tr>
<tr>
<td>Ligularia amplexicaulis DC.(^1)</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2790–2930</td>
<td>PU/EES/KH-15137</td>
<td>Himalayas to S. Tibet</td>
</tr>
<tr>
<td>Ligularia fischeri (Ledeb.) Turcz.(^3)</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2570–3540</td>
<td>PU/EES/KH-15138</td>
<td>NE Pak. to S. Siberia &amp; Japan; Himalayas in India</td>
</tr>
<tr>
<td>Myriactis nepalensis Less.(^1)</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>1980–3000</td>
<td>PU/EES/KH-15150</td>
<td>Himalayas from Afg. to SW China &amp; SE Asia</td>
</tr>
<tr>
<td>Picris hieracioides Sibth. &amp; Sm.(^1)</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2430–3000</td>
<td>PU/EES/KH-15169</td>
<td>Temp. Eurasia; Himalayas in India</td>
</tr>
<tr>
<td>Saussurea albenscens Hook. f. &amp; Thomson(^1)</td>
<td>Ph</td>
<td>SA</td>
<td>3010–3020</td>
<td>PU/EES/KH-15203</td>
<td>NE Afg. to Nepal</td>
</tr>
<tr>
<td>Saussurea costus (Falc.) Lipsch.(^1)</td>
<td>Ph</td>
<td>SA</td>
<td>3050–3060</td>
<td>PU/EES/KH-15206</td>
<td>W. Himalayas</td>
</tr>
<tr>
<td>Saussurea roylei C.B. Clarke(^4)</td>
<td>Ph</td>
<td>SA</td>
<td>3130–3140</td>
<td>PU/EES/KH-15204</td>
<td>NW Himalayas</td>
</tr>
<tr>
<td>Saussurea taraxacifolia (Lindl.) Wall. ex DC.(^1)</td>
<td>Ph</td>
<td>SA</td>
<td>3800–3810</td>
<td>PU/EES/KH-15205</td>
<td>Himalayas from Kashmir to Bhutan, Xizang</td>
</tr>
<tr>
<td>Senecio chrysanthemoides DC.(^1)</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2420–3150</td>
<td>PU/EES/KH-15212</td>
<td>Afg. to SC China &amp; Indo-China</td>
</tr>
<tr>
<td>Serratula pallida DC.(^1)</td>
<td>Ph</td>
<td>MC</td>
<td>2430–2440</td>
<td>PU/EES/KH-15213</td>
<td>N. Pak. to Nepal</td>
</tr>
<tr>
<td>Sisyrinchium orientalis L.(^1)</td>
<td>Tufted Ph</td>
<td>BP</td>
<td>2200–2210</td>
<td>PU/EES/KH-15217</td>
<td>E. Europe to Asia &amp; Australia</td>
</tr>
<tr>
<td>Solidago virga-aurea L.(^1)</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2670–3810</td>
<td>PU/EES/KH-15220</td>
<td>W. Europe to C. Siberia &amp; Phip.; Himalayas in India</td>
</tr>
<tr>
<td>Tamarix ramosissima Sch.Bip.(^1)</td>
<td>Ph</td>
<td>SA</td>
<td>3010–3810</td>
<td>PU/EES/KH-15229</td>
<td>Kashmir to SW China</td>
</tr>
<tr>
<td>Taraxacum officinale (L.) Weber ex F.H.Wigg.(^1)</td>
<td>Semi-prostrate Ph</td>
<td>BP/MC/SA</td>
<td>1920–3410</td>
<td>PU/EES/KH-15230</td>
<td>Cosmopolitan</td>
</tr>
<tr>
<td>Tussilago farfara L.(^1)</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2670–3130</td>
<td>PU/EES/KH-15236</td>
<td>Palearctic region; Himalayas in India</td>
</tr>
<tr>
<td>Xanthium spinosum L.(^1)</td>
<td>Ph</td>
<td>BP</td>
<td>2230–2240</td>
<td>PU/EES/KH-15128</td>
<td>C. &amp; E. Canada to Mexico, Peru to S. South America</td>
</tr>
<tr>
<td>Convolvulaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Convolvulus arvensis L.(^1)</td>
<td>Climbing &amp; prostrate Ph</td>
<td>Ah or Ph</td>
<td>2440–2460</td>
<td>PU/EES/KH-15078</td>
<td>Eurasia; throughout India</td>
</tr>
<tr>
<td>Crassulaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedum ewersii Ledeb.(^1)</td>
<td>Ph</td>
<td>SA</td>
<td>3790–3810</td>
<td>PU/EES/KH-15210</td>
<td>Siberia to Afg. &amp; N. China; W. Himalayas in India</td>
</tr>
<tr>
<td>Cupressaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juniperus semiglobosa Regel(^2)</td>
<td></td>
<td>MC</td>
<td>2450–2500</td>
<td>PU/EES/KH-10008</td>
<td>SE Iran to C. Asia, Himalayas from Pak. to Uttarakhand</td>
</tr>
<tr>
<td>Juniperus squamata Buch.-Ham. ex D.Don(^2)</td>
<td>Monoeocious bushy, semi-prostrate S/ET</td>
<td>SA</td>
<td>3150–3440</td>
<td>PU/EES/KH-1015</td>
<td>N. Afg. to China</td>
</tr>
<tr>
<td>Cyperaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carex testacea Wahlenb.(^1)</td>
<td>Rhizomatous creeping Ph</td>
<td>SA</td>
<td>2800–2920</td>
<td>PU/EES/KH-15058</td>
<td>From Caucasus &amp; Iran to Pak., Kashmir &amp; Mongolia</td>
</tr>
<tr>
<td>Dioscoreaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dioscorea deltoidea Wall. ex Griseb.(^1)</td>
<td>Climbing Ph</td>
<td>BP/SA</td>
<td>1880–2810</td>
<td>PU/EES/KH-15091</td>
<td>Himalayas to SC China &amp; Indo-China</td>
</tr>
<tr>
<td>Family/Taxon</td>
<td>Life-form</td>
<td>Forest type</td>
<td>OER</td>
<td>Voucher no.</td>
<td>Phytogeographic distribution</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-----</td>
<td>-------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Elaeagnaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hippophae rhamnoides L.</td>
<td>Dioecious</td>
<td>DT</td>
<td>MC</td>
<td>2400–2500</td>
<td>PU/EES/KH-1204</td>
</tr>
<tr>
<td>Equisetaceae</td>
<td>Erect or prostrate rhizomatous</td>
<td>Ph</td>
<td>BR/SA</td>
<td>2320–3060</td>
<td>PU/EES/KH-15100</td>
</tr>
<tr>
<td>Euphorbiaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euphorbia esula L.</td>
<td>Erect</td>
<td>Ph</td>
<td>MC</td>
<td>2600–2760</td>
<td>PU/EES/KH-151104</td>
</tr>
<tr>
<td>Euphorbia pilosella L.</td>
<td>Ph</td>
<td>SA</td>
<td>2920–2930</td>
<td>PU/EES/KH-15105</td>
<td>C. Asia, N. Pak. to Himalayas</td>
</tr>
<tr>
<td>Euphorbia wallichii Hook.</td>
<td>Ph</td>
<td>SA</td>
<td>3140–3540</td>
<td>PU/EES/KH-15106</td>
<td>Himalayas from Afg. to W. Himalayas to Sikkim</td>
</tr>
<tr>
<td>Gentianaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gentiana carinata (D.Don) Griseb.</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2570–3000</td>
<td>PU/EES/KH-15111</td>
<td>Himalayas from Pak. to Uttarakhand</td>
</tr>
<tr>
<td>Gentiana moorcroftiana Wall. ex G.Don</td>
<td>Aromatic, dwarf, creeping mat forming herb</td>
<td>SA</td>
<td>3790–3800</td>
<td>PU/EES/KH-15251</td>
<td>Himalayas from Kashmir to Nepal</td>
</tr>
<tr>
<td>Gentiana tianschanica Rupr. ex Kusn.</td>
<td>Ah</td>
<td>SA</td>
<td>3790–3800</td>
<td>PU/EES/KH-15112</td>
<td>Himalayas &amp; China</td>
</tr>
<tr>
<td>Lomatogonium caeruleum (Royle) Rehder</td>
<td>Tufted</td>
<td>Ph</td>
<td>3790–3810</td>
<td>PU/EES/KH-15140</td>
<td>Himalayas from Kashmir to Nepal</td>
</tr>
<tr>
<td>Swertia picola D.Don</td>
<td>Ah</td>
<td>SA</td>
<td>2810–2820</td>
<td>PU/EES/KH-15146</td>
<td>Himalayas from Pak. to Bhutan</td>
</tr>
<tr>
<td>Swertia petiolaris D.Don</td>
<td>Rhizomatous</td>
<td>BP/MC/SA</td>
<td>2310–3210</td>
<td>PU/EES/KH-151228</td>
<td>E. Afg. to W. &amp; C. Himalayas</td>
</tr>
<tr>
<td>Geraniaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geranium pusillum L.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>1920–2920</td>
<td>PU/EES/KH-15113</td>
<td>Europe to W. Himalayas</td>
</tr>
<tr>
<td>Geranium wallichianum D.Don ex Sweet</td>
<td>Ah</td>
<td>BP/MC/SA</td>
<td>1920–3810</td>
<td>PU/EES/KH-15114</td>
<td>E. Afg. to Himalayas &amp; Tibet</td>
</tr>
<tr>
<td>Hamamelidaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parrotiopsis jacquemontiana (Decne.) Rehder</td>
<td>DS/small DT</td>
<td>BP</td>
<td>2100–2300</td>
<td>PU/EES/KH-1201</td>
<td>E. Afg. to W. Himalayas</td>
</tr>
<tr>
<td>Hypericaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypericum perforatum L.</td>
<td>Ah or Bh</td>
<td>BP/MC/SA</td>
<td>1980–3540</td>
<td>PU/EES/KH-15121</td>
<td>Europe to China, NW Africa, SW Sudan; W. Himalayas in India</td>
</tr>
<tr>
<td>Iridaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iris hooleriana Foster</td>
<td>Ah</td>
<td>MC/SA</td>
<td>2560–3810</td>
<td>PU/EES/KH-15123</td>
<td>Afg. to W. Himalayas</td>
</tr>
<tr>
<td>Juglandaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamiaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinopodium umbrosum (M.Bieb.) Kuntze</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2200–3000</td>
<td>PU/EES/KH-15074</td>
<td>Caucasus to N. Mya. ; W. Himalayas in India</td>
</tr>
<tr>
<td>Clinopodium vulgarum L.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>1920–3280</td>
<td>PU/EES/KH-15075</td>
<td>Medit., Europe to Siberia &amp; W. Himalayas</td>
</tr>
<tr>
<td>Lamium album L.</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2560–2930</td>
<td>PU/EES/KH-15117</td>
<td>Paleartic region; W. Himalayas in India</td>
</tr>
<tr>
<td>Nepeta erecta (Royle ex Benth.) Bentham.</td>
<td>Ph</td>
<td>MC</td>
<td>2700–2770</td>
<td>PU/EES/KH-15151</td>
<td>E. Afg. to W. Himalayas</td>
</tr>
<tr>
<td>Nepeta laevigata (D.Don) Hand.-Mazz.</td>
<td>Ph</td>
<td>BP/MC</td>
<td>2200–2410</td>
<td>PU/EES/KH-15152</td>
<td>Himalayas from Afg. to SW China</td>
</tr>
<tr>
<td>Origanum vulgare L.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2310–3210</td>
<td>PU/EES/KH-15155</td>
<td>Eurasia; Himalayas in India</td>
</tr>
<tr>
<td>Phlomis bracteosa Royle ex Bentham.</td>
<td>Rhizomatous</td>
<td>Ph</td>
<td>2920–3800</td>
<td>PU/EES/KH-15166</td>
<td>E. Afg. to Himalayas</td>
</tr>
<tr>
<td>Phlomis cashmeriana Royle ex Bentham.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2310–2910</td>
<td>PU/EES/KH-15167</td>
<td>Afg. to W. Himalayas</td>
</tr>
<tr>
<td>Salvia hians Royle ex Bentham.</td>
<td>Erect</td>
<td>Ph</td>
<td>2590–2600</td>
<td>PU/EES/KH-15198</td>
<td>Himalayas from Kashmir to Nepal</td>
</tr>
<tr>
<td>Family/Taxon</td>
<td>Life-form</td>
<td>Forest type</td>
<td>OER</td>
<td>Voucher no.</td>
<td>Phytogeographic distribution</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-----</td>
<td>-------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><em>Salvia moorcroftiana</em> Wall. ex Benth.</td>
<td>Aromatic Ph</td>
<td>MC</td>
<td>2720–2730</td>
<td>PU/EES/KH-15199</td>
<td>Himalayas from Pak. to W. Nepal</td>
</tr>
<tr>
<td><em>Salvia nubicola</em> Wall. ex Sweet</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2700–2920</td>
<td>PU/EES/KH-15200</td>
<td>E. Afg. to Himalayas</td>
</tr>
<tr>
<td><em>Stachys floccosa</em> Benth.</td>
<td>Erect Ph</td>
<td>BP/MC/SA</td>
<td>2390–2710</td>
<td>PU/EES/KH-15223</td>
<td>Himalayas from Afg., Pak. to Kashmir</td>
</tr>
<tr>
<td><em>Stachys sericea</em> Wall. ex Benth.</td>
<td>Ph</td>
<td>SA</td>
<td>2920–2930</td>
<td>PU/EES/KH-15224</td>
<td>Kashmir to SE Tibet</td>
</tr>
<tr>
<td><em>Thymus linearis</em> Benth.</td>
<td>Ah</td>
<td>MC/SA</td>
<td>2500–3000</td>
<td>PU/EES/KH-15250</td>
<td>N. Iran to Xinjiang &amp; Himalayas</td>
</tr>
</tbody>
</table>

**Leguminosae**

| *Lathyrus humilis* (Ser.) Spreng. | Ah or Ph | SA | 3110–3120 | PU/EES/KH-15130 | E. Europe to temp. Asia & W. Himalayas |
| *Lathyrus laevigatus* (Walldst. & Kit.) Gren. | Ph | MC/SA | 2670–3060 | PU/EES/KH-15131 | Himalayas from Pak. to W. Nepal |
| *Lathyrus pratensis* L.² | Ph | BP/MC/SA | 2720–3240 | PU/EES/KH-15132 | Europe to Mongolia & Himalayas, Morocco, Ethiopia & Yemen |
| *Leonurus cardiaca* L. | Scrambling Ph | SA | 2920–2930 | PU/EES/KH-15133 | Europe, Himalayas from Pak. to Nepal |
| *Lespedeza cuneata* (Dum.Cours.) G.Don | Ah or Ph | SA | 2920–2930 | PU/EES/KH-15134 | Europe, Himalayas from Pak. to Nepal |
| *Medicago sativa* Linn. | Prostrate or decumbent Ph | BP | 1920–3120 | PU/EES/KH-15135 | Europe & N. Asia, Himalayas in India |
| *Medicago lupulina* L. | Erect or procumbent Ph | BP/MC | 1880–2370 | PU/EES/KH-15144 | Asia, Africa & Europe |
| *Medicago minima* (L.) L. | Ah or Ph | MC | 2770–2780 | PU/EES/KH-15145 | Temp. Eurasia to India, tropical Africa to SW. Arabian Peninsula |
| *Oxytropis cachemiriana* Cambess. | Creeping annual or short-lived Ph | SA | 3790–3800 | PU/EES/KH-15160 | N. Pak. to W. Himalayas |
| *Oxytropis mollis* Benth. | Ph | SA | 3790–3800 | PU/EES/KH-15161 | India, Pakistan & Xizang |
| *Robinia pseudoacacia* L.³ | DT | MC | 2330–2340 | PU/EES/KH-1012 | Native to N. America |
| *Trifolium pratense* L.² | Erect or decumbent Ph | BP/MC | 1890–2370 | PU/EES/KH-15136 | Europe to Mongolia & Indian Subcontinent |
| *Trifolium repens* L. | Erect or decumbent Ph | BP/MC/SA | 1920–3540 | PU/EES/KH-15137 | Europe to Mongolia & Himalayas |
| *Malva rosea* L'Hér. ex Aiton | Ph | SA | 3800–3810 | PU/EES/KH-15139 | Kashmir to Eurasia |

**Liliaceae**

| *Fritillaria roylei* Hook. | Ph | SA | 3800–3900 | PU/EES/KH-15252 | Pak. to C. China |

**Malvaceae**

| *Malva neglecta* Wallr. | Ph | BP/MC/SA | 2310–2940 | PU/EES/KH-15142 | Canary Islands, Morocco, Europe to C. Asia & W. Himalayas |

**Meliaceae**

| *Trillium govanianum* Wall. ex D.Don | Erect or spreading Ph | SA | 3050–3310 | PU/EES/KH-15233 | E. Afg. to Himalayas |

**Oleaceae**

| *Syringa emodi* Wall. ex Royle | DT | MC | 2450–2500 | PU/EES/KH-1205 | Pak. to Nepal & Tibet |

**Onagraceae**

<p>| <em>Cypripedium cordigerum</em> D.Don | Ph | SA | 2950–2960 | PU/EES/KH-15087 | N. Pak. to Himalayas &amp; S. Tibet |</p>
<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Epipactis helleborine</em> (L.) Crantz</td>
<td>Rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>2330–2960</td>
<td>PU/EES/KH-15096</td>
<td>NW Africa, Europe to China; Himalayas in India</td>
</tr>
<tr>
<td><em>Epipactis royleana</em> Lindl.</td>
<td>Rhizomatous Ph</td>
<td>MC/SA</td>
<td>2700–2920</td>
<td>PU/EES/KH-15099</td>
<td>E. Afg. to C. Asia &amp; Himalayas</td>
</tr>
<tr>
<td>Orobanche alba Stephan</td>
<td>Rhizomatous aromatic Ph</td>
<td>MC/SA</td>
<td>2770–3160</td>
<td>PU/EES/KH-15156</td>
<td>Europe, Afg., Pak., W. Himalayas &amp; Tibet</td>
</tr>
<tr>
<td><em>Pedicularis pectinata</em> Wall. ex Benn.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2310–3810</td>
<td>PU/EES/KH-15163</td>
<td>W. Himalayas from Pak. to W. Nepal</td>
</tr>
<tr>
<td><em>Epipactis helleborine</em> (L.) Crantz</td>
<td>Rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>1880–3120</td>
<td>PU/EES/KH-15158</td>
<td>Europe to Japan; W. Himalayas in India</td>
</tr>
<tr>
<td><em>Orobanchaceae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oxalis acetosella</em> L.</td>
<td>Tufted Ph</td>
<td>BP/MC/SA</td>
<td>1880–2950</td>
<td>PU/EES/KH-15159</td>
<td>Cosmopolitan</td>
</tr>
<tr>
<td><em>Oxalis corniculata</em> L.</td>
<td>Rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>2330–2960</td>
<td>PU/EES/KH-15160</td>
<td>Himalayas in India</td>
</tr>
<tr>
<td><em>Oxalis alba</em></td>
<td>Rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>2770–3160</td>
<td>PU/EES/KH-15161</td>
<td>Himalayas from Pak. to W. Nepal</td>
</tr>
<tr>
<td><em>Papaveraceae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Corydalis stewartii</em> Fedde</td>
<td>Rhizomatous Ah or Bh</td>
<td>BP</td>
<td>2200–2210</td>
<td>PU/EES/KH-15080</td>
<td>Afg. to Nepal</td>
</tr>
<tr>
<td><em>Phytolaccaceae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phytolacca acinosa</em> Roxb.</td>
<td>Ph</td>
<td>BP/MC</td>
<td>2270–2500</td>
<td>PU/EES/KH-15168</td>
<td>Kashmir to SW China</td>
</tr>
<tr>
<td><em>Pinaceae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Abies pindrow</em> (Royle ex D.Don) Royle</td>
<td>Coniferous ET</td>
<td>BP/MC/SA</td>
<td>2220–3300</td>
<td>PU/EES/KH-1001</td>
<td>N. Afghanistan to Nepal</td>
</tr>
<tr>
<td><em>Cedrus deodara</em> (Roeb. ex D.Don) G.Don</td>
<td>Coniferous ET</td>
<td>BP</td>
<td>1810–2200</td>
<td>PU/EES/KH-1005</td>
<td>NE Afg. to W. Nepal &amp; NW India</td>
</tr>
<tr>
<td><em>Pinus wallichiana</em> A.B.Jacks.</td>
<td>Coniferous ET</td>
<td>BP/MC/SA</td>
<td>1800–3140</td>
<td>PU/EES/KH-1010</td>
<td>Himalayas from Afg. to Tibet</td>
</tr>
<tr>
<td><em>Plantaginaceae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Plantago lanceolata</em> L.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>1920–2930</td>
<td>PU/EES/KH-15172</td>
<td>Palaeartic &amp; Nearctic regions; Himalayas in India</td>
</tr>
<tr>
<td><em>Plantago major</em> L.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2200–3160</td>
<td>PU/EES/KH-15173</td>
<td>Europe, N. &amp; C. Asia, introduced all over the world</td>
</tr>
<tr>
<td><em>Veronica persica</em> Poir.</td>
<td>Ph</td>
<td>SA</td>
<td>2950–2960</td>
<td>PU/EES/KH-15241</td>
<td>Native to Iran, now a worldwide weed; Himalayas in India</td>
</tr>
<tr>
<td><em>Poaceae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Agrostis gigantea</em> Roth</td>
<td>Rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>2250–2850</td>
<td>PU/EES/KH-15010</td>
<td>Palaeartic region, introduced in Nearctic; Himalayas in India</td>
</tr>
<tr>
<td><em>Brachypodium sylvaticum</em> (Huds.) P .Beauv.</td>
<td>Tufted Ph</td>
<td>BP/MC</td>
<td>2250–2510</td>
<td>PU/EES/KH-15040</td>
<td>Eurasia; throughout India</td>
</tr>
<tr>
<td><em>Bromus inermis</em> Leyss.</td>
<td>Rhizomatous Ph</td>
<td>BP/MC</td>
<td>2050–2760</td>
<td>PU/EES/KH-15041</td>
<td>Palaeartic &amp; Nearctic regions; W. Himalayas in India</td>
</tr>
<tr>
<td><em>Bromus japonicus</em> Thunb.</td>
<td>Ah</td>
<td>BP/MC/SA</td>
<td>2250–2950</td>
<td>PU/EES/KH-15042</td>
<td>Medit. to temp. Eurasia; W. Himalayas in India</td>
</tr>
<tr>
<td><em>Bromus pectinatus</em> Thunb.</td>
<td>Ah</td>
<td>BP/MC/SA</td>
<td>2250–2300</td>
<td>PU/EES/KH-15043</td>
<td>Europe, Iran &amp; Afg. eastwards through India to China, Pak., Sudan through Ethiopia to Egypt, Sinai &amp; Arabia</td>
</tr>
<tr>
<td><em>Calamagrostis pseudophragmites</em> (Haller) Koeler</td>
<td>Creeping rhizomatous tufted Ph</td>
<td>MC/SA</td>
<td>2450–3800</td>
<td>PU/EES/KH-15049</td>
<td>Europe to Japan &amp; Himalaya; Himalayas in India</td>
</tr>
<tr>
<td><em>Cynosurus cristatus</em> (L.) Pers.</td>
<td>Stoloniferous Ph with rhizomes</td>
<td>BP/MC/SA</td>
<td>1920–2930</td>
<td>PU/EES/KH-15083</td>
<td>Temp. &amp; Subtropical Old World to Australia; throughout India</td>
</tr>
<tr>
<td><em>Elymus dahuricus</em> Griseb.</td>
<td>Tufted Ph</td>
<td>MC</td>
<td>2430–2780</td>
<td>PU/EES/KH-15094</td>
<td>Temp. Asia; Himalayas in India</td>
</tr>
<tr>
<td><em>Koeleria macrantha</em> (Lede.) Schult.</td>
<td>Rhizomatous Ph</td>
<td>MC/SA</td>
<td>2460–3810</td>
<td>PU/EES/KH-15124</td>
<td>Temp. N. Hemisphere to Mexico; Himalayas in India</td>
</tr>
<tr>
<td><em>Lolium perenne</em> L.</td>
<td>Ph</td>
<td>MC</td>
<td>2420–2430</td>
<td>PU/EES/KH-15139</td>
<td>N. Africa, Europe to Siberia &amp; Himalayas</td>
</tr>
<tr>
<td><em>Oryzopsis gracilis</em> (Mez) Pilg.</td>
<td>Ah or Ph</td>
<td>BP/MC</td>
<td>1920–2630</td>
<td>PU/EES/KH-15157</td>
<td>Iran to China</td>
</tr>
<tr>
<td><em>Phleum alpinum</em> L.</td>
<td>Trailing or creeping Ph</td>
<td>BP/MC/SA</td>
<td>2250–3140</td>
<td>PU/EES/KH-15165</td>
<td>Palaeartic &amp; Nearctic regions; Himalayas in India</td>
</tr>
</tbody>
</table>
### Floristic survey across three coniferous forests of Kashmir Himalaya

Dar et al.


<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Poa alpina</em> L.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>1980–3150</td>
<td>PU/EES/KH-15174</td>
<td>Temp. N. Hemisphere to Mexico; W. Himalayas in India</td>
</tr>
<tr>
<td><em>Poa pratensis</em> L.</td>
<td>Tufted Ph</td>
<td>BP/MC/SA</td>
<td>2070–2990</td>
<td>PU/EES/KH-15175</td>
<td>Paleartic &amp; Nearctic regions; Himalayas in India</td>
</tr>
<tr>
<td><em>Polygono sibirica</em> (L.) Lam.</td>
<td>Caespitose or tufted Ah</td>
<td>BP/MC</td>
<td>1920–2770</td>
<td>PU/EES/KH-15122</td>
<td>Temp. Asia to Himalayas</td>
</tr>
<tr>
<td><em>Vulpia myuros</em> (L.) C.C.Gmel.</td>
<td>Prostrate Ph</td>
<td>BP/MC</td>
<td>2260–2450</td>
<td>PU/EES/KH-15249</td>
<td>Europe to Taiwan &amp; Sri Lanka., Arabian Peninsula &amp; Kenya; throughout India</td>
</tr>
</tbody>
</table>

### Polemoniaceae

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Polemonium caeruleum</em> L.</td>
<td>Rhizomatous Ph</td>
<td>MC/SA</td>
<td>2590–2960</td>
<td>PU/EES/KH-15178</td>
<td>Europe to C. Siberia &amp; Caucasus, Himalayas from Pak. to W. Nepal</td>
</tr>
</tbody>
</table>

### Polygonaceae

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aconogonon alpinum</em> (All.) Schur</td>
<td>Ph</td>
<td>BP</td>
<td>2300–2400</td>
<td>PU/EES/KH-15003</td>
<td>Paleartic; W. Himalayas in India</td>
</tr>
<tr>
<td><em>Oxiria digyna</em> (L.) Hill</td>
<td>Ph</td>
<td>SA</td>
<td>2830–3160</td>
<td>PU/EES/KH-15161</td>
<td>Paleartic &amp; Nearctic regions; Himalayas in India</td>
</tr>
<tr>
<td><em>Polygonum aviculare</em> L.</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2210–2950</td>
<td>PU/EES/KH-15177</td>
<td>Paleartic &amp; Nearctic regions; Himalayas in India</td>
</tr>
<tr>
<td><em>Polygonum capitata</em> (Buch.-Ham. ex D.Don) H.Gross</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2200–3150</td>
<td>PU/EES/KH-15164</td>
<td>Himalayas from Pak. to Nepal</td>
</tr>
<tr>
<td><em>Rheum webbianum</em> Royle</td>
<td>Ph</td>
<td>BP</td>
<td>1920–1930</td>
<td>PU/EES/KH-15119</td>
<td>Himalayas from Pak. to Nepal</td>
</tr>
<tr>
<td><em>Rumex nepalensis</em> Sprenge</td>
<td>Erect Ph</td>
<td>BP/MC/SA</td>
<td>1920–3410</td>
<td>PU/EES/KH-15197</td>
<td>Pak., Persia, SW China, Turkey, N. Africa &amp; Italy</td>
</tr>
</tbody>
</table>

### Primulaceae

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Androsace rotundifolia</em> Sm.</td>
<td>Rhizomatous Ph</td>
<td>MC</td>
<td>2600–2750</td>
<td>PU/EES/KH-15017</td>
<td>Himalayas from Pak. to Nepal</td>
</tr>
<tr>
<td><em>Androsace sarmentosa</em> Wall.</td>
<td>Ph</td>
<td>MC</td>
<td>2700–2800</td>
<td>PU/EES/KH-15018</td>
<td>Himalaya, Nepal &amp; Tibet</td>
</tr>
<tr>
<td><em>Primula macrophylla</em> D. Don</td>
<td>Erect Ph</td>
<td>MC/SA</td>
<td>2720–3150</td>
<td>PU/EES/KH-15190</td>
<td>Himalayas from Afg. to SE Tibet</td>
</tr>
</tbody>
</table>

### Pteridaceae

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Adiantum capillus-veneris</em> L.</td>
<td>Epilithic perennial fern</td>
<td>BP/MC/SA</td>
<td>1950–3000</td>
<td>PU/EES/KH-15007</td>
<td>Neartic, Neotropical, Afrotropical, Australasian, Indomalayan &amp; Paleartic regions; throughout India</td>
</tr>
<tr>
<td><em>Pteris cretica</em> L.</td>
<td>Rhizomatous Ph</td>
<td>BP</td>
<td>2370–2380</td>
<td>PU/EES/KH-15192</td>
<td>S. Africa, Europe to E. Asia; throughout India</td>
</tr>
</tbody>
</table>

### Ranunculaceae

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aconitum chasmanthum</em> Stapf ex Holmes</td>
<td>Ph</td>
<td>SA</td>
<td>3200–3800</td>
<td>PU/EES/KH-15004</td>
<td>Himalayas from Pak. to Nepal &amp; Mongolia</td>
</tr>
<tr>
<td><em>Aconitum heterophyllum</em> Wall. ex Royle</td>
<td>Rhizomatous Ph</td>
<td>MC/SA</td>
<td>2700–3810</td>
<td>PU/EES/KH-15005</td>
<td>Himalayas from Pak. to C. Nepal</td>
</tr>
<tr>
<td><em>Actaea spicata</em> L.</td>
<td>Rhizomatous Ph</td>
<td>MC/SA</td>
<td>2500–2931</td>
<td>PU/EES/KH-15006</td>
<td>E. Afg. to Himalaya</td>
</tr>
<tr>
<td><em>Anemone obtusiloba</em> Lindl.</td>
<td>Ph</td>
<td>SA</td>
<td>3200–3300</td>
<td>PU/EES/KH-15019</td>
<td>Himalayas, Mongolia, NC China &amp; Kazakhstan</td>
</tr>
<tr>
<td><em>Aquilegia pubiflora</em> Wall. ex Royle</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2500–3200</td>
<td>PU/EES/KH-15020</td>
<td>Afg., Pak., &amp; W. Himalayas</td>
</tr>
<tr>
<td><em>Caltha palustris</em> L.</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2800–2950</td>
<td>PU/EES/KH-15048</td>
<td>Paleartic &amp; Nearctic regions; Himalayas in India</td>
</tr>
<tr>
<td><em>Delphinium roylei</em> Munz</td>
<td>Ph</td>
<td>BP</td>
<td>2200–2210</td>
<td>PU/EES/KH-15088</td>
<td>Pak. &amp; Kashmir</td>
</tr>
<tr>
<td><em>Delphinium vestitum</em> Wall. ex Royle</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2520–3120</td>
<td>PU/EES/KH-15089</td>
<td>Himalayas from Pak. to E. Nepal</td>
</tr>
<tr>
<td><em>Ranunculus hirtellus</em> Royle</td>
<td>Rhizomatous Eh</td>
<td>BP/MC</td>
<td>2250–2780</td>
<td>PU/EES/KH-15193</td>
<td>Himalayas from Kashmir to Sikkim, Tibet &amp; W. China</td>
</tr>
<tr>
<td><em>Ranunculus laetius Wall. ex Hook. f. &amp; J.W. Thomson</em></td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2200–2990</td>
<td>PU/EES/KH-15194</td>
<td>Himalayas from Afg. to SW China</td>
</tr>
</tbody>
</table>
### Floristic survey across three coniferous forests of Kashmir Himalaya

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranunculus palmatifidus Riedl</td>
<td>Erect Ph</td>
<td>BP/MC/SA</td>
<td>2310–2930</td>
<td>PU/EES/KH-15195</td>
<td>W. Himalayas</td>
</tr>
<tr>
<td>Thalictrum minus L.</td>
<td>Ph</td>
<td>BP</td>
<td>2310–2340</td>
<td>PU/EES/KH-15231</td>
<td>Himalayas from Pak. to Nepal &amp; temp. Eurasia</td>
</tr>
</tbody>
</table>

**Rosaceae**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrimonia pilosa Lede.</td>
<td>Rhizomatous Ph</td>
<td>BP/MC</td>
<td>2200–2600</td>
<td>PU/EES/KH-15011</td>
<td>N. &amp; EC Europe to Japan &amp; N. Indo-China</td>
</tr>
<tr>
<td>Alchemilla trolii Rothm</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2750–3000</td>
<td>PU/EES/KH-15012</td>
<td>W. Himalayas &amp; Pak.</td>
</tr>
<tr>
<td>Crataegus songoric K. Koch</td>
<td>DS/Small DT</td>
<td>BP</td>
<td>2100–2200</td>
<td>PU/EES/KH-15202</td>
<td>Iran to NW China &amp; W. Himalayas</td>
</tr>
<tr>
<td>Filipendula vestita (Wall. ex G. Don) Maxim</td>
<td>Ph</td>
<td>MC</td>
<td>2420–2780</td>
<td>PU/EES/KH-15107</td>
<td>Afg., Pak., Nepal &amp; W. Himalayas</td>
</tr>
<tr>
<td>Fragaria nubicola (Hook. f.) Lindl. ex Lacaita</td>
<td>Stoloniferous Ph</td>
<td>BP/MC/SA</td>
<td>1880–3540</td>
<td>PU/EES/KH-15108</td>
<td>Himalayas from Afg. to Mya.</td>
</tr>
<tr>
<td>Geum elatum Wall. ex G. Don</td>
<td>Rhizomatous Ph</td>
<td>MC/SA</td>
<td>2720–3800</td>
<td>PU/EES/KH-15115</td>
<td>Himalayas from Pak. to SE Tibet &amp; SC China</td>
</tr>
<tr>
<td>Geum roylei Wall. ex F.Bolle</td>
<td>Ph</td>
<td>BP/MC/SA</td>
<td>2200–3120</td>
<td>PU/EES/KH-15116</td>
<td>Himalayas from Afg. to C. Nepal</td>
</tr>
<tr>
<td>Potentilla indica (Andrews) Th.Wolf</td>
<td>Ph</td>
<td>BP/MC</td>
<td>2120–2790</td>
<td>PU/EES/KH-15187</td>
<td>Indomalayan, E. Asia, Indian Himalayas</td>
</tr>
<tr>
<td>Potentilla anserina L.</td>
<td>Ph</td>
<td>MC/SA</td>
<td>2790–3000</td>
<td>PU/EES/KH-15184</td>
<td>Palearctic &amp; Nearctic regions; Indian Himalayas</td>
</tr>
<tr>
<td>Potentilla eriocarpa Wall. ex Lehm.</td>
<td>Ph</td>
<td>SA</td>
<td>2930–2940</td>
<td>PU/EES/KH-15186</td>
<td>Pak. to SW China</td>
</tr>
<tr>
<td>Potentilla nepalensis Hook.</td>
<td>Ph</td>
<td>BP/MC</td>
<td>2260–2790</td>
<td>PU/EES/KH-15188</td>
<td>NE Pak. to W. &amp; C. Himalayas</td>
</tr>
<tr>
<td>Prunus curnuta (Wall. ex Royle) Steud.</td>
<td>DT</td>
<td>MC</td>
<td>2700–2800</td>
<td>PU/EES/KH-1017</td>
<td>Himalayas from Afg. to Mya. &amp; SW China</td>
</tr>
<tr>
<td>Rosa brunonii Lindl.</td>
<td>Climbing S</td>
<td>MC</td>
<td>2580–2600</td>
<td>PU/EES/KH-1208</td>
<td>NE Afg. to China &amp; Mya., Himalayas in India</td>
</tr>
<tr>
<td>Rosa webbiana Wall. ex Royle</td>
<td>DS</td>
<td>BP</td>
<td>2310–2400</td>
<td>PU/EES/KH-1207</td>
<td>C. Asia to W. Himalayas, Tibet &amp; Afg.</td>
</tr>
<tr>
<td>Sibbaldia cuneata Schouw ex Kunze</td>
<td>Ah</td>
<td>BP/MC/SA</td>
<td>2200–3810</td>
<td>PU/EES/KH-15216</td>
<td>Afg. to SW China; Himalayas in India</td>
</tr>
<tr>
<td>Sorbus lanata (D.Don) S.Schauer</td>
<td>DT</td>
<td>SA</td>
<td>3040–3050</td>
<td>PU/EES/KH-1016</td>
<td>Afg. to W. Himalayas to Nepal</td>
</tr>
</tbody>
</table>

**Rubiaceae**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galium boreale L.</td>
<td>Climbing Ah</td>
<td>BP/MC/SA</td>
<td>2330–3310</td>
<td>PU/EES/KH-15110</td>
<td>Subarctic &amp; temp. N. Hemisphere; throughout India</td>
</tr>
</tbody>
</table>

**Salisaceae**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Populus alba L.</td>
<td>Dioecious DT</td>
<td>MC</td>
<td>2430–2440</td>
<td>PU/EES/KH-1014</td>
<td>C. &amp; S. Europe to Xinjiang &amp; W. Himalayas</td>
</tr>
<tr>
<td>Populus ciliata Wall. ex Royle</td>
<td>Dioecious DT</td>
<td>BP</td>
<td>2240–2250</td>
<td>PU/EES/KH-1011</td>
<td>N. Pak. to China &amp; Mya.; Himalayas in India</td>
</tr>
</tbody>
</table>

**Sapindaceae**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acer caesium Wall. ex Brandis</td>
<td>Andromonoecious DT</td>
<td>MC/SA</td>
<td>2420–3000</td>
<td>PU/EES/KH-1002</td>
<td>E. Afg. to N. &amp; EC China; W. Himalayas in India</td>
</tr>
<tr>
<td>Aesculus indica (Wall. ex Cambess.) Hook.</td>
<td>DT</td>
<td>MC</td>
<td>2750–2800</td>
<td>PU/EES/KH-1003</td>
<td>Afg., Nepal, Pak., E. &amp; W. Himalayas</td>
</tr>
</tbody>
</table>

**Saxifragaceae**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bergenia ligulata Engl.</td>
<td>Ph</td>
<td>MC</td>
<td>2750–2800</td>
<td>PU/EES/KH-15038</td>
<td>E. Afghanistan to China; Himalayas in India</td>
</tr>
</tbody>
</table>

**Sphagneticaceae**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scleranthus decomposita Royle ex Benth.</td>
<td>Ph</td>
<td>SA</td>
<td>2920–3280</td>
<td>PU/EES/KH-15209</td>
<td>C. Asia; W. Himalayas from Afg. to Kumaon</td>
</tr>
<tr>
<td>Verbascum thapsus L.</td>
<td>Prostrate Ah</td>
<td>MC/SA</td>
<td>2620–3150</td>
<td>PU/EES/KH-15242</td>
<td>Naturalized throughout the N. Hemisphere; Indian Himalayas</td>
</tr>
</tbody>
</table>

**Solanaceae**

<table>
<thead>
<tr>
<th>Family/Taxon</th>
<th>Life-form</th>
<th>Forest type</th>
<th>OER</th>
<th>Voucher no.</th>
<th>Phytogeographic distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atropa belladonna L.</td>
<td>Ph</td>
<td>MC</td>
<td>2700–2800</td>
<td>PU/EES/KH-15037</td>
<td>Afg., Iran, Pak. &amp; W. Himalayas</td>
</tr>
<tr>
<td>Hyoscyamus niger L.</td>
<td>Bb or Ph</td>
<td>SA</td>
<td>3140–3150</td>
<td>PU/EES/KH-15120</td>
<td>Palearctic region; Himalayas in India</td>
</tr>
<tr>
<td>Family/Taxon</td>
<td>Life-form</td>
<td>Forest type</td>
<td>OER</td>
<td>Voucher no.</td>
<td>Phytogeographic distribution</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
<td>-------------</td>
<td>------</td>
<td>-------------</td>
<td>---------------------------------------------------</td>
</tr>
<tr>
<td>Taxaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urticaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urtica dioica L.</td>
<td>Rhizomatous creeping Ph</td>
<td>BP/MC/SA</td>
<td>2200–3000</td>
<td>PU/EES/KH-15237</td>
<td>Paleartic, introduced in Neotropic &amp; Nearctic regions; throughout India</td>
</tr>
<tr>
<td>Violaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viola biflora L.</td>
<td>Erect rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>2200–3120</td>
<td>PU/EES/KH-15245</td>
<td>Paleartic, Mya.; Indian Himalayas</td>
</tr>
<tr>
<td>Viola odorata L.</td>
<td>Prostrate rhizomatous Ph</td>
<td>BP/MC/SA</td>
<td>1980–2960</td>
<td>PU/EES/KH-15247</td>
<td>Iran, Iraq, introduced in India &amp; Pak. &amp; Medit. region &amp; Caucasia</td>
</tr>
<tr>
<td>Viola pilosa Blume</td>
<td>Rhizomatous prostrate Ah or Ph</td>
<td>BP/MC/SA</td>
<td>1880–2940</td>
<td>PU/EES/KH-15248</td>
<td>Afg., Pak., Indomalayan; throughout India</td>
</tr>
<tr>
<td>Xanthorrhoeaceae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eremurus himalaicus Baker</td>
<td>Ph</td>
<td>SA</td>
<td>3530–3550</td>
<td>PU/EES/KH-15102</td>
<td>Afg., Pak. W. Himalayas &amp; Tajikistan</td>
</tr>
</tbody>
</table>


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 chasmanthus* (CR), *Trillium govanianum*, *Aconitum heterophyllum*, *Taxus wallichiana*, & *Atropa acuminata* (EN), and *Cyripedium cordigerum* (VU) were found occasionally in the present study and requires immediate conservational priorities across the landscape. Besides climate change and overgrazing, 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
REFERENCES


Floristic survey across three coniferous forests of Kashmir Himalaya

Dar et al.

20344


Delhi, 52 pp.


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

Arun Pratap Singh

Entomology Branch, Forest Research Institute, Chakarata Road, P.O. New Forest, Dehradun, Uttarakhand 248006, India.
ranoteaps@gmail.com

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 physiogeographical 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.
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; Kermken 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/o 1o 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: C₁–C₃, where “C₁” signifies ‘C’ lower western Himalayan temperate forest (other 2 being “C₂ upper west Himalayan temperate forest” and “C₃ 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 dialata = 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-subtype’ 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 km², 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.
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 km² 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 1889; Hannyngton 1910–11; Ollenbach 1930; Shull 1958, 1962; Baidur 1993; Smetacek 2002, 2004, 2012; Bhardwaj et al. 2012; Bhardwaj & Uniyal 2013; Singh &
Butterflies across different forest types in Uttarakhand

Singh


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.


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-
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 parasokra parasokra Eliot, 1987 (Singh & Singh 2022) and records like White-ringed Meadowbrown, Hyponepheto 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.
Butterflies across different forest types in Uttarakhand

Figure 3. Seasonality of butterflies in Uttarakhand.

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.

(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.,
Butterflies across different forest types in Uttarakhand Singh

Butterflies across different forest types in Uttarakhand are more diverse in the latter two than in the former. The diversity of nectar and larval food plants available in broad leaved or mixed conifer-broad leaved forests, as compared to the pure conifer forest stands support 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 Kharus 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 Shiwalik 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.
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 Himalayan Upper Oak/Fir Forest; 12/C1d Western Mixed Coniferous Forest, respectively (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 Himalyan Sub-alpine Fir Forest in Uttarakhand.
Figure 14. Important cluster of sites holding species of conservation priority in 14/152 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.
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 Shiwalk/Dun; one in Bhabar; and one in Taari 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 butterfly taxa especially in the ‘Lesser Himalaya’ where the number of PAs are almost negligible. This type of approach rather than solely based on a broader geographic scale, in restoring linkages and corridors in the PA network, is more of a sub-regional or state level 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 Shiwalk/Dun; one in Bhabar; and one in Taari 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 butterfly 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 richness 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 sustainable and inclusive butterfly ecotourism activities in the state.

**REFERENCES**


Butterflies across different forest types in Uttarakhand

Singh


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


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

<table>
<thead>
<tr>
<th>Name</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Corbett National Park</td>
<td>520.82</td>
</tr>
<tr>
<td>2 Gangotri National Park</td>
<td>2390</td>
</tr>
<tr>
<td>3 Govind National Park</td>
<td>558.88</td>
</tr>
<tr>
<td>4 Nanda Devi National Park</td>
<td>624.6</td>
</tr>
<tr>
<td>5 Rajaji National Park</td>
<td>819.54</td>
</tr>
<tr>
<td>6 Valley of Flowers National Park</td>
<td>87.50</td>
</tr>
<tr>
<td>7 Askot Wildlife Sanctuary</td>
<td>600</td>
</tr>
<tr>
<td>8 Asan Conservation Reserve</td>
<td>4.44</td>
</tr>
<tr>
<td>9 Binsar Wildlife Sanctuary</td>
<td>45.59</td>
</tr>
<tr>
<td>10 Govind Wildlife Sanctuary</td>
<td>481.05</td>
</tr>
<tr>
<td>11 Jhilim Conservation Reserve</td>
<td>37.84</td>
</tr>
<tr>
<td>12 Kedarnath Wildlife Sanctuary</td>
<td>975.20</td>
</tr>
<tr>
<td>13 Benog/Mussoorie Wildlife Sanctuary</td>
<td>10.82</td>
</tr>
<tr>
<td>14 Nandhaur Wildlife Sanctuary</td>
<td>269.96</td>
</tr>
<tr>
<td>15 Pawalgarh Conservation Reserve</td>
<td>58.25</td>
</tr>
<tr>
<td>16 Sonanadi Wildlife Sanctuary</td>
<td>301.18</td>
</tr>
<tr>
<td>17 Naina Devi Bird Conservation Reserve</td>
<td>111.90</td>
</tr>
</tbody>
</table>
### Appendix II. Vegetation Composition of Forest Sub-types Sampled in the State Taken up for Study.

<table>
<thead>
<tr>
<th>Forest sub-type</th>
<th>Area (km²)</th>
<th>Percent of state cover</th>
<th>Dominant trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 3C/C2a Moist Shiwalik Sal Forest</td>
<td>3158</td>
<td>12.97</td>
<td>Shorea robusta, Anogeissus latifolia, Terminalia tomentosa, T. bellerica, Adina cordifolia, Lannea coronandra, Mallotus philippensis.</td>
</tr>
<tr>
<td>2 3C/C2c Moist Terai Sal Forest</td>
<td>542</td>
<td>2.19</td>
<td>Shorea robusta, Adina cordifolia, Talata, Terminalia tomentosa, Syzygium cuminii, Litsea glutinosa, Lagerstroemia parviflora, Cordia dichotoma,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Putranjiva roxburghii, Litsea monopetela, Pogostemon benghalensis.</td>
</tr>
<tr>
<td>3 SB/C1a Dry Shiwalik Sal Forest</td>
<td>236</td>
<td>1.5</td>
<td>Shorea robusta, Anogeissus latifolia, Buchanania lanzan, Terminalia tomentosa, Bauhinia variegata, Emblica officinalis, Accacia catechu,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pinus roxburghi, Schleichera oleosa, Cassia fistula, Zizyphus xylopyrus (B. vahlii-shrub).</td>
</tr>
<tr>
<td>4 SB/C2 Northern Dry Mixed Deciduous</td>
<td>678</td>
<td>2.82</td>
<td>Anogeissus latifolia, Boswellia serrata, Accacia catechu, Shorea robusta, Bauhinia spp., Bauhanania lanzan, Diospyros tomentosa, Terminalia</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td>bellerica, Kadiacalyxina, Sterculia lappex, Myrtagnya parviflora, Angle marmelos, Butea monosperma, Flacourtia indica, Zizyphus mauritiana.</td>
</tr>
<tr>
<td>5 S/152 Khair-Sissu Forest</td>
<td>236</td>
<td>0.98</td>
<td>Dalbergia sissoo, Accacia catechu, Zizyphus mauritana, Ehretia laevis, Holoptelea integrifolia.</td>
</tr>
<tr>
<td>6 9/C1b Upper or Himalayan Chir Pine</td>
<td>6278</td>
<td>26.07</td>
<td>Pinus roxburhi, Quercus leucotrichophora, Nyssa aquatica, Rhododendron arboratum, Pyrus pashia, Myrica esculanta, Pyrazantha crenulata,</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td>Symplocos crapeaeidae.</td>
</tr>
<tr>
<td>7 12/C1a Ban Oak Forest</td>
<td>4798</td>
<td>20.23</td>
<td>Quercus leucotrichophora, Rhododendron arboratum, Nyssa aquatica, Rhus seridatula, Symplocos crapeaeidae, Bentonithia capitata, Carpinus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>viminea, Betula alnoides.</td>
</tr>
<tr>
<td>8 12/C1b Moru Oak Forest</td>
<td>9317</td>
<td>3.95</td>
<td>Quercus floribunda, Q. leucotrichophora, Pinus wallichiana, Betula alnoides, Carpinus viminea, Acer caesium, Michilus dutehi, Aesculus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>indica, Abies pindrow, Picea smithiana, Juglans regia.</td>
</tr>
<tr>
<td>9 12/C1c Moist Deodar Forest</td>
<td>485</td>
<td>1.96</td>
<td>Cedrus deodara, Pinus wallichiana, Quercus leucotrichophora.</td>
</tr>
<tr>
<td>10 12/C1d Western Mixed Coniferous-</td>
<td>513</td>
<td>2.19</td>
<td>Pinus smithiana, Cedrus deodara, Abies pindrow, Picea smithiana, Quercus floribunda, Q. semecarpifolia, Q. leucotrichophora, Acer caesium,</td>
</tr>
<tr>
<td>Spruce, Blue Pine, Silver Fir</td>
<td></td>
<td></td>
<td>A. pictum, A. acuminatum, Euonymus lacera, Taxus baccata, Betula alnoides.</td>
</tr>
<tr>
<td>11 12/C1e Moist Temperate Deciduous</td>
<td>246</td>
<td>1.07</td>
<td>Alnus nepatensis, Aesculus indica, Acer caesium, A. pictum, Carpinus viminea, Ulmus wallichiana, Betula alnoides, Juglans regia, Fraxinus</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td>micrantha, Quercus leucotrichophora, Q. floribunda, Q. semecarpifolia, Prunus cortnetu, Rhododendron arboratum.</td>
</tr>
<tr>
<td>12 12/C2a Khasru Oak Forest (Q.</td>
<td>227</td>
<td>0.99</td>
<td>Quercus semecarpifolia, Abies pindrow, Betula alnoides, Q. floribunda, Acer caesium, Ilex diprena, Taxus baccata.</td>
</tr>
<tr>
<td>semecarpifolia)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 12/C2b West Himalayan Upper Oak/Fir</td>
<td>1087</td>
<td>4.57</td>
<td>Abies pindrow, Picea smithiana, Quercus semecarpifolia, Q. floribunda, Pyrus lanata, Acer caesium, Melosia dilinariaefolia, Euonymus lacera,</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td>Ilex diprena, Sorbus siliola, Rhododendron arboratum, R. barbatum, Ulmus wallichiana, Aesculus indica, Corylus colurna.</td>
</tr>
<tr>
<td>14 12/251 Low Level Blue Pine Forest</td>
<td>384</td>
<td>1.54</td>
<td>Pinus wallichiana, Quercus leucotrichophora.</td>
</tr>
<tr>
<td>15 13/C2b Dry Deodar Forest</td>
<td>363</td>
<td>1.46</td>
<td>Cedrus deodara, Pinus wallichiana, Picea smithiana, Corylus colurna.</td>
</tr>
<tr>
<td>16 14/C1a West Himalayan Sub-Alpine</td>
<td>195</td>
<td>0.78</td>
<td>Abies spectabilis, Pinus wallichiana, Picea smithiana, Rhododendron campanulatum, Taxus baccata, Prunus padus.</td>
</tr>
<tr>
<td>High Level Fir Forest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 14/C1b West Himalayan Sub-Alpine</td>
<td>583</td>
<td>2.47</td>
<td>Abies spectabilis, Acer ceppodioicicum, Betula utilis, Quercus semecarpifolia, Rhododendron campanulatum, R. anthopogon, Nyssa aquatica,</td>
</tr>
<tr>
<td>Birch/ Fir Forest</td>
<td></td>
<td></td>
<td>Sorbus siliola, Rhododendron arboratum, R. barbatum, Ulmus wallichiana, Aesculus indica, Corylus colurna.</td>
</tr>
<tr>
<td>18 14/152 Deciduous Sub-Alpine Scrub</td>
<td>200</td>
<td>0.86</td>
<td>Betula utilis.</td>
</tr>
<tr>
<td>19 15/C1 Birch/Rhododendron Scrub</td>
<td>136</td>
<td>0.56</td>
<td>Betula utilis, Rhododendron campanulatum, Sorbus siliola, Quercus semecarpifolia.</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 15/E1 Dwarf Rhododendron Scrub</td>
<td>32</td>
<td>0.13</td>
<td>Rhododendron anthopogon, R. lepidotum, R. campanulatum, Ilex diprena.</td>
</tr>
</tbody>
</table>

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).

<table>
<thead>
<tr>
<th>Butterfly species</th>
<th>Butterfly species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Eurema hecabe (Linnaeus, 1758)</td>
<td>43 Danaus chrysippus chrysippus (Linnaeus, 1758)</td>
</tr>
<tr>
<td>2 Catopsilia pomona (Fabricius, 1775)</td>
<td>44 Lethe verma verma (Kollar, [1844])</td>
</tr>
<tr>
<td>3 Ypthima nikaea (Linnaeus, 1758)</td>
<td>45 Ypthima inca Hewitson, [1865]</td>
</tr>
<tr>
<td>4 Pieris candia indicus Evans, 1926</td>
<td>46 Ypthima baldus baldus (Fabricius, 1775)</td>
</tr>
<tr>
<td>5 Calostrina huegelii huegelii (Moore, 1882)</td>
<td>47 Pareronia hippia (Fabricius, 1787)</td>
</tr>
<tr>
<td>6 Aporia agathon (Gray, 1831)</td>
<td>48 Castalus rosimon rosimon (Fabricius, 1775)</td>
</tr>
<tr>
<td>7 Junonia iphita iphita (Cramer, [1779])</td>
<td>49 Heliocharis tamu tamu (Kollar, [1844])</td>
</tr>
<tr>
<td>8 Callerebia nirula (Moore, 1865)</td>
<td>50 Acraea issoria issoria (Hübner, [1819])</td>
</tr>
<tr>
<td>9 Aplis caschimirensis aesis (Fruhstorfer, 1912)</td>
<td>51 Lampides boeticus (Linnaeus, 1767)</td>
</tr>
<tr>
<td>10 Papilio polytes romulus Cramer, [1875]</td>
<td>52 Cyrestis thyodamos ganesha Kollar, 1848</td>
</tr>
<tr>
<td>11 Pseudozizeeria maha maha (Kollar, [1844])</td>
<td>53 Jamides celena celena (Cramer, [1775])</td>
</tr>
<tr>
<td>12 Aesyclettes puspa (Horsfield, [1828])</td>
<td>54 Delias belladonna horsfieldi (Gray, 1831)</td>
</tr>
<tr>
<td>13 Aulocera sahaya sahaya (Kollar, [1844])</td>
<td>55 Neopithecops zalmora zalmora (Butler, [1870])</td>
</tr>
<tr>
<td>14 Dodona durga durga (Kollar, [1844])</td>
<td>56 Euploea mcleber mcleber (Cramer, [1777])</td>
</tr>
<tr>
<td>15 Leptosia nina Fabricius, 1793</td>
<td>57 Euapia lilaea lilaea (Hewitson, [1869])</td>
</tr>
<tr>
<td>16 Neptis hyas varma varma Moore, 1872</td>
<td>58 Sephora dichroma Kollar, [1844])</td>
</tr>
<tr>
<td>17 Vanessa indica indica (Herbst, 1794)</td>
<td>59 Issoria issoria Doherty, 1886</td>
</tr>
<tr>
<td>18 Euploea core core (Cramer, [1780])</td>
<td>60 Protagoras dubiosis indica (Evans, [1925])</td>
</tr>
<tr>
<td>19 Arhopala amantes amantes Swinhoe, 1866</td>
<td>61 Junonia atlites ardens (Linnaeus, 1763)</td>
</tr>
<tr>
<td>20 Pieris brassicae (Linnaeus, 1758)</td>
<td>62 Callerebia annada caeca (Cramer, [1775])</td>
</tr>
<tr>
<td>21 Neptis mahendra mahendra Moore, 1872</td>
<td>63 Ypthima nareda (Kollar, [1844])</td>
</tr>
<tr>
<td>22 Gonepteryx rhamni nepalensis Doubleday, 1847</td>
<td>64 Danaus genutia genutia (Cramer, [1779])</td>
</tr>
<tr>
<td>23 Vanessa lanata (Linnaeus, 1758)</td>
<td>65 Papilio demoleus demoleus Linnaeus, 1758</td>
</tr>
<tr>
<td>24 Calostrina lavanduliris limbatus Moore, 1879)</td>
<td>66 Mycalesis perseus perseus Fabricius, 1798</td>
</tr>
<tr>
<td>25 Ypthima huebneri Kirby, 1871</td>
<td>67 Arhopala ganesa ganesa (Moore, [1858])</td>
</tr>
<tr>
<td>26 Junonia lemonias lemonias (Linnaeus, 1758)</td>
<td>68 Colias erate (Esper, 1805)</td>
</tr>
<tr>
<td>27 Lethe sidonia (Hewitson, 1863)</td>
<td>69 Eurema blonde (Boisduval, 1836)</td>
</tr>
<tr>
<td>28 Ariadne merione tapestria (Moore, 1884)</td>
<td>70 Junonia hierta hierta (Fabricius, 1798)</td>
</tr>
<tr>
<td>29 Lesiommata schaka schaka Kollar, [1844])</td>
<td>71 Pretanica sita sita (Kollar, [1844])</td>
</tr>
<tr>
<td>30 Symphenia ilaea khasiana Moore, [1875]</td>
<td>72 Zizeeria karsandra (Moore, 1865)</td>
</tr>
<tr>
<td>31 Phaon atlantica phaonatlantica (Drury, [1773])</td>
<td>73 Cupha eranthis elatus (Sulzer, 1776)</td>
</tr>
<tr>
<td>32 Callerebia hybrida Butler, 1880</td>
<td>74 Atalyma perius perius (Linnaeus, 1758)</td>
</tr>
<tr>
<td>33 Arhopala atrax (Hewitson, 1862)</td>
<td>75 Kaniska canace canace (Linnaeus, 1763)</td>
</tr>
<tr>
<td>34 Callerebia scanda scanda (Kollar, [1844])</td>
<td>76 IXIAS pyrena (Linnaeus, 1764)</td>
</tr>
<tr>
<td>35 Parantica aglea melanoides Moore, 1883</td>
<td>77 Zizina erts erts (Fabricius, 1878)</td>
</tr>
<tr>
<td>36 Athyma apalina apalina Kollar, 1844</td>
<td>78 Hypolimnas bolina jacintha (Drury, 1773)</td>
</tr>
<tr>
<td>37 Heliocharis sena (Kollar, [1844])</td>
<td>79 Chrysoperephus birupa Moore, 1877</td>
</tr>
<tr>
<td>38 Protagoras nora aartates (Moore, [1875])</td>
<td>80 Acraea terpsicore (Linnaeus, 1758)</td>
</tr>
<tr>
<td>39 Catopsilia pyranthe Linnaeus, 1758</td>
<td>81 Lycana phloeas baratala (Moore, 1884)</td>
</tr>
<tr>
<td>40 Colias fieldi Minetres, 1855</td>
<td>82 Delias eucharis (Drury, 1773)</td>
</tr>
<tr>
<td>41 Ypthima nakane Moore, [1875]</td>
<td>83 Celaenorrhinus leucocera (Kollar, [1844])</td>
</tr>
<tr>
<td>42 Cepora neriussa phryne Fabricius, 1775)</td>
<td>84 Junonia almana almana (Linnaeus, 1758)</td>
</tr>
<tr>
<td>85 Junonia ornitha (Linnaeus, 1758)</td>
<td></td>
</tr>
</tbody>
</table>
### Butterflies across different forest types in Uttarakhand

<table>
<thead>
<tr>
<th>Butterfly species</th>
<th>Butterfly species</th>
</tr>
</thead>
<tbody>
<tr>
<td>86 Pelopidas mathias mathias (Fabricius, 1798)</td>
<td>130 Aporia leucadice (Eversmann, 1843)</td>
</tr>
<tr>
<td>87 Melanitis leda leda (Linnaeus, 1758)</td>
<td>131 Polytremis ektola ektola (Hewitson, 1869)</td>
</tr>
<tr>
<td>88 Charaxes bharata C. &amp; R. Felder, [1867]</td>
<td>132 Symbrenthia hysepis kotanda Moore, [1875]</td>
</tr>
<tr>
<td>89 Argyrinis childreni sakontalae Kollar, [1848]</td>
<td>133 Megisba malaya sikkima Moore, 1884</td>
</tr>
<tr>
<td>90 Exakizephyrus icana icana (Moore, [1875])</td>
<td>134 Neptis ananta ananta Moore, [1858]</td>
</tr>
<tr>
<td>91 Libythea lepita lepita Moore, [1858]</td>
<td>135 Graphium namius namius (Esper, 1799)</td>
</tr>
<tr>
<td><strong>B. Common</strong></td>
<td><strong>C. &amp; R. Felder, [1860]</strong></td>
</tr>
<tr>
<td>92 Euthalia patola patola (Kollar, [1844])</td>
<td>136 Beleniis aurata aurata (Fabricius, 1793)</td>
</tr>
<tr>
<td>93 Pantaoria hardania hardania (Stoll, [1790])</td>
<td>137 Pseudergolis wedah wedah (Kollar, [1844])</td>
</tr>
<tr>
<td>94 Orinoma damaris damaris Gray, 1846</td>
<td>138 Arhopala dodona dodona (Moore, [1858])</td>
</tr>
<tr>
<td>95 Tanacea lepidea lepidea (Butler, 1868)</td>
<td>139 Chiades lajus lajus (Stoll, [1780])</td>
</tr>
<tr>
<td>96 Chilades pandava pandava (Horsfield, [1829])</td>
<td>140 Poritia hewitsoni hewitsoni Moore, [1866]</td>
</tr>
<tr>
<td>97 Papilio proteron proteron Cramer, [1775]</td>
<td>141 Piers melete ajaka Moore, 1865</td>
</tr>
<tr>
<td>98 Lycaena panava (Westwood, 1852)</td>
<td>142 Lethe isana isana (Kollar, [1844])</td>
</tr>
<tr>
<td>99 Talcada nyseus nyseus (Guérin-Méneville, 1843)</td>
<td>143 Leptates plinius plinius (Fabricius, 1793)</td>
</tr>
<tr>
<td>100 Oriens gola pseudolus (Mabille, 1883)</td>
<td>144 Neptis sankara sankara (Kollar, [1844])</td>
</tr>
<tr>
<td>101 Dodona diopsea nosta Fruhstorfer, 1912</td>
<td>145 Rapala nissa nissa (Kollar, [1844])</td>
</tr>
<tr>
<td>102 Moduca procris (Cramer, [1777])</td>
<td>146 Byasa laterrelli laterrelli (Donovan, 1826)</td>
</tr>
<tr>
<td>103 Rapala manea schistacea (Moore, 1879)</td>
<td>147 Lethe nicetas (Hewitson, 1863)</td>
</tr>
<tr>
<td>104 Pseudocaeladenia fath (Kollar, [1844])</td>
<td>148 Trumala septentrionis septentrionis (Butler, 1874)</td>
</tr>
<tr>
<td>105 Byasa polyeuctes leticus (Fruhstorfer, 1908)</td>
<td>149 Parnara guttatus mangala (Moore, [1866])</td>
</tr>
<tr>
<td>106 Elymnias hypermnestra undularis (Drury, 1773)</td>
<td>150 Eurema andersoni jordani Corbet &amp; Pendlebury, 1932</td>
</tr>
<tr>
<td>107 Euthalia lubentina lubentina (Cramer, [1777])</td>
<td>151 Stabchionia nicea nicea (Gray, 1846)</td>
</tr>
<tr>
<td>108 Zemeris flegyas flegyas (Cramer, [1780])</td>
<td>152 Auzokia donova donova (Moore, [1858])</td>
</tr>
<tr>
<td>109 Rhaphiceru moorei moorei (Butler, 1867)</td>
<td>153 Celaenorrhinus patula de Nicéville, 1889</td>
</tr>
<tr>
<td>110 Callerebia hyagriya hyagriya (Moore, [1858])</td>
<td>154 Pelopidas assamensis (de Nicéville, 1882)</td>
</tr>
<tr>
<td>111 Hypolycaena othena othena Hewitson, [1865]</td>
<td>155 Symphaedra nois (Forster, 1771)</td>
</tr>
<tr>
<td>112 Dodona eugenes Bates, [1868]</td>
<td>156 Abisara fylla (Westwood, [1851])</td>
</tr>
<tr>
<td>113 Sarangosa dasahara (Moore, [1866])</td>
<td>157 Graphium sarpedon sarpedon (Linnaeus, 1758)</td>
</tr>
<tr>
<td>114 Eurema brigitte rubella (Wallace, 1867)</td>
<td>158 Troiades aeneus (C. &amp; R. Felder, 1860)</td>
</tr>
<tr>
<td>115 Mycalesis mineus mineus (Linnaeus, 1758)</td>
<td>159 Hastinalis nama nama (Doubleday, 1844)</td>
</tr>
<tr>
<td>116 Abisara bifasciata suffusa Moore, 1882</td>
<td>160 Neptis nato yerbunii Butler, 1886</td>
</tr>
<tr>
<td>117 Euthalia aconthea garuda (Moore, [1858])</td>
<td>161 Vagrans egista sinha (Kollar, [1844])</td>
</tr>
<tr>
<td>118 Rapala varuna orseis (Hewitson, [1863])</td>
<td>162 Heliophorus oda (Hewitson, 1865)</td>
</tr>
<tr>
<td>119 Graphium cloranthis cloranthis (Westwood, 1841)</td>
<td>163 Oriens goloides (Moore, [1868])</td>
</tr>
<tr>
<td>120 Curetis acuta dentata Moore, 1879</td>
<td>164 Argynnis hyperbius hyperbius (Linnaeus, 1763)</td>
</tr>
<tr>
<td>121 Heliophorus moorei coruscans (Moore, 1882)</td>
<td>165 Trumala imiai exaractis (Gmelin, 1790)</td>
</tr>
<tr>
<td>122 Notocrypta curvijacis curvijacis (C. &amp; R. Felder, 1862)</td>
<td>166 Udara albocereuleus albocereuleus (Moore, 1879)</td>
</tr>
<tr>
<td>123 Eurema laeta laeta (Boisdovul, 1836)</td>
<td>167 Zizula hylax hylax (Fabricius, 1775)</td>
</tr>
<tr>
<td>124 Celatuxia marginata marginata (de Nicéville, [1884])</td>
<td>168 Matinga ari (Moore, [1866])</td>
</tr>
<tr>
<td>125 Papilio bionar polycor Boisdovul, 1836</td>
<td>169 Pachliopta aristolochiae aristolochiae (Fabricius, 1775)</td>
</tr>
<tr>
<td>126 Lethe confusa confusa Aurivillius, [1898]</td>
<td>170 Athyma selephonora selephonora (Kollar, [1844])</td>
</tr>
<tr>
<td>127 Lethe dura gymnriei (Moore, [1892])</td>
<td>171 Lethe europa niladana Fruhstorfer, 1911</td>
</tr>
<tr>
<td>128 Callimia inachius inachius (Doyère, [1840])</td>
<td>172 Libythea myrrha sanguinalis Fruhstorfer, 1898</td>
</tr>
<tr>
<td>129 Catochrysops strabo strabo (Fabricius, 1793)</td>
<td>173 Ypthima astereope mahratto Moore, 1884</td>
</tr>
<tr>
<td>130 Aporia leucadice (Eversmann, 1843)</td>
<td>174 Tarucus indica Evans, 1932</td>
</tr>
<tr>
<td>Butterfly species</td>
<td>Butterfly species</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>175 Litoria dilectus dilectus (Moore, 1879)</td>
<td>219 Neope pulaha pandyia (Talbot, 1947)</td>
</tr>
<tr>
<td>176 Borbo cinnara (Wallace, 1866)</td>
<td>220 Telinga lepcha lepcha (Moore, 1880)</td>
</tr>
<tr>
<td>177 Pelopidas subochracea (Moore, 1878)</td>
<td>221 Archopala rama rama (Kollar, [1844])</td>
</tr>
<tr>
<td>178 Ixias marianne (Cramer, [1779])</td>
<td>222 Euchrysops crexius crexius (Fabricius, 1798)</td>
</tr>
<tr>
<td>179 Argynnus kama Moore, (1858)</td>
<td>223 Spindasis vulcanus vulcanus (Fabricius, 1775)</td>
</tr>
<tr>
<td>180 Telinga heri (Moore, [1858])</td>
<td>224 Notocrypta feithameli allosa (Moore, [1866])</td>
</tr>
<tr>
<td>181 Taractrocera danna (Moore, 1865)</td>
<td>225 Telicota colon colon (Fabricius, 1775)</td>
</tr>
<tr>
<td>182 Telicota bambusae bambusae (Moore, 1878)</td>
<td>226 Parnassius hardwickei Gray, 1831</td>
</tr>
<tr>
<td>183 Chrysazephyrus sylva Kollar, 1848</td>
<td>227 Neptis cartica cartica Moore, 1872</td>
</tr>
<tr>
<td>184 Labocala lilliana ignatius (Plötz, 1882)</td>
<td>228 Rapaia iarius sorya (Kollar, [1844])</td>
</tr>
<tr>
<td>185 Pelopidas sinensis (Mabille, 1877)</td>
<td>229 Papilio paris paris Linnaeus, 1758</td>
</tr>
<tr>
<td><strong>C. Fairly Common (Median)</strong></td>
<td><strong>230 Athyma asura asura Moore, [1858]</strong></td>
</tr>
<tr>
<td>186 Delias sanaka sanaka (Moore, [1858])</td>
<td><strong>231 Arcicia deo agrestis nazira (Moore, [1866])</strong></td>
</tr>
<tr>
<td>187 Pontia daplidice Moorei (Bober, [1907])</td>
<td><strong>232 Deudorix epiphias epiphias (Moore, [1858])</strong></td>
</tr>
<tr>
<td>188 Lethe rohria rohria (Fabricius, 1879)</td>
<td><strong>233 Rapaia selira (Moore, 1874)</strong></td>
</tr>
<tr>
<td>189 Tagoipes ligiografia ligiigeria Moschter, 1878</td>
<td><strong>234 Burara jaina jaina (Moore, [1866])</strong></td>
</tr>
<tr>
<td>190 Autocera saraswati saraswati (Kollar, [1844])</td>
<td><strong>235 Iambrix salsola salsola (Moore, [1866])</strong></td>
</tr>
<tr>
<td>191 Mycalesis visala visala Moore, (1858)</td>
<td><strong>236 Meandrus lactinus lactinus (Fruhstorfer, 1902)</strong></td>
</tr>
<tr>
<td>192 Neptis melba melba Evans, 1912</td>
<td><strong>237 Papilio astor astor Moore, 1864</strong></td>
</tr>
<tr>
<td>193 Symbrenthia brabira brabra Moore, 1872</td>
<td><strong>238 Charaxes bernardus hierax C. &amp; R. Felder, [1867]</strong></td>
</tr>
<tr>
<td>194 Everes argiades diporides Chapman, 1908</td>
<td><strong>239 Mycalesis francisca sanatana Moore, [1858]</strong></td>
</tr>
<tr>
<td>195 Jamiades bochus bochus (Stoll, [1782])</td>
<td><strong>240 Neptis soma butleri Elliot, 1969</strong></td>
</tr>
<tr>
<td>196 Tarucus nara (Kollar, 1848)</td>
<td><strong>241 Neptis zaida zaida Doubleday, [1848]</strong></td>
</tr>
<tr>
<td>197 Papilio machaon Linnaeus, 1758</td>
<td><strong>242 Hypolycaena kina kina Hewitson, [1869]</strong></td>
</tr>
<tr>
<td>198 Hypolimnas misipus (Linnaeus, 1764)</td>
<td><strong>243 Borbo bevani (Moore, 1878)</strong></td>
</tr>
<tr>
<td>199 Spialia galba galba (Fabricius, 1793)</td>
<td><strong>244 Sarangesa purandara purandara Moore, 1882</strong></td>
</tr>
<tr>
<td>200 Papilio clytia clytia Linnaeus, 1758</td>
<td><strong>245 Graphium eurus caschmirensis (Rothschild, 1895)</strong></td>
</tr>
<tr>
<td>201 Melanitis pheidima belo Moore, [1858]</td>
<td><strong>246 Hestina persimilis zella Butler, 1869</strong></td>
</tr>
<tr>
<td>202 Tarucus venosus Moore, 1882</td>
<td><strong>247 Paralasa kalinda kalinda Moore, 1865</strong></td>
</tr>
<tr>
<td>203 Athyma cama cama Moore, [1858]</td>
<td><strong>248 Polygonia c-album cognata Moore, [1899]</strong></td>
</tr>
<tr>
<td>204 Celastrina gigas (Hemming, 1928)</td>
<td><strong>249 Telinga nicotia (Westwood, [1850])</strong></td>
</tr>
<tr>
<td>205 Byasa dasaradha ravana (Moore, [1858])</td>
<td><strong>250 Freyeria trochylus orientalis Forster, 1980</strong></td>
</tr>
<tr>
<td>206 Neptis sappho astola Moore, 1872</td>
<td><strong>251 Pratapa icetas icetas (Hewitson, [1865])</strong></td>
</tr>
<tr>
<td>207 Luxura atymnus continentalis Fruhstorfer, [1912]</td>
<td><strong>252 Caprona agastis agastis Moore, [1858]</strong></td>
</tr>
<tr>
<td>208 Oreoicyx varduana varduana (Moore, [1875])</td>
<td><strong>253 Celaenorrhinus mundu (Moore, 1884)</strong></td>
</tr>
<tr>
<td>209 Shizygaephes unha rha (Hewitson, [1865])</td>
<td><strong>254 Celaenorrhinus pulomaya pulomaya (Moore, [1866])</strong></td>
</tr>
<tr>
<td>210 Surendra quercetorum quercetorum (Moore, [1858])</td>
<td><strong>255 Suastus gremius gremius (Fabricius, 1798)</strong></td>
</tr>
<tr>
<td>211 Graphium agamennon agamennon (Linnaeus, 1758)</td>
<td><strong>256 Udaspes fulus (Cramer, [1775])</strong></td>
</tr>
<tr>
<td>212 Neope yama buckleyi Talbot, 1947</td>
<td><strong>257 Ypthima kedarnathensis Singh, 2007</strong></td>
</tr>
<tr>
<td>213 Neptis clinia praedicita Smeltekop, 2011</td>
<td><strong>258 Helioptilus brahma brahma (Moore, [1858])</strong></td>
</tr>
<tr>
<td>214 Phaedyma columnella ophiana (Moore, 1872)</td>
<td><strong>259 Ampitia diacorides diacorides (Fabricius, 1793)</strong></td>
</tr>
<tr>
<td>215 Everes lacturnus assamica Tyler, 1915</td>
<td><strong>260 Burara oedipodea belesis (Mabille, 1876)</strong></td>
</tr>
<tr>
<td>216 Horaga anxy anxy (Moore, [1858])</td>
<td><strong>261 Sovia lucasi (Mabille, 1876)</strong></td>
</tr>
<tr>
<td>217 Atrophaneura varuna astorion (Westwood, 1842)</td>
<td><strong>262 Polyomma discreta discreta (Elwes &amp; Edwards, 1897)</strong></td>
</tr>
<tr>
<td>218 Euritis consimilis consimilis (Westwood, [1851])</td>
<td><strong>263 Papilio arcurus arcurus Rothschild, 1908</strong></td>
</tr>
</tbody>
</table>
Butterflies across different forest types in Uttarakhand

<table>
<thead>
<tr>
<th>Butterfly species</th>
<th>Butterfly species</th>
</tr>
</thead>
<tbody>
<tr>
<td>264 Dilipa morgiana (Westwood, [1851])</td>
<td>308 Baoris farri (Moore, 1878)</td>
</tr>
<tr>
<td>265 Nymphalis xanthomelas fervescens (Stichel, [1908])</td>
<td>309 Bibasis sena sena (Moore, [1866])</td>
</tr>
<tr>
<td>266 Colotroctra mayri (Kollar, [1844])</td>
<td>310 Athropeuera aidoneus (Doubleday, 1845)</td>
</tr>
<tr>
<td>267 Spindasis ictis ictis (Hewitson, 1865)</td>
<td>311 Graphium garhwalica (Katayama, 1988)</td>
</tr>
<tr>
<td>268 Zeusus chrysamallus Hübner, [1819]</td>
<td>312 Aporia agathon caphusa (Moore, 1872)</td>
</tr>
<tr>
<td>269 Caprona ransonnetti potiphera (Hewitson, 1873)</td>
<td>313 Gonepteryx mahaguru mahaguru Gustel, [1857]</td>
</tr>
<tr>
<td>270 Potanthus doro (Kollar, [1844])</td>
<td>314 Ariadne aridane pallidior (Fruhstorfer, 1899)</td>
</tr>
<tr>
<td>271 Tagiades menaka menaka (Moore, [1866])</td>
<td>315 Charaxes solon solon (Fabricius, 1793)</td>
</tr>
<tr>
<td>272 Tarucus callinara (Butler, 1886)</td>
<td>316 Pantoporia sandoka davidsoni Eliot, 1969</td>
</tr>
<tr>
<td>273 Anthene emolus emolus (Godart, [1824])</td>
<td>317 Tanaecia Juli appioides (Ménétriers, 1857)</td>
</tr>
<tr>
<td>274 Aulocera brahminus (Blanchard, 1853)</td>
<td>318 Ypthima avanta Moore, [1875]</td>
</tr>
<tr>
<td>275 Symbrenthia niphandra hysudra Moore, 1874</td>
<td>319 Flas asoka (de Nicéville, 1884)</td>
</tr>
<tr>
<td>276 Freyeria puthi (Kollar, [1844])</td>
<td>320 Petrelaea dana (de Nicéville, [1884])</td>
</tr>
<tr>
<td>277 Iraota timoleon timoleon (Stoll, [1790])</td>
<td>321 Rapala pheretima paterina (Hewitson, [1863])</td>
</tr>
<tr>
<td>278 Tajuria cippus cippus (Fabricius, 1798)</td>
<td>322 Sinthusa chandrana chandrana (Moore, 1882)</td>
</tr>
<tr>
<td>279 Tajuria dioeus diaeus (Hewitson, [1865])</td>
<td>323 Spalgis epius epius (Westwood, [1851])</td>
</tr>
<tr>
<td>280 Chaespes benjiminii japonica (Murray, 1875)</td>
<td>324 Virchola isorates (Fabricius, 1793)</td>
</tr>
<tr>
<td>281 Hyarotis adraustus prabo (Moore, [1866])</td>
<td>325 Dodana ouida phegea Fruhstorfer, 1914</td>
</tr>
<tr>
<td>282 Pelopidas conjuncta conjuncta (Herrich-Schäffer, 1869)</td>
<td>326 Celaenorhinus pera pera de Nicéville, 1889</td>
</tr>
<tr>
<td>283 Graphium doson axionides (Page &amp; Treadaway, 2014)</td>
<td>327 Coladenia indirani indirani (Moore, [1866])</td>
</tr>
<tr>
<td>284 Aporia agathon phryxe (Boisdouvalé, 1836)</td>
<td>328 Ochlopes brahmo (Moore, 1878)</td>
</tr>
<tr>
<td>285 Charaxes dolon dolon Westwood, [1848]</td>
<td>329 Odontoptillum angulata angulata (C. Felder, 1862)</td>
</tr>
<tr>
<td>286 Mimathyma ambica ambica (Kollar, [1844])</td>
<td>330 Seseria dohertyi dohertyi (Watson, 1893)</td>
</tr>
<tr>
<td>287 Ypthima indecora Moore, 1882</td>
<td>331 Teractrocera moei (Fabricius, 1793)</td>
</tr>
<tr>
<td>288 Ancema ctesia ctesia (Hewitson, [1865])</td>
<td>332 Papilio alcmenor alcmenor C. &amp; R. Felder, [1864]</td>
</tr>
<tr>
<td>289 Chaetopodacta odota pelei Forster, 1980</td>
<td>333 Papilio memnon agenor Linneaus, 1758</td>
</tr>
<tr>
<td>290 Curetis bulis bulis (Westwood, [1851])</td>
<td>334 Parassius epaphus Oberthür, 1879</td>
</tr>
<tr>
<td>291 Thermozephyrus axatus axatus (Westwood, [1851])</td>
<td>335 Appias larla (Doubleday, 1842)</td>
</tr>
<tr>
<td>292 Virachola perse perse (Hewitson, [1863])</td>
<td>336 Appias ilbythea (Fabricius, 1775)</td>
</tr>
<tr>
<td>293 Aeromachus stigmata stigmata (Moore, [1878])</td>
<td>337 Aglais rizana (Moore, 1872)</td>
</tr>
<tr>
<td>294 Celaenorhinus bhanananda (Moore, [1866])</td>
<td>338 Athyma inara inara Westwood, 1850</td>
</tr>
<tr>
<td>295 Tagiades jotapes ravi (Moore, [1866])</td>
<td>339 Euploea midamus (Linneaus, 1758)</td>
</tr>
<tr>
<td>296 Gandaca harina assimaco Moore, 1906</td>
<td>340 Hyponephele pulchella (C. &amp; R. Felder, [1867])</td>
</tr>
<tr>
<td>297 Neptis narayana Moore, 1858</td>
<td>341 Lethe askawinana Tyler, 1939</td>
</tr>
<tr>
<td>299 Arhopala paraganesa paraganesa (de Nicéville, 1882)</td>
<td>343 Everes hugeli hugeli (Gistel, 1857)</td>
</tr>
<tr>
<td>300 Azanus ubaldaus (Stoll, [1782])</td>
<td>344 Heliophorus indicus (Fruhstorfer, 1908)</td>
</tr>
<tr>
<td>301 Aeromachus dubius Elwes &amp; Edwards, 1897</td>
<td>345 Horago viola Moore, 1882</td>
</tr>
<tr>
<td>302 Bedalmetia exclamationis (Fabricius, 1775)</td>
<td>346 Pratapa deva lila Moore, [1884]</td>
</tr>
<tr>
<td>303 Aargynnis jainadeva jainadeva Moore, 1864</td>
<td>347 Spindasis elima uniformis (Moore, 1882)</td>
</tr>
<tr>
<td>304 Aulocera padma padma (Kollar, [1844])</td>
<td>348 Tajuria jehana jehana Moore, [1884]</td>
</tr>
<tr>
<td>305 Lethe baladeva aisa Fruhstorfer, 1911</td>
<td>349 Baoris pagana (de Nicéville, 1887)</td>
</tr>
<tr>
<td>306 Lethe sinorix sinorix (Hewitson, [1863])</td>
<td>350 Colotis kemara (Moore, 1878)</td>
</tr>
<tr>
<td>307 Spindasis nipalicus (Moore, 1884)</td>
<td>351 Erinota toru Evans, 1941</td>
</tr>
<tr>
<td>308 Baoris farri (Moore, 1878)</td>
<td>352 Pedesta masuriensis masuriensis (Moore, 1878)</td>
</tr>
</tbody>
</table>
Butterflies across different forest types in Uttarakhand

Singh

Appendix IV. Butterfly taxa of conservation priority in Uttarakhand.

<table>
<thead>
<tr>
<th>Family/Scientific name</th>
<th>Common name</th>
<th>Distribution</th>
<th>Associated forest sub-type*</th>
<th>Abundance status</th>
<th>WPA status</th>
<th>Altitudinal distribution (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A PAPILLIONIDAE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Byasa dasara daravana (Moore, 1858)</td>
<td>Great Windmill</td>
<td>WH; CH</td>
<td>12C1a; 12/ C1b</td>
<td>NR</td>
<td>NA</td>
<td>150–2750</td>
</tr>
<tr>
<td>2 Graphium eurous caschmirensis (Rothschild, 1895)</td>
<td>Six-bar Swordtail</td>
<td>WH; CH</td>
<td>12C1a</td>
<td>NR</td>
<td>NA</td>
<td>1000–2800</td>
</tr>
<tr>
<td>3 Graphium garhwalica (Katayama, 1988)</td>
<td>Garhwal Swordtail</td>
<td>WH; CH</td>
<td>12C1a</td>
<td>R</td>
<td>NA</td>
<td>1600–2300</td>
</tr>
<tr>
<td>4 Parnassius charltonius Gray, [1853]</td>
<td>Regal Apollo</td>
<td>WH; PA</td>
<td>12C1a</td>
<td>R</td>
<td>NA</td>
<td>3600–4400</td>
</tr>
<tr>
<td>B PIERIDAE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Aporia agathon caphusa (Moore, 1872)</td>
<td>Garhwal Great Blackvein</td>
<td>WH; CH</td>
<td>14/C1a</td>
<td>NR</td>
<td>NA</td>
<td>1200–3050</td>
</tr>
<tr>
<td>6 Aporia agathon phryxe (Boisduval, 1836)</td>
<td>Kashmir Great Blackvein</td>
<td>WH</td>
<td>12C1a</td>
<td>NR</td>
<td>NA</td>
<td>Up to 2100</td>
</tr>
<tr>
<td>7 Delias acalis pyramus (Wallace, 1867)</td>
<td>Redbreast Jezebel</td>
<td>WH; CH</td>
<td>3C/C2a</td>
<td>NR</td>
<td>NA</td>
<td>Up to 1500</td>
</tr>
<tr>
<td>8 Delias sanaca sanaca (Moore, [1858])</td>
<td>Pale Jezebel</td>
<td>WH</td>
<td>12/C1a; 12/ C1b</td>
<td>NR</td>
<td>Sch-I</td>
<td>1200–3000</td>
</tr>
<tr>
<td>9 Gonepteryx mahaguru mahaguru Gistel, 1857</td>
<td>Lesser Brimstone</td>
<td>WH; CH</td>
<td>12/C1a; 12/ C2c</td>
<td>NR</td>
<td>NA</td>
<td>Above 2100</td>
</tr>
<tr>
<td>C NYMPHALIDAE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Aglois nitana (Moore, 1872)</td>
<td>Mountain Tortoiseshell</td>
<td>WH; EH</td>
<td>14/152</td>
<td>R</td>
<td>Sch-II</td>
<td>2400–4500</td>
</tr>
<tr>
<td>11 Lethe dura gommie (Moore, [1892])</td>
<td>Scarce Lilacfark</td>
<td>WH; EH</td>
<td>12/C1a; 12/ C2b</td>
<td>VR</td>
<td>Sch-I</td>
<td>1800–2200</td>
</tr>
<tr>
<td>12 Polygonia c-album agnicula (Moore, 1872)</td>
<td>Nepalese Comma</td>
<td>WH; CH</td>
<td>14/C1a</td>
<td>R</td>
<td>Sch-II</td>
<td>2200–4500</td>
</tr>
<tr>
<td>13 Ypthima parasakra parasakra Eliot, 1887</td>
<td>Dubious Five-ring</td>
<td>WH; CH</td>
<td>12/251</td>
<td>R</td>
<td>NA</td>
<td>2000–2700</td>
</tr>
<tr>
<td>14 Argyron jainadeva jainadeva Moore, 1864</td>
<td>Highbrown Silverspot</td>
<td>WH</td>
<td>14/C1a</td>
<td>NR</td>
<td>NA</td>
<td>2400–4700</td>
</tr>
<tr>
<td>15 Callerebia hyagriva hyagriva (Moore, 1858)</td>
<td>Brown Argus</td>
<td>WH</td>
<td>9/C1b</td>
<td>R</td>
<td>Sch-II</td>
<td>1500–2400</td>
</tr>
<tr>
<td>16 Callerebia scanda scanda (Kollar, [1844])</td>
<td>Pallid Argus</td>
<td>WH</td>
<td>12/C1a; 12/ C1b; 12/ C1d</td>
<td>NR</td>
<td>NA</td>
<td>1200–2800</td>
</tr>
<tr>
<td>17 Charaxes dolon dolon Westwood, [1848]</td>
<td>Stately Nawab</td>
<td>WH; CH</td>
<td>12/C1a; 9/ C1b</td>
<td>R</td>
<td>Sch-II</td>
<td>1430–1900</td>
</tr>
<tr>
<td>18 Euthalia patala patala (Kollar, [1844])</td>
<td>Grand Duchess</td>
<td>WH</td>
<td>12/C1a</td>
<td>NR</td>
<td>NA</td>
<td>400–2500</td>
</tr>
<tr>
<td>19 Hestina persimilis zeilo Butler, 1869</td>
<td>Siren</td>
<td>WH</td>
<td>12/C1a; 3C/ C2a</td>
<td>R</td>
<td>Sch-II</td>
<td>750–1460</td>
</tr>
<tr>
<td>Family/Scientific name</td>
<td>Common name</td>
<td>Distribution</td>
<td>Associated forest sub-type*</td>
<td>Abundance status</td>
<td>WPA status</td>
<td>Altitudinal distribution (m)</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------</td>
<td>--------------</td>
<td>-----------------------------</td>
<td>-----------------</td>
<td>------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>20 Hyponephe davendra davendra (Moore, [1865])</td>
<td>White-ringed Meadowbrown</td>
<td>WH; PA</td>
<td>12/C1c</td>
<td>R</td>
<td>Sch-II</td>
<td>900–2400</td>
</tr>
<tr>
<td>21 Hyponephe lepulchella (C. &amp; R. Felder, [1867])</td>
<td>Tawny Meadowbrown</td>
<td>WH; PA</td>
<td>12/C2b</td>
<td>NR</td>
<td>NA</td>
<td>3000–3600</td>
</tr>
<tr>
<td>22 Lethe baladeva aiso Frustorfer, 1911</td>
<td>Treble Silverstripe</td>
<td>WH; CH</td>
<td>12/C1a; 12/C2c</td>
<td>R</td>
<td>Sch-II</td>
<td>1800–2200</td>
</tr>
<tr>
<td>23 Lethe dakwania Tytler, 1939</td>
<td>White-wedged Woodbrown</td>
<td>WH</td>
<td>12/C2c</td>
<td>R</td>
<td>NA</td>
<td>2300–3900</td>
</tr>
<tr>
<td>24 Lethe gaalpara gaalpara (Moore, [1866])</td>
<td>Large Goldenfork</td>
<td>WH; CH</td>
<td>12/C2c</td>
<td>R</td>
<td>Sch-II</td>
<td>1800–3000</td>
</tr>
<tr>
<td>25 Lethe isano isana (Kollar, [1844])</td>
<td>Common Goldenfork</td>
<td>WH</td>
<td>12/C1a; 12/C1d; 9/C1b</td>
<td>R</td>
<td>NA</td>
<td>1500–2700</td>
</tr>
<tr>
<td>26 Mycalesis suaveolens ranotei Smetacek, 2012</td>
<td>Wood-Mason’s Bushbrown</td>
<td>WH; CH</td>
<td>12/C1a</td>
<td>R</td>
<td>Sch-II</td>
<td>1700–2133</td>
</tr>
<tr>
<td>27 Neope pulaha pandyia (Talbot, 1947)</td>
<td>Veined Labyrinth</td>
<td>WH</td>
<td>12/C1a; 12/C2c; 12/2S1</td>
<td>R</td>
<td>Sch-II</td>
<td>1500–3050</td>
</tr>
<tr>
<td>28 Neope yama buckleyi Talbot, 1947</td>
<td>Dusky Labyrinth</td>
<td>WH; CH</td>
<td>12/C1a; 12/C2c</td>
<td>NR</td>
<td>Sch-II</td>
<td>1200–2370</td>
</tr>
<tr>
<td>29 Neptis anantaananta Moore, [1858]</td>
<td>Yellow Sailer</td>
<td>WH</td>
<td>3/C/C2a; 3/C/C2c; 12/C1a</td>
<td>NR</td>
<td>NA</td>
<td>2100–4800</td>
</tr>
<tr>
<td>30 Neptis clinia praejecta Smetacek, 2011</td>
<td>Sullied Sailer</td>
<td>WH</td>
<td>3/C/C2a; 3/C/C2c; 12/C1a</td>
<td>NR</td>
<td>NA</td>
<td>Low</td>
</tr>
<tr>
<td>31 Neptis sankara sankara (Kollar, [1844])</td>
<td>Broad-bodied Sailer</td>
<td>WH</td>
<td>12/C1a; 12/C2c</td>
<td>NR</td>
<td>NA</td>
<td>800–2500</td>
</tr>
<tr>
<td>32 Neptis Zaida Zaida Doubleday, [1848]</td>
<td>Pale Green Sailer</td>
<td>WH; CH</td>
<td>3/C/C2a; 12/C1a</td>
<td>R</td>
<td>Sch-II</td>
<td>900–2500</td>
</tr>
<tr>
<td>33 Nymphalis xanthomelas fervescens (Sichel, [1908])</td>
<td>Large Tortoiseshell</td>
<td>WH; CH</td>
<td>12/C1a; 12/C2b; 14/C1a</td>
<td>NR</td>
<td>NA</td>
<td>900–3200</td>
</tr>
<tr>
<td>34 Paralasa kalinda kalinda Moore, 1865</td>
<td>Scarce Mountain Argus</td>
<td>WH</td>
<td>3/C/C2a; 3/C/C2c; 12/C1a</td>
<td>R</td>
<td>NA</td>
<td>2700–3900</td>
</tr>
<tr>
<td>35 Polyconia c-album cognata Moore, [1899]</td>
<td>Kumaon Comma</td>
<td>WH</td>
<td>12/C1a; 12/C2c</td>
<td>NR</td>
<td>NA</td>
<td>2100–4800</td>
</tr>
<tr>
<td>36 Sephisa dichroa (Kollar, [1844])</td>
<td>Western Courtier</td>
<td>WH; CH</td>
<td>12/C1a; 12/C1b; 12/C2c</td>
<td>NR</td>
<td>NA</td>
<td>1500–2740</td>
</tr>
<tr>
<td>37 Ypthima avanta Moore, [1875]</td>
<td>Jewel Five-ring</td>
<td>WH; CH</td>
<td>12/C1a; 12/C2c</td>
<td>R</td>
<td>Sch-II</td>
<td>1000–2600</td>
</tr>
<tr>
<td>38 Ypthima indecora Moore, 1882</td>
<td>Western Five-ring</td>
<td>WH; CH</td>
<td>12/C1a; 12/C2c</td>
<td>NR</td>
<td>NA</td>
<td>1300–1700</td>
</tr>
<tr>
<td>39 Ypthima kedarnathensis Singh, 2007</td>
<td>Garhwal Six-ring</td>
<td>WH; CH</td>
<td>12/C1a; 12/C2c</td>
<td>R</td>
<td>NA</td>
<td>1600–2200</td>
</tr>
</tbody>
</table>

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 Eupha megalosia milionia (Hewitson, [1869]) | Water Hairstreak | WH; CH | 12/C1a | NR | NA | 1200–2000 |
| 47 Helicophorus moorei coruscans (Moore, 1882) | Azure Sapphire | WH; CH | 12/C1a; 12/C2c | NR | NA | 1300–3000 |
| 48 Pratap 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; 9/C2a | R | Sch-II | Up to 1820 |
Butterflies across different forest types in Uttarakhand

Singh

<table>
<thead>
<tr>
<th>Family/Scientific name</th>
<th>Common name</th>
<th>Distribution</th>
<th>Associated forest sub-type</th>
<th>Abundance status</th>
<th>WPA status</th>
<th>Altitudinal distribution (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 Spindasis elimauni formi s (Moore, 1882)</td>
<td>Scarce Shot Silverline</td>
<td>WH; CH</td>
<td>3C/C2a</td>
<td>NR</td>
<td>Sch II</td>
<td>Up to 2700</td>
</tr>
<tr>
<td>S2 Thermoozyphorus ataxus ataxus (Westwood, [1851])</td>
<td>Wonderful Hairstreak</td>
<td>WH; CH</td>
<td>12/C1a; 12/C2c</td>
<td>R</td>
<td>NA</td>
<td>1800–2400</td>
</tr>
<tr>
<td>E RIODINIDAE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S3 Dodona dioea nostia Fruhstorfer, 1912 Lesser Punch</td>
<td>WH</td>
<td>12/C1a; 12/C2c</td>
<td>R</td>
<td>Sch II</td>
<td>1800–3000</td>
<td></td>
</tr>
<tr>
<td>S4 Dodona ouida phlegra Fruhstorfer, 1914 Mixed Punch</td>
<td>WH; CH</td>
<td>12/C1a; 12/C2c</td>
<td>NR</td>
<td>NA</td>
<td>1200–2400</td>
<td></td>
</tr>
<tr>
<td>F HESPERIIDAE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5 Celaenorrhinus peropero deNicéville, 1889 Mussoorie Spotted Flat</td>
<td>WH</td>
<td>12/C1a</td>
<td>R</td>
<td>NA</td>
<td>1500–2000</td>
<td></td>
</tr>
<tr>
<td>S6 Potanthus dara (Kollar, [1844]) Himalayan Dart</td>
<td>WH; CH</td>
<td>12/C1a; 12/C2a</td>
<td>R</td>
<td>NA</td>
<td>1830–2590</td>
<td></td>
</tr>
<tr>
<td>S7 Suvio lucasi (Mabille, 1876) Lucas’s Ace</td>
<td>WH; EH</td>
<td>9/C1b</td>
<td>R</td>
<td>NA</td>
<td>1800–2000</td>
<td></td>
</tr>
<tr>
<td>S8 Thoressa aina (de Nicéville, 1889) Garhwal Ace</td>
<td>WH; CH</td>
<td>12/C1a</td>
<td>R</td>
<td>NA</td>
<td>1370–2800</td>
<td></td>
</tr>
</tbody>
</table>


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

Jagan Nath Adhikari 1, Janak Raj Khatiwada 2, Dipendra Adhikari 3, Suman Sapkota 4, Bishnu Prasad Bhattarai 5, Deepak Rijal 6 & Lila Nath Sharma 7

1 Central Department of Zoology, Institute of Science and Technology, Tribhuvan University, Kathmandu, Nepal.
2 Department of Zoology, Birendra Multiple Campus, Bharatpur, Chitwan, Nepal.
3 Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu 610041, China.
4 Small Mammals Conservation and Research Foundation, PO Box 9092, Kathmandu, Nepal.
5 Friends of Nature (FON), Kathmandu, Nepal.
6 USAID Program for Aquatic Natural Resource Improvement, Paani Program, Baluwatar, Kathmandu, Nepal.
7 Forest Action Nepal, Bagdol Lalitpur, Nepal.

1 jagan.adhikari@bimc.tu.edu.np (corresponding author), 2 janakrajkhatiwada@gmail.com, 3 dipenadk2005@gmail.com,
4 suman.palpa99.ss@gmail.com, 5 bishnu.bhattarai@cdz.tu.edu.np, 6 deepak_rijal@dai.com, 7 lilanathsharma@gmail.com

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.
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), including 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
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).

$$\text{Shannon index (H)} = \frac{1}{\sum \ln p_i}$$

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, $\Sigma$ 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).

$$\text{Simpson index (D)} = \sum p_i \ln p_i$$

Where $p$ is the proportion ($n/N$) of individuals of one particular species found ($n$) divided by the total number of individuals found ($N$), $\Sigma$ 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.

\[ S = a \times \ln(1 + \frac{n}{S}) \]

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 Ichthyophaga ichthyaetus, Lesser Fish Eagle Ichthyophaga 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
pulverulentus, & Lesser Adjutant Leptoptilos javanicus; and six Near Threatened species: Grey-headed Fish-eagle Ichthyophaga ichthyaetus, River Lapwing Vanellus duvaucelii, Asian Woollyneck Ciconia episcopus, Painted Stork Mycteria leucocephala, Oriental Darter Anhinga melanogaster, and Alexandrine Parakeet Psitacula 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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Protected wetland</th>
<th>Non-protected wetland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Inside Shuklaphanta National Park, Kanchanpur</td>
<td>Inside Sati Karnali Community Forest User Group, Tikapur, Kailali</td>
</tr>
<tr>
<td>Geographic location</td>
<td>N28.922883/E80.176317</td>
<td>N28.453533/E81.07378</td>
</tr>
<tr>
<td>Elevation</td>
<td>175 m</td>
<td>158 m</td>
</tr>
<tr>
<td>River basin</td>
<td>Mahakali</td>
<td>Karnali</td>
</tr>
<tr>
<td>Nature of lake</td>
<td>Oxbow</td>
<td>Oxbow</td>
</tr>
<tr>
<td>Area</td>
<td>369 hectare</td>
<td>25 hectare</td>
</tr>
<tr>
<td>Temperature</td>
<td>Average temperature 25.9 °C (14.3–32 °C, warmest month May and coldest month January)</td>
<td>Average temperature 24.6 °C (15.6–32 °C, warmest month May and coldest month January)</td>
</tr>
<tr>
<td>Rainfall</td>
<td>1,579 mm</td>
<td>1,757 mm</td>
</tr>
<tr>
<td>Feeder</td>
<td>Rainwater</td>
<td>Rani Kulo</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Surrounded by dense Sal (Shorea robusta) forest. Associated tree species are Kusum (Scheへira oleosa), Saaj (Terminalia alata), Rohini (Mallotus philippensis), Jamun (Syzygium cumini), Bhelar (Trevisia nudiflora) Common shrub species: Rudilo (Pogostemon bengalensis), Asare (Murraya koenighii) and Bhati (Cladera dendron viscosum). The lake is surrounded by elephant grass (Saccharum spontaneum), Narenga (Narenga porphyrocoma) on south, west and east Khatiwada et al. (2019)</td>
<td>Surrounded by riverine type and dominated by Sissoo (Dalbergia sissoo), Simal (Bombax ceiba), Vellar (Trevisia nudiflora) and Khayer (Acacia catechu). Sindhure (Mallotus philippensis) and Shirish (Albizia chinensis) Common shrub species: Asare (Murraya koenighii), Bhati (Cladera dendron viscosum). This area is well known for rattan cane (Calamus tenuis). Khatiwada et al. (2019)</td>
</tr>
<tr>
<td>Disturbance</td>
<td>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</td>
<td>Anthropogenic activities such as fishing, collection of snails, other aquatic products, grazing are very common.</td>
</tr>
<tr>
<td>Management authority</td>
<td>Shuklaphanta National Park</td>
<td>Sati Karnali Community Forest User Group</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Table 2. The diversity and dominance indices of birds in protected and non-protected wetlands.</th>
<th>Winter</th>
<th>Summer</th>
<th>Total</th>
<th>Winter</th>
<th>Summer</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Species richness</td>
<td>118</td>
<td>94</td>
<td>104</td>
<td>86</td>
<td>122</td>
<td>107</td>
</tr>
<tr>
<td>Dominance_D</td>
<td>0.019</td>
<td>0.03</td>
<td>0.021</td>
<td>0.03</td>
<td>0.019</td>
<td>0.018</td>
</tr>
<tr>
<td>Shannon_H</td>
<td>4.512</td>
<td>4.21</td>
<td>4.29</td>
<td>4.19</td>
<td>4.47</td>
<td>4.38</td>
</tr>
<tr>
<td>Evenness_e^H/S</td>
<td>0.68</td>
<td>0.69</td>
<td>0.69</td>
<td>0.67</td>
<td>0.66</td>
<td>0.672</td>
</tr>
<tr>
<td>Equitability_j</td>
<td>0.917</td>
<td>0.921</td>
<td>0.921</td>
<td>0.92</td>
<td>0.92</td>
<td>0.921</td>
</tr>
<tr>
<td>Fisher_alpha</td>
<td>37.21</td>
<td>31</td>
<td>34.51</td>
<td>27.43</td>
<td>31.54</td>
<td>27.31</td>
</tr>
</tbody>
</table>
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 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
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 swamplike 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...
protected and non-protected wetland birds of Nepal

Adhikari et al.

20378

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 et al.


Appendix 1. Bird species with their abundance observed in protected and non-protected wetlands in Winter and Summer. Relative abundance (RA) refers to the 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.

<table>
<thead>
<tr>
<th>Order/Family/ Common name</th>
<th>Zoological name</th>
<th>RA in Winter</th>
<th>RA in Summer</th>
<th>Total RA( %)</th>
<th>IUCN category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Order ACCIPITRIFORMES</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Family Accipitridae</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>1 Black Kite</td>
<td>Milvus migrans (Boddart, 1783)</td>
<td>0.004</td>
<td>0.5</td>
<td>0.007</td>
<td>0.554</td>
</tr>
<tr>
<td>2 Crested Serpent-eagle</td>
<td>Spilornis cheela (Latham, 1790)</td>
<td>0.002</td>
<td>0.125</td>
<td>0.001</td>
<td>0.111</td>
</tr>
<tr>
<td>3 Grey-headed Fish-eagle</td>
<td>Icthyophaga ichthyaetus (Horsfield, 1821)</td>
<td>0.002</td>
<td>0.503</td>
<td>0.001</td>
<td>0.443</td>
</tr>
<tr>
<td>4 Lesser Fish-eagle</td>
<td>Icthyophaga humilis (Müller &amp; Schlegel, 1841)</td>
<td>0.604</td>
<td>0</td>
<td>0.005</td>
<td>0</td>
</tr>
<tr>
<td>5 Egyptian Vulture</td>
<td>Neophron percnopterus (Linnaeus, 1758)</td>
<td>0.001</td>
<td>0</td>
<td>0.001</td>
<td>0</td>
</tr>
<tr>
<td>Order Pandionidae</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>6 Osprey</td>
<td>Pandion haliaetus (Linnaeus, 1758)</td>
<td>0.002</td>
<td>0</td>
<td>0.003</td>
<td>0</td>
</tr>
<tr>
<td>Order ANSERIFORMES</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Family Anatidae</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>7 Bar-headed Goose</td>
<td>Anser indicus (Latham, 1790)</td>
<td>0.005</td>
<td>0</td>
<td>0</td>
<td>0.233</td>
</tr>
<tr>
<td>8 Common Pochard</td>
<td>Aythya ferina (Linnaeus, 1758)</td>
<td>1.915</td>
<td>1.509</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9 Common Shelduck</td>
<td>Tadorna tadorna (Linnaeus, 1758)</td>
<td>1.017</td>
<td>1.509</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10 Common Teal</td>
<td>Anas crecca Linnaeus, 1758</td>
<td>0.004</td>
<td>0.628</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11 Gadwall</td>
<td>Morega strepera (Linnaeus, 1758)</td>
<td>0.004</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12 Lesser Whistling-duck</td>
<td>Dendrocopos javanicus (Horsfield, 1821)</td>
<td>0.91</td>
<td>6.92</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13 Mallard</td>
<td>Anas platyrhynchos Linnaeus, 1758</td>
<td>0.002</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14 Ruddy Shelduck</td>
<td>Tadorna ferruginea (Pallas, 1764)</td>
<td>0.002</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Order BUCEROTIFORMES</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Family Bucerotidae</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>15 Indian Grey Hornbill</td>
<td>Ocyeria birostris (Scopoli, 1786)</td>
<td>0.002</td>
<td>0</td>
<td>0.003</td>
<td>0.111</td>
</tr>
<tr>
<td>Family Upupidae</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>16 Common Hoopoe</td>
<td>Upupa epops Linnaeus, 1758</td>
<td>0.006</td>
<td>0.25</td>
<td>0.008</td>
<td>0.222</td>
</tr>
<tr>
<td>Order CAPRIMULGIFORMES</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Family Apodidae</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>17 House Swift</td>
<td>Apus nipalensis (Hodgson, 1836)</td>
<td>2.052</td>
<td>2.77</td>
<td>3.04</td>
<td>2.328</td>
</tr>
<tr>
<td>Order CHARADRIIFORMES</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Family Charadriidae</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>18 Grey-headed Lapwing</td>
<td>Vanellus cinereus (Blyth, 1842)</td>
<td>0.004</td>
<td>0.251</td>
<td>0.005</td>
<td>0</td>
</tr>
<tr>
<td>19 Red-wattled Lapwing</td>
<td>Vanellus indicus (Boddart, 1783)</td>
<td>0.004</td>
<td>0.503</td>
<td>0.007</td>
<td>0.665</td>
</tr>
<tr>
<td>20 River Lapwing</td>
<td>Vanellus duvaucelli (Lesson, 1826)</td>
<td>0.004</td>
<td>0.628</td>
<td>0.004</td>
<td>0.665</td>
</tr>
<tr>
<td>21 Yellow-wattled Lapwing</td>
<td>Vanellus malabaricus (Boddart, 1783)</td>
<td>0.004</td>
<td>1.006</td>
<td>0.005</td>
<td>1.219</td>
</tr>
<tr>
<td>Family Jacanidae</td>
<td></td>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>22 Bronze-winged Jacana</td>
<td>Metopidius indicus (Latham, 1790)</td>
<td>0.81</td>
<td>0.628</td>
<td>1.019</td>
<td>0.312</td>
</tr>
<tr>
<td>Order/Family/ Common name</td>
<td>Zoological name</td>
<td>RA in Winter</td>
<td>RA in Summer</td>
<td>Total RA(%)</td>
<td>IUCN category</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----------------</td>
<td>--------------</td>
<td>--------------</td>
<td>-------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Family Scopacidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23 Common Sandpiper</td>
<td>Actitis hypoleucos Linnaeus, 1758</td>
<td>0.004</td>
<td>0</td>
<td>0.003</td>
<td>0</td>
</tr>
<tr>
<td>24 Green Sandpiper</td>
<td>Tringa ochropus Linnaeus, 1758</td>
<td>0.012</td>
<td>0.503</td>
<td>0.007</td>
<td>0.554</td>
</tr>
<tr>
<td>25 Marsh Sandpiper</td>
<td>Tringa stagnatilis (Bechstein, 1803)</td>
<td>0.004</td>
<td>0.503</td>
<td>0.003</td>
<td>0.443</td>
</tr>
<tr>
<td>26 Wood Sandpiper</td>
<td>Tringa glareola Linnaeus, 1758</td>
<td>0.002</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Order CICONIIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Ciconiidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 Asian Openbill</td>
<td>Anastomus ascitans (Boddaert, 1783)</td>
<td>0.71</td>
<td>1.509</td>
<td>0.009</td>
<td>1.77</td>
</tr>
<tr>
<td>28 Asian Woollyneck</td>
<td>Ciconia episcopus (Boddaert, 1783)</td>
<td>0.002</td>
<td>0.125</td>
<td>0.003</td>
<td>0.886</td>
</tr>
<tr>
<td>29 Black Stork</td>
<td>Ciconia nigra (Linnaeus, 1758)</td>
<td>0.002</td>
<td>0</td>
<td>0.003</td>
<td>0</td>
</tr>
<tr>
<td>30 Lesser Adjutant</td>
<td>Leptoptilos javanicus (Horsfield, 1821)</td>
<td>0</td>
<td>0.252</td>
<td>0</td>
<td>0.252</td>
</tr>
<tr>
<td>31 Painted Stork</td>
<td>Mycteria leucocephala (Pennant, 1769)</td>
<td>0.002</td>
<td>0.252</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Order COLUMBIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Columbidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 Grey-capped Emerald Dove</td>
<td>Chalcophaps indica (Linnaeus, 1758)</td>
<td>0.008</td>
<td>1.006</td>
<td>1.011</td>
<td>0.997</td>
</tr>
<tr>
<td>33 Oriental Turtle-dove</td>
<td>Streptopelia orientalis (Latham, 1790)</td>
<td>0.004</td>
<td>0.503</td>
<td>0.005</td>
<td>0.443</td>
</tr>
<tr>
<td>34 Red Turtle-dove</td>
<td>Streptopelia tranquebarica (Hermann, 1804)</td>
<td>0.004</td>
<td>0.503</td>
<td>0.005</td>
<td>0.554</td>
</tr>
<tr>
<td>35 Rock Dove</td>
<td>Columba livia Gmelin, 1789</td>
<td>0.005</td>
<td>0</td>
<td>0.004</td>
<td>0</td>
</tr>
<tr>
<td>36 Western Spotted Dove</td>
<td>Spilopelia suratensis (Gmelin, 1789)</td>
<td>0.019</td>
<td>0.628</td>
<td>0.008</td>
<td>4.212</td>
</tr>
<tr>
<td>Order CORACIIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Alcedinidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37 Common Kingfisher</td>
<td>Alcedo atthis (Linnaeus, 1758)</td>
<td>0.005</td>
<td>0.628</td>
<td>0.007</td>
<td>0.554</td>
</tr>
<tr>
<td>38 Pied Kingfisher</td>
<td>Ceryle rudis (Linnaeus, 1758)</td>
<td>0</td>
<td>0.252</td>
<td>0.001</td>
<td>0</td>
</tr>
<tr>
<td>39 Stork-billed Kingfisher</td>
<td>Pelargopopsis capensis (Linnaeus, 1766)</td>
<td>0.002</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40 White-breasted Kingfisher</td>
<td>Halcyon smyrnensis (Linnaeus, 1758)</td>
<td>0.07</td>
<td>0.88</td>
<td>0.012</td>
<td>2.1</td>
</tr>
<tr>
<td>Family Coraciidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41 Indian Roller</td>
<td>Coracias benghalensis (Linnaeus, 1758)</td>
<td>0.05</td>
<td>0.628</td>
<td>0.007</td>
<td>0.554</td>
</tr>
<tr>
<td>Family Meropidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42 Asian Green Bee-eater</td>
<td>Merops orientalis Latham, 1802</td>
<td>1.018</td>
<td>2.138</td>
<td>2.013</td>
<td>2.106</td>
</tr>
<tr>
<td>44 Chestnut-headed Bee-eater</td>
<td>Merops leschenaulti Vieillot, 1817</td>
<td>0.004</td>
<td>0.503</td>
<td>0.005</td>
<td>0.222</td>
</tr>
<tr>
<td>Order CUCULIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Cuculidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45 Banded Bay Cuckoo</td>
<td>Cacomantis sonneratii (Latham, 1790)</td>
<td>0.002</td>
<td>0.252</td>
<td>0.003</td>
<td>0.222</td>
</tr>
<tr>
<td>46 Common Hawk-cuckoo</td>
<td>Hierococcyx varius (Vahl, 1797)</td>
<td>0.002</td>
<td>0.252</td>
<td>0.003</td>
<td>0.222</td>
</tr>
<tr>
<td>47 Greater Coucal</td>
<td>Centropus sinensis (Stephens, 1815)</td>
<td>0.002</td>
<td>0.252</td>
<td>0.003</td>
<td>0.222</td>
</tr>
<tr>
<td>48 Indian Cuckoo</td>
<td>Cuculus micropterus Gould, 1837</td>
<td>0.003</td>
<td>0.377</td>
<td>0.004</td>
<td>0</td>
</tr>
<tr>
<td>Order/Family/ Common name</td>
<td>Zoological name</td>
<td>RA in Winter</td>
<td>RA in Summer</td>
<td>Total RA( %)</td>
<td>IUCN category</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>49 Lesser Coucal</td>
<td>Centropus bengalensis (Gmelin, 1788)</td>
<td>0.008</td>
<td>1.006</td>
<td>0.009</td>
<td>0.776</td>
</tr>
<tr>
<td>50 Western Koel</td>
<td>Eudynamys scolopaceus (Linnaeus, 1758)</td>
<td>0.002</td>
<td>0</td>
<td>0.003</td>
<td>0</td>
</tr>
<tr>
<td>Order FALCONIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Falconidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51 Red-headed Falcon</td>
<td>Falco chicquera Daudin, 1800</td>
<td>0.002</td>
<td>0</td>
<td>0.003</td>
<td>0</td>
</tr>
<tr>
<td>Order GALLIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Phasianidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52 Black Francolin</td>
<td>Francolinus francolinus (Linnaeus, 1766)</td>
<td>0.004</td>
<td>0.252</td>
<td>0.003</td>
<td>0.221</td>
</tr>
<tr>
<td>53 Common Peafowl</td>
<td>Pavo cristatus Linnaeus, 1758</td>
<td>3.052</td>
<td>2.767</td>
<td>4.047</td>
<td>2.328</td>
</tr>
<tr>
<td>54 Common Quail</td>
<td>Coturnix coturnix (Linnaeus, 1758)</td>
<td>0.004</td>
<td>0</td>
<td>0.008</td>
<td>0</td>
</tr>
<tr>
<td>55 Red Junglefowl</td>
<td>Gallus gallus (Linnaeus, 1758)</td>
<td>0.804</td>
<td>0.503</td>
<td>0.005</td>
<td>0.443</td>
</tr>
<tr>
<td>56 Common Coot</td>
<td>Fulica atra Linnaeus, 1758</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0.554</td>
</tr>
<tr>
<td>Order GRUIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Railidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>57 Ruddy-breasted Crane</td>
<td>Zapornia fusca (Linnaeus, 1766)</td>
<td>0.015</td>
<td>0</td>
<td>0.017</td>
<td>0</td>
</tr>
<tr>
<td>58 Watercock</td>
<td>Gallicrex cinerea (Gmelin, 1789)</td>
<td>0.01</td>
<td>1.258</td>
<td>0.004</td>
<td>0</td>
</tr>
<tr>
<td>59 White-breasted Waterhen</td>
<td>Amaurornis phoenicurus (Pennant, 1769)</td>
<td>0.003</td>
<td>0.377</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Order PASSERIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family Alaudidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 Rufous-winged Lark</td>
<td>Mirafra assamica Horsfield, 1840</td>
<td>0.715</td>
<td>1.88</td>
<td>2.017</td>
<td>1.33</td>
</tr>
<tr>
<td>61 Sand Lark</td>
<td>Alaudula rapti (Blyth, 1844)</td>
<td>0.002</td>
<td>0.25</td>
<td>0</td>
<td>0.221</td>
</tr>
<tr>
<td>Family Cisticolidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>62 Scarlet Minivet</td>
<td>Pericrocotus flammeus (Forster, 1781)</td>
<td>0.006</td>
<td>0.754</td>
<td>0.009</td>
<td>0.665</td>
</tr>
<tr>
<td>63 Jungle Prinia</td>
<td>Prinia sylvatica Jerdon, 1840</td>
<td>0.005</td>
<td>0.628</td>
<td>0.005</td>
<td>0</td>
</tr>
<tr>
<td>64 Zitting Cisticola</td>
<td>Cisticola juncidis (Rafinesque, 1810)</td>
<td>0.004</td>
<td>0.503</td>
<td>0.004</td>
<td>0.443</td>
</tr>
<tr>
<td>Family Corvida</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65 Grey Treepie</td>
<td>Dendrocitta formosae Swinhoe, 1863</td>
<td>0.002</td>
<td>0</td>
<td>0.003</td>
<td>0</td>
</tr>
<tr>
<td>66 House Crow</td>
<td>Corvus splendens Vieillot, 1817</td>
<td>0.915</td>
<td>1.88</td>
<td>1.012</td>
<td>2.439</td>
</tr>
<tr>
<td>67 Large-billed Crow</td>
<td>Corvus macrorhynchos Wagler, 1827</td>
<td>0.004</td>
<td>0.503</td>
<td>0.008</td>
<td>1.441</td>
</tr>
<tr>
<td>68 Red-billed Blue Magpie</td>
<td>Urocissa erythrorrhyncha (Boddart, 1783)</td>
<td>0.002</td>
<td>0.25</td>
<td>0.003</td>
<td>0.221</td>
</tr>
<tr>
<td>69 Rufous Treepie</td>
<td>Dendrocitta vagabunda (Latham, 1790)</td>
<td>0.004</td>
<td>0.503</td>
<td>0.004</td>
<td>0.554</td>
</tr>
<tr>
<td>Family Dicruridae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70 Ashy Drongo</td>
<td>Dicrurus leucophaeus Vieillot, 1817</td>
<td>0.005</td>
<td>0.628</td>
<td>0.007</td>
<td>0.55</td>
</tr>
<tr>
<td>71 Black Drongo</td>
<td>Dicrurus macraceros Vieillot, 1817</td>
<td>1.015</td>
<td>1.88</td>
<td>2.017</td>
<td>1.88</td>
</tr>
<tr>
<td>72 Greater Racquet-tailed Drongo</td>
<td>Dicrurus paradiseus (Linnaeus, 1766)</td>
<td>0.004</td>
<td>0.503</td>
<td>0.003</td>
<td>0.44</td>
</tr>
<tr>
<td>73 Lesser Racquet-tailed Drongo</td>
<td>Dicrurus remifer (Temminck, 1823)</td>
<td>0.002</td>
<td>0.252</td>
<td>0.003</td>
<td>0.221</td>
</tr>
<tr>
<td>Order/Family/ Common name</td>
<td>Zoological name</td>
<td>RA in Winter</td>
<td>RA in Summer</td>
<td>Total RA (%)</td>
<td>IUCN category</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----------------</td>
<td>--------------</td>
<td>--------------</td>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>74 White-bellied Drongo</td>
<td>Dicrurus caerulescens (Linnaeus, 1758)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75 Scaly-breasted Munia</td>
<td>Lonchura punctulata (Linnaeus, 1758)</td>
<td>0.005</td>
<td>0.628</td>
</tr>
<tr>
<td></td>
<td></td>
<td>76 Barn Swallow</td>
<td>Hirundo rustica Linnaeus, 1758</td>
<td>1.023</td>
<td>2.642</td>
</tr>
<tr>
<td></td>
<td></td>
<td>77 Wire-tailed Swallow</td>
<td>Hirundo smithi Leach, 1818</td>
<td>2.026</td>
<td>3.144</td>
</tr>
<tr>
<td></td>
<td></td>
<td>78 Grey-backed Shrike</td>
<td>Lanius tephronotus (Vigors, 1831)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>79 Common Babbler</td>
<td>Argya caudata (Dumont, 1823)</td>
<td>0.004</td>
<td>0.503</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80 Jungle Babbler</td>
<td>Turdoides striata (Dumont, 1823)</td>
<td>1.014</td>
<td>1.761</td>
</tr>
<tr>
<td></td>
<td></td>
<td>81 Large Grey Babbler</td>
<td>Argya malcolmi (Sykes, 1832)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>82 Black-naped Monarch</td>
<td>Hypothymis azurea (Boddart, 1783)</td>
<td>0.905</td>
<td>0.628</td>
</tr>
<tr>
<td></td>
<td></td>
<td>83 White Wagtail</td>
<td>Motacilla alba Linnaeus, 1758</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>84 White-browed Wagtail</td>
<td>Motacilla flava Linnaeus, 1758</td>
<td>0.004</td>
<td>0.503</td>
</tr>
<tr>
<td></td>
<td></td>
<td>85 Black Redstart</td>
<td>Phoenicurus ochruros (Gmelin, 1774)</td>
<td>0</td>
<td>0.629</td>
</tr>
<tr>
<td></td>
<td></td>
<td>86 Common Stonechat</td>
<td>Saxicola torquatus (Linnaeus, 1766)</td>
<td>1.017</td>
<td>1.761</td>
</tr>
<tr>
<td></td>
<td></td>
<td>87 Grey Bushchat</td>
<td>Saxicola ferreus Gray, 1846</td>
<td>0.002</td>
<td>0.251</td>
</tr>
<tr>
<td></td>
<td></td>
<td>88 Indian Robin</td>
<td>Saxicola ruficollis (Linnaeus, 1766)</td>
<td>0.002</td>
<td>0.251</td>
</tr>
<tr>
<td></td>
<td></td>
<td>89 Oriental Magpie-robin</td>
<td>Copsychus saularis (Linnaeus, 1758)</td>
<td>1.017</td>
<td>1.257</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90 Pied Bushchat</td>
<td>Saxicola caprata (Linnaeus, 1766)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>91 White-capped Water-redstart</td>
<td>Phoenicurus leucocephalus (Vigors, 1831)</td>
<td>0.005</td>
<td>0.628</td>
</tr>
<tr>
<td></td>
<td></td>
<td>92 White-tailed Stonechat</td>
<td>Saxicola leucura (Blyth, 1847)</td>
<td>0.004</td>
<td>0.503</td>
</tr>
<tr>
<td></td>
<td></td>
<td>93 Black-hooded Oriole</td>
<td>Oriolus xanthornus (Linnaeus, 1758)</td>
<td>0.004</td>
<td>0.503</td>
</tr>
<tr>
<td></td>
<td></td>
<td>94 Chestnut-shouldered Bush-sparrow</td>
<td>Gymnoris xanthocollis (Burton, 1838)</td>
<td>1.015</td>
<td>1.257</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95 House Sparrow</td>
<td>Passer domesticus (Linnaeus, 1758)</td>
<td>1.026</td>
<td>3.144</td>
</tr>
<tr>
<td></td>
<td></td>
<td>96 Baya Weaver</td>
<td>Ploceus philippinus (Linnaeus, 1766)</td>
<td>0.01</td>
<td>1.257</td>
</tr>
<tr>
<td></td>
<td></td>
<td>97 Black Bulbul</td>
<td>Pycnonotus sinensis (Gmelin, 1789)</td>
<td>1.01</td>
<td>1.257</td>
</tr>
<tr>
<td></td>
<td></td>
<td>98 Red-vented Bulbul</td>
<td>Pycnonotus cafer (Linnaeus, 1766)</td>
<td>0.006</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>99 Red-whiskered Bulbul</td>
<td>Pycnonotus jocosus (Linnaeus, 1758)</td>
<td>1.017</td>
<td>2.012</td>
</tr>
<tr>
<td>Order/Family/ Common name</td>
<td>Zoological name</td>
<td>RA in Winter</td>
<td>RA in Summer</td>
<td>Total RA(%)</td>
<td>IUCN category</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------</td>
<td>--------------</td>
<td>--------------</td>
<td>-------------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Family: Scotocercidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 Pale-footed Bush-warbler</td>
<td>Hemitesia pallidipes (Blanford, 1872)</td>
<td>0.002</td>
<td>0.251</td>
<td>0.003</td>
<td>0.221</td>
</tr>
<tr>
<td>Family: Sturnidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>101 Asian-pied Starling</td>
<td>Gracupica contra (Linnaeus, 1758)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.886</td>
</tr>
<tr>
<td>102 Common Myna</td>
<td>Acridotheres tristis (Linnaeus, 1766)</td>
<td>1.015</td>
<td>1.886</td>
<td>2.019</td>
<td>1.99</td>
</tr>
<tr>
<td>103 Jungle Myna</td>
<td>Acridotheres fuscus (Wagler, 1827)</td>
<td>1.012</td>
<td>1.509</td>
<td>1.015</td>
<td>2.1</td>
</tr>
<tr>
<td>Family: Zosteropidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>104 Indian White-eye</td>
<td>Zosterops palpebrosus (Temminck, 1824)</td>
<td>0.002</td>
<td>0.251</td>
<td>0.003</td>
<td>0.221</td>
</tr>
<tr>
<td>Order: PELECANIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family: Ardeidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>105 Cattle Egret</td>
<td>Bubulcus ibis (Linnaeus, 1758)</td>
<td>0.805</td>
<td>0.628</td>
<td>0.005</td>
<td>7.649</td>
</tr>
<tr>
<td>106 Great White Egret</td>
<td>Ardea alba Linnaeus, 1758</td>
<td>0.006</td>
<td>0</td>
<td>0.007</td>
<td>0</td>
</tr>
<tr>
<td>107 Grey Heron</td>
<td>Ardea cinerea Linnaeus, 1758</td>
<td>0.004</td>
<td>0.503</td>
<td>0.005</td>
<td>0.443</td>
</tr>
<tr>
<td>108 Indian Pond Heron</td>
<td>Ardea cinerea Linnaeus, 1758</td>
<td>0</td>
<td>0</td>
<td>0.04</td>
<td>0.332</td>
</tr>
<tr>
<td>109 Intermediate Egret</td>
<td>Ardea intermedia Wagler, 1829</td>
<td>0.003</td>
<td>0.628</td>
<td>0.004</td>
<td>0.554</td>
</tr>
<tr>
<td>110 Little Egret</td>
<td>Egretta garzetta (Linnaeus, 1766)</td>
<td>0.004</td>
<td>0.503</td>
<td>0.005</td>
<td>0.997</td>
</tr>
<tr>
<td>111 Purple Heron</td>
<td>Ardea purpurea Linnaeus, 1766</td>
<td>0.004</td>
<td>0</td>
<td>0.005</td>
<td>0.443</td>
</tr>
<tr>
<td>Family: Theristicinidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>112 Red-naped Ibis</td>
<td>Pseudibis papillosa (Temminck, 1824)</td>
<td>0.004</td>
<td>0.503</td>
<td>0.005</td>
<td>0.11</td>
</tr>
<tr>
<td>Order: PICIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family: Megalaimidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>113 Brown-headed Barbet</td>
<td>Psilopogon zeylonicus (Gmelin, 1788)</td>
<td>0.002</td>
<td>0.251</td>
<td>0.003</td>
<td>0.221</td>
</tr>
<tr>
<td>114 Coppersmith Barbet</td>
<td>Psilopogon haemacephalus (Müller, 1776)</td>
<td>0.005</td>
<td>0.628</td>
<td>0.005</td>
<td>0.55</td>
</tr>
<tr>
<td>Family: Picidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>115 Brown-capped Pygmy</td>
<td>Picoides nanus (Vigors, 1832)</td>
<td>0</td>
<td>1.509</td>
<td>0</td>
<td>1.77</td>
</tr>
<tr>
<td>116 Great Slaty Woodpecker</td>
<td>Mulleripicus pulverulentus (Temminck, 1826)</td>
<td>0.002</td>
<td>0.251</td>
<td>0.003</td>
<td>0</td>
</tr>
<tr>
<td>117 Indian Pygmy</td>
<td>Picoides nanus (Vigors, 1832)</td>
<td>1.012</td>
<td>0.503</td>
<td>1.012</td>
<td>0</td>
</tr>
<tr>
<td>118 Lesser Yellow_maple</td>
<td>Picus chlorolophus Vieillot, 1818</td>
<td>0.004</td>
<td>0</td>
<td>0.005</td>
<td>0</td>
</tr>
<tr>
<td>119 Greater Flameback</td>
<td>Chrysocolaptes guttacristatus (Tickell, 1833)</td>
<td>0.808</td>
<td>0.503</td>
<td>0.78</td>
<td>0.44</td>
</tr>
<tr>
<td>120 Yellow-crowned Woodpecker</td>
<td>Leptopicus mahottensis (Latham, 1801)</td>
<td>0.005</td>
<td>0.628</td>
<td>0.004</td>
<td>0.554</td>
</tr>
<tr>
<td>Order: PSITTACIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family: Psittacidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>121 Plum-headed Parakeet</td>
<td>Pitta sa cyaneocephala (Linnaeus, 1766)</td>
<td>2.021</td>
<td>1.257</td>
<td>2.025</td>
<td>0.997</td>
</tr>
<tr>
<td>122 Alexandrine Parakeet</td>
<td>P. eupatria (Linnaeus, 1766)</td>
<td>2.019</td>
<td>1.257</td>
<td>0</td>
<td>0.886</td>
</tr>
<tr>
<td>123 Rose-ringed Parakeet</td>
<td>P. krameri (Scopoli, 1769)</td>
<td>1.01</td>
<td>1.509</td>
<td>2.016</td>
<td>1.33</td>
</tr>
<tr>
<td>124 Slaty-headed Parakeet</td>
<td>P. himalayana (Lesson, 1832)</td>
<td>3.031</td>
<td>4.02</td>
<td>2.02</td>
<td>2.439</td>
</tr>
</tbody>
</table>
### Protected and non-protected wetland birds of Nepal

Adhikari et al.

#### 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 research 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.

#### Table: Protected and non-protected wetland birds of Nepal

<table>
<thead>
<tr>
<th>Order/Family/ Common name</th>
<th>Zoological name</th>
<th>RA in Winter</th>
<th>RA in Summer</th>
<th>Total RA (%)</th>
<th>IUCN category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Order STRIGIFORMES</strong></td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>Family Strigidae</td>
<td></td>
<td>Protected</td>
<td>Non-protected</td>
<td>Protected</td>
<td>Non-protected</td>
</tr>
<tr>
<td>125 Jungle Owlet</td>
<td>Glaucidium radiatum (Tickell, 1833)</td>
<td>0.001</td>
<td>0</td>
<td>0.001</td>
<td>0</td>
</tr>
<tr>
<td>126 Spotted Owlet</td>
<td>Athene brama (Temminck, 1821)</td>
<td>0.001</td>
<td>0</td>
<td>0.001</td>
<td>0</td>
</tr>
</tbody>
</table>

| Order SULIFORMES          |                 | Protected    | Non-protected | Protected    | Non-protected |
| Family Anhingidae         |                 | Protected    | Non-protected | Protected    | Non-protected |
| 127 Oriental Darter       | Anhinga melanogaster Pennant, 1769 | 0.002 | 0.125 | 0 | 0 | 0.117 | 0.058 | NT |

| Family Phalacrocoracidae  |                 | Protected    | Non-protected | Protected    | Non-protected |
| 128 Great Cormorant       | Phalacrocorax carbo (Linnaeus, 1758) | 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 |
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

Jayasilan Mohd-Azlan 1, 3, 4, Joon Yee Yong 2, Nabila Norshuhadah Mohd Hazzrol 3, Philovenny Pengiran 4, Arianti Atong 5 & Sheema Abdul Aziz 6

1, 3, 4 Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia. 
2, 6 Project Pteropus, Rimba, 22-3A Casa Kiara 2, Jalan Kiara 5, 50480 Kuala Lumpur, Malaysia. 

1 azlan@unimas.my, 2 joonyee@rimbaresearch.org, 3 nabila.mhazzy@gmail.com, 4 philovennypengiran26@gmail.com, 5 arianti@sarawakforestry.com, 6 sheema@rimbaresearch.org (corresponding author)

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.
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 & Tuttle 1991; Mildenstein et al. 2016; Low et al. 2021). 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 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.

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.
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 statewide 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

1. Have you ever seen a flying fox?
   - Yes
   - No

2. 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

3. If yes, when did the last time you saw a flying fox?
   - a) January–March
   - b) April–June
   - c) July–September
   - d) October–December

4. Has anyone in the area you reside been hunting flying foxes?
   - Yes
   - No

5. 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

6. If yes, how long have you been hunting?
   - a) weeks
   - b) months
   - c) years

### Part 2. Flying Fox Hunters and Consumers

1. Have you ever hunted or killed flying foxes before?
   - Yes
   - No

2. If yes, for what purpose?
   - a) Food
   - b) Traditional medicine
   - c) Pest control
   - d) Source of income

3. 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

4. If yes, how did you get to the hunting area?
   - a) Boat
   - b) Car
   - c) Lorry
   - d) Motorcycle
   - e) On foot

5. 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

6. 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–1800 hrs
   - e) 1800 hrs–2100 hrs
   - f) 2100 hrs–0000 hrs
   - g) 0000 hrs–0300 hrs
   - h) 0300 hrs–0600 hrs

7. 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

8. 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

9. 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

10. What motivates you to hunt?

11. Do you get moral support from your local community to hunt flying foxes?
   - Yes
   - No

12. How does the local community in the area you reside feel about you hunting flying foxes?

13. Have you ever consumed or cooked flying fox meat?
   - Yes
   - No

14. If yes, how did you process the meat?

15. If yes, what other ingredients did you mix with the flying fox meat?

16. Which parts of a flying fox are used as traditional medicine?
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.](image)

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

<table>
<thead>
<tr>
<th>Price range per bat (MYR)</th>
<th>Number of Respondents</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–15</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td>16–30</td>
<td>15</td>
<td>65</td>
</tr>
<tr>
<td>31–60</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2. The reported price of P. vampyrus meat at the time of last purchase by 23 respondents in western Sarawak, Malaysian Borneo.
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).](image-url)
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 effectiveness 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; Stuebig 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...
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.
Local hunting practices and perceptions of Flying Fox in western Sarawak

Mohd-Azlan et al.

vampyurus 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. vampyurus 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. vampyurus 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


Local hunting practices and perceptions of Flying Fox in western Sarawak

Mohd-Azlan et al.


Tollington, S., Z. Karemum, A. Augustin, K. Lalchand, 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


Author details: Dr. Mohd-Azlan Jayaqilan is an Associate Professor at the Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak (UNIMAS). He conducts research on mammal ecology, threatened species, and protected areas. Mr. Yoon Joo Yee is a Research Associate under Project Pteropus. He is also a student at the Department of Biological Sciences, Sunway University, Malaysia. He is pursuing his MSc on durian (Durio zibethinus) pollination networks across Peninsular Malaysia. Ms. Nabila Norsihahudah Mohd Hazzrol is a student at the Department of Zoology, Universiti Malaysia Sarawak (UNIMAS). She worked on ethnozoology for her undergraduate project. Dr. Sheema Abdul Aziz is the co-founder & President of Rimba, and Principal Investigator of Project Pteropus. Her work focuses on fruit bat conservation in Peninsular Malaysia through conducting research on bat-plant interactions and bat-human interactions, especially for flying foxes.

Author contributions: Jayaqilan Mohd-Azlan conceived and designed the study, contributed materials, collected the data, wrote the paper, and reviewed drafts of the paper. Joon Yee Yong contributed analysis tools, prepared figures and/or tables, wrote the paper, and reviewed drafts of the paper. Joon Yee Yong contributed analysis tools, prepared figures and/or tables, wrote the paper, and reviewed drafts of the paper. Joon Yee Yong contributed analysis tools, prepared figures and/or tables, wrote the paper, and reviewed drafts of the paper. Sheema Abdul Aziz helped conceptualise the study, contributed analysis tools, prepared figures and/or tables, wrote the paper, and reviewed drafts of the paper.

Acknowledgements: We thank the Malaysian Ministry of Higher Education Fundamental Research Grant Scheme (FRGS/1/2020/W881/ UNIMAS/01/3) and the United States Fish and Wildlife Service (USFWS) for funding this research under the regional Southeast Asian Bat Conservation Research Unit (SEABCRU) project: ‘Identifying and Addressing Factors Contributing to Flying Fox Trafficking in Southeast Asia’ (F17AP00829), along with SEABCRU and Mabuwaya Foundation for coordinating the work under this grant. We are grateful to UNIMAS, Sarawak Forestry Corporation and Forest Department Sarawak (WPNP907.4.4/14-71 & WP043/2017) for facilitating this project. We appreciate the assistance given by Ms. Shazna Shamat and all the village heads during interviews, and the advice given by Tigga Kingston for study design. We are also indebted to Kanitha Krishnasamy and Tom Hughes and Jimmy Lee of EcoHealth Alliance, for sharing further details and insights regarding the hunting, consumption and trade of flying foxes in Malaysia. Lastly, we are grateful to Gopalsamy Reuben Clements for providing technical advice and assistance.
Supplementary Table 1. ‘Flying Fox’ in local Sarawakian languages.

<table>
<thead>
<tr>
<th>Ethnic group</th>
<th>Local names for flying foxes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iban</td>
<td>Entambah/Semawak</td>
</tr>
<tr>
<td>Malay</td>
<td>Keluang</td>
</tr>
<tr>
<td>Salako</td>
<td>Ka’uangk</td>
</tr>
<tr>
<td>Bidayuh</td>
<td>Jingwat</td>
</tr>
<tr>
<td>Melanau</td>
<td>Keluang/Nawai</td>
</tr>
</tbody>
</table>

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

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

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

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

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.
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.

Identification: Collected specimens were identified based on morphological observation and comparison with published keys and descriptions (Awasti 2007; Mishra & Uperti 2017). Species confirmation was done using various chemical colour tests such as potassium hydroxide (K), paraphenylenediamine (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 four species from one genus, and Ramalinaceae with one species. Among 17 genera, Parmotrema and Heteroderma were found to be dominant in the study area with nine species each followed by Usnea (6 species), Sticta, Pseudocyphellaria and Hypotrachyna with four species each, Coccocarpia, Parmelina 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 tormentose 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 (Awasti 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).
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, 0.05–0.4 mm 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, 10.006N to 77.243E, 1,582 m, on rock, July, Aswathi Anilkumar & Stephen Sequeira (2497).
Recorded from Madhya Pradesh and Rajasthan.

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, 10.008N 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.

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, rhizinate; apothecia not seen (Image 6).
Cortex K’, 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.
Table 1. Enumeration of macro lichens from Mathikettan Shola National Park.

<table>
<thead>
<tr>
<th>Species</th>
<th>Family</th>
<th>Thallus type and substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Coccocarpia palmicola</td>
<td>Coccocarpaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>2 Coccocarpia pellita (Ach.) Mull. Arg. Em. R. Sant.</td>
<td>Coccocarpaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>3 Coccocarpia sp.</td>
<td>Coccocarpaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>4 Collema auriforme (With.) Coppins &amp; J.R. Laundon</td>
<td>Collemaetaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>5 Leptogium cyanescens (Rabenh.) Körb.</td>
<td>Collemaetaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>6 Leptogium marginella (Sw.) Gray</td>
<td>Collemaetaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>7 Lobaria japonica (Zahlbr.). Asahina</td>
<td>Peltigeraeae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>8 Pseudocyphellaria argyraceae (Bory ex Delise) Vain.</td>
<td>Peltigeraeae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>9 Pseudocyphellaria aurata (Sm. &amp; Ach.) Vain.</td>
<td>Peltigeraeae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>10 Pseudocyphellaria ceylonensis H. Magn.</td>
<td>Peltigeraeae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>11 Pseudocyphellaria crocata (L.) Vain.</td>
<td>Peltigeraeae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>12 Pseudocyphellaria intricata (Delise) Vain.</td>
<td>Peltigeraeae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>13 Sticta duplilimbata (Hue) Vain.</td>
<td>Peltigeraeae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>14 Sticta limbata (Sm.) Ach. Peltigeraeae</td>
<td>Foliose Corticolous</td>
<td></td>
</tr>
<tr>
<td>15 Sticta orbicularis (R. Br.) Hue Peltigeraeae</td>
<td>Foliose Corticolous</td>
<td></td>
</tr>
<tr>
<td>16 Sticta weigeli (Ach.) Vain. Peltigeraeae</td>
<td>Foliose Corticolous</td>
<td></td>
</tr>
<tr>
<td>17 Canoparmelia pustulecence (Kurk.) Elix</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>18 Canoparmelia texana (Tuck.) Elix &amp; Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>19 Hypotrachyna cirrhata (Fr.) Divakar, A. Crespo, Sipman, Elix &amp; Lumbsch</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>20 Hypotrachyna dostylifera (Vain.) Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>21 Hypotrachyna infirma (Kurk.) Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>22 Hypotrachyna nepalense (Taylor) Divakar, A. Crespo, Sipman, Elix &amp; Lumbsch</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>23 Myelochroa xantholepis (Mont. &amp; Bosch) Elix &amp; Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>24 Parmelina usambarensis (Steiner &amp; Zahlbr.) Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>25 Parmotrema chinense (Osbeck) Hale &amp; Ahti</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>26 Parmotrema indicum Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>27 Parmotrema tinctorum (Despr. ex Ny1) Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>28 Parmotrema reticulatum (Taylor) Choisy</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>29 Parmotrema citrinum (Ach.) Choisy</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>30 Parmotrema praesorediosum (Ny1) Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>31 Parmotrema habitationum (Geyln.) Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>32 Parmotrema cristifurum (Taylor) Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>33 Parmotrema stuppeum (Taylor) Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>34 Usnea baileyi (Stirt.) Zahlbr.</td>
<td>Parmeliaceae</td>
<td>Fruticose Corticolous</td>
</tr>
<tr>
<td>35 Usnea rigidula (Stirt.) G. Awashti</td>
<td>Parmeliaceae</td>
<td>Fruticose Corticolous</td>
</tr>
<tr>
<td>36 Usnea thomsoni Strit.</td>
<td>Parmeliaceae</td>
<td>Fruticose Corticolous</td>
</tr>
<tr>
<td>37 Usnea pectinate Taylor</td>
<td>Parmeliaceae</td>
<td>Fruticose Corticolous</td>
</tr>
<tr>
<td>38 Usnea picta (J. Steiner) Mot.</td>
<td>Parmeliaceae</td>
<td>Fruticose Corticolous</td>
</tr>
<tr>
<td>39 Usnea subflorida (Zahlbr.) Mot.</td>
<td>Parmeliaceae</td>
<td>Fruticose Corticolous</td>
</tr>
<tr>
<td>40 Xanthoparmelia cogensis (B. Stein) Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>41 Xanthoparmelia pseudocognensis Hale</td>
<td>Parmeliaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>42 Heteroderma bory (Fée) Kr.P. Singh &amp; S.R. Singh</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>43 Heteroderma comosa (Eschw.) Follman &amp; Redon</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>44 Heteroderma hypocaesia (Yasuda) D.D. Awashti</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>45 Heteroderma incana (Stirton) D. D. Awashti</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>46 Heteroderma ixiographa (Vain.) D. D. Awashti</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>47 Heteroderma japonica (Sato) Swinc. &amp; Krog</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>48 Heteroderma obscura (Ny1) Trevv.</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>49 Heteroderma speciosa (Wulf.) Trevv.</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>50 Heteroderma tagashii (Kurk.) D.D. Awashti</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>51 Pheophysia hispida (Ach.) Moberg</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>52 Pheophysia arborescens (Nord.) Moberg</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>53 Physcia tribocoides Nyl.</td>
<td>Physciaceae</td>
<td>Foliose Corticolous</td>
</tr>
<tr>
<td>54 Ramalina conduplicans Vain.</td>
<td>Ramalinaceae</td>
<td>Fruticose Corticolous</td>
</tr>
<tr>
<td>55 Ramalina pacifica Asahina</td>
<td>Ramalinaceae</td>
<td>Fruticose Corticolous</td>
</tr>
</tbody>
</table>
4. *Sticta duplolimbata* (Hue) Vain.

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

Cortex K-, medulla P-, KC-, C-. 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


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


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

Swapnali Gole¹, Prasad Gaidhani², Srabani Bose³, Anant Pande⁴ & Jeyaraj Antony Johnson⁵

¹ Wildlife Institute of India, P. O. Box 18, Chandrabani, Dehradun, Uttarakhand 248001, India.
² prasadgaidhani10@gmail.com, ³ srabanibose11081995@gmail.com, ⁴ anant@wii.gov.in,
⁵ jaj@wii.gov.in, ⁶ ksvikumarwii@gmail.com (corresponding author)

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 ± 12.7%) and shoot density (103.5 ± 68.3 shoots/ m²) 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/m²) than the epibenthic macrofauna (0.4 ± 1.5 individuals/m²), 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/m²). 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.
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 Lakshadeep 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 °N and 92.2–93.95 °E) and encompasses 836 islands, islets, and rocky outcrops with a total geographical area of 8,249 km² (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°N & 92.910°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,
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./m²).

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 handheld 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/ m²). 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/m²) 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/ m²), whereas *C. rotundata* added to maximum total biomass (44.0 ± 56.1 g/ m²; 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 foraminifers. 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. / m²) was much lower than infaunal assemblages (73.5 ± 129.7 ind. /m²; Table 2).
Table 1. Seagrass meadow characteristics of Pokkadera seagrass meadow, Mayabunder, North and Middle Andaman district of Andaman & Nicobar Islands.

<table>
<thead>
<tr>
<th>Meadow characteristics</th>
<th>Seagrass species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Halophila beccarii</em></td>
</tr>
<tr>
<td>Mean seagrass cover (%)</td>
<td>30 ± 34.7</td>
</tr>
<tr>
<td>Shoot density (shoots/ m²)</td>
<td>103.5 ± 68.3</td>
</tr>
<tr>
<td>Shoot length (cm; n= 10)</td>
<td>3.2 ± 2.8</td>
</tr>
<tr>
<td>Total Biomass (above and below; dry weight) (g/ m²)</td>
<td>1.3 ± 2.2</td>
</tr>
<tr>
<td>Sea surface temperature- (°C)</td>
<td>37.3 ± 0.7</td>
</tr>
</tbody>
</table>

(Values expressed as mean ± standard deviation).

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

<table>
<thead>
<tr>
<th>Faunal groups</th>
<th>Infaunal (ind. / m²)</th>
<th>Epifaunal (ind. / m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastropods</td>
<td>188.9 ± 151.8</td>
<td>1 ± 1.7</td>
</tr>
<tr>
<td>Bivalves</td>
<td>129.2 ± 391</td>
<td>0.1 ± 0.7</td>
</tr>
<tr>
<td>Polychaetes</td>
<td>27.1 ± 52.2</td>
<td>not recorded</td>
</tr>
<tr>
<td>Nematodes</td>
<td>11.1 ± 26</td>
<td>not recorded</td>
</tr>
<tr>
<td>Foraminifera</td>
<td>11.1 ± 27.4</td>
<td>not recorded</td>
</tr>
<tr>
<td>Asteroids</td>
<td>not recorded</td>
<td>0.1 ± 0.7</td>
</tr>
<tr>
<td>Brachyurans</td>
<td>not recorded</td>
<td>0.6 ± 3.5</td>
</tr>
<tr>
<td>Decapods</td>
<td>not recorded</td>
<td>0.1 ± 0.7</td>
</tr>
</tbody>
</table>

**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**


Leopardas, V., W. Uy & M. Nakaoka (2014). Benthic macrofaunal assemblages in multispecific seagrass meadows of the southern Philippines: Variation among vegetation dominated by different...
New distribution record of Ocean Turf Grass Gole et al.


Author details: Swapnali Gole is working on dugongs and seagrasses in the Andaman Islands, as a part of the CAMPA_Dugong Project, Wildlife Institute of India. Her doctoral research is on the ecology of seagrass habitats and associated macro-benthic invertebrates in the Andaman Islands. Prasad Gaidhani worked as an intern with the Wildlife Institute of India’s CAMPA_Dugong Project in the Andaman Islands. His primary research interests encompass species research, community-based conservation with special emphasis on human-wildlife conflict, across different sea/landscapes. Sraban Bose is working on seagrass and its associated microbenthic fauna, as a part of the CAMPA Dugong Project, Wildlife Institute of India. Her research interest in on understanding the role of benthic fauna in the critical dugong habitat and also taxonomical study of microbenthic fauna. Anant Pande’s work is focused on understanding drivers of population decline of marine mammal and seabird populations, developing strategies for their conservation and management. His work involves conducting field assessments of marine megafauna populations to provide evidence-based inputs to policy makers. Jayaraj Antony Johnson has been working on taxonomy, ecology and biology of Indian fishes. His research included species distribution patterns, community structure, spatio-temporal changes in resource (food and space) partitioning among co-existing species, conservation of rare and threatened species, e-flow assessment and effects of human disturbance on aquatic resources. Currently he is coordinating the freshwater fish monitoring project under MoEFCC’s Long-term Ecological Observation (LTEO) programme. Sivakumar Kuppusamy has been working on conservation and management of aquatic biodiversity especially marine biodiversity of India as well as of Antarctica. His research involves understanding species distribution pattern, species ecology and behavioural ecology. Currently he is coordinating the MoEFCC-CAMPA funded project on the recovery of Dugong and its habitats in India. He has also involved in the developing a detail project report for the Project Dolphin.

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. JAI—supervision of the field work, reviewing the manuscript. SK—study design, supervision of the field work and data analysis, reviewing the manuscript.
An inventory of new orchid (Orchidaceae) records from Kozhikode, Kerala, India

M. Sulaiman $^{1,3}$, C. Murugan $^2$ & M.U. Sharief $^3$

$^{1-3}$Botanical Survey of India, Southern Regional Centre, TNAU Campus, Coimbatore, Tamil Nadu 641003, India.

$^1$sulai.anbu@gmail.com (corresponding author), $^2$sivanthimurugan@rediffmail.com, $^3$shariefbsi@yahoo.co.in

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.
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. Horticulturists 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 the 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 bounded 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 km² (Economic Review 2019). The study areas, viz., Kakkad, Kakkiyam, 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°C and the maximum between 28.2 and 32.9°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 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 km² (Economic Review 2019). The study areas, viz., Kakkad, Kakkiyam, 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°C and the maximum between 28.2 and 32.9°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 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 km² (Economic Review 2019). The study areas, viz., Kakkad, Kakkiyam, 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°C and the maximum between 28.2 and 32.9°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 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 km² (Economic Review 2019). The study areas, viz., Kakkad, Kakkiyam, 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°C and the maximum between 28.2 and 32.9°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 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.
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*, *Luisia macrantha*, *Oberonia josephi*, *O. sebastiana*, *O. verticillata*, *Robiquetta 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

(Continue with the rest of the text)
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 Kakayam (tropical evergreen forests), Malabar Wildlife Sanctuary (tropical semi-evergreen forests, tropical evergreen forests, and grasslands), Kakad & Pathuppadi (tropical semi-evergreen forests), and Kuttiyadi, Peruvannamuzhy, & Thamarasserry (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**


Table 2. Orchid enumeration of Kozikode district, Kerala.

<table>
<thead>
<tr>
<th>Name of the species</th>
<th>Life form</th>
<th>Flowering &amp; fruiting</th>
<th>Voucher No. (MH)</th>
<th>Locality</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Acampe ochracea (Lindl.) Hochr.</td>
<td>E</td>
<td>Nov–May</td>
<td>145445</td>
<td>Anjulimukku (Peruvannamuzhy)</td>
<td>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.</td>
</tr>
<tr>
<td>2 Acampe praemorsa (Roxb.) Blatt. &amp; McCann</td>
<td>E</td>
<td>Feb–Nov</td>
<td>145444</td>
<td>Kuttyadi</td>
<td>India (Andhra Pradesh, Odisha, Goa, Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, Daman &amp; Diu, Dadara &amp; Nagar Haveli, Jharkhand, Chhattisgarh, Madhya Pradesh, and Rajasthan), Sri Lanka, Nepal, Myanmar, and Seychelles.</td>
</tr>
<tr>
<td>3 Aerides crispa Lindl.</td>
<td>E</td>
<td>May–Aug</td>
<td>145414</td>
<td>Ambalapara (Kakkayam)</td>
<td>India (Goa, Gujarat, Maharashtra, Karnataka, Kerala, Tamil Nadu, and Dadara &amp; Nagar Haveli), Sri Lanka, Myanmar, and Bangladesh.</td>
</tr>
<tr>
<td>4 Aerides ringens (Lindl.) C.E.C.Fisch.</td>
<td>E</td>
<td>Feb–Nov</td>
<td>145446</td>
<td>Kuttyadi</td>
<td>India (Andhra Pradesh, Odisha, Goa, Gujarat, Karnataka, Kerala, and Tamil Nadu) and Sri Lanka.</td>
</tr>
<tr>
<td>5 Bulbophyllum aureum (Hook.f.) J.J.Sm.</td>
<td>E</td>
<td>Jan–Feb</td>
<td>145449</td>
<td>Athozhi (Kuttyadi)</td>
<td>India (Kerala and Tamil Nadu) Endemic to Western Ghats.</td>
</tr>
<tr>
<td>6 Bulbophyllum rhedel Manilai &amp; C.S.Kumar</td>
<td>E</td>
<td>May–Aug</td>
<td>145411</td>
<td>Ambalapara (Kakkayam)</td>
<td>India (Kerala) Endemic to Western Ghats.</td>
</tr>
<tr>
<td>7 Bulbophyllum sterile (Lam.) Suresh</td>
<td>E</td>
<td>Apr–Nov</td>
<td>14541</td>
<td>Sankaranpusha camp (Kakkayam)</td>
<td>India (Andhra Pradesh, Goa, Maharashtra, Karnataka, Kerala and Tamil Nadu), Nepal, Bangladesh and Myanmar.</td>
</tr>
<tr>
<td>8 Bulbophyllum stocksi (Benth. ex Hook.f.) J.J.Verm., Schuit. &amp; de Vogel</td>
<td>E</td>
<td>Sep–Nov</td>
<td>145412</td>
<td>Ambalapara (Kakkayam)</td>
<td>India (Maharashtra, Karnataka, Kerala and Tamil Nadu), Myanmar and Bangladesh.</td>
</tr>
<tr>
<td>9 Calanthe sylvatica (Thouars) Lindl.</td>
<td>T</td>
<td>Sep–Nov</td>
<td>145438</td>
<td>Sothupara (Kakkayam)</td>
<td>India (Assam, Mizoram, West Bengal, Karnataka, Kerala, and Tamil Nadu), Bhutan, Nepal, Sri Lanka, China, Myanmar, Indonesia, Japan, Malaysia, Thailand, India, China, Madagascar, and Africa.</td>
</tr>
<tr>
<td>10 Cheirostylis parvifolia Lindl.</td>
<td>T</td>
<td>Jun–Sep</td>
<td>145431</td>
<td>Ambalapara Grass land (Kakkayam)</td>
<td>India (Maharashtra, Karnataka, Kerala, Tamil Nadu, and Odisha) and Sri Lanka.</td>
</tr>
<tr>
<td>11 Cleisostoma tenuifolium (L.) Garay</td>
<td>E</td>
<td>Jan–Dec</td>
<td>145447</td>
<td>Pathuppadi</td>
<td>India (Goa, Maharashtra, Karnataka, Kerala, and Tamil Nadu), Sri Lanka, and Thailand.</td>
</tr>
<tr>
<td>12 Coelogyne brevicapra Lindl.</td>
<td>E</td>
<td>Jan–Apr</td>
<td>145403</td>
<td>Ambalapara (Kakkayam)</td>
<td>India (Karnataka, Kerala, and Tamil Nadu) and Sri Lanka.</td>
</tr>
<tr>
<td>13 Cottonia peduncularis (Lindl.) Rchb.f.</td>
<td>E</td>
<td>Jan–Apr</td>
<td>145415</td>
<td>Kakkayam</td>
<td>India (Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, and Odisha) and Sri Lanka.</td>
</tr>
<tr>
<td>15 Cymbidium aloifolium (L.) Sw.</td>
<td>E</td>
<td>Mar–Jun</td>
<td>145439</td>
<td>Kakkad</td>
<td>India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Uttarakhand, Goa, Maharashtras, Karnataka, Kerala, Tamil Nadu, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, and Andaman &amp; Nicobar Islands), Sri Lanka, China, Myanmar, Bangladesh, Laos, Cambodia, Vietnam, Malaysia, and Indonesia.</td>
</tr>
<tr>
<td>16 Dendrobium herbaceum Lindl.</td>
<td>E</td>
<td>Oct–Nov</td>
<td>145415</td>
<td>Athihkote R.F. (Malabar Wildlife Sanctuary)</td>
<td>India (Mizoram, West Bengal, Andhra Pradesh, Odisha, Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, and Andaman &amp; Nicobar Islands), Sri Lanka, China, Myanmar, Bangladesh, Laos, Cambodia, Vietnam, Malaysia, and Indonesia.</td>
</tr>
<tr>
<td>17 Dendrobium heterocarpum Wall. ex Lindl.</td>
<td>E</td>
<td>Feb–Apr</td>
<td>145410</td>
<td>Ambalapara (Kakkayam)</td>
<td>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.</td>
</tr>
<tr>
<td>18 Dendrobium heyneanum Lindl.</td>
<td>E</td>
<td>Sep–Nov</td>
<td>145430</td>
<td>Ambalapara (Kakkayam)</td>
<td>India (Karnataka, Kerala, and Tamil Nadu) Endemic to Western Ghats.</td>
</tr>
<tr>
<td>Name of the species</td>
<td>Life form</td>
<td>Flowering &amp; fruiting</td>
<td>Voucher No. (MH)</td>
<td>Locality</td>
<td>Distribution</td>
</tr>
<tr>
<td>--------------------</td>
<td>-----------</td>
<td>---------------------</td>
<td>------------------</td>
<td>----------</td>
<td>--------------</td>
</tr>
<tr>
<td>Dendrobium (\text{macrostachyum} ) Lindl.</td>
<td>E</td>
<td>Mar–Jun</td>
<td>145427</td>
<td>Atthikode R.F. (Malabar Wildlife Sanctuary)</td>
<td>India (Arunachal Pradesh, West Bengal, Uttarakhand, Odisha, Goa, Maharashtra, Karnataka, Kerala, Tamil Nadu, and Jharkhand), Srilanka, Nepal, Bangladesh, Indonesia, Thailand, and Vietnam.</td>
</tr>
<tr>
<td>Dendrobium (\text{nanum} ) Hook.f.</td>
<td>E</td>
<td>Sep–Nov</td>
<td>145419</td>
<td>Atthikode R.F. (Malabar Wildlife Sanctuary)</td>
<td>India (Goa, Maharashtra, Karnataka, Kerala, and Tamil Nadu). Endemic to Eastern and Western Ghats.</td>
</tr>
<tr>
<td>Dendrobium (\text{nodosum} ) Daleell</td>
<td>E</td>
<td>Mar–Jun</td>
<td>145403</td>
<td>Ambalappara (Kakkayam)</td>
<td>India (Goa, Maharashtra, Karnataka, Tamil Nadu, and Kerala). Endemic to Western Ghats.</td>
</tr>
<tr>
<td>Dendrobium (\text{ovatum (L.)} ) Kraenzl.</td>
<td>E</td>
<td>Jan–Dec</td>
<td>145448</td>
<td>Thamarassery</td>
<td>India (Andhra Pradesh, Gujarat, Goa, Maharashtra, Karnataka, Kerala, and Tamil Nadu). Endemic to Eastern and Western Ghats.</td>
</tr>
<tr>
<td>Dendrobium (\text{salaccense (Blume)} ) Lindl.</td>
<td>E</td>
<td>Sep–Nov</td>
<td>145409</td>
<td>Ambalappara (Kakkayam)</td>
<td>India (Assam, Meghalaya, Mizoram, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Odisha, Karnataka, Kerala, and Andaman &amp; Nicobar Islands), Srilanka, Bhutan, China, Indonesia, Laos, Malaysia, Myanmar, Thailand, and Vietnam.</td>
</tr>
<tr>
<td>Diploprora (\text{championii (Lindl.)} ) Hook.f.</td>
<td>E</td>
<td>Aug–Sep</td>
<td>145421</td>
<td>Atthikode R.F. (Malabar Wildlife Sanctuary)</td>
<td>India (Meghalaya, Arunachal Pradesh, Sikkim, West Bengal, Odisha, Karnataka, Kerala, and Andaman &amp; Nicobar Islands), Srilanka, China, Bangladesh, Myanmar, Thailand, and Vietnam.</td>
</tr>
<tr>
<td>Eulophia (\text{nuda (Lindl.)} ) Lindl.</td>
<td>T</td>
<td>Sep–Oct</td>
<td>145435</td>
<td>Atthikode R.F. (Malabar Wildlife Sanctuary)</td>
<td>India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Uttarakhand, Uttar Pradesh, Jharkhand, Bihar, Madhya Pradesh, Chhattisgarh, Punjab, Odisha, Andhra Pradesh, Maharshtra, Karnataka, Kerala, Tamil Nadu, and Andaman &amp; Nicobar Islands), Srilanka, Bhutan, China, Indonesia, Malaysia, and Singapore.</td>
</tr>
<tr>
<td>Eulophia (\text{zollingeri (Rchb.f.) J.J.Sm.} )</td>
<td>T</td>
<td>Jan–Feb</td>
<td>145435</td>
<td>Atthikode R.F. (Malabar Wildlife Sanctuary)</td>
<td>India (Assam, Meghalaya, Nagaland, Arunachal Pradesh, Sikkim, West Bengal, Karnataka, Kerala, and Andaman &amp; Nicobar Islands), Srilanka, Bhutan, Nepal, Srilanka, Nepal, Malaysia, Philippines, and Singapore.</td>
</tr>
<tr>
<td>Geodorum (\text{densiflorum (Lamk.) Schlech.} )</td>
<td>T</td>
<td>Apr–Nov</td>
<td>145440</td>
<td>Atthikode R.F. (Malabar Wildlife Sanctuary)</td>
<td>India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Sikkim, West Bengal, Uttarakhand, Andhra Pradesh, Odisha, Go, Karnataka, Maharashtra, and Tamil Nadu). Endemic to Eastern and Western Ghats.</td>
</tr>
<tr>
<td>Habenaria (\text{diphylla Dalz.} )</td>
<td>T</td>
<td>Aug–Sep</td>
<td>145451</td>
<td>Atthikode grass land (Malabar Wildlife Sanctuary)</td>
<td>India (Meghalaya, Sikkim, West Bengal, Himachal Pradesh, Uttarakhand, Odisha, Andhra Pradesh, Go, Karnataka, Maharashtra, and Tamil Nadu). Endemic to Eastern and Western Ghats.</td>
</tr>
<tr>
<td>Habenaria (\text{heyneana Lindl.} )</td>
<td>T</td>
<td>Aug–Sep</td>
<td>145433</td>
<td>Ambalappara grass land (Kakkayam)</td>
<td>India (Andhra Pradesh, Goa, Karnataka, Kerala, and Tamil Nadu). Endemic to Eastern and Western Ghats.</td>
</tr>
<tr>
<td>Habenaria (\text{longicorniculata J.Graham} )</td>
<td>T</td>
<td>Aug–Sep</td>
<td>145423</td>
<td>Atthikode grass land (Malabar Wildlife Sanctuary)</td>
<td>India (Andhra Pradesh, Odisha, Gujarat, Goa, Maharshtra, Karnataka, Kerala, Tamil Nadu, Jharkhand, Chhattisgarh, Madhya Pradesh, and Rajasthan).</td>
</tr>
<tr>
<td>Habenaria (\text{viridiflora (Sw.) R. Br.} )</td>
<td>T</td>
<td>Aug–Dec</td>
<td>145451</td>
<td>Atthikode grass land (Malabar Wildlife Sanctuary)</td>
<td>India (Assam, Karnataka, Kerala, Maharashtra, and Tamil Nadu). Endemic to Eastern and Western Ghats.</td>
</tr>
<tr>
<td>Name of the species</td>
<td>Life form</td>
<td>Flowering &amp; fruiting</td>
<td>Voucher No. (MH)</td>
<td>Locality</td>
<td>Distribution</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-----------</td>
<td>----------------------</td>
<td>------------------</td>
<td>------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Liparis elliptica Wight</td>
<td>E</td>
<td>Sep–Oct</td>
<td>145427</td>
<td>Kakkayam R.F.</td>
<td>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.</td>
</tr>
<tr>
<td>Liparis viridiflora (Blume) Lindl.</td>
<td>E</td>
<td>Aug–Dec</td>
<td>145428</td>
<td>Sankaranpuzha (Kakkayam)</td>
<td>India (Manipur, Meghalaya, Arunachal Pradesh, Sikkim, Odisha, Andhra Pradesh, Karnataka, Kerala, Tamil Nadu), Sri Lanka, China, Bangladesh, Myanmar, Bhutan, India, Bangladesh, Malaysia, Nepal, China, Myanmar, Thailand, Laos, and Vietnam.</td>
</tr>
<tr>
<td>Luisia macrantha Blatt. &amp; McCann</td>
<td>E</td>
<td>Feb–Nov</td>
<td>145408</td>
<td>Ambalappara (Kakkayam)</td>
<td>India (Karnataka and Kerala). Endemic to Western Ghats.</td>
</tr>
<tr>
<td>Oberonia bicornis Lindl.</td>
<td>E</td>
<td>Aug–Nov</td>
<td>145420</td>
<td>Sankaranpuzha (Kakkayam)</td>
<td>India (Manipur, Meghalaya, Arunachal Pradesh, Sikkim, Odisha, Maharashatra, Karnataka, Kerala, and Tamil Nadu), Sri Lanka, and Bangladesh. Endemic to peninsular India.</td>
</tr>
<tr>
<td>Oberonia brunoniana Wight</td>
<td>E</td>
<td>Aug–Dec</td>
<td>145419</td>
<td>Sankaranpuzha (Kakkayam)</td>
<td>India (Andhra Pradesh, Goa, Maharashatra, Karnataka, Kerala, and Tamil Nadu). Endemic to Western Ghats.</td>
</tr>
<tr>
<td>Oberonia ensiformis (Sm.) Lindl.</td>
<td>E</td>
<td>Aug–Dec</td>
<td>145402</td>
<td>Sankaranpuzha (Kakkayam)</td>
<td>India (Odisha, Maharashatra, Karnataka, Kerala, and Tamil Nadu). Endemic to Peninsular India.</td>
</tr>
<tr>
<td>Oberonia proudlockii King &amp; Pantl.</td>
<td>E</td>
<td>Aug–Dec</td>
<td>145402</td>
<td>Sankaranpuzha (Kakkayam)</td>
<td>India (Odisha, Maharashatra, Karnataka, Kerala, and Tamil Nadu). Endemic to Peninsular India.</td>
</tr>
<tr>
<td>Oberonia sebastiana B.V.Shetty &amp; Vivek.</td>
<td>E</td>
<td>Aug–Nov</td>
<td>145442</td>
<td>Anjulimukku (Kuttiyadi)</td>
<td>India (Kerala and Tamil Nadu). Endemic to Western Ghats.</td>
</tr>
<tr>
<td>Oberonia verticillata Wight</td>
<td>E</td>
<td>Aug–Nov</td>
<td>145418</td>
<td>Sankaranpuzha (Kakkayam)</td>
<td>India (Goa, Maharashatra, Karnataka, Tamil Nadu, and Kerala). Endemic to Western Ghats.</td>
</tr>
<tr>
<td>Peristylus aristatus Lindl.</td>
<td>T</td>
<td>Aug–Sep</td>
<td>145434</td>
<td>Sankaranpuzha (Kakkayam)</td>
<td>India (Goa, Karnataka, Kerala, Maharashatra, and Tamil Nadu), Nepal, Pakistan, Myanmar, Malaysia, and Indonesia.</td>
</tr>
<tr>
<td>Phalaenopsis mysorensis C.J.Saldanha</td>
<td>E</td>
<td>Feb–Apr</td>
<td>145407</td>
<td>Ambalappara Grass land (Kakkayam)</td>
<td>India (Karnataka and Kerala). Endemic to Eastern and Western Ghats.</td>
</tr>
<tr>
<td>Pholidota imbricata Hook. f.</td>
<td>E</td>
<td>Jan–Mar</td>
<td>145428</td>
<td>Thamarrassery</td>
<td>India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, Arunachal Pradesh, Sikkim, West Bengal, and Chhattisgarh), and Pakistan, Sri Lanka, and Bangladesh.</td>
</tr>
<tr>
<td>Porpax exilis (Hook.f) Schuit., Y.P.Ng &amp; H.A.Pedersen</td>
<td>E</td>
<td>Feb–Apr</td>
<td>145404</td>
<td>Ambalappara (Kakkayam)</td>
<td>India (Goa, Karnataka, Kerala, Maharashatra, and Tamil Nadu). Endemic to Eastern and Western Ghats.</td>
</tr>
</tbody>
</table>
Delhi, 157 pp.


Bishen Singh Mahendra Pal Singh, Dehra Dun, 357 pp.


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


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


1Department of Plant Sciences, Faculty of Science, University of Colombo, P.O. Box 1490, Colombo 03, Sri Lanka.
2Department of Information and Communication Technology, University of Sri Jayawadenepura, Gangodawila, Nupegoda, Sri Lanka.
3Central Environmental Authority, P.O. Box 104, Denizil Kobbeckaduwa Mawatha, Sri Jayawadenepura Kotte, Sri Lanka.
4Department of Plant Sciences, Faculty of Science, University of Colombo, P.O. Box 1490, Colombo 03, Sri Lanka.

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 km2 and declining habitat, coupled with a high risk of extinction, it is placed under the 'Critically Endangered' category in the International Union for 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 km2 and 4.000 km2, 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.
INTRODUCTION

Sri Lanka is a tropical island with a total land area of 65,610 km² 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 (Meyers 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 ecological and geographical 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 km² (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
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


Image 2. The study site in Walawwe-Watta Wathurana Swamp Forest.
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 km² 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.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* Koster., *Dipterocarpus hispidus* Thwaites, *Cullenia rosayroana* Koster., *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 km² and AOO 4.000 km², 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 Batapotlle 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 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...
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,i,ii,iii) category, where declines can be seen in EOO, AOO, and habitat quality. However, the category c(ii,iii,iv,v) 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 rosaryroana* Kosterm., *Durio zeylanicus* Auct., *Humbolditia 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**


Plant diversity of Point Calimere Wildlife Sanctuary and fodder species grazed by the Blackbuck *Antilope cervicapra* L.

Ashutosh Kumar Upadhyay 1, A. Andrew Emmanuel 2, Ansa Sarah Varghese 3 & D. Narasimhan 4

1 Central National Herbarium, Botanical Survey of India, Acharya Jagdish Chandra Bose Indian Botanic Garden, Howrah, West Bengal 711103, India.
2 Door No. 1, Block-I, Met Quarters, College Road, Chennai, Tamil Nadu 600006, India.
3 Inchackal (H), Cherukole, P.O, Mavelikara, Alappuzha, Kerala 690104, India.
4 Department of Botany, Madras Christian College (Autonomous) Tambaram, Tamil Nadu 600059, India.

ashutoshpdh196@gmail.com (corresponding author), emmanuel.andrew29@gmail.com, ansa.svarghese@gmail.com, narasimhand@gmail.com

**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 *Antilope 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 *Avicennia officinalis* (L.) Thwaites, Dog's Tooth Grass *Cynodon dactylon* (L.) Pers., Feather Finger Grass *Chloris virgata* Sw., 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 habitats, Nagapattinam District, tropical dry evergreen forests, Fodder species, alien species, habitat, survey, Bishnoi community.

Editor: L.A.K. Singh, Bhubaneswar, Odisha, India.

Date of publication: 26 January 2022 (online & print)


Copyright: © Upadhyay et al. 2022. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use, reproduction, and distribution of this article in any medium by providing adequate credit to the author(s) and the source of publication.

Funding: None.

Competing interests: The authors declare no competing interests.

**Author details:** Mr. ASHUTOSH KUMAR UPADHYAY has worked in University of Agricultural Sciences (GKVK) as a Junior Research Fellow. He was recently working on the Taxonomy and Ethnobotany of Elatostema J.R.Forster & G.Forster in India. Mr. A. ANDREW EMMANUEL has a master’s degree from Madras Christian College in Botany and a degree in Education. He is interested in plant ecology and plant-animal interaction. Currently he is a teacher handling Biology and Biotechnology. Ms. ANSA SARAH VARGHESE has worked on the Flora of Rishi Valley School, Andhra Pradesh and has good knowledge of Angiosperm taxonomy. She has also been part of several research programs on Plant breeding at ICAR-IIHR. Dr. D. NARASIMHAN is a retired Head of Department of Botany, Madras Christian College. During his tenure he worked extensively towards botanising various parts of India. He currently is a member of Tamil Nadu State Biodiversity Board.

**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.

**Acknowledgements:** The authors wish to thank Mr. S. Soundarajan, IFS, wildlife warden (Retd.), Nagapattinam District for facilitating us to carry out the study. We would also like to thank Mr. Leslie Lawrence, assistant professor, Department of Botany, Madras Christian College and Dr. Sheeba J. Irwin for their help during the study. We also extend our gratitude to all the field personnel of Point Calimere Bird and Wildlife Sanctuary for their involved help during the field studies. AKU would also like to thank the Director, Botanical Survey of India for providing lab facilities.
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) Vallenadu Sanctuary, Tuticorin; (c) Point Calimere Wildlife Sanctuary, Kodiakkarai; (d) Sathymangalam 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, Kodiakkara 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
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, Convolulaceae, 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.Alton. 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.,
Plants of Point Calimere WS and fodder grazed by Blackbuck

Upadhyay et al.

Table 1. Suggested fodder species for introduction in Point Calimere Wildlife Sanctuary.

| 1. Grass species for Blackbucks | Cynodon dactylon (L.), Blue panic grass Panicum coloratum L., Panicum curviflorum Horne., Torpedo grass Panicum repens L., Setaria flava (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 | Desmodocysta bipinnata (L.) Stapf, Dimeria avenacea (Retz.) C.E.C.Fisch., Manusaris myurus L., Indian comet grass Perotis indica (L.) Kunz, Trachys mucicata (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 Butea monosperma Lam., Flame of the forest Butea monosperma (Lam.) Kunz, 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. |

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 faces 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 Maatu-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
REFERENCES


Appendix I. List of plants observed at Point Calimere Wildlife Sanctuary

<table>
<thead>
<tr>
<th>Sno</th>
<th>Binomial &amp; Common names</th>
<th>Family</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GRASSES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Aeluropus lagopoides (L.) Thwaite</td>
<td>Poaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>2</td>
<td>Stapfochloa elata (Desv.) P.M.Peterson</td>
<td>Poaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>3</td>
<td>Chloris virgata Sw.</td>
<td>Poaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>4</td>
<td>Cyodon barberi Rang. &amp; Tudul.</td>
<td>Poaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>5</td>
<td>Cyodon dactylon (L.) Pers.</td>
<td>Poaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>6</td>
<td>Dactyloctenium aegyptium (L.) Wild.</td>
<td>Poaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>7</td>
<td>Eragrostis sp.</td>
<td>Poaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>8</td>
<td>Eragrostis tenella (L.) P.Beav. ex Roem. &amp; Schult</td>
<td>Poaceae</td>
<td>Low mounds</td>
</tr>
<tr>
<td>9</td>
<td>Eragrostis viscosa (Retz.) Trin.</td>
<td>Poaceae</td>
<td>Low mounds</td>
</tr>
<tr>
<td>10</td>
<td>Panicum sp.</td>
<td>Poaceae</td>
<td>High mounds and Inundated plains</td>
</tr>
<tr>
<td>11</td>
<td>Penotis indica (L.) Kunze</td>
<td>Poaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>12</td>
<td>Spinifex littoreus (Burm.f) Men.</td>
<td>Poaceae</td>
<td>Sand dunes</td>
</tr>
<tr>
<td><strong>SEDES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Cyperus dubius Rottb.</td>
<td>Cyperaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>2</td>
<td>Fimbristyliis acuminate Vahl</td>
<td>Cyperaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>3</td>
<td>Fimbristyliis argentea (Rottb.) Vahl</td>
<td>Cyperaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>4</td>
<td>Fimbristyliis falcata (Vahl) Kunth</td>
<td>Cyperaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>5</td>
<td>Fimbristyliis sp.</td>
<td>Cyperaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td><strong>HERBS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Achyranthes aspera L.</td>
<td>Amaranthaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>Sno</td>
<td>Binomial &amp; Common names</td>
<td>Family</td>
<td>Habitat</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------</td>
<td>-------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>2</td>
<td>Ouret lanata (L.) Kuntze</td>
<td>Amaranthaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Peelai, Sirupeelai</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Solanum brachiata Roxb.</td>
<td>Amaranthaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Kolliam, Pavaloppundu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Asystasia gongetica (L.) T. Anderson</td>
<td>Acanthaceae</td>
<td>Inundated plains with sparse trees and low mounds</td>
</tr>
<tr>
<td>5</td>
<td>Boerhavia diffusa L.</td>
<td>Nyctaginaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Moorakattai</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Cressa cretica L.</td>
<td>Convolvulaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Vuppoo marikkazhudhu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Croton bonelandianus Baill.</td>
<td>Euphorbiaceae</td>
<td>Inundated plains with sparse trees and low mounds</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Rail poondu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Cyananthium cinereum (L.) H. Rob.</td>
<td>Asteraceae</td>
<td>Low mounds with sparse trees</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Mookthippoondu, Sahadevi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Epaltes divaricata (L.) Cass.</td>
<td>Asteraceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>10</td>
<td>Epaltes sp.</td>
<td>Asteraceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>11</td>
<td>Genusporum sp.</td>
<td>Lamiaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>12</td>
<td>Jectocoma indica (Wild.) K.A.Sheph. &amp; Paul G.Wilson</td>
<td>Amaranthaceae</td>
<td>Halophytic</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Pavazhappundu, Sirumari</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Leucasi diffusa Benth.</td>
<td>Lamiaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>14</td>
<td>Ocimum americanum L.</td>
<td>Lamiaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Ganjaankorai, Nai thulasi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Ocimum tenuiflorum L.</td>
<td>Lamiaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Thulasi, Rama thulasi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Oldenlandia herbacea (L.) Roxb.</td>
<td>Rubiaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>17</td>
<td>Oldenlandia umbellata L.</td>
<td>Rubiaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>18</td>
<td>Vicia indica (L.) DC.</td>
<td>Lamiaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Jimikipoop, Mookuthippoondu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Platostoma menthoides (L.) A.J.Paton</td>
<td>Lamiaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Ganjaankorai</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Ruellia patula Lacz.</td>
<td>Acanthaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>21</td>
<td>Synostemon bacciformis (L.) G.L.Webster</td>
<td>Rubiaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Pavazhappundu, Sirumari</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Sesuvium portulacorastum (L.) L.</td>
<td>Aizoaceae</td>
<td>Halophytic</td>
</tr>
<tr>
<td>23</td>
<td>Spermacoce hispida L.</td>
<td>Rubiaceae</td>
<td>Sand dunes</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Nathaihuori</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Suaeda maritima (L.) Dumort.</td>
<td>Amaranthaceae</td>
<td>Halophytic</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Nari yumari, Uppukkeerai</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Suaeda vermiculata Forsk.ex I.F. Gmel.</td>
<td>Amaranthaceae</td>
<td>Halophytic</td>
</tr>
<tr>
<td>26</td>
<td>Tephrosia maxima (L.) Pers.</td>
<td>Fabaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Kollukaai vaela, Periya kozhinji</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Tephrosia purpurea (L.) Pers.</td>
<td>Leguminosae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Kozhinji, Kollukaai vaela</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Vahlia dichotomum (Murray) Kuntze</td>
<td>Vahliaaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Pani payaru</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Vigna trilobata (L.) Verdc.</td>
<td>Fabaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Pani payaru</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CLIMBER / LIANA**

<table>
<thead>
<tr>
<th>Sno</th>
<th>Binomial &amp; Common names</th>
<th>Family</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abrus precatorius L.</td>
<td>Fabaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Kudumani</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Asparagus racemosus Wild.</td>
<td>Asparagaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Thaneeer vitaan kizhangu, Sadhavaeri</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Capparis brevippina DC.</td>
<td>Capparaceae</td>
<td>High mound with sparse trees</td>
</tr>
<tr>
<td>4</td>
<td>Capparis zeylanica L.</td>
<td>Capparaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Athondai</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Cissus quadrangularis L.</td>
<td>Vitaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Pirandai</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Cissus vitiginea L.</td>
<td>Vitaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Chembirandai, Mudai naari</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Coccinia grandis (L.) Voigt</td>
<td>Cucurbitaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td></td>
<td>Tamil name: Kovai</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sno</td>
<td>Binomial &amp; Common names</td>
<td>Family</td>
<td>Habitat</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>8</td>
<td>Gmelina asiatica L.</td>
<td>Lamiaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>9</td>
<td>Jasminum angustifolium (L.) Willd.</td>
<td>Oleaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>10</td>
<td>Jasminum cuspidatum Rottler</td>
<td>Oleaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>11</td>
<td>Olax scandens Roxb.</td>
<td>Oleaceae</td>
<td>Low mound with sparse trees</td>
</tr>
<tr>
<td>12</td>
<td>Pentatropis capensis (L. f.) Bullock</td>
<td>Apocynaceae</td>
<td>Halophytic</td>
</tr>
<tr>
<td>13</td>
<td>Rivea hypocotyliformis (Desr.)Choisy</td>
<td>Convolvulaceae</td>
<td>Low mound with sparse trees</td>
</tr>
<tr>
<td>14</td>
<td>Scutia myrtina (Burm. f.) Kurz</td>
<td>Rhamnaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>15</td>
<td>Solanum trifoliatum L.</td>
<td>Solanaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>16</td>
<td>Vincetoxicum indicum (Burm.f.) Mabb.</td>
<td>Apocynaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td></td>
<td><strong>SHRUBS &amp; SUB-SHRUBS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Azima tetrapanthe Lam.</td>
<td>Salvadoreaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>2</td>
<td>Acacia sp.</td>
<td>Fabaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>3</td>
<td>Guilandina bonduc L.</td>
<td>Fabaceae</td>
<td>Inundated plains and sand dunes</td>
</tr>
<tr>
<td>4</td>
<td>Calotropis gigantea (L.) W.T.Aiton</td>
<td>Apocynaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>5</td>
<td>Canthium parviflorum</td>
<td>Rubiaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>6</td>
<td>Catunaregam spinosa (Thum.) Tirveng.</td>
<td>Rubiaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>7</td>
<td>Chamaemorus humilis L.</td>
<td>Arecaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>8</td>
<td>Crotonia laburnifolia L.</td>
<td>Fabaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>9</td>
<td>Crotalaria pallida</td>
<td>Fabaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>10</td>
<td>Dichrostachys cinerea (L.) White &amp; Arn.</td>
<td>Fabaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>11</td>
<td>Diospyros herroreza (Willd.) Bakh.</td>
<td>Ebenaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>12</td>
<td>Ehretia microphylla Lam.</td>
<td>Boraginaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>13</td>
<td>Fueggia leucopityrus Willd.</td>
<td>Phyllanthaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>14</td>
<td>Glycosmis mauritiana (Lam.) Tanaka</td>
<td>Rutaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>15</td>
<td>Grewia carpinifolia Juss.</td>
<td>Malvaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>16</td>
<td>Gymnosporia emarginata (Willd.) Thwaites</td>
<td>Celastraceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>17</td>
<td>Hygrophila auriculata (Schumach.) Heine</td>
<td>Acanthaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>18</td>
<td>Lantana camara L.</td>
<td>Verbenaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>19</td>
<td>Opuntia dillenii (Ker Gawl.) Haw.</td>
<td>Cactaceae</td>
<td>Inundated plains and low mounds</td>
</tr>
<tr>
<td>20</td>
<td>Pandanus odorifer (Forsk.) Kuntze</td>
<td>Pandanaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>21</td>
<td>Prosopis juliflora (Sw.) DC.</td>
<td>Fabaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>22</td>
<td>Psilotrichum eliotii Baker</td>
<td>Amaranthaceae</td>
<td>Inundated plains and low mounds</td>
</tr>
<tr>
<td>23</td>
<td>Senna auriculata (L.) Roxb.</td>
<td>Fabaceae</td>
<td>Inundated plains and low mounds</td>
</tr>
<tr>
<td>24</td>
<td>Senna occidentalis (L.) Link</td>
<td>Fabaceae</td>
<td>Inundated plains and low mounds</td>
</tr>
<tr>
<td>25</td>
<td>Senna timoriensis (D.C.) H.S. Irwin &amp; Barneby</td>
<td>Fabaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>Sno</td>
<td>Binomial &amp; Common names</td>
<td>Family</td>
<td>Habitat</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>26</td>
<td>Suaeda monoica Forssk. ex J.F. Gmel.</td>
<td>Amaranthaceae</td>
<td>Halophytic</td>
</tr>
<tr>
<td>27</td>
<td>Vitex negundo L. Tamil name: Nochi, Vennochi</td>
<td>Lamiaceae</td>
<td>High mound with sparse trees</td>
</tr>
<tr>
<td>28</td>
<td>Volkameria inermis L. Tamil name: Pinchil, Pinarichangangupp</td>
<td>Lamiaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>29</td>
<td>Ziziphus jujuba Mill. Tamil name: Illandhai</td>
<td>Rhamnaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>30</td>
<td>Ziziphus oenopolia (L.) Mill. Tamil name: Soorai pazham, Soorai mullu</td>
<td>Rhamnaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
</tbody>
</table>

**SMALL AND BIG TREES**

<table>
<thead>
<tr>
<th>Sno</th>
<th>Binomial &amp; Common names</th>
<th>Family</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Albizia lebbeck (L.) Bentth. Tamil name: Vaagai</td>
<td>Fabaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>2</td>
<td>Avicennia marina (Forsk.) Vierh. Tamil name: Venkandal, Vellaikkandal</td>
<td>Avicenniaceae</td>
<td>Mangrove</td>
</tr>
<tr>
<td>3</td>
<td>Azadirachta indica A. Juss. Tamil name: Vaembu, Vaepam</td>
<td>Meliaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>4</td>
<td>Cassia fistula L. Tamil name: Kondrai, Sanakkondrai</td>
<td>Fabaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>5</td>
<td>Casuarina equisetifolia L. Tamil name: Savukku</td>
<td>Casuarinaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>6</td>
<td>Excoecaria agallocha L. Tamil name: Thillai</td>
<td>Euphorbiaceae</td>
<td>Mangrove</td>
</tr>
<tr>
<td>7</td>
<td>Ficus benghalensis L. Tamil name: Aai, Ichi</td>
<td>Moraceae</td>
<td>Sand dunes</td>
</tr>
<tr>
<td>8</td>
<td>Lanorea coronandecolea (Houtt.) Mer. Tamil name: Odihiya maram, Othi</td>
<td>Anacardiaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>9</td>
<td>Manilkara hexandra (Roxb.) Dubard Tamil name: Kannupalai, Paala maram</td>
<td>Sapotaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>10</td>
<td>Peltophorium pterocarpum (DC.) Backer ex K. Heyne Tamil name: Iyalaavaagi, Perugondrai</td>
<td>Fabaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>11</td>
<td>Pithecellobium dulce (Roxb.) Bentth. Tamil name: Kudukkaai puli</td>
<td>Fabaceae</td>
<td>Inundated plains and high mounds</td>
</tr>
<tr>
<td>12</td>
<td>Pongamia pinnata (L.) Pierre Tamil name: Punga maram</td>
<td>Fabaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>13</td>
<td>Premna serratifolia L. Tamil name: Munnai</td>
<td>Lamiaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>14</td>
<td>Salvadora persica L. Tamil name: Chittu vila, Kalanxa</td>
<td>Salvadoraceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>15</td>
<td>Thespesia populnea (L.) Sol. ex Correa Tamil name: Poovarasu</td>
<td>Malvaceae</td>
<td>Inundated plains</td>
</tr>
</tbody>
</table>

**CREEPERS**

<table>
<thead>
<tr>
<th>Sno</th>
<th>Binomial &amp; Common names</th>
<th>Family</th>
<th>Habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grona triflora (L.) H. Ohashi &amp; K. Ohashi Tamil name: Sirupulladi</td>
<td>Fabaceae</td>
<td>Inundated plains</td>
</tr>
<tr>
<td>2</td>
<td>Euphorbia thymifolia L. Tamil name: Sittrapaladai</td>
<td>Euphorbiaceae</td>
<td>Low level shady moist area</td>
</tr>
<tr>
<td>3</td>
<td>Evolvulus alsinoides (L.) L. Tamil name: Vishnuvarandi</td>
<td>Convolvulaceae</td>
<td>Inundated plains with sparse trees</td>
</tr>
<tr>
<td>4</td>
<td>Ipomoea pes-caprae (L.) R. Br. Tamil name: Attukkal, Kudhirai kulambu</td>
<td>Convolvulaceae</td>
<td>Sand dunes</td>
</tr>
</tbody>
</table>
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


1 Puspawomin, 1830 Mahatab Road, Old Town, Bhubaneswar, Odisha 751002, India.
2 National Chambal Sanctuary, Morena, Madhya Pradesh 476001, India.
3 Pawar Kothi, Dusshera Maidan, near G.R. Medical College, Gwalior, Madhya Pradesh 474009, India.

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.
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.
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.

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).
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 km². 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.

<table>
<thead>
<tr>
<th>English name (Common Name)</th>
<th>Scientific name</th>
<th>Location</th>
<th>Total raptor counts (max 14 surveys)</th>
<th>Total years when seen (max 14)</th>
<th>IUCN Red List status</th>
<th>Migratory status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Cinereous Vulture</td>
<td>Aegypius monachus</td>
<td>Chambal, Kuno</td>
<td>4</td>
<td>3</td>
<td>NT</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>2  Egyptian Vulture</td>
<td>Neophron percnopterus</td>
<td>Chambal, Kuno</td>
<td>999</td>
<td>14</td>
<td>EN</td>
<td>Resident</td>
</tr>
<tr>
<td>3  White-rumped Vulture (Indian White-backed Vulture)</td>
<td>Gyps bengalensis</td>
<td>Chambal, Kuno</td>
<td>80</td>
<td>14</td>
<td>CR</td>
<td>Resident</td>
</tr>
<tr>
<td>4  Indian Vulture (Longbilled Vulture)</td>
<td>Gyps indicus</td>
<td>Chambal, Kuno</td>
<td>12</td>
<td>6</td>
<td>CR</td>
<td>Resident</td>
</tr>
<tr>
<td>5  Red-headed Vulture</td>
<td>Sarcogyps calvus</td>
<td>Chambal, Kuno</td>
<td>30</td>
<td>13</td>
<td>CR</td>
<td>Resident</td>
</tr>
<tr>
<td>6  Griffon Vulture (Eurasian Griffon)</td>
<td>Gyps fulvus</td>
<td>Kuno</td>
<td>4</td>
<td>4</td>
<td>LC</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>7  Western Osprey (Osprey)</td>
<td>Pandion haliaetus</td>
<td>Chambal</td>
<td>562</td>
<td>14</td>
<td>LC</td>
<td>Winter visitor, seen till May</td>
</tr>
<tr>
<td>8  Black-shouldered Kite</td>
<td>Elanus axillaris</td>
<td>Chambal, Kuno</td>
<td>39</td>
<td>9</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>9  Black Kite (Common Pariah Kite)</td>
<td>Milvus migrans</td>
<td>Chambal, Kuno</td>
<td>62</td>
<td>8</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>10 Shikra</td>
<td>Accipiter badius</td>
<td>Chambal</td>
<td>74</td>
<td>14</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>11 Western Marsh Harrier (Eurasian Marsh Harrier)</td>
<td>Circus aeruginosus</td>
<td>Chambal</td>
<td>38</td>
<td>13</td>
<td>LC</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>12 Common Buzzard</td>
<td>Buteo buteo</td>
<td>Chambal</td>
<td>4</td>
<td>3</td>
<td>LC</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>13 White-eyed Buzzard</td>
<td>Butastur teesa</td>
<td>Chambal, Kuno</td>
<td>2</td>
<td>2</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>14 Crested Honey Buzzard (Oriental Honey Buzzard)</td>
<td>Pernis ptilorhynchus</td>
<td>Chambal, Kuno</td>
<td>4</td>
<td>4</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>15 Bonelli’s Eagle</td>
<td>Aquila fasciata</td>
<td>Chambal, Kuno</td>
<td>29</td>
<td>10</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>16 Pallas’s Fish Eagle</td>
<td>Haliaeetus leucoryphus</td>
<td>Chambal</td>
<td>0</td>
<td>0</td>
<td>EN</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>17 Tawny Eagle</td>
<td>Aquila rapax</td>
<td>Chambal</td>
<td>11</td>
<td>5</td>
<td>VU</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>18 Crested Serpent Eagle</td>
<td>Spilornis cheela</td>
<td>Chambal</td>
<td>5</td>
<td>4</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>19 Changeable Hawk Eagle</td>
<td>Nisaetus cirrhatus (Spizaetus cirrhatus)</td>
<td>Chambal</td>
<td>5</td>
<td>4</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>20 Common Kestrel</td>
<td>Falco tinnunculus</td>
<td>Chambal</td>
<td>29</td>
<td>10</td>
<td>LC</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>21 Eurasian Hobby</td>
<td>Falco subbuteo</td>
<td>Chambal</td>
<td>6</td>
<td>6</td>
<td>LC</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>22 Laggar Falcon</td>
<td>Falco jugger</td>
<td>Chambal</td>
<td>27</td>
<td>13</td>
<td>NT</td>
<td>Resident</td>
</tr>
<tr>
<td>23 Red-necked Falcon</td>
<td>Falco chicquera</td>
<td>Chambal</td>
<td>9</td>
<td>7</td>
<td>NT</td>
<td>Resident</td>
</tr>
<tr>
<td>24 Spotted Owlet</td>
<td>Athene brama</td>
<td>Chambal</td>
<td>4</td>
<td>4</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>25 Western Barn Owl (Barn Owl)</td>
<td>Tyto alba</td>
<td>Chambal, Kuno</td>
<td>5</td>
<td>4</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>26 Dusky Eagle Owl</td>
<td>Bubo coromandus</td>
<td>Chambal</td>
<td>4</td>
<td>4</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>27 Brown Fish Owl</td>
<td>Ketupa zeylonensis</td>
<td>Kuno</td>
<td>5</td>
<td>4</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>28 Indian Scops Owl</td>
<td>Otus bakkamoena</td>
<td>Kuno</td>
<td>7</td>
<td>5</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>29 Mottled Wood Owl</td>
<td>Strix occidentalis</td>
<td>Kuno</td>
<td>5</td>
<td>4</td>
<td>LC</td>
<td>Resident</td>
</tr>
<tr>
<td>30 Indian Eagle-Owl (Rock Eagle-Owl)</td>
<td>Bubo bengalensis</td>
<td>Kuno</td>
<td>5</td>
<td>4</td>
<td>LC</td>
<td>Resident</td>
</tr>
</tbody>
</table>
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
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 2. Year-wise survey with record of total numbers of species, raptor birds, and the trend of their index ratio.**

<table>
<thead>
<tr>
<th>Year</th>
<th>Species no.</th>
<th>Raptor count</th>
<th>Bird count / Species count index</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>11</td>
<td>116</td>
<td>10.5</td>
</tr>
<tr>
<td>2004</td>
<td>17</td>
<td>188</td>
<td>11.1</td>
</tr>
<tr>
<td>2005</td>
<td>17</td>
<td>160</td>
<td>9.4</td>
</tr>
<tr>
<td>2006</td>
<td>17</td>
<td>171</td>
<td>10.1</td>
</tr>
<tr>
<td>2007</td>
<td>10</td>
<td>153</td>
<td>15.3</td>
</tr>
<tr>
<td>2008</td>
<td>18</td>
<td>166</td>
<td>9.2</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
<td>111</td>
<td>11.1</td>
</tr>
<tr>
<td>2010</td>
<td>15</td>
<td>85</td>
<td>5.7</td>
</tr>
<tr>
<td>2011</td>
<td>14</td>
<td>170</td>
<td>12.1</td>
</tr>
<tr>
<td>2012</td>
<td>13</td>
<td>90</td>
<td>6.9</td>
</tr>
<tr>
<td>2013</td>
<td>14</td>
<td>148</td>
<td>10.6</td>
</tr>
<tr>
<td>2014</td>
<td>16</td>
<td>163</td>
<td>10.2</td>
</tr>
<tr>
<td>2015</td>
<td>22</td>
<td>176</td>
<td>8.0</td>
</tr>
<tr>
<td>2016</td>
<td>15</td>
<td>173</td>
<td>11.5</td>
</tr>
</tbody>
</table>
| **Total** | 209 | 2070          | **Average** 14.9 | 147.9 | 9.9

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.
Raptors observed (1983–2016) in National Chambal Gharial Sanctuary

Singh et al.

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).

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Anonymous 2021 (RTR)</th>
<th>Sultana 2013 (STR)</th>
<th>Kuno – Palpur (Tharmalingam et al 2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cinereous Vulture</td>
<td>Aegypius monachus</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2 Egyptian Vulture</td>
<td>Neophron percnopterus</td>
<td>N</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>3 White-rumped Vulture</td>
<td>Gyps bengalensis</td>
<td>N</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>4 Indian Vulture</td>
<td>Gyps indicus</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>5 Red-headed Vulture</td>
<td>Sarcogyps calvus</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>6 Griffon Vulture</td>
<td>Gyps fulvus</td>
<td>N</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>7 Western Osprey</td>
<td>Pandion haliaetus</td>
<td>N</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>8 Black-shouldered Kite</td>
<td>Elanus axillaris</td>
<td>P</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>9 Black Kite</td>
<td>Milvus migrans</td>
<td>P</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>10 Shikra</td>
<td>Accipiter badius</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>11 Western Marsh Harrier</td>
<td>Circus aeruginosus</td>
<td>N</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>12 Common Buzzard</td>
<td>Buteo buteo</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>13 White-eyed Buzzard</td>
<td>Buteo buteo</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>14 Crested Honey Buzzard</td>
<td>Pernis ptilorhynchus</td>
<td>P</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>15 Bonelli’s Eagle</td>
<td>Aquila fasciata</td>
<td>N</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>16 Pallal’s Fish Eagle</td>
<td>Haliaeetus leucoryphus</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>17 Tawny Eagle</td>
<td>Aquila rapax</td>
<td>N</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>18 Crested Serpent Eagle</td>
<td>Spilornis cheela</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>19 Changeable Hawk Eagle</td>
<td>Nisaetus cirrhatus</td>
<td>N</td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>20 Common Kestrel</td>
<td>Falco tinnunculus</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>21 Eurasian Hobby</td>
<td>Falco subbuteo</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>22 Laggar Falcon</td>
<td>Falco jugger</td>
<td>N</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>23 Red-necked Falcon</td>
<td>Falco chicquera</td>
<td>N</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>24 Spotted Owlet</td>
<td>Athene brama</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>25 Western Barn Owl</td>
<td>Tyto alba</td>
<td>P</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>26 Dusky Eagle Owl</td>
<td>Bubo coromandus</td>
<td>P</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>27 Brown Fish Owl</td>
<td>Ketupa zeylonensis</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>28 Indian Scops Owl</td>
<td>Otus bakkamoena</td>
<td>P</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>29 Mottled Wood Owl</td>
<td>Strix ocellata</td>
<td>N</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>30 Indian Eagle-Owl</td>
<td>Bubo bengalensis</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

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 amphibia, 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**


Raptors observed (1983–2016) in National Chambal Gharial Sanctuary

Singh et al.

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 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
Raptors observed (1983–2016) in National Chambal Gharial Sanctuary


ceratotherium simum (NCS) में विकसित होती है। वर्तमान काल में, आंतरराष्ट्रीय वन्यसंरक्षण क्षेत्र, भारतीय जंगली घासीदार, दक्षिणी भारत, जंगल, शास्त्रीय जंगल, वन्यजीव अभ्यारण्य के पाररजस्थततक तंत्र को बनाए रखते हैं।

抢抓机遇把握发展新机遇
### Table: Year-wise presence and count record of different raptor species in National Chambal Sanctuary (NCS)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aegypius monachus</td>
<td>Cinereous Vulture</td>
<td>NT, rare, winter visitor</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Neophron percnopterus</td>
<td>Egyptian Vulture</td>
<td>EN, common</td>
<td>O</td>
<td>11</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>62</td>
<td>N</td>
<td>116</td>
<td>98</td>
<td>72</td>
<td>60</td>
<td>41</td>
<td>22</td>
<td>88</td>
<td>36</td>
<td>61</td>
<td>94</td>
<td>67</td>
</tr>
<tr>
<td>3</td>
<td>Gyps bengalensis</td>
<td>White-rumped Vulture</td>
<td>CR, rare, resident</td>
<td>O</td>
<td>32</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>304</td>
<td>N</td>
<td>8</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>Gyps indicus</td>
<td>Indian Vulture</td>
<td>CR, rare, resident</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>4</td>
<td>N</td>
<td>3</td>
<td>6</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Sarcogyps calvus</td>
<td>Red-headed Vulture</td>
<td>CR, rare, resident</td>
<td>O</td>
<td>2</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>1</td>
<td>2</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Gyps fulvus</td>
<td>Griffon Vulture</td>
<td>LC, rare, winter visitor</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Pandion haliaetus</td>
<td>Western Osprey</td>
<td>LC, winter visitor, up to summer</td>
<td>O</td>
<td>4</td>
<td>N</td>
<td>N</td>
<td>28</td>
<td>N</td>
<td>27</td>
<td>30</td>
<td>23</td>
<td>30</td>
<td>50</td>
<td>51</td>
<td>40</td>
<td>39</td>
<td>73</td>
<td>59</td>
<td>59</td>
<td>57</td>
<td>55</td>
</tr>
<tr>
<td>8</td>
<td>Milvus migrans</td>
<td>Black-shouldered Kite</td>
<td>LC, common, resident</td>
<td>O</td>
<td>3</td>
<td>N</td>
<td>N</td>
<td>8</td>
<td>N</td>
<td>11</td>
<td>N</td>
<td>12</td>
<td>N</td>
<td>5</td>
<td>6</td>
<td>N</td>
<td>9</td>
<td>N</td>
<td>6</td>
<td>N</td>
<td>6</td>
<td>N</td>
</tr>
<tr>
<td>9</td>
<td>Accipiter badius</td>
<td>Shikra</td>
<td>LC, common, resident</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>2</td>
<td>3</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Circus aeruginosus</td>
<td>Western Marsh Harrier</td>
<td>LC, occasional, winter visitor</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>3</td>
<td>4</td>
<td>N</td>
<td>6</td>
<td>N</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>Buteo buteo</td>
<td>Common Buzzard</td>
<td>LC, rare, winter visitor</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>4</td>
<td>N</td>
<td>3</td>
<td>4</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Butastur teesa</td>
<td>White-eyed Buzzard</td>
<td>LC, rare, resident</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>8</td>
<td>11</td>
<td>N</td>
<td>12</td>
<td>N</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>13</td>
<td>Pernis ptilorhynchus</td>
<td>Crested Buzzard</td>
<td>LC, occasional, resident</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>4</td>
<td>N</td>
<td>2</td>
<td>3</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Aquila fasciata</td>
<td>Bonelli’s Eagle</td>
<td>LC, occasional, resident</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>4</td>
<td>N</td>
<td>3</td>
<td>4</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>Aquila clanga</td>
<td>Harrier Buzzard</td>
<td>LC, occasional, resident</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>4</td>
<td>N</td>
<td>3</td>
<td>4</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Aquila nipalensis</td>
<td>Pallas’s Fish Eagle</td>
<td>LC, rare, winter visitor</td>
<td>O</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>17</td>
<td>Aquila chocoraja</td>
<td>Ayulu raptor</td>
<td>LC, rare, winter visitor</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>4</td>
<td>N</td>
<td>3</td>
<td>4</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
</tr>
</tbody>
</table>

**Supplement Table A.** Year-wise presence and count record of different raptor species in National Chambal Sanctuary (NCS). Data for 1983-85 contains information for checking against previous studies. Surveys conducted during 1987-1989 and 1991-2002 were limited to certain stretches of NCS and for raptors are treated as “No data.” *(NCS = National Chambal Sanctuary; CR = Critically Endangered; VU = Vulnerable; EN = Endangered; NT = Near Threatened; LC = Least Concern).*
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Crested Serpent Eagle</td>
<td>Spilornis cheela</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>5</td>
<td>4</td>
<td>LC, occasional, resident</td>
</tr>
<tr>
<td>19</td>
<td>Changeable Hawk Eagle</td>
<td>Spizaetus cirrhatus</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>5</td>
<td>4</td>
<td>LC, occasional, resident</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Common Kestrel</td>
<td>Falco tinnunculus</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>3</td>
<td>N</td>
<td>4</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>29</td>
<td>10</td>
<td>LC, occasional, winter visitor</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Eurasian Hobby</td>
<td>Falco subbuteo</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>6</td>
<td>6</td>
<td>LC, rare, winter visitor</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Laggar Falcon</td>
<td>Falco jugger</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>27</td>
<td>13</td>
<td>NT, rarely resident</td>
</tr>
<tr>
<td>23</td>
<td>Red-necked Falcon</td>
<td>Falco chicquera</td>
<td>O</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>2</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>1</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>24</td>
<td>Spotted Owlet</td>
<td>Athene brama</td>
<td>O</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>4</td>
<td>4</td>
<td>LC, rare, resident</td>
</tr>
<tr>
<td>25</td>
<td>Western Barn Owl</td>
<td>Tyto alba</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>LC, rare, resident</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Dusky Eagle Owl</td>
<td>Bubo coromandus</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>4</td>
<td>4</td>
<td>LC, rare, resident</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Brown Fish Owl</td>
<td>Ketupa flaviventris</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>5</td>
<td>4</td>
<td>LC, rare, resident</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Indian Scops Owl</td>
<td>Otus bakkamoena</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>5</td>
<td>LC, rare, resident</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Mottled Wood Owl</td>
<td>Strix occidentalis</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>5</td>
<td>4</td>
<td>LC, occasional, resident</td>
</tr>
<tr>
<td>30</td>
<td>Indian Eagle Owl</td>
<td>Bubo bengalensis</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>N</td>
<td>1</td>
<td>N</td>
<td>5</td>
<td>4</td>
<td>LC, occasional, resident</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL raptor species seen during concerned survey</td>
<td></td>
<td>List 10</td>
<td></td>
<td>No data</td>
<td>3</td>
<td>No data</td>
<td>11</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>10</td>
<td>18</td>
<td>10</td>
<td>15</td>
<td>14</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>22</td>
<td>15</td>
<td>2070</td>
<td>209</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOTAL no of raptor birds counted in the year</td>
<td></td>
<td>Noted presence, good localities, and total number (Sharma and Singh 1986)</td>
<td>66</td>
<td>No data</td>
<td>339</td>
<td>No data</td>
<td>116</td>
<td>188</td>
<td>160</td>
<td>171</td>
<td>153</td>
<td>166</td>
<td>111</td>
<td>85</td>
<td>170</td>
<td>90</td>
<td>148</td>
<td>163</td>
<td>176</td>
<td>173</td>
<td>2070</td>
<td>209</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Index: Ratio Bird / Spp numbers</td>
<td></td>
<td>6.6</td>
<td>113.0</td>
<td>10.5</td>
<td>11.1</td>
<td>9.4</td>
<td>10.1</td>
<td>15.3</td>
<td>9.2</td>
<td>11.1</td>
<td>5.7</td>
<td>12.1</td>
<td>6.9</td>
<td>10.6</td>
<td>10.2</td>
<td>8.0</td>
<td>11.5</td>
<td>Average Index 2003-2016 = 9.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 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

<table>
<thead>
<tr>
<th>Species Sl. No</th>
<th>English name</th>
<th>Scientific name</th>
<th>IUCN Status</th>
<th>Status in Wildlife Act, 1972</th>
<th>Cites Appendix</th>
<th>Migratory status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cinereous Vulture</td>
<td>Aegypius monachus</td>
<td>NT</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>2</td>
<td>Egyptian Vulture</td>
<td>Neophron percnopterus</td>
<td>EN</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>3</td>
<td>White-rumped Vulture (Synonym: Indian White-backed Vulture)</td>
<td>Gyps bengalensis</td>
<td>CR</td>
<td>Schedule-I</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>4</td>
<td>Indian Vulture (Synonym: Long-billed Vulture)</td>
<td>Gyps indicus</td>
<td>CR</td>
<td>Schedule-I</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>5</td>
<td>Red-headed Vulture</td>
<td>Sarcogyps calvus</td>
<td>CR</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>6</td>
<td>Griffon Vulture (Synonym: Eurasian Griffon)</td>
<td>Gyps fulvus</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>7</td>
<td>Western Osprey (Synonym: Osprey)</td>
<td>Pandion haliaetus</td>
<td>LC</td>
<td>Schedule-I</td>
<td>II</td>
<td>Winter visitor, seen till May</td>
</tr>
<tr>
<td>8</td>
<td>Black-shouldered Kite</td>
<td>Elanus axillaris (syn: E. caerules)</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>9</td>
<td>Black Kite (Syn: Common Pariah Kite)</td>
<td>Milvus migrans</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>10</td>
<td>Shikra</td>
<td>Accipiter badius</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>11</td>
<td>Western Marsh Harrier (Synonym: Eurasian Marsh Harrier)</td>
<td>Circus aeruginosus</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>12</td>
<td>Common Buzzard</td>
<td>Buteo buteo</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>13</td>
<td>White-eyed Buzzard</td>
<td>Butastur teesa</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>14</td>
<td>Crested Honey Buzzard (Synonym: Oriental Honey Buzzard)</td>
<td>Pernis ptilorhynchus</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>15</td>
<td>Bonelli’s Eagle</td>
<td>Aquila fasciata (syn: Hieraaetus fasciatus)</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>16</td>
<td>Pallas’s Fish Eagle</td>
<td>Haliaeetus leucoryphus</td>
<td>EN</td>
<td>No mention</td>
<td>II</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>17</td>
<td>Tawny Eagle</td>
<td>Aquila rapax</td>
<td>VU</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>18</td>
<td>Crested Serpent Eagle</td>
<td>Spilornis cheela</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>19</td>
<td>Changeable Hawk Eagle</td>
<td>Nisaetus cirrhatus, Syn. Spizaetus cirrhatus</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>20</td>
<td>Common Kestrel</td>
<td>Falco tinnunculus</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>21</td>
<td>Eurasian Hobby</td>
<td>Falco subbuteo</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Winter visitor</td>
</tr>
<tr>
<td>22</td>
<td>Laggar Falcon</td>
<td>Falco jugger</td>
<td>NT</td>
<td>Schedule-I</td>
<td>I (One)</td>
<td>Resident</td>
</tr>
<tr>
<td>23</td>
<td>Red-necked Falcon</td>
<td>Falco chicquera</td>
<td>NT</td>
<td>Schedule-I</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>24</td>
<td>Spotted Owlet</td>
<td>Athene brama</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>25</td>
<td>Western Barn Owl (Synonym: Barn Owl)</td>
<td>Tyto alba</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>26</td>
<td>Dusky Eagle Owl</td>
<td>Bubo coromandus</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>27</td>
<td>Brown Fish Owl</td>
<td>Ketupa zeylonensis (Synonym: Bubo zeylonensis)</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>28</td>
<td>Indian Scops Owl</td>
<td>Otus bakkamoena</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>29</td>
<td>Mottled Wood Owl</td>
<td>Strix ocellata</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
<tr>
<td>30</td>
<td>Indian Eagle-Owl (Synonym: Rock Eagle Owl)</td>
<td>Bubo bengalensis</td>
<td>LC</td>
<td>Schedule-IV</td>
<td>II</td>
<td>Resident</td>
</tr>
</tbody>
</table>
Nesting success of Sharpe’s Longclaw (*Macronyx sharpei* Jackson, 1904) around the grasslands of lake Ol’bolossat Nyandarua, Kenya

Hamisi Ann Risper¹, Charles M. Warui² & Peter Njoroge³

1 Department of Biological Science, Mount Kenya University, PO BOX 342-01000, Thika, Kenya.
2 School of Pure and Applied Sciences, Murang’a University of Technology, PO BOX 75-10200, Murang’a, Kenya.
3 Department of Ornithology, National Museums of Kenya, PO BOX 40658- 00100 Nairobi, Kenya.

E-mail: risperhamisi@gmail.com (corresponding author), cmwarui@yahoo.com, pnjoroge@museums.or.ke

**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 lead 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.
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 (Colllias & Colllias 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 (Normet 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 km² and its open waters cover 4 km². 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.
The climate is sub-humid throughout the year and is mainly influenced by the surrounding highlands. Lake Ol’Bolessat 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 x 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 ≤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 feces 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, 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.

<table>
<thead>
<tr>
<th>No. of nest</th>
<th>Nest Location</th>
<th>Status at Discovery</th>
<th>Tussock size</th>
<th>No. of nest</th>
<th>No. of eggs</th>
<th>No. of chicks</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Makindu</td>
<td>Construction</td>
<td>25.0</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>Chick fledged</td>
</tr>
<tr>
<td>2</td>
<td>Rurii</td>
<td>Laying</td>
<td>21.5</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Faeces found</td>
</tr>
<tr>
<td>3</td>
<td>Nduthi</td>
<td>Construction</td>
<td>24</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Nest abandoned</td>
</tr>
<tr>
<td>4</td>
<td>Kirima</td>
<td>Fledging</td>
<td>23</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Kanguo</td>
<td>Laying</td>
<td>27</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Munyeki</td>
<td>Laying</td>
<td>25</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Makereka</td>
<td>Fledging</td>
<td>24</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Daily nest survival for natural and artificial nests.

<table>
<thead>
<tr>
<th>Study site</th>
<th>DSPa</th>
<th>DSPp</th>
<th>DSRa 95%</th>
<th>DSRp 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mukindu</td>
<td>94.12</td>
<td>80.00</td>
<td>20.67</td>
<td>3.00</td>
</tr>
<tr>
<td>Rurii</td>
<td>75.00</td>
<td>90.47</td>
<td>0.01</td>
<td>6.0</td>
</tr>
<tr>
<td>Nduthi</td>
<td>84.61</td>
<td>90.47</td>
<td>1.30</td>
<td>6.0</td>
</tr>
<tr>
<td>Kirima</td>
<td>96.50</td>
<td>84.61</td>
<td>40.14</td>
<td>1.30</td>
</tr>
<tr>
<td>Kanguo</td>
<td>92.86</td>
<td>90.47</td>
<td>14.56</td>
<td>6.0</td>
</tr>
<tr>
<td>Munyeki</td>
<td>92.86</td>
<td>66.70</td>
<td>26.35</td>
<td>0.003</td>
</tr>
<tr>
<td>Makereka</td>
<td>95.00</td>
<td>66.70</td>
<td>26.35</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Key: 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.

1.29; p= 0.11).

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.
The study has also found that daily natural nest survival of Sharpe’s Longclaw is higher in grasslands around Lake O’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 attack 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 O’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 nestlings. 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 predators. 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


Monadjem, A. & M.Z. Virani (2016). Habitat associations of birds at
Nesting success of Sharpe's Longclaw of lake Ol’bolossat Nyandarua


Population, distribution and diet composition of Smooth-coated Otter 
*Lutrogale perspicillata* Geoffroy, 1826 in Hosur and Dharmapuri 
Forest Divisions, India

Nagarajan Baskaran 1, Raman Sivaraj Sundarraj 2 & Raveendranathanpillai Sanil 3

1 Asian Nature Conservation Foundation, Centre for Ecological Sciences, Indian Institute of Science, Bengaluru, Karnataka 560012, India. 
2 Present Address: Department of Zoology & Wildlife Biology, A.V.C. College (Autonomous), Mannampandal, Mayiladuthurai, Tamil Nadu 609305, India. 
3 Department of Zoology & Wildlife Biology, Government Arts College, Udhagamandalam, Tamil Nadu 643002, India.

**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 Karnata 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.

**Editor:** Nicole Duplaix, Oregon State University, Corvallis, USA. 
**Date of publication:** 26 January 2022 (online & print)


**Copyright:** © Baskaran et al. 2022. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use, reproduction, and distribution of this article in any medium by providing adequate credit to the author(s) and the source of publication.

**Funding:** Asian Nature Conservation Foundation, C/o. Centre for Ecological Sciences, Indian Institute of Science, Bangalore and Kenneth Anderson Nature Society, Hosur, Tamil Nadu.

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


**Author contributions:** NB—conceiving the concept, planning & execution, data analysis & writing. RSS—data collection, entry & preliminary analysis. RS—helping in data analysis & writing.

**Acknowledgements:** We are grateful to the Tamil Nadu Forest Department for permitting this study and the Asian Nature Conservation Foundation (ANCF) for funding. We also thank Mr. K.G. Avinash, GIS Expert, ANCF in helping us to produce the distribution maps.
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). The Smooth-coated Otter is threatened by habitat loss and fragmentation, predation, pollution, and human activities such as fishing, farming, and tourism (Anoop 2001; Anoop & Hussain 2005; Shenoy 2005; Shenoy et al. 2006). In particular, the Cauvery Wildlife Sanctuary is an important habitat for the Smooth-coated Otter in the study area (Baskaran et al. 2010).

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.

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...
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 m² quadrat for trees, 5 m² quadrat shrubs, and 1 m² 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 $F= \text{number of spraints containing a given prey category divided by total number of spraints} \times 100$ (Jenkins et al. 1979), (ii) Relative percentage frequency $R= \text{number of occurrences of a food category divided by total number of occurrences of all prey categories} \times 100$ (Rowe-Rowe 1977), and (iii) Dry weight $Dw= \text{dry weight of a given food category divided by total dry weight of all prey categories} \times 100$. 
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 ($\chi^2 = 11.358, df = 2, P < 0.01$), in islands with shrub/grass cover ($\chi^2 = 40.595, df = 2, P < 0.001$), and in areas with lower water current ($U = 1098, P < 0.05$) and human disturbance ($\chi^2 = 33.379, df = 2, P < 0.001$) (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 ($\text{Coefficient} \pm \text{SE} = 0.133 \pm 0.034, P < 0.001$) and vegetation cover ($\text{Coefficient} \pm \text{SE} = 0.031 \pm 0.005, P < 0.001$) influenced the otter abundance positively, while the human disturbance influenced negatively ($\text{Coefficient} \pm \text{SE} = -0.664 \pm 0.190, P < 0.01$) 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 calbasu* occurred in 15 out of 21 scats, and also contributed 90% of dry weight of all the food depth.
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>
<thead>
<tr>
<th>Factor</th>
<th>Category (n)</th>
<th>Otter abundance mean ± se</th>
<th>Kruskal–Wallis (χ²) / Mann–Whitney U</th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank type</td>
<td>Earthen (37)</td>
<td>0.41 ± 0.180</td>
<td>1.36</td>
<td>2</td>
<td>0.507</td>
</tr>
<tr>
<td></td>
<td>Sandy (45)</td>
<td>0.84 ± 0.270</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stony (43)</td>
<td>0.51 ± 0.271</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water depth</td>
<td>Low (26)</td>
<td>0.12 ± 0.085</td>
<td>11.358</td>
<td>2</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Medium (58)</td>
<td>0.40 ± 0.165</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High (41)</td>
<td>1.20 ± 0.355</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>River width</td>
<td>Low (30)</td>
<td>0.93 ± 0.437</td>
<td>0.715</td>
<td>2</td>
<td>0.699</td>
</tr>
<tr>
<td></td>
<td>Medium (65)</td>
<td>0.58 ± 0.178</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High (30)</td>
<td>0.30 ± 0.153</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>Low (17)</td>
<td>0.0</td>
<td>40.595</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Medium (59)</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High (49)</td>
<td>1.53 ± 0.329</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water current</td>
<td>Low (29)</td>
<td>1.10 ± 0.410</td>
<td>10.98</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>High (96)</td>
<td>0.45 ± 0.140</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human disturbance</td>
<td>Low (28)</td>
<td>2.32 ± 0.520</td>
<td>33.379</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Medium (57)</td>
<td>0.18 ± 0.062</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High (40)</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient ± Std. error</th>
<th>P</th>
<th>model (R²)</th>
<th>F</th>
<th>model (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.348 ± 0.523</td>
<td>0.507</td>
<td>0.545</td>
<td>33.616</td>
<td>0.000</td>
</tr>
<tr>
<td>Water depth</td>
<td>0.133 ± 0.034</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human disturbance</td>
<td>-0.664 ± 0.190</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation cover</td>
<td>0.031 ± 0.005</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 Ichiebera 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

### 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.

<table>
<thead>
<tr>
<th>Group ID</th>
<th>Survey blocks used</th>
<th>Total number of individuals</th>
<th>Group size mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12 to 15</td>
<td>5</td>
<td>4.0 ± 0.45</td>
</tr>
<tr>
<td>2</td>
<td>18 to 25</td>
<td>4</td>
<td>3.3 ± 0.18</td>
</tr>
<tr>
<td>3</td>
<td>33 to 37</td>
<td>5</td>
<td>4.2 ± 0.37</td>
</tr>
<tr>
<td>4</td>
<td>45 to 49</td>
<td>5</td>
<td>3.7 ± 0.63</td>
</tr>
<tr>
<td>5</td>
<td>52 to 57</td>
<td>7</td>
<td>5.5 ± 0.96</td>
</tr>
<tr>
<td>6</td>
<td>62 to 68</td>
<td>5</td>
<td>3.5 ± 0.21</td>
</tr>
<tr>
<td>7</td>
<td>71 to 74</td>
<td>5</td>
<td>3.7 ± 0.33</td>
</tr>
<tr>
<td>Total</td>
<td>12 to 74</td>
<td>36</td>
<td>3.8 ± 0.16</td>
</tr>
</tbody>
</table>

### Table 4. Frequency of occurrence of various prey items identified from Smooth-coated Otter spraints in the study area December 2009–March 2010.

<table>
<thead>
<tr>
<th>Prey items</th>
<th>Occurrence</th>
<th>Dry weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent frequency</td>
<td>Relative percent frequency</td>
</tr>
<tr>
<td>Insects</td>
<td>9.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Molosucus</td>
<td>9.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Crab</td>
<td>4.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Pisces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labeo callbasu</td>
<td>71.4</td>
<td>34.1</td>
</tr>
<tr>
<td>Channa argus</td>
<td>9.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Masatcembalus sp.</td>
<td>14.3</td>
<td>6.8</td>
</tr>
<tr>
<td>Tor khudree</td>
<td>9.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Notopterus notopterus</td>
<td>4.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Unidentified fish</td>
<td>33.3</td>
<td>15.9</td>
</tr>
<tr>
<td>Frog</td>
<td>28.6</td>
<td>13.6</td>
</tr>
<tr>
<td>Reptile</td>
<td>9.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Birds</td>
<td>4.8</td>
<td>2.3</td>
</tr>
</tbody>
</table>

**Note:** The dry weight (%) is calculated based on the frequency of occurrence.
(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, molluscs, 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**


Jayaram, K.C. (1994). The freshwater fishes of India, Pakistan,


Utilization of home garden crops by primates and current status of human-primate interface at Galigamuwa Divisional Secretariat Division in Kegalle District, Sri Lanka

Charmalie Anuradhi Dona Nahallage, Dahanakge Ayesha Madushani Dasanayake, Dilan Thisaru Hewamanna & Dissanayakalage Tharaka Harshani Ananda

Centre for Multidisciplinary Research, Department of Anthropology, Faculty of Humanities and Social Sciences, University of Sri Jayewardenepura, Gangodawila, Nugegoda, 10250, Sri Lanka.

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.
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 Macaque *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...
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 incidences 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 °C. Agriculture is the main economic sector in the area. The land extent is 127 km². 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>
<thead>
<tr>
<th>GN Division</th>
<th>Total No. of houses in each GN Division</th>
<th>Number of houses surveyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aruggammana</td>
<td>368</td>
<td>214</td>
</tr>
<tr>
<td>Hathnapitiya</td>
<td>303</td>
<td>136</td>
</tr>
<tr>
<td>Karagala</td>
<td>232</td>
<td>150</td>
</tr>
</tbody>
</table>

![Image 1. Study area: A—Kegalle District | B—Galigamuwa Divisional Secretariat Division | C—Three GN divisions (Hathnapitiya, Karagala, and Aruggammana).](image-url)
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 5).

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 8).

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.
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 2. Occupation of the informants in each GN divisions.

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Hathnapitiya</th>
<th>Aruggammana</th>
<th>Karagala</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>%</td>
<td>Frequency</td>
</tr>
<tr>
<td>No occupation (housewives)</td>
<td>67</td>
<td>49</td>
<td>54</td>
</tr>
<tr>
<td>Government sector</td>
<td>27</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>Private sector</td>
<td>24</td>
<td>18</td>
<td>33</td>
</tr>
<tr>
<td>Commercial farming</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Self-employment</td>
<td>13</td>
<td>10</td>
<td>66</td>
</tr>
<tr>
<td>Security service</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>136</td>
<td>100</td>
<td>214</td>
</tr>
</tbody>
</table>

Table 3. Size of the Home garden.

<table>
<thead>
<tr>
<th>GN Division</th>
<th>Hathnapitiya</th>
<th>Aruggammana</th>
<th>Karagala</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of home garden</td>
<td>N</td>
<td>Valid Percent</td>
<td>N</td>
</tr>
<tr>
<td>Less than 1 acre (less than 4,047 m²)</td>
<td>103</td>
<td>93</td>
<td>126</td>
</tr>
<tr>
<td>Between 1.1 to 5 acres (4,047–20,234 m²)</td>
<td>5</td>
<td>5</td>
<td>63</td>
</tr>
<tr>
<td>More than 5 acres (more than 20,234 m²)</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>111</td>
<td>100</td>
<td>192</td>
</tr>
<tr>
<td>Not responded</td>
<td>25</td>
<td>22</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>136</td>
<td>100</td>
<td>214</td>
</tr>
</tbody>
</table>
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 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             |
| Cardamom                        | 0               | 0              | 0             |
| Other                           | 12              | 7              | 7             |

| Table 5. Monthly income obtained from home gardening. |
|-----------------------------------------------|----------------|----------------|----------------|
| GN Division                                  | Present | Present | Present |
| Income                                       | 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                                  | Hathanapitiya (%) | 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                                  | Hathanapitiya (%) | Aruggammana (%) | Karagala (%)  |
| Morning 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             |
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-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

### Table 8. The crops utilized by animals.

<table>
<thead>
<tr>
<th>GN Division</th>
<th>Hathnapitya (%)</th>
<th>Aruggammana (%)</th>
<th>Karagala (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut</td>
<td>22</td>
<td>29</td>
<td>21</td>
</tr>
<tr>
<td>Vegetables</td>
<td>19</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Banana</td>
<td>15</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Yams (kiri ala, casava)</td>
<td>12</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Pepper</td>
<td>4</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Areca nut</td>
<td>3</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Jack Fruit</td>
<td>4</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Pineapple</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tea</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Avocado</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rubber</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Bread Fruit</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Betel</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Durian</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Nutmeg</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Cardamom</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Clove</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>11</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

### Table 9. Types of property damage caused by Toque Macaques and Purple-faced Leaf Langur.

<table>
<thead>
<tr>
<th>Type of Damage</th>
<th>Hathnapitya (%)</th>
<th>Aruggammana (%)</th>
<th>Karagala (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage household goods</td>
<td>15</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>Consume foods that are inside the house</td>
<td>35</td>
<td>31</td>
<td>37</td>
</tr>
<tr>
<td>Defecate inside the house</td>
<td>25</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Damage roofs</td>
<td>24</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>Other types of damages</td>
<td>1</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Purple-faced Leaf Langur</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Damage roof</td>
<td>15</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>No damage</td>
<td>85</td>
<td>99</td>
<td>100</td>
</tr>
</tbody>
</table>

### Table 10. Methods used to reduce the crop damage by Toque Macaques.

<table>
<thead>
<tr>
<th>GN Division</th>
<th>Hathnapitya (%)</th>
<th>Aruggammana (%)</th>
<th>Karagala (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catapult</td>
<td>21</td>
<td>33</td>
<td>30</td>
</tr>
<tr>
<td>Firecrackers</td>
<td>42</td>
<td>36</td>
<td>30</td>
</tr>
<tr>
<td>Masks</td>
<td>10</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Hanging tin cans</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nets to cover crops</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Boards</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Shouting</td>
<td>11</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Black cloth</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Air rifles</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Use of dogs</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Clapper board</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>11</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>
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, run away 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 (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**


Hill, C.M. & A. Webber (2010). Perceptions of nonhuman primates


Revival of Eastern Swamp Deer *Rucervus duvaucelii ranjitsinhi* (Groves, 1982) in Manas National Park of Assam, India

Nazrul Islam¹, Aftab Ahmed², Rathin Barman³, Sanatan Deka⁴, Bhaskar Choudhury⁵, Prasanta Kumar Saikia⁴ & Jyotishman Deka⁶

¹-⁵ Greater Manas Recovery Project, Wildlife Trust of India, F-13, Sector-8, Noida, Uttar Pradesh 201301, India.

² Animal Ecology and Wildlife Biology Lab, Department of Zoology, Gauhati University, Guwahati, Assam 781014, India.

³ Directorate of Manas Tiger Reserve, Barpeta Road, Assam 781315, India.

4 nazrul@wti.org.in (corresponding author), ¹ aftab@wti.org.in, ³ rathin@wti.org.in, ⁴ sanatan@wti.org.in, ⁵ bhaskar@wti.org.in, ⁶ saikiapk@rediffmail.com, ⁷ jyotidekak551@gmail.com

**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, rewilding, Swamp Deer, Tiger prey, translocation.
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.
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 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 Park.
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

Revival of Eastern Swamp Deer in Manas NP

Islam et al.


Trypanosoma evansi infection in a captive Indian Wolf Canis lupus pallipes – molecular diagnosis and therapy

Manojita Dash1, Sarat Kumar Sahu2, Santosh Kumar Gupta3, Niranjana Sahoo4 & Debarat Mohapatra5

1 Centre for Wildlife Health, College of Veterinary Science & Animal Husbandry, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha 751003, India
2 Nandankanan Zoological Park, Po-Barang, Khordha District, Odisha 754005, India.
3 Department of Preventive Veterinary Medicine and Epidemiology, College of Veterinary Medicine & Animal Husbandry, Odisha University of Agriculture & Technology, Bhubaneswar, Odisha 751003, India
4 manojita.dash@gmail.com, 2 sahu.sarat77@gmail.com (corresponding author), 3 santoshkumargupta67@gmail.com, 4 niranjasahoo@hotmail.com, 5 debabrat73@gmail.com

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.

Editor: Rajeshkumar G. Jani, Anand Agricultural University, Anand, India. Date of publication: 26 January 2022 (online & print)

Citation: © Dash et al. 2022. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use, reproduction, and distribution of this article in any medium by providing adequate credit to the author(s) and the source of publication.

Funding: This study is a part of normal healthcare activity of the zoo (Nandankanan Zoological Park) which is under the control of ‘Forest and Environment Department, Government of Odisha’. No separate fund has been received from any agency for this study.

Competing interests: The authors declare no competing interests.

Author details: Manojita Dash, MSc Biotechnology—She is working as Senior Research Fellow at Centre for Wildlife Health (CWH), CVSc & AH, OUAT, Bhubaneswar. She is actively involved in the processing of bio-samples collected from Nandankanan Zoological Park as well as various other zoos and sanctuaries of Odisha. She is well versed with handling of sophisticated instruments used in analysis of the bio-samples, data interpretation, statistical analysis. Sarat Kumar Sahu, MVSc, Veterinary Microbiology—He is working as Veterinary Assistant Surgeon at Nandankanan Zoological Park since more than 11 years. He is actively involved in treatment, preventive health care, conservation and scientific research related to captive and free ranging wild animals. Santosh Kumar Gupta—He has completed M.V.Sc in Veterinary Clinical Medicine, Ethics and Jurisprudence from College of Veterinary Science, Guwahati, Assam and has been engaged as Research Associate at Centre for Wildlife Health, OUAT. He has keen interest in Wildlife and conservation science and has been carrying out scientific research work at Nandankanan Zoological Park. Niranjana Sahoo, MVSc, PhD—He is the Professor and Head, Department of Veterinary Epidemiology and Preventive Medicine, and Director, Teaching Veterinary Clinical Complex, CVSc & AH, OUAT. He is also the Coordinator, Centre for Wildlife Health (CWH), OUAT. CWH is serving as the microbiological, molecular and forensic diagnostic hub for captive and free ranging wild animal diseases of the entire Odisha state. Debarat Mohapatra—He has done MVSc in Veterinary Clinical Medicine. He is currently working as Medicine Specialist at Nandankanan Zoological Park since last six years. He has keen interest in treatment and preventive healthcare of captive wild animals of the zoo.

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.

Acknowledgements: Authors are thankful to the Director, Nandankanan Zoological Park, Odisha for extending necessary facilities to carry out this in situ study and to publish this manuscript.
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. 2003; 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 Nandankanana Zoological Park (NK2P), India.

CASE HISTORY AND OBSERVATION

The NK2P 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

Coprophilic 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 MgCl2, 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°C for 10 mins followed by 35 cycles consisting of 30 secs at 94°C, 30 secs at 55°C, and 30 secs at 72°C. The last extension step was 10 mins at 72°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 ×10^9/mm³) neutrophil (56%), platelets count (180 × 10^9/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...
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 bilirubin (0.80 mg/dl)

Quinapyramine sulphate and chloride @ 4.0 mg/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 chemoprophylaxis 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°F), pale mucous membrane, bilateral lacrimation, and generalised debility. These observations were in agreement with the findings of Rani.

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

Table 1. Pre- and post-treatment haemato-biochemical values of an Indian Wolf with Trypanosoma evansi infection.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Days of blood collection</th>
<th>Reference range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24.ix.2019 (Pre-treatment)</td>
<td>18.x.2019 (Post-treatment)</td>
</tr>
<tr>
<td><strong>Hematology</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haemoglobin (g %)</td>
<td>6.0</td>
<td>13.0</td>
</tr>
<tr>
<td>Total leucocyte (10^3/mm³)</td>
<td>5.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Neutrophil (%)</td>
<td>56.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Eosinophil (%)</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Lymphocyte (%)</td>
<td>41.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Monocyte (%)</td>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>Basophil (%)</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Platelet (×10^3/µl)</td>
<td>180.0</td>
<td>226.0</td>
</tr>
<tr>
<td><strong>Biochemistry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALT (IU/L)</td>
<td>10.3</td>
<td>331.1</td>
</tr>
<tr>
<td>AST (IU/L)</td>
<td>830.4</td>
<td>159.8</td>
</tr>
<tr>
<td>ALP (IU/L)</td>
<td>96.1</td>
<td>26.3</td>
</tr>
<tr>
<td>BUN (mg/dl)</td>
<td>178.2</td>
<td>63.8</td>
</tr>
<tr>
<td>Creatinine (mg/dl)</td>
<td>4.4</td>
<td>2.18</td>
</tr>
<tr>
<td>Glucose (mg/dl)</td>
<td>25.7</td>
<td>117.2</td>
</tr>
<tr>
<td>Total protein (g/dl)</td>
<td>7.63</td>
<td>6.4</td>
</tr>
<tr>
<td>Albumin (g/dl)</td>
<td>1.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Globulin (g/dl)</td>
<td>5.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Cholesterol (mg/dl)</td>
<td>272.7</td>
<td>178.5</td>
</tr>
<tr>
<td>Triglyceride (mg/dl)</td>
<td>418.7</td>
<td>39.7</td>
</tr>
<tr>
<td>Calcium (mg/dl)</td>
<td>11.1</td>
<td>10.9</td>
</tr>
<tr>
<td>Phosphorous (mg/dl)</td>
<td>11.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Magnesium (mg/dl)</td>
<td>2.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Total Bilirubin (mg/dl)</td>
<td>0.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

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 diminazene@ 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 chemoprophyaxis 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


COVID-19 and civil unrest undoing steady gains in karst conservation and herpetological research in Myanmar, and an impediment to progress

Evan S.H. Quah 1, Lee L. Grismer 2, Perry L. Wood, Jr. 3, Aung Lin 4 & Myint Kyaw Thura 5

1 Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, Malaysia.
2 School of Biological Sciences, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia.
3 Herpetology Laboratory, Department of Biology, La Sierra University, 4500 Riverwalk Parkway, Riverside, California 92515, USA.
4 Department of Herpetology, San Diego Natural History Museum, PO Box 121390, San Diego, California, 92112, USA.
5 Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, Michigan 48109-1085, USA.
6 Fauna and Flora International, No.34-D/9, San Yae Twin Street, Kabaraye Bagoda Road, Bahan Township, Yangon, Myanmar.
7 Myanmar Environment Sustainable Conservation, Yangon, Myanmar.
1 evanquah@ums.edu.my (corresponding author), 2 lgrismer@lasierra.edu, 3 perryleewoodjr@gmail.com, 4 aung.lin@fauna-flora.org, 5 mgmyint.banca@gmail.com

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).
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


Connette, G.M., P. Oswald, M.K. Thura, K.J.L. Connette, M.E.
COVID-19 and political unrest hindering karst conservation in Myanmar

Quah et al.


Morphological characterization and mt DNA barcode of a tiger moth species, Asota ficus (Fabricius, 1775) (Lepidoptera: Noctuoidea: Erebidae: Aganainae) from India

Aparna Suresschandra Kalawate 1, K.P. Dinesh 2 & A. Shabnam 3

1, 2 Zoological Survey of India, Western Regional Centre, Vidya Nagar, Sector-29, P.C.N.T. (PO), Rawet Road, Akurdi, Pune, Maharashtra 411044, India
3 devarpanento@gmail.com (corresponding author), kpdinesh.zsi@gmail.com, shabnamansari9113@gmail.com

Abstract: The members of the genus Asota are widely distributed from Africa, India, Sri Lanka, Myanmar, and Malayasian 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).


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 metathoracic 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...
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 ¤ÌL 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
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]  
Type Species: *Phalaena javana* (Cramer, [1780])

*Asota ficus* (Fabricius, 1775)  
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
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 genitalia (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.

<table>
<thead>
<tr>
<th>GenBank Accession No.</th>
<th>Locality</th>
<th>Species name as per NCBII</th>
<th>Publication details as per NCBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GU662348.1</td>
<td>Thailand: Chiang Mai</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>2 OL630456.1</td>
<td>India: Maharashstra, Nasik, Saptashrungigadh,</td>
<td>Asota ficus</td>
<td>Current study</td>
</tr>
<tr>
<td>3 OL630457.1</td>
<td>India: Maharashstra, Jalgoon</td>
<td>Asota ficus</td>
<td>Current study</td>
</tr>
<tr>
<td>4 HQ990842.1</td>
<td>Pakistan</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>5 KC499430.1</td>
<td>India: Tamil Nadu, Kalkad</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>6 MG783922.1</td>
<td>India: Maharashtra</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>7 KC499429.1</td>
<td>China: Yunnan</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>8 KI013139.1</td>
<td>India: Assam</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>9 KX860794.1</td>
<td>Pakistan: Punjab</td>
<td>Asota ficus</td>
<td>Ashfaq et al. (2017)</td>
</tr>
<tr>
<td>10 MG783907.1</td>
<td>India: Maharashtra</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>11 JF858113.1</td>
<td>India: Namri NP</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>12 HQ990838.1</td>
<td>Pakistan</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>13 JF858114.1</td>
<td>Pakistan</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>14 HQ990840.1</td>
<td>Pakistan</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>15 HQ990841.1</td>
<td>Pakistan</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>16 GU662343.1</td>
<td>Thailand: Chiang Mai</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>17 HQ990839.1</td>
<td>Pakistan</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>18 MG783872.1</td>
<td>India: Maharashtra</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>19 MG783923.1</td>
<td>India: Maharashtra</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>20 MG783857.1</td>
<td>India: Maharashtra</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>21 MG783890.1</td>
<td>India: Maharashtra</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>22 MG783877.1</td>
<td>India: Maharashtra</td>
<td>Asota ficus</td>
<td>Unpublished</td>
</tr>
<tr>
<td>24 KU722731.1</td>
<td>Comoros: Grande Comore</td>
<td>Asota comorana</td>
<td>Unpublished</td>
</tr>
<tr>
<td>25 KU722737.1</td>
<td>Comoros: Grande Comore</td>
<td>Asota comorana</td>
<td>Unpublished</td>
</tr>
<tr>
<td>26 KR085638.1</td>
<td>Zambia: Victoria Falls</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>27 KR085639.1</td>
<td>Zambia: Lusaka Ridgeway</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>28 GU662438.1</td>
<td>Nigeria: Laeinde</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>29 GU662439.1</td>
<td>Cameroon: North Province</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>30 HM395501.1</td>
<td>Gabon: WoleuNamib/Tchimbile</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>31 HQ573636.1</td>
<td>Gabon: Ogooue-Ivindo</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>32 KR736264.1</td>
<td>Nigeria: Oyo</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>33 GU662439.1</td>
<td>Cameroon: North Province</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>34 KR070811.1</td>
<td>Kenya: Kajiado North</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>35 KU722731.1</td>
<td>Comoros: Grande Comore</td>
<td>Asota comorana</td>
<td>Unpublished</td>
</tr>
<tr>
<td>36 KU722737.1</td>
<td>Comoros: Grande Comore</td>
<td>Asota comorana</td>
<td>Unpublished</td>
</tr>
<tr>
<td>37 KR085638.1</td>
<td>Zambia: Victoria Falls</td>
<td>Asota speciosa</td>
<td>Unpublished</td>
</tr>
<tr>
<td>38 KI013139.1</td>
<td>Laos: Nang Phoa</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>39 KI013145.1</td>
<td>Laos: Nang Phoa</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>40 KI013127.1</td>
<td>Laos: Namha protected area,</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>41 KC499568.1</td>
<td>Indonesia: Kalimantan Barat</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>42 KC499567.1</td>
<td>China: Hainan</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>43 KF491909.1</td>
<td>Malaysia</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>44 HQ569811.1</td>
<td>Thailand: Nan</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>45 HQ569810.1</td>
<td>India: Meghalaya</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>46 HQ569809.1</td>
<td>VietNam: Tam Dao</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>47 GU662423.1</td>
<td>Thailand: Chiang Mai</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>48 GU662331.1</td>
<td>Thailand: Chiang Mai</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
<tr>
<td>49 JN401278.1</td>
<td>Japan</td>
<td>Neochera inops</td>
<td>Zahiri et al. (2012)</td>
</tr>
<tr>
<td>50 HQ569812.1</td>
<td>Malaysia: Sarawak</td>
<td>Neochera inops</td>
<td>Unpublished</td>
</tr>
</tbody>
</table>
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 data 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**


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
Morphological characters and mtDNA barcode of *Asota ficus* Kalawate et al.

20510


Distribution of Smooth-coated Otters *Lutrogale perspicillata* (Mammalia: Carnivora: Mustelidae): in Ratnagiri, Maharashtra, India

Swanand Patil\(^1\) & Kranti Yardi\(^2\)

\(^1\)Arcane Conservancy (www.arcaneconservancy.org/home, A/207 Saikrupa BS Road, Dadar West, Mumbai, Maharashtra, 400028, India.

\(^2\)Bharati Vidyapeeth Deemed University Institute of Environment Education and Research, Pune, Maharashtra 411043, India.

\(^{1}\)swanandpatil6@gmail.com (corresponding author), \(^{2}\)kranti@bvieer.edu.in

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).
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.

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
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**

Oters 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.


Table 1. Table showing positive correlation of 0.663 between otter and fishing activity.

<table>
<thead>
<tr>
<th>Correlations</th>
<th>Fishing activity</th>
<th>Otter sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing Activity</td>
<td>Pearson Correlation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>54</td>
</tr>
<tr>
<td>Otter_Sign</td>
<td>Pearson Correlation</td>
<td>.663**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>54</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 3. Plot of fishing intensity v/s otter signs.
Distribution of Smooth-coated Otters in Ratnagiri, Maharashtra

Patil & Yardi

20516

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


© Arcane Conservancy

Image 8. Fresh otter scat/ defecation area.
Wildlife at the crossroads: wild animal road kills due to vehicular collision on a mountainous highway in northwestern Himalayan region

Muzaffar A. Kichloo 1, Asha Sohil 2 & Neeraj Sharma 3

1 Department of Environmental Sciences, Govt. Degree College, Banihal, Union Territory of Jammu & Kashmir 182146, India.
2 P.G. Department of Environmental Sciences, University of Jammu, Union Territory of Jammu & Kashmir 180006, India.
3 Institute of Mountain Environment, Bhaderwah Campus University of Jammu, Union Territory of Jammu & Kashmir 182222, India.

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 illegal 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
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...
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 overran 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,
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 Kaziranga National Park, Assam, India. A preliminary report of reptilian mortality on road due to vehicular movements over two time periods, 9 years apart: a case study in Mediterranean farmland.


Chen, H.-L., E.E. Posthumus & J.L. Koprowski (2021). 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**


### Table 1. Road kills recorded on NH-244 during the sampling period.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>IUCN status</th>
<th>Number</th>
<th>Habitat type</th>
<th>Altitude (in m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mammals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Panthera pardus</td>
<td>Common Leopard</td>
<td>VU</td>
<td>2</td>
<td>PF, BD</td>
<td>1000–1415</td>
</tr>
<tr>
<td>2. Vulpes vulpes</td>
<td>Red Fox</td>
<td>LC</td>
<td>3</td>
<td>PF, BD, OS</td>
<td>1224–1580</td>
</tr>
<tr>
<td>3. Canis aureus</td>
<td>Golden Jackal</td>
<td>LC</td>
<td>12</td>
<td>PF, BD, OS, UR</td>
<td>990–1332</td>
</tr>
<tr>
<td>4. Paguma larvata</td>
<td>Himalayan Palm Civet</td>
<td>LC</td>
<td>2</td>
<td>PF, BD</td>
<td>890–940</td>
</tr>
<tr>
<td>5. Viverricula indica</td>
<td>Small Indian Civet</td>
<td>LC</td>
<td>2</td>
<td>OF, UR</td>
<td>934–1244</td>
</tr>
<tr>
<td>6. Macaca mulatta</td>
<td>Rhesus Macaque</td>
<td>LC</td>
<td>7</td>
<td>PF, BD, OS, UR</td>
<td>910–1310</td>
</tr>
<tr>
<td>7. Eoglaucomys fimbriatus</td>
<td>Kashmir Flying Squirrel</td>
<td>LC</td>
<td>2</td>
<td>PF</td>
<td>1100–1246</td>
</tr>
<tr>
<td>Birds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Gyps himalayensis</td>
<td>Himalayan Vulture</td>
<td>NT</td>
<td>2</td>
<td>PF</td>
<td>1250</td>
</tr>
<tr>
<td>9. Milvus migrans</td>
<td>Black Kite</td>
<td>LC</td>
<td>3</td>
<td>OS, UR</td>
<td>1140–1402</td>
</tr>
<tr>
<td>10. Pycnonotus cafer</td>
<td>Red-vented Bulbul</td>
<td>LC</td>
<td>2</td>
<td>OS</td>
<td>1016–1456</td>
</tr>
<tr>
<td>11. Acredotheres tristis</td>
<td>Common Myna</td>
<td>LC</td>
<td>3</td>
<td>OS, UR</td>
<td>944–1113</td>
</tr>
<tr>
<td>Reptiles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Snake sp.</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>UR</td>
<td>943–1105</td>
</tr>
<tr>
<td>13. Calotes sp.</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>OS, UR</td>
<td>946–1510</td>
</tr>
</tbody>
</table>

VU—Vulnerable | NT—Near Threatened | LC—Least Concern | PF—Pine forests | OS—Open Scrub | BD—Broadleaved mixed | UR—Urban areas.
Road kills on mountainous highway in Himalaya

Kichloo et al.


Robiquetia gracilis (Lindl.) Garay—a new record to the flora of Anamalai Hills, Tamil Nadu, India

B. Subbaiyan, V. Ganesan, P.R. Nimal Kumar & S. Thangaraj Panneerselvam

1 Anamalai Tiger Reserve Forest Pollachi, Tamil Nadu, India.
2 Coimbatore, Tamil Nadu, India.
3 Orchid Conservationist, Plantart Botanic Private Limited, Coimbatore, Tamil Nadu, India.
4 Anamalai Tiger Reserve Forest Pollachi, Tamil Nadu, India.

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.
Robiquetia gracilis (Lindl.) Garay


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,
Robiquetia gracilis - new record to the flora of Anamalai Hills

Subbaiyan et al.


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

Ipomoea laxiflora H.J. Chowdhery & Depta (Convolvulaceae): new records for the Western Ghats and semiarid regions

Sachin M. Patil1, Ajit M. Vasava2, Vinay M. Raole3 & Kishore S. Rajput4

1 Department of Botany, Shivaji University, Kolhapur, Maharashtra 416004, India.
2-4 Department of Botany, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat 390002, India.

1 sach2010d@gmail.com, 2 ajitvsv@gmail.com, 3 vinaysar@rediffmail.com, 4 ks.rajput15@yahoo.com (corresponding author)

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 & Depta 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 & Depta. 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 & Depta,
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; pedioles 7–12 cm, purple-green, long, glabrous; flowers 3–7 in lax cymes, monoeocious, 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...
Ipomoea laxiflora – new record for the Western Ghats

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
2–4 mm long, linear, caducous; calyx 5, fused, green with purple tinge at tip; lobes 0.7–0.9 × 0.2–0.3 cm, ovate-lanceolate, 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 semi-arid regions of India. About 30–80 individuals were found per locality and the area of occupancy (AOO) is 150–250 km² 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*.
**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.


**References**


Counting the cost: high demand puts *Bunium persicum* (Boiss.) B.Fedtsch. in jeopardy

Monika Sharma 1©, Manisha Mathela 2©, Rupali Sharma 3©, Himanshu Bargali 4©, Gurinderjit S. Goraya 5© & Amit Kumar 6©

1–6 Wildlife Institute of India, Dehradun, Uttarakhand 248002, India.
1 monika.iirs@gmail.com, 2 manishamathela@gmail.com, 3 rupalisharma060@gmail.com, 4 himanshubargali@rediffmail.com, 5 gurinder9@hotmail.com, 6 amit@wii.gov.in (corresponding author)

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...
High demand puts Bunium persicum in jeopardy

Sharma et al.

High demand puts Bunium persicum in jeopardy

Sharma et al.

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, Pichorhiza kurroa Royle ex. Benth (Kadu) 900–1,500 INR kg⁻¹, and Daedylorhiza 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, Sikim, & 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 Daedylorhiza 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).

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
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 of 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


First record of Parasitic Jaeger Stercorarius parasiticus (Aves: Charadriiformes: Stercorariidae) from inland freshwater Inle Lake, Myanmar

Sai Sein Lin Oo1, Myint Kyaw2, L.C.K. Yun3, Min Zaw Tun4, Yar Zar Lay Naung5, Soe Naing Aye6 & Swen C. Renner7

1Department of Zoology, University of Mandalay, 05032 Maha Aung Myay Township, Mandalay, Myanmar.
2Popa Mountain Park, Kyaupkadaung, Mandalay Region, Myanmar.
7Ornithology, Natural History Museum Vienna, Burgring 7, 1010 Vienna, Austria.

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 offshore 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
First record of Parasitic Jaeger from Inle Lake, Myanmar


First record of Parasitic Jaeger from Inle Lake, Myanmar

Oo et al.

... cushion of 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


...
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 1 variety) are given. The book is a useful tool for botanists, taxonomists and more general scientific community.
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 Peninsulare 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 brevissima* 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.
The opinions expressed by the authors do not reflect the views of the Journal of Threatened Taxa, Wildlife Information Liaison Development Society, Zoo Outreach Organization, or any of the partners. The journal, the publisher, the Managing Editor, JoTT, the partners are not responsible for the accuracy of the political boundaries shown in the maps by the authors.
Estimating the completeness of orchid checklists and atlases: a case study from southern Italy
– Antonio Croce, Pp. 20311–20322

A floristic survey across three coniferous forests of Kashmir Himalaya, India – a checklist
– AsHaq Ahmad Dar, Akhtar Hussain Malik & NarayanasaWamy Parthasarathy, Pp. 20323–20345

Associations of butterflies across different forest types in Uttarakhand, western Himalaya, India: implications for conservation planning
– Arun Pratap Singh, Pp. 20346–20370

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

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

New distribution record of globally threatened Ocean Turf Grass Halophila beccarii in western semi-arid biogeographic region suggestions for parametric studies on ecological continuity in Khathiar-Gir Ecoregion, India

Plant diversity of Point Calimere Wildlife Sanctuary and fodder species grazed by the Blackbuck Antelope cervicapra L.
– Ashutosh Kumar Upadhya, A. Andrew Emmanuel, Ansa Sarah Varghese & D. Narasimhan, Pp. 20463–20480

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

Nesting success of Sharpe’s Longclaw (Macronyctes sharpei Jackson, 1904) around the grasslands of lake Ol’bolosat Nyandarua, Kenya

Population, distribution and diet composition of Smooth-coated Otter Lutrogale perspicillata in Hosur and Dharmapuri Forest Divisions, India
– Nagarajan Baskaran, Raman Sivaraj Sundarraj & Raveendranathanngallai Sanil, Pp. 20469–20477

Utilization of home garden crops by primates and current status of human-primate interface at Galigamuwa Divisional Secretariat Division in Kegalle District, Sri Lanka
– Charmalie Anuradhi Dhe Dona Nahallage, Dahanakge Ayeshsa Madushani Dasanayake, Dilan Thisaru Hewamanna & Dissanayakakilage Tharaka Harshani Ananda, Pp. 20478–20487

Revival of Eastern Swamp Deer Rucerurus davuaucelli ranjitsinhi (Groves, 1982) in Manas National Park of Assam, India

Trypanosoma evansi infection in a captive Indian Wolf Canis lupus pallipes – molecular diagnosis and therapy
– Manojita Dash, Sarat Kumar Sahu, Santosh Kumar Gupta, Niranjanah Sahoo & Debarat Mohapatra, Pp. 20494–20499

COVID-19 and civil unrest undoing steady gains in karst conservation and herpetological research in Myanmar, and an impediment to progress

Distribution of Smooth-coated Otters Lutrogale perspicillata (Mammalia: Carnivora: Mustelidae): in Ratnagiri, Maharashtra, India
– Swanand Patil & Kranti Yardy, Pp. 20511–20516

Wildlife at the crossroads: wild animal road kills due to vehicular collision on a mountainous highway in northwestern Himalayan region
– Muzaffar A. Kichloo, Asha Sohil & Neeraj Sharma, Pp. 20517–20522

First record of Parasitic Jaeger Stercorarius parasiticus (Aves: Charadriiformes: Stercorariidae) from inland freshwater Inle Lake, Myanmar

Book Review

Capparis of India
– V. Sampath Kumar, Pp. 20537–20538

The Journal of Threatened Taxa (JoTT) is dedicated to building evidence for conservation globally by publishing peer-reviewed articles online every month at a reasonably rapid rate at www.threatenedtaxa.org. All articles published in JoTT are registered under Creative Commons Attribution 4.0 International License unless otherwise mentioned. JoTT allows unrestricted use, reproduction, and distribution of articles in any medium by providing adequate credit to the author(s) and the source of publication.