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Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Caption: Grey Fox *Urocyon cinereoargenteus* in central California. © Maximilian Allen.

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COMMUNICATION

Distribution and habitat preferences of the Chinese Pangolin *Manis pentadactyla* (Mammalia: Manidae) in the mid-hills of Nepal

Suman Acharya [1], Hari Prasad Sharma [2], Rajeev Bhattarai [3], Beeju Poudyal [4], Sonia Sharma [5] & Suraj Upadhaya [6]

[1] Anthropology and Environmental Policy, Department of Anthropology, University of Maine, Orono, ME 04469, USA.
[1] Climate Change Institute, University of Maine, Orono, ME, 04469, USA.
[1,4,6] Himalayan Conservation and Research Institute, Dolpa 21400, Nepal.
[2] Central Department of Zoology, Tribhuvan University, Kathmandu 44618, Nepal.
[3] University of Maine, School of Forest Resources, Orono, ME, 04469, USA.
[5] Department of Forest, Ministry of Forests and Environment, Kathmandu, 44600, Nepal.
[6] Department of Natural Resource Ecology and Management, Iowa State University, Ames, IA 50010, USA.
[1] suman.acharya@maine.edu (corresponding author), [2] hpsharma@cdztu.edu.np, [3] rajeev.bhattarai@maine.edu,
[4] beeju.poudyal@gmail.com, [5] me.sonia07@gmail.com, [6] surajupadhaya99@gmail.com

Abstract: The Chinese Pangolin is a 'Critically Endangered' species, which is estimated to have declined by over 90% in the last 21 years due to increased anthropogenic activities on the species and its habitat. Only a few pieces of research on the Chinese Pangolin have been done throughout Nepal; there is little information among the mammal species of Nepal, especially on distribution and habitat preference. This study was set to assess the distribution and habitat preferences of the Chinese Pangolin in Panauti municipality, central Nepal. We identified the most preferred habitat of the Chinese Pangolin using different covariates. Its preferred habitat was found ranging 1,450–1,600 m of elevation within a moderate slope of 5–25° steepness, forested areas in west-facing slopes. The maximum number of burrows of the species were found to be distributed in open canopy (0–50 % coverage). The increase anthropogenic activities in the agricultural land and deforestation in forested land has negatively impacted the occurrence of the Chinese Pangolin. We recommend that the community-based conservation initiatives like community forestry programs should be robustly implemented in the study area for better conservation of species and habitat in the coming years.

Keywords: Critically Endangered species, distribution, habitat, pangolin, wildlife.

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Author details: Suman Acharya is a PhD candidate in Anthropology and Environmental Policy and Climate Change Institute at the University of Maine, USA and a social science researcher at Himalayan Conservation and Research Institute, Nepal. He works on power and politics of climate change adaptation, collective action theory, and wildlife conservation. Sonia Sharma is an Assistant Forest Officer under the Ministry of Forests and Environment at the Divisional Forest Office, Dailekh, Nepal. Her research areas include human dimensions of natural resource management and human-wildlife conflict. Suraj Upadhaya is a postdoctoral research associate in the Department of Natural Resource Ecology and Management, Iowa State University, and director at Himalayan Conservation and Research Institute. He conducts research and teaches in the areas of socio-ecological systems and human dimensions of natural resource management. His academic and professional's goals are to explore the dynamic relationship between natural resources and people, ensure the sustainability of natural resources in developed and developing countries, and channel his research to benefit the underprivileged population. Hari Prasad Sharma is a faculty member at Tribhuvan University. He studies wildlife ecology and human-wildlife interaction in Nepal. His research is focused on species' habitat utilization, conservation, and niche modeling. Beeju Poudyal is a Conservation Program Director at Himalayan Conservation and Research Institute. Ms. Poudyal specializes in human dimensions of natural resources management, human-wildlife conflict, watershed management, and ecosystem services. Rajeev Bhattarai is a PhD student at the University of Maine (School of Forest Resources). He works with linking forest health to remote sensing.

Author contributions: SA—research design, data collection, data analysis and interpretation, drafting manuscript, critical review, revisions at different stages. HPS—methodology design, write up, data analysis, revisions at different stages. RB—drafting manuscript, and revisions at different stages. BP—draft manuscript preparation, reviewing, editing. SS—conceptualization, drafting manuscript, reviewing, editing. SU— conceptualization, writing: draft preparation, data analysis, reviewing, editing.

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INTRODUCTION

Anthropogenic activities like illegal hunting and trading, deforestation, wildfire, increased agricultural landscape, and habitat fragmentation are the major threats to the biodiversity conservation in the contemporary world (Nepstad et al. 1999; Wolfe et al. 2005; Jha & Bawa 2006; Gibson et al. 2011; Laurance et al. 2014; Abood et al. 2015). The major impact of these activities can be found on flora and fauna. To minimize the anthropogenic effects, several areas are demarcated under the protected areas system for biodiversity conservation around the world (Bruner et al. 2001; Naughton-Treves et al. 2005). However, a majority of anthropogenic threats are highly confined outside the protected areas that accounts for approximately 86% of the earth's total land (Deguignet et al. 2014) and are highly vulnerable in terms of species distribution and habitat management (Sharma & Acharya 2017). The established protected areas in most of the countries including Nepal do not cover all threatened species under the protected area system (Jnawali et al. 2011; Polak et al. 2016). As other wildlife species, the pangolin's more suitable habitat is predicted outside the protected area of Nepal (Sharma et al. 2020a; DNPWC & DoF 2018), and the species is also facing survival threats due to similar anthropogenic activities that have reduced the distribution of the pangolin (Challender et al. 2014; Acharya 2015; Kaspal et al. 2016; Katuwal et al. 2017; Acharya et al. 2018; Sharma et al. 2020a,b).

Nepal hosts two species of pangolin out of eight species distributed across the world: The Chinese Pangolin *Manis pentadactyla* and the Indian Pangolin *M. crassicaudata* (Baral & Shah 2008; Jnawali et al. 2011; Challender et al. 2019). Indian Pangolins are distributed below 500 m and Chinese Pangolins are distributed in lower regions as well as mountain areas with a maximum elevation of 2,400 m (Baral & Shah 2008; Jnawali et al. 2011; Kaspal et al. 2016; Sharma et al. 2020a). Globally, the Chinese Pangolin is found in Bangladesh, Bhutan, China, Hong Kong, India, Japan, Lao, Myanmar, Nepal, Taiwan, Thailand, and Vietnam (Challender et al. 2019). In Nepal, the Chinese Pangolin is distributed from east to west at the extreme limits of the Gandaki Province (Baral & Shah 2008; Jnawali et al. 2011; Acharya 2016; Katuwal et al. 2017; Acharya et al. 2018; Suwal et al. 2020; Sharma et al. 2020a,b,c). Within these geographic regions, the Chinese Pangolin inhabits forests, agricultural lands, degraded landscape, and nearby human settlements (Katuwal et al. 2017; Sharma et al. 2020a,b) and its occurrence is influenced by forest canopy, soil, distance to water sources, distance to human settlements, road or foot path, and slope (Wu et al. 2003; Acharya 2016; Katuwal et al. 2017; Sharma et al. 2020a,b). Generally, its distribution in these habitats will be supported by food availability such as termites and ants (Challender et al. 2019).

However, the species is protected in different nations including Nepal with strong national laws and acts (Challender & Waterman 2017; Challender et al. 2019), the population status of the species is declining day by day mainly due to poaching for meat and scales in China and Vietnam (Pantel & Chin 2009; Challender & Heywood 2012; Heinrich et al. 2016; Ghimire et al. 2020; Sharma et al. 2020d) and these threats are assumed in almost all countries including Nepal (DNPWC & DoF 2018; Challender et al. 2019). Therefore, the IUCN Red List categorized the species under 'Critically Endangered' (Challender et al. 2019), under protected mammal species in Nepal, and Appendix I on CITES. In spite of these status, the detail site specific information on the Chinese Pangolin and its habitat especially on distribution and habitat preference is little known, therefore, we aimed to provide the site specific information on the habitat preferences of the Chinese Pangolin for developing a management plan.

MATERIALS AND METHODS

Study Area

We performed this study in the Balthali of Panauti Municipality (former Balthali Village Development Committee) in Kavrepalanchowk district of Nepal. The study area is located outside the protected area system and will be more crucial for designing the site-specific management plan for long term conservation of the Chinese Pangolin. The study area comprises 9.5km^2 (27.54^{0}N, 85.54^{0}E), and ranges at 1,300–1,900 m of elevation. The area is occupied by agricultural land, grassland, and forest. This area is quite famous for multiple agricultural products like rice, wheat, potato, barley, maize, pea, and mustard. These two sentences are combined as: The area is inhabited by many fauna and flora such as Leopard Panthera pardus, Indian Palm Squirrel *Funambulus penantii*, Golden Jackal *Canis aureus*, Porcupine *Hystrix* spp. Mongoose *Herpestes auropuncatatus*, and Yellow-throated Marten *Martes flavigula*. Balthali supports mixed types of forest species including Pine *Pinus roxburghii*, Nepalese Alder *Alnus nepalensis*, Wild Himalayan Pear *Pyrus pashia*, Wild Himalayan Cherry *Prunus cerasoides*, and Needlewood *Schima wallichii*.

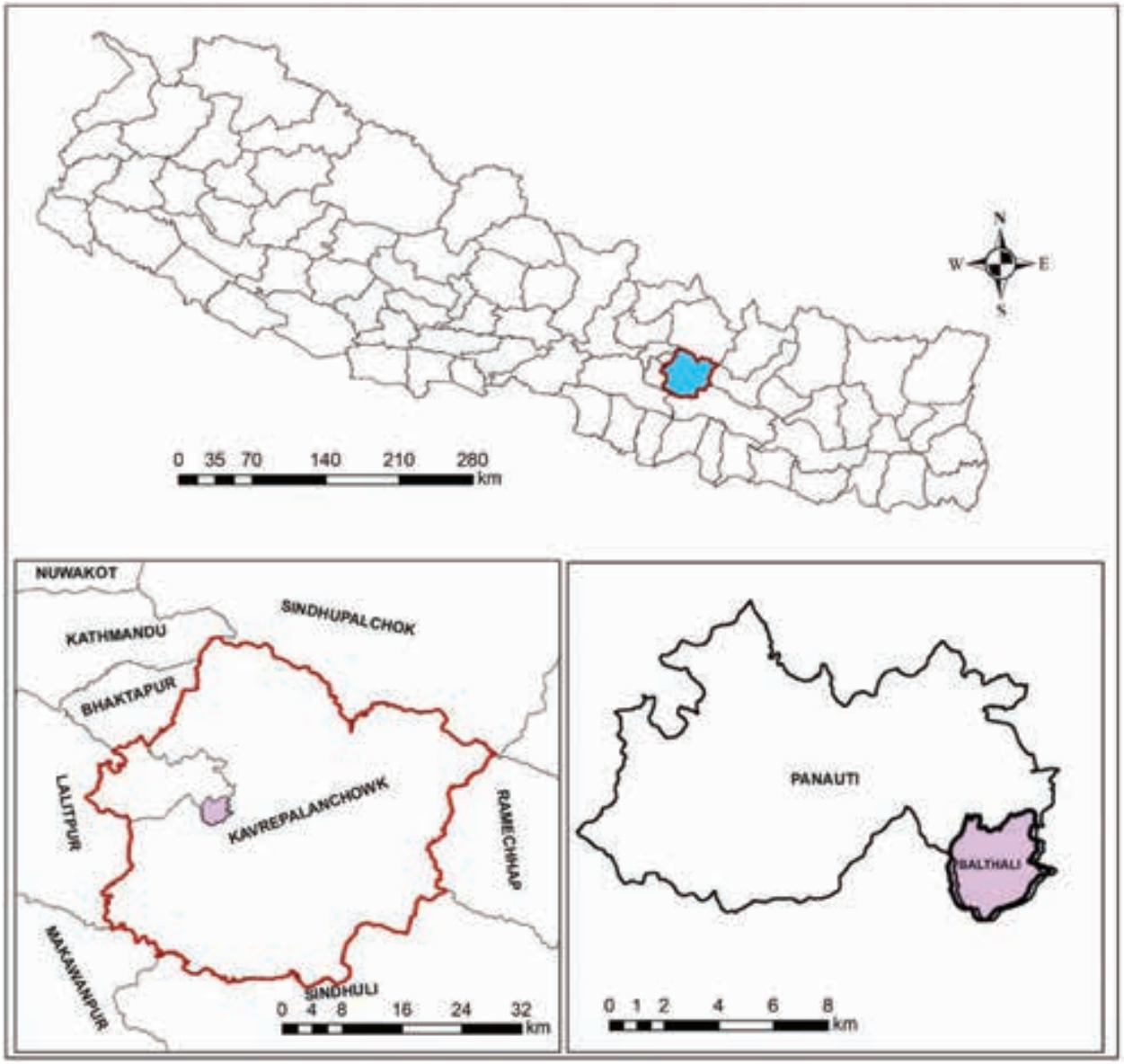

Figure 1. Location of the study area (Balthali of Panauti municipality) in Kavrepalanchowk district, mid-hills of Nepal.

Methods

We collected data between December 2017 to March 2018. A reconnaissance survey was carried out in the first week of December 2017 in the study area to identify the potential sites of the pangolin. It was performed in consultation with local people and district forest officials before we initiated our fieldwork. After confirmation of the Chinese Pangolin's presence in the study area, a random sampling technique was followed to collect data. We followed the method applied by Katuwal et al. (2017); however, we modified it based on our study area in which we divided the study area into 160 grids and each grid was 250 × 250 m. We established 10 × 10 m of plot at the center of each alternate grid to collect the information on pangolin presence records.

We recorded slope, aspect, elevation, canopy, and habitat information in each plot, which are influencing factors for the Chinese Pangolin occurrence (Katuwal et al. 2017; DNPWC & DoF 2018; Sharma et al. 2020b). However, the present study was not able to include all influencing factors such as food, nearest distance to road and other anthropogenic factors because of financial and time constraints. We noticed the slope and aspect of each plot using a clinometer, and elevation and spatial locations by global positioning system (GPS) Etrex 10 (Garmin Ltd., Olathe, Kansas). We recorded the canopy

cover by using a crucial mobile application (Gap Light Analysis Mobile Application) (Tichy 2016; Sharma et al. 2020b) and categorized into open (0–50%) and close (50–100%) canopy. We identified the habitat types into forest, shrubs, grassland, and agricultural land. However, we did not notice the occurrence of Chinese Pangolins in shrubs and grassland during our study period, therefore we excluded these variables for data analysis. We noticed the presence/absence of Chinese Pangolin based on its signs such as burrows, scratches, and feces. We categorized burrows as old and new burrows based on scratches and pugmarks (Katuwal et al. 2017) and presence of any types of burrows recognized as presence.

Data Analysis

We calculated the descriptive statistics (Mean +SD) of the continuous variables. We used logistic regression to estimate the effects of slope, aspect, canopy cover, elevation, habitat types on the presence of Chinese Pangolin. We ran all combinations of variables without interactions. As our sample size was small, we adjusted Akaike information criterion (AIC) for small samples as suggested by Burnham & Anderson (2002). We used this AIC to rank the models. The relative strength of evidence for each model were estimated using the Akaike model weights. To estimate 95% confidence intervals for each independent variable we conducted model averaging of all the models.

RESULTS

Distribution of Chinese Pangolin

We found altogether 258 burrows of Chinese Pangolin in the study area. These coordinates were plotted in the Arc GIS map to depict the distribution in the Balthali of Panauti municipality (Figure 2).

Habitat preference

The presence of the Chinese Pangolin was found in 47 plots (59%) out of 80 plots. The observed plots were found at 1,300–1,895 m of elevation (mean 1,562.13 ±14.61 m SD). Mean elevation of plots with and without pangolin was 1,564.93 ± 17.94 m and 1,556.35 ± 25.15 m, respectively. Elevation class of 1,450–1,600

Figure 2. Potential preferred habitat of Chinese Pangolin *Manis pentadactyla* within existing land cover for the year 2010. Landcover source: ICIMOD

m hosts the highest evidence of Chinese Pangolin presence. The studied plots were found from 5–<30° slope. The Chinese Pangolin's occurrences were found between 5–25° slopes. Mean slope of plots with and without pangolin was 17.11 ± 1.15° and 22.23 ± 1.57°, respectively. Comparatively more Chinese Pangolin presence (44%) was found in west aspect and followed by the east aspect (30%), south (19%) and the least was found in north aspect (7%), respectively. We found that 78% of Chinese Pangolin presence was detected in open canopy whereas only 22% of presence was found in close canopy. Similarly, 60% of Chinese Pangolin presence was detected in forest land followed by 40% in agricultural land.

Using the Akaike information criterion adjusted for small samples (AIC), our model revealed that the best-supported models included canopy, habitat and slopes followed by the model containing canopy, habitat, slope, and aspect (Table 1). Chinese Pangolin preferred habitat with 0–50% of tree canopy, i.e., open canopy. Increased tree canopy had negative effects on the occurrence of Chinese Pangolin (Table 2). They preferred to live at lower slope (10–20°), and the number of their occurrences decreases with increasing slope (Table 2). Their occurrences was greatly influenced by habitat including forest and majority of the presence was detected in forested areas than agricultural areas. West facing slopes supported the occurrence of Chinese Pangolin (Table 2; Figure 3). Their occurrence was decreased with increasing elevation (Table 2).

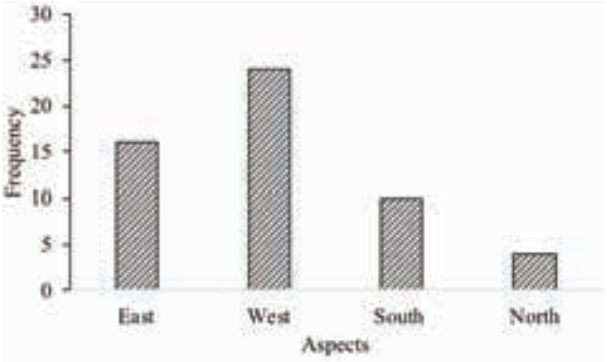

Figure 3. Aspect wise distribution of the Chinese Pangolin.

DISCUSSION

In our study both forest and agricultural lands support the occurrence of Chinese Pangolin may be due to the availability of higher food such as ants and termites. These are the major habitats in Nepal (Gurung 1996; Bhandari & Chalise 2014; Katuwal et al. 2017; Suwal et al. 2020; Sharma et al. 2020a,b) for the species. Among these habitats, the forest supports the higher proportion of occurrence, which might be due to food availability in the forest and less disturbances, which was also indicated by Sharma et al. (2020a) in mid-mountain regions of Nepal. The forest provides ample space and food for pangolins because ants and termites are found abundantly in this habitat (Okwakol 2000; Ellwood 2002; Lee et al. 2017), that could support the robust presence of its population in forest (Swart et al. 1999). The pangolin prefers the west slope probably for getting sunlight before foraging.

We also documented 40% of the pangolins preferred agricultural land as a suitable habitat. The occurrence of the Chinese Pangolin is higher in those settlement areas that are near to forest and surrounded by shrubs and diverse forest vegetation (Carter & Glimour 1989; Acharya 2006; Sharma et al. 2020a,b). As the presence of farmers in agricultural land for their daily chores disturb the movement of the pangolins, therefore the species preferred forest adjoining the agricultural land (Katuwal et al. 2017; Sharma et al. 2020b). Moreover, during our survey we directly observed the presence of shrubs, small trees, ants, termites, and tree leaves in the agricultural land that promote habitat preference of the pangolins (Richer et al. 1997). However, increase in insecticides use, habitat destruction due to construction works in agricultural land, and deforestation has affected the presence and distribution of the pangolins (Acharya et al. 2018).

Our study revealed that the elevation range of 1,300–1,895 m hosts the occurrence of Chinese Pangolins, and most preferred range was 1,450–1,600 m of elevation located in the mid-mountain regions of Nepal. This range also fall under the predicted suitable habitat for the Chinese Pangolins (Sharma et al. 2020a; Suwal et al. 2020) and field based (Thapa et al. 2014; Dorji et al. 2017; Wu et al. 2020) except 200–1,000 m of elevation in Taiwan (Sun et al. 2019). Their preferences might be due to increased forest in the mountain regions of Nepal.

We report the Chinese Pangolins prefer open canopy forest (0–50% coverage) such that the increase in canopy coverage has negative effect on its occurrence. The occurrence of large number of fallen logs and cut stumps in open canopy forest might support the occurrence of ants and termites. However, Katuwal et al. (2017) claimed the presence of Chinese Pangolin in dense canopy cover, which might support in the habitat protection from erosion.

Table 1. Logistic regression models describing the occurrence of the Chinese Pangolin in Balthali of Panauti municipality, Kavrepalanchowk for 2017 year, ranked according to the Akaike information criterion adjusted for small sample size (AICc). Model parameters include aspect (°), canopy (%), elevation (m), slope (°), habitat (agricultural/forest), (presence/absence). K is the number of parameters, ΔAICc is the difference between the AICc value of the best-supported model and successive models, LogLik is used for a model fitted by maximum likelihood and *Wi* is the Akaike model weight.

Models	K	LogLik	AICc	ΔAICc	*Wi*
Canopy + Habitat + Slope	4	-34.358	76.7	0	0.448
Aspect + Canopy + Habitat + Slope	5	-34.01	78	1.3	0.234
Canopy + Elevation + Habitat + Slope	5	-34.232	78.5	1.75	0.187
Aspect + Canopy + Elevation + Habitat + Slope	6	-33.956	79.9	3.2	0.091
Canopy + Slope	3	-39.144	84.3	7.57	0.01
Aspect + Canopy + Slope	4	-38.537	85.1	8.36	0.007
Canopy + Habitat	3	-39.758	85.5	8.8	0.006
Aspect + Canopy + Habitat	4	-38.913	85.8	9.11	0.005
Canopy + Elevation + Slope	4	-39.016	86	9.31	0.004
Aspect + Canopy + Elevation + Slope	5	-38.295	86.6	9.87	0.003
Canopy + Elevation + Habitat	4	-39.752	87.5	10.79	0.002
Aspect + Canopy + Elevation + Habitat	5	-38.91	87.8	11.1	0.002
Habitat + Slope	3	-42.243	90.5	13.77	0
Canopy	2	-43.566	91.1	14.41	0
Elevation + Habitat + Slope	4	-41.672	91.3	14.63	0
Aspect + Canopy	3	-42.689	91.4	14.66	0
Aspect + Habitat + Slope	4	-42.105	92.2	15.49	0
Aspect + Canopy + Elevation	4	-42.199	92.4	15.68	0
Canopy + Elevation	3	-43.205	92.4	15.69	0
Aspect + Elevation + Habitat + Slope	5	-41.591	93.2	16.47	0
Habitat	2	-46.038	96.1	19.36	0
Aspect + Habitat	3	-45.474	96.9	20.23	0
Elevation + Habitat	3	-45.803	97.6	20.89	0
Aspect + Elevation + Habitat	4	-45.31	98.6	21.9	0
Slope	2	-47.361	98.7	22.01	0
Aspect + Slope	3	-46.983	100	23.25	0
Elevation + Slope	3	-47.353	100.7	23.99	0
Aspect + Elevation + Slope	4	-46.981	102	25.25	0
Null	1	-50.446	102.9	26.18	0
Aspect	2	-49.82	103.6	26.92	0
Elevation	2	-50.409	104.8	28.1	0
Aspect + Elevation	3	-49.754	105.5	28.79	0

This study found that the burrows of Chinese Pangolin were distributed between 5–25° slopes, so that they can move easily in the area to avoid the terrain slope. In most of the areas of Nepal a maximum number of burrows was recorded at 15–22° slopes (Sharma et al. 2020b). Sharma et al. (2020a,b) argued that the presence of large number of burrows in lower slope could be due to the presence of plethora of fallen logs and prey species (ants and termites). However, Wu et al. (2003), Dorji et al. (2017), and Suwal et al. (2020) noticed the preferred slopes for Chinese Pangolin was <50°. The presence of the pangolin in varied slope recorded in different locations might be due to physiographic condition of the locality.

In conclusion, Balthali of Panauti municipality is one of the suitable places in Nepal that supports the

Table 2. Model averaged parameter estimates and 95 % confidence limits (CL) for Chinese Pangolin occurrence. Variables detail was described in Table 1. Significant variables are in bold.

	Estimate	SE	Lower 95% CL	Upper 95% CL	Z	p
(Intercept)	6.623250	2.708539	1.24022	12.00627	2.412	**0.015886**
Canopy	-0.063462	0.017954	-0.09922	-0.0277020	3.478	**0.000505**
Habitat	-2.473016	0.964771	-4.39456	-0.5514705	2.522	**0.011654**
Slope	-0.112887	0.038628	-0.18983	-0.0359469	2.876	**0.004032**
Aspect	0.252597	0.303325	-0.35166	0.8568507	0.819	0.412599
Elevation	-0.001260	0.002520	-0.00628	0.0037597	0.492	0.622816

pangolins occurrences. The Chinese Pangolin's suitable habitat is influenced by habitat and habitat related covariates, therefore, we recommend the development and implementation of extensive conservation strategies such as community-based conservation initiatives like community forestry programs for species conservation to prevent the loss of this critically endangered species from the earth.

REFERENCES

Acharya, K.P. (2006). Linking trees on farms with biodiversity conservation in subsistence farming systems in Nepal. *Biodiversity and Conservation* 15: 631–646. https://doi.org/10.1007/s10531-005-2091-7

Acharya, S. (2015). Pains of the pangolin. The Kathmandu Post https://kathmandupost.com/opinion/2015/02/22/pains-of-the-pangolin/ accessed 02 May 2020

Acharya, S. (2016). Assessment of conservation threats and habitat management of Chinese Pangolin (*Manis pentadactyla*) in Balthali VDC of Kavreplanchowk Nepal. B.Sc. Dissertation. Institute of Forestry, Tribhuvan University, Pokhara, Nepal.

Acharya, S., S. Rayamajhi, S. Sharma, S. Upadhaya, S. Joshi & S. Lamichhane (2018). Anthropogenic Threats to Survival of the Critically Endangered Chinese Pangolins (*Manis pentadactyla*) and their Habitat in Kavrepalanchowk Nepal. Journal of Biodiversity & Endangered Species 6(218): 2.

Abood, S.A., J.S.H. Lee, Z. Burivalova, J. Garcia-Ulloa & L.P. Koh (2015). Relative contributions of the logging, fiber, oil palm, and mining industries to forest loss in Indonesia. *Conservation Letters* 8(1): 58–67.

Baral, H.S. & K.B. Shah (2008). *Wild Mammals of Nepal*. Himalayan Nature, Kathmandu, 55pp.

Bhandari, N. & M.K. Chalise (2014). Habitat and distribution of Chinese Pangolin (*Manis pentadactyla* Linnaeus, 1758) in Nagarjun Forest of Shivapuri-Nagarjun National Park, Nepal. *Nepalese Journal of Zoology* 2: 18–25.

Bruner, A.G., R.E. Gullison, R.E. Rice & G.A. da Fonseca (2001). Effectiveness of parks in protecting tropical biodiversity. *Science* 291(5501): 125–128.

Burnham, K.P. & D.R. Anderson (2002). *Model Selection and Multimodal Inference: A Practical Information - Theoretic Approach. 2nd Edition*. Springer-Verlag, New York, xxvi+488pp. https://doi.org/10.1007/b97636

Carter, A.S. & D.A. Gilmour (1989). Increase in tree cover in private farmland in central Nepal. Mt. Res. Dev. 9, 381–391. Accessed May 02, 2020. https://doi.org/10.2307/3673586

Challender, D.W.S. & L. Hywood (2012). African pangolins under increased pressure from poaching and intercontinental trade. *Traffic Bulletin* 28(1): 53–55.

Challender, D. & C. Waterman (2017). Implementation of CITES Decision2 17.239 B) and 17.240 on Pangolins *(Manis* spp.*)*. Prepared by IUCN for the CITES Secretariat. SC69 Doc 57.

Challender, D., S. Wu, P. Kaspal, A. Khatiwada, A. Ghose, N. Ching-Min Sun, R.K. Mohapatra & T.L. Suwal (2019). *Manis pentadactyla* (errata version published in 2020). The IUCN Red List of Threatened Species 2019: e.T12764A168392151. Downloaded on 20 May 2020. https://doi.org/10.2305/IUCN.UK.2019-3.RLTS.T12764A168392151.en

Deguignet, M., D. Juffe-Bignoli, J. Harrison, B. MacSharry, N.D. Burgess & N. Kingston (2014). United Nations list of protected areas.

Dorji, D. (2017). Distribution, habitat use, threats and conservation of the Critically Endangered Chinese Pangolin *(Manis pentadactyla)* in Samtse District, Bhutan. Unpublished. Rufford Small Grants, UK. https://www.rufford.org/projects/dago_dorji

DNPWC & DoF (2018). Pangolin Conservation Action Plan for Nepal (2018–2022). Kathmandu, Nepal: Department of National Parks and Wildlife Conservation and Department of Forests.

Ellwood, M.D., D.T. Jones & W.A. Foster (2002). Canopy ferns in lowland dipterocarp forest support a prolific abundance of ants, termites, and other invertebrates. *Biotropica* 34: 575–583.

Ghimire, P., N. Raut, P. Khanal, S. Acharya & S. Upadhaya (2020). Species in peril: assessing the status of the trade in pangolins in Nepal. *Journal of Threatened Taxa* 12(8): 15776-15783. https://doi.org/10.11609/jott.5698.12.8.15776-15783

Gibson, L. T.M. Lee, L.P. Koh, B.W. Brook, T.A. Gardner, J. Barlow, C.A. Peres, C.J.A. Bradshaw, W.F. Laurance, T.E. Lovejoy & N.S Sodhi (2011). Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature* 478(7369): 378–381.

Government of Nepal (2016). Ministry of finance. Nepal: Economic Survey. Kathmandu.

Gurung, J.B. (1996). A pangolin survey in Royal Nagarjung Forest in Kathmandu, Nepal. *Tiger Paper* 23: 29–32.

Heinrich, S., T.A. Wittmann, T.A. Prowse, J.V. Ross, S. Delean, C.R. Shepherd & P. Cassey (2016). Where did all the pangolins go? International CITES trade in pangolin species. *Global Ecology and Conservation* 8: 241–253. https://doi.org/10.1016/j.gecco.2016.09.007

ICIMOD (2013). Land cover of Nepal 2010 [Data set]. ICIMOD. https://doi.org/10.26066/rds.9224

Jha, S. & K.S. Bawa (2006). Population growth, human development, and deforestation in biodiversity hotspots. *Conservation Biology* 20: 906–912.

Jnawali, S.R., H.S. Baral, S. Lee, K.P. Acharya, G.P. Upadhyay, M. Pandey, R. Shrestha, D. Joshi, B.R. Laminchhane, J. Griffiths, A.P. Khatiwada, N. Subedi & R. Amin (compilers) (2011). The Status of Nepal Mammals. The National Red List Series, Department of National Parks and Wildlife Conservation, Kathmandu, Nepal.

Katuwal, H.B., K.R. Neupane, D. Adhikari, M. Sharma & S. Thapa (2015). Pangolins in Eastern Nepal: Trade and Ethno-Medicinal

Importance. Journal of threatened Taxa 7(9): 7563–7567. https://doi.org/10.11609/JoTT.o4202.7563-7

Katuwal, H.B., H.P. Sharma & K. Parajuli (2017). Anthropogenic impacts on the occurrence of the critically endangered Chinese pangolin *(Manis pentadactyla)* in Nepal. Journal of Mammalogy 98(6): 1667–1673. https://doi.org/10.1093/jmammal/gyx114

Kaspal, P., K.B. Shah & H.S. Baral (2016). SAALAK (i.e. Pangolin). Himalayan Nature, Kathmandu, Nepal.

Laurance, W.F., J. Sayer & K.G. Cassman (2014). Agricultural expansion and its impacts on tropical nature. *Trends in Ecology & Evolution* 29(2): 107–116.

Lee, R.H., K. Cheung, J.R. Fellowes & B. Guenard (2017). Insights into the Chinese Pangolin's *(Manis pentadactyla)* diet in a peri-urban habitat: a case study from Hong Kong. *Tropical Conservation Science* 10: 1–7.

Naughton-Treves, L., M.B. Holland & K. Brandon (2005). The role of protected areas in conserving biodiversity and sustaining local livelihoods. *Annual Review of Environment and Resources* 30: 219–252.

Nepstad, A. Verssimo, A. Alencar, C. Nobre, E. Lima, P. Lefebvre, P. Schlesinger, C. Potter, P. Moutinho, E. Mendoza, M. Cochrane & V. Brooks (1999). Large-scale impoverishment of Amazonian forests by logging and fire. *Nature* 398(6727): 505–508.

Okwakol, M.J.N. & M.B. Sekamatte (2007). Review article soil macrofauna research in ecosystems in Uganda. *African Journal of Ecology* 45: 2–8.

Pantel, S., & S.Y. Chin (2009). Proceedings of the workshop on trade and conservation of Pangolins native to South and Southeast Asia, 30 June – 2 July 2008. Singapore Zoo. TRAFFIC Southeast Asia.

Polak, T., J.E., Watson, J.R., Bennett, H.P., Possingham, R.A. Fuller & J. Carwardine (2016). Balancing ecosystem and threatened species representation in protected areas and implications for nations achieving global conservation goals. *Conservation Letters* 9(6): 438–445.

Richer, R.A., I.M. Coulson & M. Heath (1997). Foraging behaviour and ecology of the Cape Pangolin *(Manis temminckii)* in north-western Zimbabwe. *African Journal of Ecology* 35: 361–369.

Sharma, H.P., B. Rimal, M. Zhang & S. Sharma (2020a). Potential distribution of the critically endangered Chinese Pangolin *(Manis pentadactyla)* in different land covers of Nepal: Implications for conservation. *Sustainability* 12(1282): 1–13.

Sharma, S. & S. Acharya (2017). Human-Rhesus macaque conflict at Pumdivumdi/ Tallokodi, Pokhara, West Nepal. *Banko Janakari* 27(2): 46–50.

Sharma, S., H.P. Sharma, C. Chaulagain, H.B. Katuwal & J.L. Belant (2020b). Estimating occupancy of Chinese Pangolin *(Manis pentadactyla)* in a protected and non-protected area of Nepal. *Ecology and Evolution* 10(10): 4303–4313. https://doi.org/10.1002/ece3.6198

Sharma, S., H.P. Sharma, H.B. Katuwal & J.L. Belant (2020c). Knowledge of the Critically Endangered Chinese Pangolin *(Manis pentadactyla)* by local people in Sindhupalchok, Nepal. *Global Ecology and Conservation* 32: p.e01052. https://doi.org/10.1016/j.gecco.2020.e01052

Sharma, S., H.P. Sharma, H.B. Katuwal, C. Chaulagain & J.B. Belant (2020d). People's Knowledge of Illegal Chinese Pangolin Trade Routes in Central Nepal. *Sustainability* 12(12): 4900.

Sun, N.C.M., B. Arora, J.-S. Lin, W.-C. Lin, M-J. Chi, C-C. Chen & C.J-C. Pei (2019). Mortality and morbidity in wild Taiwanese pangolin *(Manis pentadactyla pentadactyla)*. *PLoS One* 14: e0198230. https://doi.org/10.1371/journal.pone.0198230

Suwal, T.L., A. Thapa, S. Gurung, P.C. Aryal, H. Basnet, K. Basnet, K.B. Shah, S. Thapa, S. Koirala, S. Dahal & H.B. Katuwal (2021). Predicting the potential distribution and habitat variables associated with pangolins in Nepal. *Global Ecology and Conservation* 23(2020): e01049. https://doi.org/10.1016/j.gecco.2020.e01049

Thapa, P., A.P. Khatiwada, S.C. Nepali & S. Poudel (2014). Distribution and conservation status of Chinese Pangolin *(Manis pentadactyla)* in Nangkholyang VDC, Taplejung, Eastern Nepal. American Journal of Zoological Research 2, 16-21. Available at: https://doi.org/10.12691/ajzr-2-1-3

Tichý, L. (2016). Field test of canopy cover estimation by hemispherical photographs taken with a smartphone. *Journal of Vegetation Science* 27: 427–435. https://doi.org/10.1111/jvs.12350

Wolfe, N.D., P. Daszak, A.M. Kilpatrick & D.S. Burke (2005). Bushmeat hunting, deforestation, and prediction of zoonotic disease. *Emerging Infectious Diseases* 11: 1822–1827.

Wu, S., N.C.M. Sun, F. Zhang, Y. Yu, G. Ades, T.L. Suwal & Z. Jiang (2020). Pangolins Science, Society and Conservation; Chapter 4 – Chinese Pangolin *Manis pentadatyla* (Linnaeus, 1758), 49–70pp. https://doi.org/10.1016/B978-0-12-815507-3.00004-6

Wu, S.B., N.F. Liu, G.Z. Ma, Z.R. Xu & H. Chen (2003). Habitat selection by Chinese Pangolin *(Manis pentadactyla)* in winter in Dawuling Natural Reserve. *Mammalia* 67(4): 493–502. https://doi.org/10.1515/mamm-2003-0403

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COMMUNICATION

On the occurrence of the Himalayan Wolf *Canis lupus,* L. 1758 (Mammalia: Carnivora: Canidae) in the Gaurishankar Conservation Area, Nepal; its existence confirmed through sign and visual evidence in Rolwaling Valley

Bishnu Prasad Pandey [1], Shankar Man Thami [2], Rabin Shrestha [3] & Mukesh Kumar Chalise [4]

[1–3] Gaurishankar Conservation Area Project (GCAP), Head Quarters, Singati Dolakha. C/O National Trust for Nature Conservation (NTNC), P.O. Box. no. 3712, Khumaltar, Lalitpur, Nepal.

[4] Tribhuvan University, Central Department of Zoology (TU/CDZ), Kirtipur, Kathmandu, Nepal.

[4] Nepal Biodiversity Research Society (NEBORS), Lalitpur, Nepal.

[1] pandeybp@gmail.com (corresponding author), [2] thamishankar@gmail.com, [3] rabin.metlar@gmail.com, [4] mukesh57@hotmail.com

Abstract: The Himalayan Wolf *Canis lupus* L., a top predator of the Third Pole, is proposed to be of a distinct wolf lineage (*C. himalayensis*) relative to the Holarctic Grey Wolf as described by mtDNA analyses. A biodiversity survey organized by the Gaurishankar Conservation Area Project (GCAP) has captured images of wolves in three different regions, and the study team has observed wolf scats in five additional regions above the tree line in Rolwaling Valley. Further, interviews with local herders provided evidence of wolf depredation of livestock in the area. The Rolwaling Valley in the Gaurishankar Conservation Area was the study area which was divided into 12, 4 x 4 km (16 km^2) grid cells, each supplied with one camera trap operated continuously from June to November 2019 (only 6 out of 12 cameras functioned for the duration of our study). Wolf detections were recorded by camera traps from Yalung Pass (4,956 m), Tsho-Rolpa glacial Lake (4,536 m) and the Dudhkunda ridgeline (5,091 m). The photo capture rate index (PCRI) for wolves was 0.71. Our study reports the first photographic evidence of the Himalayan Wolf in the Rolwaling Valley.

Keywords: Camera trap, PCRI, Scat.

Nepali: चिनको तिब्बती पठार लगायत नेपाल, भारत समेतका उच्च हिमाली क्षेत्रमा पाइने हिमाली ब्वाँसो यस क्षेत्रको खाद्य शृंखलाको उच्चस्थानमा रहि पर्यावरणलाई जीवन्त राख्ने प्राणी हो । बंसाणु विश्लेषणबाट यस क्षेत्रमा पाइने ब्वाँसो युरोप, एसिया लगायतमा पाइने प्रजाति भन्दा फरक रहेको भनि प्रमाणित गरिसकेको छ, यद्दपी बाहिरी आवरणबाटमात्र छुट्टयाउन मुस्किल छ । राष्ट्रिय प्रकृति संरक्षण कोष, गौरीसंकर संरक्षण क्षेत्र आयोजनाले त्रिभुवन विश्वविद्यालय तथा जैविक विविधता अध्ययन समाज, ललितपुर समेतको सहकार्यमा संरक्षण क्षेत्रको रोल्वालिङ उपत्यकामा गरेको जैविक विविधता अध्ययनको क्रममा यस उपत्यकाका तीन स्थान(दुधकुण्डको डाँडा ५०९१ मी., च्छोरोल्पा हिमताल ४५३६ मी. र येलुङ भञ्ज्याङ ४९५६ मी.) मा ब्वाँसोको तस्वीर खिच्न सफल भएबाट यस क्षेत्रमा बिगत लामो अवधीदेखि ब्वाँसोको अवस्थितीबारेको रहेको सूचना अभावको अवस्था चिर्दै नेपालमा संरक्षित प्रजातिमा सूचीकृत यो प्रजातिको विचरण गौरीसंकर संरक्षण क्षेत्रमा रहेको प्रमाणित भएको छ । यसको अतिरिक्त स्थानीय बासिन्दाहरुसँगको छलफल तथा अनुसन्धानका क्रममा गरिएको स्थलगत निरिक्षणको क्रममा अन्य ५ स्थानमा समेत ब्वाँसोको उपस्थिति रहेको देखिएको छ । यस उपत्यकाको अलावा नुम्बुर हिमाल क्षेत्रको नुम्बुर उपत्यकामा समेत ब्वाँसोको चिन्हहरु भेटिएको छ । यसअनुसन्धानका क्रममा ब्वाँसोको उपस्थिति वृक्षरेखा भन्दा माथिका सबै मोहोडाहरु, खोलाकिनार, तथा चुचुराहरू, मानवबस्ती नजिक तथा पदमार्गमा समेत पाइएको छ । सुनपाती, डालेचुक तथा धुपीका पोथ्रा एवं बगर, हिमपहिरो र हिमनदी रहेको क्षेत्रमा समेत ब्वाँसो पाइएको छ । अनुसन्धानका लागि उपत्यकाको क्षेत्रलाई १६ वर्ग किलोमिटरका वर्गाकार क्षेत्र निर्धारण गरि सबैक्षेत्रहरुमा एउटाको दरले 'तातो रगतको उपस्थिति पत्तालगाइ स्वचालित रूपमा संचालन हुने' क्यामेरा जडान गरिएको थियो । अनुसन्धान कार्य २०७६ जेष्ठ देखि पुससम्म ६ महिना संचालन गरिएकोथियो । त्यस उपत्यकामा ब्वाँसोको संख्या यकिन गर्न नसकिएपनि त्यहाँ प्रति १०० रातमा ०.७१ पटक तस्वीर खिच्न सकिने देखिएको छ ।

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INTRODUCTION

The Himalayan Wolf *Canis lupus* is a top predator of the Third Pole (Prater 1971; Menon 2003; Chetri et al. 2017; Boitani et al. 2018; Werhahn et al. 2020). It was proposed to be a distinct wolf lineage (*C. himalayensis*; Aggarwal et al. 2007) relative to the Holarctic Grey Wolf as described by mtDNA analyses (Sharma et al. 2004; Chetri et al. 2016; Chetri et al. 2017; Werhahn et al. 2017; Boitani et al. 2018). Categorized as 'Least Concern' by the IUCN (Boitani et al. 2018), it is considered 'Critically Endangered' by the National Red List in Nepal (Jnawali et al. 2011). International trade is generally prohibited by CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora) with the Himalayan Wolves in Nepal listed under Annex 1 (listed species are the most endangered species and are threatened with extinction; CITES 2019). Furthermore, capture, killing, and trade are strictly prohibited as well by declaring this species under Schedule-I in Nepal by The National Parks and Wildlife Protection Act, 1973 (NLC 1973).

In and around the lap of the Himalaya, wolves were recorded by researchers at the Indo-Pakistan Himalaya and also from the Himachal Pradesh and Uttarakhand states of India near the western border of Nepal above 3,500 m (Sharma et al. 2004; Bhattacharya & Sathyakumar 2010; Chetri et al. 2016; Werhahn et al. 2017). In Nepal, the wolf is reported from all the Himalayan protected area systems and adjoining wilderness areas above 4,000 m (Subba et al. 2017). The areas that are considered main wolf habitat in Nepal include Manasalu and Annapurna Conservation Area (Chetri et al. 2016, 2017, Subba et al. 2017), Shey Phoksundo National Park and Humla district of western Nepal (Werhahn et al. 2017; Subba et al. 2017), Dhorpatan Hunting Reserve (Jnawali et al. 2011), and Kanchenjungha Conservation Area (Jnawali et al. 2011; Subba et al. 2017); and now its existence has also been confirmed in the Gaurishankar Conservation Area (this study).

RESEARCH METHODS

Study area

The Gaurishankar Conservation Area (GCA) is one of the newest protected areas of Nepal, covering 2,179 km² in the northern part of the Ramechhap, Dolakha, and Sindhupalchok districts of the Bagmati Province of Federal Democratic Republic of Nepal (Bajracharya et al. 2011, NLC 2074 VS). It extends between 85°46.8'-86°34.8' East & 27°34.2'-28°10' North, and ranges in elevation 980–7,134 m (Bajracharya et al. 2011; GCAP 2013). The GCA was established in 2010 (GoN 2010) connecting two national parks in the high mountains (i.e., Sagarmatha National Park in the east and Langtang National Park in the west) with the northern boundary extending to the Nepal-China border (Bajracharya et al. 2011). The valley is situated in the northeastern corner of the GCA, approximately 50 km west of Mt. Everest (Sacherer 2011).

Our study area included 16 major vegetation types, river valleys of Koshi River basin, snow-capped mountains, and temperate-alpine grasslands supporting 565 species of vascular plants, 76 (71 species described in GCAP, 2013 and five added from this study) species of mammals, 252 species of birds, 12 species of amphibians, 27 reptiles, and 27 species of fishes (Bajracharya et al. 2011; GCAP 2013). The Rolwaling valley (hereafter, "the valley" unless otherwise indicated) is home to elusive mountain species including Snow Leopard *Panthera uncia*, Red Panda *Ailurus fulgens*, Musk Deer *Moschus leucogaster*, Red Fox *Vulpes vulpes*, Himalayan Monal *Lophophorus impejanus*, Satyr Tragopan *Tragopan satyra*, and many more species. The valley elevation ranges 2,000–7,134 m.

Gaurishankar Conservation Area includes two 'beyul' (a Tibetan word meaning sacred) valleys named Lapchi and Rolwaling where the majority of human inhabitants (i.e., the Sherpa community) follow Buddhism where as in other valleys, there is a mosaic of Hindu-Buddhist religion occurring (Bajracharya et al. 2011; Sacherer 2011; GCAP 2013). The Rolwaling valley is sacred landscape guided by Tibetan Buddhism and inhabited by the Sherpa community. Followers of the 'Padmasambhava' sects of Buddhism (Sacherer 2011) strictly obey and maintain a ban on animal sacrifice and consumption of animal meat, and people in this region believe that consuming meat products and burning of garlic brings misfortune (Lama 2019). Thus, wild animals are not harvested for their meat, providing some measure of wildlife protection. Traditionally, the valley dwellers rely on the agro-pastoral economy with transhumance animal herding, the primary cause of human-wolf negative interaction in this valley. Although, the killing of animals is prohibited, the last known wolf pack in this area was poisoned by Yak herders ~50 years ago (Sherpa 2019).

The Rolwaling Valley (215 km²) covers the landscapes of lower temperate forests up to the alpine zone. Major vegetation types of the study area were *Quercus* forests, lower-temperate mixed broadleaved forests, upper

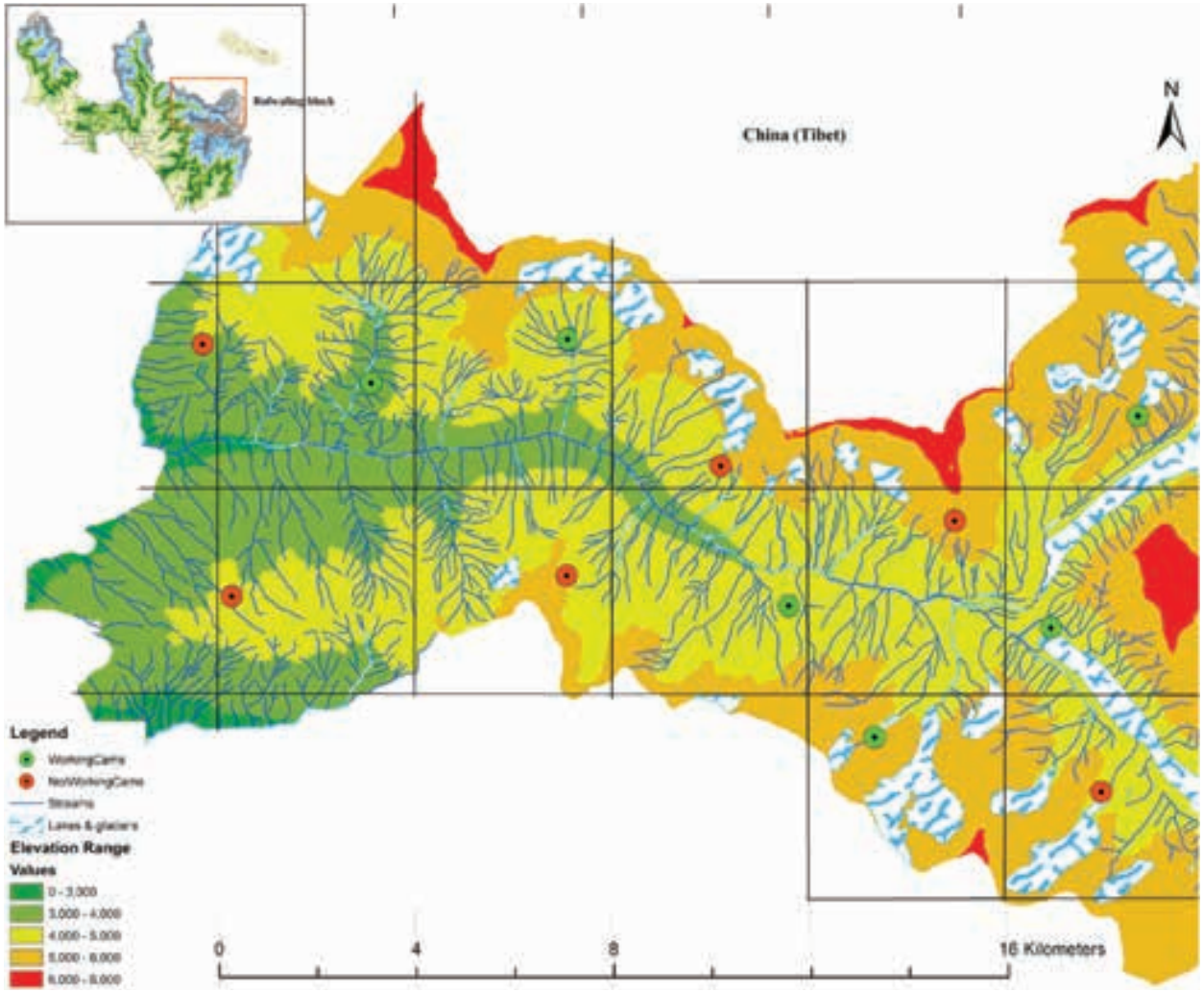

Figure 1. Research blocks in Gaurishankar Conservation Area.

temperate broadleaved forests, rhododendron forests, and upper temperate conifer forests (Bajracharya, et al. 2011). The higher areas are covered by *Abies-Juniper* forests and birch-rhododendron forests, whereas the alpine zone comprises alpine shrub land, scrubland, open grassland, glaciers, and rocky outcrops (Bajracharya et al. 2011; GCAP 2013). Himalayan Tahr *Hemitragus jemlahicus*, Hanuman Langur *Semnopithecus* schistaceus., Common Goral *Naemorhedus goral*, Assamese Monkey *Macaca assamensis*, Himalayan Monal, Blood Pheasant, Royal's Pika *Ochotona roylei* are frequently observed along the trails while pellets of Red Panda *Ailurus fulgens,* Musk Deer *Moschus leucogaster* and Himalayan Serow *Capricornis thar* are visible in off trails. Scats and fresh tracks of Snow Leopard *Panthera uncia*, common Leopard *Panthera pardus*, Wolf, Red Fox, and Weasels *Mustella* sp. are common along the forest trails used by local herders, livestock, and wildlife. Important prey species for top predators of high mountain; the Blue Sheep has neither been reported by researchers (Ale et al. 2010) nor by the local herders in this valley (Lama 2019; Sherpa 2019) though historical collection of Blue Sheep horn is reported in Ale et al. (2010).

Blocks and grids

We divided the GCA into five blocks as defined by geographical barriers and ease of research management and we selected the Rolwaling Valley block for this study. A recent research objective in this valley was to assess mammalian diversity, with grids created to target Snow Leopard detection (Jackson et al. 2005). The valley covers 215 km^2 with accessible areas divided into 16 km^2 square grids (Figure 1) following Jackson et al. (2005). We focused our monitoring efforts on those grids above 3,000 m targeting large mammals

of the upper temperate-alpine region with low human habitation (Bajimaya 2000). Altogether, we placed one camera in each of the12 grids that were 3,000–5,500 m in elevation.

Camera trapping

In the current study, the target species were the elusive species of the highlands including the Snow Leopard, Wolf, Lynx and their prey species. Camera trapping was selected as the primary method given feasibility and logistical challenges. (i.e., limited resources precluded transect and genetic surveys).

The study team tried to minimize disturbance to wildlife throughout the survey, although livestock herders traveled periodically to the survey area. Cameras were placed far from major trekking routes and the primary trails used by herders were omitted for camera security reasons. This also minimized the chance of capturing images of non-target animals (livestock) and humans. Cameras were left unattended for an extended period (around six months), during which the possibility of wildlife occurrence was estimated to be the highest based on various signs and marks of animals.

Bushnell Trophy Camera Brown (Model 119436) and Bushnell Trophy Camera w/viewscreen (Model 119455) were used for monitoring animals. Cameras operated continuously for six months between 09 June and 09 November 2019. Cameras were set to image capture mode with one minute lag between triggers with three images captured per trigger. No fixed camera height was applied as per the objective of the study but cameras were set to focus around 30 cm height over the trail i.e. some cameras were tilted to achieve the specified focal height.

We identified sites of likely animal movement within each grid by visually examining the site characteristics. The sites with high frequency of signs of animal like tracks, scat deposits, pellets, rubbing on trees, scent marks, and trail junctions were selected for camera installment, following the Snow Leopard monitoring manual for Nepal (Bajimaya 2000). Moreover, valley bottoms and ridgelines, where the likelihood of megafauna movement is high (Jackson et al. 2005), were also selected for camera deployment. No baits or trail modifications were used.

Data analysis

Photocapturerate index (PCRI) is used as an index of animal abundance because of its general relationship with the density of target species (Rovero & Marshall 2009: Lahkar et al. 2018). Although, its application is better suited to the prey species (Rovero & Marshall 2009; Lahkar et al. 2018), we applied it to predators as well because of limited data available for capture recapture analysis and because individual identification of wolves was not reliable.

We calculated total operation time summing up data from all cameras that were functional (6 out of 12) (i.e., six cameras were not functional: four cameras triggered continuously resulting in filled SD cards within a couple of days, rain water leakage damaged the storage device in one camera, and one camera was lost during this study). Every photo event was recorded by a photo analysis using a digital projector. To define a photographic event, 30 minutes between events of same species was used to assure independent data points.

Additional lines of evidence

Wolf scats were opportunistically observed and recorded during other field work. Also, interviews were conducted with local herders to obtain information on wolf depredation of livestock in the area.

RESULTS AND DISCUSSION

The PCRIs for mammals and birds were calculated separately (Table 1). Among mammals, Pika was the most frequently photographed, followed by cattle (Yak), Red Fox, Yellow-bellied Weasel, and Wolf (0.71 animals per 100 nights, i.e., 0.71 PCRI values) (Table 1). Ungulate prey species that are frequently observed along mountain slopes, such as the Himalayan Tahr, Common Goral, and the Himalayan Serow, had lower PCRI values. However, game birds such as Blood Pheasant, Himalayan Snow Cock, and Himalayan Monal, were frequently photographed (Table 1).

Based on the photographic evidence, all wolf detections consisted of single wolves, no packs or pairs were detected in the six captures of wolf (Figure 2). Sniffing on scent sprays and travel were common behaviors observed. The movements of wolf were recorded by three cameras located at 5,091 m, 4,536 m, and 4,956 m in the Rolwaling Valley. This is the first ever photographic record of wolf presence, not only in Rolwaling Valley, but also in the GCA.

Wolves were captured during early morning (07:12:14), mid-day (14:07:19 & 16:47:03), and night (01:22:02, 04:05:35, 20:57:31). All the capture sites were in open grass land and moraines above tree line. No preference over the geographical aspects was observed as animals were caught on southern, valley bottom,

Table 1. Photo capture rate index (PCRI) values for captured animals.

Mammals			Birds		
Species	**Events**	**PCRI**	**Species**	**Events**	**PCRI**
Pika	75	8.85	Blood Pheasant	28	3.30
Cattle	66	7.78	Himalayan Snow Cock	25	2.95
Red Fox	23	2.71	Red-billed Chough	20	2.36
Yellow-bellied Weasel	8	0.94	Himalayan Monal	14	1.65
Wolf	**6**	**0.71**	Blue Whistling Thrush	6	0.71
Common Goral	4	0.47	Alpine Accentor	2	0.24
Himalayan Serow	3	0.35	Hoopoe	2	0.24
Stone Marten	3	0.35	Snow Partridge	2	0.24
Snow Leopard	3	0.35	Laughing Thrush	1	0.12
Human	2	0.24	Raptor	1	0.12
Yellow-throated Marten	2	0.24	Tibetan Snow Cock	1	0.12
Himalayan Tahr	1	0.12	Yellow-billed Chough	1	0.12
Musk Deer	1	0.12			
Red Panda	1	0.12			
Small cat	1	0.12			
Total mammal events	198		Total bird events	103	

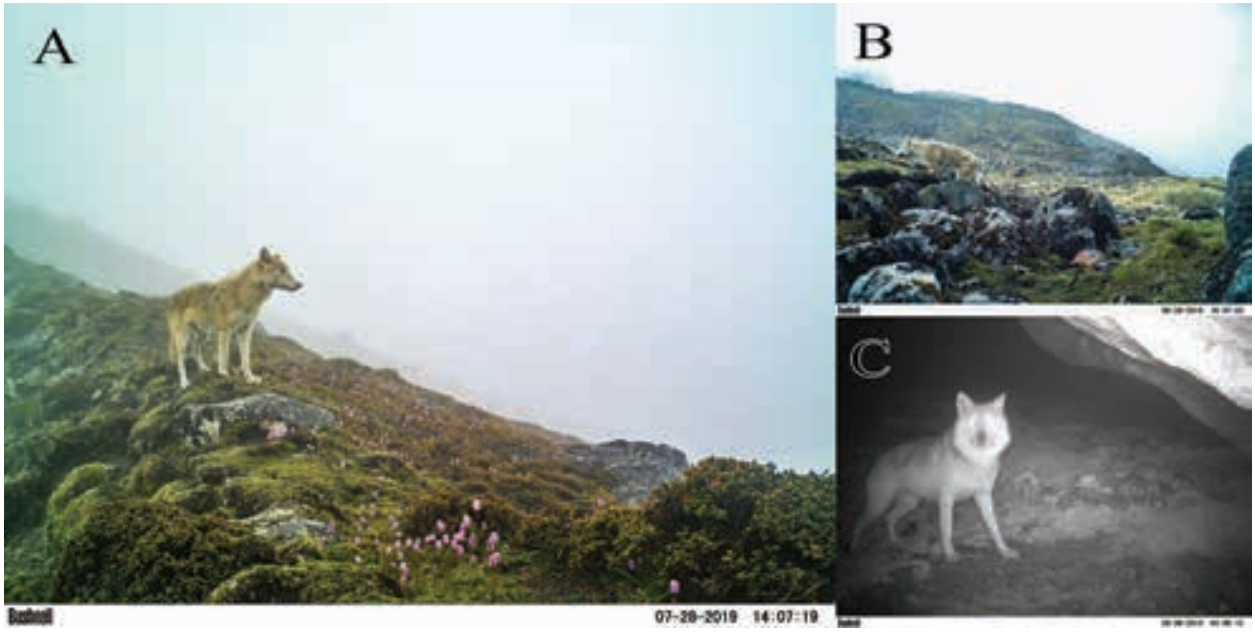

Image 1. Photographs from all sites of Wolf captures: A—from Dudhkunda ridgeline | B—from Yalung pass | C—from Tsho-Rolpa glacial lake. © NTNC/GCAP.

and northern aspects. Interestingly, the Wolf and Snow Leopards were using the same trails and deposited their signs in front of the camera. The other predators captured were Red Fox, Yellow-bellied Weasel were captured on the sites where Wolves were captured; so were the Pika, Yak, and Snow Cocks. The cameras in the periphery recorded Musk Deer, Red Panda, Himalayan Monal, Blood Pheasant *Ithaginis cruentus,* Goral, Himalayan Tahr, Himalayan Serow, and some small birds. Despite evidence of frequent human disturbances (such as tourist's visits, animal herding, pilgrimage), just a single event was recorded by a camera during our study.

Image 2. Scat observed in: a—Dudhkunda moraine at 4,735 m | b—Ramding up at 4,072 m | c—Gumdel at 4,017m. © Authors.

Table 2. Other signs of wolf presence in the Rolwaling valley.

Place	Altitude (in m)	Aspect (degrees)	Slope (degrees)	Sign type	Age	Habitat	Vegetation	Disturbance	Remarks
Ramding Up	4,072	110	22	Scat	Fresh	Scrubland	*Rhododendron anthopogon*	Mountaineering & Grazing	During site selection
Beding-Na	3,967	192	23	Livestock depredation	Old	Scrubland	*Juniperus*sp	Trekking & Grazing	Inferred from interview
Na	4,413	262	40	Livestock depredation	Fresh/ old	Scrubland	*Rhododendron anthopogon*	Trekking & Grazing	Inferred from interview
TshoRolpa-Dudhkunda	4,735	312	5	Scat	Old	Moraine	*Rhododendron anthopogon*	Trekking & Grazing	During site selection
Dudhkunda lekh (near camera trap)	5,060	265	28	Scat	Old	Open grassland	Grasses	Grazing	During site selection
Dudhkunda	4,872	187	15	Scat	Old	Glacier	*Rhododendron anthopogon*	Trekking & Grazing	During site selection
Gumdel (outside this valley)	4,017	307	38	Scat	Fresh (collected in 2016)	Scrubland	*Abies spectabilis*	Grazing	During reconnaissance survey

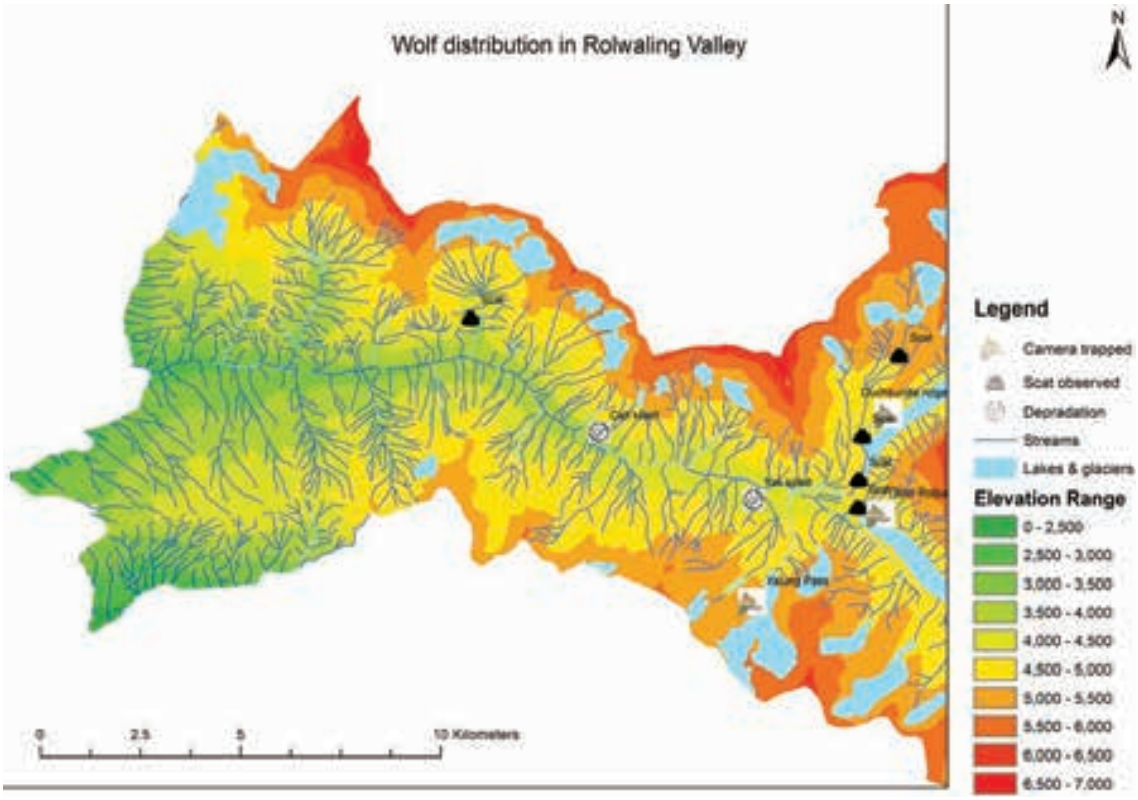

Figure 2. Wolf detections from camera traps, scat, and depredations recorded in the Rolwaling Valley, Nepal during 2019.

Scat observation and depredation history

Scats of wolves were observed during transect walks for finding suitable camera sites (Figure 3). Identifiable scats were observed over 3,900 m on *Rhododendron anthopogon* dominated scrublands, on the human/domestic animal tracks. Also, tracks were observed in moraines. Recently, a couple of livestock depredation events near Naa village of the valley were recorded. In both occasions herders had managed to chase down small packs of Wolves (Lama 2019; Sherpa 2019). Table 2 and Figure 2 show the sites where signs of Wolf were found and general site characteristics. Earlier, a reconnaissance survey carried out by GCAP (2016) also observed Wolf scat in the Numbur Valley (behind Yalung Peak).

Although, the presence of the wolf in GCA was reported based on interviews and indirect signs (Bajracharya et al. 2011), our study confirms its presence through photographs, scat observations, and information from livestock depredations (Figure 4). This paper reports the first visual proofof the wolf in Rolwaling Valley. To our knowledge, this is probably the first ever photograph of the wolf in the Gaurishankar landscapes visually confirming its re-colonization in the valley.

CONCLUSION

This study provides the first ever photographic evidence confirming the presence of the Himalayan Wolf in the northern area (Rolwaling region) of GCA in Nepal. Six wolf-detection events were obtained by camera trapping, all consisting of single wolves. Also, the five wolf scats and tracks that were observed during camera sites selection and depredation information from local interviewees further confirmed the wolf's presence in this area. The sites, where the evidence of wolf were confirmed, also overlapped with areas used by snow leopard and red foxes. Although, this study was not intended to quantify human-carnivore conflict, interviews confirmed that Snow Leopards are not the only predators in Rolwaling region that accounts for human wildlife interactions, especially in relation to the depredation of domesticated animals such as mountain goat and sheep, as well as Yak and 'Djokpa' (cross breed between Yak and cow). Our study aimed to assess the mega faunal biodiversity in the Rolwaling area. Additional research is warranted, specifically a more in-depth assessment of the status, habitat range, behavior and ecological role of the Wolf. In part because wolves may be contributing to human wildlife conflict in the high Himalayan regions, conservation interventions may be needed to prevent local extinction of this species as a result of human-retaliatory killings. Furthermore, because the taxonomy of this Wolf is being debated and may result in a unique species identified, we suggest a precautionary conservation strategy be developed and implemented.

REFERENCES

Ale, S.B., K. Thapa, R. Jackson & D. Smith (2010). The fate of snow leopards in and around Mt. Everest. IUCN SSC, Cat Specialist Group. *CAT News* (N°53 Autumn 2010) http://www.catsg.org/index.php?id=188

Aggarwal, R.K., T. Kivisild, J. Ramadevi & L. Singh (2007). Mitochondrial DNA coding region sequences support thephylogenetic distinction of two Indian wolf species. *Journal of Zoological Systematics and Evolutionary Research* 45: 163–172. https://doi.org/10.1111/j.1439-0469.2006.00400.x

Ancrenaz, M., A.J. Hearn, J. Ross, R. Sollmann & A. Wilting (2012). *Handbook of Wildlife Monitoring using Camera-traps.* Bornean Biodiversity & Ecosystems Conservation Programme Phase II (BBEC II) in Sabah, Malaysia Secretariat.

Bajimaya, S. (2000). *Snow Leopard Manual; Field study techniques for the Kingdom of Nepal (ED. R.M. Jackson and K. Froede.* Worldwide Fund for Nature (WWF), Kathmandu, Nepal.

Bajracharya, S.B., G. Basnet, F. Kharel, K.B. Shah, H.S. Baral & R. Charmakar (2011). *Gaurishankar Conservation Area; A Treasure House of Himalayan Bidodiversity.* National Trust for Nature Conservation. Lalitpur, Nepal.

Bhattacharya, T. & S. Sathyakumar (2010). Sighting of Tibetan wolf *Canis lupus chanko*in the Greater Himalayan range of Nanda Devi Biosphere Reserve, Uttarakhand, India; a new record. *Journal of Threatened Taxa* 2(12): 1345–1348. https://doi.org/10.11609/JoTT.o2423.1345-8

Boitani, L., M. Phillips & Y. Jhala (2018). *Canis lupus.* The IUCN Red List of Threatened Species 2018: e.T3746A119623865. https://doi.org/10.2305/IUCN.UK.2018-2.RLTS.T3746A119623865.en

Chalise, M.K. (2016). *Nepal's Wildlife (नेपालका वन्यजन्तु)* Part 4. Nepal Biodiversity Research Society (NEBORS), Lalitpur, Nepal.

Chetri, M., Y.V. Jhala, S.R. Jnawali, N. Subedi, M. Dhakal & B. Yumnam (2016). Ancient Himalayan wolf (*Canis lupus chanko)* lineage in Upper Mustang of the Annapurna Conservation Area, Nepal (ED K. M. Helgen). *ZooKeys* 582: 143–156.

Chetri, M., M. Odden & P. Wegge (2017). Snow leopard and wolf; Food, habits and prey selection in the Central Himalayas, Nepal. *Public Library of Science (PLOS) One* 12(2).

CITES (2020). *Convention on International Trade in Endangered Species of Wild Fauna and Flora.* UNEP. https;//cites.org/eng/app/appendices.php Accessed on 20 February 2020.

GCAP (2013). *Gaurishankar Conservation Area Management Plan for 2013–2017.* National Trust for Nature Conservation, Gaurishankar Conservation Area Project, Dolakha, Nepal.

GoN (2010). "Nepal Gazzette, Section 59, Number 38, Dated January 11, 2010." *Notice of Ministry of Forests and Soil Conservation.* Kathmandu: Government of Nepal.

GoN (2010). "Nepal Gazzette, Section 60, Number 14 Dated July 19, 2010." *Notice of Ministry of Forests and Soil Conservation.* Kathmandu: Government of Nepal.

Guil, G., S. Agudín, N. El-Khadir, M. ernandez-Olalla, J. Figueredo, F.G. Domínguez, P. Garzon, G. Gonzalez, J. Muñoz-Igualada, J. Oria & F. Silvestre (2010). Factors conditioning the camera-trapping efficiency for the Iberian lynx (*Lynx pardinus*). *European Journal of Wildlife Research* 56(4): 633–640.

Jackson, R.M., J.D. Roe, R. Wangchuk & D.O. Hunter (2005). "*Camera-Trapping of Snow Leopards*." Snow Leopard Conservancy & Department of Wildlife Protection, Jammu & Kashmir State.

Jnawali, S.R., H.S. Baral, S. Lee, K.P. Acharya, G.P. Upadhyay, M. Pandey, R. Shrestha, D. Joshi, B.R. Lamichhane, J. Griffiths, A.P. Khatiwada, N. Subedi & R. Amin (2011). *The Status of Nepal's Mammals.* The World Conservation Union (IUCN), Nepal.

Kelly, M.J. (2008). Design, evaluate, refine: camera trap studies for elusive species. *Animal Conservation* 11(3): 182–184.

Lahkar, D., M.F. Ahmed, R.H. Begum, S.K. Das, B.P. Lahkar, H.K. Sarma & A. Harihar (2018). Camera-trapping survey to assess diversity, distribution and photographic capture rate of terrestrial mammals in the aftermath of the ethnopolitical conflict in Manas national park, Assam, India. *Journal of Threatened* Taxa 10(8): 12008-12017. https://doi.org/10.11609/jott.4039.10.8.12008-12017

Lama, N.G. (2019). Interview by Bishnu Prasad Pandey. Interview about the mammalian diversity and culture in Rolwaling Valley.

Menon, V. (2003). *A Field Guide to Indian Mammals.* Dorling Kindersley (India) Pvt. Limited, 164pp.

NLC (2072 VS). *National Parks and Wildlife Conservation Act, 1973* (unofficial translation). Nepal Law Commission, Kathmandu, Nepal.

NLC (2074 VS). *स्थानीय सरकार संचालन ऐन, २०७४ (translated as "Local Government Administration Act, 2074 VS").* Act No. 26 belonging to the Year 2074 (2016/17). Nepal Law Commission, Kathmandu.

Prater, S.H. (1971). *The Book of Indian Animals.* Twelfth reprint, 2005. Volume 3. Bombay Natural History Society, Bombay.

Rovero, F. & A.R. Marshall (2009). Camera trapping photographic rate as an index of density in forest ungulates. *Journal of Applied Ecology* 46: 1011–1017. https://doi.org/10.1111/j.1365-2664.2009.01705.x

Sacherer, J. (2011). Rolwaling: A Sacred Buddhist Valley in Nepal. *Sacredscapes and Pilgrimage Systems*, by Rana P.B. Singh. Shubhi Publications, New Delhi.

Sharma, D.K., J.E. Maldonado, Y.V. Jhala & R.C. Fleischer (2004). *Ancient wolf lineages in India. Proceedings of the Royal Society of London*. Royal Society of London.

Sherpa, P.G. (2019). Interview by Bishnu Prasad Pandey. Interview about the mammalian diversity and culture in Rolwaling Valley.

Silveira, L., A.T.A. Jacomo, J. Alexandre & F. Diniz-Filho (2003). Camera trap, line transect census and track surveys: a comparative evaluation. *Biological Conservation* 114: 351–355.

Subba, S.A., A.K. Shrestha, K. Thapa, S. Malla, G.J. Thapa, S. Shrestha, S. Shrestha, N. Subedi, G.P. Bhattarai & R. Ottvall (2017). Distribution of Grey Wolves *Canis lupus lupus* in the Nepalese Himalaya: implications for conservation management. *Oryx* 51(3): 403–406. https://doi.org/10.1017/S0030605316000296

Werhahn, G., H. Senn, J. Kaden, J. Joshi, S. Bhattarai, N. Kusi, C. Sillero-Zubiri & D.W. Macdonald (2017). Phylogenetic evidence for the ancient Himalayan wolf: towards a clarification of its taxonomic status based on genetic sampling from western Nepal. *Royal Society Open Science* (rsos.royalsocietypublishing.org) Volume 4.

Werhahn, G., Y. Liu, Y. Meng, C. Cheng, Z. Lu, L. Atzeni, Z. Deng, S. Kun, X. Shao, Q. Lu, J. Joshi, A.M. Sherchan, D. Karmacharya, H.K. Chaudhary, N. Kusi, B. Weckworth, S. Kachel, T. Rosen, Z. Kubanychbekov, K. Karimov, J. Kaden, M. Ghazali, D.W. Macdonald, C. Sillero-Zubiri & H. Senn (2020). Himalayan wolf distribution and admixture based on multiple genetic markers. *Journal of Biogeography* 47: 1272–1285. https://doi.org/10.1111/jbi.13824

Author details: Mr. Bishnu Prasad Pandey, Conservation Officer at National Trust for Nature Conservation (NTNC), Gaurishankar Conservation Area Project, Unit Conservation Office, Chaku, Sindhupalchok, Nepal. Prof. Dr. Mukesh Kumar Chalise, Professor of Zoology at Tribhuvan University, Central department of Zoology, Kirtipur, Nepal and President at Nepal Biodiversity Research Society (NEBORS), Lalitpur, Nepal. Mr. Shankarman Thami, Natural Resource Conservation Assistant (NRCA) at National Trust for Nature Conservation (NTNC)/ Gaurishankar Conservation Area Project (GCAP). Mr. Rabin Shrestha, Natural Resource Conservation Assistant (NRCA) at National Trust for Nature Conservation (NTNC)/Gaurishankar Conservation Area Project (GCAP).

Author contributions: BPP—team leader for research design, field work, data analysis, mapping and manuscript preparation. MKC—research design, data analysis, manuscript preparation and review. He was the mentor for this study. ST—fieldwork, data gathering, sorting, analysis, map work and manuscript preparation and review. RS–data gathering, sorting, analysis, map work and manuscript preparation and review.

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Group size, crowding, and age class composition of the threatened Sambar *Rusa unicolor* (Kerr, 1792) (Mammalia: Cetartiodactyla: Cervidae) in the semi-arid regions of northeastern Rajasthan, India

Deepak Rai [1] & **Kalpana** [2]

[1,2] Animal Behaviour and Wildlife Conservation Laboratory, Department of Zoology, Kurukshetra University, Thanesar, Kurukshetra, Haryana 136119, India.
[1] drbkuk@gmail.com (corresponding author), [2] kpoonia138@gmail.com

Abstract: Grouping characteristics and population growth dynamics of Sambar were studied in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) in Rajasthan, India from July 2018 to June 2019. Following the scan sampling method, a total of 117 sightings of Sambar (N= 488 individuals) were recorded in BJCR, and 106 in BJ (N= 389 individuals), during 24 fortnightly visits. The data revealed that besides solitary sightings of Sambar, groups ranging from 2–11 and 2–12 individuals were observed in BJCR and BJ, respectively. The overall mean group size and mean crowding of Sambar were 4.2±0.2 S.E. and 5.3 respectively in BJCR, and 3.7±0.2 S.E. and 5.0 respectively in BJ. The sex ratio was skewed towards females. The overall adult male: adult female: fawn ratio was 74.4: 100: 47.1 (N= 488 individuals) in BJCR while the ratio was 92.6: 100: 41.1 (N= 389 individuals) in BJ. As far as the social organization of Sambar is concerned, six types of herds were recorded in the present study. It is urged that sambar populations outside protected area also need simultaneous strategies for conservation attention.

Keywords: Population structure, sex ratio, ungulates.

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Author details: Dr. Deepak Rai is an Associate Professor in Department of Zoology, Kurukshetra University, Kurukshetra, Haryana, India. His field of research includes ornithology, animal ecology and wildlife conservation. Ms. Kalpana is a research scholar and pursuing her PhD from Department of Zoology, Kurukshetra University, Kurukshetra.

Author contributions: Deepak Rai and Kalpana conceived and designed the study. Kalpana collected the field data and prepare rough draft of the manuscript. Deepak Rai guided the research, analyzed the data and wrote the final draft of the manuscript.

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INTRODUCTION

Group size and population structure are basic aspects of mammal population monitoring and effective conservation planning (Bagchi et al. 2008; Debata & Swain 2019). Group size varies widely between and within species (Barrette 1991; Ramesh et al. 2012a) and the group size of ungulates is a reflection of resource distribution, habitat structure, home range, mating systems, intraspecific competition, and predation risk (Pulliam & Caraco 1984; Lagory 1986; Raman 1997; Simcharoen et al. 2014). For example, many ungulates show large group sizes when food resources are adequate, but when food is in limited supply they fragment into smaller groups (Karanth & Sunquist 1992; Bagchi et al. 2003; Ramesh et al. 2012b). Ungulates also tend to assemble in larger groups in open habitats, but not in dense scrubland. Thus observed group sizes indicate a balance between the benefits of group living, such as better foraging efficiency and safety from predators, and the costs, such as competition for food resources (Krebs et al. 1972).

Ungulates show a fission-fusion system of fluid group formation where individuals are free to leave or join a given group (Barrette 1991; Raman 1997). Depending on the various ecological factors involved, two measures of group size are commonly used: mean group size and typical group size. Mean group size is measured from an outsider's point of view, while typical group size is assessed from the perspective of group members (i.e., as crowding; Jarman 1974; Reiczigel et al. 2005; Reiczigel et al. 2008). The age structure of a population is represented in terms of the distribution of number of individuals from each age class which corresponds to fecundity, mortality, reproductive status and population increase of a particular species (Clutton-Brock et al. 1980). The reproductive potential of a species can be calculated from sex ratio of that species (Ramesh et al. 2012a,b).

Sambar *Rusa unicolor* (Kerr, 1792) is the largest deer species in southern and southeastern Asia. In the Indian subcontinent, the species is widely distributed and occurs in 208 protected areas (Sankar & Goyal 2004; Timmins et al. 2015). Sexes of *Rusa unicolor* are distinguished by size (males 225–320 kg; females <180 kg), the presence or absence of antlers (present only in males), and body coloration (generally lighter color of females and young than the males) (Jain et al. 2018). The males have longer hair on the upper surface of the neck and back. The wild population of this species is under stress due to loss of its natural habitats, anthropogenic activities such as hunting, poaching, urban expansion and agriculture expansion (Chatterjee et al. 2014). The Sambar is listed as 'Vulnerable' as per the IUCN Red List (2008) due to an estimated decline of 30%–50% population over the past three generation (Timmins et al. 2015) and it is also listed in Schedule III of the Indian Wildlife Protection Act (IWPA) 1972.

Various ecological and behavioral aspects including group size as well as density of Sambar were studied in Kanha National Park (Schaller 1967; Poruse 1996), Bandipur National Park (Johnsingh 1983), Mundanthurai (Johnsingh & Sankar 1991), Nagarhole National Park (Karanth & Sunquist 1992), Mudumalai (Verman & Sukumar 1993, Ramesh et al. 2012a), Corbett National Park (Pant et al. 1999), Periyar Tiger Reserve (Harikumar et al. 1999), Pench Tiger Reserve (Biswas & Sankar 2002), Ranthambore Tiger Reserve (Bagchi et al. 2003), and Sariska National Park (Chatterjee et al. 2014). But few studies have been conducted on Sambar in northeastern Rajasthan. Hence the present study was conducted to obtain information on group size including crowding, population structure, variation in social organization and other ecological aspects with respect to Sambar, which will be helpful in planning effective conservation strategies for this threatened species.

MATERIALS AND METHODS

Study areas

The present study was carried out in two selected study sites, namely, Bir Jhunjhunu Conservation Reserve (BJCR), district Jhunjhunu and Bairasar Johad (BJ), village Bairasar Bara, district Churu of state Rajasthan from July 2018 to June 2019.

Bir Jhunjhunu Conservation Reserve, Jhunjhunu (BJCR)

The area lies between 28.158° N & 75.416° E alongside the Jhunjhunu-Chirawa state highway, and covers an area of 1,047 ha (Figure 1). As far as the floral diversity of the area is concerned, 440 plant species were identified (Dev & Singh 2016). In this study area, Sambar coexists with other mammals including Nilgai *Boselophus tragocamelus*, Chinkara *Gazella bennettii*, Desert Fox *Vulpes vulpes*, and the wildcat *Felis silvestris*, and around 95 bird species (Shekhawat & Bhatnagar 2014).

Bairasar Johad (BJ), village Bairasar Bara

Bairasar Johad, village Bairasar Bara (28.88°N & 75.641°E) is part of tehsil Rajgarh of district Churu

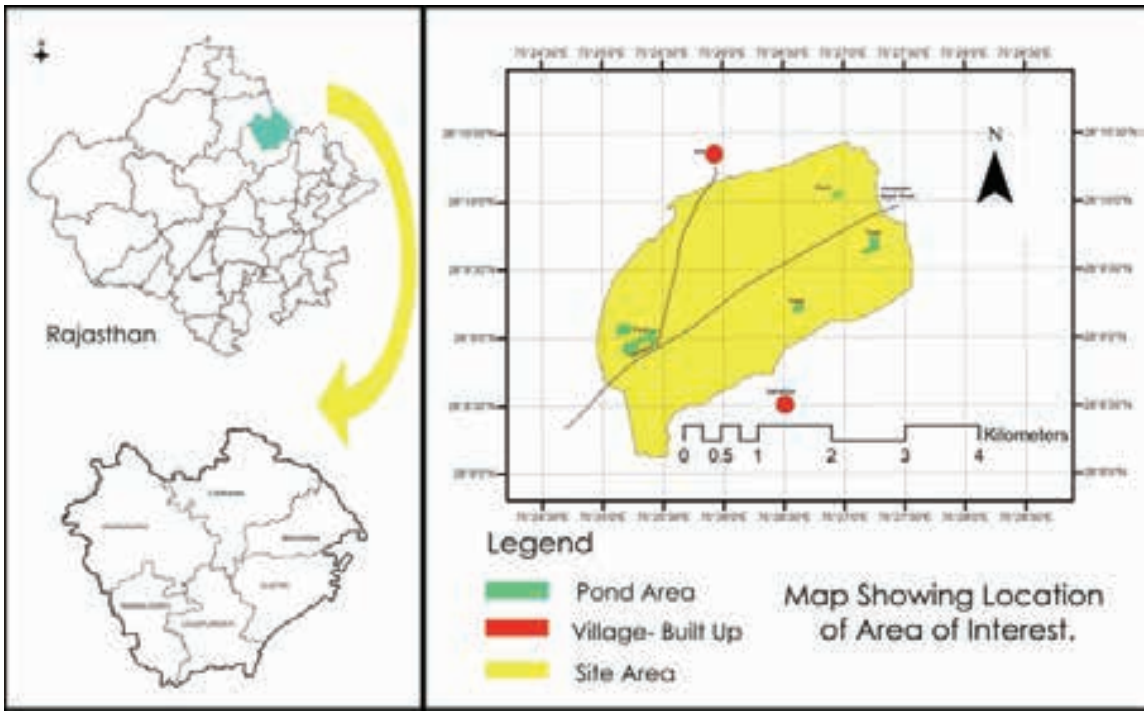

Figure 1. Bir Jhunjhunu Conservation Reserve (BJCR) in district Jhunjhunu, Rajasthan (India) (Rai & Kalpana 2019).

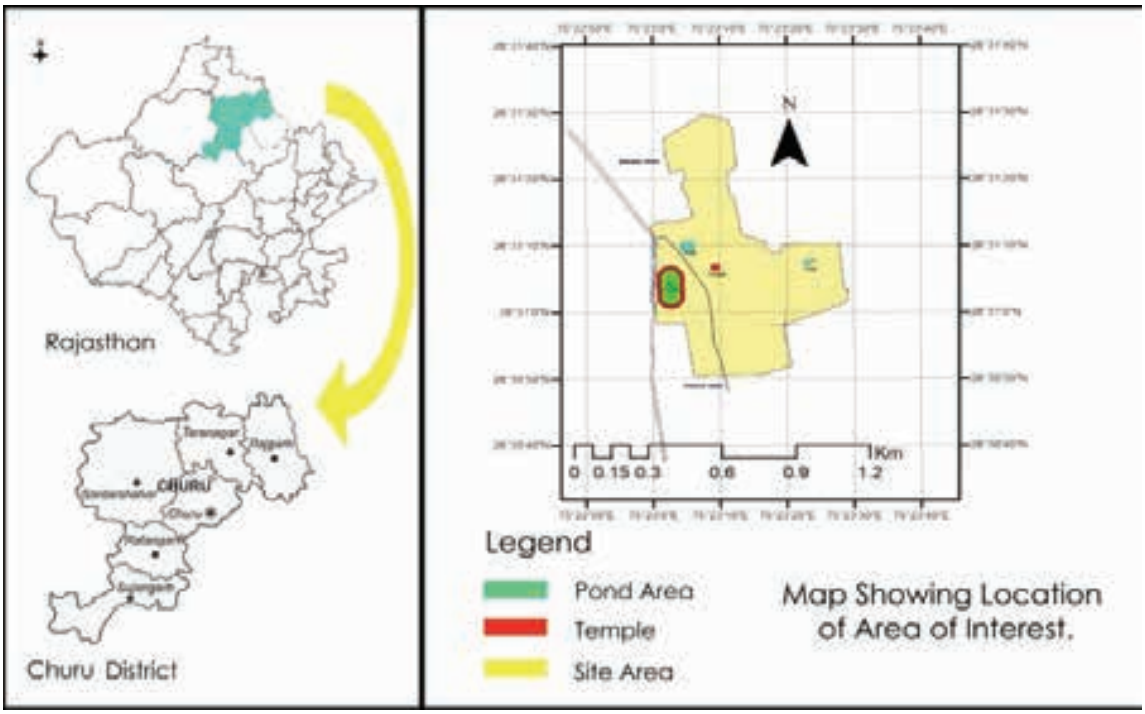

Figure 2. Bairasar Johad (BJ), village Bairasar Bara in district Churu, Rajasthan (India) (Rai & Kalpana 2019).

(Rajasthan) and is bordered by the Rajgarh-Jhunjhunu state highway (Figure 2). This region covers an area of about 14.72 ha. Dominant wild fauna found in the study area include Nilgai, Chinkara, and Sambar (Dev & Singh 2016).

Both the study sites are situated in the shekhawati region of India's Thar desert. Climatic conditions are semi-arid, and there are three distinct seasons: summer

(March to June), monsoon (July to October), and winter (November to February). Summers are very hot (up to 50°C) and winters cold (0°C) (Dev & Singh 2016). Annual rainfall varies 300–400 mm. Major soil types are sand, sandy loam and salt affected black soil. The study areas were divided into three major habitats: fallow land, scrubby forest, and agricultural fields. The vegetation of this semi-arid region falls under the category of tropical desert thorn species predominantly of xerophytes (Dev & Singh 2016).

Data collection and analysis

To obtain information on group size, population structure and herd composition of Sambar, 24 fortnightly visits were conducted from July 2018 to June 2019 in accordance with Chopra & Rai (2009) and Rai & Jyoti (2019). Data collection was done using the scan sampling method (Altmann 1974) from random observation points. The time of observation was divided into three diurnal phases: morning (0630–1100), noon (1100–1500), and evening (1500–1800). The observations were made in different phases during different visits on a periodic basis.

On each sighting of Sambar, the following information was recorded: sex, age class, group size as well as number of groups. A group was defined following Schaller (1967) as a number of the individuals in different age classes exhibiting cohesive activity (movement in the same direction) and close proximity to each other (less than 30 m apart).

Age class composition was based on earlier studies (Schaller 1967) and recorded individuals were categorized as: adult male (>1 feet antlers), sub-adult male (spike and <1 feet antlers), adult female (morphological characters), sub-adult female (height of individuals above the adult female belly and morphological characters), and fawn (size equal and less to the height of mother's belly).

Groups of Sambar were categorized as: (i) lone territorial male/female; (ii) unimale-unifemale group consisting of one adult male & one adult female; (iii) female group consisting of adult female(s), sub-adult female(s), & fawn(s); (iv) bachelor group consisting of adult male(s) & sub-adult male(s); (v) harem consisting of one adult male, adult female(s), sub-adult female(s), & fawn(s); and (vi) mixed group consisting of adult(s) & sub-adult(s) of both sexes and fawn(s) (Image 1).

The ratio of adult male: adult female: fawn was calculated. Mean crowding and mean group size was calculated by using the program Flocker1.0 (Reiczigel & Rozsa 2006; Reiczigel et al. 2008) and obtained data was also cross checked by using the following formulae as per Jarman (1982) who used typical group size instead of mean crowding.

$$\text{Mean group size of Sambar} = \frac{\text{Number of Sambar seen}}{\text{Number of sightings}}$$

$$\text{Mean crowding} = \frac{\sum_{i=0}^{i=n}(x_i)2}{N}$$

where,

x_i= number of individuals in the i^{th} group/sighting

n= number of groups

N= total number of individuals

Statistical analysis of the data was done by using Mann-Whitney test (U) to determine the significant differences in mean group size of Sambar between two seasons and Kruskal Wallis test (K) between all the three seasons using SPSS 16.0 packages.

RESULTS AND DISCUSSION

During the field surveys from July 2018 to June 2019 in Bir Jhunjhunu Conservation Reserve, 117 sightings of Sambar comprising 488 individuals were recorded varying from a minimum of one to a maximum of 11 individuals per group sighting during 24 fortnightly visits (Figure 3). Similarly, in Bairasar Johad, a total of 106 sightings of Sambar comprising of 389 individuals were observed with group size varying of 1–12 individuals per group sighting (Figure 4). As far as the variation in number of group sightings per periodic visit was concerned, a minimum of three to a maximum of six group sightings were made during the visits. The overall mean group size observed was 4.17±0.20 S.E. and mean crowding was 5.34 in Bir Jhunjhunu Conservation Reserve. Similarly, the overall mean group size and mean crowding value was 3.67±0.21 S.E. and 5.04, respectively, in Bairasar Johad (Table 1). The highest mean group size was observed during summer season and the lowest mean group size was observed during monsoon season in both of the study sites. The highest mean crowding was recorded during the summer season in Bir Jhunjhunu Conservation Reserve while in Bairasar Johad the highest mean crowding was recorded in winter season. It probably coincides with scarcity of food resources in the study areas during summer and winter seasons. Lowest value of mean crowding was observed in monsoon season when group size of Sambar increased due to adult male joining female group during breeding season. Therefore, variation in group size was lower in monsoon season. Earlier, similar observations on group size have been observed by Bagchi et al. (2008).

Mann Whitney U test and Kruskal Wallis test results

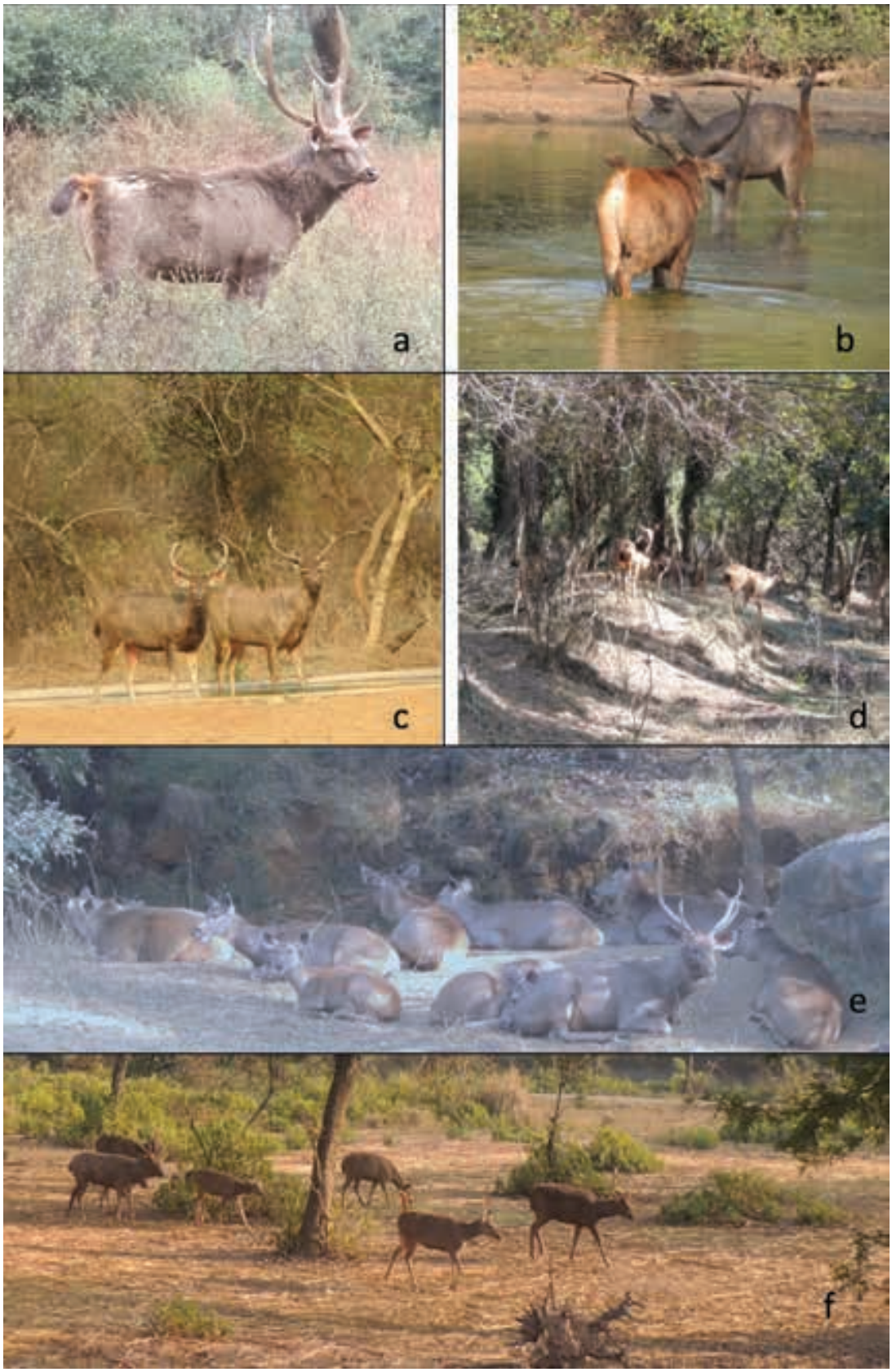

Image 1. Different types of herds of Sambar recorded during field visits at Bir Jhunjhunu Conservation Reserve, Jhunjhunu (a, b & d) and Bairasar Johad (c, e & f): a—lone territorial male (LTM) | b—unimale-Unifemale (UM-UF) | c—bachelor herd (BH) | d—female herd (FH) | e—harem herd (HH) | f—mixed herd. © Deepak Rai.

Table 1. Seasonal grouping patterns of Sambar in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) Rajasthan from July 2018 to June 2019.

Season	NG	LGO	NA	MC	MeC	MGS±S.E.	MeGS	Group size (% of Groups)			
								1	2–5	6–10	>10
Bir Jhunjhunu Conservation Reserve											
Monsoon, 2018 (July to October)	39	8	149	4.88	5.00	3.82±0.32	4.00	17.95	58.97	23.08	0
Winter, 2018-2019 (November to February)	40	11	160	5.38	5.00	4.00±37	4.00	17.5	60.00	20.00	2.50
Summer, 2019 (March to June)	38	9	179	5.70	6.00	4.71±0.35	5.00	13.16	44.74	42.10	0
Annual (2018-2019)	**117**	**11**	**488**	**5.34**	**5.00**	**4.71±0.20**	**4.00**	**16.24**	**54.70**	**28.20**	**0.85**
Bairasar Johad, village Bairasar Bara											
Monsoon, 2018 (July to October)	35	7	123	4.46	5.00	3.51±0.31	4.00	20.00	65.71	14.28	0
Winter, 2018-19 (November to February)	37	12	141	5.84	6.00	3.81±0.46	3.00	21.62	54.05	18.92	5.40
Summer, 2019 (March to June)	34	8	125	4.71	4.00	3.68±0.33	3.50	14.70	64.70	20.59	0
Annual (2018-2019)	**106**	**12**	**389**	**5.04**	**5.00**	**3.67±0.21**	**3.00**	**17.87**	**61.32**	**18.92**	**1.89**

NG—Number of groups | NA—Number of animals | LGO—Largest group observed | MC—Mean crowding | MeC—Median crowding | MGS—Mean group size | MeGS—Median group size | SE—Standard error.

revealed that the group size of sambar were not significantly different between the two seasons and three seasons in both study sites ($p > 0.05$ in all cases) due to frequent observation of group size range of 1–5 individuals. The mean group size was in accordance with the previous studies conducted in different parts of India (Table 2). Sambar were most frequently observed in groups of 2–5 individuals, followed by 6–10, while the lowest numbers of sightings were for groups of more than 12 individuals (Table 1). Largest group sightings of 11 individuals and 12 individuals were recorded in fallow land in Bir Jhunjhunu Conservation Reserve and Bairasar Johad, respectively, as solitary animals were more vulnerable to predators in open areas than in the forested habitat due to more time spent in alertness than foraging activity (Estes 1974; Barrette 1991). In contrast, smaller groups were recorded in scrubby forest areas, possibly due to difficulties in maintaining contacts with others owing to low visibility, as reported by Lagory (1986). The obtained results were in accordance with Schaller (1967) and Ramesh et al. (2009), which revealed that size of the group is correlated with habitat openness, i.e., open or fallow land. Forage abundance also influenced group size, as the largest groups were observed in winter in both study sites owing to more clumped distribution of food. Conversely, when food is evenly dispersed and locally sparse, large groups breaks up into smaller foraging units (Jarman 1974). According to previous studies, predation has been proposed as a factor influencing grouping behavior in Sambar, but our study area did not have any large carnivores except for a few feral dogs that posed threats to fawns (Khan et al. 1995; Raman 1997).

For population studies the mean group size is useful when population is normally distributed because mean group size is an observed-centered measurement that gives equal weightage to all groups but in clumped distribution of population, crowding phenomenon is more useful because crowding is a more animal-centered index of group size which gives the measures of the group size that the average individual finds itself in (Reiczigel et al. 2005). Similar studies based on crowding phenomenon had been reported for Sambar in Mudumalai Tiger Reserve, Western Ghats (Ramesh et al. 2012a) and some mega herbivores including Gaur *Bos Gaurus*, Elephant *Elephas maximus*, and Chital *Axis axis* (Bagchi et al. 2008; Debata & Swain 2019).

Data regarding the population structure of Sambar revealed that, of the 488 individual sightings of Sambar recorded in Bir Jhunjhunu Conservation Reserve (July 2018 to June 2019), 18.5% were adult males, 18.7% sub-adult males, 24.8% adult females, 26.4% sub-adult females, and 11.7% fawns. Similarly, in Bairasar Johad, of 389 individual sightings, 22.6% were adult males, 19.3% sub-adult males, 24.4% adult females, 23.7% sub-adult females, and 10.0% fawns (Figure 5; Table 3).

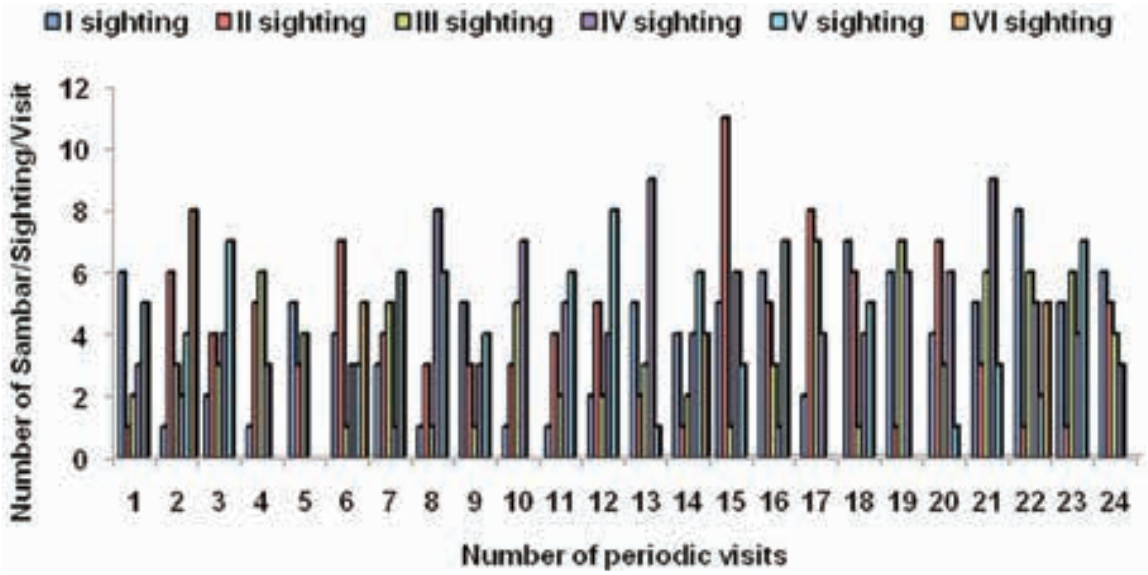

Figure 3. Number of Sambar group sightings/visit and number of individuals/group sighting in Bir Jhunjhunu Conservation Reserve (BJCR), Jhunjhunu during July 2018 to June 2019.

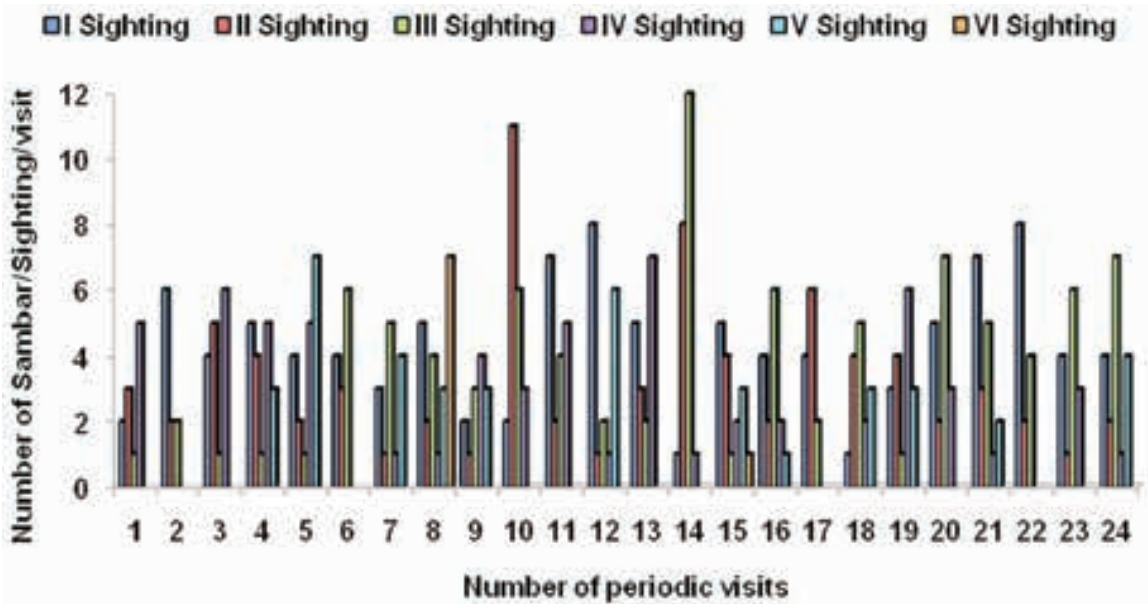

Figure 4. Number of Sambar group sightings/visit and number of individuals/group sighting in Bairasar Johad (BJ) in village Bairasar Bara during July 2018 to June 2019.

Newborn fawns were also observed throughout the year, with a peak fawning period from March to June in both study sites. The overall adult male: adult female: fawn ratio was 74.4: 100: 47.1 (N= 488 individuals) in Bir Jhunjhunu Conservation Reserve, while in Bairasar Johad the ratio was 92.6: 100: 41 (N= 389 individuals) (Table 4). A sex ratio skewed towards females was recorded in both study areas, which may be due to the illegal hunting of adult males. The absence of predators in the study area may also have made males more susceptible to mortality from intra-male competition. A Sambar sex ratio skewed towards females was also reported in Nagarahole and Mudumalai national parks by Karanth & Sunquist (1992) and Ramesh et al. (2012a), respectively, and a similar imbalance was detected in other species, including Gaur, Elephant, Chital, and Blackbuck (Ramesh et al. 2012a,b; Rai & Jyoti 2019).

Singh (1995) mentioned that a single dominant male

Table 2. Mean Group size and Sex ratio of Sambar *Rusa unicolor* from different protected areas of India.

Study site	Mean group size	Adult male: Adult female	Source
Bir Jhunjhunu Conservation Reserve	4.71	0.9: 1	Present Study
Bairasar Johad	3.67	0.7: 1	Present Study
Bandipur National Park	-	0.3: 1	Johnsingh 1983
Nagarahole National Park	1.7	0.4: 1	Karanth & Sunquist 1992
Gir National Park	-	0.5: 1	Khan et al. 1995
Pench Tiger Reserve	1.7	-	Biswas & Sankar 2004
Sariska National Park	4.00	0.1: 1	Chatterjee et al. 2014
Ranthambhor National Park	3.7	-	Bagchi et al. 2004
Mudumalai National Park	3.6	0.4: 1	Ramesh et al. 2012a

tiger breeds with 2–3 females in its territory at 2–4 years gap for each tigress. Further, the male doesn't participate in parental care and better males in the hierarchy wait to replace him in the population, and therefore, survival of an equal or higher proportion of males in a tiger population is an ecological burden. On this account, certain biological characteristics related to sex ratio of wildlife may be comparable among herbivore and carnivore populations, where male of the species displays dominance hierarchy and has the most prominent role only to sire the progeny with one or more females, seasonally or at longer intervals.

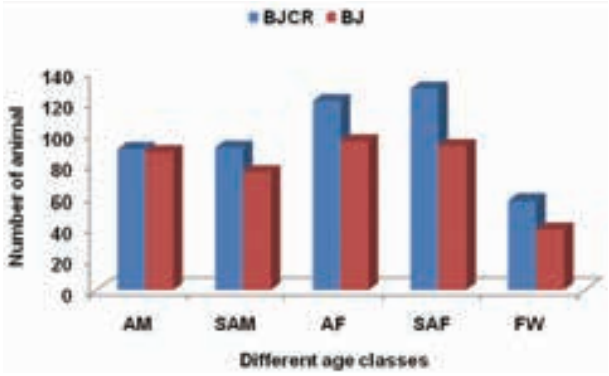

Figure 5. Population structure (different age classes) of Sambar recorded in Bir Jhunjhunu Conservation Reserve (BJCR) Jhunjhunu and Bairasar Johad (BJ) village Bairasar Bara, Rajasthan from July 2018 to June 2019. AM—Adult male | SAM—Sub-adult male | AF—Adult female | SAF—Sub-adult female | FW—Fawn.

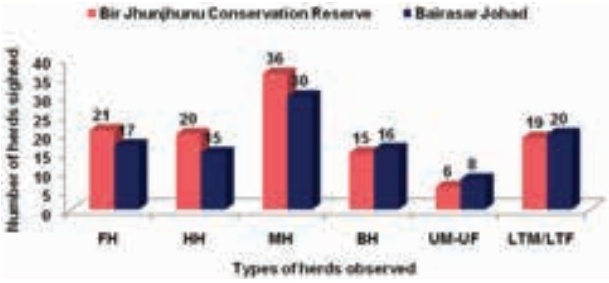

Figure 6. Different types of herds of Sambar observed in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) Rajasthan from July 2018 to June 2019. FH—Female herd | HH—Harem herd | MH-Mixed herd | BH—Bachelor herd | UM-UF—Unimale-Unifemale | LTM—Lone territorial male/female.

Table 3. Age structure of Sambar in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) Rajasthan from July 2018 to June 2019.

Season(s)	AM		SAM		AF		SAF		FW		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	
Bir Jhunjhunu Conservation Reserve, Jhunjhunu											
Monsoon, 2018 (July–October)	29	19.46	33	22.15	32	21.48	40	26.84	15	10.07	149
Winter, 2018–19 (November–February)	25	15.62	24	15.00	46	28.75	45	28.12	20	12.50	160
Summer, 2019 (March–June)	36	20.11	34	18.99	43	24.02	44	24.58	22	12.29	179
Annual data	**90**	**18.44**	**91**	**18.65**	**121**	**24.79**	**129**	**26.43**	**57**	**11.68**	**488**
Bairasar Johad, village Bairasar Bara											
Monsoon, 2018 (July–October)	27	22.50	27	22.50	29	23.58	30	24.39	10	8.13	123
Winter, 2018–19 (November–February)	33	23.40	28	19.86	36	25.53	30	21.28	14	9.93	141
Summer, 2019 (March–June)	28	22.40	20	16.00	30	24.00	32	25.6	15	12.00	125
Annual data	**88**	**22.62**	**75**	**19.28**	**95**	**24.42**	**92**	**23.65**	**39**	**10.02**	**389**

Table 4. Sex ratio of Sambar in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) Rajasthan from July 2018 to June 2019.

Season(s)	Adult male	Adult female	Fawn	Number of individuals classified
Bir Jhunjhunu Conservation Reserve, Jhunjhunu				
Monsoon, 2018 (July–October)	90.62	100	46.87	76
Winter, 2018–19 (November–February)	54.35	100	43.48	91
Summer, 2019 (March–June)	83.72	100	51.16	101
Overall Annual	**74.38**	**100**	**47.10**	**268**
Bairasar Johad, village Bairasar Bara				
Monsoon, 2018 (July–October)	93.10	100	34.48	66
Winter, 2018–19 (November–February)	91.66	100	37.83	83
Summer, 2019 (March–June)	93.33	100	50.00	73
Overall Annual	**92.63**	**100**	**41.05**	**222**

The observed seasonal variation in the number of newly born fawns in this study was considered to be an index of the breeding cycle. Maximum numbers of newly born fawns were observed during the summer, which indicates that the peak rutting season was in winter (November to December) when all male Sambar were carrying hard antlers. Antler cycles are convenient indicators of the reproductive status of male deer (Sankar & Goyal 2004). In Sambar the development of hard antlers in males, sore patch, territoriality wallowing and courtship behavior may indicate their rutting period.

As far as the type of herd is concerned, along with 19 lone territorial males, 36 mixed herds, 15 bachelor herds, 20 harem herds, 21 female herds, and six unimale-unifemale pairs were recorded in Bir Jhunjhunu Conservation Reserve. While in Bairasar Johad, along with 20 lone territorial males, 30 mixed herds, 16 bachelor herds, 15 harem herds, 17 female herds, and eight unimale-unifemale pairs were observed (Figure

Table 5. Seasonal variations in the herd sighting of Sambar, range of number of individuals seen/sighting and the mean number of individuals seen/ sighting±S.E. in Bir Jhunjhunu Conservation Reserve (BJCR) and Bairasar Johad (BJ) from July 2018 to June 2019.

Season	Type of Herds seen	Total sightings (N)		Range of group size seen/sighting		Mean group size seen/sighting±S.E.	
		Bir Jhunjhunu	Bairasar Johad	Bir Jhunjhunu	Bairasar Johad	Bir Jhunjhunu	Bairasar Johad
Monsoon, 2018 (July–October)							
	LTM/LTF	7	7	1	1	1±0	1±0
	MxH	13	11	2 to 8	3 to 7	5.46±0.47	4.54±0.38
	BH	6	4	2 to 4	2 to 4	3.50±0.56	3.00±0.57
	HH	5	5	4 to 5	3 to 6	4.40±0.24	4.80±0.58
	FH	7	6	2 to 6	2 to 7	4.00±0.63	4.33±0.71
	UF-UM	1	2	2	2	2±0	2±0
Winter, 2018–2019 (November–February)							
	LTM/LTF	7	8	1	1	1±0	1±0
	MxH	10	8	3 to 9	3 to 12	5.80±0.64	6.50±1.00
	BH	4	7	2 to 5	2 to 5	3.50±0.64	3.00±0.43
	HH	6	5	5 to 11	4 to 11	5.66±1.11	7.00±1.14
	FH	10	5	2 to 6	2 to 5	4.10±0.40	3.40±0.50
	UF-UM	3	4	2	2	2±0	2±0
Summer, 2019 (March–June)							
	LTM/LTF	5	5	1	1	1±0	1±0
	MxH	13	11	3 to 9	4 to 8	6.61±0.34	5.54±0.43
	BH	5	5	2 to 5	2 to 4	4.20±0.58	2.60±0.40
	HH	9	6	3 to 7	3 to 5	5.11±0.42	3.75±0.47
	FH	4	4	2 to 4	2 to 7	4.25±0.62	3.85±0.63
	UF-UM	2	2	2	2	2±0	2±0
Annual (2018–19)		**117**	**106**	**1 to 11**	**1 to 12**	**4.17±0.20**	**3.66±0.21**

LTM—Lone territorial male/female |UM-UF—Unimale-Unifemale | MxH—Mixed herd | BH—Bachelor herd | HH—Harem herd | FH—Female herd.

6). Seasonal variations in the herd sighting of Sambar, range of number of individuals seen/sighting and the mean number of individuals seen/sighting±S.E. was also calculated in Bir Jhunjhunu Conservation Reserve and Bairasar Johad (Table 5). Variation in herd size in relation to social behavior and rutting behavior indicates that aggregation during rutting season facilitates social interaction and breeding opportunities. Based on the seasonal variation in habitat utilization and forage abundance, the obtained results of crowding revealed the clumped distribution of Sambar in both the study areas. Therefore, based on the changed distribution pattern of Sambar, evaluation of effectiveness as well as revision of conservation strategies are needed for long term survival of Sambar populations in unprotected and protected areas.

REFERENCES

Altmann, J. (1974). Observational study of behavior: sampling methods. *Behaviour* 49: 227–265. https://doi.org/10.1163/156853974X00534

Bagchi, S., S.P. Goyal & K. Sankar (2003). Habitat separation among ungulates in dry tropical forests of Ranthambhore national park, Rajasthan. *Tropical Ecology* 44(2): 175–182.

Bagchi, S., S.P. Goyal & K. Sankar (2008). Social organisation and population structure of ungulates in a dry tropical forest in western India (Mammalia, Artiodactyla). *Mammalia* 72: 44–49. https://doi.org/10.1515/MAMM.2008.008

Barrette, C. (1991). The size of Axis deer fluid groups in Wilpattu National Park, Sri Lanka. *Mammalia* 55: 207–220. https://doi.org/10.1515/mamm.1991.55.2.207

Biswas S. & K. Sankar (2002). Prey abundance and food habit of tigers (*Panthera tigris tigris*) in Pench National Park, Madhya Pradesh, India. *Journal of Zoology* 256: 411–420. https://doi.org/10.1017/S0952836902000456

Chatterjee, D., K. Sankar, Q. Qureshi, P.K. Malik & P. Nigam (2014). Ranging pattern and habitat use of sambar (*Rusa unicolor*) in Sariska Tiger Reserve, Rajasthan, Western India. *DSG Newsletter* 26: 60–71.

Chopra, G. & D. Rai (2009). A study on the ecology of Nilgai (*Boselaphus tragocamelus* Pallas) and its status as an unconventional pest of agriculture in and around Beer-Sonty reserve forest, Haryana, India. *Journal of Applied and Natural Science* 1(2): 245–249. https://doi.org/10.31018/jans.v1i2.81

Clutton-Brock, T.H., S.D. Albon & P.H. Harvey (1980). Antlers, body size and breeding group size in Cervidae. *Nature* 285: 565–567.

Debata, S. & K.K. Swain (2019). Group size and population structure of vulnerable Gaur in an isolated tropical deciduous forest of eastern India. *Proceeding of the National Academy of Sciences* 89(1): 89–94. https://doi.org/10.11609/jott.2658.9.11.10953-10955

Dev, K. & P. Singh (2016). Mammalian diversity of Shekhawati region in arid zone of Thar Desert, India. *International Journal of Biological Sciences* 3: 16–22.

Estes, R.D. (1974). Social organization of the African bovids, pp. 166–205. In: Geist, V. & F. Walther (eds.). *The Behaviour of Ungulates and its Relation to Management - Volume I*. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland, 940pp.

Harikumar, G., B. Thomas, K.J. Joseph & V.J. Zacharias (1999). Population dynamics of Sambar *Cervus unicolor*, in Periyar Tiger Reserve. *Indian Forester* 125(10): 995–1003.

IUCN (2008). IUCN Red List of threatened species. Version 2008. www.iucnredlist.org.

Jain, P., A. Bhasin, G. Talukdar & B. Habib (2018). Distribution and population status of Sambar *Rusa unicolor* (Mammalia: Cetartiodactyla: Cervidae) from Aravalli landscape with a note on its first record from Aravalli Hills of Haryana, India. *Journal of Threatened Taxa* 10(10): 12357–12362. https://doi.org/10.11609/jott.4011.10.10.12357-12362

Jarman, P.J. (1974). The social organisation of antelope in relation to their ecology. *Behaviour* 48: 216–267. https://doi.org/10.1163/156853974X00345

Johnsingh, A.J.T. (1983). Large mammalian prey-predators in Bandipur. *Journal of the Bombay Natural History Society* 80: 1–57.

Johnsingh, A.J.T. & K. Sankar (1991). Food plants of chital, sambar and cattle on Mundanthurai Plateau, Tamil Nadu, South India. *Mammalia* 55: 57–66. https://doi.org/10.1515/mamm.1991.55.1.57

Karanth, K.U. & M.E. Sunquist (1992). Population structure, density and biomass of large herbivores in the tropical forests of Nagarahole, India. *Journal of Tropical Ecology* 8: 21–35. https://doi.org/10.1017/S0266467400006040

Khan, J.A., R. Chellam & A.J.T. Johnsingh (1995). Group size and age-sex composition of three major ungulate species in Gir Lion Sanctuary, Gujarat, India. *Journal of the Bombay Natural History Society* 92: 295–302.

Kerr, R. (1792). The animal kingdom, or zoological system of the celebrated Sir Charles Linnaeus; Class I. Mammalia; containing a complete systematic description, arrangement, and nomenclature, of all the known species and varieties of the Mammalia, or animals which give suck to their young; being a translation of that part of the Systema Naturae, as lately published, with great improvements, by Professor Gmelin of Goettingen. J. Murray & R. faulder, London, UK.

Krebs, J.R., M.H. MacRoberts & J.M. Cullen (1972). Flocking and feeding in the Great tit *Parus major*- an experimental study. *Ibis* 114: 507–530. https://doi.org/10.1111/j.1474-919X.1972.tb00852.x

Lagory, K.E. (1986). Habitat, group size, and the behaviour of white-tailed deer. *Behaviour* 98: 168–179. https://doi.org/10.1163/156853986X00955

Pant, A., S.G. Chavan, P.S. Roy & K.K. Das (1999). Habitat analysis for sambar in Corbett National Park using remote sensing and GIS. *Journal of Indian Society Remote Sensing* 27(3): 133–139.

Poruse, M.C. (1996). Wildlife Habitat Analysis for Sambar in Kanha National Park Using Remote Sensing. *Journal of Indian Society Remote Sensing* 17(14): 919–935.

Pulliam, H.R. & T. Caraco (1984). Living in groups: is there an optimal group size? pp. 122–148. In: Krebs, J.R. & N.B. Dviers (eds.). *Behavioral Ecology: An Evolutionary Approach*. 2nd Edition. Blackwell Scientific Publication, Oxford, 493pp.

Rai, D. & Jyoti (2019). Crowding, Group size and Population structure of Blackbuck, *Antilopecervicapra* (Linnaeus, 1758) in semi-arid habitat of Haryana, India. *Journal of Threatened Taxa* 11(9): 14194–14203. https://doi.org/10.11609/jott.4788.11.9.14194-14203

Rai, D. & Kalpana (2019). Opinion survey on the ecology of Sambar, *Rusa unicolor* (Artiodactyla, Cervidae) and its status with respect to crop damage in districts Jhunjhunu and Churu, Rajasthan (India). *Journal of Applied and Natural Science* 11(2): 468–477. https://doi.org/10.31018/jans.v11i2.2092

Raman, T.R.S. (1997). Factors influencing seasonal and monthly changes in the group size of chital or axis deer in southern India. *Journal of bioscience* 22: 203–218. https://doi.org/10.1007/BF02704733

Ramesh, T., V. Snehalatha, K. Sankar & Q. Qureshi (2009). Food habits and prey selection of tiger and leopard in Mudumalai Tiger Reserve, Tamil Nadu, India. *Journal of Scientific Transactions Environment and Technovation* 2: 170–181.

Ramesh, T., K. Sankar, B. Qureshi & R. Kalle (2012a). Group size, sex and age composition of Chital (*Axis axis*) and Sambar (*Rusa unicolor*) in a deciduous habitat of Western Ghats. *Mammalian Biology* 77: 53–59. https://doi.org/10.1016/j.mambio.2011.09.003

Ramesh, T., K. Sankar, B. Qureshi & R. Kalle (2012b). Group size and population structure of megaherbivores (Gaur *Bos gaurus*

and Asian Elephant *Elephas maximus*) in a deciduous habitat of Western Ghats, India. *Mammal Study* 37: 47–54. https://doi.org/10.3106/041.037.0106

Reiczigel, J., Z. Lang, L. Rozsa & B. Tothmeresz (2005). Properties of crowding indices and statistical tools to analyze crowding data. *Journal of Parasitology* 91: 245–252. https://doi.org/10.1645/GE-281R1

Reiczigel, J. & L. Rozsa (2006). Flocker 1.0. Available at www.behav.org/flocker/ Accessed on 20 September 2018.

Reiczigel, J., Z. Lang, L. Rozsa & B. Tothmeresz (2008). Measures of sociality: two different views of group size. *Animal Behaviour* 75: 715–721. https://doi.org/10.1016/j.anbehav.2007.05.020

Sankar, K. & S.P. Goyal (2004). Ungulates of India. *ENVIS Bulletin: Wildlife and Protected Areas* 7(1): 163–170.

Schaller, G.B. (1967). *The Deer and the Tiger: A Study of Wildlife in India.* The University of Chicago Press, Chicago, USA, 384pp.

Shekhawat, D.S & C. Bhatnagar (2014). Guild, status, and diversity of avian fauna in the Jhunjhunu district, Rajasthan, India. *Journal of Asia-Pacific Biodiversity* 7(3): 262–267. https://doi.org/10.1016/j.japb.2014.06.001

Simcharoen, A., T. Savini, G.A. Gale, E. Roche, V. Chimchome & J.L. Smith (2014). Ecological factors that influence Sambar (*Rusa unicolor*) distribution and abundance in western Thailand: implications for tiger conservation. *Raffles Bulletin of Zoology* 62: 100–106.

Singh, L.A.K. (1995). Sex-identification technique and sex-ratio in tiger: doubts and clarifications. *Indian Forester* 21(10): 885–894.

Timmins, R.J., R. Steinmetz, B.H. Sagar, K.N. Samba, J.W. Duckworth, I.M. Anwarul & B.P.L. Chan (2015). *Rusa unicolor*. The IUCN Red List of Threatened Species. https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T41790A22156247.en

Varman, K.S. & R. Sukumar (1993). Ecology of sambar in Mudumalai Sanctuary, southern India, pp. 273–284. In: 'Deer of China: biology and management: proceedings of the International Symposium on Deer of China'. Elsevier, New York.

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Study on the impacts of LULC change on the wildlife habitat and the livelihood of people in and around Dampa Tiger Reserve, Mizoram, India

Sushanto Gouda [1], Janmejay Sethy [2], Netrapal Singh Chauhan [3] & Harendra Singh Bargali [4]

[1–3] Amity Institute of Forestry and Wildlife, Amity University, Noida, Uttar Pradesh 201313, India.
[4] The Corbett Foundation, Village & P.O. Dhikuli, Ramnagar, Uttarakhand 244715, India.
[1] sushantogouda@gmail.com, [2] jsethy@amity.edu (corresponding author), [3] nschauhan@amity.edu, [4] hsbargali@gmali.com

Abstract: Anthropogenic activities are a matter of serious concern in the Indian Himalayan region due to adverse impacts on wildlife and habitats. This study examines resource use patterns by local people in relation to the habitat of Malayan Sun Bear in and around Dampa Tiger Reserve in Mizoram. Standard questionnaire surveys and vegetation sampling methods were used for data collection and analysis. It was found that 221.3 km2 (33.3%) of the forested areas have high human interference in the form of logging, indiscriminate tree falling and fuel wood collection, while 26% was moderately affected and 18% of the reserve had no impact. Among vegetation resources, fuel wood was used in the highest quantity (28%) followed by bamboo and edible plants (21%) and (11%), respectively. Ethno-zoological usage comprises of parts of animals like snake, bear, monitor lizard, and porcupine. Sun bears were considered pests that feed on maize, cucumber, sweet potato and pumpkins grown in 'jhum' crop fields. Anthropogenic pressures from farm-bush hunting, monoculture, and unplanned roads have contributed to severe biodiversity loss, and must be constrained for the conservation of sun bear and their habitat in the region. The Land Use/ Land Cover on human built-up, jhum land (current and abandoned jhum/shifting cultivation), forests (dense and open), bamboo forest, plantation etc. were used to develop maps for each village. The land use pattern for the eight villages studied. Information obtained from MIRSAC and its mapping in Arcview shows that highest number of agricultural land was in villages of West Phaileng (319sq.ha) and Damparengpui (283.8sq.ha). Closed or dense forest was in highest proportion in Phuldungsei and least in Tuipuibari (120sq.ha). Grazing activities was relatively low or absent in most part of DTR. Abandoned jhum fields were in largest number in Damparengpui (939.60sq.ha) followed by Silsuri (881.17sq.ha) and Serhmun (880.99sq.ha).

Keyword: Bear-Human interactions, conservation, foraging, habitat fragmentation, human interference, Malayan Sun Bear, monoculture.

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Author details: Sushanto Gouda—research scholar in Amity Institute of Forestry and Wildlife, Amity University. His interest in animal biotechnology and ecology. Janmejay Sethy—currently working as Assistant Professor, Amity Institute of Forestry and Wildlife, Amity University. His interest in animal ecology and conservation biology. And also interest in bear ecology and endangered species management. Netrapal Singh Chauhan—currently working as Professor and Director, Amity Institute of Forestry and Wildlife, Amity University. His interest in human-wildlife interactions and population management. Harendra Singh Bargali—currently working as Deputy Director in Corbett Foundation. His interest in bear ecology, human-wildlife conflict and conservation biology.

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INTRODUCTION

Forest and wildlife are integral components of a dynamic ecosystem. The recent exponential growth in human populations and encroachment towards protected areas (PAs) have led wildlife populations and their habitats to declined so drastically this has been referred to as an "ongoing sixth mass extinction" by Barrueto et al. (2014) and Ceballos et al. (2017). The depletion of wildlife species has been intimately linked to the food demands and livelihood dependency of forest-dwellers in tropical rainforest regions of the world (Nasi et al. 2008), who rely on forests for timber, firewood, and other non-timber forest products (NTFPs) such as fodder, medicine, food, and raw materials for making handicrafts and construction of houses (Sahoo et al. 2010). As human populations continue to expand, so does pressure on protected lands (Jones et al. 2018; Broekhuis et al. 2019).

Human-induced chronic changes or anthropogenic pressures in the form of forest fires, habitat fragmentation or destruction, and changes in land use patterns, are common around PA's in India. In the Himalayan region, deforestation and forest degradation are major concerns for floral and faunal diversity (Dhyani et al. 2013; Mohanta & Chauhan 2014). Changes in land use patterns and increases in agricultural areas have greatly affected the habitat, food selection pattern and conservation of sun bear in the northeastern states of India, including Arunachal Pradesh, Manipur, Nagaland, and Mizoram (Chauhan & Lalthunpuia 2008; Sethy & Chauhan 2013). Anthropogenic activities often harm wild animals directly through agriculture, human settlement, transportation, and indirectly by disturbing the ecological balance, cross-species transmission of pathogens, pollution, and climate change (MacRae 2011; Becker et al. 2015). Many of these activities have received little attention, resulting in an alteration of habitat use, foraging behavior of animals and severe human-wildlife negative interactions (Sih et al. 2011; Becker et al. 2018). Bears being large omnivores have a continuous interspecies competition with humans for space and food in several niches of an ecosystem (Ladle et al. 2018; Sethy & Chauhan 2018). At the population level, bears appear to be less selective in their habitat choice; however, during sedentary and stop-over phase, they move across forest slope and distance close to the road inciting conflict with humans across their home ranges (Cozzi et al. 2016). Easy bioavailability of anthropogenic food resources in agricultural crop fields is reported to attract bears more towards human settlements than their natural foraging grounds (Bargali et al. 2012; Can et al. 2014). Through this study, we wanted to better understand changes in land use and land cover patterns in the context of conserving of Malayan Sun Bear habitats in and around Dampa Tiger Reserve, Mizoram. We also aimed to collect information on bear-human interaction and the dependency of locals on forest resources.

Land use and land cover changes (LULC) represent a serious threat to ecosystem sustainability as naturally vegetated forms give way to manmade vegetation (Lambin & Geist 2007). Such conversion is known reduce the availability of energy, water and nutrients supplies to ecosystems. On the other hand, it also facilitates the invasion of natural system by exotic species (Kamusoko 2007).

MATERIALS AND METHODS

Study area

Dampa Tiger Reserve (DTR) is situated in the Mamit district of Mizoram, India. DTR has an area of about 500 km^2 and a buffer region of over 448 km^2 with 15 fringe villages and population of over 22,500 tribal from the Mizo, Reang (Bru) and Chakma communities (Image 1). The reserve is home to several endemic and rare species like Red Serow *Capricornis rubidus*, Clouded Leopard *Neofelis nebulosa*, Golden Cat *Catopuma temminckii*, and Great Hornbill *Buceros bicornis* (Gouda et al. 2016; Sethy et al. 2017; Singh & Macdonald 2017). DTR is one the last remaining habitats for Malayan Sun Bear *Helarctos malayanus* in Mizoram and also among the few in the northeastern states of India (Sethy & Chauhan 2013; Gouda et al. 2020). The region is under extreme threat due to the rapid increase in the human settlement, practice of shifting cultivation and other monoculture activities (Chauhan & Lalthunpuia 2008; Raman 2011). Livelihood of locals is mostly depended on the agriculture system of slash & burn and other forest products.

Questionnaire Survey

Data on anthropogenic activities was acquired through a set of questionnaires adapted for similar work by Aiyadurai et al. (2010). The survey was conducted from April 2015 to March 2016. Villages and households were selected based on information from key informants (village headmen, teachers, forest officials). Male members of the family were prefer over females for the survey as they spent more time in crop

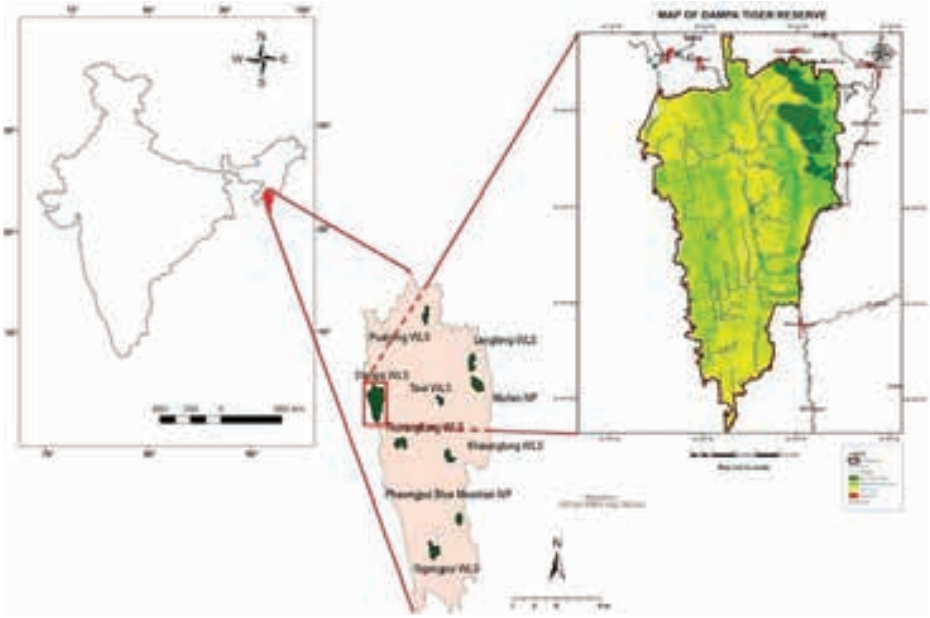

Image 1. Dampa Tiger Reserve, Mizoram, India.

fields and surrounding forested areas than females. In the survey, female respondents provided additional information on consumption of food items by bears and other incidences of crop-raiding. The survey was carried out in the presence of a field assistant from the local community having thorough knowledge of local dialects. Questions were generally asked at respondent's home mainly at dusk time as most villagers return from their fields during these hours. Each interview lasted for about 20–30 minutes, depending on how the respondent interacts with us in the survey. Questions related to encounters with sun bear, land-use pattern, livelihood options, collection of forest products, hunting, use of animals or their parts as sources of ethno-medicine were enquired. The questions were both open- and close-ended (Appendix I) (Aiyadurai et al. 2010).

Transect survey and Data analysis

Evidence on the presence of Malayan Sun Bear such as digging signs, scats and claw marks, remains of fruit/food materials was documented through transect surveys using Steinmetz & Garshelis (2007). The surveys consist of 3–4 persons walking through a pre-determined transect path of 2–2.5 km. Vegetation sampling was carried along the transect using the layout represented in Appendix II. Plant species were identified using their local name based on Sawmiliana (2003).

Presence of humans including settlements, forest cover, and agricultural land in eight villages around DTR were acquired through the Indian Remote Sensing satellite data (LISS-III and Cartosat-I) and digitized using QGIS software for preparation of land use land cover (LULC) maps.

RESULTS

The extent of biotic pressures

In the study 760 households were surveyed, of which 60% of respondents practiced slash & burn (jhum) cultivation on more than a hectare of agricultural land, while 33% had less than a hectare and 5.9% of surveyed individuals had no agricultural land and were involved in other activities like small scale business, forest guard, and daily wage labors. Of the 500 km^2 of DTR, about 221.3 km^2 (33.3%) were found to have high human interference and were less occupied by sun bears. An area of 111.1 km^2 (26%) was regarded as moderately affected, while 96.9 km^2 (22.5%) was affected to a lower extent. Only 70.7 km^2 (18%) of the core region was without any form of biotic pressures with intact vegetation (Table 1).

The land use pattern for all the villages is represented in Image 2. Information obtained from MIRSAC and its mapping shows that highest number of agricultural land is in villages of West Phaileng (319 ha^2) and Damparengpui (283.8 ha^2). Closed or dense forest was in highest proportion in Phuldungsei and least in Tuipuibari (120 ha^2) (Table 2). Grazing activities was relatively low or absent in most part of DTR (Figure 1). Abandoned jhum fields were in largest number in Damparengpui (939.60 ha^2) followed by Silsuri (881.17 ha^2) and Serhmun (880.99 ha^2) (Figure 1).

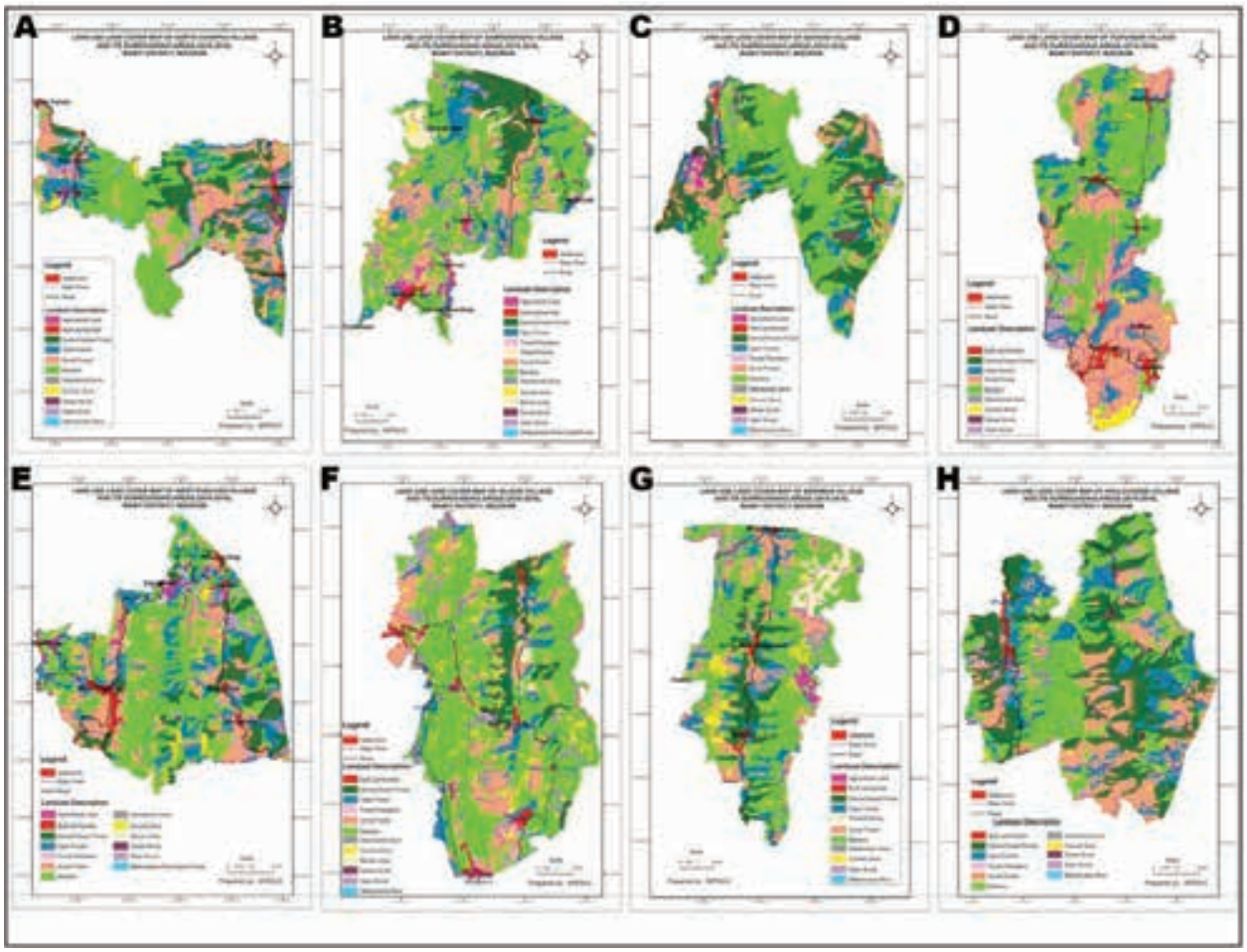

Image 2. Villages around Dampa Tiger Reserve and their LULC pattern: a—N. Chhippui | b—Damparengpui | c—Saithah | d—Tuipuibari | e—W. Phaileng | f—Silsuri | g—Serhmun | h—Phuldungsei.

Usage of forest resources

In the study area, it appeared that the locals rely heavily on forest resources for their livelihood. Forest products in the form of NTFPs, food materials, and medicines were collected from the buffer region and the surrounding forest patches or community forest. Locals in the region collect 21% of their bamboo, 2.8% of timber, 28% of fuel wood, and 11% of food and medicines from the forest. About 37% of respondents were recorded collecting all the above from the buffer region. Various plant species were used as food items, including young leaves of *Acacia* sp., *Eurya japonica*, & *Garcinia lancifolia*, tubers of *Amomum dealbatum* and shoots of *Adiantum caudatum*, *Diplazium esculentum*, *Dysoxylum procerum*, & *Melocana bambosoides*. Tree species like *Anogeissus acuminata, Vitex penducularis, Schima wallichii, Syzygium cumini*, and *Albizzia* sp. were used for their timber quality. Fuel wood mostly comprises of bamboo sp., *Derris robusta, Castanopsis tribuloides, Anogeissus acuminata, Vitex penducularis, Schima wallichii*, and *Albizzia chinensis*. Areas of fuel wood collection ranged 1–5 km away from the village boundary. During winter 25–30 kg (54.24%) of fuel wood was required per household every day; whereas in summer it was only 10–15 kg per day. The fuel wood requirement was very low (18.22%) in monsoon than winter and the summer. These variations in fuel wood

Table 1. Extent of biotic pressure and affected areas in Dampa Tiger Reserve.

Value designated	Extent of biotic pressure	Affected area in each category (km^2)	% Area affected
0	Nil	70.7	18.1
1	Low	96.9	22.5
2	Medium	111.1	26.1
3	High	221.3	33.3

Table 2. Geographical variables in surrounding villages of Dampa Tiger Reserve.

Village	Geographical variables (Area in ha²)								
	Agricultural land	Dense/ Closed forest	Open forest	Grazing land	Scrub forest	Abandoned jhum	Current jhum	Barren rocky	Open shrub
Damparengpui	283.80	1536.01	1794.04	356.53	2386.64	939.60	450.93	82.52	206.23
Chhippui	147.82	1808.35	1490.60	0.0	2459.64	166.16	139.98	0.0	438.59
Serhmun	129.68	1204.44	1387.01	621.41	1625.27	880.99	562.23	0.0	52.04
Tuipuibari	0.0	120.03	1639.44	0.0	3877.62	272.73	256.73	0.0	389.40
West Phaileng	319.02	1544.43	2850.23	0.0	3122.85	367.14	540.22	12.62	580.24
Phuldungsei	0.0	5743.53	3451.12	0.0	4355.98	365.33	240.61	0.0	346.59
Saithah	186.87	4458.07	1709.37	0.0	2203.62	161.98	112.83	0.0	163.43
Silsuri	0.0	1095.04	1067.13	0.0	2539.53	881.17	815.90	103.89	292.51

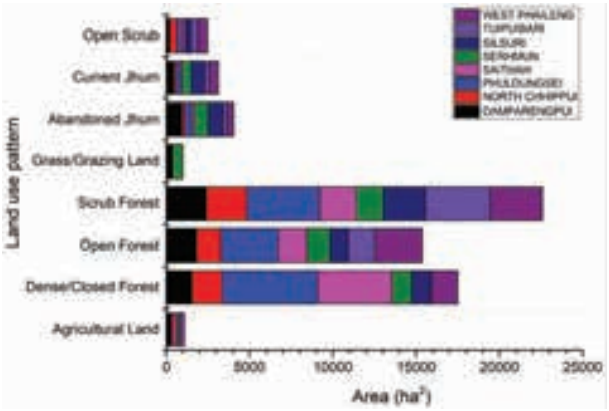

Figure 1. Land use pattern in surrounding areas of Dampa Tiger Reserve.

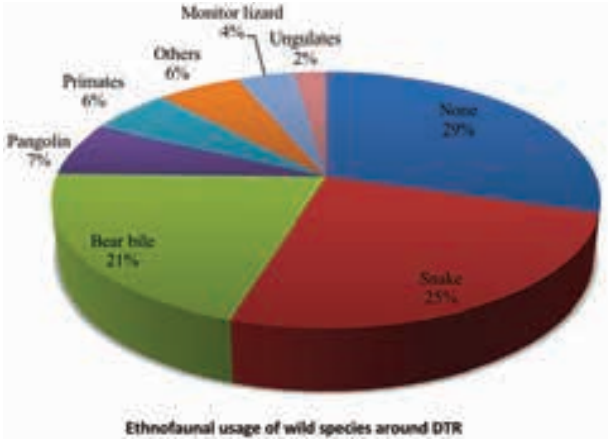

Figure 2. Usage of faunal resources by locals from villages around Dampa Tiger Reserve.

requirement can be attributed to the low temperature around DTR during winter and also the fact that Mizoram receives heavy rainfall in the monsoon that leads the local villagers to stock up woods during winters for their use in monsoon season. In two divisions of DTR, Teirei and Phuldungsei forest divisions, the frequency of lopped trees varied considerably with p value of <0.004, c^2= 89.16, df= 5.

In the survey it was found that while some animals were hunted for medicinal value, the Malayan Sun Bear was generally considered to be a 'pest' that feeds on maize, cucumber, sweet potato, and pumpkins grown in adjacent areas of the reserve (Sethy & Chauhan 2013). A few cases of bear attacks on humans in jhum crop fields were reported in the region before and during the study period. Bear species were hunted mainly for their bile and as retaliation for crop-raiding and crop depredation. Bile of both Asiatic Black Bear *Ursus tibetanus* and Malayan Sun Bear were found to be used for the treatment of appendix pain and other stomach problems by local medicine men. Different parts of animals like fats of snakes (*Python molurus*), bear bile, pancreas of monitor lizard (*Varanus Indicus*) and porcupine (*Hystrix cristata*), were often used against different health ailments. The hunting accounts and the ethno-zoological usage of bear and other wild animals are shown in Figure 2.

DISCUSSION

Agricultural crop fields around DTR are adjacent to the reserve areas with no proper demarcation or barriers, allowing animals and humans trespass through easily. Fruits and vegetables like maize, pumpkin, papaya, sweet potato, and cucumber grown in shifting crop fields or jhum fields also act as excellent anthropogenic attractants for sun bears and other wild species (Barrueto et al. 2014; Mohanta & Chauhan 2014; Becker et al. 2018). Such attraction of wild animals

towards human inhabited areas may result in crop-raiding and depredation, or even death of humans or animals during sudden face-offs. High numbers of agriculture crop fields and abandoned jhum fields in West Phaileng and Damparengpui can be attributed to the 22,587 people whose livelihood is dependent on the forest and its resources (Sahoo et al. 2010; Mizoram population census 2011). The LULC data suggest that the forest cover was least in Tuipuibari and West Phaileng as these villages have several commercial outlets and military posts. Among the population in the fringe villages, it was notices that 37% of locals use all types of forest product such as timber, vegetation, edible food items, followed by bamboo and fuel wood as studied previously by Sahoo et al. (2010).

In the past few decades, the fallow period of shifting cultivation has reduced to 2–3 years from 20–25 years, adding more abandoned land to the region. Areas under shifting cultivation have also declined by 58% between 1997–98 and 2010–2011, replaced by permanent wet paddy fields and farmlands (Raman 2001). The change in land use patterns around the reserve could cause serious alterations in distribution and health dynamics of bears as they move to distant regions in search of food (Nielsen et al. 2013). Monoculture plantations of Oil Palm *Elaeis guineensis*, Teak *Tectona grandis*, Rubber *Hevea brasiliensis*, and Betel *Areca catechu* have also reduced forest cover and caused forest fragmentation (Mohanta & Chauhan 2014). Garden hunting (farm-bush hunting), roads, recreation, and resource extraction are other anthropogenic disturbances that lead to biodiversity loss and negatively effect ecological processes and ecosystem services (Crooks et al. 2017). During interviews many farmers acknowledged that bears come to crop fields to forage, especially for cucumber, pumpkin, and maize; however, the damage caused is negligible compared with that of Wild Boars *Sus scrofa* and Asian Elephants *Elephas maximus*, which indeed develops a negative perspective towards conservation of wildlife. While the Malayan Sun Bear was not the prime factor of crop-raiding around DTR, accidental death of bears in traps and snares placed for Wild Boars were raised during the interview. During the study period, one black bear cub (from Tuipuibari) and one sun bear cub (from Serhmun) were rescued by the forest department, which were later released to the wild. Although, previously some amount in the form of crop damage compensation was received by local farmers, it was reported to be delay or ignored during the study period. Lack of support from forest officials for adaptation of alternative livelihood options (non-bear food) such as the distribution of nursery seedling for betel and rubber were some additional points highlighted by locals to mitigate bear-human interactions and other associated human-induced pressure. Development of local markets for the sale of local vegetables, ginger and chilli, were requested by villagers in the interview.

During the study period, it was found that the use of body parts of bear and other wild species had reduced as the younger generation discontinued their use. Although cases of hunting and poaching have followed a drip trend, increase in human settlement, road networks and setting up of permanent farmlands continuous to buffer areas of DTR continue to affect the movement of Malayan Sun Bears. Hence it is important to identify the levels of anthropogenic pressure and maintain the ecological integrity, especially with several wildlife species around.

CONCLUSION

Dampa Tiger Reserve is part of a complex human land-use mosaic that experiences variable forms of biotic and anthropogenic pressure. The reserve is one of the few remaining habitats of Malayan Sun Bears in India, and therefore proper knowledge on changes in ecological variables and extent of anthropogenic activities is necessary to conserve bears and their habitat. Research has shown the importance of environmental heterogeneity on the growth of individuals and populations, and understanding how these spatial and temporal dynamics affect the sun bear populations will be crucial to identify and prioritize management and conservation planning. This study can be used as a reference for similar species, and also for other natural habitats of the Malayan Sun Bear in India and throughout southeastern Asia.

REFERENCES

Aiyadurai, A., N.J. Singh & E.J. Milner-Gulland (2014). Wildlife hunting by indigenous tribes: A case study from Arunachal Pradesh, north-east India. *Oryx* 1–9. https://doi.org/10.1017/S0030605309990937

Barrueto, M., A.T. Ford & A.P. Clevenger (2014). Anthropogenic effects on activity patterns of wildlife at crossing structures. Anthropogenic effects on activity patterns of wildlife at crossing structures. *Ecosphere* 5(3): 27. https://doi.org/10.1890/ES13-00382.1

Bargali, H.S., N. Akhtar & N.P.S. Chauhan (2012). The Sloth bear activity and movement in highly fragmented and disturbed habitat in central India. *World Journal of Zoology* 7(4): 312–319.

Becker, D.J., D.G. Streicker & S. Altizer (2015). Linking anthropogenic resources to wildlife-pathogen dynamics: a review and meta-analysis. *Ecology Letters* 18: 483–495. https://doi.org/10.1111/ele.12428

Becker, D.J., R.J. Hall, K.M. Forbes, R.K. Plowright & S. Altizer (2018). Anthropogenic resource subsidies and host– parasite dynamics in wildlife. *Philogy Transition Royal Society* B 373: 20170086 https://doi.org/10.1098/rstb.2017.0086

Broekhuis, F., E.K. Madsen & B. Klaassen (2019). Predators and pastoralists: how anthropogenic pressures inside wildlife areas influence carnivore space use and movement behavior. *Animal Conservation* 22(4): 404–416. https://doi.org/10.1111/acv.12483

Can, O.E., N.D'Cruze, D.L. Garshelis, J. Beecham & D.W. Macdonald (2014). Resolving Human-Bear Conflict: A Global Survey of Countries, Experts, and Key Factors. *Conservation Letters* 7(6): 501–513. https://doi.org/10.1111/conl.12117

Ceballos, G., P.R. Ehrlich & R. Dirzo (2017). Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proceeding of the National Academic of Science* 114: E6089–E6096. https://doi.org/10.1073/pnas.1704949114

Chauhan, N.P.S. & Lalthunpuia (2008). Status and distribution of Malayan Sun Bear (*Helarctos malayanus*) in north-eastern states, India. *Indian Forester* 134(10): 1339–1348.

Choudhury, A.U. (2011). Records of Sloth Bear and Malayan Sun Bear in North East India. Final report to International Association for Bear Research and Management (IBA), Guwahati, Assam, India: The Rhino Foundation for Nature in North East, India, 53pp.

Cozzi, G., M. Chynoweth, J. Kusak, E. Coban, A. Coban, A. Ozgul & C. Sekercioglu (2016). Anthropogenic food resources foster the coexistence of distinct life history strategies: year-round sedentary and migratory brown bears. *Journal of Zoology* 300: 142. https://doi.org/10.1111/jzo.12365

Dhyani, D., S. Dhyani & R.K. Maikhuri (2013). Assessing Anthropogenic Pressure and Its Impact on *Hippophaesalicifolia*Pockets in Central Himalaya, Uttarakhand. *Journal of Mountain Science* 10(3): 464–471. https://doi.org/10.1007/s11629-013-2424-z

Fedriani, J.M., T.K. Fuller & R.M. Sauvajot (2001). Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. *Ecography* 24: 325–331. https://doi.org/10.1034/j.1600-0587.2001.240310x

Fraser, D. & A.M. MacRae (2011). Four types of activities that affect animals: Implications for animal welfare science and animal ethics philosophy. *Animal Welfare* 20(4): 581–590.

Gouda, S., J. Sethy & N.P.S. Chauhan (2016). First photo capture of Asiatic golden cat in Dampa Tiger Reserve, Mizoram, India. *CAT News* 64: 26–27.

Gouda, S., N.P.S. Chauhan & J. Sethy (2020). Status and distribution of Malayan sun bear (*Helarctosmalayanus*) in Dampa Tiger Reserve, Mizoram, India. *Journal of Wildlife and Biodiversity* 3(4): 45–56.

Jones, K.R., O. Venter, R.A. Fuller, J.R. Allan, S.L. Maxwell, P.J. Negret & J.E. Watson (2018). One-third of global protected land is under intense human pressure. *Science* 360: 788.

Kamusoko, C (2007). Land use/cover change and landscape fragmentation analysis in the Bindura district, Zimbabwe. Land Degrade. Dev.18, 221–233.

Ladle, A., R. Steenweg, B. Shepherd & M.S. Boyce (2018). The role of human outdoor recreation in shaping patterns of grizzly bear-black bear co- occurrence. *PLoS ONE* 13(2): e0191730. https://doi.org/10.1371/journal.pone.0191730

Lambin, E. & H. Geist (2007). Causes of Land-use and Land-cover Change. The Encyclopedia of Earth. Lambin EF, Geist HJ, Lepers E (2003) Dynamics of Land-use and Land-cover Change in Tropical Regions. *Annual Review of Environmental Resources* 28: 205–241.

Mohanta, R & N.P.S. Chauhan (2014). Anthropogenic threats and its conservation on Himalayan Brown Bear (*Ursus arctos*) habitat in Kugti wildlife sanctuary, Himachal Pradesh, India. *Asian Journal of Conservation Biology* 3(2): 175–180.

Nasi, R., D. Brown, D. Wilkie, E. Bennett, C. Tutin, G. Van-Tol & T. Christophersen (2008). Conservation and use of wildlife-based resources: the bushmeat crisis. Secretariat of the Convention on Biological Diversity, Montreal, and Center for International Forestry Research (CIFOR), Bogor. Technical Series no. 33, 50.

Raman, T.R.S. (2001). Effect of Slush and Burn shifting cultivation on rainforest birds iin Mizoram, Northeast India. *Conservation Biology* 15(3): 685–698.

Sahoo, U.K., J. Lalremruata, L. Jeeceelee, J.H. Lalremruati, C. Lalliankhuma & H. Lalramnghinglova (2010). Utilization of non-timber forest products by the tribal around Dampa Tiger Reserve in Mizoram. *The Bioscan* 3: 721–729.

Sethy, J. & N.P.S. Chauhan (2013). Human-sun bears conflict in Mizoram, North East India: Impact and conservation management. *International Journal of Conservation Science* 4: 317–328.

Sethy, J., S. Gouda & N.P.S. Chauhan (2017). Confirm occurrence and photographic evidence of marbled cat from Dampa Tiger Reserve, Mizoram, India, *CAT News* 65: 26–27.

Sethy, J. & N.P.S. Chauhan (2018). Dietary preference of Malayan sun bear (*Helarctosmalayanus*) in Namdapha Tiger Reserve, Arunachal Pradesh, India, *Wildlife Biology* (Bio One) 2018(1): wlb.00351. https://doi.org/10.2981/wlb.00351

Sih, A., M.C.O. Ferrari & D.J. Harris (2011). Evolution and behavioral responses to human-induced rapid environmental change. *Evolution and Application* 4: 367–387. https://doi.org/10.1111/j.1752-4571.2010.00166.x

Singh, P. & D.W. Macdonald (2017). Populations and activity patterns of clouded leopards and marbled cats in Dampa Tiger Reserve, India. *Journal of Mammalogy* 98(5): 1453–1462. https://doi.org/10.1093/jmammal/gyx104

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COMMUNICATION

Characterisation of breeding habitat of Grizzled Giant Squirrel *Ratufa macroura* (Mammalia: Sciuridae) in Chinnar Wildlife Sanctuary, Western Ghats, India

Kiran Thomas [1] & P.O. Nameer [2]

[1] Department of Wildlife and Habitat Management, Forest College and Research Institute, Osmania University, Hyderabad, Mulugu, Telangana 502279, India.

[2] Centre for Wildlife Studies, College of Forestry, Kerala Agricultural University, Thrissur, Kerala 680656, India.

[1] kiranzthomas@gmail.com, [2] nameer.po@kau.in (corresponding author)

Abstract: The Grizzled Giant Squirrel (GGS) *Ratufa macroura* (Pennant, 1769) is a 'Near Threatened' and endemic giant squirrel distributed in southern India and Sri Lanka. In India, the species is distributed in more than 10 locations between Cauvery Wildlife Sanctuary in Karnataka in the north and Srivilliputhur Grizzled Squirrel Wildlife Sanctuary in Tamil Nadu in the south. A study was conducted in the riparian habitats of Chinnar Wildlife Sanctuary in Kerala to understand the habitat characteristics, including the drey site use of GGS. The vegetation of the GGS habitat was studied using the quadrat method, and the dreys were counted using the transects. A total of 95 species of trees were identified from the riverine vegetation, and the GGS used 36 species of trees for drey construction. Most of the dreys were found on *Mangifera indica, Terminalia arjuna, Ficus microcarpa, Diospyros ebenum*, and *Pongamia pinnata*. However, the GGS may prefer trees such as *Mitragyna parviflora, Diospyros ebenum, Ficus microcarpa, Albizia procera, Acacia nilotica*, and *Acacia leucophloea* for drey construction. The study also highlights the usage of large trees with extensive crown by the GGS for various activities such as feeding, resting, moving, and nesting, thus signifying the necessity for protecting the remaining riverine habitat at Chinnar Wildlife Sanctuary to ensure the long-term conservation of GGS. We recommend an urgent restoration by restocking with already existing, native tree species of the riverine habitat due to the extremely poor regeneration of trees in the riverine habitat that support the only population of the GGS in Kerala.

Keywords: Conservation, drey construction, Kerala, large trees, population, riverine habitat, vegetation.

Malayalam: പശ്ചിമഘട്ടത്തിലും ശ്രീലങ്കയിലും മാത്രം കാണപ്പെടുന്ന ഒരിനം അണ്ണാനാണ് ചാമ്പൽ മലയണ്ണാൻ. ഇത് IUCNന്റെ വിശകലനത്തിൽ വംശനാശ ഭീഷണി നേരിടുന്ന ഒരിനം മലയണ്ണാൻ ആണ്. തെക്കേ ഇന്ത്യയിൽ, കർണാടകത്തിലെ കാവേരി വന്യജീവിസങ്കേതത്തിന്റെയും തെക്കു ശ്രീവില്ലിപുത്തൂർ ചാമ്പൽ മലയണ്ണാൻ വന്യജീവി സങ്കേതത്തിന്റെയും ഇടയിലായി പത്തിടങ്ങളിൽ ഇവയെ കാണപ്പെടുന്നുണ്ട്. കേരളത്തിലെ ചിന്നാർ വന്യജീവി സങ്കേതത്തിൽ നടത്തിയ ഒരു പഠനത്തിന്റെ അടിസ്ഥാനത്തിൽ, ചിന്നാറിലെ പുഴയോര കാടുകളിൽ 95ഇനം മരങ്ങൾ ഉണ്ടെന്നും, അതിൽ 36ഇനം മരങ്ങളിൽ ചാമ്പൽ മലയണ്ണാൻ കൂട് കൂട്ടുന്നതായും കണ്ടെത്തി. ഇതിൽ തന്നെ കൂടുതൽ കൂടുകളും മാവ്, അർജുൻ, ആൽമരം, കരി മരം, ഉങ്ങു എന്നിവയിലായിരുന്നു. കൂടാതെ മഞ്ഞക്കടമ്പ്, ഇത്തി, വെള്ളവാക, കരിവേലം, വെള്ളവേലം എന്നിവയും മലയണ്ണാൻ കൂടു കൂട്ടുവാൻ ഉപയോഗിക്കുന്നതായി കാണുന്നു. വലുതും വിശാലമായശാഖകളും മേലാപ്പും ഉള്ള മേൽപറഞ്ഞഗണത്തിൽപെട്ട വൃക്ഷങ്ങളാണ് ഇവ ഭക്ഷണത്തിനും, വിശ്രമത്തിനും, സഞ്ചാരത്തിനും, മറ്റുമായി കൂടുതലായി ആശ്രയിക്കുന്നത്. ഈ വൃക്ഷങ്ങളുടെ തൈകളുടെ പുനരുജ്ജീവന നിരക്ക് ചിന്നാർ വന്യജീവി സങ്കേതത്തിൽ വളരെ കുറവാണെന്ന് ഈ പഠനത്തിൽ ഞങ്ങൾക്കു കാണാൻ കഴിഞ്ഞു. ആയതിനാൽ മേൽ സൂചിപ്പിച്ച മരങ്ങളുടെ പുനരുജ്ജീവനപ്രക്രിയ അടിയന്തരമായി ചിന്നാറിലെ പുഴക്കാടുകളിൽ നടപ്പാക്കേണ്ടതായിട്ടുണ്ട്. ഇത് കേരളത്തിലെ ചാമ്പൽ മലയണ്ണാനെ കാണപ്പെടുന്ന ഏക ആവാസവ്യവസ്ഥയുടെയും, ചാമ്പൽ മലയണ്ണാനിന്റെയും നിലനിൽപ്പിനു അത്യന്താപേക്ഷിതമാണ്.

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Author details: KIRAN THOMAS worked on ecology of the Grizzled Giant Squirrel for his Master's dissertation and is currently Assistant Professor Department of Wildlife and Habitat Management in FCRI, Hyderabad. His research interest is small mammal ecology. P.O. NAMEER is Professor & Head (Wildlife) with Kerala Agricultural University and works primarily on the vertebrate ecology and biogeography in the Western Ghats.

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INTRODUCTION

The Grizzled Giant Squirrel (GGS) is endemic to southern India (Kerala, Karnataka, and Tamil Nadu) and Sri Lanka (Image 1). GGS shows one of the most important paradigms of isolated populations. In India, it is known to occur in severely fragmented locations, and a few with connections including Srivilliputhur Grizzled Squirrel Wildlife Sanctuary (Joshua & Johnsingh 1994), Theni Forest Division (Babu et al. 2013), Palani Hills (Davidar 1989), Anamalai Tiger Reserve (Kumar et al. 2002), Sirumalai (Sathasivam et al. 2008), Thiruvannamalai Forest Division (Babu & Kalaimani 2014), Hosur Forest Division (Baskaran et al. 2011), Athur & Dharmapuri (Paulraj 1991; Paulraj & Kasinathan 1993), Pakkamalai Reserve Forest, Gingee (Vimalraj et al. 2018), Cauvery Wildlife Sanctuary-Shivanasamudra Falls and Mekedatu on the Cauvery river basin (Karthikeyan et al. 1992; Kumara & Singh 2006); and Chinnar Wildlife Sanctuary (Chinnar WS) in Kerala (Ramachandran 1989; 1993, Senthilkumar et al. 2007; Thomas & Nameer 2018).

The GGS has three subspecies, with one present in southern India while all the three subspecies present in Sri Lanka (Ellerman 1961; Moore & Tate 1965; Phillips 1984; Corbet & Hill 1992; Menon 2014). *Ratufa macroura dandolena* is the smallest among the three races of GGS globally and is seen in southern India and Sri Lanka. In comparison, the other two races, *Ratufa macroura macroura* and *Ratufa macroura melanochra*, are endemic to Sri Lanka. The home range of the GGS is between 0.197 ha and 0.611 ha (Joshua 1992). There are less than 500 mature individuals of GGS in India (Joshua et al. 2008; Goonatilake 2019). However, a recent study estimated the population of the GGS and found a considerably low population in Chinnar WS than the previous estimate (Thomas & Nameer 2018).

Though the Chinnar WS has an extent of 90.44 km^2, the distribution of GGS is confined to a narrow stretch of riparian vegetation along the Chinnar and Pambar rivers and their tributaries. Either side of this riparian vegetation is surrounded by scrub jungle to dry deciduous forests not used by GGS. The actual extent of the riverine habitat preferred by GGS comes to only 2 km^2 which is around 2% of the total area of the sanctuary. The previous studies on GGS in Chinnar WS (Ramachandran 1989, 1993; Senthilkumar et al. 2007; Thomas & Nameer 2018) revealed that the animal's habitat is patchy in distribution and limited by the treeless areas in Chinnar WS (Ramachandran 1993). However, in Srivilliputhur WS and Sri Lanka, the GGS exploits the plantations of mango, coconut, and tamarind (Joshua 1992; Phillips 1984). The significant conservation challenges being faced by the GGS in Chinnar are increased predation risk due to opening up of the canopy due to natural and anthropogenic effects (Thomas et al. 2017), hybridisation between GGS and Indian Giant Squirrel (Thomas et al. 2018), disturbance in the habitat because of tourism and road kills (Ramachandran 1993).

Image 1. Grizzled Giant Squirrel *Ratufa macroura* at Chinnar Wildlife Sanctuary.

Although there are some studies on the habitat and nesting behaviour of this species (Joshua & Johnsingh 1994; Senthilkumar et al. 2007), a detailed study on the drey site usage of the species is not available. The information about drey site usage will be helpful for the long-term conservation of GGS.

MATERIALS AND METHODS

Study area

The study was conducted between April 2013 to May 2014 in the Chinnar WS, Kerala, southern India. It is located between Lat- 10.250–10.350, Long- 77.083–77.266 in the Kerala part of southern Western Ghats, in Idukki district (Figure 1). Though the Chinnar WS supports the only known population of GGS in Kerala, the GGS is seen in the Anamalai Tiger Reserve, in Tamil Nadu too, which is adjacent to the Chinnar WS. The terrain of Chinnar is undulating, with altitudes ranging 440–2,372 m. Chinnar supports different vegetation

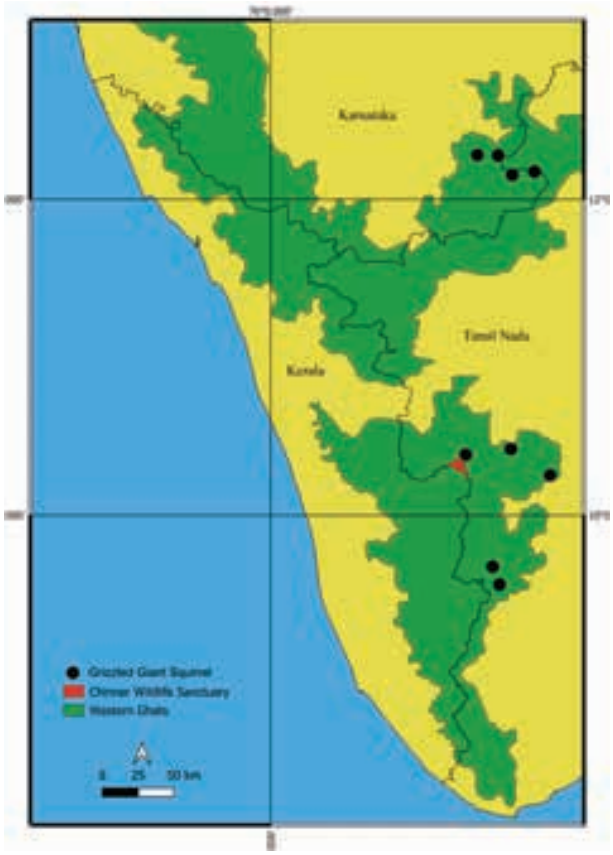

Figure 1. Location map of Chinnar Wildlife Sanctuary and other nearby populations of Grizzled Giant Squirrel in southern Western Ghats, India.

types such as southern tropical thorn forest (scrub jungle), southern dry mixed deciduous forest (dry deciduous forest), southern moist mixed deciduous forest (moist deciduous forest), tropical riparian fringing forest (riparian forest), southern montane wet temperate forest (shola forests), and southern montane wet grassland (grasslands) (Anonymous 2012; Champion & Seth 1968). The dominant vegetation among these is the dry deciduous forest followed by scrub jungle, mainly found in the plains and lower altitudes. The dry deciduous and scrub jungle together constitute about 70% of the total forest area in Chinnar (Thomas et al. 2017). However, the GGS in Chinnar WS are primarily seen only in the riverine forests along the Chinnar and Pambar rivers and tributaries which account for only about 2% of the Chinnar WS (Ramachandran 1993; Thomas & Nameer 2018).

Sampling of the Grizzled Giant Squirrel dreys

Eight, 1,000 m long transects were laid randomly after the reconnaissance survey done in the riparian habitats of Chinnar WS. These transects were walked twice a month for 12 months and recorded details of all the sighted dreys such as the number of dreys, tree species, tree height, and drey height.

Vegetation sampling

A total of 100, 10 x 10 m, quadrats were sampled for studying the vegetation in the riverine habitats in Chinnar WS. The 100m^2 (10 x 10 m) quadrats were laid at every 100m on five transects in the riverine habitats. In each quadrat, all trees with >10 cm GBH were enumerated, where the name of each tree species, the height of the tree in meters and girth at breast height in meters were recorded. The vegetation characters of tree species were quantified by calculating the following eight parameters as detailed below (after Pascal 1988).

1. Density (D) = Number of individuals/hectare

2. Relative Density (RD) = $\frac{\text{Number of individuals of the species}}{\text{Number of individuals of all species}} \times 100$

3. Abundance (A) = $\frac{\text{Total Number of individuals of the species}}{\text{Number of quadrats of occurrence}}$

4. Percentage Frequency (PF) = $\frac{\text{Number of quadrats of occurrence}}{\text{Total Number of quadrats studied}} X\ 100$

5. Relative Frequency (RF) = $\frac{\text{Percentage frequency of individuals species}}{\text{Sum Percentage Frequency of all species}}\ X\ 100$

6. Basal Area (BA) = $\frac{GBH^2}{4\Pi}$

7. Relative Basal Area (RBA) = $\frac{\text{Basal area of the species}}{\text{Basal area of all species}} X\ 100$

8. Important Value Index (IVI) = RD + RF + RBA

Statistical analysis

We calculated the selectivity index (Ivlev 1961) to find out the relationship between the vegetation and the drey site preference by the GGS. We also performed a linear regression model to find out the relationship between the height of the tree species and the drey height.

RESULTS

Tree species composition and diversity in riparian habitat at Chinnar Wildlife Sanctuary

A total of 95 tree species were recorded from the riparian habitats of Chinnar WS. The ten most dominant

Table 1. Vegetation characteristics of riparian habitat of Chinnar Wildlife Sanctuary, Western Ghats, India.

Tree species@	D	RD	A	PF	RF	BA	RBA	IVI	RIVI
Pongamia pinnata	182	21.11	2.60	3.50	12.99	0.03	0.45	34.55	11.52
Terminalia arjuna	74	8.58	1.45	2.55	9.46	0.23	3.28	21.33	7.11
Mangifera indica	48	5.57	1.45	1.65	6.12	0.21	2.91	14.60	4.87
Pterocarpus marsupium	1	0.12	1.00	0.05	0.19	0.87	12.22	12.52	4.17
Alphonsea sclerocarpa	53	6.15	3.12	0.85	3.15	0.04	0.52	9.82	3.27
Ficus benghalensis	4	0.46	1.00	0.20	0.74	0.56	7.88	9.09	3.03
Syzygium cumini	26	3.02	1.53	0.85	3.15	0.17	2.46	8.63	2.88
Ficus microcarpa	25	2.90	1.32	0.95	3.53	0.09	1.31	7.73	2.58
Sapindus tetraphylla	22	2.55	1.38	0.80	2.97	0.02	0.32	5.84	1.95
Spondias pinnata	1	0.12	1.00	0.05	0.19	0.38	5.33	5.63	1.88
Lepisanthes senegalensis	19	2.20	1.46	0.65	2.41	0.07	0.95	5.57	1.86
Diospyros ebenum	23	2.67	1.92	0.60	2.23	0.04	0.61	5.51	1.84
Melia dubia	7	0.81	1.40	0.25	0.93	0.27	3.76	5.50	1.83
Psychoteris subintegra	23	2.67	1.77	0.65	2.41	0.01	0.08	5.16	1.72
Ficus racemosa	2	0.23	1.00	0.10	0.37	0.30	4.22	4.83	1.61
Mallotus philippensis	14	1.62	1.27	0.55	2.04	0.04	0.53	4.20	1.40
Jatropha sp.	18	2.09	1.64	0.55	2.04	0.00	0.06	4.19	1.40
Emblica officinalis	1	0.12	1.00	0.05	0.19	0.28	3.88	4.18	1.39
Gyrocarpus asiaticus	13	1.51	1.44	0.45	1.67	0.05	0.77	3.95	1.32
Calophyllum inophyllum	5	0.58	1.67	0.15	0.56	0.19	2.70	3.83	1.28
Albizia odoratissima	6	0.70	1.50	0.20	0.74	0.17	2.36	3.80	1.27
Schleichera oleosa	11	1.28	1.10	0.50	1.86	0.04	0.60	3.73	1.24
Albizia lebbeck	3	0.35	1.50	0.10	0.37	0.20	2.84	3.56	1.19
Manilkara hexandra	1	0.12	1.00	0.05	0.19	0.22	3.06	3.36	1.12
Artocarpus hirsutus	10	1.16	1.25	0.40	1.48	0.04	0.57	3.21	1.07
Euphorbia sp.	14	1.62	1.75	0.40	1.48	0.01	0.08	3.19	1.06
Tamarindus indica	11	1.28	1.10	0.50	1.86	0.01	0.00	3.13	1.04
Hopea parviflora	7	0.81	1.00	0.35	1.30	0.07	0.97	3.08	1.03
Dalbergia latifolia	10	1.16	2.00	0.25	0.93	0.05	0.75	2.84	0.95
Garuga floribunda	5	0.58	1.00	0.25	0.93	0.09	1.33	2.84	0.95
Cassia fistula	9	1.04	1.50	0.30	1.11	0.05	0.67	2.82	0.94
Chloroxylon swietenia	2	0.23	1.00	0.10	0.37	0.15	2.08	2.68	0.89
Commiphora caudata	10	1.16	1.67	0.30	1.11	0.03	0.39	2.66	0.89
Gmelina arborea	10	1.16	2.00	0.25	0.93	0.04	0.57	2.65	0.88
Garcinia gummi-gutta	7	0.81	1.17	0.30	1.11	0.05	0.65	2.57	0.86
Ceiba pentandra	2	0.23	2.00	0.05	0.19	0.15	2.08	2.49	0.83
Bauhinia racemosa	6	0.70	1.50	0.20	0.74	0.06	0.87	2.31	0.77
Stereospermum chelonoides	5	0.58	1.25	0.20	0.74	0.07	0.97	2.29	0.76
Albizia procera	6	0.70	1.20	0.25	0.93	0.04	0.58	2.21	0.74
Canarium strictum	5	0.58	1.00	0.25	0.93	0.05	0.67	2.17	0.72
Vitex altissima	3	0.35	3.00	0.05	0.19	0.11	1.59	2.12	0.71
Cassine paniculata	6	0.70	1.50	0.20	0.74	0.05	0.68	2.12	0.71
Anthocephalus cadamba	1	0.12	1.00	0.05	0.19	0.13	1.78	2.08	0.69
unidentified sp.2	4	0.46	1.00	0.20	0.74	0.06	0.87	2.08	0.69
Santalum album	7	0.81	1.17	0.30	1.11	0.01	0.15	2.07	0.69
Olea dioica	5	0.58	1.25	0.20	0.74	0.05	0.67	1.99	0.66
Phyllanthus emblica	5	0.58	1.25	0.20	0.74	0.04	0.61	1.94	0.65
Garuga pinnata	8	0.93	2.00	0.20	0.74	0.02	0.26	1.93	0.64
Randia dumetorum	6	0.70	1.00	0.30	1.11	0.01	0.08	1.89	0.63

Tree species@	D	RD	A	PF	RF	BA	RBA	IVI	RIVI
Acacia leucophloea	6	0.70	2.00	0.15	0.56	0.04	0.63	1.88	0.63
Strychnus nux-vomica	5	0.58	1.25	0.20	0.74	0.04	0.53	1.86	0.62
Drypetes sepiaria	5	0.58	1.25	0.20	0.74	0.04	0.50	1.83	0.61
Strychnos potatorum	5	0.58	1.25	0.20	0.74	0.03	0.45	1.77	0.59
Ficus albiphyla	1	0.12	1.00	0.05	0.19	0.10	1.46	1.76	0.59
Anogeissus latifolia	6	0.70	2.00	0.15	0.56	0.03	0.38	1.63	0.54
Azadirachta indica	4	0.46	1.00	0.20	0.74	0.02	0.30	1.51	0.50
Ixora brachiata	4	0.46	1.00	0.20	0.74	0.02	0.25	1.45	0.48
Mitragyna parvifolia	3	0.35	1.00	0.15	0.56	0.03	0.47	1.38	0.46
Memecylon umbellatum	2	0.23	1.00	0.10	0.37	0.05	0.77	1.38	0.46
Ficus sp.	2	0.23	1.00	0.10	0.37	0.05	0.74	1.34	0.45
unidentified sp.8	5	0.58	1.25	0.20	0.74	0.03	0.01	1.33	0.44
Excoecaria oppositifolia	2	0.23	1.00	0.10	0.37	0.05	0.70	1.30	0.43
Mallottus alba	5	0.58	2.50	0.10	0.37	0.02	0.34	1.29	0.43
Streblus asper	4	0.46	1.33	0.15	0.56	0.01	0.18	1.20	0.40
Aporosa cardiosperma	1	0.12	1.00	0.05	0.19	0.06	0.85	1.15	0.38
Acacia nilotica	2	0.23	1.00	0.10	0.37	0.04	0.52	1.12	0.37
Ziziphus oenoplia	4	0.46	1.33	0.15	0.56	0.01	0.09	1.11	0.37
Canthium umbellatum	5	0.58	2.50	0.10	0.37	0.01	0.15	1.10	0.37
Crotalaria pellida	2	0.23	1.00	0.10	0.37	0.03	0.47	1.08	0.36
Holigarna arnotiana	1	0.12	1.00	0.05	0.19	0.05	0.75	1.06	0.35
unidentified sp.4	4	0.46	2.00	0.10	0.37	0.01	0.20	1.03	0.34
Ziziphus xylopyrus	1	0.12	1.00	0.05	0.19	0.05	0.70	1.00	0.33
Manilkara roxburghiana	2	0.23	1.00	0.10	0.37	0.02	0.35	0.95	0.32
Grewia tiliifolia	1	0.12	1.00	0.05	0.19	0.04	0.63	0.93	0.31
Alseodaphnae semecarpifolia	2	0.23	1.00	0.10	0.37	0.02	0.32	0.92	0.31
Miliusa tomentosa	1	0.12	1.00	0.05	0.19	0.04	0.58	0.88	0.29
unidentified sp.6	3	0.35	1.50	0.10	0.37	0.01	0.14	0.86	0.29
Canthium dicoccum	2	0.23	1.00	0.10	0.37	0.02	0.25	0.85	0.28
unidentified sp.1	1	0.12	1.00	0.05	0.19	0.03	0.47	0.78	0.26
Plumeria alba	1	0.12	1.00	0.05	0.19	0.03	0.47	0.78	0.26
Sapindus trifoliatus	2	0.23	1.00	0.10	0.37	0.01	0.17	0.77	0.26
Ziziphus mauritiana	2	0.23	1.00	0.10	0.37	0.01	0.15	0.76	0.25
Helicteres isora	3	0.35	1.50	0.10	0.37	0.002	0.03	0.75	0.25
Lepisanthes tetraphylla	2	0.23	1.00	0.10	0.37	0.01	0.14	0.74	0.25
Bamboo sp.	2	0.23	1.00	0.10	0.37	0.01	0.12	0.73	0.24
Euphorbia trigona	2	0.23	1.00	0.10	0.37	0.01	0.12	0.73	0.24
unidentified sp.3	3	0.35	3.00	0.05	0.19	0.01	0.17	0.70	0.23
Terminalia paniculata	1	0.12	1.00	0.05	0.19	0.03	0.38	0.68	0.23
unidentified sp.5	1	0.12	1.00	0.05	0.19	0.03	0.38	0.68	0.23
Ailanthus triphysa	1	0.12	1.00	0.05	0.19	0.02	0.23	0.53	0.18
Acacia intsia	1	0.12	1.00	0.05	0.19	0.01	0.15	0.46	0.15
Ficus hispida	1	0.12	1.00	0.05	0.19	0.01	0.14	0.44	0.15
Acacia catechu	1	0.12	1.00	0.05	0.19	0.01	0.09	0.39	0.13
unidentified sp.7	1	0.12	1.00	0.05	0.19	0.006	0.06	0.37	0.12
Chukrasia tabularis	1	0.12	1.00	0.05	0.19	0.001	0.02	0.32	0.11
Total	862	100	127.74	26.95	100	7.13	100	300	100

@—arranged in the descending order of the IVI index value | D—density (trees/ha) | RD—relative density | A—abundance | PF—percentage frequency | RF—relative frequency | BA—basal area (m^2/ha.) | RBA—relative basal area | IVI—important value index | RIVI—relative important value index.

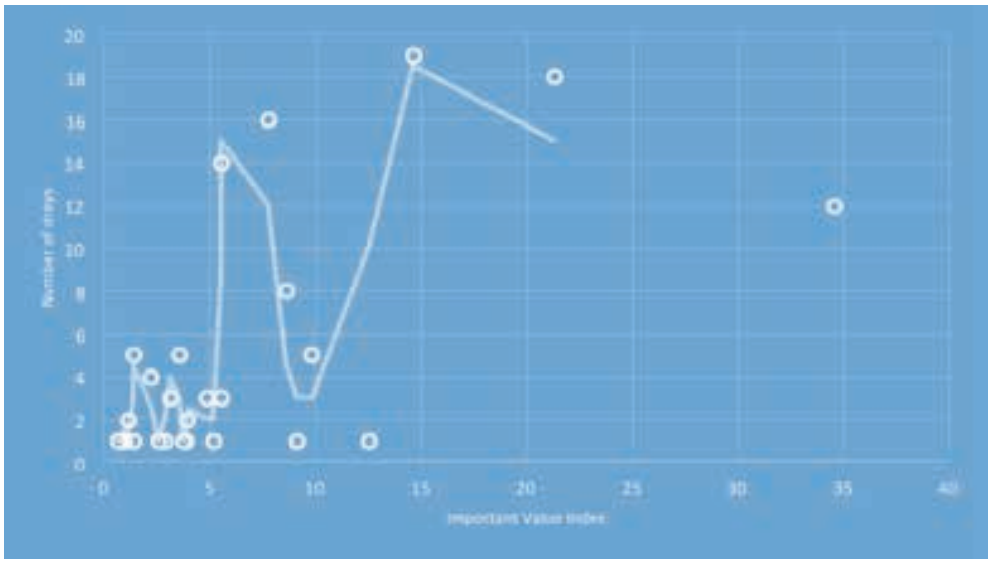

Figure 2. Relationship between the Important Value Index of the riparian vegetation and the number of dreys of Grizzled Giant squirrels at Chinnar Wildlife Sanctuary.

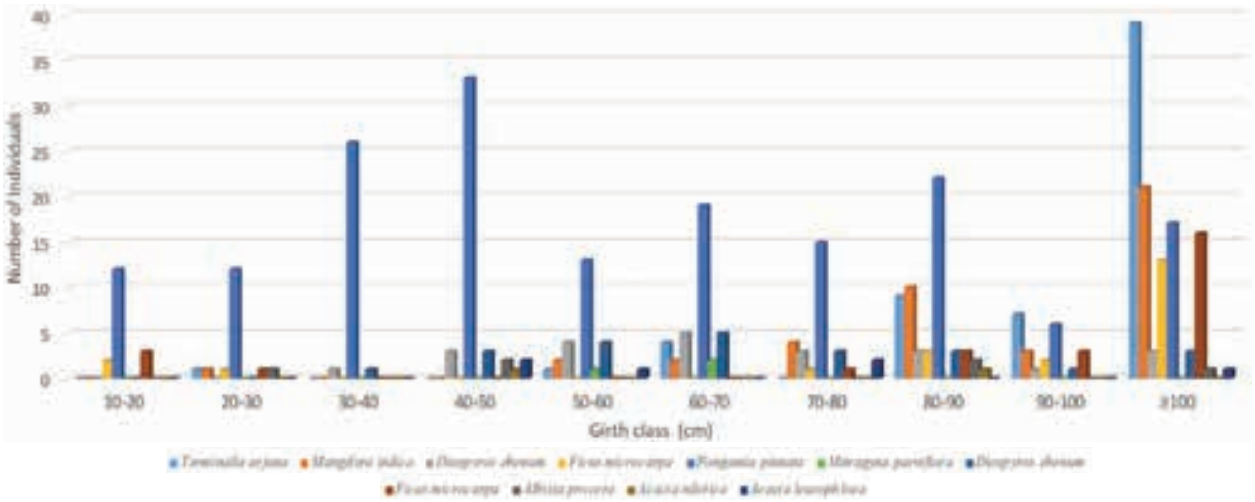

Figure 3. The girth class distribution of selected tree species used by the Grizzled Giant Squirrel for drey construction at Chinnar Wildlife Sanctuary.

tree species in the GGS habitat were *Pongamia pinnata, Terminalia arjuna, Mangifera indica, Pterocarpus marsupium, Alphonsea sclerocarpa, Ficus benghalensis, Syzygium cumini, Ficus microcarpa, Sapindus tetraphylla*, and *Spondias pinnata* (Table 1). The riparian habitat of the GGS is also characterised by a tree density of 862 trees per hectare and a tree basal area of 7.13 m^2/ha.

Characterising of the drey site occurrence of Grizzled Giant Squirrels

The GGSs were found to be using about 36 trees in Chinnar WS for drey construction (Table 2), and a total of 144 dreys were recorded. The following five species were found holding 54.86 % of the total dreys. The five species were *Mangifera indica* (n= 19) *Terminalia arjuna* (n= 18), *Ficus microcarpa* (n= 16), *Diospyros ebenum* (n= 14), and *Pongamia pinnata* (n= 12). The correlation studies between the important value index (IVI) of the trees and drey numbers showed (Figure 2) that there is no correlation between the dominant trees and the drey selection. This also suggests that the choice of nesting trees by the GGS is not random, and going by the ranks of the Ivlev index indicate that the GGS may have a preference for the trees such as *Mitragyna*

Table 2. Tree use preference by Grizzled Giant Squirrel for drey construction at Chinnar Wildlife Sanctuary, Western Ghats, India.

Tree species@	Family	Number of dreys	Habit	IVI	Ivlev index
Mitragyna parviflora	Rubiaceae	5	Deciduous	1.38	0.567
Diospyros ebenum	Ebenaceae	14	Evergreen	5.51	0.435
Ficus microcarpa	Moraceae	16	Evergreen	7.73	0.349
Albizia procera	Fabaceae	4	Deciduous	2.21	0.288
Acacia nilotica	Fabaceae	2	Deciduous	1.12	0.282
Acacia leucophloea	Fabaceae	1	Deciduous	0.63	0.227
Albizia lebbeck	Fabaceae	5	Deciduous	3.56	0.168
Mangifera indica	Anacardiaceae	19	Evergreen	14.6	0.131
Sapindus trifoliatus	Sapindaceae	1	Evergreen	0.77	0.130
Hopea parviflora	Dipterocarpaceae	1	Evergreen	0.97	0.015
Tamarindus indica	Fabaceae	3	Evergreen	3.13	-0.021
Syzygium cumini	Myrtaceae	8	Evergreen	8.63	-0.038
Terminalia arjuna	Combretaceae	18	Evergreen	21.33	-0.085
Memecylon grande	Melastomataceae	1	Evergreen	1.38	-0.160
Ficus racemosa	Moraceae	3	Evergreen	4.83	-0.234
Melia dubia	Meliaceae	3	Deciduous	5.5	-0.294
Alphonsea sclerocarpa	Annonaceae	5	Deciduous	9.82	-0.325
Gyrocarpus asiaticus	Hernandiaceae	2	Deciduous	3.95	-0.328
Garcinia gummi-gutta	Guttiferae	1	Evergreen	2.57	-0.440
Dalbergia latifolia	Fabaceae	1	Deciduous	2.85	-0.481
Pongamia pinnata	Leguminosae	12	Evergreen	34.55	-0.484
Schleichera oleosa	Sapindaceae	1	Deciduous	3.73	-0.577
Calophyllum inophyllum	Guttiferae	1	Evergreen	3.83	-0.586
Psychotria subintegra	Rubiaceae	1	Evergreen	5.16	-0.675
Ficus benghalensis	Moraceae	1	Evergreen	9.09	-0.802
Pterocarpus marsupium	Fabaceae	1	Deciduous	12.52	-0.852

@—arranged in the descending order of Ivlev index

parviflora, Diospyros ebenum, Ficus microcarpa, Albizia procera, Acacia nilotica, and *Acacia leucophloea* for drey construction.

Regeneration of the trees in the riverine habitat in Chinnar WS

The regeneration of the trees used by the GGS for drey construction was extremely low in Chinnar WS (Figure 3), as evidenced by the absence of individuals in the lower girth classes for most tree species. Ideally, the girth class distribution of the tree species in an undisturbed forest should have been showing an inverse 'J' pattern (Pascal 1988). In contrast, at Chinnar riverine patch, the plants with lower girth classes were more or less completely absent for most of the trees except *Pongamia pinnata*.

Relationship between the tree height and the drey height

The linear regression model analysis clearly showed a strong correlation between the height of the tree and the height at which the drey was constructed (R= 0.9483, P <0.0001) (Figure 4). It can also be deduced from this graph that the GGSs showed more significant variation in the height of the trees used to construct the dreys, which varied from 5 m to 30 m (Figure 4), with most of the drey height being between 15 to 20 m. However, it is interesting to note that the tree height influences the drey height in the respective habitat (Figure 5a,b).

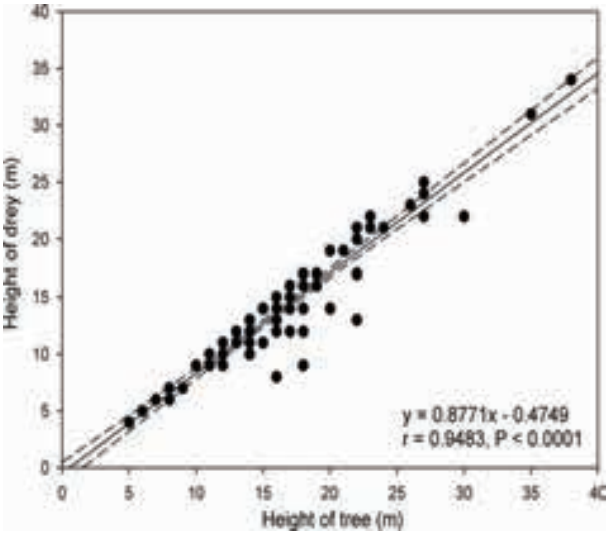

Figure 4. Relationship between drey height and tree height in Chinnar Wildlife Sanctuary, Western Ghats, India. Dashed line is 95% confidence interval of regression line.

DISCUSSION

The GGS were found using large, mature trees for the drey construction in the riverine habitat at Chinnar WS. The dreys were built just below the canopy of the trees. GGS's usually prefer significantly larger trees with greater girth and taller trees with multiple branches for drey construction (Senthilkumar et al. 2007). The selection of mature trees with greater canopy continuity could facilitate easy movement to and from the drey in all directions, equip the animal by providing a significant advantage to escape from predators and to move to other parts of the home range for foraging and other activities. The extent to which GGS is using a habitat depends on the composition of tree species and structural attributes of the forests canopy, predominantly the canopy continuum. Discontinuous forests are known to restrict their movement and dispersal because of their arboreal habit. Most of the arboreal dwellers and GGS prefer those habitats that provide dense canopy cover and higher canopy height (Baskaran et al. 2011; Nagarajan et al. 2011).

The observations in this study corroborate the findings of previous studies that giant squirrels prefer areas with canopy connectivity to live and build their dreys (Baskaran et al. 2011). The first branching height of the tree increases with its total height; hence the drey would have to be higher on taller trees. This may be helping the animal to escape from predation and effective utilisation of its entire home range for resources.

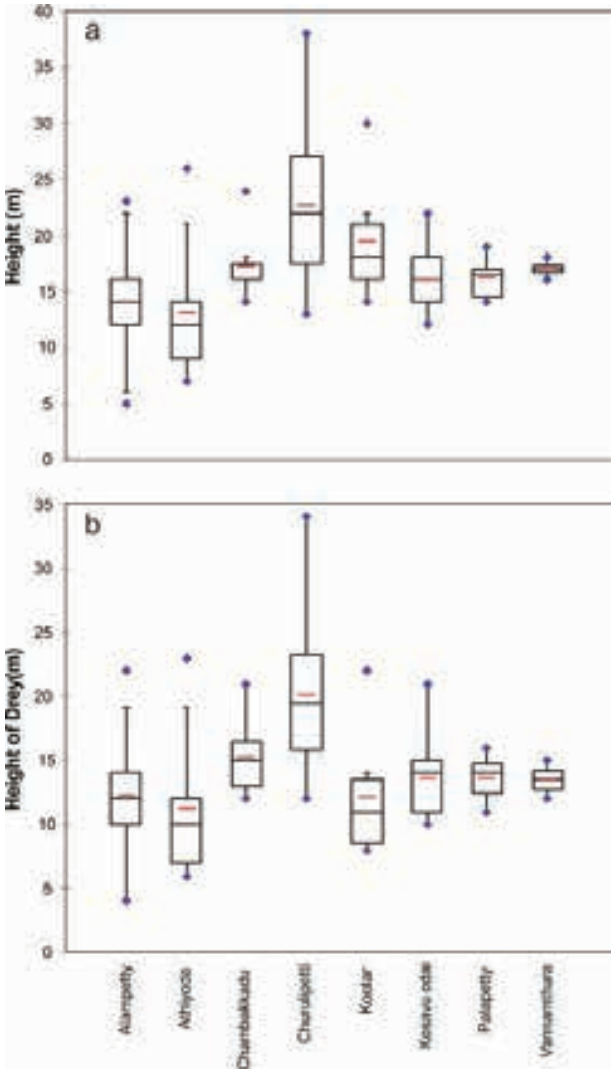

Figure 5. Height of the tree (a) and height at which the drey was constructed (b) in eight riparian locations of Chinnar Wildlife Sanctuary.

The GGS in Chinnar WS was found to construct globular dreys using leaves and twigs. One pair of GGS makes multiple dreys within their home range, similar to other giant squirrels (Prater 1971; Srinivas et al. 2008). The GGS was found to construct multiple dreys at a time. The construction and use of multiple dreys might provide conveniently placed insulated nesting places throughout the territory or reduce drey predation (Borges 2015). Drey rotation may also help to avoid extremes of weather conditions like temperature and rainfall. The rotation of the drey will also reduce ectoparasite load.

In the Sitanadi WS, 77.68% of the dreys of giant squirrels were found on deciduous trees, while 22.32 % were located on the evergreen trees (Kanoje 2008). However, in the present study, 73.61 % of nesting trees

were evergreen.

The extremely poor regeneration of the tree species used by the GGS for the drey construction at Chinnar WS is a matter of concern. It warrants urgent restoration programmes at Chinnar riverine habitat with the most suitable native tree species.

REFERENCES

Babu, S. & A. Kalaimani (2014). New site record of Grizzled Giant Squirrel *Ratufa macroura* from Thiruvannamalai Forest Division, Eastern Ghats, Tamil Nadu, India. *Journal of Threatened Taxa* 6(2): 5492–5493. https://doi.org/10.11609/JoTT.o3680.5492-3

Babu, S., G. Srinivas, H.N. Kumara, K. Tamilarasu & S. Molur (2013). CEPF Western Ghats Special Series: Mammals of the Meghamalai landscape, southern Western Ghats, India - a review. *Journal of Threatened Taxa* 5(15): 4945–4952. https://doi.org/10.11609/JoTT.o3596.4945-52

Baskaran, N., K. Senthilkumar & M. Saravanan (2011). A new site record of the Grizzled Giant Squirrel *Ratufa macroura* (Pennant, 1769) in the Hosur forest division, Eastern Ghats, India and its conservation significance. *Journal of Threatened Taxa* 3(6): 1837–1841. https://doi.org/10.11609/JoTT.o2632.1837-41

Borges, R.M. (2015). Indian Giant Squirrel (*Ratufa indica*), pp 483–500. In: Johnsingh, A.J.T & N. Manjrekar (eds.). *Mammals of South Asia-Vol. II*. The University Press, India, 799pp.

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India*. Government of India Press, Delhi, 404pp.

Corbet, G.B. & J.E. Hill (1992). *The Mammals of the Indo-Malayan region: A systematic review*. Natural History Museum Publications, Oxford University Press, Oxford. 496 pp.

Davidar, P. (1989). Grizzled Giant Squirrel, *Ratufa macroura* – distribution in Kudirayar. *Journal of the Bombay Natural History Society* 86(3): 437.

Ellerman, J.R. (1961). *The fauna of India including Pakistan, Burma and Ceylon. Mammalia –2nd Edition, Vol. 3. Rodentia*. The Zoological Survey of India, Calcutta, 884pp.

Goonatilake, de A. (2019). *Ratufa macroura*. In The IUCN Red List of Threatened Species2019:e.T19381A22261644. Downloaded on 13 July 2019. https://doi.org/10.2305/IUCN.UK.2019.1.RLTS.T19381A22261644.en

Hammer, Ø., D.A.T. Harper & P.D. Ryan (2001). Past: Paleontological Statistics Software Package for education and data analysis. *Paleontologia Electronica* 4: 1–9.

Joshua, J. (1992). Ecology of the endangered Grizzled Giant Squirrel (*Ratufa macroura*) in Tamil Nadu, South India. Ph.D. Thesis. Bharathidasan University, Tiruchirapalli, Tamil Nadu, 191pp.

Joshua, J. & A.J.T. Johnsingh. (1994). Impact of biotic disturbances on the habitat and population of the endangered Grizzled Giant Squirrel, *Ratufa macroura* in South India. *Biological Conservation* 68: 29–34.

Joshua, J., W.L.D.P.T.S. de A. Goonatilake & S. Molur (2008). *Ratufa macroura*. In IUCN 2010. IUCN Red List of Threatened Species. Downloaded on 06 June 2018.

Kanoje, R.S. (2008). Nesting sites of Indian giant squirrels in Sitanadi Wildlife Sanctuary, India. *Current Science* 95: 882–884.

Karthikeyan, S., J.N. Prasad & B. Arun (1992). Grizzled Giant Squirrel *Ratufa macroura* Thomas and Wroughton at Cauvery valley in Karnataka. *Journal of the Bombay Natural History Society* 89(3): 360–361.

Kumar, M.A., M. Singh, S.K. Srivastava, A. Udhayan, H.N. Kumara & A.K. Sharma (2002). Distribution patterns, relative abundance and management of mammals in Indira Gandhi Wildlife Sanctuary, Tamil Nadu, India. *Journal of the Bombay Natural History Society* 99(2): 184–210.

Kumara, H.N. & M. Singh (2006). Distribution and relative abundance of giant squirrel and flying squirrel in Karnataka, India. *Mammalia* 70: 40–47.

Menon, V. (2014). *Indian Mammals: A Field Guide*. Hachette book publishing India Pvt. Ltd., Gurgaon, Haryana, 528pp.

Moore, J.C. & G.H.H. Tate (1965). A study of diurnal squirrels, Sciurinae of the Indian and Indo – Chinese subregion. *Fieldiana Zoology* 48: 1–351.

Nagarajan, B., S. Venkatesan, J. Mani, S.K. Srivastava & A.A. Desai (2011). Some aspects of the ecology of the Indian Giant Squirrel *Ratufa indica* (Erxleben, 1777) in the tropical forests of Mudumalai Wildlife Sanctuary, southern India and their conservation implications. *Journal of Threatened Taxa* 3: 1899–1908. https://doi.org/10.11609/JoTT.o2593.1899-908

Pascal, J.P. (1988). *Wet Evergreen Forests of Western Ghats of India: Ecology, Structure, Floristic composition and Succession.* French Institute, Pondicherry, 337pp.

Paulraj, S. (1991). Grizzled Giant Squirrel in the final throes of extinction process. *Zoos' Print* 6(10): 1–2.

Paulraj, S. & N. Kasinathan (1993). Scanty known Grizzled Giant Squirrel (*Ratufa macroura*) of India: status and conservation. *Indian Forester* 119: 828–833.

Phillips, W.W.A. (1984). *Manual of the Mammals of Sri Lanka. 3rd Edition.* Wildlife and Nature Protection Society of Sri Lanka, Sri Lanka.

Prater, S.H. (1971). *The book of Indian animals*. Bombay Natural History Society, Mumbai, 324 pp.

Ramachandran, K.K. (1989). Endangered Grizzled Giant Squirrel habitat. *Journal of Bombay, Natural History Society* 86 (1): 94–95.

Ramachandran, K.K. (1993). Status survey and distribution of endangered Grizzled Giant Squirrel in Chinnar Wildlife Sanctuary, Kerala, India. *Indian Journal of Forestry* 16(3): 226–231.

Sathasivam, K., V. Santharam, K.V. Sudhakar & T.B. Narayanan (2008). An unreported population of the Grizzled Giant Squirrel *Ratufa macroura*. *Journal of the Bombay Natural History Society* 105(2): 213.

Senthilkumar, K., G. Agoramoorthy & M.J. Hsu. (2007). Population size, density and conservation status of Grizzled Giant Squirrel in Chinnar Wildlife Sanctuary, India. *Mammalia* 71: 89–94pp.

Srinivas, V., P.D. Venugopal & S. Ram (2008). Site occupancy of the Indian Giant Squirrel *Ratufa indica* (Erxleben) in Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu, India. *Current Science* 95(7): 889–894.

Thomas, K. & P.O. Nameer (2018). Alarming population status of the Grizzled Giant Squirrel (*Ratufa macroura*) (Mammalia: Rodentia: Sciuridae) in Chinnar Wildlife Sanctuary, Western Ghats. *Journal of Threatened Taxa* 10(10): 12350–12356. https://doi.org/10.11609/jott.3536.10.10.12350-12356.

Thomas, K., A.A. Das & P.O. Nameer (2017). A report on the predation of Grizzled Giant Squirrel (*Ratufa macroura*) by Changeable Hawk-Eagle (*Nisaetus cirrhatus*), from Western Ghats, South India. *Zoo's Print* 32(4): 11–14.

Thomas, K., D.K. Vinodkumar, J. Mathews, M. Shaji & P.O. Nameer (2018). A report on the possible interbreeding between Grizzled Giant Squirrel *Ratufa macroura* and Malabar Giant Squirrel *Ratufa indica* from Chinnar Wildlife Sanctuary, Kerala, southern Western Ghats. *Journal of Threatened Taxa* 10(15): 13024–13028. https://doi.org/10.11609/jott.3995.10.15.13024-13028

Vimalraj, S., K. Raman, D.A. Reddy, B. Harikrishnan, B.M. Krishnakumar & K.M. Selvan (2018). A new sight record and range extension of the Grizzled Giant Squirrel *Ratufa macroura dandolena* (Mammalia: Rodentia: Sciuridae) in the Eastern Ghats of southern peninsular India. *Journal of Threatened Taxa* 10(1): 11240–11242. https://doi.org/10.11609/jott.3932.10.1.11240-11242

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COMMUNICATION

Seasonal prey availability and diet composition of Lesser Asiatic Yellow House Bat *Scotophilus kuhlii* Leach, 1821

Shani Kumar Bhartiy [1] & Vadamalai Elangovan [2]

[1,2]Department of Zoology, Babasaheb Bhimaro Ambedkar University, Lucknow, Uttar Pradesh 226025, India

[1] shanikumarbhartiy@gmail.com (corresponding author), [2] elango70@yahoo.com

Abstract: Diet is an important factor in understanding bat ecology and conservation. This study assessed seasonal prey availability and diet composition of the Asiatic Lesser Yellow House Bat *Scotophilus kuhlii* in various districts of Uttar Pradesh between January 2016 to December 2018. Fecal and insect samples were collected seasonally using sweep nets between 1800 and 1900 h. From each location 20 fecal pellets were selected for analysis and searched for taxonomically recognizable remnants. The analysis revealed that *S. kuhlii* fed on Coleoptera, Diptera, Hymenoptera, Isoptera, Orthoptera, Odonata, Blattodae, Lepidoptera, and Hemiptera, identified from legs, antennae and wings/elytra in fecal pellets. Seasonal variation in the presence of isolated insect remnants and insect abundance at foraging grounds was observed. Thus *S. kuhlii* is a voracious feeder and plays an important role as a pest control agent.

Keywords: Food item, insect abundance, remnants, season

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Author details: Shani Kumar Bhartiy has completed his PhD on "Effect of urbanization of roosting, feeding and reproductive behaviour of Asiatic Lesser Yellow Bat, *Scotophilus kuhlii*" and currently working on roosting ecology of insectivorous bats. V. Elanovan is Professor in the Department of Zoology, Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh and working on behavioural ecology of bats for the last two decades. VE is currently working on "conventional and alternative reproductive strategies of Indian Flying Fox".

Author contributions: SKB performed the experimental work and data analysis and drafted the manuscript. VE designed the experiment and edited the manuscript.

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INTRODUCTION

Foraging behavior has a vital role in evolutionary biology and ecology, with major contributions to survival, growth and reproductive success (Kramer 2001). Bats are nocturnal animals with many endangered and declining species throughout the world (Voigt et al. 2016). They are important components of ecosystems, acting as predators and seed dispersing agents (Kalka & Kalko 2006; Tang et al. 2008). Insectivorous bats are usually classified according to their foraging strategy as aerial hawkers, or as foliage gleaners such as *Myotis nattereri. Barbastella barbastellus* (Findley 1993; Patterson et al. 2003). Several kinds of nocturnal insects, such as moths, mantids, lacewings, orthopterans, and beetles, have evolved tympanic organs that are sensitive to bat echolocation calls (Fenton et al. 1998).

One of the important factors in understanding bat ecology and conservation is diet. Insect abundance can change due to factors such as climate changes and variation in the availability of food resources in surrounding habitats (Wolda 1988), which ultimately effects diversity and abundance of bat food resources (Hails 1982; Janzen & Pond 1975; Kingslover 1989; Tulp & Schekkerman 2008). Several studies have reported that tropical insects undergo seasonal changes in abundance, at least for those parts of the tropics where seasons are alternate (Dobzhansky & Pavan 1950; Owen & Chanter 1970, 1972; Janzen & Pond 1975; Wolda 1978). Whitaker (1995) suggested that insectivorous bats generally select among available food, but become more opportunistic when food becomes limited.

Michal et al. (2012) reported that *Myotis nattereri* consumed food highest in late summer and early autumn and lowest in cold weather. The most common insect orders consumed by bats are Coleoptera, Lepidoptera, Diptera, Hymenoptera, and Isoptera (Verts et al. 1999; Pavey et al. 2001). Bats have several morphological adaptations that allow them to capture and handle prey in flight and their teeth are also a more important component for chewing (Evans & Samson 1998). While wing morphology helps the bats to do various maneuvers during flight (Norberg & Rayner 1987) direct observation of foraging behaviour of insectivorous bats typically is not possible hence most authors have necessarily used fecal pellet analyses to quantify diet compositions (Whitaker et al. 1977). However, a thorough understanding of prey use among insectivorous bats requires knowledge of prey availability in surrounding habitats. Understanding the foraging ecology of insectivorous bats is further hindered by limited knowledge of how diet varies within species.

Diet composition is influenced by food availability, seasonal variations, and strategies with which a particular bat species responds to these changes (Swift & Racey 1983; Shiel et al. 1991; Catto et al. 1994). Insectivorous bats may indicate flexible exploitation of available food resources in the diet composition, foraging occasionally and less selective feeding (Belwood & Fenton 1976; Swift et al. 1985; Rydell 1986; Hoare 1991). Among the prey categories, they consume large quantities of lepidopterans (moths), coleopterans (beetles), dipterans (flies), homopterans (cicadas, leafhoppers), and hemipterans (true bugs) (Anthony & Kunz 1977; Ross 1961; Leelapaibul et al. 2005) which are mostly pests of agro crops (Harris 1970). Bats are therefore known as ravenous feeders of nocturnal insects which damage a large number of crops annually (Harris 1970).

Several earlier studies reported that *Scotophilus kuhlii* foraged predominately in open environments, as well as at the edge of the cluttered environments such as the crowns of trees within the urban environment, around street lights, agriculture fields, and over water bodies (Zhu et al. 2012). It echolocates at a frequency of 45.72 kHz, can detect prey over long distances in open habitats, and may catch relatively large prey (Zhu et al. 2012). Its echolocation calls were relatively broadband frequency-modulated with the fourth harmonic up to 200 kHz during the flight (Neuweiler 1984). Thus we predicted the diet composition of *S. kuhlii* varied with season. Therefore, the main aim of this study was to access the seasonal food preference and diet composition of *S. kuhlii* in Uttar Pradesh.

MATERIALS AND METHODS

Study area

The study was carried out in various districts of Uttar Pradesh between January 2016 and December 2018. The geographical area of the state is 240,928 km^2 which constitutes 7.3% of the total area of the country. The climate of Uttar Pradesh is characterized by temperature ranging from 5°C in winter to 45°C in summer. Annual rainfall varies from 1,000 mm to 1,200 mm of which about 90% occurs from June to September which is the south-west monsoon. India is home to an extraordinary variety of climatic regions, ranging from tropical in the south to temperate and alpine in the Himalayan north, where elevated regions receive sustained snowfall in the winter.

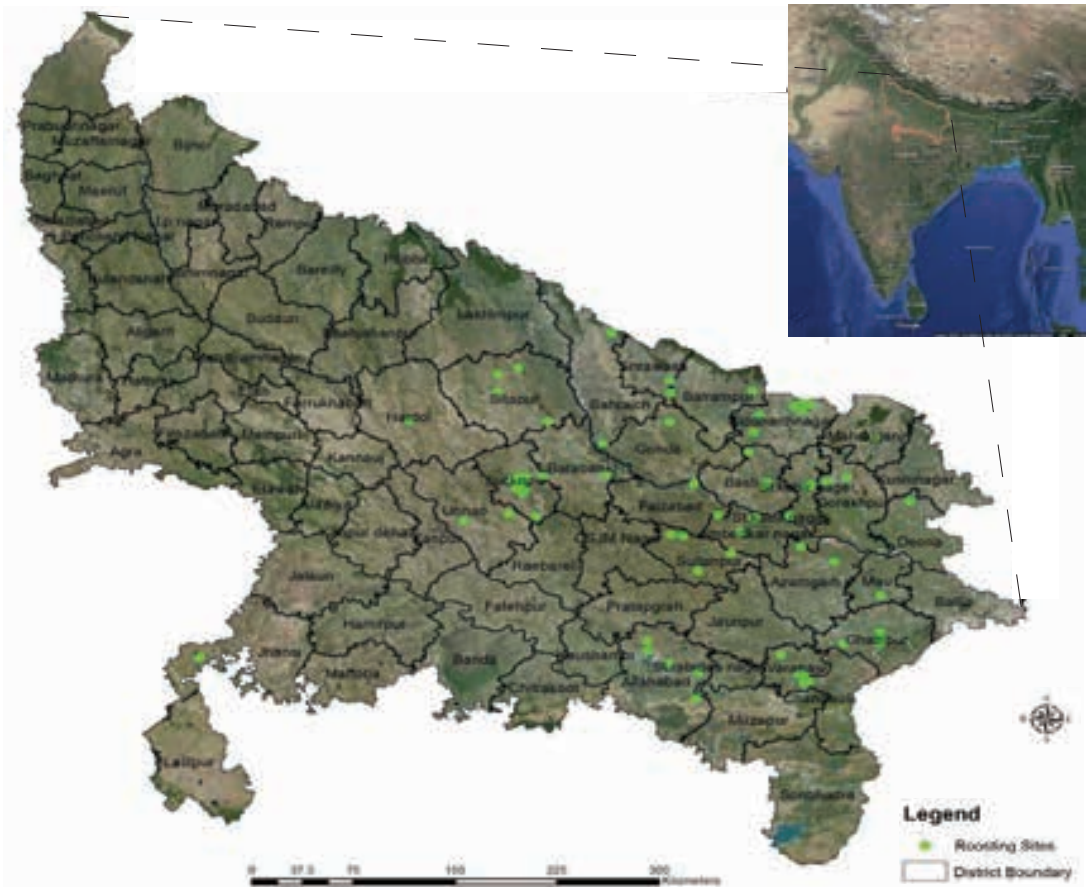

Figure 1. Map of the study area (Uttar Pradesh). Green circles represent sampling locations.

Sample collection

The fecal pellets were collected seasonally by spreading polythene sheets (10 x 14 cm) on the attic floor and in front of the roost entrance at 216 roosts in 24 districts (Figure 1). Fecal pellets from these roosts were collected in the summer months (March–June), monsoon (July–October) and winter (November–February). Sampling was performed in the morning after the bats returned to the roost, at about one-month interval at various roosting sites of Uttar Pradesh, which is the biggest state of India. Simultaneously, we collected insects from foraging grounds surrounding the roosting sites using sweep nets (radius 20 cm) from 1800 to 1900 h in the evenings where possible. All investigated roosts were located near man-made structures including monuments, abandoned buildings, temples, and trees where bats hunted for prey. From each location, average one gram pellets approximately 25 to 50 pellets were collected, and among them, only 20 pellets were taken at random and analyzed monthly.

Pellet analysis

We collected fresh guano pellets only, and thus the date of collection reflected recent diets. Fecal pellets were soaked in distilled water, then completely dissected with a needle, forceps, and tweezers and searched for recognizable remnants. The analysis was done using a light microscope (BR BIOCHAM, 1402923) with 10x magnification. The identification of remnants was done examining legs, antennae, and wings or elytra. Members of Arthropoda were identified to the order as well as family level using published identification guides and keys (Mroczkowski 1955; Trojan 1957; Pławilszczikow 1972; Smreczyński 1976; Stebnicka 1978; Trautner & Gaigenmuller 1987; Prashad 2010). We made permanent slides of identified insect parts and matched the remnants for confirming order and families. The remaining pellets were kept at -4 °C for further analysis. Results are expressed in terms of relative frequency of occurrence;

Percentage frequency (%F): This is the number of occurrences of the category, divided by the number of samples analyzed, multiplied by 100. Whereas for

percentage volume (%V): Sum of individual volume divide by total volume of the sample multiplied by 100 following the formulae given by Whitaker (1988). The food items were categorized into three classes based on the frequency of remnants: basic food (>20%), constant food (5–20%), chance food (<5%) as described by Ramanujam & Verzhutskii (2004). Insect availability was categorized based on the total captured insects a month, namely, absent (0), rare (<5), common (5 to 10) and abundant (>10). Kruskal Wallis H test (KW) was applied to determine diet variation and seasonal variation based on the frequency of each dietary item, at p <0.05 significance level (SPSS, 21).

RESULTS

Seasonal food preference by *S. kuhlii*

A total of 11 families of insects were identified corresponding to nine insect orders based on the leg, antenna, and wing or elytral fragments (Table 1). About 3,048 isolated remnants from a total of 720 pellets were analyzed. A total of 26.83% of remnants could be identified to order and family level; the remaining 73.5% remnants were unidentified.

Insect orders consumed by *S. kuhlii*

The percentage frequency of identified remnants of prey items consumed by *S. kuhlii* during summer, showed that Order Coleoptera (39%), Diptera (25%), and Lepidoptera (23%) formed basic food, followed by Orthoptera (19%), Isoptera (14%), Hemiptera (11%), Hymenoptera (11%), Odonata (5.8%), and Blattodea (7.8%) forming the constant food of total frequency in the sample, while no chance food items were encountered in the fecal pellets in summer (Figure 2). Followed by monsoon, two most important insect orders such as Lepidoptera (47%). Coleoptera (43%), Orthoptera (27%), and Diptera (21%) were forming the basic food of the total frequency of the sample. While Hymenoptera (13.5%), Isoptera (10%), and Hemiptera (10%) were forming the constant food and Odonata (6.7%) and Blattodae (1.5%) formed the chance food of the total frequency in the sample (Figure 2). In winter, Coleoptera (30%) and Hemiptera (25%) were forming the basic food of the total frequency of consumed diet in the sample. Orders Diptera (5.1%), Orthoptera (8.3%), and Lepidoptera (14%) were forming the constant food, and, Hymenoptera (2.6%), Isoptera (1.5%), and Odonata (1.5%) formed the chance food of the total frequency of consumed diet in the sample (Figure 2).

The percentage volume of remnants of prey items consumed by *S. kuhlii* during the summer showed that the orders Coleoptera (11%), Diptera (6.3%), Lepidoptera (5.632%), Orthoptera (5.3%), Isoptera (3.5%), Hemiptera (2.8%), Hymenoptera (2.5%), Blattodea (2.3%), and Odonata (1.3%) total percentage volume in the summer sample (Figure 4). Monsoons, followed by Coleoptera (10%), Lepidoptera (9.8%), Orthoptera (5.9%), Diptera (5.1%), Hemiptera (2.9%), Hymenoptera (2.7%), Isoptera (2.3%), Odonata (1.7%) Hymenoptera (2.7%), and Blattodea (0.28%) total percentage volume in the monsoon sample (Figure 4). In winter, Coleoptera (7.3%), Hemiptera (4.6%), Lepidoptera (2.9%), Orthoptera (1.8%), Odonata (1.4%), Diptera (0.75%), Hymenoptera (0.46%), and Isoptera (0.37%) the total percentage volume in the winter samples, consumed by *S. kuhlii* (Figure 4).

Insect families consumed by *S. kuhlii*

The percent frequency of insect families consumed by *S. kuhlii,* such as Gryllidae (25.18%) formed basic food, while Cerambycidae (7.03%), Culicidae (8.88%), Apidae (5.92%), Termitidae (10.37%), Acrididae (15.18%), Erebidae (13.33%), and Pentatomidae (5.55%) formed constant food, and, Formicidae (4.07%) and Crambidae (4.44%) formed chance food of the total frequency in the sample in summer (Figure 3). In the monsoon, Crambidae (21.70%) formed basic food, followed by families Culicidae (9.75%), Formicidae (11.95%), Termitidae (10.24%), Acrididae (7.07%), Gryllidae (14.14%), Erebidae (8.04%), & Pentatomidae (9.02%) forming constant food, and Cerambycidae (4.14%), & Apidae (3.90%) formed chance food (Figure 3) of the total frequency of the sample. In the winter, families Cerambycidae (15.52%), Apidae (6.21%), Acrididae (10.55%), Erebidae (18.01%), Crambidae (17.39%), Lasiocampidae (11.80%), & Pentatomidae (12.42%) formed constant food, and Culicidae (3.72%) & Termitidae (1.86%) formed chance food (Figure 3).

A significant variation was observed over seasons among the families of insects consumed by *S. kuhlii* such as Culicidae (H= 19.16, p <0.001), Formicidae (H= 22.92, p <0.001), Termitidae (H= 6.67, p <0.035), Acrididae (H= 5.74, p <0.05), Gryllidae (H= 24.51, p <0.0001), Crambidae (H= 24.86, p <0.0001), Lasioampidae (H= 22.82, p <0.0001), & Pentatomidae (H= 8.52, p <0.014) except Cerambycidae (H= 1.38, p <0.50), Apidae (H= 1.83, p >0.399), & Erebidae (H= 1.74, p <0.41) (Figure 3).

Table 1. The mean and SD of partially digested insect fragments consumed by *Scotophilus kuhlii* in three different seasons in Uttar Pradesh, India.

		Summer			Monsoon			Winter	
	Wings	Antenna	Legs	Wings	Antenna	Legs	Wings	Antenna	Legs
Order	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Col	15.8 ± 2.87	18.0 ± 9.12	2.5 ± 1.73	21.7 ± 2.08	19.7 ± 6.65	2.7 ± 3.78	10.2 ± 3.83	10.8 ± 5.93	0.6 ± 0.89
Dip	5.8 ± 2.21	6.5 ± 2.38	0.7 ± 0.95	16.7 ± 1.52	9.0 ± 3.46	-	5.8 ± 1.30	3.4 ± 0.54	0.8 ± 1.30
Hym	14.3 ± 3.77	12.0 ± 1.25	0.3 ± 0.50	11.3 ± 4.16	13.3 ± 3.21	-	6.6 ± 4.15	7.4 ± 2.88	-
Iso	3.0 ± 1.82	4.5 ± 1.20	0	5.0 ± 2.64	6.7 ± 1.52	-	5.0 ± 2.64	6.7 ± 1.52	-
Ort	10.3 ± 3.68	10.5 ± 1.91	2.5 ± 3.00	11.3 ± 5.68	14.3 ± 3.21	0.3 ± 0.577	5.4 ± 2.07	7.4 ± 2.70	-
Odo	8.5 ± 2.88	10.5 ± 3.31	1.5 ± 1.91	10.0 ± 3.00	12.0 ± 2.00	0.7 ± 0.577	3.8 ± 2.04	6.4 ± 2.70	0.4 ± 0.89
Bla	11.5 ± 30	3.8 ± 2.36	0.25 ± 0.50	6.7 ± 1.15	9.7 ± 6.42	-	3.8 ± 2.38	3.4 ± 1.14	-
Lep	7.3 ± 3.09	7.0 ± 2.94	0.5 ± 1.00	6.3 ± 1.52	10.3 ± 5.68	-	5.6 ± 1.51	5.2 ± 1.09	0.4 ± 0.54
Hem	10.0 ± 2.94	6.5 ± 0.57	0.75 ± 0.95	7.3 ± 4.04	7.3 ± 4.50	-	3.2 ± 0.44	4.4 ± 1.51	-

Col—Coleoptera | Dip—Diptera | Hym—Hymenoptera | Iso—Isoptera | Ort—Orthoptera | Odo—Odonata | Bla—Blattodea | Lep—Lepidoptera | Hem—Hemiptera.

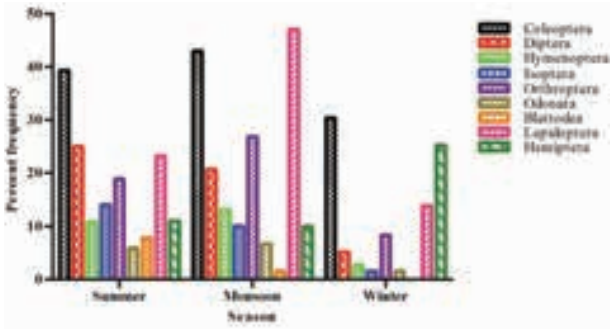

Figure 2. The percent frequency of insect orders consumed by *Scotophilus kuhlii*.

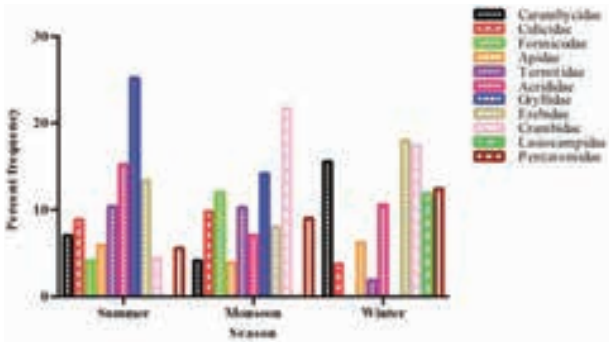

Figure 3. The percent frequency of insect families consumed by *Scotophilus kuhlii*.

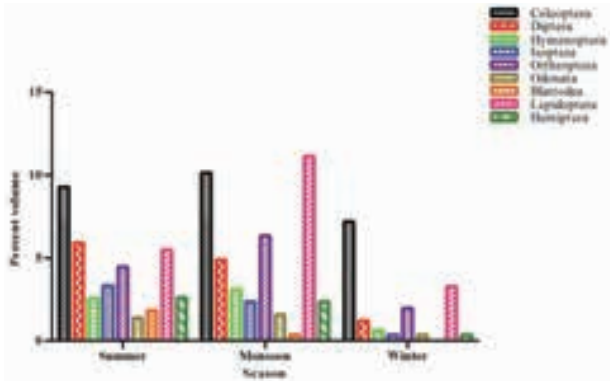

Figure 4. The percent volume of insect remnants consumed by *Scotophilus kuhlii*.

Seasonal prey availability at foraging grounds

A total of 23 insect families corresponding to nine orders were captured from various foraging grounds. A statistically significant variation in insect abundance was observed with respect to seasons in the foraging grounds. Lepidopterans were the most dominant at all locations with family Erebidae (H= 2.07, p >0.35) being abundant in March, October and November and common in January months, followed by Crambidae (H= 1.32, p >0.51) which was more abundant in October and November and common in February. Family Geometridae (H= 5.34, p >0.69) was more abundant in April and October, while in the remaining months it was rare or absent, similarly, family Noctuidae (H= 0.29, p >0.96) was more abundant in May and October while in remaining months, it was rare or absent. Family Limcadidae (H= 5.96, p <0.05) was more abundant in October month and rare in September and November months. Family Lasiocampidae (H= 3.08, p >0.21) was more abundant in December and common in March and September months (Table 2). Hemiptera, was second most captured in the whole sampling, with family Cicadellidae (H= 3.14, p >0.200) being more abundant in October and common in December; family Reduviidae (H= 1.56, p >0.45) was more abundant in

Table 2. Insect abundance at various study sites.

Taxon		Summer				Monsoon				Winter			
Order	**Family**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
Coleoptera	Elmidae	0	0	0	*	***	*	*	0	0	0	0	0
Coleoptera	Cerambycidae	0	0	0	0	0	0	0	*	**	**	0	0
Coleoptera	Carabidae	**	***	*	0	0	0	0	0	0	0	0	0
Diptera	Culicidae	*	**	0	**	***	**	0	0	0	0	0	0
Diptera	Tipulidae	0	0	*	**	***	**	*	*	*	0	0	0
Hymenoptera	Apidae	0	*	***	**	***	*	0	0	0	0	0	0
Hymenoptera	Formicidae	0	0	*	**	***	*	0	0	0	0	0	0
Isoptera	Termitidae	0	0	*	***	***	*	0	0	0	0	0	0
Orthoptera	Acrididae	***	***	***	**	**	0	***	0	0	0	0	**
Orthoptera	Gryllidae	0	***	***	***	***	0	***	0	0	0	0	0
Odonata	Anisoptera	0	0	0	*	**	**	***	0	0	0	0	0
Lepidoptera	Erebidae	***	*	0	0	0	0	0	***	***	0	**	*
Lepidotera	Crambidae	*	*	*	0	*	*	*	***	***	0	0	**
Lepidotera	Geometridae	*	***	*	0	0	0	0	***	0	0	0	0
Lepidotera	Noctuidae	0	*	***	*	0	0	0	***	*	*	0	0
Lepidotera	Limcadidae	0	0	0	0	0	0	*	***	*	0	0	0
Lepidotera	Cicadillidae	0	0	0	0	0	0	0	***	*	**	0	0
Lepidotera	Lasiocampidae	**	0	0	0	0	0	**	0	*	***	0	0
Hemiptera	Reduviidae	***	*	*	0	*	0	***	*	*	*	0	0
Hemiptera	Pentatomidae	0	***	0	0	***	*	***	0	0	0	0	0
Hemiptera	Lygacidae	0	0	0	0	0	***	**	*	0	0	0	0
Hemiptera	Ischneumonidae	*	0	0	0	0	0	***	0	0	0	*	*
Mantodea	Mantidae	*	0	0	0	0	0	0	0	0	0	*	***

The insect abundance was classified as: Absent (0), Rare (*), Common (**), Abundant (***).

March and September, while in remaining months it was rare, followed by, Pentatomidae (H= 10.15, p >0.006) that was more abundant in April, July, and August. Family Lygaeidae (H= 11.22, p <0.004) was more abundant in August and common in September month, whereas Ischneumonidae (H= 0.58, p >0.74) was more abundant only in September. Coleoptera, was the third most captured insect order during sampling, including family Elmidae (H= 10.30, p <0.006) was more abundant in July and rare in June, August, and September; Carambycidae (H= 8, p <0.014) was common in November and December, and Carabidae (H= 1.32, p >0.51) was more abundant in April and common in March. Among Dipterans, family Culicidae (H= 6.91, p <0.031) was more common in April, June, and August, and abundant in July, whereas, Tipulidae (H= 13.61, p <0.001) was more abundant in July and common in June and August (Table 2). Among Hymenopterans, Apidae (H= 10.71, p <0.005) was more abundant in May and July and common in June, whereas Formicidae (H= 6.09, p <0.047) was more common in June and abundant in July month (Table 2). Among Isoptera, Termitidae (H= 4.94, p >0.08) was more abundant in June and July while rare in May and August than any other month (Table 2). Among Orthopterans, Acrididae (H= 11.38, p <0.003) was more abundant in March to May and September, while it was common in June, July, and February. Family Gryllidae (H= 12.03, p <0.002) was abundant in April to July and September than any other month (Table 2). Among Odonata, Anisoptera (H= 19.02, p <0.001) was more common in July and August while more abundant in September. Among Mantodea, family Mantidae (H= 5.14, p >0.76) was more abundant in February and rare in March than any other month (Table 2).

DISCUSSION

In the present study, a clear seasonal variation was observed in the diet of *S. kuhlii*. Studies by Barclay (1985), Ramanujam & Werzuski (2004), and Zhu et al. (2012) showed that *S. kuhli* fed mainly on Hemiptera and Coleoptera; Coleoptera (most often); Hemiptera, Coleoptera, Odonata, Homoptera and Trichoptera, respectively. Srinivasulu et al. (2010) reported that this species mainly feeds on Diptera, Coleoptera, and Hymenoptera, which include Anisopodidae, Chironomidae, Culicidae, Scatophagidae, Carabidae, Scarabidae, and Ichnemonidae. The results of our study showed that in Uttar Pradesh, *S. Kuhlii* fed mainly Coleoptera, Lepidoptera, Orthoptera, Diptera, Hemiptera, and Hymenoptera in all seasons. Our study showed that families Gryllidae and Acrididae were major foods in the diet of *S. kuhlii*, while Erebidae, Termitidae, and Culicidae were secondary foods in summer. Family Acrididae (Grasshopper) was maximum captured in March to September, and disappeared August to January, while Gryllidae (Crickets) were maximum captured in April to September and disappeared from August to March, and Culicidae was maximum captured in July, June, and April. Some small insect groups are not consumed by bats even if they are very abundant in their habitats (Pereira et al. 2002; Jaskuła & Hejduk 2005) because they provide lower energy content compared to larger prey items. Our study showed that Apidae and Formicidae were preferred by *S. kuhlii* in summer. Andreas et al. (2012) reported low diversity and abundance of the food supply during the winter, with diversity and abundance peaking in the summer season. Our result showed Crambidae, Gryllidae, Formicidae were major food items in the diet of *S. kuhlii* in the monsoon season. Though, Crambidae (Grass-moths) was captured maximum in October and November and totally absent in December and January and again appeared in February to May but was rare, Gryllidae (Crickets) were maximum captured in April to July and September, Formicidae (Ants) were captured maximum in July, disappeared September to April and appeared again in May as the third major food item in the diet of *S. kuhlii* in the monsoon. Lynch et al. (1988) reported that Formicidae peak in June, but species richness was nearly as high in May, July and August. Whitaker et al. (1994) reported that ants were the most consumed prey, followed by Coleoptera and Lepidoptera. Our result showed Erebidae, Crambidae, Lasiocampidae, Cerambycidae, Pentatomidae, and Acrididae were the major food items in *S. kuhlii's* diet in the winter when other prey were limited. Kunz et al. (1995) reported that moths have highly fatty body and are a more energy-rich source, therefore bats feed maximum on them. More moths were fed on by *S. kuhlii* in winter, which helps during breeding when more energy is required.

Insectivorous bats deliver economically valuable ecological services and decrease health risks to humans by reducing dependence on pesticides. Leelapaibul et al. (2005) reported that insectivorous bats act as biological pest control agents in the agricultural fields, feeding on pests belonging to Homoptera, Lepidoptera, Hemiptera, and Coleoptera in farms. Our study showed that *S. kuhlii* consumed several types of insects belonging to Coleoptera, Diptera, Isoptera, Hymenoptera, Orthoptera, Odonata, Blattodae, Lepidoptera, and Hemiptera and may be a good pest controlling agent. A study on *Scotophilus leucogaster* by Barclay (1984) showed that it had a varied diet from throughout the year as well as from season to season and night to night. These changes in diet and dietary diversity likely correspond to changes in insect abundance and distribution. The diet of *S. kuhii* and collected insect abundance showed a correlation in the seasonal variation which occurred due to choice of prey related to habitat use by *S. kuhlii* and climatic conditions.

CONCLUSION

Scotophilus kuhlii is a medium sized insectivorous bat. It fed on 11 families of insects corresponding to nine orders. Although 23 families of insects belonging to eight orders were collected from the foraging grounds, it was observed that this species consumed few families among the captured insect families at the foraging grounds. The diet of *S. kuhii* and collected insect abundance showed a correlation between seasonal variations in diet choice. The results revealed that *S. kuhlii* is an opportunistic feeder, and its diet varied from season to season.

REFERENCES

Andreas, M., A. Reiter & P. Benda (2012). Prey selection and seasonal diet changes in the western barbastelle bat (*Barbastella barbastellus*). *Acta Chiropterologica* 14(1): 81–92. https://doi.org/10.3161/150811012X654295

Anthony, E.L.P. & T.H. Kunz (1977). Feeding strategies of the little brown bat, *Myotis lucifugus*, in Southern New Hampshire. *Ecology* 58: 775–786. https://doi.org/10.2307/1936213

Barclay, R.M.R. (1984). Observations on the migration, ecology and behaviour of bats at Delta Marsh, Manitoba. *Canadian Field-Naturalist* 98: 331–336.

Barclay, R.M.R. (1985). Long-versus short-range foraging strategies

of hoary (*Lasiurus cinereus*) and silver-haired (*Lasionycteris noctivagans*) bats and the consequences for prey selection. *Canadian Journal of Zoology* 63: 2507–2515. https://doi.org/10.1139/z85-371

Belwood, J.J & M.B. Fenton (1976). Variation in the diet of *Myotis lucifugus* (Chiroptera: Vespertilionidae). *Canadian Journal of Zoology* 54: 1674–1678. https://doi.org/10.1139/z76-194

Catto, C.M.C., A.M. Hutson & P.A. Racey (1994). The diet of *Eptesicus serotinus* in southern England. *Folia Zoologica* 43: 307–314.

Dobzhansky, T. & C. Pavan (1950). Local and seasonal variations in relative frequencies of species of *Drosophila* in Brazil. *Journal of Animal Ecology* 19: 1–14. https://doi.org/10.2307/1566

Evans, A.R. & G.D. Samson (1998). The effect of tooth shape on the break down of insects. *Journal of Zoology* (London) 246: 391–400. https://doi.org/10.1111/j.1469-7998.1998.tb00171.x

Fenton, M.B., I.L. Rautenbach, J. Rydell, H.T. Arita, J. Ortega, S. Bouchard, M.D. Hovorka, B. Lim, D. Odhrun, C.V. Portfors, W.M. Scully & M.J. Vonhof (1998). Emergence, echolocation, diet and foraging behavior of *Molossus ater* (Chiroptera: Molossidae). *Biotropica* 30: 314–320.

Findley, J.S. (1993). Bats: A Community Perspective. Cambridge University Press, Cambridge, United Kingdom, 167pp.

Hails, C.J. (1982). A comparison of tropical and temperate aerial insect abundance. *Biotropica* 14: 310–313. https://doi.org/10.2307/2388092

Harris, K.M. (1970). The sorghum midge.*Pest Articles & News Summaries* 16(1): 36–42.

Hoare, L.R. (1991). The diet of *Pipistrellus pipistrellus* during the pre-hibernal period. *Journal of Zoology (London)* 225: 665–670. https://doi.org/10.1111/j.1469-7998.1991.tb04334.x

IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.

Janzen, D.H. & C.M. Pond (1975). Comparison, by sweep sampling, of the arthropod fauna of secondary vegetation in Michigan, England, and Costa Rica. *Transactions of the Royal Entomological Society of London* 127: 33–50.

Jaskuła, R. & J. Hejduk (2005). Carabidae (Coleoptera) in the diet of a greater mouse-eared bat *Myotis myotis* (Chiroptera; Vespertilionidae), pp. 197–204. In: Skłodkowski et al. (eds.). Protection of Coleoptera in the Baltic Sea Region. SGGW, Warsaw.

Kalka, M. & E.K.V. Kalko (2006). Gleaning bats as underestimated predators of herbivorous insects: diet of *Micronycteris microtis* (Phyllostomidae) in Panama. *Journal of Tropical Ecology* 22: 1–10.

Kingslover, J.C. (1989). Weather and the population dynamics of insects: integrating physiology and population ecology. *Physiological Zoology* 62: 314–334.

Kramer, D.L. (2001). Foraging behavior, pp. 232–246. In. Fox, C.W. & D.A. Roff (eds.). *Evolutionary Ecology: Concepts and Case Studies*, 650pp.

Kunz, T.H., J.O. Whitaker, Jr. & M.D. Wadanoli (1995). Dietary energetics of the insectivorous Mexican free-tailed bat (*Tadarida brasiliensis*) during pregnancy and lactation. *Oecologia* 101: 407–415. https://doi.org/10.1007/BF00329419

Leelapaibul, W, S. Bumrungsri & A. Pattanawiboon (2005). Diet of wrinkle-lipped free-tailed bat (*Tadarida plicata* Buchannan, 1800) in central Thailand: insectivorous bats potentially act as biological pest control agents. *Acta Chiropterologica* 7: 111–119. https://doi.org/10.3161/1733-5329(2005)7[111:DOWFBT]2.0.CO;2

Lynch, J.F, A.K. Johnson & E.C. Balinsky (1988). Spatial and temporal variation in the abundance and diversity of ants (Hymenoptera: Formicidae) in the soil and litter layers of a Maryland forest. *American Midland Naturalist* 119: 31–44.

Michal, A., A. Reiter & P. Benda (2012). Dietary composition, resource partitioning and trophic niche overlap in three forest foliage-gleaning bats in Central Europe. *Acta Chiropterologica* 14(2): 335–345. https://doi.org/10.3161/150811012x661657

Mroczkowski, M. (1955). Klucze do oznaczania owadow Polski. Część XIX Chrząszcze - Coleoptera. Zeszyt 25 Omarlicowate - Silphidae. PWN, Warsaw in Polish.

Neuweiler, G. (1984). Foraging ecology and audition in echolocating bats. *Trends in Ecology and Evolution* 4: 160–166. https://doi.org/10.1016/0169-5347(89)90120-1

Norberg, U.M. & J.M.V. Rayner (1987). Ecological morphology and flight in bats (Mammalia, Chiroptera): Wing adaptations, flight performance, foraging strategy and echolocation. *Philosophical Transaction of the Royal Society, London* 316: 335–427. https://doi.org/10.1098/rstb.1987.0030

Owen, D.F. & D.O. Chanter (1970). Species diversity and seasonal abundance in tropical Ichneumonidae. *Oikos* 21: 142–144. https://doi.org/10.2307/3543849

Owen, D.F. & D.O. Chanter (1972). Species diversity and seasonal abundance in Charanes butterflies (Nymphalidae) .*Journal of Entomology* 46: 135–143. https://doi.org/10.111/j.1365-3032.1972.tb00119.x

Patterson, B.D., M.R. Willig & R.D. Stevens (2003). Trophic strategies, niche partitioning, and patterns of ecological organization. pp. 536–579. In: Kunz, T.H. & M.B. Fenton, (eds.). *Bat Ecology.* University of Chicago Press, Chicago, 779pp.

Pavey, C.R., C.J. Burwell, J.E. Grunwald, C.J. Marshall & G. Neuweiler (2001). Dietary benefits of twilight foraging by insectivorous bats. *Hipposideros speoris*. *Biotropica* 33: 670–681.

Pereira, M.J.R., H. Rebelo, A. Rainho & J.M. Palmeirim (2002). Prey selection by *Myotis myotis* (Vespertilionidae) in a Mediterranean region. *Acta Chiropterologica* 4: 183–193. https://doi.org/10.3161/001.004.0207

Pławilszczikow, N. (1972). Klucz do oznaczania owadow. PWRiL, Warsaw [in Polish].

Prasad, R. & G.C. Sachan (Eds.) (2010). *Elements of Entomology Frist Edition*. Arihant Electric Press, Meerut, India, 570pp.

Ramanujam, M.E. & B. Verzhutskii (2004). The prey of the Greater False Vampire Bat *M. lyra* E. Geoffroy at Kaliveli, Tamilnadu. *Zoos' Print Journal* 19(10): 1655–1656. https://doi.org/10.11609/JoTT.ZPJ.1165.1655-6

Ross, A. (1961). Notes on food habits of bats. *Journal of Mammalogy* 42: 66–71.

Rydell, J. (1986). Foraging and diet of the northern bat *Eptesicus nilssoni* in Sweden. *Holarctic Ecology* 9: 272–276. https://www.jstor.org/stable/3682073

Shiel, C.B., C.M. Mcaney & J.S. Fairley (1991). Analysis of the diet of Natterer's bat *Myotis nattereri* and the common long-eared bat *Plecotus auritus* in the West of Ireland. *Journal of Zoology* (London) 223: 299–305. https://doi.org/10.1111/j.1469-7998.1991.tb04766.x

Smreczyński, S. (1976). Ryjkowce - Curculionidae. Podrodzina Curculioninae. Plemiona: Nanophyini, Mecinini, Cionini, Anoplini, Rhynchaenini. Klucze do oznaczania owadow Polski, cz. XIX, z. 98f, Warsaw [in Polish].

Srinivasulu, B., C. Srinivasulu & P. Venkateshwarlu (2010). First record of Lesser Yellow House Bat *S. kuhlii* Leach, 1821 from Secunderabad, Andhra Pradesh, India with a note on its diet. *Journal of Threatened Taxa* 2(10): 1234–1236. https://doi.org/10.11609/JoTT.o1989.1234-6

Stebnicka, Z. (1978). Zukowate - Scarabaeidae. Grupa podrodzin: *Scarabaeidae pleurosticti*. Klucze do oznaczania owadow Polski, cz. XIX, z. 28b, Warsaw [in Polish].

Swift, S.M. & P.A. Racey (1983). Resource partitioning in two species of vespertilionid bats (Chiroptera) occupying the same roost. *Journal of Zoology* (London) 200: 249–259. https://doi.org/10.1111/j.1469-7998.1983.tb05787.x

Swift, S.M., P.A. Racey & M.I. Avery (1985). Feeding ecology of *Pipipistrellus pipistrellus* (Chiroptera: Vespertilionidae) during pregnancy and lactation. II. Diet. *Journal of Animal Ecology* 54: 217–225. https://doi.org/10.2307/4631

Tang, Z.H., M. Cao, L.X. Sheng, X.F. Ma, A. Walsh & S.Y. Zhang (2008). Seed dispersal of *Morus macroura* (Moraceae) by two frugivorous bats in Xishuangbanna, SW China. *Biotropica* 40: 127–131. https://doi.org/10.1111/j.1744-7429.2007.00307.x

Trautner, J. & K. Gaigenmuller (1987). Tiger Beetles, Ground Beetles: Illustrated Key to the Cicindelidae and Carabidae of Europe. Aichtal, Germany, 487pp

Trojan, P. (1957). Klucze do oznaczania owadow Polski. Część XVIII Muchowki - Diptera. Zeszyt 1 - wstępny. PWN, Warsaw [in Polish].

Tulp, I. & H. Schekkerman (2008). Has prey availability for arctic birds advanced with climate change? Hindcasting the abundance of arctic arthropods using weather and seasonal variation. *Arctic* 61: 48–60. https://doi.org/10.14430/arctic6

Verts, B.J., L.N. Carraway & J.O. Whitaker (1999). Temporal variation in prey consumption by big brown bats, *Eptesicus fuscus* in a maternity colony. *Science* 73: 114–120.

Ramanujam, M.E. & B. Verzhutskii (2002). Food of Indian False Vampire bat *M lyra. Journal of Mammology* 40(4): 545–546.

Voigt, C.C., L. Aguirre, K. Phelps, C. Schoeman, J. Vanitharani & A. Zubaid (2016). Bats and buildings: the conservation of synanthropic bats. 427–453pp. In: Bats in the anthropocene: Conservation of bats in a changing world. Springer, London.

Whitaker, J.O., Jr. (1988). Food habits analysis of insectivorous bats, pp. 171–190. In: Kunz, T.H. (ed.). *Ecological and behavioral methods for the study of bats.* Smithsonian Institution Press, Washington, 533pp.

Whitaker, J.O. Jr. (1995). Food of the big brown bat *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. *American Midland Naturalist* 134: 346–350.

Whitaker, J.O. Jr., C. Maser & L.E. Keller (1977). Food habits of bats of western Oregon. *Northwest Science* 51: 46–55.

Whitaker, J.O. Jr., B. Shalmon & T.H. Kunz (1994). Food and feeding habits of insectivorous bats from Israel. *Zeitschrift Saugelierkunde* 59: 74–81.

Wolda, H. (1978). Fluctuations in abundance of tropical insects. *American Naturalist* 112**:** 1017–1045.

Wolda, H. (1988). Insect Seasonality: Why? *Annual Review of Ecology and Systematics* 19: 1–18. https://doi.org/10.1146/annurev.es.19.110188.000245

Zhu, G., A. Chmura, L. Zhang (2012). Morphology, echolocation calls and diet of *Scotophilus kuhlii* (Chiroptera: Vespertilionidae) on Hainan Island, south China. *Acta Chiropterologica* 14(1):175–181. https://doi.org/10.3161/150811012X654394

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COMMUNICATION

Bird composition, diversity and foraging guilds in agricultural landscapes: a case study from eastern Uttar Pradesh, India

Yashmita-Ulman [1] & Manoj Singh [2]

[1] Department of Silviculture & Agroforestry, College of Horticulture & Forestry, Acharya Narendra Deva University of Agriculture and Technology, Ayodhya, Uttar Pradesh 224229, India.

[2] Department of Zoology, Kalinga University, Naya Raipur, Chhattisgarh 492101, India.

[1] yashmita2018@gmail.com, [2] msingh.zooku@gmail.com (corresponding author)

Abstract: Birds have a significant role in maintaining the ecological balance of agro-ecosystems. But yet there is no documentation related to bird diversity in the agricultural landscapes of eastern Uttar Pradesh. This study was conducted from March 2019 to February 2020 using fixed radius point count method in Ayodhya district of eastern Uttar Pradesh. A total of 139 bird species belonging to 107 genera, 49 families and 15 orders were recorded from the study area. Passeriformes was the most dominant order with 28 families and 76 species. Accipitridae and Muscicapidae were the most diverse families with 11 species each and RDi value of 7.91. Among the recorded bird species, 105 species (76%) were resident, 29 species (21%) were winter visitors and only 5 species (4%) were summer visitors. According to the feeding guilds, omnivores (46 species, 33%) were highly represented, followed by insectivores (31%), carnivores (25%), granivores (6%), frugivores (4%) and nectarivores (1%). The Sohawal tehsil was found to have the highest species richness and a Shannon-Weiner diversity index (133, 4.30). *Aquila nipalensis* and *Neophron percnopterus* were the two 'Endangered' species, *Antigone antigone* and *Clanga hastata* were the two 'Vulnerable' species and *Ciconia episcopus*, *Gyps himalayensis, Mycteria leucocephala* and *Psittacula eupatria* were the four 'Near Threatened' species found in this region. In addition to this, the region also supported 31 species (22%) whose global population trend is decreasing. This study provides a baseline data on the bird diversity present in agricultural landscapes of this region. Based on which further studies should be designed to understand the factors influencing the diversity of birds in these agricultural landscapes which are continuously subjected to anthropogenic pressures.

Keywords: Ayodhya, Avifauna checklist, community parameters, feeding guilds, relative diversity, species richness.

Hindi: पारिस्थितिकी तंत्र के पारिस्थितिक संतुलन को बनाए रखने में पक्षियों की महत्वपूर्ण भूमिका होती है लेकिन अभी तक पूर्वी उत्तर प्रदेश के कृषि परिदृश्य में पक्षी विविधता से संबंधित कोई भी शोध उपलब्ध नहीं है। यह अध्ययन पूर्वी उत्तर प्रदेश के अयोध्या जिले में निश्चित त्रिज्या बिंदु गणना पद्धति का उपयोग करके मार्च 2019 से फरवरी 2020 तक आयोजित किया गया था। अध्ययन क्षेत्र से 107 वंशो 49 कुलों 15 गणो से संबंधित कुल 139 पक्षी प्रजातियों को दर्ज किया गया था। 28 कुलों और 76 प्रजातियों के साथ पैसेरीफार्मिस सबसे प्रमुख गण था, एस्सीपिट्रीडी और मस्सीकैपिडी सबसे अधिक विविधता वाले कुल थे जिनमें से प्रत्येक में 11 प्रजातियां थी और आरडीआई मान 7.91 था। दर्ज की गई पक्षी प्रजातियों में 105 प्रजातियां स्थानीय थी 21% प्रजातियां शीतकालीन आगंतुक थी और केवल 5 प्रजातियां विषम कालीन आगंतुक थी। फीडिंग गिल्ड के अनुसार 40 प्रजातियां सर्वाहारी थी इसके बाद 21% कीटभक्षी, 25% मांसाहारी, 6% दानाभक्षी, 4% फलभक्षी और 1% मकरंद आहारी थी। सोहावल तहसील में उच्चतम प्रजाति समृद्धि और शैनन विनर विविधता सूचकांक (133,4.30) पाया गया। एक्विला निपालेंसिस और नियोफ्रान पक्नोप्टेरस दो संकटग्रस्त प्रजातियां थी, एंटीगोन और क्लैंगा हस्तटा दो सुभेय (वलनेरेबरल) प्रजातियां थी और सिकानिया एपिस्कोपस, जिप्स हिमालयेंसिस, माक्टेरिया ल्यूकोसेफला और सिटाकुला यूपेट्रिया चार संभावित संकटग्रस्त प्रजातियां थी जो इस क्षेत्र में पाई जाती है। इसके अलावा इस क्षेत्र में पाई जाने वाली प्रजातियों में से ३१ प्रजाति ऐसी भी थीं जिनकी वैश्विक जनसंख्या लगातार कम हो रही है। यह अध्ययन कृषि परिदृश्य में पक्षियों की विविधता को समझने के लिए भविष्य के अनुसंधानो के लिए एक महत्वपूर्ण साधन साबित हो सकता है, विशेषकर उन क्षेत्रों के लिए जो मानव जनित दबावों का सामना कर रहे हैं।

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INTRODUCTION

Agriculture is the most dominant land use in the tropical and sub-tropical regions of the world. In India, nearly 60.45% of the total land is under agriculture (Anonymous 2021a). Even if the area under protected area is as small as 15.40% globally (Anonymous 2021b) and 5.00% (Anonymous 2021c) in India, the conservationists have always concentrated on natural forests or protected areas for species conservation. But lately, the focus has been slowly changing to conservation outside protected areas. Recent studies have highlighted the importance of human-dominated agroforestry systems and agricultural landscapes in conservation of common to globally concerned vertebrates and invertebrates (Athreya et al. 2010; Sundar & Subramanya 2010). Birds play a vital role in maintaining the ecological balance in agro-ecosystems (Haslem & Bennett 2008). An agricultural system provides food like grains, seeds, fruits, green vegetation, plants, grasses, insects, arthropods and rodents to the birds (O'Connor & Shrubb 1986; Asokan et al. 2009). Birds, therefore, play a dual role of pests by feeding on grains and seeds as well as of bio-control agents by feeding on insect pests of agricultural crops (Borad et al. 2000). Thus, they act as both friend and foe of farmers. In addition to this, birds also have functional roles of seed dispersal, pollination, scavenging, nutrient deposition etc. (Dhindsa & Saini 1994; Whelan et al. 2008; Sekercioglu 2012) making them beneficial to nature and thus humans. The occurrence of birds in agricultural systems is influenced by many factors such as the crop type, structural complexity, i.e., vertical stratification formed by the grasses, shrubs and trees, type of management and landscape composition (Taft & Haig 2006; Bruggisser et al. 2010; Wretenberg et al. 2010). Most of the agricultural lands are intermingled with agroforestry & horticultural trees, wetlands, remnant vegetation, natural forest fragments, grasslands and poultry farms influencing the bird diversity positively.

Uttar Pradesh is the top most producer of food grains in the country and also is one of the most intensively cultivated regions of the world (Ramankutty & Foley 1998). This State has undergone various developments and mechanizations in its farming systems due to rapid urbanization and industrialization. Some of them include excessive use of pesticides and fertilizers, intensive agriculture, very good network of irrigation etc. which have altered the agro-ecosystems as well as the bird composition. Some studies show evidences that the existence of birds in agricultural lands depends on low-intensity agricultural practices (Doxa et al. 2010). To study the impacts of agricultural mechanization on birds, it is important to first record the bird diversity present in this most dominant land use system of Uttar Pradesh. It is also important that the birds which act as bio-control agents and bio-indicators of the agro-ecosystems should be conserved in these landscapes. This study, therefore, aims to produce a checklist of birds associated with agricultural fields which can then be further used as a baseline for detailed investigation and research.

The avian diversity in agricultural landscapes has been studied by different authors in different states of India. Work has been done on bird composition and diversity in the agricultural fields of Punjab (Malhi 2006), Karnataka (Basavarajappa 2006), Maharashtra (Abdar 2014), West Bengal (Hossain & Aditya 2016), Uttarakhand (Elsen et al. 2016), Odisha (Mukhopadhyay & Mazumdar 2017), Telangana (Narayana et al. 2019) and Haryana (Kumar & Sahu 2020). Studies have also been conducted on bird diversity in paddy fields (Borad et al. 2000; Jayasimhan & Pramod 2019). Sundar (2006, 2009), Sundar & Subramanya (2010), Sundar & Kittur (2012, 2013) have studied bird composition in agricultural fields and their use by birds in western Uttar Pradesh. Studies have also been undertaken on bird diversity in wetlands and bird sanctuaries (Kumar & Kanaujia 2016; Mishra et al. 2020), and protected areas (Javed & Rahmani 1998; Iqubal et al. 2003, Khan et al. 2013) in Uttar Pradesh. However, there has been no study on the bird diversity in agricultural landscapes of eastern Uttar Pradesh. In this context, the present study is designed to document the bird species composition and diversity in the agricultural landscapes of Ayodhya district, eastern Uttar Pradesh.

MATERIALS AND METHODS

Study area

This study was conducted in five tehsils namely, Sohawal, Rudauli, Milkipur, Sadar and Bikapur of Ayodhya district, eastern Uttar Pradesh (Figure 1). The details of each tehsil are given in Table 1. Two study sites were chosen in each tehsil (Figure 1). Ayodhya district is situated between 26.7730 °N and 82.1458 °E. It has an elevation of 93 m above mean sea level and has an area of 2,764 km^2 (Anonymous 2021d). The net cultivated area in the district is 1,710 km^2 and the total forest area is 3,038 km^2 (Anonymous 2021d). The city of Ayodhya is situated on the banks of the river Saryu. The climate is humid subtropical (Kumar 2018) experiencing three major seasons, i.e., summers (March to June), rainy (July to October) and winters (November to February) (Sundar

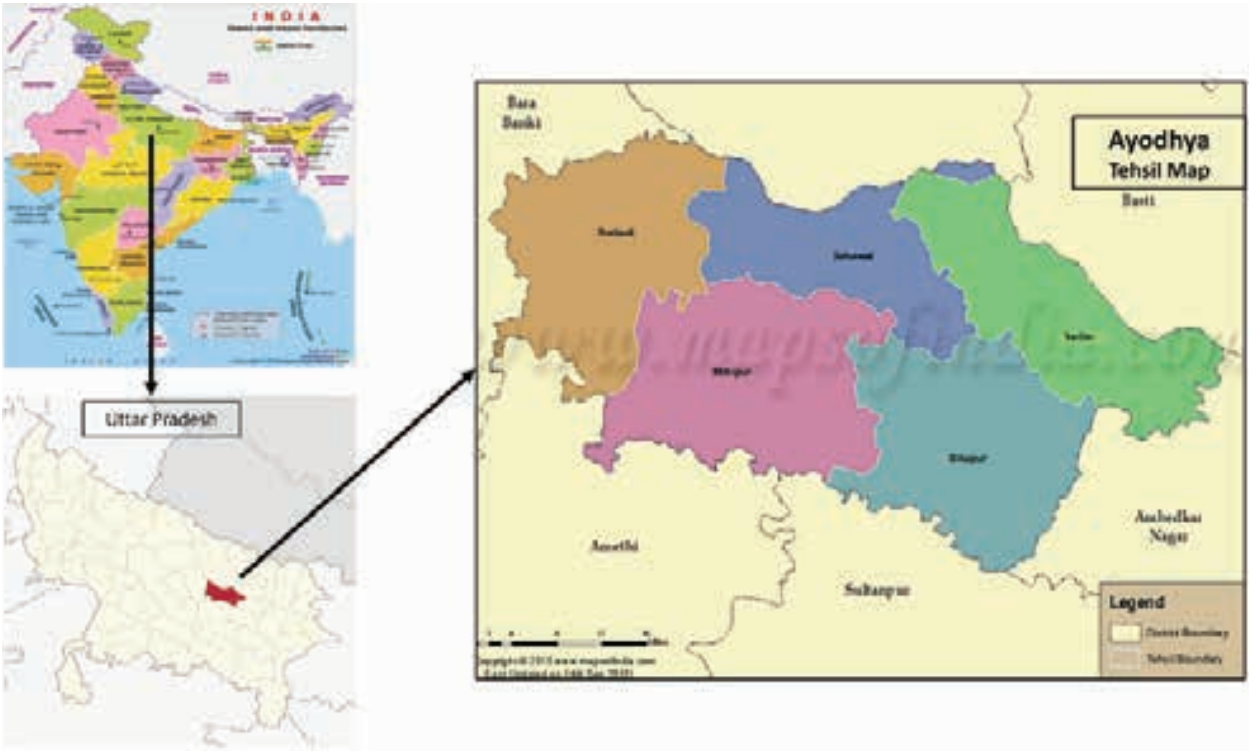

Figure 1. The study area and locations of selected agricultural landscapes of Ayodhya district, eastern Uttar Pradesh, India.

& Kittur 2012). The district receives annual rainfall of 1,067 mm. The average temperature during summers is 32 ^{0}C and in winters is 16 ^{0}C (Anonymous 2021d). The area also experiences heat and cold waves at times (Kumar 2018). The topography of the district is plain. The soil varies from clay soil to sandy soil across the district and is suitable for raising horticultural and agricultural crops. Agriculture is dependent on rain, tube-wells and canals for irrigation. This region is inhabited by small, marginal and landless farmers. The main cropping system of the area is rice-wheat cropping system (Anonymous 2021d). *Saccharum officinarum* is the main cash crop grown which serves as the raw material for the jaggery and sugar industries in Sadar tehsil. Apart from this, crops like *Cajanus cajan, Vigna mungo, Vigna radiata, Cicer arietinum, Sorghum bicolor, Zea mays, Hordeum vulgare, Brassica* sp., vegetable (e.g., *Solanum tuberosum*), fruit crops (*Mangifera indica, Psidium guajava*) and fodder crops are also grown (Anonymous 2021d).

Method

In each tehsil, two sites were selected randomly. Bird surveys were conducted using fixed radius, point-count method (Bibby et al. 2000) in selected sites on a monthly basis between 0600h to 0830h from March 2019 to February 2020. In every tehsil, a transect of 1 km in length was laid in each of the two sites and five permanent point counts were marked at every 250 m distance on each transect. So, in each tehsil 10 point counts were marked, making a total of 50 point counts in Ayodhya district. The birds were recorded in 30 m radius from the point count. At every point count, a five minutes settling down time was given before recording the birds. Species were recorded for 10 minutes at every point count. Each point count was surveyed 24 times during the entire study period. Birds were recorded directly using a pair of field binoculars (Nikon 7x35). On sighting the birds, the species name, number of individuals and habitat were recorded. Birds flying across were not counted. The opportunistic counts during the other time of the day were also included. Bird identification was done following Grimmett et al. (2011). Praveen et al. (2020) was followed for the taxonomic position (order and family), common names and scientific names of species observed. According to the observations made in the field and following Ali & Ripley (1987), the species were also classified into six major feeding guilds, i.e., insectivorous (feeds exclusively on insects), carnivorous (feeds mainly on non-insect invertebrates and vertebrates), granivorous (feeds mainly on grains/seeds), frugivorous (feeds mainly on fruits), nectarivores (feeds mainly on nectar) and omnivorous (feeds on both plant and animal

parts). The IUCN Red List (2021) was followed to compile the global population trend (decreasing, increasing, stable, unknown) of the recorded species.

Species richness was calculated as total number of bird species recorded in the study area.

The following community parameters were calculated using the below given formulae at each tehsil:

[i] Relative diversity of bird families (RDi) (Torre-Cuadros et al. 2007)

$$RDi = \frac{\text{Number of bird species in a family}}{\text{Total number of species}} \times 100$$

[ii] Shannon Weiner index (Shannon & Weiner 1963)

$$H' = \Sigma^{s}_{i=1} p_i \ln p_i$$

where, p_i is often the proportion of individuals belonging to the 'i'th species in the dataset and 's' is the species richness. The values usually lies between 1 and 4 where 1 shows less diversity and 4 shows high diversity.

[iii] Simpson's index (Simpson 1949)

This was calculated according to Simpson (1949) to measure the concentration of dominance (CD) of bird species.

$$CD = \Sigma^{s}_{i=1} (p_i)^2$$

where pi is the proportion of the IVI of the 'i'th species and IVI of all the species (ni/N). The values of Simpson's index is limited to 1 where 1 shows dominance by a single species.

[iv] Pielou's evenness index (Pielou 1966)=H'/ $\log_{10} N(S)$

where H' is the Shanon Weiner diversity index and 'S' is the total number of species. This index ranges from 0 (no evenness) to 1 (complete evenness).

[v] Sorenson's similarity coefficient (Sorenson 1948)

$$\text{Sorenson similarity coefficient} = \frac{2C}{A+B}$$

where C is the number of species common to both sites, A is the total number of species in site A and B is the total number of species in site B. Sorenson's coefficient gives a value between 0 and 1, the closer the value is to 1, the more the communities have in common.

RESULTS

A total of 139 species of birds belonging to 107 genera, 49 families and 15 orders were recorded from the study area (Table 2). Passeriformes was the most dominant order with 28 families and 76 species followed by Accipitriformes (1 family and 11 species) (Figure 2). Falconiformes and Bucerotiformes were the least dominant orders with one family and one species each (Figure 2). According to the residential status of the birds, 105 bird species (76%) were resident, 29 bird species (21%) were winter visitors and only 5 bird species (4%) were summer visitors (Figure 3). As far as the feeding guilds were concerned, six foraging guilds were found in the study area. Omnivores (46 species, 33%) were highly represented, followed by insectivores (31%) whereas, nectarivores (1 species, 1%) was the least represented guild (Figure 4).

Accipitridae and Muscicapidae were the most diverse families (11 species each, RDi= 7.91), followed by Ardeidae, Columbidae and Cuculidae (7 species each, RDi= 5.04). On the other hand, 18 families namely, Aegithinidae, Bucerotidae, Coraciidae, Dicaeidae, Dicruridae, Falconidae, Glareolidae, Gruidae, Monarchidae, Nectariniidae, Paridae, Rallidae, Sittidae, Stenostiridae, Turdidae, Upupidae, Vangidae & Zosteripidae were least represented (1 species each, RDi= 0.72) (Table 3).

Sohawal tehsil had the highest species richness and Shannon-Weiner diversity index (133, 4.30), followed by Rudauli (126, 4.28), Milkipur (119, 4.25) and Bikapur (114, 4.23) (Table 4). Whereas the lowest species richness and Shannon-Weiner diversity index was found in Sadar (98, 3.86) (Table 4). The Simpson's Dominance index indicated that all sites were highly diverse in terms of bird species and no single bird species was dominant (Table 4). The Pielou's Evenness index was the highest in Bikapur (0.89), followed by Rudauli and Milkipur (0.88 each), Sohawal (0.87) and the lowest in Sadar (0.84). This index highlighted that the bird communities in each tehsil was nearly even i.e. all the species were equally represented (Table 4). The Sorenson's Similarity index indicated that all the sites were almost similar in diversity (Table 5). The highest similarity existed between the sites of Rudauli and Milkipur (0.94), followed by Sohawal and Rudauli (0.93) and the lowest similarity existed between the sites of Sohawal and Sadar (0.82) (Table 5).

Of the 139 species recorded, two species (1.44%) were 'Endangered', two species (1.44%) were 'Vulnerable', four species (2.88%) were 'Near Threatened' and the rest (131 species, 94.24%) were 'Least Concern' according to the IUCN Red List (Table 2). With regard to the global population trend, this area supported 66 globally stable bird species (48%), 31 globally decreasing species (22%), 28 globally increasing species (20%) and 14 species (10%) whose global population trend was unknown (Figure 5). In addition to this, 15 species recorded from this area were listed in Appendix II of CITES and one species was under Appendix III of CITES (Table 2). According to the

Table 1. General characteristics of the selected agricultural landscapes in Ayodhya District, eastern Uttar Pradesh, India.

Name of tehsil	Co-ordinates	Features
Sohawal	26.694°N, 81.974°E	Rice-wheat cropping system along with mustard and sugarcane dominates in the area. The area has orchards of *Mangifera indica.* Trees of *Eucalyptus* sp. and *Tectona grandis* are planted on the field boundaries in agroforestry systems. The area has large to small sized wetlands. The main source of water is the tube wells.
Rudauli	26.698°N, 81.611°E	Rice-wheat is the major cropping system in this area. Mustard, vegetables, fruits are also grown in this area. The study area is adjacent to Rudauli Forest Reserve. Apart from this, the area has orchards and agroforestry systems in which *Eucalyptus* sp. is planted on the boundaries of the fields. It has very few small sized water bodies. Agricultural activities are dependent upon tube wells.
Milkipur	26.632°N, 81.910°E	Wheat, mustard, sugarcane, rice, bajra are grown in this area. This area has good patches of tall wooded trees, plantations, orchards, agroforestry systems, grasses and wetlands. The irrigation is done through canals and tube wells.
Bikapur	26.616°N, 82.194°E	Wheat, mustard and rice are the major crops grown in this area. There are some orchards and few small sized water bodies available in this area. Tube wells are used for irrigation purpose.
Sadar	26.793°N, 82.158°E	Wheat, rice and sugarcane are the major crops grown in this area. There are many jaggery and sugar industries located in this area. There are some orchards and wetlands available in this area. This area is mostly influenced by urbanization.

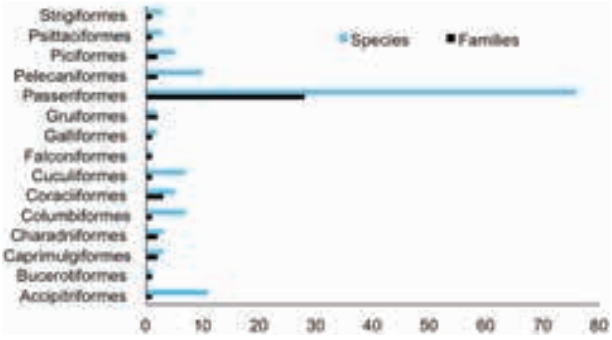

Figure 2. Composition of avian community in selected agricultural landscapes of Ayodhya district, eastern Uttar Pradesh, India.

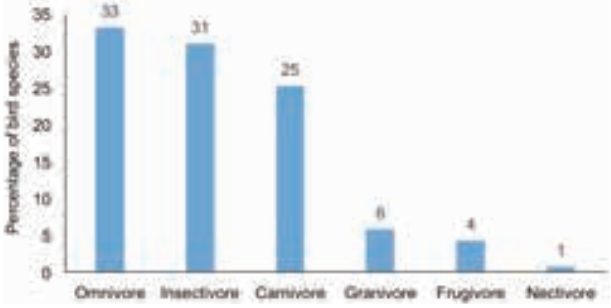

Figure 4 Guild-based classification of avian species recorded in agricultural landscapes of Ayodhya district, eastern Uttar Pradesh, India.

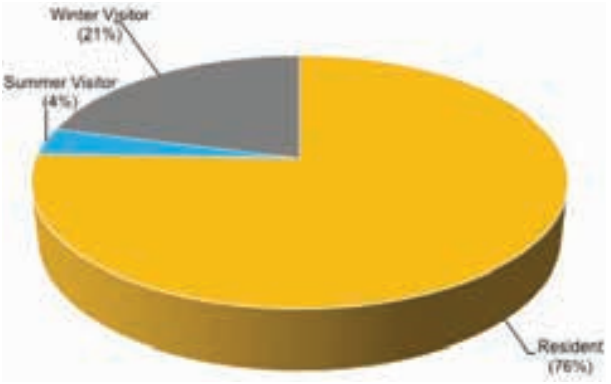

Figure 3. Seasonal status of avian species recorded from agricultural landscapes of Ayodhya district, eastern Uttar Pradesh, India.

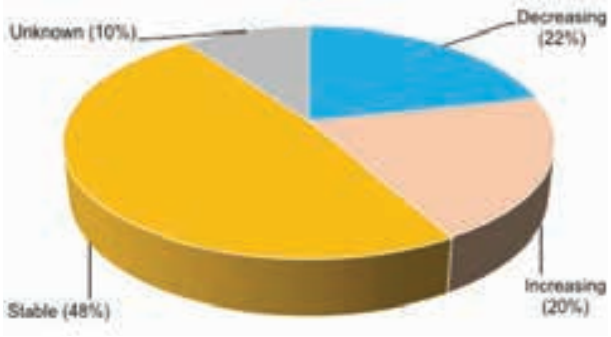

Figure 5. Comparison of global status of avifaunal species recorded in selected agricultural landscapes of Ayodhya district, eastern Uttar Pradesh, India.

IWPA (1972), out of 139 species, 11 species were under Schedule I, one species was in Schedule V and the rest were in Schedule IV (Table 2).

DISCUSSION

Agricultural landscape is the preferred habitat for 45% of the birds of the Indian subcontinent (Sundar & Subramanya 2010), however some species are known to visit this landscape only occasionally (Sekercioglu et al. 2012). This might be one of the reasons for finding 139 bird species in the agricultural landscapes of Ayodhya

Table 2. Checklist and status of avifauna recorded in agricultural landscapes of Ayodhya district, eastern Uttar Pradesh, India.

	Order/Family/Common name	Scientific name	Residential status	Feeding status	Conservation status			Global status	Sites					Image No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		SHW	RDL	MKP	BKP	SDR	
Accipitriformes Accipitridae (11)														
1	Black Kite	*Milvus migrans* (Boddaert, 1783)	R	C	LC	II	I	→	√	√	√	√	√	
2	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	R	C	LC	II	I	→	√	√	√	√	√	
3	Crested Serpent Eagle	*Spilornis cheela* (Latham, 1790)	R	C	LC	-	IV	→	√	√	√	√	×	2g
4	Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)	R	C	EN	-	I	↓	√	√	√	√	√	2c
5	Himalayan Vulture	*Gyps himalayensis* (Hume, 1869)	WV	C	NT	II	I	→	×	×	√	√	×	
6	Indian Spotted Eagle	*Clanga hastata* (Lesson, 1831)	R	C	VU	II	I	↓	√	√	√	√	√	
7	Shikra	*Accipiter badius* (Gmelin, 1788)	R	C	LC	II	I	→	√	√	√	√	√	2h
8	Short-toed Snake Eagle	*Circaetus gallicus* (Gmelin, 1788)	R	C	LC	II	I	→	√	√	√	√	×	
9	Steppe Eagle	*Aquila nipalensis* (Hodgson, 1833)	WV	C	EN	II	I	↓	√	×	×	√	×	
10	Western Marsh-harrier	*Circus aeruginosus* (Linnaeus, 1758)	WV	C	LC	II	I	↑	√	√	√	×	×	
11	White-eyed Buzzard	*Butastur teesa* (Franklin, 1831)	R	C	LC	II	I	→	√	√	√	√	√	
Bucerotiformes Bucerotidae (1)														
12	Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	R	O	LC	-	IV	→	√	√	×	√	√	
Caprimulgiformes Apodidae (2)														
13	Asian Palm Swift	*Cypsiurus balasiensis* (Gray, 1829)	R	I	LC	-	IV	→	√	√	√	√	√	
14	Indian House Swift	*Apus affinis* (Gray, 1830)	R	I	LC	-	IV	↑	×	√	×	×	×	
Upupidae (1)														
15	Common Hoopoe	*Upupa epops* (Linnaeus, 1758)	R	O	LC	-	IV	↓	√	√	√	√	√	1c
Charadriiformes Charadriidae (2)														
16	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	R	O	LC	-	IV	?	√	√	√	√	√	
17	Yellow-wattled Lapwing	*Vanellus malabaricus* (Boddaert, 1783)	R	C	LC	-	IV	→	√	√	√	×	×	
Glareolidae (1)														
18	Small Pratincole	*Glareola lactea* (Temminck, 1820)	R	I	LC	-	IV	?	√	√	√	√	√	
Columbiformes Columbidae (7)														
19	Eurasian Collared Dove	*Streptopelia decaocto* (Frivaldszky, 1838)	R	G	LC	-	IV	↑	√	√	√	√	√	

	Order/Family/Common name	Scientific name	Residential status	Feeding status	Conservation status			Global status	Sites					Image No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		SHW	RDL	MKP	BKP	SDR	
20	Laughing Dove	*Streptopelia senegalensis* (Linnaeus, 1766)	R	G	LC	-	IV	→	√	√	√	√	√	
21	Oriental Turtle Dove	*Streptopelia orientalis* (Latham, 1790)	WV	G	LC	-	IV	→	√	√	√	×	√	
22	Red Collared Dove	*Streptopelia tranquebarica* (Hermann, 1804)	R	G	LC	-	IV	↓	√	√	√	√	√	
23	Rock Pigeon	*Columba livia* (Gmelin, 1789)	R	G	LC	-	IV	↓	√	√	√	√	√	
24	Spotted Dove	*Streptopelia chinensis* (Scopoli, 1786)	R	G	LC	-	IV	↑	√	√	√	√	√	
25	Yellow-footed Green Pigeon	*Treron phoenicopterus* (Latham, 1790)	R	F	LC	-	IV	↑	√	√	√	√	√	2e
Coraciiformes Alcedinidae (2)														
26	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	R	C	LC	-	IV	?	√	√	√	√	√	2b
27	White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	R	C	LC	-	IV	↑	√	√	√	√	√	1a
Coraciidae (1)														
28	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	R	C	LC	-	IV	↑	√	√	√	√	√	
Meropidae (2)														
29	Blue-tailed Bee-eater	*Merops philippinus* (Linnaeus, 1767)	SV	I	LC	-	IV	→	√	√	√	√		
30	Green Bee-eater	*Merops orientalis* (Latham, 1801)	R	I	LC	-	IV	↑	√	√	√	√		
Cuculiformes Cuculidae (7)														
31	Asian Koel	*Eudynamys scolopaceus* (Linnaeus, 1758)	R	O	LC	-	IV	→	√	√	√	√	√	
32	Common Hawk Cuckoo	*Hierococcyx varius* (Vahl, 1797)	R	O	LC	-	IV	→	√	√	√	√	×	
33	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	R	O	LC	-	IV	→	√	√	√	√	√	
34	Grey-bellied Cuckoo	*Cacomantis passerinus* (Vahl, 1797)	SV	I	LC	-	IV	→	√	×	×	×	×	
35	Indian Cuckoo	*Cuculus micropterus* (Gould, 1838)	SV	O	LC	-	IV	↓	√	√	√	×	×	
36	Pied Cuckoo	*Clamator jacobinus* (Boddaert, 1783)	SV	O	LC	-	IV	→	√	√	√	√	×	
37	Sirkeer Malkoha	*Taccocua leschenaultii* (Lesson, 1830)	R	O	LC	-	IV	→	√	×	×	×	×	
Falconiformes Falconidae (1)														
38	Common Kestrel	*Falco tinnunculus* (Linnaeus, 1758)	WV	C	LC	II	IV	↓	√	√	√	√	√	
Galliformes Phasianidae (2)														
39	Grey Francolin	*Francolinus pondicerianus* (Gmelin, 1789)	R	O	LC	-	IV	→	√	√	√	√	√	
40	Indian Peafowl	*Pavo cristatus* (Linnaeus, 1758)	R	O	LC	III	I	→	√	√	√	√	√	

	Order/Family/Common name	Scientific name	Residential status	Feeding status	Conservation status			Global status	Sites					Image No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		SHW	RDL	MKP	BKP	SDR	
Gruiformes Gruidae (1)														
41	Sarus Crane	*Antigone antigone* (Linnaeus, 1758)	R	O	VU	-	IV	↓	√	√	√	√	×	1h
Rallidae (1)														
42	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	R	O	LC	-	IV	?	√	√	√	√	√	
Passeriformes Acrocephalidae (2)														
43	Blyth's Reed Warbler	*Acrocephalus dumetorum* (Blyth, 1849)	WV	O	LC	-	IV	↑	×	√	√	×	×	
44	Booted Warbler	*Iduna caligata* (Lichtenstein, 1823)	WV	I	LC	-	IV	↑	×	×	×	×	√	
Aegithinidae (1)														
45	Common Iora	*Aegithina tiphia* (Linnaeus, 1758)	R	O	LC	-	IV	?	√	√	√	√	√	
Alaudidae (4)														
46	Ashy-crowned Sparrow-Lark	*Eremopterix griseus* (Scopoli, 1786)	R	O	LC	-	IV	→	√	√	√	√	√	
47	Bengal Bushlark	*Mirafra assamica* (Horsfield, 1840)	R	O	LC	-	IV	→	√	√	√	√	√	
48	Crested Lark	*Galerida cristata* (Linnaeus, 1758)	R	O	LC	-	IV	↓	√	√	√	√	√	
49	Sand Lark	*Alaudala raytal* (Blyth, 1845)	R	O	LC	-	IV	→	√	√	√	√	×	
Campephagidae (3)														
50	Large Cuckooshrike	*Coracina macei* (Lesson, 1831)	R	I	LC	-	IV	↓	√	×	×	×	×	
51	Long-tailed Minivet	*Pericrocotus ethologus* (Bangs & Phillips, 1914)	WV	I	LC	-	IV	↓	√	√	×	×	√	
52	Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	R	I	LC	-	IV	→	√	√	√	√	×	
Cisticolidae (4)														
53	Ashy Prinia	*Prinia socialis* (Sykes, 1832)	R	I	LC	-	IV	→	√	√	√	√	√	
54	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	R	I	LC	-	IV	→	√	√	√	√	√	
55	Plain Prinia	*Prinia inornata* (Sykes, 1832)	R	I	LC	-	IV	→	√	√	√	√	√	1b
56	Zitting Cisticola	*Cisticola juncidis* (Rafinesque, 1810)	R	I	LC	-	IV	↑	√	√	√	√	√	
Corvidae (3)														
57	House Crow	*Corvus splendens* (Vieillot, 1817)	R	O	LC	-	V	→	√	√	√	√	√	
58	Large-billed Crow	*Corvus macrorhynchos* (Wagler, 1827)	R	O	LC	-	IV	→	√	√	√	√	√	
59	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	R	O	LC	-	IV	↓	√	√	√	√	√	
Dicaeidae (1)														

	Order/Family/Common name	Scientific name	Residential status	Feeding status	Conservation status			Global status	Sites					Image No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		SHW	RDL	MKP	BKP	SDR	
60	Thick-billed Flowerpecker	*Dicaeum agile* (Tickell, 1833)	R	O	LC	-	IV	→	√	√	√	√	√	
Dicruridae (1)														
61	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	R	C	LC	-	IV	?	√	√	√	√	√	1d
Estrildidae (3)														
62	Indian Silverbill	*Euodice malabarica* (Linnaeus, 1758)	R	G	LC	-	IV	→	√	√	√	√	√	
63	Red Munia	*Amandava amandava* (Linnaeus, 1758)	R	O	LC	-	IV	→	√	√	√	√	√	
64	Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	R	O	LC	-	IV	→	√	√	√	√	√	
Hirundinidae (5)														
65	Barn Swallow	*Hirundo rustica* (Linnaeus, 1758)	WV	I	LC	-	IV	↓	√	√	√	√	√	
66	Plain Martin	*Riparia paludicola* (Vieillot, 1817)	R	I	LC	-	IV	↓	√	√	√	×	√	
67	Red-rumped Swallow	*Cecropis daurica* (Laxmann, 1769)	R	I	LC	-	IV	→	√	√	√	√	√	
68	Streak-throated Swallow	*Petrochelidon fluvicola* (Blyth, 1855)	R	I	LC	-	IV	↑	√	√	√	√	√	
69	Wire-tailed Swallow	*Hirundo smithii* (Leach, 1818)	R	I	LC	-	IV	↑	√	√	√	√	√	
Laniidae (3)														
70	Bay-backed Shrike	*Lanius vittatus* (Valenciennes, 1826)	R	C	LC	-	IV	→	√	√	√	√	√	
71	Brown Shrike	*Lanius cristatus* (Linnaeus, 1758)	WV	C	LC	-	IV	↓	√	×	×	×	×	
72	Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	R	C	LC	-	IV	?	√	√	√	√	√	
Leiothrichidae (3)														
73	Common Babbler	*Argya caudata* (Dumont, 1823)	R	O	LC	-	IV	→	√	√	√	√	√	
74	Jungle Babbler	*Argya striata* (Dumont, 1823)	R	O	LC	-	IV	→	√	√	√	√	√	
75	Striated Babbler	*Argya earlei* (Blyth, 1844)	R	O	LC	-	IV	↓	√	√	×	√	√	
Monarchidae (1)														
76	Indian Paradise-flycatcher	*Terpsiphone paradisi* (Linnaeus, 1758)	SV	I	LC	-	IV	→	√	√	√	×	×	
Motacillidae (6)														
77	Citrine Wagtail	*Motacilla citreola* (Pallas, 1776)	WV	I	LC	-	IV	↑	√	√	√	√	×	
78	Grey Wagtail	*Motacilla cinerea* (Tunstall, 1771)	WV	I	LC	-	IV	→	√	√	×	√	×	
79	Paddyfield Pipit	*Anthus rufulus* (Vieillot, 1818)	R	C	LC	-	IV	→	√	√	√	√	√	
80	Western Yellow Wagtail	*Motacilla flava* (Linnaeus, 1758)	WV	I	LC	-	IV	↓	√	√	×	√	×	
81	White Wagtail	*Motacilla alba* (Linnaeus, 1758)	WV	I	LC	-	IV	→	√	√	√	√	√	

	Order/Family/Common name	Scientific name	Residential status	Feeding status	Conservation status			Global status	Sites					Image No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		SHW	RDL	MKP	BKP	SDR	
82	White-browed Wagtail	*Motacilla maderaspatensis* (Gmelin, 1789)	R	I	LC	-	IV	→	√	√	√	√	×	
Muscicapidae (11)														
83	Black Redstart	*Phoenicurus ochruros* (Gmelin, 1774)	WV	I	LC	-	IV	↑	√	√	√	√	√	
84	Bluethroat	*Luscinia svecica* (Linnaeus, 1758)	WV	I	LC	-	IV	→	√	√	√	√	×	
85	Brown Rockchat	*Oenanthe fusca* (Blyth, 1851)	R	I	LC	-	IV	→	√	√	√	√	√	
86	Indian Robin	*Copsychus fulicatus* (Linnaeus, 1766)	R	C	LC	-	IV	→	√	√	√	√	√	
87	Oriental Magpie Robin	*Copsychus saularis* (Linnaeus, 1758)	R	C	LC	-	IV	→	√	√	√	√	√	
88	Pied Bushchat	*Saxicola caprata* (Linnaeus, 1766)	R	I	LC	-	IV	→	√	√	√	√	√	
89	Red-breasted Flycatcher	*Ficedula parva* (Bechstein, 1792)	WV	I	LC	-	IV	↑	×	×	√	×	×	
90	Siberian Rubythroat	*Calliope calliope* (Pallas, 1776)	WV	I	LC	-	IV	→	√	×	×	×	×	
91	Siberian Stonechat	*Saxicola maurus* (Pallas, 1773)	WV	I	LC	-	IV	→	√	√	√	×	√	1e
92	Taiga Flycatcher	*Ficedula albicilla* (Pallas, 1811)	WV	I	LC	-	IV	→	√	√	×	×	×	
93	Tickell's Blue Flycatcher	*Cyornis tickelliae* (Blyth, 1843)	R	I	LC	-	IV	→	√	√	√	√	×	
Nectariniidae (1)														
94	Purple Sunbird	*Cinnyris asiaticus* (Latham, 1790)	R	N	LC	-	IV	→	√	√	√	√	√	
Oriolidae (2)														
95	Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	R	O	LC	-	IV	→	√	√	√	√	×	
96	Indian Golden Oriole	*Oriolus kundoo* (Sykes, 1832)	R	O	LC	-	IV	?	√	√	√	√	×	
Paridae (1)														
97	Cinereous Tit	*Parus cinereus* (Vieillot, 1758)	R	I	LC	-	IV	↑	√	√	√	√	√	
Passeridae (2)														
98	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	R	O	LC	-	IV	↓	√	√	√	√	√	
99	Yellow-throated Sparrow	*Gymnoris xanthocollis* (Burton, 1838)	R	O	LC	-	IV	→	√	√	√	√	√	
Phylloscopidae (4)														
100	Blyth's Leaf Warbler	*Seicercus reguloides* (Blyth, 1842)	WV	I	LC	-	IV	→	×	√	×	×	√	
101	Common Chiffchaff	*Phylloscopus collybita* (Vieillot, 1817)	WV	I	LC	-	IV	↑	√	√	√	√	√	
102	Greenish Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)	WV	I	LC	-	IV	↑	√	√	√	×	√	
103	Hume's Warbler	*Phylloscopus humei* (Brooks, 1878)	WV	I	LC	-	IV	→	√	×	×	×	×	
Ploceidae (2)														

	Order/Family/Common name	Scientific name	Residential status	Feeding status	Conservation status			Global status	Sites					Image No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		SHW	RDL	MKP	BKP	SDR	
104	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	R	O	LC	-	IV	→	√	√	√	√	√	
105	Black-breasted Weaver	*Ploceus benghalensis* (Linnaeus, 1758)	R	O	LC	-	IV	→	√	√	√	√	√	
Pycnonotidae (2)														
106	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	R	O	LC	-	IV	↑	√	√	√	√	√	
107	Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus, 1758)	R	O	LC	-	IV	↓	√	√	√	√	√	
Sittidae (1)														
108	Indian Nuthatch	*Sitta castanea* (Lesson, 1830)	R	O	LC	-	IV	?	√	√	√	√	√	1f
Stenostiridae (1)														
109	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)	WV	I	LC	-	IV	→	√	√	√	√	×	
Sturnidae (6)														
110	Asian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	R	O	LC	-	IV	↑	√	√	√	√	√	
111	Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	R	O	LC	-	IV	↑	√	√	√	√	√	
112	Brahminy Starling	*Sturnia pagodarum* (Gmelin, 1789)	R	O	LC	-	IV	?	√	√	√	√	√	
113	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	R	O	LC	-	IV	↑	√	√	√	√	√	
114	Common Starling	*Sturnus vulgaris* (Linnaeus, 1758)	WV	O	LC	-	IV	↓	√	√	×	√	×	1g
115	Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)	R	O	LC	-	IV	↓	√	√	√	√	√	
Turdidae (1)														
116	Black-throated Thrush	*Turdus atrogularis* (Jarocki, 1819)	WV	G	LC	-	IV	?	√	√	√	×	√	
Vangidae (1)														
117	Common Woodshrike	*Tephrodornis pondicerianus* (Gmelin, 1789)	R	I	LC	-	IV	→	√	√	√	√	√	
Zosteropidae (1)														
118	Indian White-eye	*Zosterops palpebrosus* (Temminck, 1824)	R	I	LC	-	IV	↓	√	√	√	√	√	
Pelecaniformes Ardeidae (7)														
119	Black-crowned Night Heron	*Nycticorax nycticorax* (Linnaeus, 1758)	R	O	LC	-	IV	↓	√	√	√	√	×	
120	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	R	C	LC	-	IV	↑	√	√	√	√	√	
121	Grey Heron	*Ardea cinerea* (Linnaeus, 1758)	WV	C	LC	-	IV	?	√	√	√	√	√	
122	Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	R	C	LC	-	IV	?	√	√	√	√	√	
123	Intermediate Egret	*Ardea intermedia* (Wagler, 1827)	R	C	LC	-	IV	↓	√	√	√	√	√	

	Order/Family/Common name	Scientific name	Residential status	Feeding status	Conservation status			Global status	Sites					Image No.
					IUCN (2021)	CITES (2012)	IWPA (1972)		SHW	RDL	MKP	BKP	SDR	
124	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	R	C	LC	-	IV	↑	√	√	√	√	√	
125	Purple Heron	*Ardea purpurea* (Linnaeus, 1766)	R	C	LC	-	IV	↓	√	√	√	√	√	
Ciconiidae (3)														
126	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	R	C	LC	-	IV	?	√	√	√	√	√	2f
127	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	WV	C	NT	-	IV	↓	×	√	×	×	×	2d
128	Woolly-neck Stork	*Ciconia episcopus* (Boddaert, 1783)	R	C	NT	-	IV	↓	√	√	√	√	√	1h
Piciformes Picidae (3)														
129	Black-rumped Flameback	*Dinopium benghalense* (Linnaeus, 1758)	R	O	LC	-	IV	→	√	×	×	×	×	
130	Brown-capped Pygmy Woodpecker	*Yungipicus nanus* (Vigors, 1832)	R	I	LC	-	IV	↑	√	√	√	√	×	
131	Yellow-fronted Woodpecker	*Leiopicus mahrattensis* (Latham, 1801)	R	O	LC	-	IV	→	√	√	√	√	×	
Ramphastidae (2)														
132	Brown-headed Barbet	*Psilopogon zeylanicus* (Gmelin, 1788)	R	F	LC	-	IV	→	√	√	√	√	√	
133	Coppersmith Barbet	*Psilopogon haemacephalus* (Muller, 1776)	R	F	LC	-	IV	↑	√	√	√	√	√	
Psittaciformes Psittaculidae (3)														
134	Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus, 1766)	R	F	NT	II	IV	↓	√	×	√	×	×	2a
135	Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	R	F	LC	II	IV	↓	√	√	√	√	√	
136	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	R	F	LC	-	IV	↑	√	√	√	√	√	
Strigiformes Strigidae (3)														
137	Brown Fish Owl	*Ketupa zeylonensis* (Gmelin, 1788)	R	C	LC	II	IV	↓	√	×	√	√	×	
138	Mottled Wood Owl	*Strix ocellata* (Lesson, 1839)	R	C	LC	II	IV	→	√	×	×	√	×	
139	Spotted Owlet	*Athene brama* (Temminck, 1821)	R	C	LC	II	IV	→	√	√	√	√	×	

IUCN: International Union for Conservation of Nature and Natural Resources; CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora; IPWA: Indian Wildlife Protection Act; R: Resident, WV: Winter Visitor, SV: Summer Visitor; C: Carnivorous; O: Omnivorous; I: Insectivorous; F: Frugivorous; G: Granivorous; N: Nectarivore; LC: Least Concern; EN: Endangered; VU: Vulnerable; NT: Near Threatened; CITES II: Appendix-II species of CITES are the ones that are not necessarily threatened now with extinction but may become so unless trade is closely controlled; III: Appendix-III species of CITES are those species which are already regulated for trade by the country and that needs the cooperation of other countries to prevent unsustainable and illegal exploitation; IWPA I: Schedule - I species of IWPA (high priority species); IV: Schedule - IV species of IWPA (relatively low priority species); V: Schedule - V species of IWPA (vermin - species which are harmful to crops, livestock and perceived as causing problems for the society); ?: Unknown; →: Stable; ↑: Increasing; ↓: Decreasing; SHW: Sohawal; RDL: Rudauli; MKP: Milkipur; BKP: Bikapur; SDR: Sadar; √: Species recorded in the site; ×: Species not recorded in the site.

district, eastern Uttar Pradesh, India (Table 2). Similar studies in agricultural landscapes have reported 144 species in Burdwan, West Bengal (Hossain & Aditya 2016), 128 species in Nalgonda District, Telangana (Narayana et al. 2019) and 107 species in Assam (Yashmita-Ulman et al. 2021a). In India, Passeriformes is the most dominant order (Praveen et al. 2016) and was found to be the most dominant order with 28 families and 76 species (Figure 2) in this study also. This finding is also consistent with the study of Kumar & Sahu (2020). Most species that have been recorded during our study are residents followed by winter and summer visitors (Figure 3). Hossain & Aditya (2016) in West Bengal, Narayana et al. (2019) in Tamil Nadu and Kumar & Sahu (2020) in Haryana have also found that the majority of the birds recorded from agricultural landscapes were resident in nature, followed by winter visitors and summer visitors. Uttar Pradesh being a part of the Central Asian Flyway serves as a wintering site for the migratory birds travelling from northern part of Asia and parts of Europe. The migratory birds usually prefer areas having congenial environment, enormous food availability and safe and secure sites as wintering grounds (Mukhopadhyay & Mazumdar 2017). Most of the tehsils in Ayodhya district are blessed with seasonal and perennial wetlands that attract a large population of migratory birds (pers. obs.). This is one of the reasons for encountering such high numbers of migrants in the study area.

Six foraging guilds are found in the study area, omnivores being the most dominant (Figure 4). This result contradicts those of other studies (e.g., Narayana et al. 2019; Kumar & Sahu 2020) who have reported insectivores to be the most dominant feeding guild in agricultural landscapes. Out of all the avifauna recorded, 87 bird species (63%) were found in all the study sites, whereas 52 bird species (37%) are recorded only in some study sites (Table 2). The fact that the bird species observed in the study area were mainly omnivores and a majority of them were found in all the study sites, indicates that the bird species occurring in agricultural fields are generalists in nature. They might have adopted themselves to the instability of food (fields are cultivated only for some parts of the year) and therefore feed on both plant and animal matter. Family Muscicapidae is known to be the most diverse family in India (Manakadan & Pittie 2001) and our results also indicate that Muscicapidae along with Accipitridae are the most diverse families (11 species each, RDi= 7.91) (Table 3), conforming to this statement.

In the present study, Sohawal tehsil recorded the

Table 3. Relative diversity (Rdi) of various avian families in agricultural landscapes of Ayodhya district, eastern Uttar Pradesh, India.

Avian family	Number of species recorded	Rdi value
Accipitridae	11	7.91
Muscicapidae	11	7.91
Ardeidae	7	5.04
Columbidae	7	5.04
Cuculidae	7	5.04
Motacillidae	6	4.32
Sturnidae	6	4.32
Hirundinidae	5	3.60
Alaudidae	4	2.88
Cisticolidae	4	2.88
Phylloscopidae	4	2.88
Campephagidae	3	2.16
Ciconiidae	3	2.16
Corvidae	3	2.16
Estrildidae	3	2.16
Laniidae	3	2.16
Leiothrichidae	3	2.16
Picidae	3	2.16
Psittaculidae	3	2.16
Strigidae	3	2.16
Acrocephalidae	2	1.44
Alcedinidae	2	1.44
Apodidae	2	1.44
Charadriidae	2	1.44
Meropidae	2	1.44
Oriolidae	2	1.44
Passeridae	2	1.44
Phasianidae	2	1.44
Ploceidae	2	1.44
Pycnonotidae	2	1.44
Ramphastidae	2	1.44
Aegithinidae	1	0.72
Bucerotidae	1	0.72
Coraciidae	1	0.72
Dicaeidae	1	0.72
Dicruridae	1	0.72
Falconidae	1	0.72
Glareolidae	1	0.72
Gruidae	1	0.72
Monarchidae	1	0.72
Nectariniidae	1	0.72
Paridae	1	0.72
Rallidae	1	0.72
Sittidae	1	0.72
Stenostiridae	1	0.72
Turdidae	1	0.72
Upupidae	1	0.72
Vangidae	1	0.72
Zosteropidae	1	0.72

Table 4. Measurements of avian diversity and richness at agricultural landscapes of Ayodhya District, eastern Uttar Pradesh, India.

Tehsil (Study sites)	Species richness	SWI	SDI	PEI
Sohawal	133	4.3	0.01	0.87
Rudauli	126	4.28	0.01	0.88
Milkipur	119	4.25	0.01	0.88
Bikapur	114	4.23	0.01	0.89
Sadar	98	3.86	0.03	0.84

SWI—Shannon-Weiner Diversity Index | SDI—Simpson's Dominance Index | PEI—Pielou's Evenness Index.

Table 5. Sorenson's Similarity Index of avian species between selected agricultural landscapes of Ayodhya district, eastern Uttar Pradesh, India.

	Sohawal	Rudauli	Milkipur	Bikapur	Sadar
Sohawal	0.00				
Rudauli	0.93	0.00			
Milkipur	0.92	0.94	0.00		
Bikapur	0.91	0.92	0.92	0.00	
Sadar	0.82	0.86	0.84	0.84	0.00

highest species richness and Shannon-Weiner diversity index (133, 4.30) (Table 4). The bird species richness and community structure depends upon the availability of food, roosting and nesting sites (Narayana et al. 2019), anthropogenic pressure (Yashmita-Ulman et al. 2020), geographical area & size, topographical features & climatic conditions of the area. The agricultural fields in Sohawal offer food in the form of rice & wheat grains & mustard seeds from time to time. This tehsil also has a presence of very diverse habitats. It is interspersed by small to large water bodies, agroforestry systems (trees like *Eucalyptus* sp. or *Tectona grandis* planted on farm bunds), plantations of *Eucalyptus* sp. or *Tectona grandis* and orchards of *Mangifera indica* or *Psidium guajava* making the landscape heterogeneous in nature. Due to this, the area offers very diverse food supply catering to the needs of birds belonging to different foraging guilds. Sundar and Kittur (2013) have reported that agricultural fields having wetlands in vicinity support diverse bird species. Yashmita-Ulman et al. (2018) have suggested that the presence of trees on bunds or blocks increases the bird diversity in agricultural fields. All these factors might have contributed to the bird diversity positively for this site to have a high bird diversity.

In the current study, the second highest species richness (126) is reported from Rudauli tehsil. The sites selected in Rudauli have Rudauli Reserve Forest in the vicinity and the agricultural fields have patches of trees either planted on bunds or in the form of orchards and plantations which might have influenced the bird diversity positively. Yashmita-Ulman et al. (2021b) in their study have concluded that agro-ecosystems in the vicinity of forests have higher diversity. But at the same time, these selected sites have very few water bodies which might have had a negative impact on the bird diversity. Bird species richness and diversity increase in accordance to presence of vegetation and water bodies (Shih 2018). All these might be the reasons of having a good bird diversity but not at par with Sohawal tehsil. On the other hand, Sadar tehsil mostly forms the heart of the Ayodhya city, having large areas occupied by buildings, settlements and industries. The study sites in this tehsil are, therefore, adversely affected by urbanization and higher anthropogenic disturbances. The urban development leads to habitat alteration thus reducing the availability of suitable habitats for birds (Mukhopadhyay & Mazumdar 2017). This might be the reason for finding the lowest bird diversity in Sadar (Species richness= 98, Shannon Weiner diversity index= 3.86) as compared to that of other selected sites.

Overall eight species of global conservation importance namely, *Aquila nipalensis, Neophron percnopterus* (Endangered), *Antigone antigone, Clanga hastata* (Vulnerable), *Ciconia episcopus, Gyps himalayensis, Mycteria leucocephala, Psittacula eupatria* (Near Threatened) have been reported in the study area (Table 2). This region also supported, 31 species (22%) whose global population trend is decreasing (Figure 5) and 16 species which came under Appendix II and Appendix III of CITES (Table 2). These findings are consistent with the study of Kumar & Sahu (2020). The agricultural lands with diverse species composition (Yashmita-Ulman 2021c), fruiting and flowering pattern (Yashmita-Ulman 2021a), structural diversity and management activities (Peterjohn 2003) prove as suitable breeding and foraging grounds for bird species. Many bird species such as *Ploceus philippinus* (Yashmita-Ulman et al. 2017) and *Antigone antigone* (Sundar 2009) are conserved in human-dominated landscapes due to the religious and traditional beliefs of the local communities. These beliefs immensely contribute in supporting species of conservation concern and species whose global population trend is decreasing in these agricultural landscapes.

CONCLUSION

The present study is the first documentation of the bird diversity found in agricultural landscapes of Ayodhya district, Uttar Pradesh. It is evident from this study that the agricultural landscapes are a potential habitat for the rare, globally threatened and near-threatened birds as well as various other migratory and resident birds. Thus, this paper lends an insight that agricultural landscapes can be harnessed for their conservation values. But such habitats are under constant threats due to anthropogenic activities. Therefore, such landscapes must be regularly assessed for their bird diversity and populations. Further detailed studies should be conducted to understand the factors influencing the diversity of birds in agricultural landscapes and the role these landscapes play in providing feeding, nesting, roosting and breeding sites for birds.

REFERENCES

Abdar, M.R. (2014). Seasonal diversity of birds and ecosystem services in agricultural area of Western Ghats, Maharashtra state, India. *Journal of Environmental Science, Toxicology and Food Technology* 8(1): 100–105.

Ali, S. & S.D. Ripley (1987). *Compact handbook of the birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan and Sri Lanka.* Oxford University Press, Delhi, 737pp.

Anonymous (2021a). Trading Economics. Accessed on 02 January 2021. https://tradingeconomics.com/india/agricultural-land-percent-of-land-area-wb-data.html#:~:text=Agricultural%20land%20(%25%20of%20land%20area)%20in%20India%20was%20reported,compiled%20from%20officially%20recognized%20sources

Anonymous (2021b). UNEP-WCMC Accessed on 02 January 2021. https://www.unep-wcmc.org/featured-projects/mapping-the-worlds-special-places

Anonymous (2021c). ENVIS. Accessed on 02 January 2021. http://www.wiienvis.nic.in/Database/Protected_Area_854.aspx

Anonymous (2021d). Krishi Vigyan Kendra, Ayodhya. Accessed on 02 January 2021. https://ayodhya.kvk4.in/district-profile.html

Asokan, S., A.M.S. Ali & R. Manikannan (2009). Diet of three insectivorous birds in Nagapattinam District, Tamil Nadu, India: a preliminary study. *Journal of Threatened Taxa* 1(6): 327–330. https://doi.org/10.11609/JoTT.o2145.327-30

Athreya, V., M. Odden, J.D.C. Linnell & K.U. Karanth (2010). Translocation as a tool for mitigating conflict with leopards in human-dominated landscapes of India. *Conservation Biology* 25: 133–141. https://doi.org/10.1111/j.1523-1739.2010.01599.x

Basavarajappa, S. (2006). Avifauna of agro-ecosystems of maidan area of Karnataka. *Zoo's Print Journal* 21(4): 2217–2219. https://doi.org/10.11609/JoTT.ZPJ.1277.2217-9

Bibby, C.J., D.A. Hill, N.D. Burgess & S. Mustoe (2000). *Bird Census Techniques.* 2nd Edition. Academic Press, London, 302pp.

Borad, C.K., A. Mukherjee & B.M. Parashaya (2000). Conservation of the avian biodiversity in paddy (*Oryza sativa*) crop agroecosystem. *Indian Journal of Agricultural Sciences* 70(6): 378–381.

Bruggisser, O.T., Schmidt-Entling, M.H. & S. Bacher (2010). Effects of vineyard management on biodiversity at three trophic levels. *Biological Conservation* 143: 1521–8. https://doi.org/10.1016/j.biocon.2010.03.034

CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora) (2012). https://cites.org/eng/disc/species.php Accessed on 2nd January 2021.

Dhindsa, M.S. & H.K. Saini (1994). Agricultural ornithology: an Indian perspective. *Journal of Bioscience* 19(4): 391–402. https://doi.org/10.1007/BF02703176

Doxa, A., Y. Bas, M.L. Paracchini, P. Pointereau, J.M. Terres & F. Jiguet (2010). Low-intensity agriculture increases farmland bird abundances in France. *Journal of Applied Ecology* 47: 1348–56. https://doi.org/10.1111/j.1365-2664.2010.01869.x

Elsen, P.R., R. Kalyanaraman, K. Ramesh & D.S. Wilcove (2016). The importance of agricultural lands for Himalayan birds in winter. *Conservation Biology* 31(2): 416–426. https://doi.org/10.1111/cobi.12812

Grimmett, R., C. Inskipp & T. Inskipp (2011). *Birds of the Indian Subcontinent*. Oxford University Press & Christopher Helm, London, 528pp.

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

Hossain, A. & G. Aditya (2016). Avian Diversity in Agricultural Landscape: Records from Burdwan, West Bengal, India. *Proceedings of Zoological Society* 69(1): 38–51. https://doi.org/10.1007/s12595-014-0118-3

Iqubal, P., P.J.K. McGowan, J.P. Carroll & A.R. Rahmani (2003). Home range size, habitat use and nesting success of swamp francolin *Francolinus gularis* on agricultural land in northern India. *Bird Conservation International* 13: 127–138. https://doi.org/10.1017/S0959270903003113

IUCN (International Union for Conservation of Nature) (2021). https://www.iucnredlist.org/ Accessed on 27 March 2021.

IWPA (Indian Wildlife Protection Act) (1972). https://legislative.gov.in/sites/default/files/A1972-53_0.pdf Accessed on 2 January 2021.

Javed, S. & A.R. Rahmani (1998). Conservation of the avifauna of Dudwa National Park, India. *Forktail* 14: 57–66.

Jayasimhan, C.S. & P. Pramod (2019). Diversity and temporal variation of the bird community in paddy fields of Kadhiramangalam, Tamil Nadu, India. *Journal of Threatened Taxa* 11(10): 14279–14291. https://doi.org/10.11609/jott.4241.11.10.14279-14291

Khan, M.S., A. Aftab, Z. Syed, A. Nawab, O. Ilyas & A. Khan (2013). Composition and conservation status of avian species at Hastinapur Wildlife Sanctuary, Uttar Pradesh, India. *Journal of Threatened Taxa* 5(12): 4714–4721. https://doi.org/10.11609/JoTT.o3419.4714-21

Kumar, A. & A. Kanaujia (2016). A flourishing breeding colony of Asian Openbill Stork (*Anastomus oscitans*) in Nawabganj Bird Sanctuary, Uttar Pradesh. *International Journal of Extensive Research* 10: 1-4.

Kumar, P. & S. Sahu (2020). Composition, diversity and foraging guilds of avifauna in agricultural landscapes in Panipat, Haryana, India. *Journal of Threatened Taxa* 12(1): 15140–15153. https://doi.org/10.11609/jott.5267.12.1.15140-15153

Kumar, S. (2018). Cultural landscape and heritage of Ayodhya-Faizabad: A geographical analysis. PhD Thesis submitted to Department of Geography, Banaras Hindu University, Varanasi, Uttar Pradesh.

Malhi, C.S. (2006). Status of avifauna in agricultural habitat and other associated sub-habitats of Punjab. *Environment and Ecology* 24(1): 131–143.

Manakadan, R. & A. Pittie (2001). Standardized common and scientific names of the birds of the Indian subcontinent. *Buceros* 6(1): 1–37.

Mishra, H., V. Kumar & A. Kumar (2020). Population structure and habitat utilization of migratory birds at Bakhira Bird Sanctuary, Uttar Pradesh, India. *Pakistan Journal of Zoology* 52(1): 247–254. https://doi.org/10.17582/journal.pjz/2020.52.1.247.254

Mukhopadhyay, S. & S. Mazumdar (2017). Composition, diversity and foraging guilds of avifauna in a suburban area of southern West Bengal, India. *Ring* 39: 103–120. https://doi.org/10.1515/ring-2017-0004

Narayana, B.L., V.V. Rao & V.V. Reddy (2019). Composition of birds in agricultural landscapes Peddagattu and Sherpally area: a proposed

Image 1a–h. a—*Halcyon smyrnensis* | b—*Prinia inornata* | c—*Upupa epops* | d—*Dicrurus macrocerus* | e—*Saxicola maurus* | f—*Sitta castanea* | g—*Sturnus vulgaris* | h—*Antigone antigone* & *Ciconia episcopus*. © Authors.

Image 2a–h. a—*Psittacula eupatria* | b—*Alcedo atthis* | c—*Neophron percnopterus* | d – *Mycteria leucocephala* | e—*Treron phoenicopterus* |f—*Anastomus oscitans* | g—*Spilornis cheela* | h—*Accipiter badius.* © Authors.

uranium mining sites in Nalgonda, Telangana, India. *Proceedings of Zoological Society* 72(4): 355–363. https://doi.org/10.1007/s12595-018-0276-9

O'Connor, R. & M. Shrubb (1986). *Farming and birds.* Cambridge: Cambridge University Press, Cambridge, 539pp.

Peterjohn, B.G. (2003). Agricultural landscapes: can they support healthy bird populations as well as farm products. *The Auk* 120: 14–19. https://doi.org/10.1642/0004-8038(2003)120[0014:ALCTSH]2.0.CO;2

Pielou, E.C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* 13: 131–144. https://doi.org/10.1016/0022-5193(66)90013-0

Praveen, J., R. Jayapal & A. Pittie (2016). A Checklist of the birds of India. *Indian Birds* 11(5&6): 113–172.

Praveen, J., R. Jayapal & A. Pittie (2020). Taxonomic updates to the checklists of birds of India, and the South Asian region – 2020. *Indian Birds* 16(1): 12–19.

Ramankutty, N. & J.A. Foley (1998). Characterizing patterns of global land use: an analysis of global croplands data. *Global Biogeochemical Cycles* 12: 667–685. https://doi.org/10.1029/98GB02512

Sekercioglu, C.H. (2012). Bird functional diversity and ecosystem services in tropical forests, agroforests and agricultural areas. *Journal of Ornithology* 153(Suppl. 1): S153–S161. https://doi.org/10.1007/s10336-012-0869-4

Shannon, C.E. & W.W. Wiener (1963). The mathematical theory of communications. University of Illinois, Urbana, USA.

Shih, W.Y. (2018). Bird diversity of greenspaces in the densely developed city centre of Taipei. *Urban Ecosystem* 21: 379-393. https://doi.org/10.1007/s11252-017-0720-z

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

Sorenson, T. (1948). A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyses of the vegetation on Danish commons. Biologiske Skrifter/ Kongellege Danske Videnskabernes Selskab 5

Sundar, K.S.G. & S. Kittur (2012). Methodological, temporal and spatial factors affecting modeled occupancy of resident birds in the perennially cultivated landscape of Uttar Pradesh, India. *Landscape Ecology* 27: 59–71. https://doi.org/10.1007/s10980-011-9666-3

Sundar, K.S.G. & S. Kittur (2013). Can wetlands maintained for human use also help conserve biodiversity? Landscape-scale patterns of bird use of wetlands in an agricultural landscape in north India. *Biological Conservation* 168: 49–56. https://doi.org/10.1016/j.biocon.2013.09.016

Sundar, K.S.G. & S. Subramanya (2010). Bird use of rice fields in the Indian subcontinent. *Waterbirds* 33 (Special Publication 1): 44–70

Sundar, K.S.G. (2006). Flock size, density and habitat selection of four large waterbirds species in an agricultural landscape in Uttar Pradesh, India. *Waterbirds* 29(3): 365–374.

Sundar, K.S.G. (2009). Are rice paddies suboptimal breeding habitat for Sarus Cranes in Uttar Pradesh, India? *Condor* 111: 611–623. https://doi.org/10.1525/cond.2009.080032

Taft, O.W. & S.M. Haig (2006). Landscape context mediates influence of local food abundance on wetland use by wintering shorebirds in an agricultural valley. *Biological Conservation* 128: 298–307. https://digitalcommons.unl.edu/usgsstaffpub/575

Torre-Cuadros, M.D.L.A.L., S. Herrando-Perez & K.R. Young (2007). Diversity and structure patterns for tropical montane and premontane forests of central Peru, with an assessment of the use of higher-taxon surrogacy. *Biodiversity and Conservation* 16: 2965–2988. https://doi.org/10.1007/s10531-007-9155-9

Whelan, C.J., D.G. Wenny & R.J. Marquis (2008). Ecosystem services provided by birds. *Annals of the New York Academy of Sciences* 11343: 25–60. https://doi.org/10.1196/annals.1439.003

Wretenberg, J., T. Part & A. Berg (2010). Changes in local species richness of farmland birds in relation to land-use changes and landscape structure. *Biological Conservation* 143: 375–81. https://doi.org/10.1016/j.biocon.2009.11.001

Yashmita-Ulman, A. Kumar & M. Sharma (2017). Traditional homegarden agroforestry systems: Habitat for conservation of Baya Weaver *Ploceus philippinus* (Passeriformes: Ploceidae) in Assam. India. *Journal of Threatened Taxa* 9(4): 10076–10083. https://doi.org/10.11609/jott.3090.9.4.10076-10083

Yashmita-Ulman, M. Sharma & A. Kumar (2018). Agroforestry systems as habitat for avian species: assessing its role in conservation. *Proceedings of Zoological Society* 71: 127–145. https://doi.org/10.1007/s12595-016-0198-3

Yashmita-Ulman, M. Singh, A. Kumar & M. Sharma (2020). Negative human-wildlife interactions in traditional agroforestry systems in Assam, India. *Journal of Threatened Taxa* 12(10): 16230–16238. https://doi.org/10.11609/jott.5754.12.10.16230-16238

Yashmita-Ulman, M. Singh, A. Kumar & M. Sharma (2021a). Conservation of wildlife diversity in agroforestry systems in eastern Himalayan biodiversity hotspot. *Proceedings of Zoological Society* 74: 171–188. https://doi.org/10.1007/s12595-021-00361-x

Yashmita-Ulman, M. Singh, A. Kumar & M. Sharma (2021b). Agroforestry systems: a boon or bane for mammal conservation in Northeastern India? *Proceedings of Zoological Society* 74: 28–42. https://doi.org/10.1007/s12595-020-00335-5

Yashmita-Ulman, M. Singh, A. Kumar & M. Sharma (2021c). Conservation of plant diversity in agroforestry systems in a biodiversity hotspot region of northeast India. *Agricultural Research* (in press) https://doi.org/10.1007/s40003-020-00525-9

Author details: Dr. Yashmita-Ulman, is an Assistant Professor at Department of Silviculture & Agroforestry, ANDUAT, Ayodhya. She has been involved in research on wildlife. Her current interests include plant-animal interactions in agroforestry systems and forests. Dr. Manoj Singh is an Assistant Professor at Department of Zoology, Kalinga University, Chhattisgarh. He is involved in research related to bird acoustics and wildlife conservation using GIS.

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COMMUNICATION

Identification of a unique barb from the dorsal body contour feathers of the Indian Pitta *Pitta brachyura* (Aves: Passeriformes: Pittidae)

Prateek Dey [1], Swapna Devi Ray [2], Sanjeev Kumar Sharma [3], Padmanabhan Pramod [4] & Ram Pratap Singh [5]

[1–5] National Avian Forensic Laboratory, Sàlim Ali Centre for Ornithology and Natural History, Anaikatty, Coimbatore, Tamil Nadu 641108, India.
[5] Department of Life Science, School of Earth, Biological and Environmental Sciences, Central University of South Bihar, Gaya, Bihar 824236, India.
[1] pratikdey23@gmail.com, [2] swapnadray555@gmail.com, [3] sksbreeder@gmail.com, [4] neosacon@gmail.com, [5] rampratapsingh81@gmail.com (corresponding author)

Abstract: Earlier research on feather morphology emphasized comprehensively on the body contour feather than various other types of feathers. Therefore, we conducted a systematic study on all feather types of the Indian Pitta *Pitta brachyura*, a passerine bird native to the Indian subcontinent. Feather barbs from wing contour, tail contour, body contour, semiplume, down, powder down, and bristle feathers were retrieved from the bird and observed under a light microscope. Primary flight feathers from the right and left wing were longest (85.17 mm and 87.32 mm, respectively), whereas bristle feathers were the shortest (5.31 mm). The mean barb length was observed to be the highest (11.37±0.47 mm) in the wing feather followed by body contour (8.31±0.39 mm), semiplume (8.27±0.22 mm), tail feather (7.85±0.50 mm), down (6.45±0.21 mm), powder down (6.04±0.23 mm), and bristle (2.70±0.07 mm). Pearson correlation was found positive for barb length and feather length of down feathers ($r= 0.996$, $p \leq 0.05$). We observed a novel type of barb the first time from dorsal body contour feather having plumulaceous barbules at the base followed by pennaceous barbules. This unique barbule arrangement is termed 'sub-plumulaceous' as it is distinct and analogous to known 'sub-pennaceous' type arrangement found absent in passerines.

Keywords: Feather, microscopy, Pitta brachyura, sub-pennaceous.

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Author details: Prateek Dey is a doctoral candidate of zoology (avian genetics) at SACON, has a degree in Integrated M.Sc (Life Sciences) from Central University of Tamil Nadu. Currently he works on whole genome sequencing and develops feather markers, for bird species prevalent in illegal wildlife trade. Swapna Devi Ray is a researcher from ecology and environmental Science background. Previously worked as a Junior Research Biologist at National Avian Forensic Laboratory, SACON. Currently affiliated as a Ph.D. scholar at SACON working on wildlife crime, plumology and molecular markers of avian species. Dr. Sanjeev Kumar Sharma has a PhD in Animal Genetics and Breeding from National Dairy Research Institute worked as a Project Scientist at the National Avian Forensic Laboratory, SACON. He carried out significant work generating whole genome sequences and developing feather markers for select bird species prevalent in illegal trade. Dr. Padmanabhan Pramod is a Senior Principal Scientist and head of Nature Education programme at SACON. Over a period of 27 years he has carried out various research projects in the field of ecosystem assessments, eco-development and mitigation measures for the bird hazards to aircrafts. Dr. Ram Pratap Singh is Associate Professor of Life Science at the Central University of South Bihar. The primary focus of Dr. Singh's research is to understand the physiology and genetics of birds and other animals. He established National Avian Forensic Laboratory and started Genome Resource Bank at SACON.

Author contributions: R.P.S collected the sample; conceived the idea; and supervised the research. R.P.S and P.P generated the funds for the study. P.D, S.D.R and S.K.S generated the data. R.P.S and P.D wrote the manuscript and analyzed the data. All the authors reviewed the manuscript.

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The Communication published in the 26 June 2021 issue of JoTT was withdrawn due to a faulty map. The same Communication with a corrected map is published here.

INTRODUCTION

Feathers are the most numerous, elaborate, and diverse derivatives of avian integument (Gill 1995). Collectively referred to as plumage, feathers are extraordinary evolutionary innovation evolved over a million years that perform a wide variety of functions in birds from insulation, protection, mate attraction, sound production to locomotion (Gill 1995; Lovette & Fitzpatrick 2016). All birds have different types of feather assorted in their plumage (Gill 1995). These feathers vary considerably in macroscopic (colouration, texture, pattern, shape, and size) and microscopic characteristics (minute morphological appendages) (Dove 1997a). The studies on types, characterisation and microstructures of feathers give us a deeper understanding of feather form and function (Lee et al. 2016). Although a handful of studies on feather examination have been reported over the years, still many questions regarding feather morphology have not been answered (Lee et al. 2016). Morphological examination of feather structures in the present day has acquired importance in diverse range of disciplines such as phylogeny (Dove 1997a ; Bensch et al. 2009), palaeontology (Messinger 1965; Dove et al. 2010), archaeology (Harwood 2011), avian ecology (Galván 2011; Fairhurst et al. 2013), wildlife forensics (Dove & Coddington 2015), biomechanics (Kulp et al. 2018), and material sciences (Lingham-Soliar 2017).

Typically a feather is made of a central rod like staff with numerous interlocking barbs attached to it on either side. The central shaft of each barb has minute branch like structures called barbules (distal/proximal) that extend on its either side (Images 1, 2). Barbules can be either pennaceous /plumulaceous and harbour various microstructures such as hooklets, nodes, internode, cilia, villi, prongs etc. Though individual groups of feathers may vary amongst themselves on various accounts of functionality, they share vast similarities in certain basic structural characters (Gill 1995). The literature regarding the nomenclature of feather structure and its micro characteristics till date lacks uniformity and is mostly based on convenience of the authors (Lovette & Fitzpatrick 2016). The authors would also like to shed light on the fact that many intermediate and exceptions might exist within the nomenclature used in this report. Adapting from various previous text books (Chandler 1916; Gill 1995; Lovette & Fitzpatrick 2016) and research papers we have resorted to widely applicable terminology based on most logical nomenclature perceived by the authors.

Over the years very few research reports have been published on feather identification and its structural characterisation (Lee et al. 2016). A few notable and exceptional reports do exist in the discipline of feather studies. In this particular aspect, a landmark work on feather characterisation and systematic studies was done by Chandler (1916). In his work Chandler (1916) adopted a universal nomenclature for various microstructures in a feather and classified feathers into plumules (unspecialized plumules, powder down, oil gland feathers, and nestling types), filoplumes, and contour (remiges, retrices, unspecialized contour feathers, ornamental plumes, ear coverts, facial bristles, and facial ruffs). In 1965, Messinger with the help of Hargrave successfully standardized a method to identify feather fragments from archaeological feather remains (Hargrave 1965; Messinger 1965). Day in 1966 studied the microstructures of plumulaceous barbs of contour feathers to identify various species of birds, using basic methodology as described by Chandler (Day 1966). Robertson (1984) studied plumulaceous barbs of contour feathers and prepared a detailed scheme for species identification from feather microstructure. He quantified the numerical variations in feather microstructure amongst species by measuring the length of barbules and number of nodes per barbules thus addressing the lack of numerical evidences in Chandler's (1916) work. In recent times, Carla J. Dove (Dove 1997a, 2000) used plumulaceous barbs of body contour feathers to successfully demonstrate inter-species differences and develop various forensic techniques useful in identification of species. In 2015, Lee and colleagues used the microstructures in plumulaceous barbs of body contour feathers for taxonomic identification of Australian birds (Lee et al. 2016). The study was remarkable in the fact that it used simple methods inspired from Chandler (1916) to create a feather identification catalogue of various illegally traded birds in Australia.

Previous studies on feather morphology are inclined in the direction of species identification and phylogenetic differentiation (Robertson et al. 1984; Dove 1997a, 2000). Barring Chandler (1916), previous reports have cleverly avoided elaborating on micro-structural differentiation in different 'groups' of feathers, selecting mostly 'body contour feathers' from the breast region as the subject of study. Such studies elaborated more on species differentiation but created a considerable knowledge gap in the understanding of differential structural characteristics of various types of feathers present in an individual bird. Most of the previous studies on feather investigations have been conducted

either in bird species of northern America or Australia (Dove & Coddington 2015; Lee et al. 2016). Very few minor reports have been published on birds of southern Asia (Songyan et al. 1995; Lee et al. 2010) and even fewer reports about feather morphology of bird species of Indian subcontinent has ever been published. With absolutely no in-depth reports of feather morphological studies of birds of southern Asia (birds of Indian subcontinent in particular) has led to a considerable knowledge gap in this particular aspect. Therefore, our group has taken an initiative to create a feather atlas for Indian birds, and this study is a part of the same feather atlas initiative.

The main objective of this study is to quantify macro and micro characteristics of various types of feathers from different anatomical locations of an individual bird species, the Indian Pitta *Pitta brachyura*. Secondly, we aim to create the very first comprehensive report on feather morphological examinations in any endemic species of bird of the Indian subcontinent. Third, we aim to standardize a protocol that can be used for systematic identification and morphological studies of various applied aspects of feather investigations. The implications of our study can inculcate a whole range of in-depth feather analysis as a tool for feather form and function elaboration or as a phylogenetic identification tool or can be used for applied wildlife forensic research.

METHODS

Target bird description

The Indian Pitta is a member of the Pittidae family of the order Passeriformes. Classified under IUCN category as 'Least concern', one such individual was found dead in the premises (11.059^{0}N, 76.814^{0}E) of our institute and was used as a specimen for this study. The dead specimen was collected with due permission from forest department (Ref.No.WL5 (A)/2219/2018; Permit No. 14/2018). Covering a large range, the Indian Pitta migrates to various parts of peninsular India during winter (Figure 1). Generally the Indian Pitta is extant up to an elevation of 1,700 m in the entire peninsular India inhabiting deciduous and evergreen forests (Lambert & Woodcock 1996).

Feather sampling

We classified feathers broadly into contour (wings, tail, and body contour) and non contour (semiplume, down, powder down, bristle, and filoplumes) category (Gill 1995). Wing feathers were further sub-divided into primary flight feathers and secondary flight feathers following Lovette & Fitzpatrick (2016). The specimen was searched meticulously to collect all the various types of feathers. One primary flight feather, one secondary flight feather each from left and right wing was sampled along with a single feather from the tail. Similarly, one body contour from the ventral side and another body contour

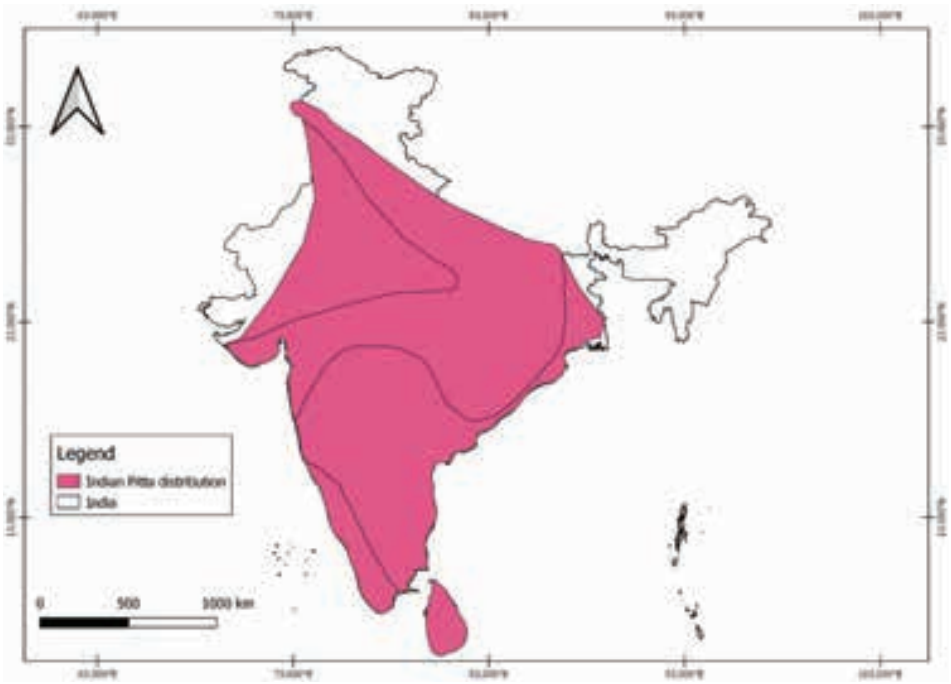

Figure 1. Species distribution map of Indian Pitta bird showing endemicity to the geographic range of Indian subcontinent. The map is adapted with permission from BirdLife International and Handbook of the Birds of the World (2017).

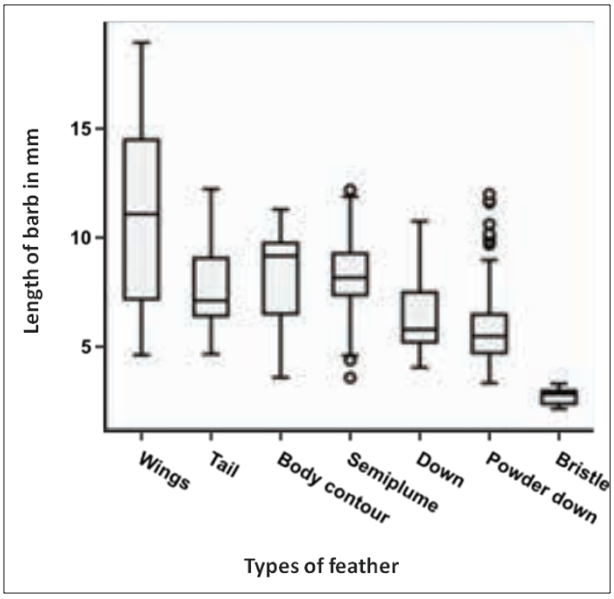

Figure 2. Numerical distribution of barb lengths in various types of feather.

from the dorsal side of the bird were sampled. In case of semiplume, two feathers each from ventral and dorsal side of the bird and one feather from the tail were sampled. One feather each from ventral portion, dorsal portion, right wing, left wing and tail were sampled for down feathers. In the same way, one feather each from ventral portion, dorsal portion, right wing, left wing, and tail were sampled for powder down feathers. Five bristle feathers were sampled from the chin and orbital region of the bird. After repeated searches through the cadaver of Indian Pitta, filoplume feathers couldn't be identified leading to omission of Filoplume observations in this study. The feathers were plucked carefully using surgical forceps (number 00) during sampling (Image 3).

Feather barb sampling

A methodical representation of the number of barbs sampled are mentioned in Table 1. After a feather was carefully plucked from the specimen, it was cleaned using 70 % ethanol solution (Lee et al. 2016). At first, each feather was placed carefully on a plain paper along with a scale, labelled properly and photographed. The length of the feather was noted and the feather was marked into three equal intervals termed 'proximal', 'intermediate', and 'distal' sections, respectively (Dove 1997b) (Image 4). For wings and tail feathers, vanes were classified as outer vane and inner vane following Chandler (1916) (Image 4). Three barbs from both vanes (inner and outer) of each section (proximal, intermediate, and distal) from a single feather from wings and tail were sampled (Image 4). A total of 18 barbs were sampled from each of the wing and tail feathers (5 feathers in total) (Table 1). For other types of feathers (body contour, semiplume, down, and powder down) five barbs from each of the three sections (proximal, intermediate, and distal) were plucked carefully following the same sampling procedure. Due to the minute size of the bristle feathers five entire bristle feathers were mounted onto separate glass slides. All the samplings of barbs were conducted carefully using surgical forceps (number 00) with minimal damage to the barbs.

Feather barb slide preparation

The sampled feather barbs/whole bristle feathers were placed onto a small drop of Xylene (Fisher Scientific, product No. 35405) on a microscope glass slide which were previously cleaned by using 70% ethanol. The drop of Xylene allowed the feather barbs to spread apart its barbules and after its evaporation kept the barbs attached onto the glass slide (Lee et al. 2016). In the meantime the slides were labelled properly using printed label stickers according to their slide codes to avoid confusion. Previously cleaned cover glasses were placed directly onto the completely dried feather barbs for dry mount (Lee et al. 2016). By using nail varnish (Nail Trend; Pearl White, India) the four sides of the cover glasses were sealed and allowed to dry for proper microscopic observations.

Macroscopic characteristics

Whole feathers were observed for macro-characteristics such as feather colour, pattern and texture following Lee et al. (2016). As mentioned above, the feathers were placed on a plain paper along with a scale, labelled properly and photographed. The slides mounted with barbs were also placed carefully on a plain paper along with a scale and photographed. Using ImageJ software distance (in the digital images) was standardized using the scale in each individual photograph (Schneider et al. 2012). Using the same ImageJ software length of feathers and length of each barb was calculated following the software as per instructions. Length of all the feather types was calculated, except powder down feathers because these feathers have extremely soft and rudimentary rachis,leading to no distinct orientation.

Microscopic characteristics

All the prepared slides were observed carefully for a number of selected microscopic features of feather barbules. These parameters include presence or absence of sub-pennaceous region, villi, nodes, prongs, hooklets

Table 1. Sampling details of types of feather, location of feathers sampled, number of barbs sampled, slides prepared, feather length in millimetre (mm) and mean barb length in millimetre (mm).

Types of feather	Location of feathers sampled	No. of barbs sampled	Number of slides prepared	Length of feather sampled (mm)	Length of barbs sampled (mm)	
					mean	±SE
Contour	Right Wing (Primary flight feather)	18	18	85.17	8.71	0.82
	Right Wing (Secondary flight feather)	18	18	76.39	14.55	0.68
	Left Wing (Primary flight feather)	18	18	87.32	8.52	0.68
	Left Wing (Secondary flight feather)	18	18	76.10	13.70	0.75
	Tail feather	18	18	37.55	7.85	0.50
	Body contour (Ventral)	15	15	28.24	7.11	0.63
	Body contour (Dorsal)	15	15	24.86	9.50	0.14
Semiplume	Ventral-1	15	15	33.66	7.88	0.35
	Ventral-2	15	15	32.55	7.30	0.26
	Near the tail	15	15	29.59	9.32	0.53
	Dorsal-1	15	15	36.59	9.04	0.49
	Dorsal-2	15	15	27.69	7.83	0.68
Downy	Dorsal	15	15	23.42	9.56	0.22
	Ventral	15	15	10.24	5.19	0.22
	Right wing	15	15	10.67	5.72	0.13
	Left wing	15	15	12.53	5.94	0.25
	Near tail	15	15	11.74	5.83	0.38
Powderdown	Right wing	15	15	*	4.99	0.19
	Left wing	15	15	*	5.52	0.31
	Ventral	15	15	*	9.48	0.40
	Dorsal	15	15	*	5.11	0.16
	Near tail	15	15	*	5.09	0.19
Bristle	Orbital region and chin	5	1	5.31	2.77	0.25
	Orbital region and chin	5	1	6.53	2.70	0.09
	Orbital region and chin	5	1	6.90	2.82	0.11
	Orbital region and chin	5	1	6.87	2.79	0.17
	Orbital region and chin	5	1	6.06	2.42	0.07
	Total of 27 different feathers sampled	Total of 370 Feather barbs sampled	Total of 350 slides prepared			

* Length of powder down feathers couldn't be calculated due to very miniscule rachis and no particular orientation of feather observed.

and ventral teeth; shape of nodes and internodes; presence of prongs, hooklets and ventral teeth on both side of barb; size of prongs and pigmentation of nodes, internodes and ramus (Image 5).

The slides were observed at 100X or 400 X magnifications under a light microscope (Weswox BXL, India) for select microstructures.

All the feather observation and recording were carried out by a single observer to minimize observer bias. Important microscopic morphological characters were photographed using binocular light microscope with an attached camera (Labomed Lx500, India) at 100X

and 400X magnifications using Image aR software.

Statistical analysis

All the analyses were performed using MS-Excel (Microsoft, U.S.A) (with XLSTAT add-in software). We calculated the length of all the sampled feathers as well as the length of barbs sampled from these feathers. For descriptive analysis the feathers were grouped into six groups (wings, tail, body contour, semiplume, down, powder down, and bristle) (Table 2). For each group the mean barb lengths, standard error, range and coefficient of variation was calculated. Comparative analysis were made and presented as box and whiskered plots (Figure 2). Correlation between the mean barb length and feather length was calculated using Pearson correlation coefficient. The feathers were grouped into four groups (contour, semiplume, down, and bristle), powder down was excluded from this analysis as the length of powder down feathers couldn't be calculated. For each feather, length of the feather was paired with mean barb length (of all the sampled barbs) during correlation analysis.

RESULTS

We observed 370 feather barbs from 27 different feathers (Table 1). We found morphological features such as hooklets and ventral teeth that were exclusive to contour and semiplume feathers only (Table 5). Features such as villi, nodes, prongs and internodes were recorded in down, powder down, semiplume feathers as well as in body contour feathers also (Table 5).

We observed a unique uncharacterized barbule arrangement in body contour feather barbs (Image 13). The barb was composed of plumulaceous barbules at the base of the barb with pennaceous barbules immediately following it (Image 13). Such unique arrangement of barbules in barbs was named as "sub-plumulaceous region" and was observed exclusively in the intermediate section of body contour feathers from the dorsal portion of the bird (Image 13). We reported in this study for the first time that bristles display microscopic morphological characteristics similar to down or powder down feathers (Image 12) (Table 5). The barbs of bristle feathers were characterized by the presence of villi, nodes, prongs and absence of hooklets and ventral teeth same as in down and powder down feather types. Even the shape of nodes was exactly similar as recorded in down and powder down feather barbs (Image 12).

Macroscopic characteristics

Primary flight feathers from the right and left wing (Table 1) were measured longest (85.17 mm and 87.32 mm, respectively), whereas bristle feather was the shortest (5.31 mm) (Table 1). The mean barb length of the wing feathers (primary and secondary flight feathers of left and right wing of contour type) was observed to be the highest (11.37±0.47 mm) and shortest in bristle (2.70±0.07 mm) (Table 2). Correlation (Pearson correlation coefficient) calculated using pair-wise comparison indicated that correlation was positively high for only the pair of barb length and feather length of down feathers ($r= 0.996$, $p \leq 0.05$) other feather types (contour, semiplume, powder down, and bristle) had no significant correlation between barb length and feather length (Table 3). The findings for various attributes (colour of feather, pattern in vanes, texture of barbs, and texture of rachis) of different feathers groups are presented in Table 4.

Microscopic characteristics

The feathers were divided into groups (wings, tail, body contour, semiplume, down, powder down, and bristle) and microscopic structures were scored in a predominantly binary (0/1) or tertiary (3/4/5) scores (Table 5).

Wings and tail were composed of entirely pennaceous barbules on feather barbs, characterized by the presence of hooklets on the distal barbules, teeth on both distal and proximal barbules and variable pigment on the rachis (Table 5; Image 6, 7). Body contour feathers were composed of barbs containing purely pennaceous barbules, purely plumulaceous barbules and both plumulaceous and pennaceous barbules (Image 8; Table 5). Semiplume feathers were composed of barbs containing purely pennaceous barbules and barbs containing purely plumulaceous barbules characterized by the presence of villi, nodes, prongs, hooklets and teeth (Image 9; Table 5). Down feathers (Image 10; Table 5), and powder down (Image 11; Table 5) were composed of barbs containing plumulaceous barbules characterized by presence of villi, nodes, and prongs. Two types of nodal shape were noticed in down feathers opposed to only singular type in powder down. Bristle feathers were characterized by presence of villi, nodes, and prongs displaying characteristics nearer to non-contour feathers (Image 12; Table 5).

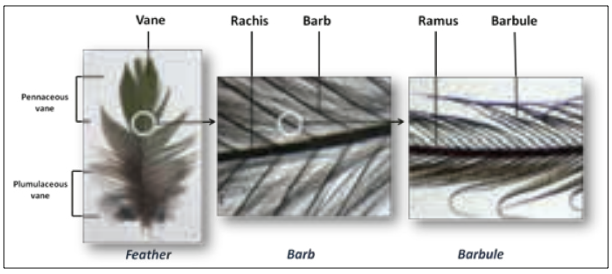

Image 1. Illustration of topography of a feather. © Prateek Dey & Swapna Devi Ray.

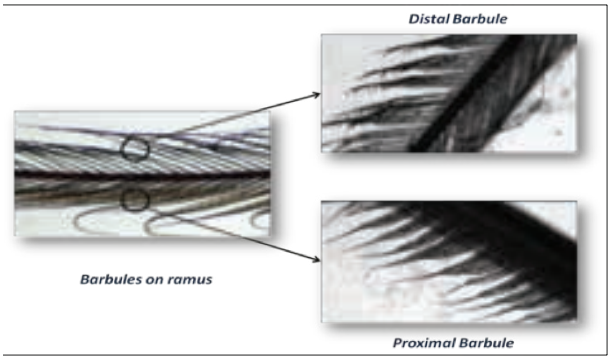

Image 2. Illustration of distal and proximal barbules on the barb of a pennaceous vane. © Prateek Dey & Swapna Devi Ray.

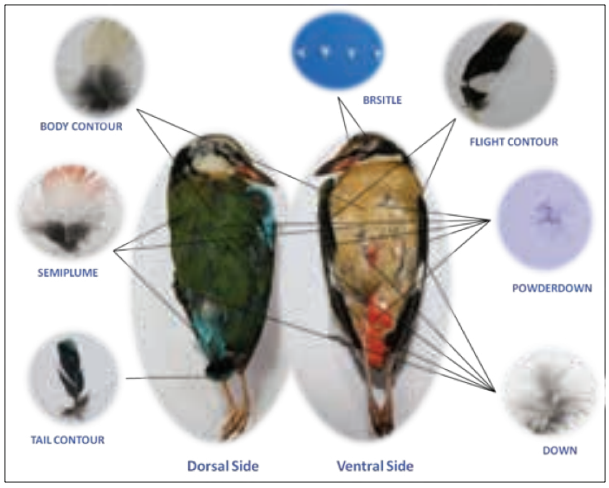

Image 3. Illustration of site of sampling of various feathers from different anatomic locations on the cadaver of Indian Pitta. © Prateek Dey & Swapna Devi Ray.

Table 2. Descriptive statistics of sampled barbs from various types of feathers.

Types of feather	No. of barbs (N)	Mean barb length (mm)	Range (mm)	Coefficient of variation (%)
Wings	72	11.37 ± 0.47	18.96–4.60	35.65
Tail	18	7.85 ± 0.50	12.23– 4.65	26.65
Body contour	30	8.31 ± 0.39	11.29–3.56	26.24
Semiplume	75	8.27 ± 0.22	12.19–3.56	23.32
Down	75	6.45 ± 0.21	10.75–4.03	28.34
Powderdown	75	6.04 ± 0.23	12.00–3.31	33.10
Bristle	25	2.70 ± 0.07	3.29–2.13	12.89

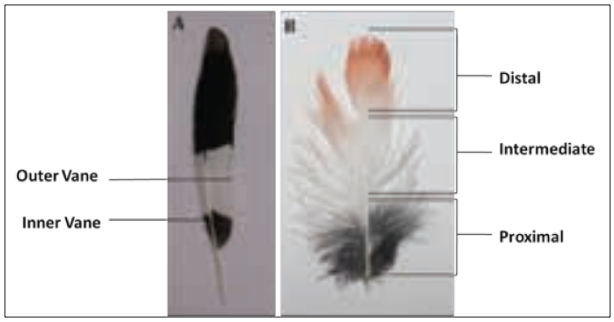

Image 4. A—Inner and outer vane in wing and tail feather | B—Sections considered on a feather for barb sampling (proximal, intermediate, and distal). © Prateek Dey & Swapna Devi Ray.

DISCUSSION

Morphological characteristics of various types of feathers were successfully studied in this report. Primarily we found, feathers grouped under same types but from different anatomical location have the exact same microscopic characteristics. In this study we have provided such evidence after macro and micro level examination of 350 slides prepared from 370 feather barbs obtained from 27 feathers sampled from an individual of Indian Pitta. Another study in such a systematic manner was conducted by Chandler (1916) without any empirical data to it's annexure. About a century later in 2021, Ray and workers systematically documented feather micro-characteristics of yellow billed babbler (Ray et al. 2021). Similarly in this study we have successfully assessed and recorded the select feather characteristics of Indian Pitta into empirical information. In this study we have successfully assessed and recorded the selected parameters into empirical information.

The identification of a unique barb in the dorsal body contour feathers for the first time sheds light on possible subtle differences even in the same type of feather but from different anatomical location. Though such a barb is an exception as in all other cases we found that feathers grouped under same type have exactly similar structure. Such a unique structure might be an adaptation to its function. Having plumulaceous barbules and pennaceous

Table 3. Pearson correlation coefficient of mean barb length and feather length of various feather types. Confidence interval 95% (p ≤0.05).

	Types of feather							
	Contour		Semiplume		Down		Bristle	
	r	p - value	r	p - value	r	p - value	r	p - value
Mean Barb length (mm) (α= 0.05, p ≤0.05) r= Pearson correlation coefficient	0.447	0.315	0.820	0.020	0.996	.000	0.287	0.640

Table 4. Details of macroscopic characteristics observed in various feather types.

Type of feather	Colour	Texture of barbs	Pattern in vanes	Texture of Rachis
Wings	Mostly black with patch of white	Stiff	Bold	Stiff
Tail	Mostly black with tinge of green at one end	Stiff	Bold	Stiff
Body contour	Black with cream/green colour at one end	Stiff, fluffy	Bold	Stiff
Semiplume	Whitish black, orange	Stiff, fluffy	Bold	Stiff
Down	Mostly black with hints of grey	Soft, fluffy	Dull	Soft
Powder down	Grey with black tinge	Soft, fluffy	Dull	NA
Bristle	White with cream complexion	Stiff	Dull	Stiffened & strongly tapered towards one end

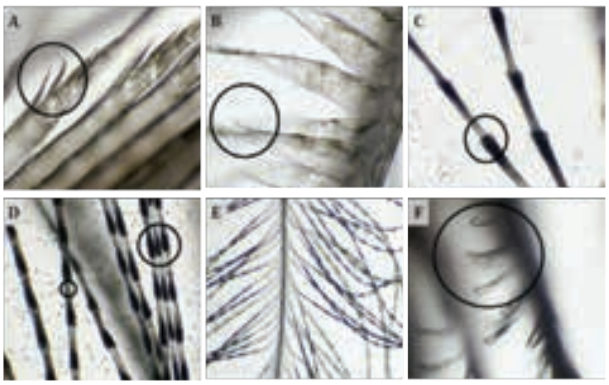

Image 5. Illustration of some of the microstructures present in a feather: A—Ventral teeth | B—Villi | C—Nodes with prongs | D—Nodes and Internodes | E—Plumulaceous barbules on a ramus | F—Hooklet. © Prateek Dey & Swapna Devi Ray.

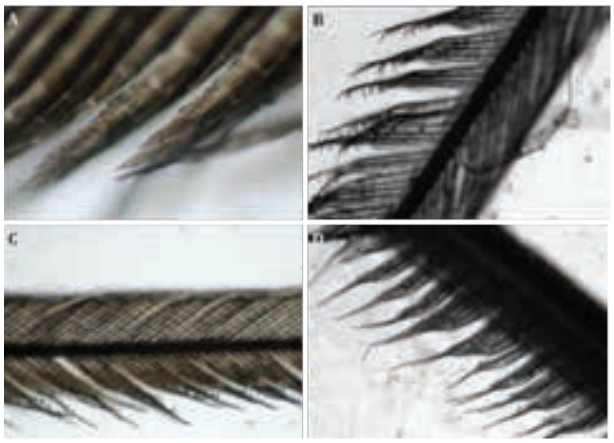

Image 6. Microscopic feather characteristics of wing feathers illustrated using light microscopy: A—Ventral teeth | B—Hooklets on distal barbule | C—Distal and Proximal barbule on ramus | D—Proximal barbule. © Prateek Dey & Swapna Devi Ray.

barbule in the same barb helps the feather in insulation as well as in flight. Such a specialized barb might be a necessity for the dorsal feathers that bear the blunt of air currents during a bird's flight. Previous studies displayed that passerines are generally characterized by the absence of sub-pennaceous region (Lee et al. 2016), possibly the presence of newly identified sub-plumulaceous region in dorsal body contour feather barbs is specific to these birds. Although more studies containing multiple passerine species from various families are needed to authenticate such a hypothesis nevertheless the above discovery is unique enough in its own right.

The bristle feathers are believed to be structurally modified contour feathers in the existing literature (Lovette & Fitzpatrick 2016). However microscopic analysis in this study placed them structurally closer to down and powder down feathers. The characteristics that separates bristle from contour feather is the absence of ventral teeth and hooklets, thus placing it closer to down and powder down types.

Correlation between barb length and feather length was significant for down feathers only. Such a correlation can be explained by the fact that length of down feather

Table 5. Details of microscopic characteristics observed in various feather types.
0—Absent | 1—Present | 3—Variable | 4—Node shape flared on one side and diminished towards other | 5—Rod shaped node | S/L—Small/Large | NA—Not applicable | D/P—Distal/Proximal barbule | STR/KNK—Straight/Kinked.

Types of feather	Micro-characteristics																
	Sub-pennaceous region	Villi	Nodes	Node shape	Prongs	Presence of prongs on both side of barb		Prong size	Hooklets	Presence of hooklets on both side of barb		Teeth	Presence of teeth on both side of barb		Internode shape	Pigmentation		
	0/1	0/1	0/1		0/1	0/1	D/P	S/L	0/1	0/1	D/P	0/1	0/1	D/P	STR/ KNK	Nodes	Inter-nodes	Ramu-s
Wings	0	0	0	NA	0	NA	NA	NA	1	0	D	1	1		NA	NA	NA	3
Tail	0	0	0	NA	0	NA	NA	NA	1	0	D	1	1		NA	NA	NA	3
Body contour	0	1	1	4	1	1		S	1	0	D	1	1		STR	1	3	3
Semiplume	0	1	1	4	1	1		S	1	0	D	1	1		STR	3	3	3
Down	0	1	1	4,5	1	1		S	0	NA	NA	0	NA	NA	STR	3	3	3
Powderdown	0	1	1	4	1	1		S	0	NA	NA	0	NA	NA	STR	3	3	3
Bristle	0	1	1	4	1	1		S	0	NA	NA	0	NA	NA	STR	3	3	3
Repeated barbs*	0	1	1	4	1	1		S	1	0	D	1	1		STR	1	3	3

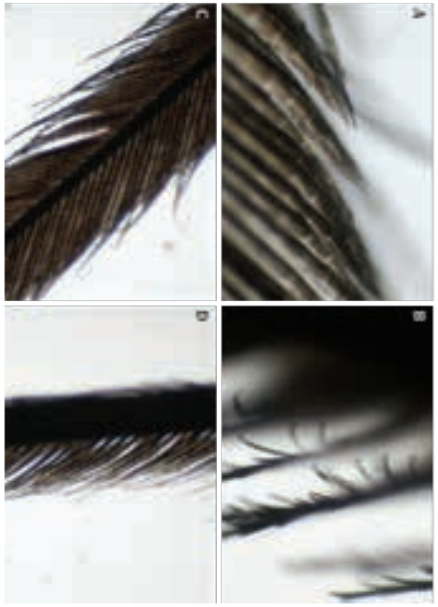

Image 7. Microscopic feather characteristics of tail feathers illustrated using light microscopy: A—Ventral teeth | B—Hooklets on distal barbule | C—Distal and Proximal barbule on ramus | D—Proximal barbule. © Prateek Dey & Swapna Devi Ray.

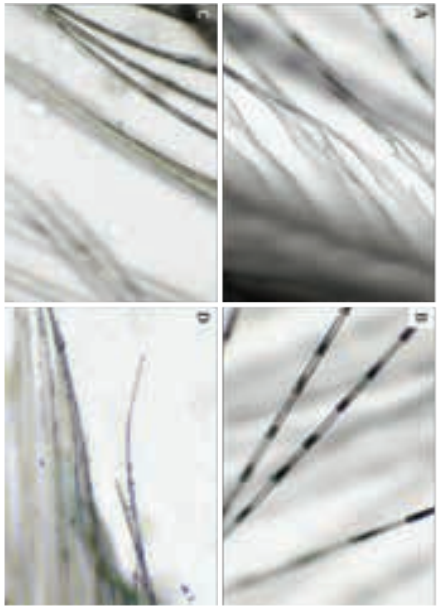

Image 8. Microscopic feather characteristics of body contour feathers illustrated using light microscopy: A—Villi | B—Nodes and prongs | C—Hooklet on distal barbule | D—Ventral teeth on proximal barbule. © Prateek Dey & Swapna Devi Ray.

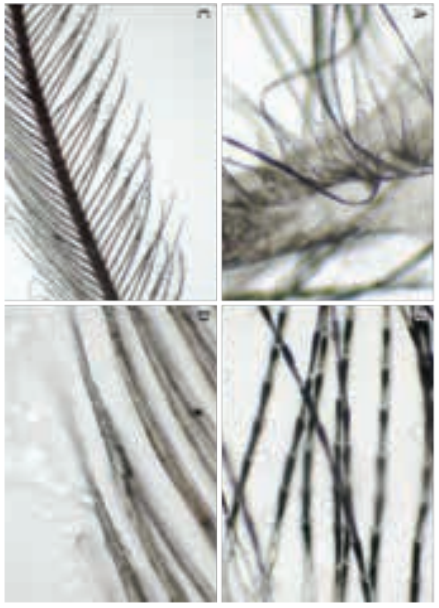

Image 9. Microscopic feather characteristics of semiplume feathers illustrated using light microscopy: A—Villi | B—Nodes and prongs | C—Hooklet on distal barbule | D—Ventral teeth on proximal barbule © Prateek Dey & Swapna Devi Ray.

barbs and length of down feathers are both essential to perform its function of insulation and thermoregulation. Whereas, barb length and feather length of other types of feather aren't correlated enough in their functionality. Through our study on the various feather types in Indian Pitta, we would like to suggest that based on barbules, feather barbs can be divided broadly into three types. These include: (i) barbs without any sub-pennaceous or sub-plumulaceous region (in case of Indian Pitta wing, tail, semiplume, down and powder down feathers), (ii) feather containing barbs with sub-pennaceous or sub-plumulaceous region (sub-plumulaceous region as present in body contour feathers from dorsal portion of Indian Pitta), and (iii) feather containing barbs which are specially modified for specific functions (bristle feathers). Such a morphology based classification of barbs, can possibly be beneficial for designing feather related studies in future.

Robertson (Robertson et al. 1984) pointed that Chandler (1916) and Day (Day 1966) had reported schemes for feather identification which lacked any corroborating evidence. Also, the works of Hargrave (1965) and Messinger (1965) were based on qualitative assessment of feather microstructures.

In 1984, Robertson et al. (1984) quantified and provided numerical data of node density and barbule length for consideration as species identification parameters; however their data demonstrated that variation in barbule length and node density within a species is considerably high and provides limited scope for inter taxa identification. Same was also established by Joannah Lee (Lee et al. 2016) through qualitative identification of feather micro characteristics. Through our result we also state that, assessment of feather microstructure qualitatively without any numerical data is capable of differentiation between various types of feather.

The studies of Robertson (1984) and Chandler (1916) state that pennaceous parts of contour feather vary hugely amongst the feathers of same individual; however, through our study we found that the pennaceous region of feathers of wings, tail, body contour, and semiplume have exactly the same microstructure, contradicting the findings of the previous studies. The similarity in micro structures is expected as the feathers performing similar functions are supposed to have exactly same microstructure. And as such the similar trend is observed in all other feather types.

Previous studies (Dove 1997b; Lee et al. 2016) have emphasized on the fact that an appropriate reference collection, well trained staff and standardized

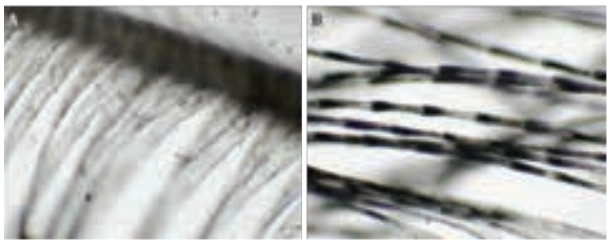

Image 10. Microscopic feather characteristics of down feathers illustrated using light microscopy: A—Villi | B—Nodes, prongs, and internodes. © Prateek Dey & Swapna Devi Ray.

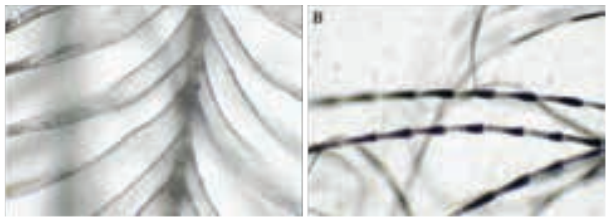

Image 11. Microscopic feather characteristics of powder down feathers illustrated using light microscopy: A—Villi | B—Nodes, prongs, and internodes. © Prateek Dey & Swapna Devi Ray.

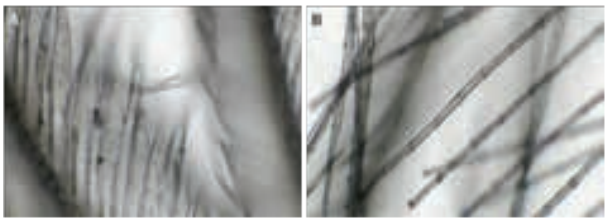

Image 12. Microscopic feather characteristics of bristle feathers illustrated using light microscopy: A—Villi | B—Nodes, prongs, and internodes. © Prateek Dey & Swapna Devi Ray.

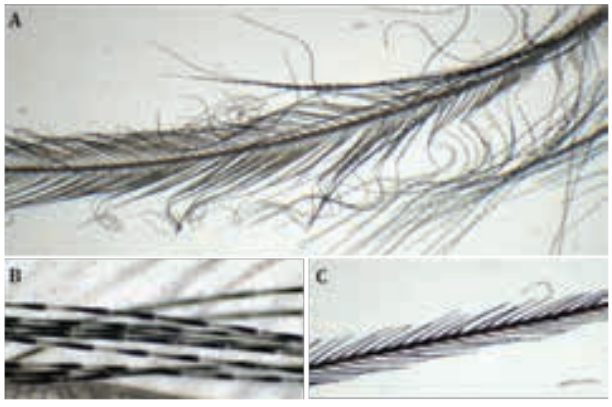

Image 13. Microscopic feather characteristics of unique feather barbs identified from dorsal body contour feather illustrated using light microscopy: A—Both pennaceous and plumulaceous barbules on the ramus of the barb | B—Nodes, Internodes, and prongs on the plumulaceous barbule | C—Distal and proximal barbule on the pennaceous barb. © Prateek Dey & Swapna Devi Ray.

techniques is necessary for such feather related studies. Through our work we have pioneered in such challenge for the first time in India and aim to create a feather identification repository armed with trained personnel to perform various feather investigations. Our study found that the technique of dry mount followed by our study (Robertson et al. 1984; Lee et al. 2016) is best suited for mounting feather barbs for observation under light microscope. The technique of mounting the barb in medium (Dove & Coddington 2015) might chaperone the delicate microstructures of villi and hooklets, leading to faulty recording of observations. Systematic studies on feather morphology helps us understand the form and functions of feathers better as well as provide us better understanding of inter-species differences in feather structures. The practical implications of our study can inculcate a whole range of in-depth feather analysis as a tool for feather form and function description or as a phylogenetic identification tool or as an aid in applied wildlife forensic research.

Data availability: Analyses reported in this article can be reproduced using the data provided by the author upon acceptance of the manuscript.

REFERENCES

Chandler, A.C. (1916). *A study of feathers, with reference to their taxonomic significance*. University of California Press, Berkeley, 274pp.

BirdLife International and Handbook of the Birds of the World (2017). Bird species distribution maps of the world, version 7.0. http://datazone.birdlife.org/species/

Bensch, S., M. Grahn, N. Müller, L. Gay & S. Akesson (2009). Genetic, morphological, and feather isotope variation of migratory willow warblers show gradual divergence in a ring. *Molecular Ecology* 18(14): 3087–3096. https://doi.org/10.1111/j.1365-294X.2009.04210.x

Day, M.G. (1966). Identification of hair and feather remains in the gut and faeces of stoats and weasels. *Journal of Zoology* 148(2): 201–217. https://doi.org/10.1111/j.1469-7998.1966.tb02948.x

Dove, C.J. (1997a). Quantification of Microscopic Feather Characters Used in the Identification of North American Plovers. *The Condor* 99(1): 47–57.

Dove, C.J. (1997b). Quantification of Microscopic Feather Characters Used in the Identification of North American Plovers. *The Condor* 99(1): 47–57.

Dove, C.J. (2000). A Descriptive and Phylogenetic Analysis of Plumulaceous Feather Characters in Charadriiformes. *Ornithological Monographs* 51: 1–163.

Dove, C.J., & C.P.J. Coddington (2015). Forensic Techniques Identify the First Record of Snowy Owl (*Bubo scandiacus*) Feeding on a Razorbill (*Alca torda*). *The Wilson Journal of Ornithology* 127(3): 503–506. https://doi.org/10.1676/14-176.1

Dove, C.J., P.G. Hare & M. Heacker (2005). Identification of ancient feather fragments found in melting alpine ice patches in southern Yukon. *Arctic* 1: 38–43.

Fairhurst, G.D., T.A. Marchant, C. Soos, K.L. Machin & R.G. Clark (2013). Experimental relationships between levels of corticosterone in plasma and feathers in a free-living bird. *Journal of Experimental Biology* 216(21): 4071–4081. https://doi.org/10.1242/jeb.091280

Dove, C.J., N.F. Dahlan & M. Heacker (2009). Forensic bird-strike identification techniques used in an accident investigation at Wiley Post Airport, Oklahoma, 2008. *Human-Wildlife Conflicts* 3(2): 179–185. https://doi.org/10.26077/ace5-s883

Galván, I. (2011). Feather microstructure predicts size and colour intensity of a melanin-based plumage signal. *Journal of Avian Biology* 42(6): 473–479. https://doi.org/10.1111/j.1600-048X.2011.05533.x

Gill, F.B. (1995). *Ornithology*. Macmillan, New York City.

Hargrave, L.L. (1965). Identification of Feather Fragments by Microstudies. *Memoirs of the Society for American Archaeology* (19): 202–205.

Harwood, H.P. (2011). Identification and description of feathers in Te Papa's Maori cloaks. *Tuhinga* 22: 125–147.

Kulp, F.B., L. D'Alba, M.D. Shawkey & J.A. Clarke (2018). Keratin nanofiber distribution and feather microstructure in penguins. *The Auk* 135(3): 777–787. https://doi.org/10.1642/AUK-18-2.1

Lambert, F.R. & M. Woodcock (1996). *Pittas, broadbills and asities*. Pica.

Lee, E., H. Lee, J. Kimura & S. Sugita (2010). Feather Microstructure of the Black-Billed Magpie (*Pica pica sericea*) and Jungle Crow (*Corvus macrorhynchos*). *Journal of Veterinary Medical Science* 72(8): 1047–1050. https://doi.org/10.1292/jvms.09-0482

Lee, J., S.D. Sarre, L. Joseph & J. Robertson (2016). Microscopic characteristics of the plumulaceous feathers of Australian birds: a preliminary analysis of taxonomic discrimination for forensic purposes. *Australian Journal of Forensic Sciences* 48(4): 421–444. https://doi.org/10.1080/00450618.2015.1076034

Lingham-Soliar, T. (2017). Microstructural tissue-engineering in the rachis and barbs of bird feathers. *Scientific Reports* 7: 45162. https://doi.org/10.1038/srep45162

Lovette, I.J., & J.W. Fitzpatrick (Eds.) (2016). *Handbook of Bird Biology*. John Wiley & Sons.

Messinger, N.G. (1965). Methods Used for Identification of Feather Remains from Wetherill Mesa. *Memoirs of the Society for American Archaeology* 19: 206–215.

Robertson, J., C. Harkin & J. Govan (1984). The Identification of Bird Feathers. Scheme for Feather Examination. *Journal of the Forensic Science Society* 24(2): 85–98.

Ray, S.D., P. Dey, N. Islam, S.K. Sharma, P. Pramod & R.P. Singh (2021). Comparative study of Yellow-billed Babbler (*Turdoides affinis*) feathers reveals uniformity in their microstructures among individuals. *Journal of Experimental Biology and Agricultural Sciences* 9(1): 51–64. https://doi.org/10.18006/2021.9(1).51.64

Schneider, C.A., W.S. Rasband & K.W. Eliceiri (2012). NIH Image to ImageJ: 25 years of image analysis. *Nature methods* 9(7): 671–675. https://doi.org/10.1038/nmeth.2089

Songyan, J., H. Fulan, L. Yue, L. Jiaqi & W. Xuejun (1995). Microstructure of feather of Red crowned crane (*Grus japonensis*). *Journal of Northeast Forestry University* 6(2): 71–74.

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COMMUNICATION

Moths of the superfamily Gelechioidea (Microlepidoptera) from the Western Ghats of India

Amit Katewa[1] & Prakash Chand Pathania[2]

[1]Department of Zoology and Environmantal Sciences, Punjabi University, Patiala, Punjab 147002, India.
[2]High Altitude Regional Centre, Zoological Survey of India, Saproon, Solan, Himachal Pradesh 173211, India.
[1] amitkatewa@yahoo.com, [2] pathaniapc@yahoo.co.in (corresponding author)

Abstract: Sixteen species belonging to 13 genera—*Stegasta* Meyrick, *Anarsia* Zeller, *Hypatima* Hübner, *Helcystogramma* Zeller (Gelechiidae), *Lecithocera* Herrich-Schäffer, *Hygroplasta* Meyrick, *Torodora* Meyrick (Lecithoceridae), *Apethistis* Meyrick, *Cophomantella* Fletcher, *Stathmopoda* Herrich-Schäffer, *Tonica* Walker (Oecophoridae), *Ethmia* Hübner (Ethmidae), and *Eretmocera* Zeller (Scythridae)—of the superfamily Gelechioidea have been collected from different localities of the Western Ghats. Other details such as synonymy, material examined, distribution, and remarks are also provided. Fifteen species are recorded for the first time from the Western Ghats.

Keywords: Ethyl acetate, Ethymiidae, female genitalia, forewing, Gelechiidae, Insecta, Lecithoceridae, Oecophoridae, light trap, Scythridae.

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Author details: Dr. Amit Katewa is presently working as Consultant (Dengue & Chikungunya), National Vector Borne Disease Control Programme (NVBDCP),Delhi and worked on Microlepidoptera fauna at Punjabi University, Patiala. He has more than 8 years of research experience in the same field. Dr. Prakash Chand Pathania is presently working as Scientist, High Altitude Regional Centre, Zoological Survey of India, Saproon, Solan, Himachal Pradesh and has more than 24 years of research experience in the field of taxonomy, biology and ecology of Lepidoptera.

Author contributions: AK did the field work and prepared the genital plates and PCP also did field survey and prepared the manuscript.

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INTRODUCTION

The main characters of superfamily Gelechioidea are maxillary palpus always four segmented, scaled and folded over with base of the haustellum, labial palus upturned 3rd segment long and acute, head decorated with smooth scale, cheatosemata absent, dorsal surface of hind tarsus with long, slender scales, pupal antennae meeting mesially before their apexes, larval abdominal segment 1–8 with setae L1/L2 closely approximated or on the same pinaculum (Common 1970, 1990; Hodges 1978, 1986; Minet 1990, 1991). The Western Ghats is one of the hot biodiversity spots quite diverse and unique and about 160,000 km^2 and stretches for 1,600 km from the river Tapti in the north to Cape Camorin in the south and is very rich in flora and fauna. The average height of about 1,200 m running parallel to the western coast of southern India covering six states of Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu, and Kerala. It is known by various names in different areas, i.e., as the Sahyadri mountains in Maharashtra and Karnataka, Nilagirimalai in Tamil Nadu, and Sahyaparvatam in Kerala. The highest peak of the Western Ghats is The Anaimudi peak (2,695 m) in the state of Kerala. The Anaimalai hills in the north, the Palni hills in the north-east and the Cardamom hills in the south are the three ranges that radiate to different directions. Gelechioidea is one of the large groups represented by 1,478 genera of 18,489 species on a world basis (Van Nieukerken et al. 2011).

MATERIAL AND METHODS

A survey-cum-collections tour was undertaken from 29 localities of 19 districts in the six states in the Western Ghats for the collection of superfamily Gelchioidea moths from March 2003 to October 2015 (Image 1A). The details of the visited localities are provided (Table 1). Gelechioidea (Microlepidoptera) has been collected with the help of a portable light trap (Image 1B) and single tube collecting technique and vertical sheet method. Some of moths were captured individually in glass killing tubes of various sizes (2 x 7 cm to 5 x 15 cm) charged with ethyl acetate poured over the plaster of Paris dried at the bottom of the tube from near restaurants, hotels, forest rest houses, bus depots, and railway stations around the localities being visited. As per techniques being used in lepidopterology (Lindquist 1956; Hodges 1958; Tagestad 1974; Robinson 1976; Zimmerman 1978; Nielson 1980; Sokoloff 1980; Mikkola 1986; Landry & Landry 1994), the entire collected specimens were processed for further biosystematics studies. All the collecton are deposited in the Insect Museum, Department of Zoology & Environmental Sciences, Punjabi University, Patiala and National PAU Insect Museum, Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab.

OBSERVATIONS

In the present research work, 16 species of moths of superfamily Gelechioidea have been collected and identified from the Western Ghats, India (Table 1). The details of subfamilies, genera and number of species recorded from the study area are provided below (Table 2):

Systematic Account

Phylum: Arthropoda

Subphylum: Hexapoda

Class: Insecta

Order: Lepidoptera

SUPERFAMILY GELECHIOIDEA

FAMILY GELECHIIDAE

Gelechiidae Stainton, 1854, *Insecta Br. Lepid. Tineina,*: 10 (key) and 75 (spelled as Gelechidae).

Type genus: *Gelechia* Hübner, (1825) 1816, *Vertz. bekannter Schmett*., 415.

Subfamily: GELECHIINAE

Gelechiinae Stainton, 1854, *Insecta Br. Lepid. Tineina*, 10 (key) and 75 (as Gelechidae).

Type-genus: *Gelechia* Hübner (1825) 1816, *Verz. bekannter Schmett*., 415.

I. Stegasta Meyrick

Stegasta Meyrick, 1904, *Proc. Linn. Soc. N.S.W.*, 29: 258 (key), 313.

Type-species: *Stegasta variana* Meyrick, 1904, *Proc. Linn. Soc. N.S.W.*, 29: 313 9 (key), 314, by original designation.

Diagnosis: Rose & Pathania (2004).

1. Stegasta comissata Meyrick (Image 2A)

Stegasta comissata Meyrick, 1923, *Exot. Microlepid*., 3: 18

Description: Forewing with a white spot present near apex, anal area white near base to 3/4th and costal margin, vein R4+R5 short stalked, R1 arising at middle of discal cell, male genitalia with sacculus beset with a small spine-like projection distally, costa with relatively

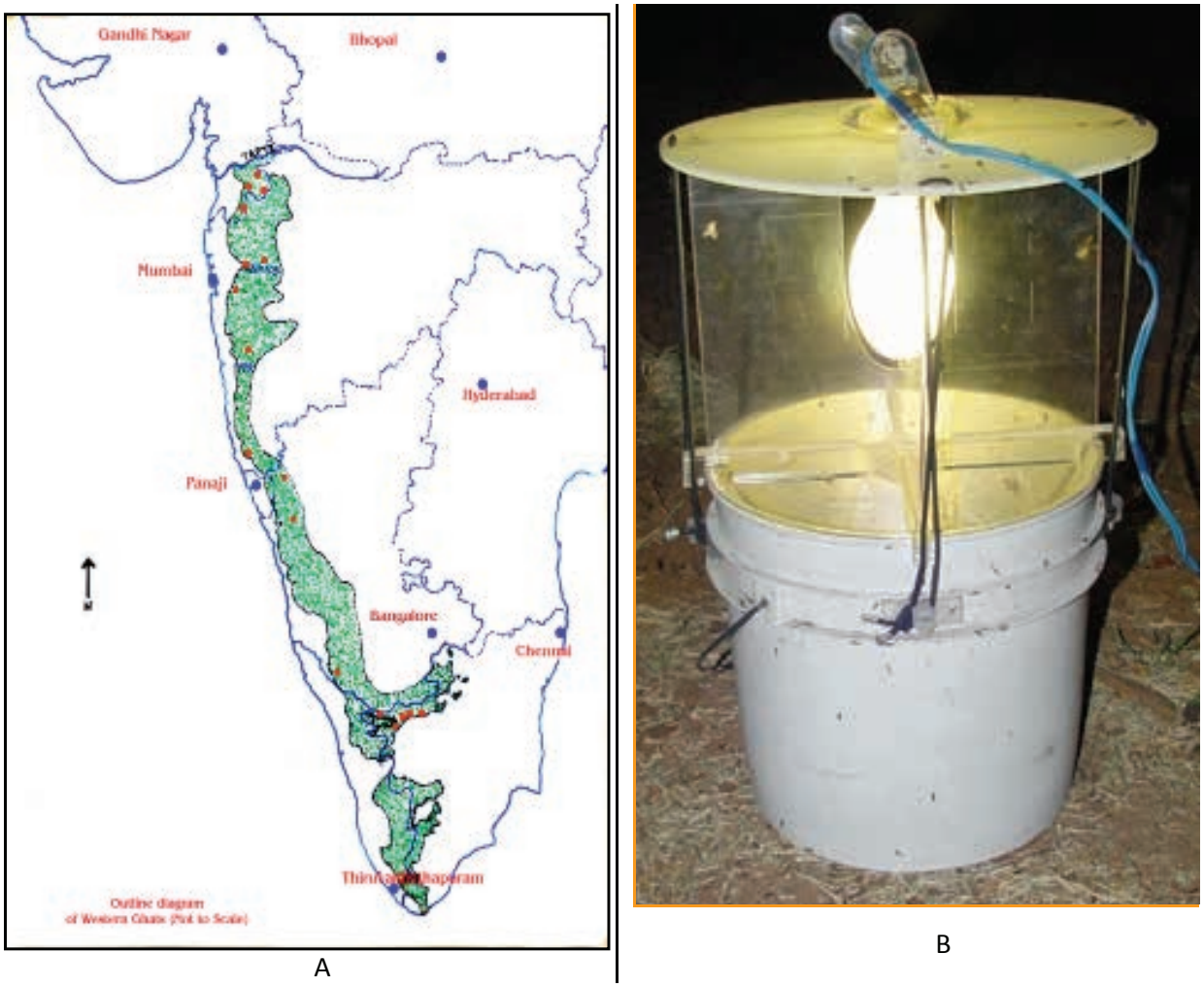

Image 1. A—Map: Area surveyed | B—Portable light trap.

Table 1. The visited states and localities during the study at the Western Ghats of India.

	State	Districts explored	Dates of collection	Localities visited
1.	Goa	Sanguem, Ponda	25–30.ii.2004	Forest Rest House, Keri and Ponda
2.	Gujarat	The Dangs	28–30.ix.2005	Ahwa, Saputara, Forest Rest House, Ahwa and Waghai
3.	Maharashtra	Pune	02.x.2005	Malshej Ghat
4.	Karnataka	Kodagu, Uttar Kannada, Dakshin Kannada, Belgaum, Mumbai, Chikmagalure, Shimoga, Kodagu	16.ix.2002 17.xi.2002 21–28.iii.2003 10.vi.2003 25.ix.2003 13–25.xi.2003 16–31.vii.2004 29.viii.2004 28.xi.2004 14–16.x.2005	Medikeri, Ganeshgudi, Jog Falls, Kulgi, Gundya, Shettihalli WS, Nisergdhama, Baghamandala, Forest Rest House, Gundya, Forest Rest House, Khanapur, Forest Rest House, Londa, Malshej Ghat, Kallathy Falls
5.	Tamil Nadu	Nilgiris	29.ix.2003 30.viii.2015	Gudalur, Dodabetta
6.	Kerala	Thiruvananthapuram, Idukki, Palakkad, Pathanamthitta, Palakka	07.x.2003 04–20.ix.2004 28.viii.2015	Vallakadavu, Agli, Forest House, Wadaserikera, Mukkali and Forest Rest House, Wadaserikera,
Total	06	19	18	29

Table 2. The number of families, subfamilies, genera, and number of species recorded during the study from the Western Ghats of India.

	Family	Subfamily	Genera	No of species
1.	Gelechiidae	Gelechiinae	*Stegasta* Meyrick	01
			Anarsia Zeller	02
			Hypatima Hübner	01
		Dichomeridinae	*Helcystogramma* Zeller	01
2.	Lecithoceridae	Lecithocerinae	*Lecithocera* Herrich-Schäffer	02
		Torodorinae	*Hygroplasta* Meyrick	01
			Torodora Meyrick	01
3.	Oecophoridae	Autostichinae	*Apethistis* Meyrick	01
		Xyloryctinae	*Cophomantella* Fletcher	01
		Stathmopodinae	*Stathmopoda* Herrich-Schäffer	01
		Oecophorinae	*Tonica* Walker	01
4.	Ethmiidae		*Ethmia* Hübner	02
5.	Scythridae		*Eretmocera* Zeller	01
	05	08	13	16

long setosed lobe basally, the latter rounded apically, aedeagus with vesica armed with a long cornutus, the latter horn-like (Rose & Pathania 2004).

Material examined: Reg. no. GEL/1-10, India, Kerala: Dist. Thiruvananthapuram, FRH, Vithura, 120m, 04.ix.2004, 01 male; Dist. Idukki, Vallakadavu, 780m, 10.ix.2004, 02 males; 12.ix.2004, 01 male; 28.viii.2015, 01 male; Karnataka:Dist. Kodagu, Medikeri, 1100m, 25.ix.2003, 01 male; Dist. Uttar Kannada, Ganeshgudi, 780m, 21.vii.2004, 02 males; Dist. Uttar Kannada, Jog Falls, 480m, 24.vii.2004, 01 male; Dist. Uttar Kannada, Kulgi, 360m, 17.vii.2004, 01 male, coll. A. Katewa and P.C. Pathania.

Distribution: India: Punjab, Uttaranchal, Jammu & Kashmir (Rose & Pathania 2004); Kerala, Karnataka (In the present study). Elsewhere. Brazil, Obidos, Santarem, Parintins, Manaos (Clarke 1969).

Genitalia: Uncus small, bifid, valvae symmetrical, elongate, broader at base and apically, costal margin slightly concave near cucullus, with a long setose lobe, apically rounded, sacculus margin almost straight, basally slightly convex, with a small spine-like projection directed towards costa at distally near cucullus, apex broader, about 3/4th length of the genitalia, with one long lobe at side, strongly sclerotized, another long spindle shaped at middle, strongly sclerotized, coecum small and broader; cornutus long, horn-like in vesica (Rose & Pathania 2004).

Remarks: Fifteen species of this genus is reported on world basis are represented in the Neotrotropical and Australian regions without any species from the Palaearctic region (Park & Omelko 1994). Two species, i.e., *Stegasta basquella* Chambers and *S. capitella* Fabricius have been known from northwestern India (Gaede 1937). Rose & Pathania (2004) have also studied this species from northern India, yet the collection and reporting of the species, from the areas under reference is a new record from Western Ghats.

II. Anarsia Zeller

Anarsia Zeller, 1839, *Isis, Leipzing*: 190.

Ananarsia Amsel, 1959, *Stuttg. Beitr Naturk*. 28 . 32. Type-species: *Anarsia lineatella* Zeller, 1839. Isis, Leipzing,: 190.

Type-species: *Tinea spartiella* Schrank, 1802, *Fauna Boica*, 2 (2): 104, by subsequent designation: Meyrick, 1925, *In Wytsman, Genera Insect.*, 184: 153.

Diagnosis: Rose & Pathania (2003c).

2. *Anarsia patulella* (Walker) (Image 2B)

Gelechia patulella Wallker, 1864, *List Specimens lepid. Insects Colln Br. Mus*., 29, p. 635; Walsingham, 1887, *in Moore, Lepid. Ceylon*, 3, p. 510 (Gelechia); Meyrick, 1913, *J. Bombay nat. Hist. Sac,* 22, p. 168, (Anarsia), Meyrick, 1925, in Wytsman, Genera Insect. 184, p 153, nr 17; Caradja & Meyrick,1935, *Microlep. Kiangsu*, p. 69.

Description: Forewing with cresent shaped spots on costa or black streak on upper surface of wing, hindwing with veins M3 and CuA1 connate from posterior angle of discal cell, male genitalia with uncus triangular or hook-like, tegumen not as above, left valva without hook-like process (Rose & Pathania 2003c).

Material examined: Reg. no. GEL/11-20, India, Karnataka: Dist. Belgaum, FRH, Khanapur, 370m, 21.iii.2003. 01 male; Dist. Kodagu, Medikeri, 1100m, 16.xi.2002, 01 male; Dist. Uttar Kannada, Ganeshgudi, 480m, 13.xi.2003, 02 males, 22.vii.2004c 01 male, 16.x.2005, 01 male; Dist. Dakshin Kannada, Gundya, 40m, 28.vii.2004, 01 male, Dist. Shimoga, Shettihalli WLS, 320m, 10.vi.2003, 01 male; Dist. Kodagu, Nisergdhama, 1080m, 17.xi.2002, 01 male; Gujarat: Dist. The Dangs, Ahwa, 520m, 29.ix.2005, 01 male, coll. A. Katewa.

Distribution: India: Uttaranchal (Rose & Pathania 2003c); Gujarat, Karnataka (In the present study). Elsewhere. Sri Lanka, Thailand, Taiwan, Australia (Park & Ponomarenko 1996).

Genitalia: Male genitalia with each valva subtrapazoidal, cucullus margin spiny apically, left valva with sacculus beset with a spine (Rose & Pathania 2003c).

Remarks: While reporting *Anarsia patulella* (Walker) as a new record from Taiwan, Park (1995) has mentioned that this species occurs almost throughout the Oriental region, including the southern part of China. He observed that the valvae in the male genitalia show certain variations but no such variation has been recorded in the presently dissected specimens. The species is recorded for the first time and is common in Karnataka and Gujarat of the Western Ghats as evident on the basis of present surveys.

3. *Anarsia reciproca* Meyrick (Image 2C)

Anarsia reciproca Meyrick, 1920, *Exot. Microlepid*., 2: 300c

Description: Forewing with small four-six black streak from base to apex in between discal cell, termen with cilia grey and black with white apices, hindwing light grey scaled, somewhat quadrate (Rose & Pathania 2003c).

Material examined: Reg. no. GEL/21-29, India, Karnataka: Dist. Kodagu, Baghamandala, 900m, 25.xi.2003, 02 males; Dist. Uttar Kannada, Ganeshgudi, 480m, 13.xi.2003, 1 male, 16.x.2005, 01 male; Gujarat: Dist. The Dangs, Saputara, 970m, 30.ix.2005, 04 males; Dist. The Dangs, Ahwa, 520m, 29.ix.2005, 01 male, coll. A. Katewa.

Distribution: India: Madras, Coimbatore (Clarke 1969), Uttaranchal, Himachal Pradesh (Rose & Pathania 2003c); Gujarat, Karnataka (In the present study).

Genitalia: Male genitalia with uncus hook like, socii beset with small hair, directed slightly posteriorly, tegumen uniformly broader throughout, valva with costa convex basally, strongly concave at middle, bearing a small, sclerotized, sparsely setosed lobe at base of costa, aedeagus gradually curved (Rose & Pathania 2003c).

Remarks: This species is earlier known from Coimbatore (Tamil Nadu) in the Western Ghats (Clarke 1969). However, its collection from states of Karnataka and Gujarat becomes new and additional record. Nine males of this species from the aforesaid localities were dissected in order to confirm their conspecificity.

III. Hypatima Hübner

*Hypatim*a Hübner, [1825]. Verz. bekannter Schmett., 415.

Al1ocota Meyrick, 1904, *Proc. Linn. Soc. N. S. W*, 29: 258. Type-Species: *Allocota simulacrella* Meyrick, 1904, *Proc. Linn. Soc N. S. W,* 29: 420.

Allocotaniana Stand, 1913, *Arch. Nat*., 79(42): 43. Type-species: *Allocota simulacrella* Meyrick, 1904, *Proc. Linn. Soc. N.S. W*, 29: 420.

Chelaria Haworth, 1828, *Lepid. Br*: 526. Type-species. *Chelaria conscripta* Haworth, 1828, *Lepid. Br.,*: 526.

Cymatomorpha Meyrick, 1904, *Proc. Linn. Soc.N.S.W.,* 29: 258. Type-species: *Cymatromorpha* euplecta Meyrick, 1904, *Proc Linn. Soc. N. S W,* 29: 57 (key) 411.

Episacta Turner, 1919, Proc. R. Soc. Qd., 31: 161. Type-species: *Chelaria discissa* Meyrick, 1916, *Exot. Microlepid*., 1: 581.

Semodictis Meyrick, 1909, *Ann. Trans. Mus*., 2: 16. Type-species: *Semodictis tetraptial* Meyrick, 1909, *Ann. Transv. Mus*., 2: 16.

Type-species: *Tinea conscriptella* Hübner, 1805, *Samml, eur. Schmett.,* 8: pl.41. fig.283 by sebsequent desigantion by Walsingham & Durrat, 1909, *Entomologists mono Mag*., 45: 48.

4. *Hypatima tephroptila* (Meyrick) (Image 2D)

Chelaria tephroptila Meyrick, 1931, *Exot. Micro*

Description: Forewing black towards costa at 1/4th to 3/4th, hindwing without bunch of long hair pencil distally on anal margin, veins M2 and M3 free on the forewing (Pathania & Rose 2003).

Material examined: Reg. no. GEL/30-32, India, Karnataka: Dist. Dakshin Kanna FRH, Gundya, 40m, 28.xi.2004, 03 males, coll. A. Katewa.

Distribution: India: Bombay, Mahableshwar (Clarke 1969), Uttaranchal (Pathania & Rose 2003); Karnataka (In the present study).

Genitalia: Male genitalia with costa strongly convex near cucullus, cucullus foot-shaped, female genitalia with ductus bursae small, broad near corpus bursae, signum large (Pathania & Rose 2003).

Remarks: The species is recorded for the first time

from the Karnataka.

Subfamily Dichomeridinae

Dichomeridinae Hampson, 1918, *Novit. zool.,* 25: 386.

Type-genus: *Dichomeris* Hübner, 1818, *Zutr Samml exot. Schmett*., 1: 25.

IV. Helcystogramma Zeller

Helcystogramma Zeller, 1877, *Horae Soc. ent. ross*., 13: 369.

Ceratophora Heinemann, 1870, *Schmett. Otl. Schweiz*, (2)(1): 325. Type-species: *Recurvaria rufescens* Haworth, 1828, *Lepid. Br*, 555.

Teuchophanes Meyrick, 1914, *Trans. ent. Soc. Lond*, .274. Type-species: *T leucopleura* Meyrick, 1914, *Trans ent. Soc. Lond*, 274

Psamathoscopa Meyrick, 1937, *Exot. Microlepid*. 5. 96. Type-species: *Onebala simplex* Walsingham, 1900, *Bull. Lpool. Mus*, 3 . 2

Anathyrsotis Meyrick, 1939, *Trans. R. ent. Soc. Lond*, 89: 55. Type-species: *A ceriochranta* Meyrick, 1939, *Trans R. ent. Soc. Lond*., 89: 55.

Type-species: *Gelechia (Helcystogramma) obseratella* Zeller, 1877, *Horae Soc. ent. ross.,* 13: 371, pI. 5, fig. 127, by susequent designation: Meyrick, 191O, *Entomologist's mon. Mag*., 46 282.

Diagnosis: Rose & Pathania 2003.

5. *Helcystogramma hibisci* (Stainton) (Image 2E)

Gelechia (?) hibisci Stainton, 1859*. Trans. ent. Soc. Land*., (2)5, p. 117.

Onebala Hibisci: Meyrick, 1925. *in Wytsman, Genera Insect,* p. 138; Gaede, 1937 *Lepid. Cat.* p.377. *Gelechia (Helcystogramma) obseratella* zeller, 1877, *Horae Soc. ent Ross,* 13, p. 371 *Croesophora eudela* Turner, 1919, *Proc. Roy. Soc. Queensland*, 31, p. 160.

Description: Forewing with anal margin with a dark semicircular bloach on medially, extending more than half distance across wing, a similar mark beyond cell, a broad preapical pale fascia extending from 2/3rd length of anterior margin to tornus, a small black spot on cell distally, hindwing with vein M2 relatively arched (Rose & Pathania 2003).

Material examined: Reg. no. GEL/33-34, India, Maharashtra: Dist. Pune, Malshej Ghat, 690m, 02.x.2005, 01 male; Gujarat: Dist. The Dangs, FRH, Ahwa, 520m, 29.ix.2005, 01 male, coll. A. Katewa.

Distribution: India: Calcutta, Himachal Pradesh, Uttaranchal, Punjab (Rose & Pathania 2003d); Gujarat, Maharashtra (In the present study). Elsewhere. South China, Taiwan, Sri Lanka, Java, Australia (Park & Hodges 1995).

Genitalia: Male genitalia with aedeagus broad and long (Rose & Pathania 2003d).

Remarks: The genus *Helcystogramma* is represented by more than eighty species in the Oriental, the Neotropical and the Palaearctic regions (Park & Hodges 1995) and eight species from India (Gaede 1937). The species *H. hibisci* (Stainton) is being reported for the first time from the Western Ghats.

Family Lecithoceridae

Lecithoceridae Le Marchand, 1947, *Revue. fr. Lepidopt.,* 11: 153 (as Lecithocerinae).

Type-genus: *Lecithocera* Herrich-Schäffer, 1853, *Syst. Bearb. Schmett. Eur*. 5: 11 (Key) 45.

Subfamily Lecithocerinae

Leithocerinae Le Marchand, 1947, *Revue. Fr. Lepidopt*., 11: 153.

Timyridae Clarke, 1953, *Cat., Type Specimens Microlepid. BMNH described by E. Myerick*, 1: 21. Type-genus: *Timyra* Walker, 1864, *List. Dprvimrnd Lepid. Insects. Colln. Br. Mus.*, 29: 782.

V. Lecithocera Herrich-Schäffer

Herrich-Schäffer, 1853, *Syst. Bearb. Schmett. Eur.,* 5: 11 [key], 45, pI. *Microlepid*. XII. figs 10, 11.

Quassitagma Gozmany, 1978, *in Amsel. et al. Microlepid. Palaearctica*, 5: 132 Type species: *Frisilia indigens* Meyrick, 1914, *Supplta ent,* 3: 50.

Recontracta Gozmany, 1978, *in Amsel et al., Microlepid. Palaearctica*, 5: 148. Type species: *Recontracta frisilina* Gozmany, 1978, *ibidem,* 5: 149.

Nyctocyrma Gozmany, 1978, *in Amsel et al., Microlepid. Palaearctica*, 5: 149. Type species. *Nyctocyrma fraudatrix* Gozmany, 1978, *ibidem*., 5: 151.

Psammoris Meyrick, 1906, *J. Bombay nat. Hlst. Soc,* 17: 149. Type species: *Psammoris carpaea* Meyrick, 1906, *ibidem*., 17' 149.

Type-species: *Carcina luticornella* Zeller, 1839, *Isis, Leipzing*,: 197, by monotypy.

Diagnosis: Pathania & Rose (2004b).

6. *Lecithocera immoblis* Meyrick (Image 2F)

Lecithocera immoblis Meyrick, 1918, *Exot. Microlepid*., 2: 103.

Description: Forwing with veins R3 free, R4+R5 stalked, Forewing with vein R3 from before anterior angle of discal cell, alar expanse 16-17mm; juxta almost excurved anteriorly (Pathania & Rose 2004b).

Material examined: Reg. no. GEL/35-38, India,

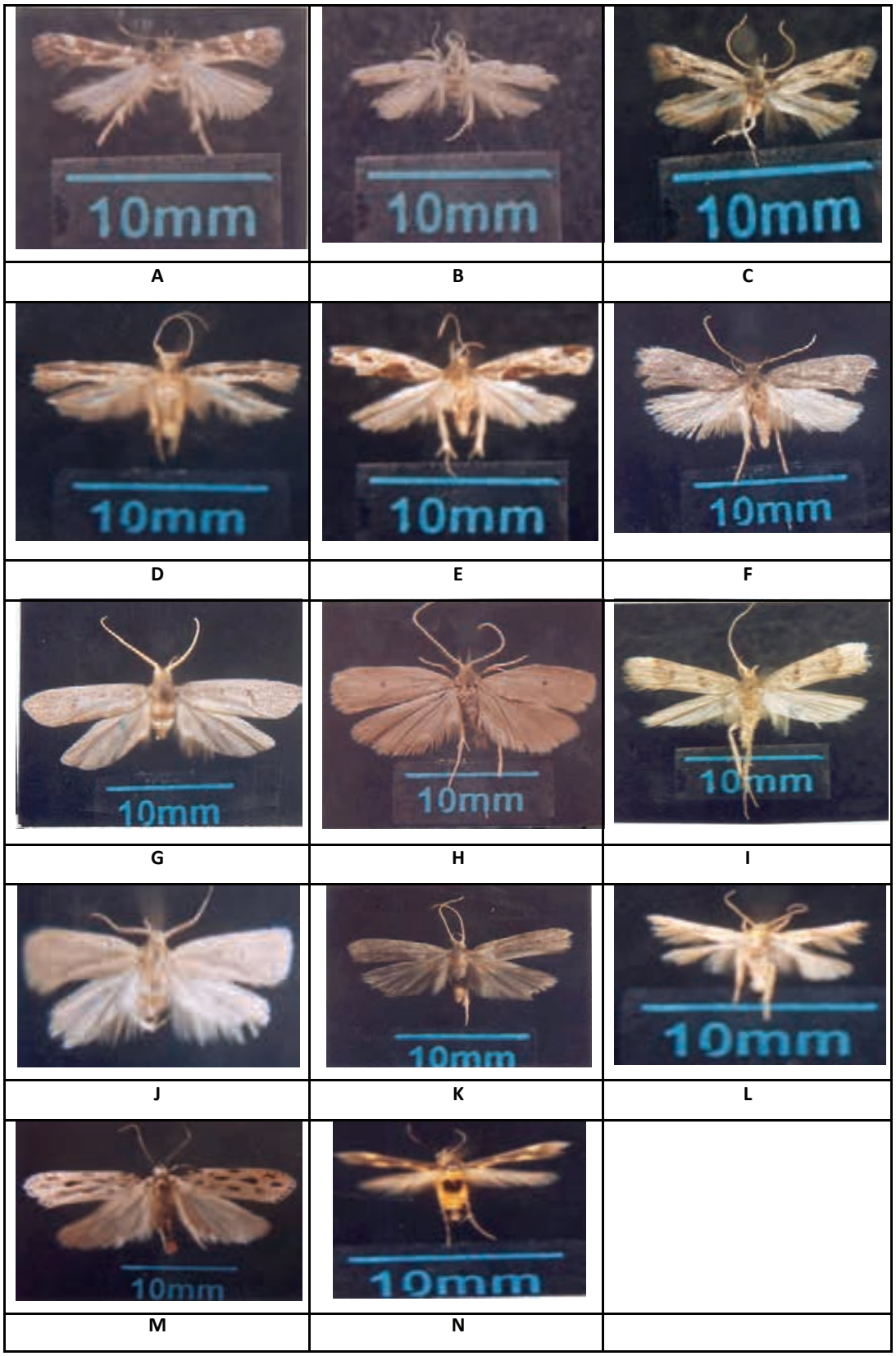

Image 2. A—*Stegasta comissata* Meyrick | B—*Anarsia patulella* (Walker) | C—*Anarsia reciproca* Meyrick | D—*Hypatima tephroptila* (Meyrick) | E—*Helcystogramma hibisci* (Stainton) | F—*Lecithocera immoblis* Meyrick | G—*Lecithocera choritis* Meyrick | H—*Hygroplasta lygaea* (Meyrick) | I—*Torodora fortis* (Meyrick) | J—*Apethistis metoeca* Meyrick | K—*Cophomantella lysimopa* (Meyrick) | L—*Stathmopoda balanarcha* Meyrick | M—*Ethmia pagiopa* Meyrick | N—*Eretmocera impectella* (Walker). © Amit Katewa & Prakash Chand Pathania.

Karnataka: Dist. Kodagu, Medikeri, 1100 m, 16.xi.2002, 01 male, 25.ix.2003, 01 male; Dist. Uttar Kannada, Kulgi, 360 m, 16.vii.2004, 01 male; Tamil Nadu: Dist. Nilgiris, Gudalur, 900 m, 29.ix.2003, 01 male, coll. A. Katewa.

Distribution: India: Coimbatore (Clarke 1965), Punjab, Himachal Pradesh, Uttaranchal (Pathania & Rose 2004b); Karnataka, Tamil Nadu (In the present study).

Genitalia: Each valva more or less rectangular, aedeagus with one of the walls fringed with conspicuous hair (Pathania & Rose 2004b).

Remarks: The species *immoblis* Meyrick is being reported from Karnataka in the Western Ghats for the first time.

7. *Lecithocera choritis* Meyrick (Image 2G)

Lecithocera choritis Meyrick, 1910, *J.Bombay nat. Hist. Soc.,* 20: 448.

Description: Alar expanse 21-24mm, forewing light fuscous in colour; hindwing with vein CuP represented near anal margin (Pathania & Rose 2004b).

Material examined: Reg. no. GEL/39-52, India, Kerala: Dist. Idukki, Vallakadavu, 780m, 10.ix.2004, 03 males; Karnataka: Dist. Kodagu, Medikeri, 1100m, 29.vii.2004, 01 male; Dist. Kodagu, Baghamandala, 900m, 31.vii.2004, 01 male; Dist. Uttar Kannada, Ganeshgudi, 480m, 20.vii.2004, 03 males, 21.vii.2004, 04 males; Dist. Uttar Kannada, Jog Falls, 480m, 24.vii.2004, 01 male; Dist. Uttar Kannada, Kulgi, 360m, 17.vii.2004, 01 male, coll. A. Katewa.

Distribution: India: Palni Hills, Nilgiri Hills (Meyrick 1910); Himachal Pradesh (Pathania & Rose 2004b); Kerala, Karnataka (In the present study).

Genitalia: Male genitalia with costa convex at base, then slightly concave, vesica with tear shaped or one Y-shaped cornuti present in aedeagus (Pathania & Rose 2004b).

Remarks: The species *choritis* Meyrick is being reported from Kerala and Karnataka in the Western Ghats for the first time.

Subfamily Torodorinae

Torodorinae Gozmany, 1978, *in Amsel et. al., Microlepid. Palaearctica*, 5: 189.

Type-genus: *Torodora* Meyrick, 1894, *Trans. ent. Soc. Land.*: 16.

VI. Hygroplasta Meyrick

Hygroplasta Meyrick, 1925, *in Wytsman, Genera Insect.,* 184: 5 [key], 244.

Type-species: *Gelechia spoliatella* Walker, 1864, *List Specimens lepid. Insects Colin Br. Mus.,* 29: 659.

8. *Hygroplasta lygaea* (Meyrick) (Image 2H)

Pachnistis lygaea Meyrick, 1911. *Journ. Bombay Nat. Hist. Soc*. 20: 707.

Description: Dorsal surface of forewing with discocellular spot relatively more prominent, discal cell with spot prominent, male genitalia with valvae small, saccus long or small, aedeagus relatively long or small (Pathania & Rose, 2004a).

Material examined: Reg. no. GEL/53-56, India, Karnataka: Dist. Uttar Kannada, Ganeshgudi, 480m, 14.x.2005, 01 male, 16.x.2005, 01 male; Dist. Kodagu, Nisergdhama, 1080m, 17.xi.2002, 01 male; Dist. Uttar Kannada, Kulgi, 360m, 17.vii.2004, 01 male, coll. A. Katewa.

Distribution: Dalhousie, Kashmir (Meyrick 1910); Himachal Pradesh, Uttaranchal (Pathania & Rose 2004a); Karnataka (In the present study).

Genitalia: Male genitalia with saccus relatively smaller, broader distally, sacculus margin concave medially, costa concave medially, aedeagus short, vesica with cornutus, female genitalia with ductus bursae open near middle of corpus bursae, signum spinde-shaped (Pathania & Rose 2004a).

Remarks: Meyrick (1925) and Fletcher (1929) considered the genus *Hygroplasta* in the family Gelechiidae but Clarke (1965) has transferred the same to the family Lecithoceridae, the arrangement being followed for the presently collected material, identified as *Hygroplasta lygaea* (Meyrick) (Pathania & Rose 2004a). The said species is being reported for the first time from the Western Ghats.

VII. *Torodora* Meyrick

Torodora Meyrick, 1894, *Trans. ent. Soc. Land*.,: 16.

Habrogenes Meyrick 1918, Ex at. Microlepid., 2: 102. Type species: *Lecithocera eupatris* Meyrick, 1910, *J. Bombay nat. Hist. Soc*., 20: 443.

Brachmia Hübner (1825) 1816, *Vertz. bekannter. Schmett*.: 419. Type species: *Tinea dimidiella* [Dennis & Schiffermular], 1775 *Ankundung syst. Werks Schmett. Wienergegend*:141

Panplatyceros Diakonoff, 1951, *Ark. Zool*, 3: 76. Type specis: *Panplatyceros serpentina* Diakonoff, 1951, Ark. Zool. 3: 76.

Type-species: *Torodora characteris* Meyrick, 1894, T*rans. ent. Soc. Land.,* 16. Clarke, 1955, *Cat. Type Specimens Microlepid. BMNH described by. E. Meyrick*, 1: 21.

Diagnosis: Rose & Pathania (2003b).

9. *Torodora fortis* (Meyrick) (Image 2I)

Lecithocera fortis Meyrick, 1918, *Exot. Microlepid*., 2: 111.

Description: Forewing with black streaks or black dots; Forewing with veins M2 and M3 connate, veins CuA1 and CuA2 short stalked; male genitalia with each valva somewhat elongated, parallel sided, Alar expanse 18mm; forewing costal margin with two, thin, black equal sized lines vertically present (Rose & Pathania 2003b).

Material examined: Reg. no. GEL/57-59, India, Kerala: Dist. Palakkad, Agli, 520m, 07.x.2003, 01 male; Karnataka: Dist. Uttar Kannada, Ganeshgudi, 480m, 21.vii.2004, 01 male; Gujarat: Dist. The Dangs, Waghai, 180m, 28.ix.2005, 01 male, coll. A. Katewa.

Distribution: India: Nilgiri Hills (Clarke 1965); North Western Shivaliks, Himachal Pradesh (Rose & Pathania 2003b); Gujarat, Kerala, Karnataka (In the present study).

Genitalia: Male genitalia with each valva with costa curved, gnathos relatively less developed, aedeagus small and narrowed, bent at middle (Rose & Pathania 2003b).

Remarks: Gozmany (1978) erected a new subfamily Torodorinae under the family Lecithoceridae. This genus contains 85 species, out of which 82 pertain to the Oriental, 02 to Palaearctic and 01 to the Ethopian regions (Park & Heppner 2000). Rose & Pathania (2003b), dealtwith nine species including *Torodora fortis (*Meyrick) from the northwestern Shivaliks. These species have been collected for the first time from Kerala, Karnataka and Gujarat of the Western Ghats.

Family Oecophoridae

Oecophoridae Bruad, 1850, *Mem. Soc. Emul. Doubs*, (1) 3 (5-6): 45 (as Aecophoridae).

Type-genu: *Oecophora* Latreille, [1796], *Precis Caracteres generiques insets,*: 146.

SUBFAMILY AUTOSTICHINAE

Autostichinae Le Marchand, 1947, *Revue fr. Lepidopt*., 11: 153.

Type-genus: *Autosticha* Meyrick, 1886, *Trans. ent. Soc. Land.,* 1886: 281.

VIII. *Apethistis* Meyrick

Apethistis Meyrick, 1908, *J. Bombay nat. Hist. Soc.,* 18: 459.

Type-species: *Apethistis metoeca* Meyrick, 1908, *ibidem*., 18: 460, by original designation.

Diagnosis: Rose & Pathania (2003a).

10. *Apethistis metoeca* Meyrick (Image 2J)

Apethistis metoeca Meyrick, 1908, *J. Bombay nat. Hist. Soc.,* 18: 460

Description: Forewing with vein Sc ending at 2/3rd of costa, vein R4 to costa near apex, hindwing with CuP vestigial, visible near anal margin only (Rose & Pathania 2003a).

Material examined: Reg. no. OECO/1-3, India, Tamil Nadu: Dist. Nilgiris, Dodabetta, 2640m, 01.x. 2003, 01 male; Gujarat: Dist. The Dangs, Ahwa, 520m, 29.ix.2005, 02 males, coll. A. Katewa.

Distribution: India: Punjab, Jammu & Kashmir (Rose & Pathania 2003a); Gujarat, Tamil Nadu (In the present study). Elsewhere. Sri Lanka (Maskeliya) (Clarke 1969),

Genitalia: Male genitalia with valvae small and broad, aedeagus slightly curved near apex, basally bulbous; female genitalia with relatively larger ostium bursae (Rose & Pathania 2003a).

Remarks: Meyrick (1908) proposed the genus *Apethistis* from Ceylon (Sri Lanka) in the family Gelechiidae. It is transferred to the family Oecophoridae (Hodges, 1978). The genus is represented by fourteen species from India (Gaede 1937; Clarke 1965), out of which two, viz., *metoeca* and *insulsa* Meyrick have studied from the northwestern Shivaliks by Rose & Pathania (2003a). The former species is a new record from the Western Ghats.

Subfamily Xyloryctinae

Xyloryctinae Meyrick, 1890, *Trans. R. Soc. S. Aust*., 13: 23 (as Xyloryctidae).

Type-genus: *Xylorycta* Meyrick. 1890, *Trans R Soc. S Aust*., 13: 25 (key), 57.

IX. *Cophomantella* Fletcher

Cophomantella Fletcher, 194O, *Entomologist's Rec. J. Var*., 52: 17.

Type-species: *Onebala elaphopis* Meyrick, 1910, *J. Bombay nat. Hist. Soc*., 20: 459, by original designation (for *Cophomantis* Meyrick, 1925).

11. *Cophomantella lysimopa* (Meyrick) (Image 2K)

Cophomantis lysimopa Meyrick, 1933, *Exot. Microlepid.* 4: 357.

Description: Forewing with vein R1 originating from much beyond middle of discal cell, hindwing with discal cell closed by arched discocellulars (Rose & Pathania 2003a).

Material examined: Reg. no. OECO/4-13, India, Goa: Dist. Sanguem, FRH, Keri, 90m, 25.ii.2004, 1 male; Dist. Ponda, Ponda, 85m, 28.ii.2004, 03 males; Kerala: Dist. Pathanamthitta, FRH, Wadaserikera, 30m, 07.ix.2004, 01

male; Dist. Thiruvananthapuram, FRH, Vithura, 120m, 04.ix.2004, 01 male, 05.ix.2004, 02 males; Dist. Idukki, Vallakadavu, 780m, 12.ix.2004, 01 male; Dist. Palakka, Mukkali, 560m, 19.ix.2004, 01 male, coll. A. Katewa.

Distribution: India: Bombay, Mahabaleshwar (Clarke 1965); Himachal Pradesh (Rose & Pathania 2003a); Goa, Kerala (In the present study).

Genitalia: Male genitalia with aedeagus small and broad, apex pointed, vesica lacking cornutus, coecum absent, juxta well developed, long, apically pointedmale genitalia with aedeagus not as above (Rose & Pathania 2003a).

Remarks: The species has been reported for the first time from Goa and Kerala of Western Ghats.

Subfamily Stathmopodinae

Stathmopodinae Janse, 1917, *Check-List S. Afr. Lepid. Heterocera*: 190 (as Stathmopodidae).

Types-genus: *Stathmopoda* Harrich-Schäffer, 1853, *Syst. Bearbeitung Schmett. Eur.,* 5: (14) key, 54; 1894, *ibidem*, 6: *Microlepid*; pl. 9 figs. 17-22, included in Fletcher 1929 within the Schreckensteiniidae.

X. *Stathmopoda* Herrich-Schäffer

Stathmopoda Herrich-Schäffer, 1853, *Syst. Bearbeitung Schmett. Eur*., 5: 14 (key), 54; 1849, *ibidem*, 6: *Microlepid.* pl. 9 figs. 17-22.

Type-species: *Phalaena pedella* Linnaeus, 1761, *Fauna Suecica (Edn 2)*: 367, by subsequent designation by Meyrick, 1914, *in Wytsman, Genera Insect*., 165: 10.

Diagnosis: Pathania et al. (2009).

12. *Stathmopoda balanarcha* Meyrick (Image 2L)

Stathmopoda balanarcha Meyrick,1916-1923, *Exot. Microlepid.,* 2: 461.

Description: Forewing with Sc ending at middle of costa, forewing elongate, basal half yellowish, distal half light fuscous scaled, black irregular spot near base of costa, costa slightly convex at base then straight (Pathania et al. 2009).

Material examined: Reg. no. OECO/14-20, India, Karnataka: Dist. Belgaum, FRH, Londa, 420m, 24.iii.2003, 01 male, 26.iii.2003, 02 males, 28.iii.2003, 03 males; Maharashtra: Dist. Mumbai, Malshej Ghat, 690m, 02.x.2005, 01 male, coll. A. Katewa.

Distribution: India: Assam, Shillong (Meyrick 1916, 1923); Punjab (Pathania et al. 2009).

Genitalia: Male genitalia with sacculus pointed apically, cucullus convex ventro-distally, aedeagus long and narrowed, apex pointed, vesica with a rod-like broad cornutus, female genitalia with corpus bursae ovate in shape, ductus seminalis open in corpus bursae near ductus bursae (Pathania et al. 2009).

Remarks: The species *S. balanarcha* Meyrick completely conform to the characterization of the genus (Pathania et al. 2009) and is a first record from the Western Ghats.

Subfamily Oecophorinae

Oecophorinae Bruand, 1850, *Mem. Soc. Emul. Doubs* (1) 3 (5-6): 45 (as Oecophoridae)

Type-genus: *Oecophora* Latreille (1796), *Precis Caracteres generiques Insectes*: 146.

XI. *TONICA* WALKER

Tonica Walker, 1864, *List Specimens lepid. Insects Colln. Br. Mus*. 29: 788.

Type-species: *Tonica terasella* Walker, 1864, *ibidem*, 29: 788, by monotypy.

13. *Tonica niviferana* (Walker) (Image 3)

Binsitta niviferana Walker, 1864, *List Specimens Lepid. Insects Colin Br. Mus*., 29: 832.

Tonica niviferana Meyrick, 1905, *Journ. Bombay Nat. Hist.Soc*. XX-167.

Description: Forewing with a black spot near base, one black scales streak and a small triangular spot present near middle of costa, vein Sc join by a bar at 3/4th with discal cell, CuP visible at anal margin (Pathania et al. 2006)

Material examined: Reg. no. OECO/21-23, India, Kerala: Dist. Pathanamthitta, FRH, Wadaserikera, 30m, 07.ix.2004, 01 female; Dist. Thiruvananthapuram, FRH, Vithura, 120m, 04.ix.2004, 01 female; Dist. Palakkad, Mukkali, 560m, 19.ix.2004, 01 female, coll. A. Katewa.

Distribution: India: Sikkim, Darjeeling, Khasi Hills (Meyrick 1910); Dehradun, Pusa (Roonwal et. al. 1964) and Kangra (Srivastava et al. 2005; Pathania et al. 2006).

Genitalia: Male genitalia with gnathos small, sacculus with pointed apex exceeding beyond each valva, coecum absent (Srivastava et al. 2005).

Larval host plant: *Bombax malabaricum* (Fletcher 1921).

Remarks: Srivastava et al. (2005) have studied the species on the basis of the male individuals collected from Kangra in western Himalaya. *Tonica niviferana* (Walker) is being reported for the first time from the Western Ghats.

Family: Ethmiidae

Ethmiidae Busck, 1909, *Proc. ent. Soc. Wash*., 11: 91.

Type-genus: *Ethmia* Hübner (1819) 1816, *Verz. bekannter Schmett*.,: 163.

XII. *Ethmia* Hübner

Ethmia Hübner [1819] 1816, *Verz. bekannter Schmett.,* 11: 163.

Type-species: *Ethmia pyrausta* Pallas (1771) *Reise Rus.Reich*. 1: 472.

Diagnosis: Pathania et al. (2006a).

14. *Ethmia hilarella* Walker (Image 4)

Ethmia hilarella Walker, 1863. *Cat. Lep. Het. B.M.* 28: 542.

Description: Vertex covered with silver grey scales, black scales at middle basally, labial palpus small, recurved, second segment long, without brush of elongate scales, black and silver grey, third segment small, acute, black and silver grey, antenna long, filiform, basally silver grey then fuscous, longer than three-fourth length of forewing, thorax silver grey with black spots, forewing silver grey scaled, elongate, three black spot at base, four row of black spot oblique, first near base of costa with three black spots, second at middle with two black spot, third at two-third from base with three spots, fourth near apex with three sports, one black spots near anal margin distally and a row of black spots on the termen, costa slightly arched, apex subacute, termen slightly convex, tornus convex, anal margin convex, termen with cilia silver grey in colour, hindwing yellow with black margin at apex,prothoracic and mesothoracic legs silver grey and black in colour, metathoracic leg yellow, hind tibia with long, hair like erect scales on the dorsal surface.

Material examined: Reg. no. ETHM/1-9, India, Karnataka: Dist. Kodagu, Baghamandala, 900m, 25.xi.2003, 02 males, 05 females; Dist. Uttar Kannada, Ganeshgudi, 480m, 13.xi.2003, 01 female; Dist. Chikmagalure, Kallathy Falls, 960m, 26.vii.2004, 01 male, coll. A. Katewa.

Distribution: India: Southern India. Elsewhere. Sri Lanka, Taiwan (Domingo et al. 2003).

Genitalia: Male genitalia with uncus long, bifurcate in shape, apex pointed, moderately sclerotised; socii absent; gnathos long, shield-like, broader at base, distally with small teeth-like structure; tegumen long and broad, broader at base, apically narrowed; two long setose lobe of labis present; vinculum ring-like, broad; saccus absent; juxta U-shaped broad; valvae symmetrical, long, broad, costal margin slightly convex, distinct, almost half the length of valva, heavily sclerotized, sacculus margin convex, cucullus with densely hair on the inner surface, margin obtuse, strongly concave distally, convex dorso-distally; aedeagus small, about two-third length of valvae, pistol-like, ankylosed, apex pointed, broader basally, coecum small, rounded; vesica lacking cornutus. Female genitalia with corpus bursae sac-like, weakly sclerotized; a slit-like signum present; ductus bursae very long, coiled, weakly sclerotized; anterior apophyses small; posterior apophyses long, tip swollen; papilla analis elongated, setosed with long and short setae.

Remarks: The species *hilarella* can be easily identified by the spots present on forewing and the black apical spot of hindwing. The male and female genitalia of this species is being described for the first time, besides being reported for the first time from area under reference.

15. *Ethmia pagiopa* Meyrick (Image 2M)

Ethmia pagiopa Meyrick, 1918, *Exot. Microlepid*., 2: 189.

Description: Forewing with black rounded or irregular spots on the upper surface, forewing with veins CuA1 and CuA2 free, hindwing with veins CuA1 and CuA2 connate; male genitlaia with uncus furcate, cucullus part of each valva without such process (Pathania et al. 2006a).

Material Examined: Reg. no. ETHM/10-11, India, Tamil Nadu: Dist. Nilgiris, Dodabetta, 2640m, 01.x.2003, 01 male, coll. A. Katewa & 30.viii.2015, 01 male, coll. P.C. Pathania.

Distribution: India: Kashmir (Meyrick 1916–1923); Himachal Pradesh, Punjab (Pathania et al. 2006a).

Genitalia: Male genitalia with labis represented by two short arms, vinculum U-shaped, cucullus with one lobe, vesica with a cornutus presen (Pathania et al. 2006a).

Remarks: The speciemens collected from the aforesaid locality has been identified as *Ethmia pagiopa* Meyrick from the account published by Pathania et al. (2006a). The reporting of the species from the Western Ghats is a new record from this hot biodiversity spot.

Family Scythridiae

Scythridae Rebel, 1901, *Staudinger & Rebel, Cat. Lepid. palaearct. Faunengeb.,* 2: 179 (as Scythridinae).

Type-genus: *Scythris* Hübner, (1825) 1816, *Vertz. bekannter Schmett*.,: 414.

XIII. *Eretmocera* Zeller

Eretmocera Zeller, 1852, *Lepid. Microptera, quae J.A. Wahlberg in Caffrourum terra collegit*,: 96.

Stantonia Staudinger, 1859, *Ent. Ztg., Stettin*., 20: 250. Type-species: *Staintonia medinella* Staudinger, 1859, ibidem, 20: 250.

Castorura Meyrick, 1887, *Proc. Linn. Soc. N.S.W*. (2) 1: 1047. Type-species: *Castorura chrysias* Meyrick, ibidem,: 1047.

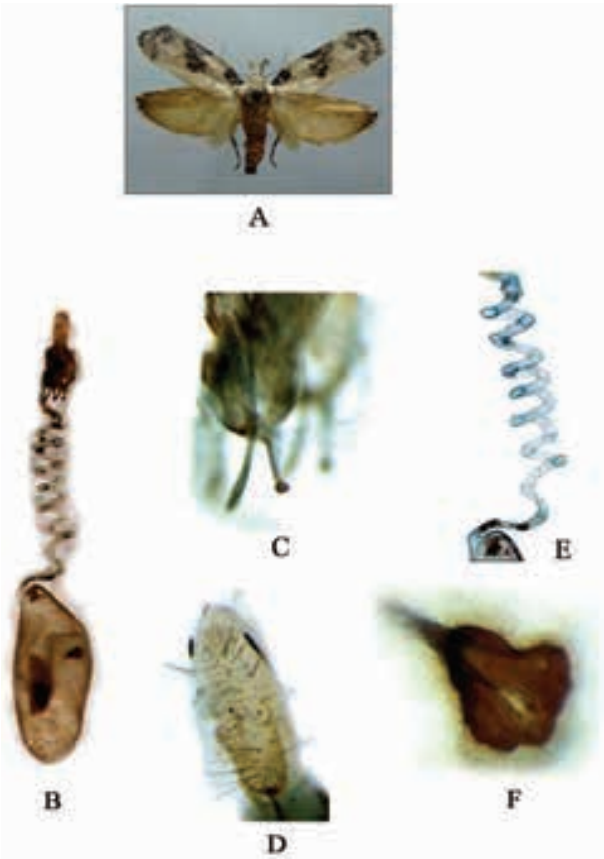

Image 3. *Tonica niviferana* (Walker). A—Adult | B—Female genitalia | C—Ostium bursae | D—Papilae analis | E—Ductus bursae | F—Signum. © Amit Katewa & Prakash Chand Pathania.

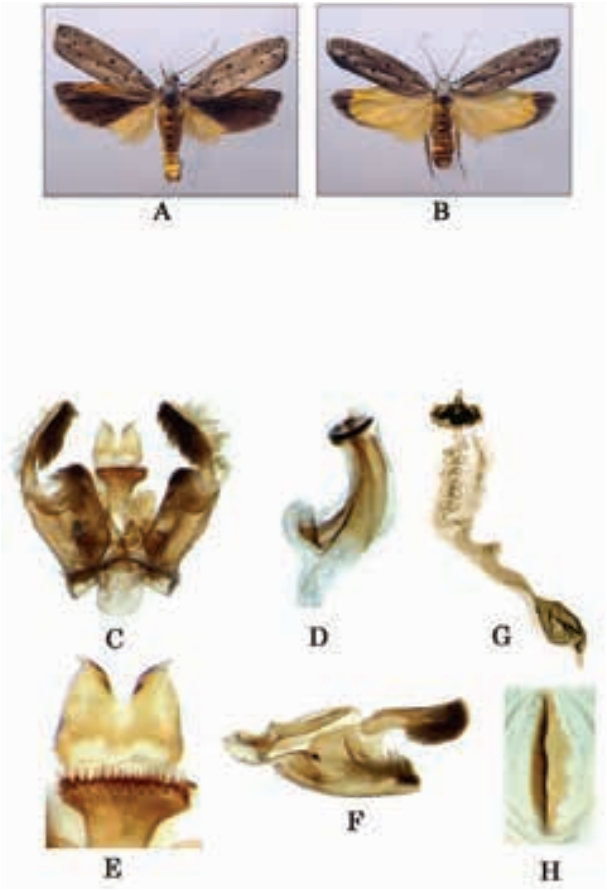

Image 4. *Ethmia hilarella* Walker. A—Adult (male) | B—adult (female) | C—male genitalia (ventral view) | D–E—Aedeagus | F—Valava | G—female genitalia | H—Signum. © Amit Katewa & Prakash Chand Pathania.

Aeraula Meyrick, 1897, *Proc. Linn. Soc. N.S.W*. 22: 298 (key), 369. Type-species: *Aeraula dioctis* Meyrick, 1897, *Proc. Linn. Soc. N.S.W.,* 22: 370.

Type-species: *Eretmocera fuscipennis* Zeller, 1852, *Lepid. Microptera. quae J.A. Wahlberg in Caffrourum terra collegit,:* 97. by subsequent designation by *Walsingham, 1889, Trans. ent. Soc. Lond*.,: 24.

16. *Eretmocera impectella* (Walker) (Image 2N)

Gelechia impectella Walker, 1864, *List Specimens Lepid. Insects Colln. Br. Mus.,* 29: 637.

Description: Forewing with four bright yellow spots, CuP present in distal half only, abdomen with bright yellow and black bands alternatively (Pathania et al. 2009).

Material Examined: Reg. no. SCTH/1-4, India, Kerala: Dist. Pathanamthitta, Wadaserikera, 30m, 07.ix.2004, 02 male; Karnataka: Dist. Uttar Kannada, Ganeshgudi, 480m, 14.x.2005, 01 male, 16.x.2005, 01 male, coll. A. Katewa.

Distribution: India: Bengal, Bihar, Punjab, Dehradun (Roonwal et al. 1964); Uttranchal, Punjab (Pathania et al. 2009).

Genitalia: Male genitalia with socii relatively small, broad, gnathos beak-like, with left arm small, aedeagus short, curved at middle (Pathania et al. 2009).

Remarks: The genus *Eretmocera* Zeller contains forty species and occurs in Afrotropical, Palaearctic, Oriental and the Australian regions, with maximum number of species reported from Africa. According to Landry (1991), "*Eretmocera* includes the most colourful moths of the Scythridids with patches of bright yellow, orange or red on the forewings and/or abdomen, contrasting with the dark piceous brown ground colour and the brilliant colouration of the abdomen. Also, the base of the proximal arm of the gnathos are fused into a long tube and the vinculum is forked basally in the male genitalia". The species is recorded for the first time from the area under reference.

REFERENCES

Clarke, J.F.G. (1965). Catalogue of the type specimens of microlepidoptera in the British Museum (Natural History) described by Edward Meyrick–5. Trustees of the British Museum (Natural History), London, 581pp.

Clarke, J.F.G. (1969). Catalogue of the type specimens of microlepidoptera in the British Museum (Natural History) described by Edward Meyrick–6. Trustees of the British Museum (Natural History), London, 537pp.

Common, I.F.B. (1990). *Moths of Australia*. E.J. Brill, Leiden, vi+535pp., 32 pls.

Common, I.F.B. (1970). Lepidoptera, The insects of Australia, chapter 3b, CSIRO, Divn. Entomology, Melbourne University Press, 1029pp.

Domingo, J., P. Huemer & J. Baixeras (2003). Ethmia penyagolosella sp. n. (Lepidoptera: Ethmiidae), a new species from Spain. *Nachrichten des Entomologischen Vereins Apollo, N.F*. 24(4): 183–188.

Fletcher, T.B. (1921). Life history of Indian Insects, Microlepidoptera. *Memoirs of the Department of Agriculture in India* 6: 1–217.

Fletcher, T.B. (1929). A list of the generic names used for Microlepidoptera. *Memoirs of the Department of Agriculture in India (Ent.) Series*, 11: 246pp.

Gaede, M. (1937). Catalogue of Gelechiidae. *Lepidopterorum Catalogus* 79: 1–630.

Hodges, R.W. (1958). A method for preparing fresh microlepidoptera for spreading. *Lepidoptera News* 12: 205.

Hodges, R.W. (1978). Gelechioidea: Cosmopterygidae, In: Dominick, R.B. et al. (ed.). The moths of America North of Mexico. 6(1): 166pp.

Hodges, R.W. (1986). Gelechioidea: Gelechiidae, In: Dominick, R.B. et al. (ed.). The moths of American North of Mexico, 7(1): 1–195.

Landry, J.F. & B. Landry (1994). A technique for setting and mounting Microlepidoptera. *Journal of the Lepidopterists'* Society 48(3): 205–227.

Lindquist, O.H. (1956). A technique for pinning and spreading small microlepidoptera. *The Canadian Entomologist* 138(1): 24–25.

Meyrick, E. (1908). Descriptions of Indian Microlepidoptera. *Journal of the Bombay Natural History Society* 18: 137–160, 437–460, 613–638, 806–832.

Meyrick, E. (1910). Descriptions of Indian Microlepidoptera. *Journal of the Bombay Natural History Society* 20: 143–168, 435–462, 706–736.

Meyrick, E. (1916–1923). Exotic Microlepidoptera 2: 1–640.

Meyrick, E. (1925). Lepidoptera; Heterocera family Gelechiadae in Wytsman, Genera Insectorum 184: 1–290.

Mikkola, K. (1986). Tower spreading, a handy method for provisional field preparation for Microlepidoptera. *Nota entomológica* 66: 101–102.

Nielson, Z. (1980). Entomology. The denish scientific to Patagonia and Tierra del Fuego 1978-1979. *Geografisk Tidsskrift* 80: 9–13.

Park, K.T. & J.B. Heppner (2000). Lecithoceridae (Lepidoptera) of Taiwan (III) Subfamily Torodrinae: genus *Torodora* Meyrick. *Transactions of Lepidopterological Society of Japan* 51(4): 287–297.

Park, K.T. & M. Omelko (1994). Two new species of Genus *Stegasta* (Lepidoptera, Gelechiidae). *Japanase Journal of Entomology* 62 (4): 867–871.

Park, K.T. & M.G. Ponomarenko (1996). Genus *Anarsia* Hübner (Lepidoptera, Gelechiidae) from Thailand, with description of nine new species. *Insecta Koreana* 13: 39–58.

Park, K.T. & R.W. Hodges (1995). Gelechiidae (Lepidoptera) of Taiwan III. Systematic Revision of the genus Dichomeris in Taiwan and Japan. *Insecta Koreana* 12: 1–101.

Park, K.T. & R.W. Hodges (1995). Gelechiidae (Lepidoptera) of Taiwan IV. Genus *Helcystogramma* zeller, with description of a new species. *The Korean Journal of Systematic Zoology* 11(2): 223–234.

Pathania, P.C. & H.S. Rose (2003). Taxonomic notes on the genus *Hypatima* Hübner (Lepidoptera: Gelechiidae) alongwith a new species from India. *Journal of Pest management & Ecnomic Zoology* 11(2): 163–171.

Pathania, P.C. & H.S. Rose (2004a). Description of one new and redescription of two known species of *Hygroplasta* Meyrick (Lepidoptera: Lecithceridae:Torodorinae) from India. *Shashpa* 11(2): 93–99.

Pathania, P.C. & H.S. Rose (2004b). Nine species including *Lecithocera gozmanyi* sp. nov. of genus *Lecithocera* Herrich-Schaffer (Lepidoptera: Lecithoceridae: Lecithocerinae) from Shiwaliks, India. *Geobios* 31(4): 225–236.

Pathania, P.C., H.S. Rose & R. Sood (2009). Taxonomic studies of members of family Scythridae (Lepidoptera) from Western Himalaya. *Journal of Insect Science* 22(2): 162–170.

Pathania, P.C., H.S. Rose & R. Sood (2006). Gelechiid diversity (Lepidoptera) from Shiwalik hills of north-western Himalaya. *Zoos' Print Journal* 21(1): 2127–2131. https://doi.org/10.11609/JoTT.ZPJ.2127-31

Pathania, P.C., H.S. Rose & R. Sood (2006a). Taxonomic studies of the genus *Ethmia* Hübner (Ethmiidae:Lepidoptera) from India. *Environment and Ecology* 24(3): 496–503.

Robinson, G.S. (1976). The Preparation of slides of Lepidoptera genitalia with special reference to microlepidoptera. *Entomologist Gazette* 27(2): 127–132.

Roonwal, M.L., R.N. Mathur, G.D. Bhasin, P.N. Chatterjee, P.K. Sen-Sharma, B. Singh, A. Chandra, R.S. Thapa & K. Krishna (1964). A systematic catalogue of the main identified entomological collection at the Forest Research Institute, Dehradun, 22–38: 197–537.

Rose, H.S. & P.C. Pathania (2003a). Significance of the genitalia in the family Oecophoridae (Lepidoptera) alongwith a new species and three new combinations from North-West India. *Panjab University Research Journal (Science)* 53: 105–132.

Rose, H.S. & P.C. Pathania (2003b). Taxonomic studies of genus *Torodora* Meyrick (Lepidoptera: Licithoceridae: Torodorinae) from North-West India. *Bioved* 14(1,2): 141–157.

Rose, H.S. & P.C. Pathania (2003c). Taxonomic studies on the genus *Anarsia* Zeller (Lepidoptera: Gelechiidae) from Shivaliks in India. *Entomon* 28(4): 329–354.

Rose, H.S. & P.C. Pathania (2003d). Two new species along with first record of the genus *Helcystogramma* Zeller (Lepidoptera: Gelechiidae) from India. *Panjab University Research Journal (Science)* 53: 81–90.

Rose, H.S. & P.C. Pathania (2004). A new species and a new record of the genus *Stegasta* Meyrick (Lepidoptera: Gelechiidae) from India. *Journal of Environmental Science* 8(2): 152–156.

Sokoloff, E. (1980). Practical hits for collecting and studying the Microlepidoptera. *Amateur Entomologist* 16: 1–39.

Srivastava, A., P. Kumar & S. Sharma (2005). Taxonomic studies on the genus Tinea Linnaeus (Lepidoptera: Tineidae) with brief account of its genitalia. *Pest management and Economic Zoology* 13(2): 251–256.

Tagestad, A.D. (1974). A technique for mounting microlepidoptera. *Journal of the Kansas Entomologiocal Society* 47: 26–30.

Van Nieukerken, E.J, L. Kaila, I.J. Kitching, N.P. Kristensen, D.C. Lees, J. Minet, C. Mitter, M. Mutanen, J.C. Regier, T.J. Simonsen, N. Wahlberg, S.H. Yen, R. Zahiri, D. Adamski, J. Baixeras, D. Bartsch, B.A. Bengtsson, J.W. Brown, S. R. Bucheli, D.R. Davis, J. Prins, W. De Prins, M.E. Epstein, P. Gentili-Poole, C. Gielis, P. Hättenschwiler, A. Hausmann, J.D. Holloway, A. Kallies, O. Karsholt, A.Y. Kawahara, S.J.C. Koster, M. Kozlov, J.D. Lafontaine, G. Lamas, J.F. Landry, S. Lee, M. Nuss, K.T. Park, C. Penz, J. Rota, A. Schintlmeister, B.C. Schmidt, J.C. Sohn, M.A. Solis, G.M. Tarmann, A.D. Warren, S. Weller, R.V. Yakovlev, A. Zolotuhin & V.V. Zwick (2011). Order Lepidoptera Linnaeus, 1758. In: Zhang, Z.-Q. (Ed.), Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness. *Zootaxa* 3148: 212–221

Zimmerman, E.C. (1978). *Microlepidoptera. Insects of Hawaii - 9*. University Press of Hawaii, Honolulu, 8: 1903pp.

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COMMUNICATION

On the diversity and abundance of riparian odonate fauna (Insecta) of the midstream Chalakkudy River, Kerala, India

C. Nitha Bose [1], C.F. Binoy [2] & Francy K. Kakkassery [3]

[1] Research and Postgraduate Department of Zoology,, St. Thomas' College (Autonomous), Thrissur, Kerala 680001, India.
[1] nithabose123@gmail.com, [2] drcfbinoy@gmail.com, [3] fkakkassery@gmail.com (corresponding author)

Abstract: The riparian Odonate insect diversity of the midstream Chalakudy River at six locations assessed from February 2018 to January 2019 has revealed the occurrence of 25 species of odonates. Among them,10 species are dragonflies belonging to seven genera of the family Libellulidae and the remaining 15 species are damselflies belonging to six families and 11 genera. Five endemic damselfly species have been recorded. *Pseudagrion indicum* is endemic to the Western Ghats, while the remaining four species, *Vestalis apicalis, Libellago indica, Dysphaea ethela*, and *Heliocypha bisignata*, are endemic to India. Diversity indices of the odonates in all the six locations were analyzed and it showed less abundance at sites where tourist activities are more and with thin native riparian vegetation. Further, the study has unequivocally revealed that thick native riparian vegetation is essential for their perching and existence. By and large, the uncontrolled tourism activities and habitat alteration interfere with the density and diversity of these endemic species.

Keywords: Damselflies, dragonflies, endemism, odonates, tourism, Western Ghats.

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Author details: Nitha Bose C, is a research scholar under the guidance of Dr. Francy K. Kakkassery and the co guidance of Dr. C.F. Binoy at the Department of Zoology, St.Thomas' College (Autonomous). Her research work is based on taxonomy and molecular phylogeny of odonates of Kerala. Dr. C.F. Binoy, has been working as Assistant Professor (Selection Grade) in the Research and Post Graduate Department of Zoology, St.Thomas' College (Autonomous). He is a research guide under the University of Calicut, guiding four doctoral students and as co-guide of three. Entomology, especially biodiversity conservation related to insects, insect ecology, pollination biology of mangrove ecosystem are the fields of interest. Dr. Francy K. Kakkassery has been working as Associate Professor and Head in the Research and Post Graduate Department of Zoology, St.Thomas' College (Autonomous). He retired from service last year after a long 30 years. He has been doing research in field Entomology, specializing in dragonflies and damselfiles, and also in aquatic biology. Six students are doing doctoral research work under his guidance.

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INTRODUCTION

Kerala has a comprehensively documented odonate fauna. The relevant works among them include that of Rao & Lahiri (1982), Mathavan & Miller (1989), Radhakrishnan (1997), Emiliyamma & Radhakrishnan (2002), Emiliyamma (2005), Palot et al. (2005), Adarsh et al. (2014), Varghese et al. (2014), Nair (2017), and Susanth & Anooj (2020). Recent works further added up the rich odonate diversity of Kerala to 174 species (Emiliyamma et al. 2020; Joshi et al. 2020). The seasonal and habitat distribution of Odonata diversity of riparian habitats such as Mula and Mutha river basins in Maharashtra was studied by Kulkarni & Subramanian (2013). Species turn over and abundance of the odonates of riparian zones depends on season and land use types. Endemics and habitat specialists are restricted to undisturbed riverine ecosystems as they possess a narrow range of habitat tolerance. Conservation of riparian zone results in the conservation of endemics of odonates (Subramanian 2007; Subramanian et al. 2008). The present study investigated the odonate diversity and abundance of midstream Chalakkudy river giving special reference to endemics.

METHODS

The survey was conducted once a month from February 2018 to January 2019 by conventional random sampling. Six locations of midstream Chalakkudy River were randomly selected for the observation of odonates. The river is 13.5 km (approximately) long from the first location to last one (Bachan 2003). The details of the study localities are given in Table 1. All the six locations are with rocky river bed and evergreen and semi evergreen forest vegetation. *Madhuca neriifolia, Syzigium occidentale, Humboldtia vahliana, Elaeocarpus*, and *Homonoia riparia* are the dominant species of flowering plants in these locations (Bachan 2010). The selected locations have been confronted with anthropogenic disturbances such as habitat alteration due to tourism activities including resorts & commercial establishments, oil palm plantations, and activities of local people. The odonates were documented and identified with the help of photographs, keys, and descriptions given in the literature (Fraser 1933, 1934, 1936; Kiran & Raju 2013). The species richness and abundance were recorded and Simpson & Shannon diversity indices and eveness values were calculated using PAST software. The observed species of odonates were categorized as VC—Very common (180–240 sightings), CO—Common (120–180 sightings), OC—Occasional (60–120 sightings), and RA—Rare (1–60 sightings)) depending upon their occurrence during the survey (Palot et al. 2005; Tiple et al. 2012).

Table 1. Odonate collection localities.

	Sample collection sites	Latitude	Longitude	Altitude (m)
L1	Ezhattumugham	10.295	76.451	39
L2	Chiklayi	10.294	76.470	46
L3	Ayyampuzha	10.292	76.478	47
L4	Vettilappara	10.289	76.512	64
L5	Athirappilly	10.285	76.558	86
L6	Athirappilly waterfalls	10.284	76.569	116

RESULTS

During the study period, 2,186 individuals of 25 species were observed. Out of these, 10 species were dragonflies of the suborder Anisoptera, belonging to seven genera and the family Libellulidae. The remaining 15 species were damselflies under the suborder Zygoptera and they come under 11 genera in six families (Tables 1, 2). Libellulidae is the only anisopteran family, which has been observed among the odonates in the present survey. *Orthetrum sabina* a well-known cannibalistic dragonfly, has been found to be very common. On the other hand, *Onychothemis testacea* was encountered very rarely during the present survey. Members of the family Coenagrionidae (6 species) were dominating in the order Zygoptera succeeded by Calopterigidae (3 species) and Platycnemididae (3 species). *Vestalis apicalis* and *Prodasineura verticalis* were common but *Aciagrion occidentale* was observed only sporadically in this region. Out of the 25 species recorded, five species are endemics and they belong to the suborder Zygoptera. But *Pseudagrion indicum* is endemic to Western Ghats, while *Vestalis apicalis* is endemic to southern and central India, *Libellago indica* is endemic to peninsular India, whereas *Dysphaea ethela* and *Heliocypha bisignata* are endemic to India (Kalkman et al. 2020). The most dominant endemic species observed in the present survey was *Dysphaea ethela* and *Heliocypha bisignata*, which exhibited a minimum level of occurrence. The percentage distribution of each endemic species is as follows: *Pseudagrion indicum* 9%, *Vestalis apicalis* 26%, *Libellago indica* 28%, *Dysphaea ethela* 34%, and *Heliocypha bisignata* 3%. The first location Ezhattumugham (L1) harboured as many as 536

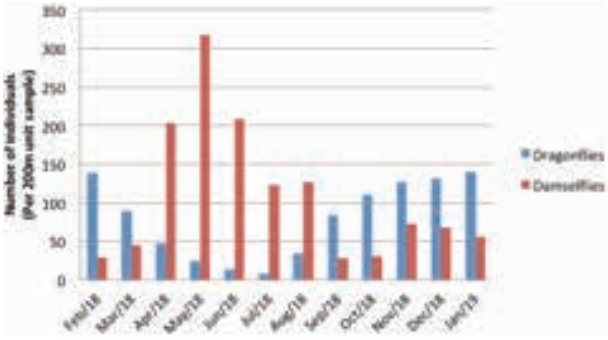

Figure 1. Abundance of dragonflies and damselflies in the Chalakudy River.

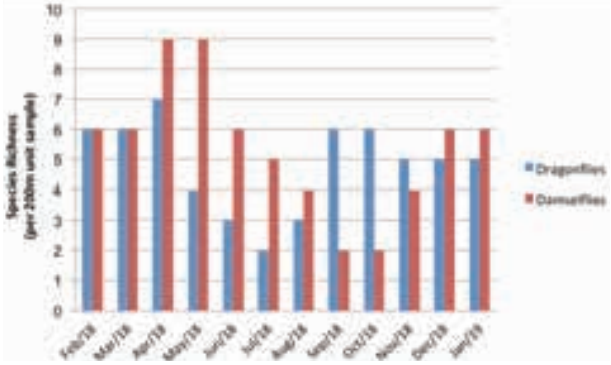

Figure 2. Species richness of dragonflies and damselflies in the Chalakudy River.

individuals in 21 species. *Vestalis apicalis* was the most abundant, and endemic species. *Onychothemis testacea* and *Zygonyx iris* were recorded only from this location. The highest number of endemics were also recorded from here. Inspite of the disturbances from tourists, this location showed a good quantity of native vegetation including emergent vegetation and shade cover and that perhaps resulted in the collection of a maximum number of individuals. The second location, Chiklayi (L2) yielded a maximum observation of 363 individuals of 17 species. *Orthetrum sabina* was the common species but *Libellago indica* was the prevalent endemic of this location. The habitat is rocky in nature with moderate shade cover and prominent emergent vegetation. Tourists' activities are appreciably low and the native vegetation is limited by oil palm plantation. Maximum value of diversity indices was shown by location. The third location, Ayyampuzha (L3) was polluted by the activities of local people and tourists to some extent. But the oil palm plantation ousted the native vegetation. From this location having traces of shoreline plants, limited shade cover, boulders and rocks, 284 individuals of 15 species were recorded of which, *Trithemis aurora* was dominant with the endemic species *Libellago indica.* Vettilappara (L4) is yet another location having least human interference with appreciable shade cover and riparian vegetation. But the native riparian vegetation is narrowed into a thin belt by the plantation crops. *Libellago indica* (endemic) and *Pseudagrion rubriceps* were the commonly found species during the study period. A total of 501 individuals belonging to 17 species were encountered in Vettilappara. Athirappilly (L5) is slightly polluted by human activities (tourism and nearby construction works) with minimum shade cover and moderate emergent vegetation. Eighteen species were recorded during the survey. *Orthetrum sabina* and *Prodasineura verticalis* were the common species

Table 2. List of dragonflies recorded from Chalakudy River.

	Scientific name (Family: Libellulidae)	Abundance	IUCN status
1	*Diplacodes trivialis* (Rambur, 1842)	O	LC
2	*Neurothemis tullia* (Drury, 1773)	O	LC
3	*Onychothemis testacea* (Laidlaw, 1902)	R	LC
4	*Orthetrum chrysis* (Selys, 1891)	R	LC
5	*Orthetrum pruinosum* (Burmeister, 1839)	R	LC
6	*Orthetrum sabina* (Drury, 1770)	VC	LC
7	*Pantala flavescens* (Fabricius, 1798)	O	LC
8	*Trithemis aurora* (Burmeister, 1839)	VC	LC
9	*Trithemis festiva* (Rambur, 1842)	C	LC
10	*Zygonyx iris* (Selys, 1869)	R	LC

VC—Very common | CO—Common | OC—Occasional | RA—Rare | EN—Endemic.

found along with the frequently encountered endemic damselfly, *Libellago indica*. Athirappilly waterfalls (L6) is another beautiful location where the tourists activities are significantly high and endowed with rocky habitat and riparian vegetation. But the presence of macrophytes and overhanging vegetation is scanty due to tourists disturbances. As a result, the numerical abundance of species recorded from this location was very less. However, the endemic dragonflies, *Dysphaea ethela* and *Vestalis apicalis* were the dominating species of this location.

Effect of flood

During the month of August of the study period, heavy down pour at Kerala led to a deluge and it badly affected the study areas. Riparian vegetation was totally destroyed. Natural soil texture was lost, soil accumulation could be found in river and river banks. As a consequence, a sudden drop in damselfly diversity

Table 3. List of damselflies recorded from Chalakudy River.

	Scientific name (Suborder: Zygoptera)	Abundance	IUCN Red List status
	Family: Calopterygidae		
1	*Neurobasis chinensis* (Linnaeus, 1758)	R	LC
2	*Vestalis apicalis* (Selys, 1873)	VC & EN	LC
3	*Vestalis gracilis* (Rambur, 1842)	C	LC
	Family: Chlorocyphidae		
4	*Libellago indica* (Fraser, 1928)	C & EN	LC
5	*Heliocypha bisignata* (Hagen in Selys, 1853)	R & EN	LC
	Family: Coenagrionidae		
6	*Aciagrion occidentale* (Laidlaw, 1919)	R	LC
7	*Agriocnemis pieris* (Laidlaw, 1919)	R	LC
8	*Agriocnemis pygmaea* (Rambur, 1842)	R	LC
9	*Ischnura rubilio* (Brauer, 1865)	R	LC
10	*Pseudagrion indicum* (Fraser, 1924)	O & EN	DD
11	*Pseudagrion rubriceps* (Selys, 1876)	C	LC
	Family: Euphaeidae		
12	*Dysphaea ethela* (Fraser, 1924)	VC & EN	LC
	Family: Platycnemididae		
13	*Copera marginipes* ((Rambur, 1842)	R	LC
14	*Copera vittatta* (Selys, 1863)	R	LC
15	*Prodasineura verticalis* (Selys, 1860)	VC	LC

was noticed just after the flood. Only two species of damselflies were recorded in the first two months after the flood, i.e., September and October 2018. But dragonfly diversity was not much affected. In the succeeding months the species richness and abundance were observed to have rebounded.

Simpson & Shannon diversity indices and evenness values of the six locations were calculated (Table 4). Maximum species richness and abundance were found at Location 1. Simpson and Shannon diversity indices (0.9197 and 2.628, respectively) were found to be equally high for location 2, while the least values were shown by Location 6 (0.8694 and 2.191, respectively). Maximum value of evenness (0.8257) was recorded at Location 3 and a minimum at Location 1.

DISCUSSION

The current study points out the role of native riparian vegetation and the impact of human interference such as habitat alteration by tourism, construction works and plantations on the density and diversity of odonate fauna. Studies revealed that riparian vegetation promotes the occurrence of invertebrates including insects and facilitates suitable habitat for insects by providing food, resting and hiding places for emergent adults and substratum for egg laying. Also the shade cover regulates water temperature and overall quality of the stream (Knight & Bottorff 1981; Ober & Hayes 2008). Moreover, the prey insects are attracted by flowering plants, which in turn form ideal food for odonates. Therefore, these conditions become more pertinent for the carnivorous odonates. The hanging plants and emergent macrophytes furnish perching sites and structures for egg laying and emergence of adults. Literature delineates the role of macrophytes and shoreline structures in oviposition, formation of larval microhabitat, emergence support and adult perching site (Samways & Steytler 1996; Schindler et al. 2003).

In the present study 15 species of damselflies and 10 dragonflies were recorded. As the damselflies are weak fliers, they may depend on their own microhabitat for food and reproduction. But the agile fliers, dragonflies are free to move to more extensive habitats according to their preferences. This is a factor of variation in species richness between the two suborders. The most commonly encountered dragonfly was *Orthetrum*

Table 4. Community structure of odonates.

Parameters/ Indices	L1 Ezhattumugham	L2 Chiklayi	L3 Ayyampuzha	L4 Vettilappara	L5 Athirappilly	L6 Athirappilly waterfall
Species richness	21	17	15	17	18	12
No. of individuals (per 200m unit sample)	536	363	284	501	377	125
Simpson 1-D	0.8983	0.9197	0.9091	0.9121	0.9064	0.8694
Shannon H	2.518	2.628	2.517	2.561	2.545	2.191
Evenness	0.5907	0.8142	0.8257	0.7617	0.7079	0.7456

Image 1. *Dysphaea ethela*

Image 2. *Pseudagrion indicum*

Image 3. *Libellago indica* (male)

Image 4. *Libellago indica* (female)

Image 5. *Vestalis apicalis*

Image 6. *Heliocypha bisignata*

sabina, which predate on other insects and exhibits cannibalistic behavior too (Iswandaru 2018). Further, adequate quantities of reeds support the occurrence of damselflies than dragonflies (Fulan et al. 2008). In the present study, L1, L2, L4 and L5 locations showed the maximum species richness, abundance and diversity. Despite the human disturbances, L1 showed the highest value of species richness and abundance. Presence of comparatively abundant native vegetation including emergent macrophytes supported the diversity in L1. Moreover, in L2, L3 and L4 sites, the native riparian vegetation is narrowed by the plantation crops. Vegetation in location L5 was destroyed as a result of resort construction. Pristine habitat loss results in the loss of odonate diversity (Rodrigues et al. 2016). But the presence of a modest percentage of riparian vegetation could hold up the diversity in these locations to some extent. Although L6 is devoid of plantation crops, the prominent disturbances from tourists have destroyed the emergent macrophytes and overhanging vegetation. This has led to the least diversity indices on species richness and abundance in L6. Another observation noticed in the present study was on the high abundance of endemic species in L1 and minimum distribution at L6. *Dysphaea ethela* and *Heliocypha bisignata* were reported to be respectively the common and rarely occurring endemic species.

As per the literature, undisturbed riparian forests are typically rich with the presence of endemics (Subramanian et al. 2008). Destruction of riparian flora and fauna could be attributed to damming, tourists activities, construction works and expanding the area for agricultural plantations leading to the declined number of species. For instance, it is evident that the fish fauna of Chalakkudy river is highly threatened by damming, deforestation and pesticide pollution (Raghavan et al. 2008). Habitat alteration interferes with the abundance of endemic odonates and supports the occurrence of generalist species like libellulids (Kalkman et al. 2008; Subramanian et al. 2008), and that is evident in the present study. Research work delineates the resilience capacity of organisms to flood (Death 2008; Golab & Sniegula 2012; Raghavan 2019). Inspite of the destructive flood during the current study, odonates showed a tendency to bounce back to pre-flood conditions within a very short time. Further studies are required to authenticate the same.

REFERENCES

Adarsh, C.K., K.S. Aneesh & P.O. Nameer (2014). A preliminary checklist of odonates in Kerala Agricultural University (KAU) campus, Thrissur District, Kerala, southern India. *Journal of Threatened Taxa* 6(8): 6127–6137. https://doi.org/10.11609/JoTT.o3491.6127-37

Bachan, A.K.H (2003). Riparian vegetation along the middle andlower zones of theChalakkudy river, Kerala, India. Project 26/2000 Sponsored by Kerala Research Programme on Local LevelDevelopment, CDS, Thiruvananthapuram

Bachan. A.K.H. (2010). Riparian flora of the Chalakkudy river basin and its ecological significance. Ph D Thesis. Department of Botany, University of Calicut, xii+882pp.

Death, R.G. (2008). The Effect of Floods on Aquatic Invertebrate Communities, pp. 113-121. *Proceedings of the Royal Entomological Society's 24th Symposium. Royal Entomological Society of London.* Cromwell Press, Trowbridge, UK.

Emiliyamma, K.G. (2005). On the Odonata (Insect) Fauna of Kottayam District, Kerala, India. *Zoo's Print Journal* 20(12): 2108–2110. https://doi.org/10.11609/JoTT.ZPJ.1338.2108-10

Emiliyamma, K.G. & C. Radhakrishnan (2002). Additions to the Odonata of (Insecta) of Thiruvananthapuram District, Kerala. *Zoo's Print Journal* 17(10): 914–917. https://doi.org/10.11609/JoTT.ZPJ.17.10.914-7

Emiliyamma, K.G., M.J. Palot & C. Charesh (2020). A new species of *Platylestes* Selys (Odonata: Zygoptera: Lestidae) from the coastal area of Kannur District, Kerala, India. *Journal of Threatened Taxa* 12(13): 16854–16860. https://doi.org/10.11609/jott.5209.12.13.16854-16860

Fraser, F.C. (1933).*The Fauna of British India including Ceylon and Burma. Odonata – Vol. I* . Taylor and Francis Ltd, London, 423pp.

Fraser, F.C. (1934).*The Fauna of British India including Ceylon and Burma. Odonata – Vol. II* . Taylor and Francis Ltd, London, 398pp.

Fraser, F.C. (1936). The Fauna of British India including Ceylon and Burma. Odonata – Vol. III . Taylor and Francis Ltd, London, 461pp.

Fulan, J.A., R. Raimundo & D. Figueiredo (2008). Habitat characteristics and dragonflies (Odonata) diversity and abundance in the Guadiana River, eastern of the Alentejo, Portugal. *Boletín de la Asociación española de Entomología* 32(3-4): 327–340.

Golab, M.J. & S. Sniegula (2012). Changes in reproductive behavior in adult damselfly Calopteryxsplendens (Odonata: Calopterygidae) in response to flood. *Entomological Science* 15(3): 280–287. https://doi.org/10.1111/j.1479-8298.2012.00516.x

Iswandaru, D. (2018). Diversity of dragonflies (Odonata) in swamp ecosystem University of Lampung. *Agricultura* 105(1–2): 101–109.

Joshi, S., K.A. Subramanian, R. Babu, D. Sawant & K. Kunte (2020). Three new species of *Protosticta* Selys, 1885 (Odonata: Zygoptera: Platystictidae) from the Western Ghats, India, with taxonomic notes on *P. mortoni* Fraser, 1922 and rediscovery of *P. rufostigma* Kimmins, 1958. *Zootaxa* 4858(2): 151–185. https://doi.org/10.11646/zootaxa.4858.2.1

Kalkman, V.J., R. Babu, M. Bedjanic, K. Conniff, T. Gyeltshen, M.K. Khan, K.A. Subramanian, A. Zia & A.G. Orr (2020). Checklist of the dragonflies and damselflies (Insecta: Odonata) of Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. *Zootaxa* 4849(1): 001–084. https://doi.org/10.11646/zootaxa.4849.1.1

Kalkman, V.J., V. Clausnitzer, K.D.B. Dijktra, A.G. Orr, D.R. Paulson & J.V. Tol (2008). Global diversity of dragonflies (Odonata) in freshwater.*Hydrobiologia*. 595: 351–363. https://doi.org/10.1007/s10750-007-9029-x

Kiran, C.G. & D. Raju (2013). *Dragonflies and Damselflies of Kerala.* Tropical Institute of Ecological Sciences, Greenleaf Publications, Kottayam, Kerala, India.

Knight, A.W. & R. Bottorff (1981). The importance of riparian vegetation to stream ecosystems. In: Warner & K.M. Hendrix (eds.). *California Riparian Systems Conference: Ecology, Conservation, and Productive Management*. University of California Press.

Kulkarni, A.S. & K.A. Subramanian (2013). Habitat and seasonal

distribution of Odonata (Insecta) of Mula and Mutha river basins, Maharashtra, India. *Journal of Threatened Taxa* 5(7): 4084–4095. https://doi.org/10.11609/JoTT.o3253.4084-95

Mathavan, S. & P.L. Miller (1989). A Collection of Dragonflies (Odonata) made in the Periyar National Park, Kerala, South India, in January 1988. *International Odonatological Society, Bilthoven, Rapid communications (supplements)* 10*:* 1–10

Nair, V.P. (2017). Dragonflies: Additions to the Odonata (Insecta) fauna of Varadoor, Kannur, Kerala, South India. Bugs R All #164. In: *Zoo's Print* 32(11): 24–30.

Ober, H.K. & J.P. Hayes (2008). Influence of forest riparian vegetation on abundance and biomass of nocturnal flying insects. *Forest Ecology and Management* 256(5): 1124–1132. https://doi.org/10.1016/j.foreco.2008.06.010

Palot, M.J., C. Radhakrishnan & V.P. Soniya (2005). Odonata (Insecta) diversity of rice field habitat in Palakkad district, Kerala.*Record of Zoological Survey of India* 104(Part 1-2): 71–77.

Radhakrishnan, C. (1997). Ecology and conservation status of entomofauna of Malabar. *Zoos' Print* 11: 2–5.

Raghavan, R. (2019). Impact of 2018 Kerala floods on aquatic biodiversity with special reference to single location endemic species. Report submitted to the Kerala State Biodiversity Board.

Raghavan, R, G. Prasad, P.H.A. Ali & B. Pereira (2008). Fish fauna of Chalakudy River, part of Western Ghats biodiversity hotspot, Kerala, India: patterns of distribution, threats and conservation needs. *Biodiversity and Conservation* 17: 3119–3131. https://doi.org/10.1007/s10531-007-9293-0

Rao, R. & A.R. Lahiri (1982). First records of odonates (Arthropoda: Insecta) from the Silent Valley and New Amarambalam Reserved Forests. *Journal of the Bombay Natural History Society* 79(3): 557–562.

Rodrigues, M.E., F.O. Roque, J.M.O. Quintero, J.C.C. Pena, D.C. Sousa & P.D.M. Junior (2016). Nonlinear responses in damselfly community along a gradient of habitat loss in a savanna landscape. *Biological Conservation* 194: 113–120. https://doi.org/10.1016/j.biocon.2015.12.001

Samways, M.J. & N.S. Steytler (1996). Dragonfly (Odonata) distribution patterns in urban and forest landscapes, and recommendations for riparian management. *Biological Conservation* 78(3): 279–288. https://doi.org/10.1016/S0006-3207(96)00032-8

Schindler, M., C. Fesl & A. Chovanec (2003). Dragonfly associations (Insecta: Odonata) in relation to habitat variables: A multivariate approach. *Hydrobiologia* 497(1)169–180. https://doi.org/10.1023/A:1025476220081

Subramanian, K.A. (2007). Endemic Odonates of the Western Ghats: Habitat distribution and conservation. *Odonata: Biology of Dragonflies.* Scientific Publishers.

Subramanian, K.A., S. Ali & T.V. Ramachandra (2008). Odonata as indicators of riparian ecosystem health a case study from south western Karnataka, India .*Fraseria (N.S.)* 7 :83–95.

Susanth, C. & S.S. Anooj (2020). Checklist of Odonata of Wayanad district, Kerala. *Indian Journal of Entomology* 82(2): 315–323. https://doi.org/10.5958/0974-8172.2020.00072.3

Tiple A.D., S. Paunikar & S.S. Talmale (2012). Dragonflies and Damselflies (Odonata: Insecta) of Tropical Forest Research Institute, Jabalpur, Madhya Pradesh, Central India. Journal of Threatened Taxa 4(4): 2529–2533. https://doi.org/10.11609/JoTT.o2657.2529-33

Varghese, A.P., P.R. Nikesh & J. Mathew (2014). Odonata (Insecta) diversity of Salim Ali Bird Sanctuary and its adjacent areas in Thattekkad, Kerala, India. *Journal of Threatened Taxa* 6(6): 5887–5893. https://doi.org/10.11609/JoTT.o3395.5887-93

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COMMUNICATION

Species diversity and abundance patterns of epiphytic orchids in Aralam Wildlife Sanctuary in Kerala, India

Jis Sebastian [1], Durairaj Kathiresan [2] & Giby Kuriakose [3]

[1,2] Department of Botany, Saraswathi Narayanan College, Perungudi, Madurai, Tamil Nadu 625022, India.
[3] Department of Botany, Sacred Heart College, Thevara P.O, Ernakulam, Kerala 682013, India.
[1] alkaeliza@gmail.com, [2] kathiresansnc@gmail.com (corresponding author), [3] giby.kuriakose@shcollege.ac.in

Abstract: Species diversity and abundance patterns of epiphytic orchids were studied in Aralam Wildlife Sanctuary, in the Western Ghats of northern Kerala. Habitats sampled were wet evergreen (EVEG), montane wet evergreen (MEVG), moist deciduous (MDEC), and semi evergreen (SEVG), on a gradient of altitude from 60 to 1,589 m. Selective tree scanning on linear line transects was deployed (n= 40) across spatial units. A total of 39 orchid species were recorded. Rarefied species richness was maximum in the EVEG (20) habitat. Best suited rank abundance models were analysed for epiphytic orchids in each habitat and checked for significant differences. Bootstrap and Jackknife-1 estimators and species accumulation curves suggested higher species richness than observed, therefore more effort in sampling was needed in order to record all epiphytic orchids of the area. The difference in species richness between habitat types was not statistically significant (ANOVA). 38% of recorded epiphytic orchid species were endemic.

Keywords: Endemic, Orchidaceae, terrestrials, Western Ghats.

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Author details: Jis Sebastian—Independent researcher in the Western Ghats. Her interest lies in orchid science and climate resilient community conservation models. Durairaj Kathiresan—Associate professor at PG department & Research Centre in Botany, Saraswathi Narayanan College, Perungudi, Madurai. Giby Kuriakose—Assistant professor and Head of the Department at Department of Botany, Sacred Heart College, Cochin, Kerala.

Author contributions: JS—data collection-compilation-analysis and writing of the manuscript; DK—guiding the data compilation- analysis and writing of the manuscript; GK—conceptualisation of the study, executing the study and fund management, guiding data collection-compilation-analysis and writing of the manuscript.

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INTRODUCTION

Epiphytes, a significant group of slow growing plants (Benzing 1990), are more associated with tropical rain forests compared to temperate forests (Webb 1959; Richards et al. 1996). Orchidaceae are dominant among tropical rainforest epiphytes, possibly due to adaptations to temporary water stress in different climates and microclimates (Benzing 2004). Orchids make major contributions to the forest communities they inhabit (Nadkarni 1994) and they are also valued for their horticultural, medicinal, ethical, and edible prospects.

The Western Ghats is home to 310 orchid species, of which 123 are not found elsewhere (Jalal & Jayanthi 2012), and in Silent Valley National Park 50% of total epiphytes recorded are orchids (Kumar 1999). The Western Ghats are now inhabited by almost 50 million people, which has resulted in extensive transformation of landscapes, over exploitation of natural resources, habitat degradation, habitat loss, and encroachment. Selective removal of orchids for ornamental and medicinal purposes without considering their ecological attributes is globally identified as a threat to orchids (Huang 2011). In order to have a conservation strategy for specific species or groups in a region, it is important to know their ecology. However, taxonomic confusion persists in the region over endemic orchid species and sub species. In a moist lowland forest in the eastern Himalaya, selective logging was found to affect structural complexity of trees and hence associated microclimates, gradually threatening pteridophytes, non-orchids, and orchids (Padmawathe et al. 2004). The extensive forests of the Western Ghats become a challenge for an ecologist when groups such as orchids with random distribution is in focus. Epiphytes have been associated with trunk size in tropical evergreen forest in the Western Ghats (Annaselvam & Parthasarathy 2001). Apart from taxonomic explorations, diversity and ecology of *Dendrobium* in Chotanagpur plateau (Kumar et al. 2011), epiphytic orchid diversity from farmer managed forests in the Western Ghats (Sinu et al. 2011), habitat studies of medicinal orchids (Jalal & Rawat 2009), and conservation strategies for orchids of western Himalaya (Jalal 2012) are the only existing ecological works on orchids from India.

In order to fill this gap, the authors have examined ecological aspects of epiphytic orchids in the Western Ghats of Kerala. This study deals with the epiphytic orchids in Aralam Wildlife Sanctuary (WS) in Kannur district of northern Kerala. Aralam WS falls in Wayanad Plateau in the southern Western Ghats. The objectives of this study were to assess patterns of species diversity, abundance, and endemism among epiphytic orchids in Aralam WS.

STUDY AREA

The Aralam WS is situated between 11.900–11.983 ^{0}N 75.783–78.950 ^{0}E spanning around 55 km^2 (Figure 1). The elevation varies from 60m to ca. 1,589m from mean sea level with two major peaks, the Katti Betta (1,145 m) and the Ambalapara (1,589 m). The temperature varies from 21°C to 40°C in the lower altitudes and 8 °C to 25 °C at the higher reaches. The south-west and the north-east monsoons together give annual rainfall between 3,745 mm and 5,052mm. The Sanctuary land slopes from the east to the west, is drained by the Cheenkannipuzha, which flows to the west. Aralam WS is known for the west coast tropical evergreen forest where the unique *Dipterocarpus-Mesua-Palaquim* sub-type is seen (Nair 1991). There are about 490 ha of Teak and Eucalyptus plantations within the forest area (Manju et al. 2009). Apart from this, the vegetation of the Sanctuary can be classified into low (0–800 m) and medium (801–1,450 m) elevation types of wet evergreen, semi evergreen, moist deciduous, and high elevation (>1,450m) montane wet evergreen or hilltop evergreen forest (Champion & Seth 1968; Ramesh 2001). The floristic composition of Ambalapara region differs considerably from shola forests (Menon 1999; KFD 2009; Manju et al. 2009). The trees of this part are stunted, usually below 20m, belonging to Laurales and Myrtales, with trunks of heavy loads of epiphytic plants. Therefore, the vegetation from 1,450 to 1,700 m elevation is treated as high elevation/ montane wet evergreen forest (MEVG).

The animal diversity of the Sanctuary was comparatively well studied (Radhakrishnan 1996; Abraham & Easa 1999; Nair 2001, 2003; Sreekumar & Balakrishnan 2001 etc), but reports on plant diversity are very few (Menon 1999) and mostly limited to bryophytes and pteridophytes (Manju et al. 2009; Dantas et al. 2016; Rajesh & Vijisha 2016). So far, 47 orchid species have been reported from the Sanctuary of which 20 are endemic to India (KFD 2009).

METHODS

Field sampling

Field sampling was done from September to November in 2015. Selective tree scanning (to ensure

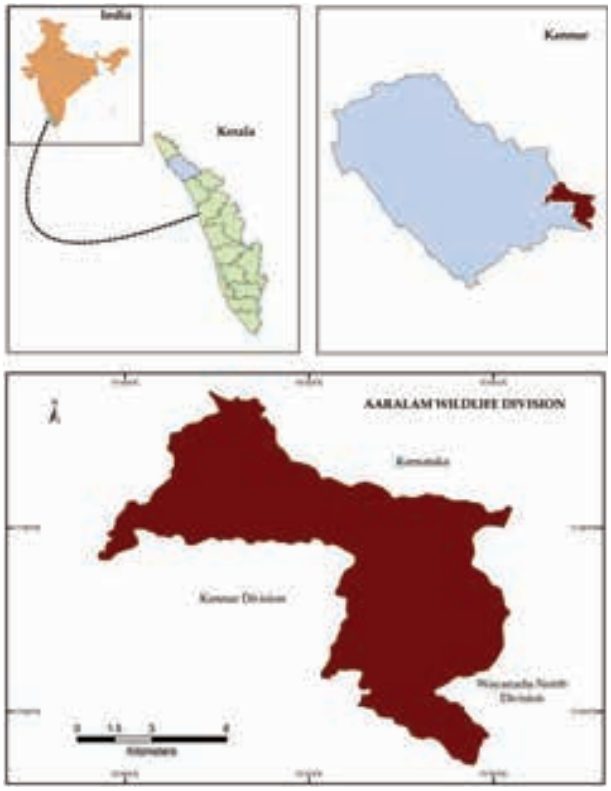

Figure 1. Aralam Wildlife Division in Kannur District, Kerala, India.

representation of vertical distribution and diversity of orchids) on linear line transects (to enable spatial scaling of orchids in heterogeneous habitats) was developed (Sebastian et al. 2017) through trial and error integrating sampling of vascular epiphyte richness and abundance (SVERA, Wolf et al. 2009) and line transects (Jacquemin et al. 2007). Transects were laid 100 m from each other in linear direction in different habitat types based on the presence of epiphytic orchids (see Table 1). A line transect was laid after finding a host tree with at least three individuals of orchids on it. Then, the next neighbouring tree was selected at the 10th meter point from the first individual and this was repeated until data collected from a total of 10 individual trees from each line transect. Data on three levels of sampling were taken from each transect. Data on characteristics of habitat, host tree, and the substrate (immediate surrounding) of orchids were recorded. Due to limitations in canopy access, orchid species were identified with a pair of binoculars (VORTEX 8X42) from ground, using the field key (Pradhan 1976, 1979; Abraham & Vatsala 1981; Joseph 1982; Kumar & Manilal 1994, 2004).

Statistical analysis

Statistical analysis of data from 40 transects was performed using statistical software R (version 3.5.0) and PAST 3.19. Orchids were ranked based on their abundance to check on singletons and doubletons. Due to the difference in the number of transects in different spatial units, rarefied diversity indices were estimated. Different habitats were compared using graphical representation of diversity indices and dominance indices in point plots to focus on difference with the help of error bars from bootstrap sampling. Rank abundance model (rad) for habitats was prepared using the best suited model (with lowest Akaike Information Criteria, AIC) to visualise the site diversity/dominance. In order to understand total species richness of epiphytic orchids in Aralam, total species was estimated based on incidence-based estimators. Species accumulation curve was prepared for species across transects in habitats using random accumulator function based on individual accumulation model. The rarefied species richness was compared across habitats. The significance of difference was tested using ANOVA and Welch T-test. The proportion of endemic species richness and abundance in the sample was plotted as a bar diagram and has been compared with a previous research paper.

Table 1. Habitat types used for the study.

Habitat types (following Ramesh 2001)	
EVEG	Wet evergreen (low-mid elevation)
MDEC	Moist deciduous
SEVG	Semi evergreen
MEVG	Montane wet evergreen (high elevation)

RESULTS AND DISCUSSION

Patterns in species diversity and abundance

In total, we found 2,831 individuals belonging to 39 species of epiphytic orchids (a complete species list is given in Table 2) from 400 individual trees (of >10cm GBH) spread across 40 transects. Also, 29 terrestrial orchids (of which, nine were unconfirmed species but morphologically distinct) were recorded from the study area. *Bulbophyllum fischeri* and *B. fuscopurpureum* were found growing both as epiphyte and terrestrial forms. The host trees sampled were grouped into 96 species and 15 unidentified species that were morphologically distinct. Among orchids, *Gastrochilus acaulis* was present in all habitats followed by *Cleisostoma tenuifolium, Cottonia peduncularis*, and *Liparis viridiflora* in three habitats each. The common species with the highest abundance was *Cleisostoma tenuifolium*. Two species

were recorded with single individuals (singletons) and another six species were represented by two individuals (doubleton) each.

Species Abundance Distribution (SAD) model, based on rank abundance of species for each habitat (Figure 2), explained the diversity of respective habitats with the help of basic models Null, Pre-emption, and Lognormal. Rank abundance models with least AIC values suggested an abundance model for each vegetation (habitat) type (Table 3). The relative abundance of species against their rank in EVEG habitat, best explained by the Null model, indicates that individuals are randomly distributed among observed species. Whereas, the Log normal model explained ranking based on relative abundance in MDEC and SEVG habitats as the abundance of species are in normal distribution with high evenness among species. Pre-emption model fitted to MEVG habitat describes least evenness among species with respect to the distribution of individuals. Interestingly, MEVG habitat had four dominant species: *Bulbophyllum fischeri, Sirhookera lanceolata, Coelogyne nervosa*, and *Conchidium microchilos,* while other species were barely represented.

EVEG habitat recorded 20 species with just 579 individuals, whereas SEVG habitat recorded 12 species with the highest abundance of 1,253 (Table 4). Biodiversity indices such as Shannon-Weiner index, Margalef & Fisher alpha showed variations with high diversity in EVEG, and the lowest was in SEVG habitat (Figure 3). Meanwhile, in a comparison of Simpson 1-D values (Figure 4), a dominance index that accounts for diversity and evenness between habitats, only EVEG and MEVG were significantly different from each other (Mann-Whitney pairwise test, df= 3, at p= 0.05). MVEG habitat had only one species in common with other habitats. Six species were found shared between MEVG and EVEG habitat with more or less equal individuals. MEVG significantly differed from EVEG with the presence of five unique species, and of which species, *Bulbophyllum fischeri* was well represented in number of individuals. Furthermore, higher abundance of species, *Dendrobium nutans* in MEVG from that of EVEG habitat could have also contributed to it. EVEG habitat with Simpson 1-D value 0.92 indicated highest diversity amongst and SEVG habitat the lowest with 0.74. SEVG habitat showed maximum abundance per species and the abundance distribution across species was found to be in normal distribution with high evenness.

The transects were standardised and rarefied species richness was estimated for minimum and maximum abundances. Total species richness was estimated for Aralam WS based on this rarefied data. One species per transect was added on average in accumulation of species for total species richness. The species observed, Sobs, was close to the bootstrap estimator which predicted a total of 46 species whereas, Chao estimator provided the highest predicted richness, 74 for the WS. This indicates the need of more transects to get a better picture about the distribution pattern of species and abundance of epiphytic orchids of Aralam WS. The relationship between species and individuals in each habitat was plotted (Figure 5). The number of species initially increased in a strong and steady manner along with the addition of individuals in habitats such as EVEG and MDEC. This clearly indicated the spacing of species in these habitats were not too far from each other. At the same time, the pattern of species accumulation was very gradual in MEVG and SEVG habitats in the beginning as a result of larger spacing between species in a wider area when compared to shorter spacing in EVEG and MDEC. Then the addition of individuals to species in SEVG reached an asymptote indicating that epiphyte assemblage in SEVG is not as diverse as other habitats but represented by high abundance. A comparison between rarefied species richness for minimum and maximum abundances in habitat types was tested (Figure 6). However, they were not statistically significantly different from each other (ANOVA at p *=0.05*, df= 3). MEVG shared only one common species between SEVG and MDEC. However, MDEC and SEVG had nine common species. Lastly, EVEG shared six species with MDEC; seven species with MEVG; seven species with SEVG. Four habitats shared only one species in common.

The total extent of the study area is just 55 km^2 and it contains at least four major habitat types, other than plantations and riparian forests. The distribution of different habitats within the study area is highly contiguous and not continuous that creates several ecotones at places. Although the present study covered maximum area in each habitat the present results clearly shows the diversity in microhabitats and microclimates within each habitat type as the estimated species richness (74 species) differed greatly to that of observed species richness (39 species). Therefore, an approach involving identification of different microhabitat and microclimate zones should be deployed to maximise the likelihood of recording maximum species in the study area. Further, species abundance pattern (Figure 2) across different habitats varies greatly and different habitats fit in with different SAD models with different patterns of distribution of species.

Table 2. The list of identified epiphytic and terrestrial orchids from Aralam Wildlife Sanctuary, Kannur.

	Species	Epiphytic	Terrestrial	Endemic**
1	*Aerides crispa*	+	-	-
2	*Aerides ringens*	+	-	-
3	*Bulbophyllum fischeri*	+	+	-
4	*Bulbophyllum fuscopurpureum*	+	+	+
5	*Bulbophyllum neilgherrense*	+	-	-
6	*Bulbophyllum tremulum*	+	-	-
7	*Chiloschista pusilla*	+	-	-
8	*Cleisostoma tenuifolium*	+	-	-
9	*Coelogyne mossiae*	+	-	+
10	*Coelogyne nervosa*	+	+	+
11	*Conchidium exile*	+	+	+
12	*Conchidium microchilos*	+	+	+
13	*Cottonia peduncularis*	+	-	-
14	*Cymbidium aloifolium*	+	-	-
15	*Dendrobium aquem*	+	-	+
16	*Dendrobium macrostachyum*	+	-	-
17	*Dendrobium microbulbon*	+	-	+
18	*Dendrobium jerdonianum*	+	-	-
19	*Dendrobium ovatum*	+	-	+
20	*Dendrobium panduratum*	+	-	-
21	*Eria reticosa*	+	+	-
22	*Gastrochilus acaulis*	+	-	-
23	*Gastrochilus flabelliformis*	+	-	+
24	*Phalaenopsis deliciosa*	+	-	-
25	*Liparis elliptica*	+	-	-
26	*Liparis viridiflora*	+	-	-
27	*Oberonia brunoniana*	+	-	+
28	*Oberonia santapaui*	+	-	+
29	*Oberonia tenuis*	+	-	-
30	*Papilionanthe subulata*	+	-	-
31	*Pholidota imbricata*	+	-	-
32	*Pomatocalpa spicata*	+	-	-
33	*Porpax jerdoniana*	+	-	+
34	*Porpax reticulata*	+	-	-
35	*Rhyncostylis retusa*	+	-	-
36	*Seidenfadeniella rosea*	+	-	+
37	*Sirhookera lanceolata*	+	+	-
38	*Smithsonia straminea*	+	-	+
39	*Bulbophyllum stocksii*	+	-	+
40	*Calanthe sylvatica*	-	+	-
41	*Cheirostylis flabellata*	-	+	-
42	*Disperis neilgherrensis*	-	+	-
43	*Eria albiflora*	-	+	+
44	*Habenaria gibsonii var. gibsonii*	-	+	-
45	*Habenaria longicorniculata*	-	+	-
46	*Habenaria perrotettiana*	-	+	+
47	*Malleola gracilis*	-	+	-
48	*Pecteilis gigantea*	-	+	-
49	*Satyrium nepalense*	-	+	-
50	*Sirhookera latifolia*	-	+	-
51	*Tainia bicornis*	-	+	-
52	*Tropidia angulosa*	-	+	-
53	*Brachycorythis iantha*	-	+	+
54	*Liparis* sp.*	-	+	-
55	*Liparis* sp.2*	-	+	-
56	*Bulbophyllum* sp.*	-	+	-
57	*Bulbophyllum* sp. 2*	-	+	-
58	*Cheirostylis* sp.*	-	+	-
59	*Oberonia* sp.*	-	+	-
60	*Spiranthes* sp.*	-	+	-
61	*Zeuxine* sp.*	-	+	-

*genus with unconfirmed species. ** Endemics (Jalal 2012; Kumar et al. 2000; Jayalakshmi 2016).

Endemism

Endemism among epiphytic orchids of Aralam WS deserves further attention, as 29% of total orchids (N= 62) and 38% of epiphytic orchids (N= 39) from the area were endemic to the Western Ghats (Figure 7). Abundance of endemic orchids alone made up 28% of total abundance. However, the difference in endemic species richness and abundance between habitats was not significant (Kruskal Wallis test, p= 0.8). Interestingly, of these endemic orchids, eight species were seen only in one habitat and five species in two habitats each. However, associations amongst species with respect to habitat could not be identified with sample size as low as 40 transects. Furthermore, three terrestrial endemics were also recorded. These terrestrial endemics such

Table 3. RAD models for habitats with the least AIC value marked in red.

	EVEG	MDEC	MEVG	SEVG
Null	117.9956	168.7757	128.51493	491.0734
Pre-emption	125.6122	197.9680	77.26034	125.5718
Lognormal	129.4657	151.8832	99.69576	102.5774

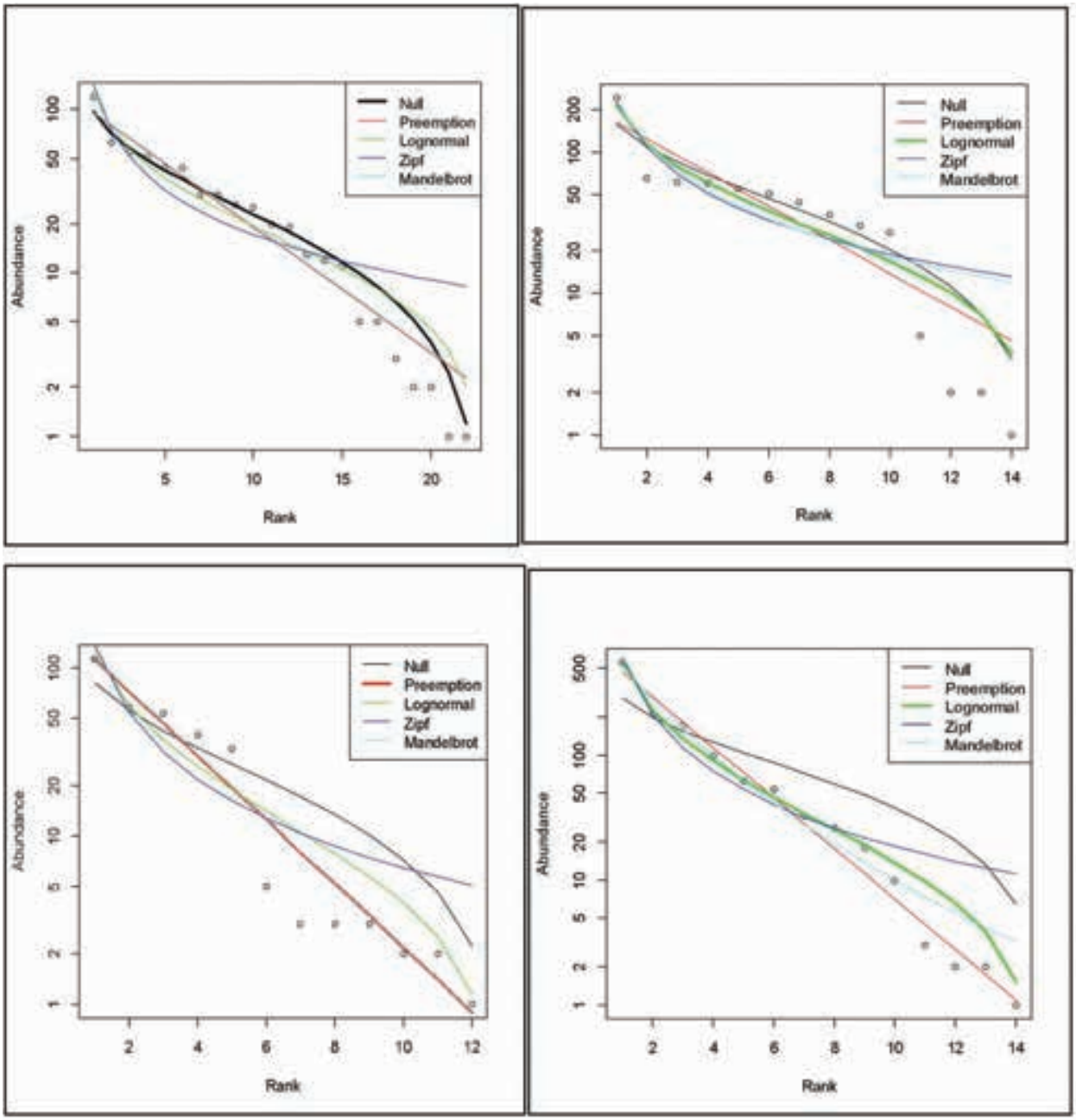

Figure 2. RAD models for habitats (clockwise) EVEG, MDEC, SEVG and MEVG.

as *Eria albiflora, Brachycorythis iantha* and *Habenaria perrotettiana* belonged to MEVG habitat but data was not sufficient to check if relationships existed with the habitat. Chao and ACE estimators suggested all endemic epiphytes of Aralam had been obtained through sampling from 40 transects. Species estimation for endemic epiphytes in Aralam WS was compared with that of entire southern western Ghats in Kerala (Figure 8). Species accumulation curve was almost stabilized at 181th transect for data on endemic epiphytic orchids from entire southern Western Ghats in Kerala (Refer Sebastian et al. 2017). Further, high endemic epiphytic species diversity and abundance was observed in EVEG habitat followed by MEVG in Aralam WS.

CONCLUSION

The total number of epiphytic orchid species recorded in this study was 62, higher than noted

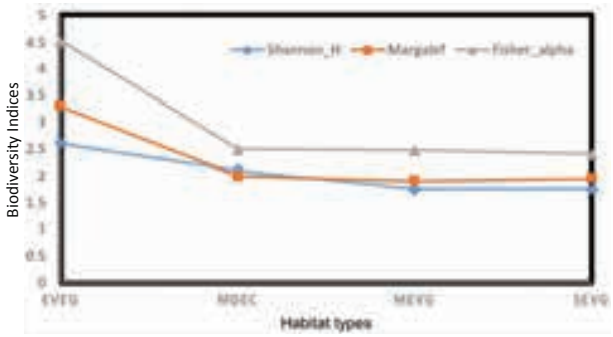

Figure 3. Graph showing diversity indices indicating epiphytic orchid diversity across habitats.

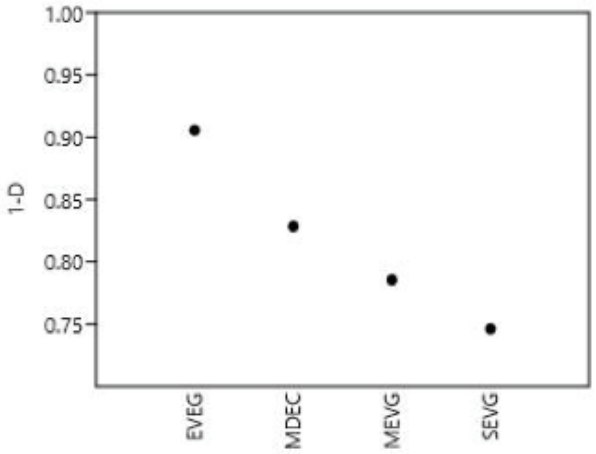

Figure 4. Simpson 1-D (difference from 1) values across habitat types.

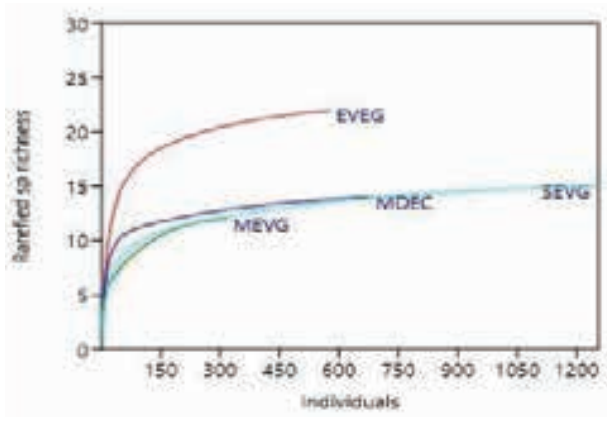

Figure 5. Species accumulation curves for habitats based on an individual accumulation model (rarefaction).

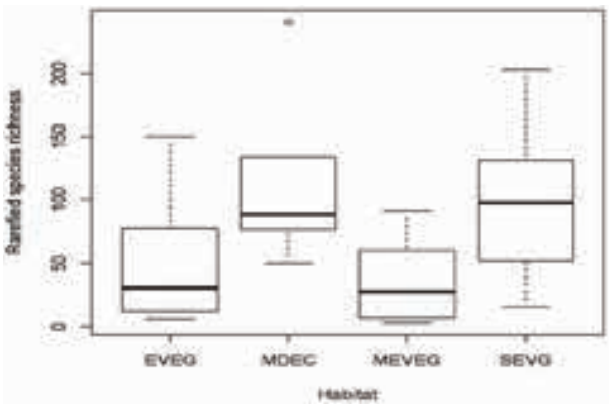

Figure 6. Comparison between rarefied species richness for minimum and maximum abundance across habitat types. The stripe shows median richness, the boxes are interquartile range and whiskers max-min.

previously by KFD (2009). Species accumulation curves suggest that there are species that are yet to be sampled from Aralam WS (Figure 5). It is also possible that the exempted Teak plantations in the WS could have added a few more species into the list.

It is remarkable that all four habitat types possessed distinct epiphytic orchid diversity, and that sharing occurred mostly along transition zones. Based on different diversity indices explored, EVEG was the most diverse habitat for epiphytic orchids. Next, MDEC, MEVG, and SEVG habitats shared a more or less equal number of species. As Annaselvam & Parthasarathy (2001) discussed, sometimes epiphytic orchids that preferred deciduous trees in low wet evergreen forests contributed largely to abundance. As per the rate of species accumulation in response to individuals, EVEG habitat clearly varied from other habitats as was also indicated by the dominance index. Nonetheless, with few more transects all habitats could have added new species. In MEVG habitat the best explained rad model pre-emption was rather steep compared to suggested models for other habitats. This indicated less species evenness in MEVG habitat. Generally, log-normal models indicate habitats that are at equilibrium or perturbation is maintained, here for SEVG and MDEC. Whereas undisturbed forest such as EVEG and MEVG, however, may not necessarily be at equilibrium and do not fit log normal, a model for undisturbed habitat. A hierarchy based on dominance was evident in MEVG with less species evenness and therefore best explained by dominance pre-emption model. Null model for EVEG indicated a more neutral community with no species interactions among them and species equivalence or in other words more random. This might be because of the random distant presence of species or individuals in EVEG when compared with MDEC, where the species distribution was rather closer. Because of the absence of distinct patterns in composition from sampled data there

Table 4. Orchid diversity across habitat types.

Orchid Diversity	Habitat			
	EVEG (N= 12)	MDEC (N= 6)	MEVG (N= 9)	SEVG (N= 13)
Rarefied species richness*	20	13	12	12
Individuals	579	679	317	1253

*rarefied at 301 individuals

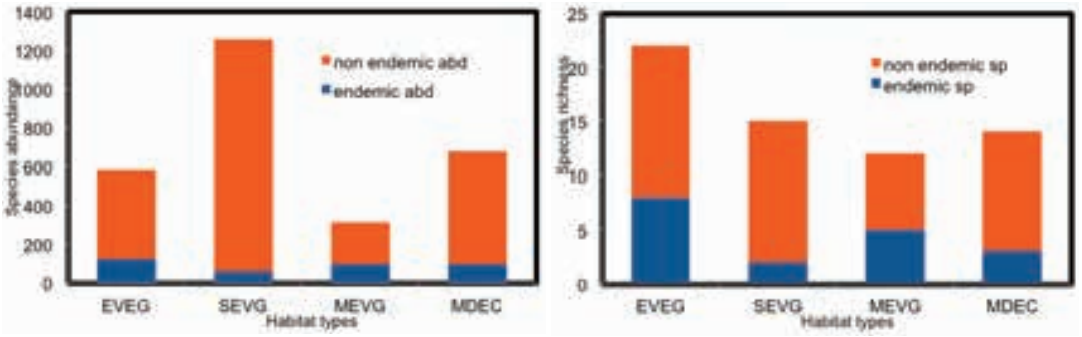

Figure 7. Pattern of (left) abundance (abd) and (right) species diversity (sp) of endemic epiphytic orchids in total sampled orchids from Aralam WS.

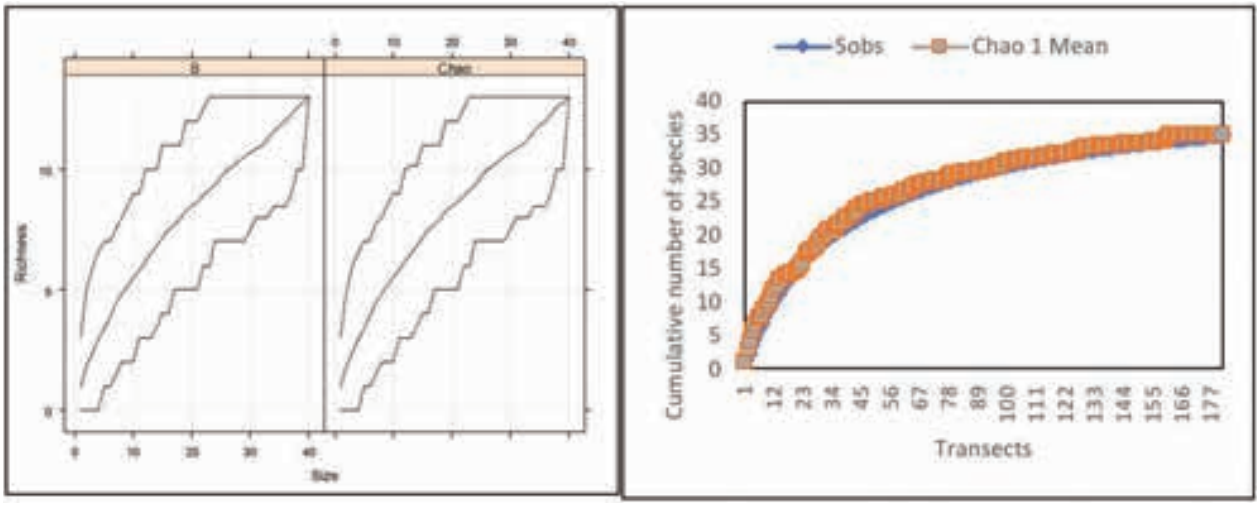

Figure 8. (left) Species richness and estimated richness using Chao in Aralam WS (right) species accumulation of endemic epiphytic orchids from 181 transects in the southern Western Ghats of Kerala, showing the observed and the estimated Chao-1 means (Refer: Sebastian et al. 2017).

was no significant difference between species richness across habitats. The trend of results suggested a possible preference of epiphytic orchids towards evergreen habitats. The two habitats of evergreen nature gathered 27 epiphytic orchid species of a total 39 species.

Wet evergreen and montane wet evergreen habitats from low to high elevations also supported both epiphytic and terrestrial endemic orchids in Aralam WS. It is suggested that long term research in these habitats could throw light on new perspectives on distribution of Endemic orchids. This area is located in Nilgiris-Silent valley-Wayanad-Kodagu region, a centre of endemism in the Western Ghats. This probably contributed to the high rate of endemism. Of 62 orchid species, 18 represented endemic orchids of the Western Ghats. Endemic orchids obtained from Aralam WS exhibited similar distribution patterns in as other studies (Sebastian et al. 2017).

The results obtained shows that all studied habitat

Image I . Some epiphytic orchids recorded from Aralam Wildlife Sanctuary. © Arun TR.

types contribute to epiphytic orchid diversity and abundance in Aralam WS. An integrated approach to address both epiphytic and terrestrial orchids might pave the way to understanding the pattern of endemism among orchids. The location, size and diversity of the Aralam WS provides an opportunity for scientists to do a full-fledged experimental study on the mechanisms behind its floral and faunal diversity.

REFERENCES

Abraham, S. & P.S. Easa (1999). Additions to the amphibian fauna of Aralam Wildlife Sanctuary. *Cobra* 38: 12–13.

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

Annaselvam, J. & N. Parthasarathy (2001). Diversity and distribution of vascular epiphytes in a tropical evergreen forest at Varagalaiar, Western Ghats, India. *Biodiversity and Conservation* 10(3): 317–329. https://doi.org/10.1023/A:1016670621331

Benzing, D.H. (1990). *Vascular Epiphytes General biology and related Biota.* Cambridge University Press, Cambridge, United Kingdom, 354pp.

Benzing, D.H. (2004). Vascular epiphytes, pp. 175–211. In: Lowman, M.D. & H.B. Rinker (eds.). *Forest Canopies*. Elsevier Academic Press, San Diego, California, USA, 501pp.

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of the Forest Types of India.* Natraj Publishers, Dehradun, India, 404pp.

Dantas, K.J., N. Sasidharan & K.V. Binu (2016). Additions to the angiosperms of the flora of Kannur district, Kerala, India from Aralam Wildlife Sanctuary. *Annals of Plant Sciences* 5(7): 1381–1388. https://doi.org/10.21746/aps.2016.07.003

Huang, H.W. (2011). Plant diversity and conservation in China: planning a strategic bio resource for a sustainable future. *Botanical Journal of the Linnaean Society* 166(3): 282–300. https://doi.org/10.1111/j.1095-8339.2011.01157.x

Jacquemyn, H., O. Honnay & T. Pailler (2007). Range size variation, nestedness and species turnover of orchid species along an altitudinal gradient on Reunion Island: Implications for conservation. *Biological Conservation* 136: 388–397. https://doi.org/10.1016/j.biocon.2006.12.008

Jalal, J.S. & G.S. Rawat (2009). Habitat studies for conservation of medicinal orchids of Uttarakhand, Western Himalaya. *African Journal of Plant Science* 3(9): 200–204.

Jalal, J.S. & J. Jayanthi (2012). Endemic orchids of peninsular India: a review. *Journal of Threatened Taxa* 4(15): 3415–3425. https://doi.org/10.11609/JoTT.o3091.3415-25

Jalal, J.S. (2012). Status, threats and conservation strategies for orchids of the western Himalaya, India. *Journal of Threatened Taxa* 4(15): 3401–3409. https://doi.org/10.11609/JoTT.o3062.3401-9

Jayalakshmi, P.S. (2016). Are the existing publications enough to study the endemic orchids of the Western Ghats?: A case study by using three major orchid publications from Kerala. MSc Thesis submitted to MG University, Kottayam, Kerala, 40pp.

Joseph, J. (1982). *Orchids of Nilgiris*. Records of the Botanical Survey of India, Howrah, Calcutta, 144pp.

KFD (2009). Aralam Wildlife Sanctuary Lifeline of Kannur. Kerala

Forests and Wildlife Department. On the Silver Jubilee of Aralam Wildlife Sanctuary, Kannur, 73pp.

Kumar, C.S. (1999). Orchids of Silent Valley, pp. 191–216. In: Manoharan, T.M., S.D. Biju, T.S. Nayar & P.S. Easa (eds.). *Silent Valley Whispers of Reason*. Kerala Forest Department, Thiruvananthapuram, Kerala, 456pp.

Kumar, C.S. & K.S. Manilal (1994). *A Catalogue of Indian Orchids*. Bishen Singh Mahendra Pal Singh, Dehradun, India, 162pp.

Kumar, C.S. & K.S. Manilal (2004). Orchids of Kerala, India, pp. 155–252. In: Manilal, K.S. & C.S. Kumar (eds.). *Orchid Memories*: *A Tribute to Gunnar Seidenfaden.* Mentor Books & IAAT, Calicut, Kerala, 265pp.

Kumar, P., Rawat G.S. & H.P. Wood (2011). Diversity and ecology of *Dendrobiums* (Orchidaceae) in Chotanagpur Plateau, India. *Taiwania* 56(1): 23–36. https://doi.org/10.6165/tai.2011.56(1).23

Kumar, S., B.V. Shetty, D. Bennett & S. Molur (2000). Report of the Conservation Assessment and Management Plan Workshop on Endemic Orchids of the Western Ghats. Zoo Outreach Organisation & CBSG South Asia, Coimbatore, India, 150pp.

Manju, C.N., Rajesh, K.P. & P.V. Madhusoodanan (2009). Contribution to the bryophyte flora of India: the Aralam Wildlife Sanctuary in the Western Ghats. *Archive for Bryology* 42: 1–12.

Menon, A.R.R. (1999). Vegetation mapping and analysis of Aralam Wildlife Sanctuary using remote sensing techniques. KFRI Research Report 168,Kerala Forest Research Institute, Peechi, Kerala, 20pp.

Nadkarni, N.M. (1994). Diversity of species and interactions in the upper tree canopy of forest ecosystems. *American Zoologist* 34(1): 70–78.

Nair, V.P. (2001). Butterflies attracted to light at Aralam Wildlife Sanctuary, Kerala. *Zoos' Print* 16(12): 670.

Nair, V.P. (2003). Congregations of Common Crow butterflies *Euploea core* (Cramer) at Aralam Wildlife Sanctuary, Kerala. *Journal of the Bombay Natural History Society* 100(2/3): 632–633.

Nair, S.C. (1991). *The southern Western Ghats: a biodiversity conservation plan*. Indian National Trust for Art and Cultural Heritage, In Monographic series: Studies in Ecology and sustainable development no.4, New Delhi, 92pp.

Padmawathe, R., Q. Qureshi & G.S. Rawat (2004). Effects of selective logging on vascular epiphyte diversity in a moist lowland forest of Eastern Himalaya, India. *Biological Conservation* 119(1): 81–92. https://doi.org/10.1016/j.biocon.2003.10.024

Pradhan, U.C. (1976). *Indian Orchids: Guide to Identification and Culture Vol I*. Premulaceae Books, Kalimpong, India, 188pp.

Pradhan, U.C. (1979). *Indian Orchids: Guide to Identification and Culture Vol II*. Premulaceae Books, Kalimpong, India, 189–747pp.

Radhakrishnan, C. (1996). Amphibians from Aralam Wildlife Sanctuary, Western Ghats, Kerala. *Zoos' Print* 11(8): 5–6.

Rajesh, K.P. & P. Vijisha (2016). Pteridophyte flora of Aralam Wildlife Sanctuary, Kerala-A preliminary analysis. *Cryptogam Biodiversity and Assessment* 1(1): 71–74. https://doi.org/0.21756/cba.v1i1.11020

Ramesh, B.R. (2001). Patterns of Vegetation, Biodiversity and Endemism in the Western Ghats. In Y. Gunnell & B. Radhakrishna, *Sahyadri-The great escarpment of the Indian Subcontinent*. Kolkata: Geological Survey of India, 1053pp.

Richards, P.W., R.P.D. Walsh, I.C. Baillie & P. Greig-Smith (1996). *The Tropical Rainforest: An Ecological Study*. Cambridge University Press, Cambridge, UK, 575pp.

Sebastian, J., S.R. Rathinavel, P.S. Jayalakshmi & G. Kuriakose (2017). An Experimental Approach to Study the Distribution of Endemic Orchids In The Southern Western Ghats, pp. 217–243. In: *Proceedings of Ecology 2017 International Symposium,* Turkey.

Sinu, P.A., G. Kuriakose & K. Chandrashekara (2011). Epiphytic orchid diversity in farmer managed Soppinabetta forests of the Western Ghats: implications for conservation. *Current Science* 101(10): 1337–1346.

Sreekumar, P.G. & M. Balakrishnan (2001). Habitat and altitude preferences of butterflies in Aralam Wildlife Sanctuary, Kerala. *Tropical Ecology* 42(2): 277–281.

Webb, L.J. (1959). A Physiognomic classification of Australian rainforests. *Journal of Ecology* 47(3): 551–570.

Wolf, J.H.D., S.R. Gradstein & N.M. Nadkarni (2009). A protocol for sampling vascular epiphyte richness and abundance. *Journal of Tropical Ecology* 25: 107–121. https://doi.org/10.1017/S0266467408005786

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Status and conservation needs of *Cycas pectinata* Buch.-Ham. in its natural habitat at Baroiyadhala National Park, Bangladesh

M.K. Hossain [1], M.A. Hossain [2], S. Hossen [3], M.R. Rahman [4], M.I. Hossain [5], S.K. Nath [6] & M.B.N. Siddiqui [7]

[1,2] Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh.
[3] Department of Forestry and Environmental Science, Rangamati Science and Technology University, Rangamati Hill District, Bangladesh.
[4] Faculty of Environment and Natural Resources, Albert-Ludwigs-Universität Freiburg, 79085 Freiburg, Germany.
[5] Project Management Unit, Forest Department, Dhaka, Bangladesh.
[6] Climate Change and Protected Area Management Officer, CREL Project, Community Development Centre (CODEC), Bangladesh.
[7] Forestry Development and Training Centre (FDTC), Bangladesh Forest Department, Kaptai, Rangamati, Bangladesh.
[1] mkhossain2009@gmail.com, [2] akhter.hossain@cu.ac.bd (corresponding author), [3] saddamhossen.cu@gmail.com,
[4] rayhanur.pavel@gmail.com, [5] iftienv@yahoo.com, [6] smati71@yahoo.com, [7] baktiar1971@gmail.com

Abstract: The widespread cycad *Cycas pectinata* was first discovered in the Bengal region by William Griffith in Baroiyadhala forest of Chattogram in 1838. In Bangladesh, this species is confined to a few hills at Baroiyadhala, Sitakunda upazila of Chattogram district. Though the Baroiyadhala forests were declared a national park in 2010, the loss of this native gymnosperm from this forest is alarming. The present study aimed to assess the status of *C. pectinata* populations in its native range, identify the drivers responsible for ongoing losses, and identify locations of *C. pectinata* occurrence in Baroiyadhala National Park suitable for in situ conservation. A random quadrat survey with 21 sample plots of 100 × 100 m was conducted during April–June 2018 in Baroiyadhala National Park. Population and growth data for *C. pectinata* were collected from each sample plot, along with observations of disturbances. Four focus group discussions (FGDs) were conducted with adjacent local people. The study revealed presence of 12 *C. pectinata* individuals per hectare and five seedlings per hectare in the study area, and significant numbers of dead and burned Cycas were also found in some sites. Based on density, five *C. pectinata* hotspots were identified for in situ conservation programs. Habitat destruction, indiscriminate fire, and unsustainable harvesting of leaves and male and female cones are responsible for rapid declines in *C. pectinata* populations in its wild habitat. Measures for protection and restoration of the species are creating awareness among the local people about ecological importance of this species; enhancing protection; banning trade of Cycas; creating opportunities of sustainable livelihood for local people to reduce dependency on forests.

Keywords: habitat destruction, in situ conservation, IUCN Red List, protected area, natural regeneration, stand structure, species association, unsustainable harvesting.

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INTRODUCTION

Cycads are an ancient group of seed plants that originated over 280 million years ago. Globally, there are 10 genera and 352 species of cycads, with 117 species belonging to the genus *Cycas* (Stevenson et al. 2018) under the Cycadaceae family. In the Indian subcontinent eight species of *Cycas* are reported, among which only *Cycas pectinata* grows naturally in Baraiyodhala, Bangladesh (Lindstrom & Hill 2007). The species was first recorded in 1826 by Buchanan-Hamilton in Bengal. Natural distribution of the species is reported from Bhutan, China, India, Laos, Myanmar, Nepal, Thailand, and Vietnam (Stevenson et al. 2018).

Cycas pectinata Buch.-Ham., commonly known as Cycas, is an evergreen palm-like tree up to 3m in height that was first discovered by William Griffith from Baroiyadhala forest of Chittagong in 1838. Additional descriptions of the species were later added by Lindstrom & Hill (2007), Khuraijam & Singh (2014), and Stevenson et al. (2018), along with many other researchers. In Bangladesh, it is naturally confined to a few hills near Baroiyadhala in Sitakunda (Khan et al. 2001; Rahman 2006; Dutta et al. 2014; Harun-Ur-Rashid et al. 2018). The present Baroiyadhala National Park (BDNP) is one of the main native sites of Cycas species in the country. The species is very important to the locals, e.g., leaves of Cycas are widely used for bouquets, megasporophylls are sold in the local markets as the seeds are thought to be aphrodisiac. The stem yields coarse sago, which with the fruits is eaten by the hill people in Sikkim (Watt 1889). Similar uses of *C. pectinata* were also reported from northeastern India by Khuraijam & Singh (2015). Singh & Khuraijam (2010) mentioned that population of this species becoming endangered in several regions of India. Widespread illegal extraction of the reproductive parts (male and female cones) limited the distribution and sustainable reproduction of *C. pectinata* (Khuraijam & Singh 2016). In addition, habitat degradation causes rapid dwindling of populations in its native ranges. Moreover, the population of wild Cycas is further decreasing due to habitat degradation and forest fire.

Few conservation measures have been taken in Bangladesh for protection of the species, aside from declaring Baroiyadhala as a National Park. If the current situation prevails and proper conservation initiatives are not initiated, it may further reduce the existing small population of *C. pectinata* and ultimately cause regional extinction (Singh & Khuraijam 2010). To conserve the remnant *C. pectinata* population in its wild habitat, it is important to know the present status (e.g., density, distribution, regeneration) and the threats of the species in its natural ranges. Unfortunately, there is dearth of information regarding the population structure, distribution, regeneration, disturbances, and prominent threats of *C. pectinata* in its natural habitat of Bangladesh.

The present study aimed to assess of the status of *C. pectinata* in its native range of BDNP, measure the extent of disturbances (i.e., death, illegal cutting, burnt), identify threats, and recommend conservation needs. Findings are expected to be helpful in preparation of a comprehensive in situ conservation plan for this species. The study is also expected to be helpful for a regional threat assessment of the species and which may turn out the species to have higher threat status than that given in global assessment.

METHODS

Study area

Baroiyadhala National Park (BDNP) lies between 22.650–22.783N latitude and 91.583–91.683E longitude covering an area of 2,933.61 ha in the hilly area of Sitakunda and Mirsharai upazilla of Chattogram district. BDNP is under the jurisdiction of Chittagong North Forest Division and includes the entire area of Baroiyadhala and Wahedpur blocks of Baroiyadhala forest beat and Kunderhat block of Bortakia forest beat under Baroiyadhala Forest Range. The National Park is located approximately 207 km south-east from Dhaka and 40 km north from Chattogram city. BDNP, consisting of tropical semi-evergreen forests, was established in 2010 through a gazette notification under Bangladesh Wild Life (Preservation) (Amendment) Act, 1974.

The area is characterized by tropical monsoon climate. The south-west monsoon provides the majority of the annual rainfall. Average annual rainfall of the area is 3,000 mm with a range of 1,611–3,878 mm. On average highest rainfall occurs in July (727 mm) and the lowest rainfall in January (5–6 mm). Temperature range of the area is 12.5–37 °C. Temperature and humidity range 7.2–38.9 °C and 67–88 % respectively round the year (Hossain 2015). The low hill ranges cover part of Hazarikhil Wildlife Sanctuary (HWS) while the rest is in the Bengal flood plain. The soils in this area range from clay to clayey loam on level ground and from sandy loam to coarse sand on hilly land.

Community Development Centre (CODEC) with support from the BFD and United States Agency for International Development (USAID) established forest co-management program in the BDNP in November 2014 under the Climate Resilient Ecosystems and Livelihoods (CREL) project (USAID 2018). It formed the co-

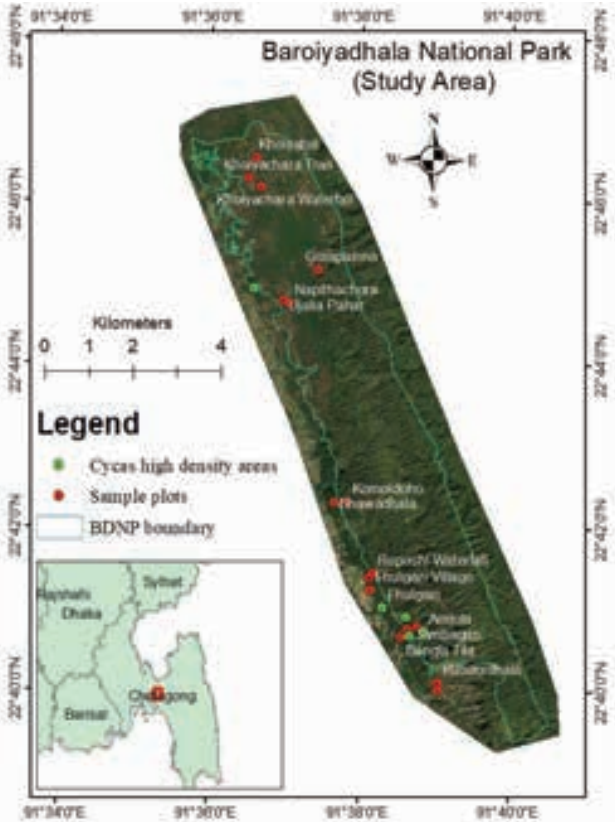

Figure 1. Location of the sample plots and high-density areas of *C. pectinata* at Baroiyadhala National Park of Bangladesh.

management committee (CMC) which had a critical role in protecting the forests. Though, now-a-days, due to lack of financial supports, the CMC activities are very limited but, apparently, the CMC played significant role in the governance and management of the protected area. The FD conducted afforestation and enrichment plantations for increasing green coverage and restoration of degraded forests. A large number of the surrounding communities from both Mirsharai and Sitakunda upazila are more or less dependent on the landscape for different types of forest resources. It is supposed that, all these may have greatly influenced the overall forest condition.

Field data collection

Field data for the study is collected *C. pectinata* population and natural regeneration related data through surveying randomly selected quadrats in the forests of BDNP. In addition, a community consultation in the form of focus group discussion (FGD) has been made to identify the threats, possible solutions to those threats and finding effective ways of conserving *C. pectinata* habitats.

Forest survey

C. pectinata occurs sporadically being mixed with other mixed- and semi-evergreen tropical hardwood tree species in the hilly terrain of BDNP. Simple random sampling (SRS) was appeared to be one of the simplest and appropriate method to study the Cycas species considering its distribution, overall forest conditions along with the time and scope of the study following Kohl & Magnussen (2016). SRS provides the same selection probability for all possible distinct samples (Schreuder et al. 2004; Kohl et al. 2006). A total of 21 quadrats of 100 × 100 m size were laid to cover a sample intensity of about 0.72%. Total height, diameter at base (10 cm above the ground) and top (just beneath the base of lowest frond), number of fronds of all the Cycas individuals were collected from each plot. The tree species occurred in the sample plots were treated as the associated tree species of *C. pectinata* and recorded with the names along with the nature of origin. Numbers of seedlings were also counted and recorded from the same sample plot to assess the natural regeneration status of this threatened species. *Cycas* having ≤10 cm total height was defined as regeneration. Disturbances (i.e., fire, illegal cutting, etc.) to the Cycas, if observed during the quadrat survey, were also recorded.

Focus group discussion

FGD is commonly used to explore and construct knowledge about a particular topic in small groups (Liamputtong 2011; Krueger & Casey 2015). It has been proved as an efficient and informative tool for conducting participatory research data collection regarding different aspects of forests at local level by Kumer & Urbanc (2020) and Egunyu et al. (2016). Encouraged by the popularity of qualitative research tools for empathizing the link between forests and society, we used FGD to explore the prevailing threats to the Cycas following the methods of Miller & Scoptur (2016) and Kumer & Urbanc (2020). Four FGDs were set for gathering community perceived information about *C. pectinata*. The local stakeholders were consulted in the FGDs at four different locations of BDNP. The FGDs were guided through a semi-structured questionnaire. Community perceived information about the distribution of the Cycas, present status in its natural territory, threats and possible control measures to the existence and natural regeneration of the species were discussed. Finally, a stakeholder consultation meeting in the Baroiyadhala CMC office was conducted to obtain community opinions and recommendations in order to prepare a future conservation strategy.

Data compilation and analysis

The quadrat survey data were compiled in MS Excel for assessing the density and stand characteristics (i.e., average height and diameter) following Sharma & Zhang (2004) and Caceres et al. (2019). Based on the higher density of Cycas individuals, five locations of higher abundance were marked in BDNP. Pearson correlation was used to compare terrestrial tree species with density of Cycas. The qualitative information gathered from the FGDs was presented as tables and visuals. Based on the FGD data, we computed the community perceived extent of the imminent threats to this species. The probable solutions to the identified threats and proposed conservation measures were emphasized as per the priority given by the communities.

RESULTS AND DISCUSSION

C. pectinata population

The quadrat survey revealed that density of *C. pectinata* individuals is 11.57±1.88 stem/ha and distribution varied across the BDNP. Inside the BDNP, numbers of individuals varied from one in Khoiyatoli to 26 stem/ha in nearby areas of Napittachara and Fhulgazi villages. The species occurs mainly in the steep hill slopes and altitudes ranging from 30–150 m. A few individuals were also found on the stream banks. However, in some localities i.e., Khoiyachara and Bhawadhala of BDNP, no *C. pectinata* were observed. Khuraijam & Singh (2014) mentioned presence of this species near water bodies in India. Moreover, they reported higher density of this species at 50–250 m altitude. The species is found at 1,250 m altitude though the usual distribution is 500–800 m (Lindstrom & Hill 2007; Osborne et al. 2007). Considering the density of *C. pectinata* in BDNP, five high density areas were identified and shown in the map (Figure 1). The *C. pectinata* specific conservation and management activities may be emphasized centering these high-density locations but not ignoring the low-density areas.

Associates tree species of *C. pectinata*

Field observations indicated that *C. pectinata* grows below the canopy of both native and exotic tree species in both natural (i.e., Amloki *Phyllanthus emblica*, Bahera *Terminalia bellirica*, Bhadi *Lannea coromandelica*, Chatim *Alstonia scholaris*, Dumur *Ficus hispida*, Kanchan *Bauhinia acuminata*, Koroi *Albizia procera*, Sheora *Streblus asper*, and Simul *Bombax ceiba*) and plantation forests (i.e., Akashmoni *Acacia auriculiformis*, Gamar *Gmelina arborea*, Jarul *Lagerstroemia speciosa*, South American Raintree *Albizia saman*, and Segun *Tectona grandis*).

Ficus hispida is the most widely occurring species (52.4% sample plots) in the study area followed by *T. grandis* and *B. acuminata* (each with 42.9% sample plots) and *A. saman* and *A. auriculiformis* (each with 38.1% sample plots). Comparatively higher positive correlations (Pearson correlation +0.41) was found between *C. pectinata* and *B. acuminata* followed by *S. asper* (Pearson correlation +0.25) and *B. ceiba* (Pearson correlation +0.20). The study indicates that positive correlation of the density of Cycas exists with only native tree species except *S. saman* (Pearson correlation +0.19) which is a naturalized exotic tree species in Bangladesh. Besides, occurrence of Kuruch *Holarrhena antidysenterica* showed comparatively higher negative correlation (Pearson correlation -0.29) with density of Cycas followed by Sungrass (*Imperata cylindrica*, -0.23). However, none of the positive correlations were statistically significant. Singh & Khuraijam (2010) mentioned Bamboo, Rattans, and Sal *Shorea robusta* as the associated species in Sikkim and West Bengal of India but in BDNP we haven't found these species in association of *C. pectinata*. It indicates growth of the Cycas with wide range of associated species.

C. pectinata stand characteristics

Stand structure of *C. pectinata* in BDNP is presented through total height (0.96 ± 0.12 m), base diameter (9.72 ± 1.21 cm), top diameter (5.11 ± 0.57 cm) and number of leaf (10 ± 0.90). The mean stem height of *Cycas* varies from 0.72 m to 1.42 m in BDNP, whereas the highest

Table 1. Stand parameters of *C. pectinata* in five identified hotspots of Baroiyadhala National Park.

Location of plots	n*	Average total height (m)	Average base dia. (cm)	Average top dia. (cm)	Average number of leaves
Dottorichora	18	0.72	9.68	4.71	10
Jambagan	26	1.42	13.58	6.78	13
Amtola	21	1.03	9.50	5.40	12
Fhulgazi	26	0.93	10.65	5.74	10
Taraghona Hill	22	0.72	5.18	2.93	7

*n= Number of individuals sampled per location.

height (1.42 m) of the species is recorded from Jambagan (Table 1). Jambagan is also represented by *Cycas* with highest average base and top diameter (13.58 cm and 6.78 cm, respectively). The average number of leaf per *Cycas* plant varied from 7 in Taraghona to 13 in Jambagan. It seems that *Cycas* in Jambagan is in better health than other hotspots. *Cycas* can grow up to 18 m as reported by Khuraijam & Singh (2014) from northeastern India where they showed that most of the Cycas were between 1–3 m height range. The mean height and DBH of this species in Assam are 3 m and 15 cm, respectively, whereas height and DBH are 1.6 m and 10 cm, respectively, in Manipur. The study methods differ, but provide an overall impression that *C. pectinata* growing in BDNP are close to those of Manipur in terms of height and diameter.

C. pectinata regeneration status

This study provides insights into the status of natural regeneration of *C. pectinata* through the assessment of the number of seedlings per hectare. The forest survey revealed that there were about five *C. pectinata* seedlings per hectare area of BDNP. The density of seedlings varied widely across the national park. In the five high density locations, the seedling density varied from 7 seedlings/ha in Dottorichora to 14 seedlings/ha in Taraghona hill (Figure 2). The reproductive rate of *C. pectinata* is also very small in Sikkim and West Bengal (Singh & Khuraijam 2010). There are a number of reasons behind the poor natural regeneration. Cycads are slowly growing plants taking 3–10 years to become sexually mature (Dyer 1965). Cycads can reproduce naturally using both short-lived seeds and stem offshoots or suckers (also called pups) (Demiray et al. 2017). The seeds of *Cycas* spp. are held in the cones for about nine months. Very few seeds germinate in nature, resulting in few seedlings in the wild and thus decline of Cycads (Forsyth & Staden 1983). Moreover, Cycads are dioecious plant and only very rarely the timing of cone development in male and female plants match (Cheek 2000; Lindstrom & Hill 2007). Woodenberg et al. (2010, 2014) mentioned rare pollination and sensitivity of seeds to desiccation as two more reasons for poor natural regeneration of Cycads.

Disturbance indicators to *C. pectinata* in the wild

Anthropogenic disturbances, i.e., cutting, collection and forest fires were observed in BDNP, which severely affected the *C. pectinata*. Illegal cutting of *Cycas* at a rate of 0.29 (± 0.21) stem/ha is observed across the study area, whereas number of *C. pectinata* damaged by fire is 0.81 (±0.61). Two percent of the *C. pectinata* population is affected by illegal cutting, while forest fires affected

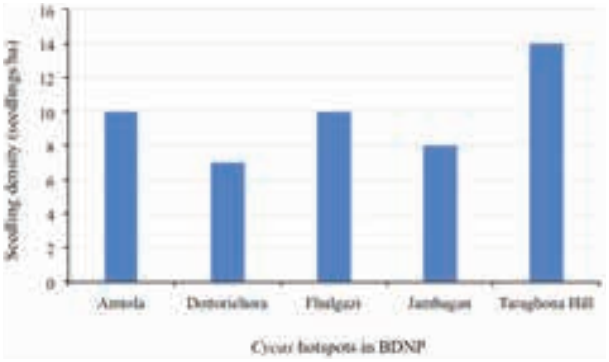

Figure 2. Density of *C. pectinata* seedlings in Baroiyadhala National Park.

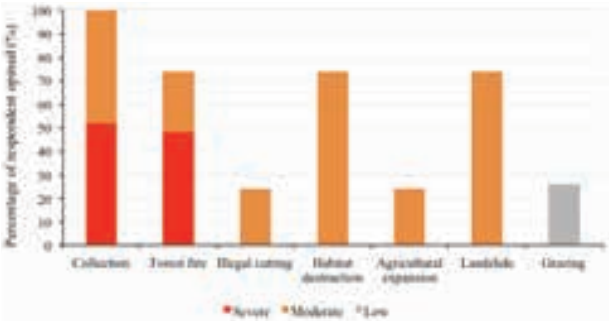

Figure 3. Percentage of respondents opined about the severity of disturbances.

about 5.9% of the population. Fire is severe in some locations of BDNP, e.g., Hutukhola and Dottorichora. Moreover, there are other anthropogenic disturbances like collection (i.e., Cycas leaf for decoration, sporophylls for medicinal purpose), habitat destruction through excessive extraction of forest resources, trade of Cycas plant, grazing, agricultural expansion, etc. (Figure 3). The forest survey indicated the number of died *C. pectinata* individuals is 1.95 (±1.21) individual/ha. Taking into account the loss due to forest fire and illegal cutting, the study estimated that about 7.8% of the total *C. pectinata* population is being lost due to the disturbances. However, the simultaneous natural regeneration of the species may fill the loss and restore the *C. pectinata* population if protected from disturbance. Mortality of *Cycas* is high in a number of locations, i.e., Hutukhola (12 individuals/ha), Dottorichora (5 individuals/ha), Ruposhijhorna (3 individuals/ha), and Khoiyatoli (2 individuals/ha).

Threats to *C. pectinata* in BDNP

The study identified 10 prominent threats to Cycas through FGD and field observation. The threats may put the species at higher danger in near future if left unattended. Fire infestation, over-exploitation of forest

Table 2. Suggestions to address threats mentioned by the participants of FGD.

	Threats	Suggestions to address the threats
1	Anthropogenic habitat destruction	· Regular patrolling by BFD staff; · Raising mass awareness among people living in vicinity of the National Park about the importance of habitat protection; · Regular meeting between BFD and local stakeholders; · Collection of monitoring data for assessing habitat indicators to track the changes of habitat quality.
2	Extraction of forest resources	· Forest law enforcement; · Creating opportunity for alternative livelihood generation of the forest dependent local people (i.e. providing AIGA, training for diversifying income sources, promoting eco-tourism etc.); · Raising mass awareness about the importance of maintaining natural habitat of *C. pectinata*; · Empowering existing CMC for persuading people to stop illegal forest resource extraction; · Regular field visits and meeting with the local people might help.
3	Cycas extraction	· Forest law enforcement for *C. pectinata* plant part (i.e. leaf, fruit) collectors and users; · Involving CMC for motivating local collectors and protecting *Cycas* population; · Banning collection of cones or sporophylls for any medicinal purpose; · Strict prohibition of selling or buying any Cycas plant parts; · Installing signboard and posters in relevant locations about the offences and associated punishments for *Cycas* collectors.
4	Fire infestation	· Enforcement of strict rules and regulations for not allowing smoking in the forest, making any fire for any purpose and doing any interference in the forest which may be a reason to create fire inside forest; · Formation of local fire response team; · Raising mass awareness about the damaging impact of fire; · Make fire lines around conservation plots; · Involving CMC for monitoring and fighting fire in BDNP.
5	Grazing	· Control grazing in terms of Forest Act and PA Management Rules; · Involving CMC to help local BFD staff to control grazing;
6	Hunting	· Informing people about the negative sides of hunting and conservation of faunal diversity; · Creating social barrier for people involving in hunting and poaching; · CMC can help prohibiting people carrying any sort of traps, guns, baits and poison etc.
7	Lack of effective management	· Recruit and allocate sufficient skilled manpower for BFD; · Train and motivate BFD staff to make them knowledgeable, dedicated and skilled for effective forest management; · Give special attention for management of *C. pectinata* in the PA management programs.
8	Lack of mass awareness	· Distributing posters and installing billboards or signboards highlighting the forest resource management and conservation issues, i.e., *C. pectinata*, biodiversity, fire infestation, forest resource extraction, AIGA, eco-tourism etc. · Conducting education and outreach activities on *C. pectinata* to the villages; · Proving training and conducting periodic campaign on concurrent issues; · Involve CMC, local government, social and religious leaders to aware local people; · Recognizing the species as an important and valuable part of our heritage and environment; · Local leaders from different social strata can be invited in different meetings, seminars and workshops on issues related to forest management, biodiversity conservation, threatened/native species conservation etc.
9	Lack of political will	· Nature loving political elites can be invited in BDNP who may motivate local politicians to help BFD local units for effective PA management; · Local politicians should be given due respect by involving them in forest management activities and inviting them in relevant seminars and workshops; · Local politicians can be made aware about the existing laws, rules and government policies regarding forest management and conservation.
10	Landslide	· Strict patrolling before the monsoon to prevent any practices that may promote landslide; · Conducting plantations with site specific/local/native species after settlement of the collided soil in landslide regions; · Identify hills (i.e., barren hills, hills with soil erosion) with prone of landslide and conduct afforestation or enrichment plantation.

resources including Cycas plant parts (e.g., leaves, fruit) are the major threats as mentioned by all the participants in FGDs (Figure 4). Cycads are of great ornamental value which makes people greedy to uproot young basal suckers, unscrupulously collect leaves and cones (Image 1) to sell in the market. Besides these, landslide and anthropogenic habitat destruction are two prominent threats that may cause significant damages to Cycas population in the future. Singh & Khuraijam (2010) also mentioned illegal trade and Cycas habitat destruction as two major threats responsible for depletion of its population in the wild of Sikkim and West Bengal, India. Similar threats are also mentioned by researchers worldwide as contributing to reduction of Cycad populations (da Silva et al. 2014; Khuraijam & Singh 2015; Demiray et al. 2017).

Strengthening patrolling and enforcement of forest law through building capacity of BFD to implement the newly adopted managerial measures are the suggested means to be taken immediately for addressing threats. Moreover, raising mass awareness is a must for making the initiatives sustainable. Table 2 describes threat-specific measures.

Image 1. *C. pectinata*: A—adult Cycas with robust stem and dense leaves | B—mature Cycas | C—male cone | D—female sporophyll | E—partial damage of Cycas by fire infestation | F—fire burnt Cycas | G—almost dead Cycas | H—cut Cycas. © Mohammed Kamal Hossain

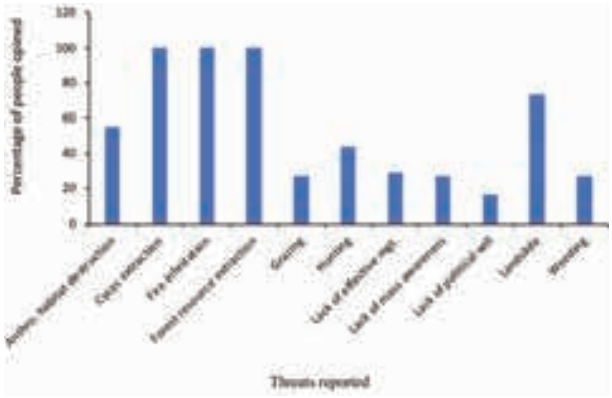

Figure 4. Percent of people opined about the threats to *C. pectinata* in BNDP (Note: here, N= 55).

Need for conservation programs

Globally, cycads are threatened with many species at high risk of extinction. There was a common belief that the species is common across northeastern India, but it is actually mostly restricted to native habitats (Whitelock 2002; Lindstrom & Hill 2007). *C. pectinata* being the most wide spread cycad is now under threat as populations are declining rapidly compared to other Cycas (Khuraijam & Singh 2014), and the species is at the verge of extinction in northeastern India. The threats originate from anthropogenic interferences including agricultural expansion through destruction of wild populations, strip mining, collection of cones for medicinal uses, domestic & commercial development, and the trade of ornamental plants (Osborne 1995; Donaldson et al. 2003; Vovides et al. 2003).

Conservation of floral resources is a must for sustainable management of the natural resources of any country. Conservation is essential to maintain the existence of life on earth (Subrahmanyam & Sambamurty 2006). According to the World Summit on Sustainable Development (WSSD), CBD is the key instrument for the conservation and sustainable use of biological diversity. It also promotes fair and equitable share of benefits arising from the use of genetic resources. The conservation methods will, however, vary according to the specific objectives of conservation, and the distribution and biological nature of the material to be conserved. Conservation methods are often used to denote in situ conservation, ex situ conservation, ecosystem conservation, static conservation, selective conservation,

conservation in use, and possibly more.

Conservation means of *C. pectinata*

A variety of conservation actions can be undertaken for threatened trees, each approach offering different merits. Not all approaches will be suitable for cycads, and the appropriate action will be dependent on the nature, distribution and habitat features of this species. Cycads are considered having a high conservation priority from both scientific and biodiversity point of view as they don't have very close living relatives (Norstog & Nicholls 1997; Donaldson 2003).

These plants have very specialized pollinators, and their re-establishment in nature is unlikely to be successful without a profound knowledge of their biology. Against this background, we firstly promote interest in, and appreciation of, these plants by propagating and growing them as horticultural subjects. Secondly, we actively encourage scientific research and the documentation thereof so that we can keep the captive and remaining wild plants alive in years to come.

The global status of *Cycas pectinata* as per IUCN Red List is 'Vulnerable' A2c due to an estimated 30% reduction in global population in past 90 years and a decline in the habitat quality (Nguyen 2010). In Bangladesh the species is not assessed yet as per IUCN Red List categories and criteria. An initiative is undertaken in 2020 by BFD under Sustainable Forest and Livelihoods (SUFAL) project to assess 1,000 plant species of Bangladesh including *C. pectinata*. (Singh & Khuraijam 2010) suggested to prohibit all international trade of this species by putting it in the Appendix I of CITES. In urban areas, *C. pectinata* are grown in gardens and private nurseries as ornamental plants, but in forest areas the species is not popular for plantation programs. Considering the rapid depletion of the population of Cycas, both in situ and ex situ conservation programs are proposed.

Further research to develop better germination techniques by studying germination behavior of the seeds and tissue culture to propagate the rare endangered cycads can be an effective way for mass production and germplasm preservation. There is also a need for ecological niche modelling and population viability analysis for *C. pectinata*. Interventions based on the lessons learned (i.e., awareness raising of the local villagers, studying ecology and environment, development of management techniques) from the cycad conservation projects (i.e., Debao Cycad Conservation Project) accomplished across the world might be helpful for undertaking the best actions.

To date no comprehensive conservation measures have been taken for the protection of the species in Baroiyadhala National Park. According to Bangladesh Wildlife (Preservation), (Amendment) Act of 1974, any kind of killing, hunting or trapping of any wildlife, agricultural activities, living or entering in to the sanctuary of any persons or destruction to the sanctuary habitat are strictly prohibited. Finally, if a proper conservation plan is taken, it will be possible to protect and conserve the remnant *C. pectinata* populations in Baroiyadhala National park. It is our foremost responsibility to protect this native species along with bringing back the natural forests.

REFERENCES

Cheek, B. (2000). An introduction to Cycad reproduction. In: Biology of Cycads. Downloaded on 26 March 2020. http://www1.biologie.uni-hamburg.de/b-online/library/cycads/reproduction.htm.

da Silva, J.A.T., W.R. Woodenberg & S. Zeng (2014). Cycads in vitro. *Plant Tissue Culture and Biotechnology* 24(2): 287-301.

de Caceres, M., S. Martín-Alcón, J.R. González-Olabarria & L. Coll (2019). A general method for the classification of forest stands using species composition and vertical and horizontal structure. *Annals of Forest Science* 76(2): 40. https://doi.org/10.1007/s13595-019-0824-0

Demiray, H., A.E. Dereboylu, Z.I. Yazici, S. Bildik, K. Bülbül, S.G. Şenol & A.F. Pirhan (2017). In vitro seed germination of *Cycas revoluta* Thunb. *Bangladesh Journal of Botany* 46(2): 559-564.

Donaldson, J., K. Hill & D. Stevenson (2003). Cycads of the world: an overview, pp. 3-8. In: Donaldson, J. (ed.). *Cycads: Status Survey and Conservation Action Plan*. IUCN, Gland, Switzerland and Cambridge, UK, United Kingdom. 8 pp.

Dutta, S., M.K. Hossain, M.A. Hossain & P. Chowdhury (2014). Floral diversity of Sitakunda Botanical Garden and Eco-Park in Chittagong, Bangladesh. *Indian Journal of Tropical Biodiversity* 22(2): 106-118.

Dyer, R.A. (1965). The cycads of southern Africa. *Bothalia* 8(4): 405-408. https://doi.org/10.4102/abc.v8i4.1636

Egunyu, F., M.G. Reed & J.A. Sinclair (2016). Learning through new approaches to forest governance: evidence from Harrop-Procter community forest Canada. *Environmental Management* 57(4):784–797. https://doi.org/10.1007/s00267-015-0652-4

Forsyth, C. & J.V. Staden (1983). Germination of *Tagetes minuta* LI Temperature effects. *Annals of Botany* 52(5): 659-666.

Harun-Ur-Rashid, M., S. Islam & S.B. Kashem (2018). Floristic diversity (Magnoliids and Eudicots) of Baraiyadhala National Park, Chittagong, Bangladesh. *Bangladesh Journal of Plant Taxonomy* 25(2): 273–288. https://doi.org/10.3329/bjpt.v25i2.39532

Hossain, M.K. (2015). Protected area management plan for Hazarikhil Wildlife Sanctuary and Baraiyadhala National Park: 2015 – 2025 Bangladesh Forest Department-Ministry of Forests and Environment, Dhaka, Bangladesh,109pp.

Khan, M., M. Rahman & M. Ali (Eds.) (2001). *Red Data Book of Vascular Plants of Bangladesh*. Bangladesh National Herbarium, Dhaka, Bangladesh,179pp.

Khuraijam, J.S. & R. Singh (2014). Population assessment and distribution of *Cycas pectinata* Buchanan-Hamilton in Northeast India. *Pleione* 8(1): 17-25.

Khuraijam, J.S. & R. Singh (2015). Ethnobotany of *Cycas pectinata* Ham. in Northeast India. *Encephalartos* 119: 18-23.

Khuraijam, J.S. & R. Singh (2016). Illegal trade of *Cycas* cones in India, Bangladesh and Myanmar. *Cycads* 1(1): 20-21.

Köhl, M., & S. Magnussen (2016). Sampling in Forest Inventories, pp 777-837. In: Pancel, L. & M. Kohl (eds.). *Tropical Forestry Handbook*. Springer, Berlin, Heidelberg, 3633pp. https://doi.org/10.1007/978-3-642-54601-3_72

Köhl, M., S. Magnussen & M. Marchetti (2006). *Sampling Methods, Remote Sensing and GIS Multiresource Forest Inventory*. Springer Berlin Heidelberg, 373pp. https://doi.org/10.1007/978-3-540-32572-7

Krueger, R. & M.A. Casey (2015). *Focus groups: a practical guide for applied research*. Sage, Thousand Oaks, California, 280pp.

Kumer, P. & M. Urbanc (2020). Focus Groups as a Tool for Conducting Participatory Research: A Case Study of Small-Scale Forest Management in Slovenia, pp 207-220. In: Nared, J. & D. Bole (eds.). *Participatory research and planning in practice*. Springer Nature Switzerland AG, Cham, 227pp. https://doi.org/10.1007/978-3-030-28014-7_13

Liamputtong, P. (2011). *Focus group methodology: principles and practice*. Sage, London, 224pp. https://doi.org/10.4135/9781473957657

Lindstrom, A. & K. Hill (2007). The genus *Cycas* (Cycadaceae) in India. *Telopea* 11(4): 463-488.

Miller, P. & P. Scoptur (2016). *Focus groups: hitting the bull's-eye*. Association for Justice, Washington DC, 262pp.

Nguyen, H.T. (2010). *Cycas pectinata*. In: The IUCN Red List of Threatened Species 2010. Downloaded on 02 January 2020. https://doi.org/10.2305/IUCN.UK.2010-3.RLTS.T42062A10617695.en

Norstog, K.J. & T.J. Nicholls (1997). *The Biology of the Living Cycads*. Cornell University Press, Ithaca., New York, USA,384pp.

Osborne, R. (1995). An overview of cycad conservation in South Africa, pp. 1-7. In: J. S. Donaldson (ed.). *Cycad Conservation in South Africa, Issues, Priorities and Actions*. Cycad Society of South Africa, South Africa. 7pp.

Osborne, R., K.D. Hill, H.T. Nguyen & P.K. Loc (2007). *Cycads of Vietnam*. Satooz, Brisbane, Australia, 116 pp.

Rahman, M. (2006). *Cycas* – a rare and endangered indigenous species of Bangladesh to the verge of extinction. *Biodiversity Bangladesh* 8(1&2): 1-4.

Schreuder, H.T., R. Ernst, & H. Ramirez-Maldonado (2004). Statistical techniques for sampling and monitoring natural resources. Gen. Tech. Rep. RMRS-GTR-126. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station, 111pp.

Sharma, M. & S.Y. Zhang (2004). Height–Diameter Models Using Stand Characteristics for *Pinus banksiana* and *Picea mariana*. *Scandinavian Journal of Forest Research* 19(5): 442-451. https://doi.org/10.1080/02827580410030163

Singh, R. & J.S. Khuraijam (2010). Status and survey of *Cycas pectinata* Buchanon-Hamilton in Sikkim and West Bengal. *Pleione* 4(2): 235-239.

Stevenson, D.W., L. Stanberg & M.A. Calonje (2018). The World List of Cycads, pp. 540-576. In: N. Li, D. W. Stevenson and M. P. Griffith (eds.). *Cycad Biology and Conservation: The 9th International Conference on Cycad Biology*, Shenzhen, China. 1-7 December 2011. Memories of the New York Botanical Garden. https://doi.org/10.21135/893275389.035

Subrahmanyam, N. & A. Sambamurty (2006). *Ecology*, 2nd edition. Alpha Science International, Oxford, 664pp.

USAID (2018). Hazarikhil wildlife sanctuary: sustaining nature, biodiversity, and local communities. United States Agency for International Development (USAID), Dhaka, Bangladesh, 6pp.

Vovides, A., M.A. Perez-Farrera, J. Gonzáles-Astorga, D. González, T. Gregory, J. Chemnic, C. Iglesias, P. Octavio-Aguilar, S. Avendafio & C. Bareenas (2003). An outline of our current knowledge on Mexican cycads (Zamiaceae, Cycadales). *Current Topics in Plant Biology* 4: 159-174.

Watt, G. (1889). *A Dictionary of the Economic Products of India*. Cosmo Publications, Delhi, India, 675pp.

Whitelock, L.M. (2002). *The Cycads*. Timber Press. Portland, Oregon, 532pp.

Woodenberg, W.R., P. Berjak & N.W. Pammenter (2010). Development of cycad ovules and seeds. 1. Implication of the ER in primary cellularisation of the megagametophyte in *Encephalartos natalensis* Dyer and Verdoorn. *Plant growth regulation* 62(3): 265-278.

Woodenberg, W.R., P. Berjak, N. Pammenter & J.M. Farrant (2014). Development of cycad ovules and seeds. 2. Histological and ultrastructural aspects of ontogeny of the embryo in *Encephalartos natalensis* (Zamiaceae). *Protoplasma* 251(4): 797-816.

সার সংক্ষেপ

১৯৩৮ সালে তৎকালীন বাংলার বারইয়াঢালা প্রাকৃতিক বন থেকে সর্বপ্রথম উইলিয়াম গ্রিফিথ *Cycas pectinata* উদ্ভিদটি রেকর্ড করেন। এই উদ্ভিদটির প্রাকৃতিক বিস্তৃতি বাংলাদেশের চট্টগ্রাম জেলার সীতাকুন্ড উপজেলার

বারইয়াঢালার পাহাড়ি অঞ্চলে সীমাবদ্ধ। এই বনাঞ্চলটি ২০১০ সালে বারইয়াঢালা জাতীয় উদ্যান হিসেবে ঘোষণা করা হলেও এর নিজস্ব (native) নগ্নবীজী উদ্ভিদের (*Cycas pectinata*) ক্রমাবনতি আশংকাজনক। এই

গবেষণার লক্ষ্য ছিল বারইয়াঢালা জাতীয় উদ্যানে *C. pectinata* উদ্ভিদটির সংখ্যা জানা, এই প্রজাতিটির গাছের সংখ্যা কমে যাওয়ার কারণ অনুসন্ধান করা এবং নিজ প্রাকৃতিক আবাসস্থলে সংরক্ষণের (*in situ* conservation) জন্য এই উদ্ভিদটির সুনির্দিষ্ট অবস্থান জানা। ২০১৮ সালের এপ্রিল-জুন মাসে বারইয়াঢালা জাতীয় উদ্যানে দৈব

চয়নের ভিত্তিতে ১০০ মি × ১০০ মি আকারের ২১ টি নমুনা স্থান (sample plot) জরিপের জন্য ঠিক করা হয়। প্রত্যেক নমুনা স্থানে *C. pectinata* গাছের সংখ্যা, উচ্চতা, বেড় মাপার পাশাপাশি এই প্রজাতিটির প্রতি যত ধরনের হুমকি বা সমস্যা পরিলক্ষিত হয়েছিল তার সবই উপাত্ত হিসেবে লিপিবদ্ধ করা হয়েছে। বনের সাথে স্থানীয় জনগণকে সম্পৃক্ত করে চারটি আলোচনা সভা (Focus Group Discussion) করা হয়েছে। এই গবেষণার ফলাফল থেকে দেখা যায় যে, গবেষণা অঞ্চলে প্রতি হেক্টরে *C. pectinata* গাছ রয়েছে ১২ টি আর চারা আছে পাঁচটি; তবে গবেষণাস্থলের বিভিন্ন স্থানে উল্লেখযোগ্য সংখ্যক মৃত ও বনের আগুনে পোড়া সাইকাস গাছ রয়েছে। সাইকাস গাছের ঘনত্ব ও বিস্তারের উপর ভিত্তি করে গবেষণাস্থলে পাঁচটি সাইকাস হটস্পট নির্ধারণ করা হয়েছে যা উক্ত প্রজাতিটিকে তার নিজ আবাস্থলে সংরক্ষণে সহযোগিতা করবে। আবাস্থল ধ্বংস, নির্বিচারে বনে আগুন লাগানো, সাইকাসের পাতা, পুরুষ ও স্ত্রী পুষ্প মঞ্জুরী অতিরিক্ত হারে সংগ্রহ করার ফলে বনে এই প্রজাতিটির গাছের সংখ্যা দ্রুত কমে যাচ্ছে। এই প্রজাতিটির সুরক্ষা ও পুনরুদ্ধারের জন্য নিকটবর্তী স্থানীয় মানুষদেরকে এই প্রজাতিটির গুরুত্ব বুঝানো, সুরক্ষার মাত্রা উন্নীতকরণ, গাছের বিভিন্ন অংশের ব্যবসা বন্ধকরণ এবং স্থানীয় মানুষের বনের উপর নির্ভরতা কমানোর জন্য টেকসই জীবিকার সুযোগ তৈরি করা প্রয়োজন।

Author details: Mohammed Kamal Hossain is Professor of the Institute of Forestry and Environmental Sciences, University of Chittagong. He received his B.Sc. (Hons.) and M.Sc. in Botany from the Chittagong University, and PhD in forestry from Aberdeen University, UK. His field of interest is Silviculture, Biodiversity Conservation, Forest Ecology, and Plantation Forestry. Md. Akhter Hossain is Assistant Professor of the Institute of Forestry and Environmental Sciences, University of Chittagong. He received his BSc (Honors) and MS in forestry from the same institute. Biodiversity conservation, forest ecology, forest inventory, ecosystem services, and community based natural resource management are his fields of interest. Saddam Hossen is working as a Lecturer in the Department of Forestry and Environmental Science, Rangamati Science and Technology University. He received his BSc (Honors) and MS in forestry from the Institute of Forestry and Environmental Sciences, University of Chittagong. His teaching and research focus on Forestry along with related fields. Md. Rayhanur Rahman, studying MSc In European Forestry under Erasmus Mundus Scholarship Programme at the University of Freiburg, Germany. Currently, he is writing his master thesis with the Chair of Forest and Environmental Policy. Mohammad Iftekher Hossain is the Project Manager of project titled "Strategic Environmental Assessment (SEA) of South West Region of Bangladesh for Conserving the Outstanding Universal Value of the Sundarbans Project" Project Management Unit (PMU), Bangladesh Forest Department, Ministry of Environment, Forest and Climate Change. Shital Kumar Nath is working as the Project Director in a USAID funded and implemented by CODEC. He received M.Sc. (Zoology) from the University of Chittagong and EMBA (Marketing) from the Southern University Bangladesh. Biodiversity conservation, ecosystem services, community-based natural resource management etc. are his fields of focus. Md. Baktiar Nur Siddiqui is Deputy Conservator of Forests of Bangladesh Forest Department. He achieved B.Sc. (Honors) in Forestry from University of Chittagong and Masters in Business Administration with Major in International and Development Economics from Bangladesh Open University. Currently he is heading the Forestry Development and Training Centre of Bangladesh.

Author contributions: MKH—conceptualization, methodology, field data collection, species identification, supervision, manuscript drafting and proof editing; MAH—field data collection, manuscript drafting, proof editing and revising; SH—methodology, field data collection, manuscript drafting; MRR—methodology, field data collection, manuscript drafting; MIH—conceptualization, methodology, communication, supervision; SKN—conceptualization, methodology, communication, supervision; MBNS—conceptualization, methodology, field data collection, communication, supervision.

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REVIEW

Limitations of current knowledge about the ecology of Grey Foxes hamper conservation efforts

Maximilian L. Allen [1], Alexandra C. Avrin [2], Morgan J. Farmer [3], Laura S. Whipple [4], Emmarie P. Alexander [5], Alyson M. Cervantes [6] & Javan M. Bauder [7]

[1,7] Illinois Natural History Survey, University of Illinois, 1816 S. Oak Street, Champaign, IL 61820, USA.
[1,2,4,6] Department of Natural Resources and Environmental Sciences, University of Illinois, 1102 S. Goodwin, Urbana, IL 61801, USA.
[3] Department of Forest and Wildlife Ecology, University of Wisconsin, 1630 Linden Drive, Madison, WI 53706, USA.
[5] Department of Animal Sciences, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA.
[1] maxallen@illinois.edu (corresponding author), [2] aavrin@illinois.edu, [3] morales1995@berkeley.edu, [4] laurasw2@illinois.edu,
[5] emmarie2@illinois.edu, [6] alyson2@illinois.edu, [7] javanvonherp@gmail.com

Abstract: Species-specific conservation is important for maintaining the integrity of ecological communities but is dependent on sufficiently understanding multiple aspects of a species' ecology. Species-specific data are commonly lacking for species in geographic areas with little research and species perceived to have insufficient charisma or economic importance. Despite their widespread distribution across central and North America and status as a furbearing mammal, little is known about the ecology of Grey Foxes *Urocyon cinereoargenteus* compared to other species of furbearing mammals. To understand what is known about this species, especially factors affecting population dynamics, we performed a systematic review of the scientific literature. We found 234 studies about Grey Foxes, with studies increasing substantially over time but with geographic gaps in the Great Plains and most of Mexico and central America. Most studies we reviewed examined relative abundance or occupancy (n= 35), habitat associations (n= 30), primarily as part of larger mammalian community studies, or spatiotemporal effects of other mammalian carnivores (n= 19), predominately Coyote *Canis latrans*. Grey Foxes were primarily forest-associated although associations with specific forest communities or anthropogenically disturbed habitats varied among studies. Multiple studies across ecoregions reported this fox as among both the most- and least-abundant mammalian carnivore. The inter-specific effects of Coyote were often, but not exclusively, negative and were likely mediated by landscape composition and human development. Importantly, very few studies examined population-effects of coyotes on Grey Foxes. Studies of population trends, demographics, and space use of Grey Foxes were comparatively rare and small inter- and intra-study sample sizes limited our ability to infer broader patterns. We suggest multiple avenues for future research to better understand the population status of this species throughout their range.

Keywords: Abundance, co-occurrence, demography, ecology, habitat, *Urocyon cinereoargenteus*.

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Author details: MLA is a carnivore ecologist at the Illinois Natural History Survey and University of Illinois. ACA is a M.S. student at the university of Illinois at Urbana-Champaign, with research focusing on effective monitoring techniques for mesocarnivores as carnivore interactions and community structure. MJF is a is a PhD student in the Department of Forest and Wildlife Ecology at the University of Wisconsin - Madison, with research focusing on urban canids and their interactions with each other, their environment, and with humans throughout North America. LSW earned her B.S. from the University of Illinois and is currently a M.S. student at Northern Michigan University, with research focusing on large carnivore ecology and environmental education. EPA is an early-stage researcher and undergraduate student at the University of Illinois at Urbana-Champaign, with research and interests centered on mammalian behavior and ecology. AMC is a M.S. student at the University of Illinois Urbana-Champaign, with research focusing on coyote and red fox interactions across the Chicago metropolitan area. JMB was a postdoctoral researcher with the Illinois Natural History Survey and is currently an Assistant Unit Leader with the U.S. Geological Survey's Arizona Cooperative Fish and Wildlife Research Unit in Tucson studying the population and landscape ecology of terrestrial vertebrates.

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INTRODUCTION

Conservation biology has seen dramatic increases in effectiveness in the last century, from increasing conservation of ecological communities through bioreserves to species-specific conservation strategies. Implementation of species-specific conservation strategies has been effective at increasing species of conservation concern. For example, captive rearing and removal of lead ammunition has brought California Condors *Gymnogyps californianus* back from the brink of extinction (Walters et al. 2010), while cultural education and habitat preservation has increased populations of Giant Pandas *Ailuropoda melanoleuca* resulting in their down-listing from the endangered species list (Swaisgood et al. 2018). Species-specific conservation can be important for maintaining the integrity of ecological communities but is dependent on sufficiently understanding multiple aspects of a species' ecology. For example, modeling population viability and evaluating potential drivers of decline requires accurate estimates of demographic parameters, such as age- and sex-specific estimates of survival and fecundity (Boyce 1992; Mumme et al. 2000; Hostetler et al. 2009). Baseline estimates of abundance or occupancy are required to evaluate population trends and identify future changes in population status, while understanding habitat associations can help better assess present and future threats to population persistence (Haines et al. 2006; Aldridge et al. 2007). However, such ecological data are commonly lacking for many species, particularly those in developing countries with relatively few resources for science and conservation (Holmgren & Schnitzer 2004; Allen et al. 2020) or those perceived to have insufficient charisma or economic importance (Fuller & Cypher 2004).

Grey Foxes *Urocyon cinereoargenteus* are one such understudied species (Image 1). Despite their widespread distribution across Central and North America and status as a furbearing mammal (Fritzell & Haroldson 1982; Fuller & Cypher 2004), little is known about their ecology compared to other species of furbearing mammal (e.g., Sillero-Zubiri et al. 2004; Gehrt et al. 2010). Grey Foxes are currently listed as 'Least Concern' by the International Union for Conservation of Nature (Roemer et al. 2016) and do not contribute to crop damage or other sources of human-wildlife conflict (Fuller & Cypher 2004). Collectively, these factors likely work to deprioritize research and monitoring efforts for this species, especially compared to their only congener, Island Foxes *Urocyon littoralis*, which is federally endangered and a focus of large research efforts (e.g., Bakker et al. 2009). A lack of such efforts makes it difficult to detect large-scale population changes. For example, grey foxes are thought to be declining in the Midwestern USA (Bauder et al. 2020) despite minimal changes to land cover composition over the past several decades (Walk et al. 2010). However, it is unclear if such putative declines are regional in nature or more widespread. The goal of this paper, therefore, was to provide a range-wide review and synthesis of the currently available scientific literature on grey foxes to better understand their population status and ecology and identify geographic and topical gaps in the literature as avenues for future research.

Image 1 . Portrait of a Grey Fox *Urocyon cinereoargenteus* in central California.

Literature Review

We performed a systematic search of the scientific literature through Web of Science on 28 May 2020 using the terms ("gray fox*" OR "grey fox*" OR "Urocyon"). We then examined each entry and removed duplicate and mismatched publications (e.g., papers about island foxes), as well as those not from peer-reviewed journals or studies of captive animals. Our literature search yielded 430 peer-reviewed studies, 234 of which included research on Grey Foxes (solely or as part of a broader mammalian community). The number of studies about this species increased substantially since the 1940s (Figure 1a). Most studies were conducted within the states of California and Texas and across the southeastern

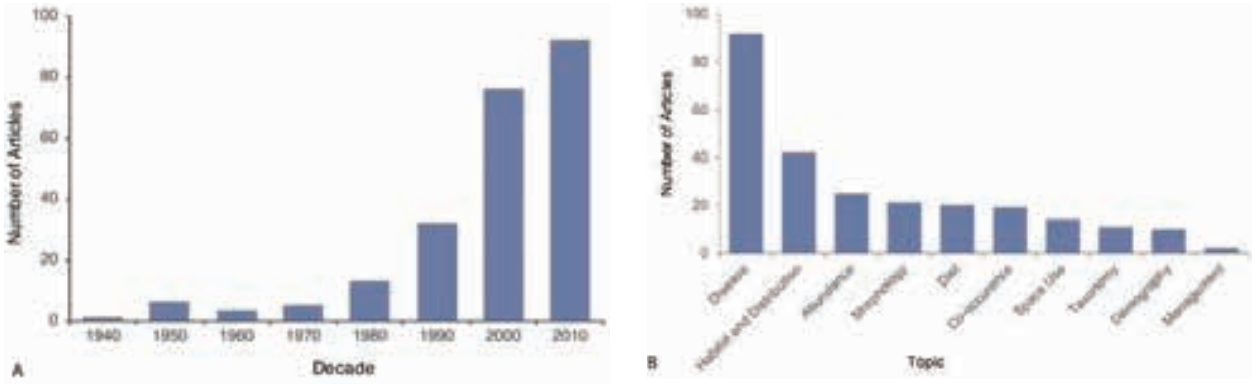


Figure 1. Number of peer-reviewed articles about Grey Foxes by decade (a) and research topic (b). An additional seven articles published in 2020 were used in our review but not included in this figure.

USA (Figure 2). Major gaps in the geographic distribution of studies about Grey Foxes included the Great Plains ecoregion in the midwestern United States and wet and dry tropical forests ecoregions across Mexico and central America (Figure 2). We further describe the geographic distribution of studies with reference to the Level I Ecological Regions of North America (Omernik & Griffith 2014; Appendix 1).

We classified the 234 studies of grey foxes into ten topical categories (Figure 1b). Most studies focused on disease (n= 92 articles) followed by habitat and distribution (n= 42 articles). All other categories had < 25 studies (Figure 1b). We focused our review on five categories we deemed most relevant to the management and conservation of these foxes defined as follows: 1) Abundance: spatiotemporal estimates of the absolute or relative number of individuals, density, or occupancy; 2) Demography: estimates of population vital rates (e.g., survival rates, mortality rates, sex ratio, mean age, litter size); 3) Habitat: modeling aspects of ecology or behavior of Grey Foxes (e.g., spatial locations, home range size, occupancy, or relative abundance) as a function of one or more habitat features (e.g., vegetation characteristics, land cover type, etc.); 4) Co-occurrence with dominant carnivores: evaluated the spatiotemporal distribution or interactions of Grey Foxes in relation to other carnivores; and 5) Space Use: spatial distribution of individual Grey Fox. We separated distribution studies from habitat studies for further consideration because the former dealt exclusively with distributional or range expansion records. We also included studies reporting occupancy estimates in abundance rather than distribution because such studies occurred across relatively limited geographic extents. We only included demography studies that reported model-based estimates of vital rates. Similarly, we excluded habitat studies that were purely descriptive and lacking an underlying statistical model. For co-occurrence with dominant carnivores, we only considered studies that statistically examined how mammalian carnivores directly affected these foxes through statistical analyses.

We found seven distribution studies (Figure 2). Three studies provided records extending the distribution of Grey Foxes in New Brunswick (Mcalpine et al. 2008), Alberta (Moore 1952), and South Dakota (Schantz 1950). Two studies also reported new within-range occurrence records in New Mexico (Anderson & Stuart 1993) and Texas (Jones & Frey 2008), USA. Peterson (1953) described the historical and contemporary distribution of this species in Ontario, and Zielinski et al. (2011) found that the distribution of these foxes in the Sierra Nevada was similar between the early 1900s and 1996–2002, but Grey Foxes were detected less frequently during 1996–2002.

Abundance

We found 25 studies that reported abundance of Grey Foxes and 10 studies reporting occupancy. All but three of the studies reported these foxes as part of the larger mammalian or carnivore community. Most studies that reported relative abundance (RAB) for this species used camera traps (n= 14), track and scat transects (n= 6), or track plots (n= 3). Hair snares (Downey et al. 2007), observations by archery deer hunters (Cooper et al. 2012), and environmental DNA (eDNA, Klymus et al. 2017) were each reported detecting Grey Foxes by a single study.

Distributions of RAB estimates from camera trap and transect studies were generally similar across ecoregions (Figure 3). Studies with relatively high RAB occurred in multiple ecoregions including the Temperate Sierras (Cunningham et al. 2006; Gallina et al. 2016), Eastern

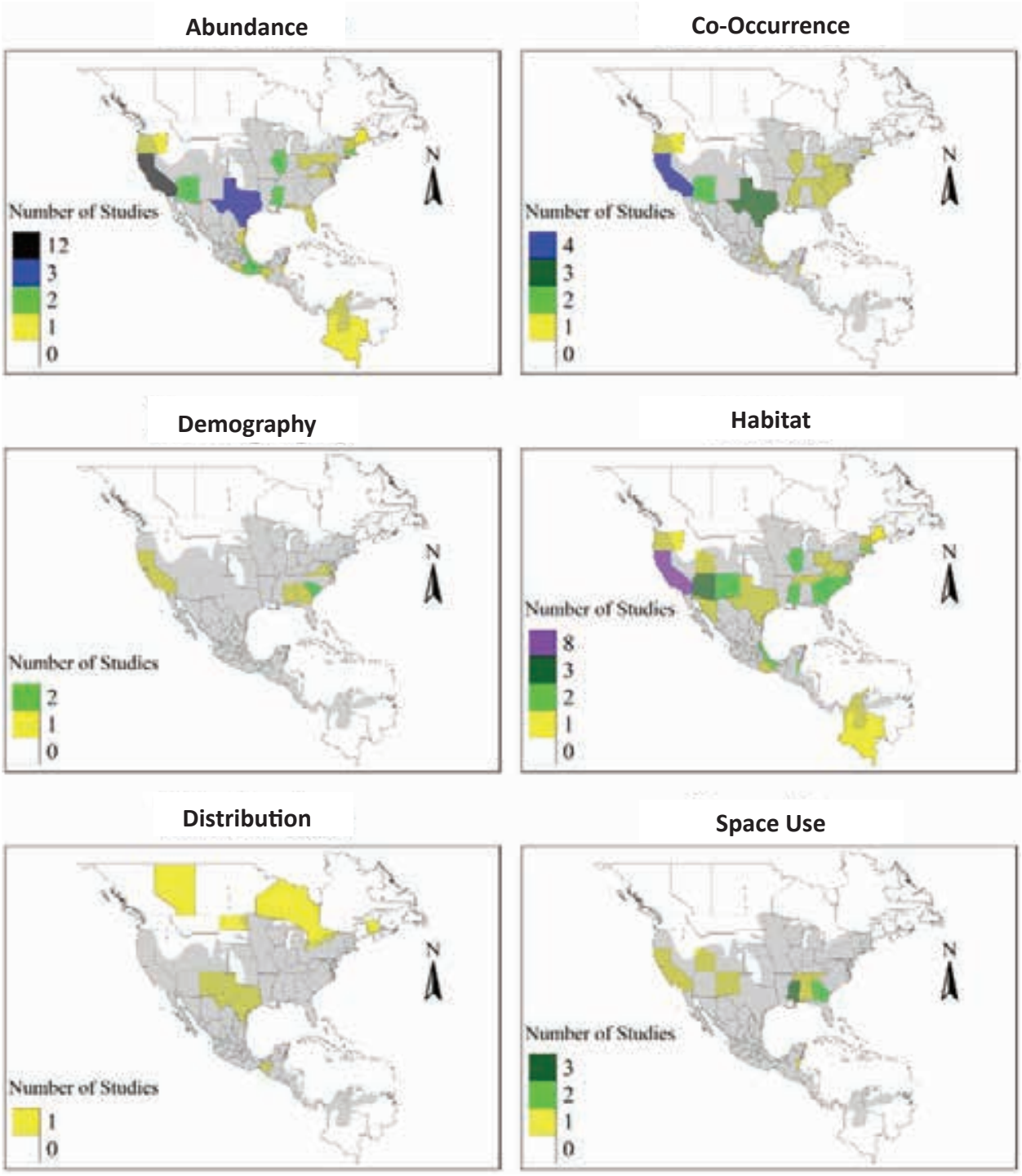


Figure 2. Geographic distribution of published peer-reviewed studies of Grey Fox ecology by category considered in this literature review. Grey shaded areas represent the contemporary distribution of Grey Foxes from the International Union for Conservation of Nature Red List (Roemer et al. 2016). Note that a single abundance, co-occurrence, and space use study were conducted in Belize.

Temperate Forests (Chamberlain et al. 1999), Tropical Wet Forests (Davis et al. 2011), Mediterranean California (Allen et al. 2017), Great Plains (Karlin & De La Paz 2015), and Marine West Coast Forests (Eriksson et al. 2019). To further explore geographic variation in abundance of Grey Foxes, we calculated the rank-order of RAB or occupancy across all mammalian carnivores detected in the study, including grey fox. We then calculated the number of studies where these foxes were in the top, middle, or bottom third ranks across seven ecoregions. Grey Foxes were among the most abundant carnivores in Mediterranean California, Northwestern Forested

Mountains, and Tropical Dry Forests ecoregions and among the least abundance carnivores in the Eastern Temperate Forests and Tropical Wet Forests ecoregions (Figure 4). This species ranked among the top third in at least one study within each ecoregion and in the bottom third in at least one study in five ecoregions. Our results indicate that Grey Foxes may show substantial intra- and inter-regional variation in abundance and highlight the value of mammalian community studies for obtaining information on their abundance and distribution.

Relatively few studies reported trends in RAB of Grey Foxes and these studies were limited in geographical scope. Long-term studies in Pennsylvania using bounty records (Richmond 1952) and in Texas using nocturnal spotlight surveys (Schwertner et al. 2006) reported positive trends over 15 and 25 years, respectively. A 15-year study in Mississippi using trapper harvest records reported stable trends (Lovell et al. 1998). Other studies evaluating temporal variation in RAB or occupancy of this species were conducted over relatively short (<3 year) periods (Chamberlain et al. 1999; Cunningham et al. 2006; Gallina et al. 2016). In contrast, Bauder et al. (2020) found evidence of declines in Grey Foxes in Illinois over 43 years and two studies in the midwestern USA found that they were the least prevalent species in the native carnivore community (Lesmeister et al. 2015; Rich et al. 2018). Lesmeister et al (2015) found that site extinction rates for these foxes were higher than site colonization rates, and other studies have suggested declines of Grey Foxes in the midwestern USA (Cooper et al. 2012). Our literature review suggests that this species can exhibit relatively high abundance in many parts of their range, but the paucity of long-term studies about these foxes make it difficult to evaluate their range-wide population status. Future Grey Fox monitoring efforts should consider the diverse factors necessary for optimizing statistical power to detect trends over a specified monitoring period, including initial abundance, sampling method, number of sites, study length, and state variable (e.g., occupancy or RAB; Maxwell & Jennings 2005; Mahard et al. 2016; Brown et al. 2017; Ward et al. 2017).

Demography

Six studies reported demographic parameter estimates and all but one was from the Eastern Temperate Forest with the sixth from Mediterranean California (Figure 2). Three studies reported mean annual survival rates of 0.58–0.69 (Table 1). Studies did not report statistically significant differences in survival between adults and juveniles or males and females (Chamberlain & Leopold 2000; Farias et al. 2005; Temple et al. 2010) although one study found that adult annual survival (0.77) was nearly twice that of juveniles (0.34; Farias et al. 2005). Reported sources of mortality for Grey Foxes included legal harvest, predation, vehicle mortality, canine distemper, canine hepatitis, and rabies (Chamberlain & Leopold 2000; Weston & Brisbin 2003; Farias et al. 2005; Glenn et al. 2009; Temple et al. 2010). Model-based estimates of annual cause-specific mortality included 0.34 for human-caused (Temple et al. 2010) and 0.42 for predator-caused (Farias et al. 2005) mortality. Coyotes *Canis latrans* were the primary cause of predation mortality (Weston & Brisbin 2003; Farias et al. 2005) although predation by Bobcats *Lynx rufus* was also reported (Farias et al. 2005). The percentage of confirmed mortalities from Coyote predation varied from 28.6% (Weston & Brisbin 2003) to 67% (Farias et al. 2005).

Estimates of other demographic parameters were only available from a single population in South Carolina, with a mean population age of 3.5 years and a slightly female-biased sex ratio (31:44; Weston & Brisbin 2003). Estimated fecundity from corpora lutea counts was 1.94–

Table 1. Survival estimates for Grey Foxes (estimates are pooled across sexes and seasons unless otherwise noted).

Study	Location	Sample size	Time period	Estimation method	Survival (95% CI)	Legal harvest
Farias et al. 2005	California	17 7 15 7 n/a n/a	Annual Adult Annual Adult Female Annual Adult Male 8-month Juvenile 8-month Juvenile Female 8-month Juvenile Male	MICROMORT	0.58 (0.39–0.85) 0.69 (0.41–1.00) 0.49 (0.27–0.88) 0.34 (0.11-0.99) 0.40 (0.11–1.00 0.30 (0.06–1.00)	No
Temple et al. 2010	Georgia	33	Annual 4-month (Breeding) 4-month (Kit-rearing) 4-month (Winter)	Kaplan-Meier	0.61 (0.41–0.81) 0.81 (0.68–0.95) 0.75 (0.55–0.94) 0.82 (0.64–0.99)	Yes
Chamberlain & Leopold 2000	Mississippi	37	Annual	Not reported*	0.56	Yes
Weston & Brisbin 2003	South Carolina	75	Annual	Krebs (1999)	0.69 (0.63–0.74)	No

* Estimated reported in Farias et al. (2005) based on calculations from data in Chamberlain & Leopold (2000).

Table 2. Summary of habitat associations of Grey Foxes, with the direction of effect presented as negative (-), positive (+), or no effect. Studies were classified as no effect when a given habitat feature was used in proportion to availability, coefficient estimates were not reported (e.g., covariate removed via step-wise model selection), or if the habitat was not the most significantly used habitat within a compositional analysis. Asterisks indicate strong empirical support and multiple symbols per study or habitat indicate multiple sampling methods or spatial scales. Habitats include forest (FRST), hardwood forest (HARD), coniferous forest (CONF), chaparral or shrub (SHRB), habitat heterogeneity (e.g., heterogeneity in landscape composition, habitat edge; HTRO), agriculture (AGRI), and anthropogenic (e.g., urban, roads; ANTH).

Citation	Location	FRST	HARD	CONF	SHRB	HTRO	AGRI	ANTH
Barrett et al. 2012	Arizona	–						
Cunningham et al. 2006	Arizona	+/–						
Reed 2011	Arizona	.						
Davis et al. 2011	Belize	–						
Harmsen et al. 2019	Belize	./+/–					.	
Borchert 2012	California	–*						
Farias et al. 2012	California		.		+*			–*
Kowalski et al. 2015	California							–*
Markovchick-Nicholls et al. 2008	California							–*
Ordenana et al. 2010	California		+*		.			–*
Patten & Burger 2018	California							–*
Schuette et al. 2014	California	+						.
Pineda-Guerrero et al. 2015	Colombia	+*					–*	
Deuel et al. 2017	Georgia		+*	+	+/+*	+	+/+*	+*
Temple et al. 2010	Georgia		+/+*	+/+*	–*/+*		–/+*	+*
Cooper et al. 2012	Illinois	+				+	–	
Lesmeister et al. 2015	Illinois	+*				+*	–*	+*/–*
LeFlore et al. 2019	Massachusetts	.					–	.
Gallina et al. 2016	Mexico	–*					+*	+*
Perez-Solano et al. 2018	Mexico	+*					–	
Rota et al. 2016	Mid-Atlantic States							./+*
Chamberlain et al. 2000	Mississippi		./+*	./+*				
Constible et al. 2006	Mississippi					–/+		
Pearman-Gillman et al. 2020	New England		.	.	.	+*	+*	.
Harrison 1993	New Mexico	+*						
Harrison 1997	New Mexico	+*/–*						+*/–*
Rich et al. 2018	Ohio	–			–		–/+	–
Eriksson et al. 2019	Oregon				+*			
Sawyer & Fendly 1994	South Carolina		./–	+*/–*				
Lombardi et al. 2017	Texas							./–*

3.6 pups/litter (Weston & Brisbin 2003), and mean litter size was 3.1 (n= 8 litters, range= 2–5; Glenn et al. 2009).

The paucity of demographic studies on Grey Foxes and their limited sample sizes and geographic scope represent a substantial gap in our understanding of their population ecology. Accurate demographic parameter estimates, particularly sex- and age-specific survival and fecundity estimates, are important for evaluating population viability and understanding causes of temporal changes in population size. We therefore encourage future studies across the species range to provide model-based demographic parameter estimates. The potential for high Coyote mortality may have important implications for population dynamics of Grey Foxes as Coyotes have expanded their distribution across North and central America (Gompper 2002; Hody & Kays 2018).

Table 3. Summary of effects of larger carnivores on spatial overlap with Grey Fox, with the direction of effect presented as negative (-), positive (+), or no effect. Studies were classified as no effect when the inter-specific effect was not reported or if predicted occupancy values were ≤0.02 between sites with and without the other carnivore (Lesmeister et al. 2015). Asterisks (*) indicate strong empirical support (*P* value < α, 95% CI excluded zero, model with inter-specific effect has greater AIC weight than an intercept- or habitat-only model, species interaction factor > 1.5 or < 0.5). Studies with multiple directions of effect refer to multiple sampling scales. Rota et al. (2016) encompassed the states of Maryland, Virginia, West Virginia, Tennessee, North Carolina, and South Carolina.

Study	Location	Bobcat (*Lynx rufus*)	Coyote (*Canis latrans*)	Fisher (*Pekania pennant*)	Jaguar (*Panthera onca*)	Ocelot (*Leopardus pardalis*)	Puma (*Puma concolor*)	Raccoon (*Procyon lotor*)	Red Fox (*Vulpes vulpes*)
Atwood et al. 2011	Texas	–*	–*						
Barrett et al. 2012	Arizona		–*					+*	
Borchert 2012	California		.						
Chamberlain & Leopold 2005	Mississippi	–	–						
Davis et al. 2011	Belize				–	–	+		
Fedriani et al. 2000	California		–*						
Green et al. 2018	California/Oregon			–*					
LeFlore et al. 2019	Massachusetts		–					–	.
Lesmeister et al. 2015	Illinois	.	./–*						+*
Lombardi et al. 2017	Texas		.						
Reed 2011	Arizona	–	–*						
Rich et al. 2018	Ohio	–	+					–	–
Rota et al. 2016	Mid-Atlantic States	–	+						+*

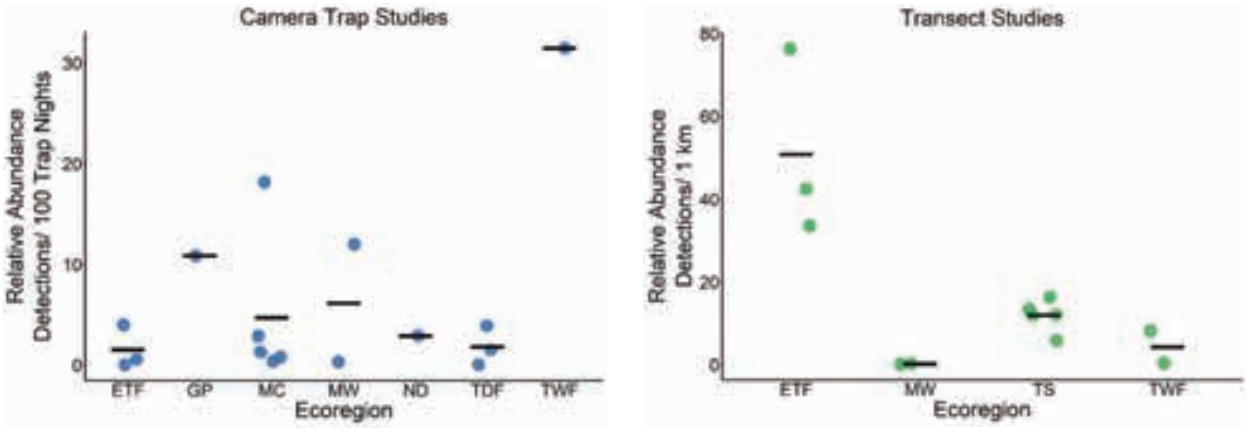


Figure 3. Relative abundance of Grey Foxes across Level I ecoregions (Omernik & Griffith 2014) from studies using camera traps (detections/100 trap nights, A) or line transect surveys (detections/1 km, B). Horizontal bars represent mean values. Ecoregions are: ETF= Eastern temperate forest, GP= Great plains, MC= Mediterranean California, MW= Marine West Coast Forest, ND= North American Desert, TDF= Tropical Dry Forest, TWF= Tropical Wet Forest, TS= Temperate Sierras.

However, our review illustrates that Coyote predation on Grey Foxes can vary widely across populations and future studies could focus on linking individual-level effects of predation from Coyotes to population-level responses of Grey Foxes.

Habitat

We found 30 studies that modeled habitat associations of Grey Foxes (Table 2) excluding an additional four studies that were purely descriptive and therefore were not included in subsequent totals. Most habitat studies used camera traps (n= 14), either in isolation or with other sampling methods, followed by transect sampling (tracks or scat; n= 8), very high frequency (VHF) (n= 6) or global positioning system telemetry (n= 1), and observations by archery deer hunters (n= 1). Studies occurred in a diverse range of landscape types including urban, natural areas surrounded or adjacent to urban areas, pinyon-juniper

forest, chaparral, eastern deciduous & coniferous forest, and tropical forest (Table 2). Studies were conducted in East Temperate Forest, Mediterranean California, Temperate Sierras, and Tropical Dry Forest ecoregions (Figure 4).

Grey Foxes were positively associated with forest environments throughout their range, although associations with other vegetation communities or structural features varied geographically (Table 2). For example, Grey Foxes in California and Oregon were often positively associated with chaparral or shrub-scrub habitats (Fedriani et al. 2000; Farias et al. 2012; Erikson et al. 2019). Several studies found weak or no association with forest-related covariates including forest cover (Rich et al. 2018), canopy cover (Davis et al. 2011; Reed 2011), distance to nearest forest (LeFlore et al. 2019), or basal area (Barrett et al. 2012) perhaps reflecting insufficient covariate variability within the study area or regional variation in habitat associations. Results from several studies suggest that these foxes may use more open forest environments (Barrett et al. 2012; Borchert 2012), edge habitats (Davis et al. 2011; Deuel et al. 2017; Harmsen et al. 2019; Pearman-Gillman et al. 2020), and heterogenous landscapes (Cooper et al. 2012; Lesmeister et al. 2015; but see Constible et al. 2006). Despite the methodological variation across studies, our review highlights the importance of forest environments for Grey Foxes across their range.

Early research indicated that Grey Foxes were closely associated with hardwood forest (Fritzell & Haroldson 1982). Studies in pine-dominated landscapes within the Eastern Temperate Forest ecoregion reported selection for hardwood forest although the degree of selection varied by spatial scale and season (Sawyer & Fendly 1994; Chamberlain et al. 2000; Temple et al. 2010; Deuel et al. 2017). Selection for mature (≥ 30-year) and 9–15-year-old pine and mixed pine-hardwood forests was also reported (Chamberlain et al. 2000). Hardwood species may offer vertical escape cover from Coyotes given the climbing abilities of Grey Foxes (Fritzell & Haroldson 1982) and small mammal prey may also be more abundant in hardwood forests (Chamberlain et al. 2000; Temple et al. 2010; Lesmeister et al. 2015). However, few studies in landscapes not dominated by coniferous forests directly compared selection of hardwood and coniferous forest (Table 2). Ordenana et al. (2010) reported positive associations with oak woodland in California but Lesmeister et al. (2015) reported an overall negative association between Grey Foxes and hardwood forests in forest-agriculture landscapes in southern Illinois. However, Lesmeister et al. (2015) found that these foxes were more likely to use hardwood forests when Coyotes were present. Our review suggests that associations of this species with hardwood forest may not be universal but rather conditional upon the broader landscape context and carnivore community. We encourage future research evaluating the role of vegetation community, structural characteristics (e.g., canopy cover), resource availability (e.g., small mammal abundance), and carnivore community on habitat suitability for Grey Foxes.

Studies evaluating associations of Grey Foxes with anthropogenic development (e.g., urbanization, roads) often reported conflicting information (Table 2). Several studies reported negative associations between Grey Foxes and anthropogenic development (e.g., Markovchick-Nicholls et al. 2008; Ordennana et al. 2010; Farias et al. 2012; Kowalski et al. 2012; Lombardi et al. 2017), yet other studies found that these foxes utilize a range of human development intensities (Harrison 1993, 1997; Riley 2006; Kapfer & Kirk 2012; Lombardi et al. 2017). Similarly, associations of Grey Foxes with agriculture varied among studies. For example, studies from forest-agriculture landscapes in the Eastern Temperate Forest ecoregion reported negative associations with agriculture (Cooper et al. 2012; Lesmeister et al. 2015) as well as positive or neutral associations (Temple et al. 2010; Deuel et al. 2017; Pearman-Gillman et al. 2020). The particular response of Grey Foxes to anthropogenic land covers may depend on factors including the intensity of human or agricultural development, resource availability, diel period, or the local carnivore community (Harrison 1997; Rota et al. 2016; Nickel et al. 2020). For example, positive association of these foxes with anthropogenic development may reflect avoidance behavior of Coyotes (Lesmeister et al. 2015; Wang et al. 2015) and agricultural edges may offer food from crops and small mammal prey (Temple et al. 2010; Cortes-Marcial et al. 2014). The impacts of anthropogenic landscape change on the habitat associations of this species therefore represents an important avenue of future research to better understand population dynamics of Grey Foxes.

Co-occurrence with Dominant Carnivores

We reviewed 19 studies that evaluated interactions between Grey Foxes and other carnivores by analyzing spatial (n= 13) or temporal overlap (n= 5) or by reporting predation events (n= 4). These studies most frequently used camera traps (n= 14), and to a lesser degree track plates (n= 3), scat collection (n= 3), radio-telemetry (n= 2), and spotlight surveys (n= 1). Studies were conducted in East Temperate Forest, Mediterranean

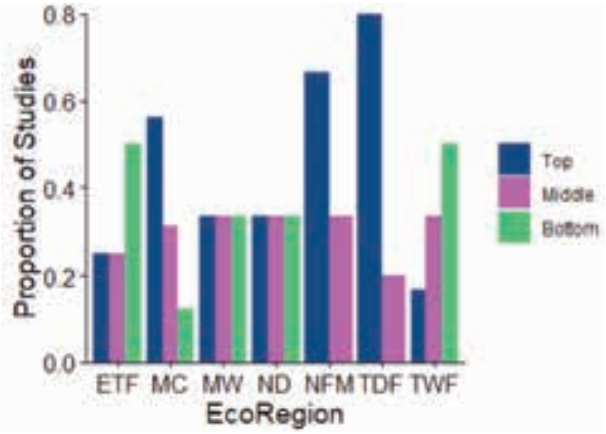


Figure 4. Proportion of studies where the rank order of abundance or occupancy of Grey Foxes was in the top, middle, or bottom third across all mammalian carnivores Results are presented by Level I ecoregion (Omernik & Griffith 2014): ETF= Eastern Temperate Forest, MC= Mediterranean California, MW=Marine West Coast Forest, ND= North American Desert, NFM= Northwestern Forested Mountains, TDF= Tropical Dry, Forest TWF= Tropical Wet Forest. Three ecoregions (Great Plains, Northern Forests, Temperate Sierras) were excluded due to only one study occurring there.

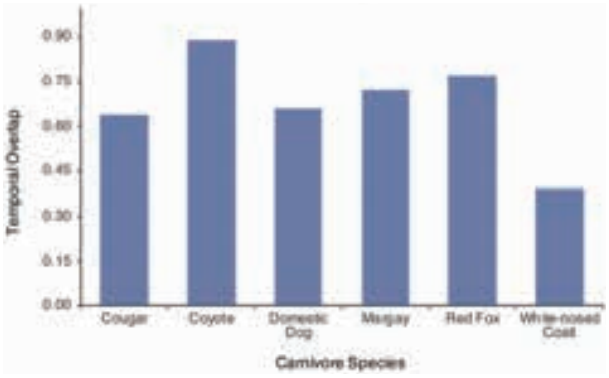


Figure 5. Estimates of temporal overlap between Grey Foxes and co-occurring mammalian carnivores (Gomez-Ortiz et al. 2019; LeFlore et al. 2019; Mella-Mendez et al. 2019). Overlap values range from zero (no overlap) to one (complete overlap).

California, Maritime West Coast Forest, Northwestern Forested Mountains, North American Deserts, Great Plains, Temperate Sierras, and Tropical Dry Forest (Figure 4).

Most studies (n= 7 of 11) that examined spatiotemporal interactions between Grey Foxes and Coyotes found evidence of negative effects of Coyotes on these foxes (Table 3), consistent with the general expectation that Coyote negatively affect smaller sympatric canids (Donadio & Buskirk 2006). In a rare experimental study, Henke & Bryant (1999) found that RAB of Grey Foxes in western Texas increased following removal of Coyotes. However, negative effects of Coyotes were often weak or not statistically significant (Borchert 2012; Lombardi et al. 2017; LeFlore et al. 2019) and two studies reported positive effects (Rota et al. 2016; Rich et al. 2018). Showing similar contrasts, LeFlore et al. (2019) reported near complete temporal overlap between Coyotes and Grey Foxes (Figure 5) while Lesmeister et al. (2015) found that these foxes were detected less frequently during nights when Coyotes were also detected. Such variability may be at least partially explained by variation in sampling unit spatial scale and landscape conditions (Lesmeister et al. 2015). For example, Chamberlain & Leopold (2005) found extensive home range overlap between Coyotes and Grey Foxes but very little core area overlap. Similarly, Rota et al. (2016) found that occupancy of this species in the presence of Coyotes increased with increasing human development although Lombardi et al. (2017) found no spatial relationships between these foxes and Coyotes within urban landscapes. We therefore encourage studies evaluating interactions within carnivore communities to consider the potential effects of scale and landscape context in their analyses.

Relatively few studies reported interactions of Grey Foxes with other carnivores (Table 3). Five of six studies including Bobcats reported negative effects on these foxes but the strength of these relationships was often low (Table 3). Interestingly, two of four studies reported strong positive relationships between occupancy of Grey Foxes and Red Foxes (Lesmeister et al. 2015; Rota et al. 2016). Davis et al. (2011) examined relationships between the RAB of Grey Foxes and three larger sympatric felids but low empirical support for inter-specific effects. However, other studies have shown that larger carnivores (i.e., Puma *Puma concolor*) can have a positive effect on Grey Foxes by directly limiting Coyotes (Allen et al. 2015, 2017). Other species may also have positive effects on Grey Foxes and more research is needed to understand the interactive relationships between Grey Foxes and the larger mammalian carnivore community.

Space Use

We found 11 studies that reported space use estimates for Grey Foxes. Ten studies used VHF telemetry and one used global positioning system (GPS) telemetry. Multiple home range estimation methods were used within and across studies including minimum convex polygons and fixed or adaptive kernel estimators (Table 4). All but three studies were conducted in the Eastern Temperate Forest (Figure 2).

Estimated home range sizes for Grey Foxes varied by almost an order of magnitude across studies (range= 0.69–6.69 km^2, Table 4). However, variation in home

Table 4. Home range (100 % and 95 %) and core area (50 %) sizes (km² and standard errors in parentheses) estimates for Grey Foxes and the number of individuals used for each estimate (n). Estimation methods include minimum convex polygons (MCP), adaptive kernel (AK), or fixed kernel (FK) estimators.

Reference	HR calculation method	Composite HR	Breeding HR	Pup-rearing HR	Non-breeding HR
Harrison 2002	95 % MCP	4.81 (1.79)			
Greenberg et al. 1994	100 % MCP	3.97 (1.51)	2.72 (0.17)[a]	2.32 (0.43)[b]	2.83 (0.42)[c]
Trapp 1978	100 % MCP	1.07			
Riley et al. 2006	95 % MCP	0.69 (0.03)°			
Chamberlain & Leopold 2000	95 % AK		3.53 (0.20)[d]	2.02 (0.20)[e]	1.66 (0.19)[f]
Temple et al. 2010	95 % FK		0.91 (0.13)[d]	1.00 (0.18)[e]	1.52 (0.32)f
Harmsen et al. 2019	95 % Kernel area*	3.31-6.69			
	HR calculation method	Winter HR (Jan–March)	Spring HR (April–June)	Summer HR (July–Sept)	Fall HR (Oct–Dec)
Deuel et al. 2017	95 % FK	2.17 (0.54)	1.61 (0.32)	2.15 (0.32)	2.01 (0.43)
	HR calculation method	Gender	Pre-mate loss HR	Post-mate loss HR	Percent Change
Chamberlain et al. 2002	95 % FK	Female	4.48	6.37	30%
		Male	2.86	17.16	83%
		Male	2.19	0.93	-58%
		Female	0.96	0.64	-33%

range estimation method and tracking duration limited our ability to determine the extent to which this variation was methodological or due to seasonal, regional, or environmental variation. For example, Chamberlain et al. (2000) and Temple et al. (2010) found that home range sizes of Grey Foxes varied seasonally but Greenberg et al. (1994) and Deuel et al. (2017) found that home range sizes were similar across seasons. Several studies reported that home range sizes were similar between sexes and among age classes (Greenberg et al. 1994; Chamberlain & Leopold 2000; Riley 2006; Temple et al. 2010; Deuel et al. 2017). Lack of inter-sexual differences in home range size may reflect the widespread presence of pair-bonding in Grey Foxes (Greenberg et al. 1994; Chamberlain et al. 2000; Riley 2006; Deuel et al. 2017). In contrast to studies of other canids (e.g., Riley et al. 2003; O'Donnell & delBarco-Trillo 2020), studies of Grey Foxes in and near urban environments found that home range size was not strongly affected by urban development (Harrison 1997; Riley 2006). The limited number and geographic distribution of studies of space use by these foxes, combined with high methodological variability, inhibit our ability to infer general patterns of space use by this species. We therefore encourage additional studies of the spatial ecology of Grey Foxes and recommend that researchers standardize tracking duration and home range estimation methods across studies to facilitate inter-study comparisons.

The degree of home range overlap varied within and between sexes. Several studies reported that intra-sex home range overlap and overlap between unbonded males and females was relatively low while home range overlap between bonded adult male-female pairs relatively high (Greenberg et al. 1994; Chamberlain et al. 2000; Riley 2006; Deuel et al. 2017). However, Deuel et al. (2017) found multiple instances of extra-home range forays in both males and females which may reflect attempted extra-pair copulations (e.g., Glenn et al. 2008). Home range overlap between adults and subadults was also relatively high (Greenberg et al. 1994). It is likely that instances of low home range overlap are explained by territoriality while high spatial overlap between bonded pairs likely reflects shared duties of pup-rearing (Nicholson et al. 1985; Chamberlain & Leopold 2000, 2002; Elbroch & Allen 2013). However, the mechanisms for maintaining or defending territorial boundaries appear to be largely unexplored in Grey Foxes. Because patterns of spatial overlap are important in ultimately influencing population density and carrying capacity, future research could focus on describing the degree of and environmental factors influencing home range overlap for Grey Foxes.

CONCLUSIONS

Our review provides a summary of the ecology of Grey Foxes for researchers and managers, while also

highlighting several existing gaps in our knowledge. We found large gaps in geographic distribution of published studies about Grey Foxes, as most studies were conducted in the southeastern or southwestern USA. In contrast, Mexico, central America, and more northerly latitudes of their range were underrepresented in our review. A paucity of demographic and space use studies was particularly striking and limits our understanding of how individual-level effects of landscape features and sympatric carnivores may affect population-level processes of Grey Foxes. Additional demographic and space use studies of Grey Foxes in anthropogenically developed landscapes within the context of the larger carnivore community could help better understand the extent to which populations of these foxes in those landscapes are self-sustaining or acting as population sinks.

While Grey Foxes can be locally abundant throughout their range, long-term data on the RAB or occupancy of these foxes is scarce and often limited to harvest records which are subject to a range of potentially confounding factors (e.g., trapper effort and pelt prices; Bauder et al. 2020). We were therefore unable to assess the population status of Grey Foxes throughout much of their range although our results largely support the hypothesized decline of these foxes in the midwestern USA. However, the mechanisms for such a decline are unclear. While our review provides evidence that Coyote can negatively affect the behavior and survival of grey foxes, the magnitude of such effects can vary and may depend on study-specific conditions such as habitat availability or resource abundance. However, the effects of competing canids are complex because of range-wide shifts, including the recent expansion of coyotes into eastern North America (Gompper 2002; Hody & Kays 2018). These changes in canid and carnivore distributions shift dynamics in communities, but they also make the lack of information on Grey Foxes more important because we do not have historical baseline data to help us interpret current Grey Fox distribution, abundance, and ecology.

We offer several suggestions for avenues of future research on Grey Foxes. First, we recommend additional demographic studies on Grey Foxes to allow for more rigorous estimates of population viability and trends. Second, we encourage researchers to examine existing data sets from mammalian carnivore community studies and furbearer harvest records to provide additional information on geographic variation of population trends in Grey Foxes. While researchers must account for temporal variation in trapper or hunter harvest effort (e.g., Bauder et al. 2020), harvest data are regularly recorded by wildlife management agencies and may represent the longest, most spatially diverse data set available for evaluating the population trends of Grey Foxes. Third, a systematic review of the effects of disease on population ecology of Grey Foxes by experts in the field would be beneficial. Finally, we encourage additional research on interactions between Grey Foxes and Coyotes to evaluate the extents to which Coyotes influence the population dynamics of these foxes. Finally, citizen science has been used to inform the ecology and management of other canids (Mueller et al. 2019) and could be a beneficial approach for future studies.

As with many studies, we encourage researchers to use analytical approaches that allow for the standardized reporting of estimates to facilitate future comparisons across studies. Methodological variation among studies we reviewed made inter-study comparisons difficult which compounded the problem of low numbers of studies. For example, our ability to compare estimates of home range sizes of Grey Foxes were greatly hindered by variation in sampling method, estimation technique, and temporal period length. Similarly, studies of habitat associations of Grey Foxes varied widely in their environmental covariates and analytical approaches which also hindered inter-study comparisons. We also encourage researchers to deposit data in open-access repositories (e.g., movebank or dryad) to facilitate future comparisons between studies.

REFERENCES

Allen, M.L., L.M. Elbroch, C.C. Wilmers & H.U. Wittmer (2015). The comparative effects of large carnivores on the acquisition of carrion by scavengers. *American Naturalist* 185(6): 822–833. https://doi.org/10.1086/681004

Allen, M.L., M.S. Gunther & C.C. Wilmers (2017). The scent of your enemy is my friend? The acquisition of large carnivore scent by a smaller carnivore. *Journal of Ethology* 35(1): 13–19. https://doi.org/10.1007/s10164-016-0492-6

Allen, M.L., A. Inagaki & M.W. Ward (2020). Cannibalism in raptors: a review. *Journal of Raptor Research* 54(4): 424-430. https://doi.org/10.3356/0892-1016-54.4.424

Anderson, R.E. & J.N. Stuart (1993). The gray fox, *Urocyon cinereoargenteus*, on the Llano Estacado of New Mexico. *The Texas Journal of Science* 45(4): 354–355.

Atwood, T.C., T.L. Fry & B.R. Leland (2011). Partitioning of anthropogenic watering sites by desert carnivores. *Journal of Wildlife Management* 75(7): 1609–1615. https://doi.org/10.1002/jwmg.225

Bakker, V.J., D.F. Doak, G.W. Roemer, D.K. Garcelon, T.J. Coonan, S.A. Morrison, C. Lynch, K. Ralls & R. Shaw (2009). Incorporating ecological drivers and uncertainty into a demographic population viability analysis for the island fox. *Ecological Monographs* 79(1): 77–108. https://doi.org/10.1890/07-0817.1

Barrett, K.J., E.L. Kalies & C.L. Chambers (2012). Predator occupancy rates in a thinned ponderosa pine forest, Arizona: a pilot study.

Wildlife Society Bulletin 36(2): 232–239. https://doi.org/10.1002/wsb.124

Bauder, J.M., M.L. Allen, A.A. Ahlers, T.J. Benson, C.A. Miller & K.W. Stodola (2020). Identifying and controlling for variation in canid trapper harvest data. *Journal of Wildlife Management* 84(7): 1234–1245. https://doi.org/10.1002/jwmg.21919

Brown, D.J., M.M. Cochrane & R.A. Moen (2017). Survey and analysis design for wood turtle population monitoring. *Journal of Wildlife Management* 81(5): 868–877. https://doi.org/10.1002/jwmg.21249

Borchert, M.I. (2012). Mammalian carnivore use of a high-severity burn in conifer forests in the San Bernardino mountains of Southern California, USA. *Hystrix-Italian Journal of Mammalogy* 23(2): 50–56. https://doi.org/10.4404/hystrix-23.2-5610

Boyce, M.S. (1992). Population viability analysis. *Annual Review of Ecology and Systematics* 23(1): 481–506.

Chamberlain, M.J., J.W. Mangrum, B.D. Leopold & E.P. Hill (1999). A comparison of attractants used for carnivore track surveys. *Proceedings of the Fifty-Third Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 53(1): 296–304.

Chamberlain, M.J. & B.D. Leopold (2000). Spatial use patterns, seasonal habitat selection, and interactions among adult gray foxes in Mississippi. *The Journal of Wildlife Management* 64(3): 742–751.

Chamberlain, M.J. & B.D. Leopold (2002). Movements and space use of gray foxes (*Urocyon cinereoargenteus*) following mate loss. *The American Midland Naturalist* 147(2): 409–412.

Chamberlain, M.J. & B.D. Leopold (2005). Overlap in space use among bobcats (*Lynx rufus*), coyotes (*Canis latrans*) and Gray Foxes (*Urocyon cinereoargenteus*). *American Midland Naturalist* 153(1): 171–179.

Cherry, M.J., K.L. Turner, M.B. Howze, B.S. Cohen, L.M. Conner & R.J. Warren (2016). Coyote diets in a longleaf pine ecosystem. *Wildlife Biology* 22(2): 64–70. https://doi.org/10.2981/wlb.00144

Constible, J.M., M. Chamberlain & B.D. Leopold (2006). Relationships between landscape pattern and space use of three mammalian carnivores in central Mississippi. *American Midland Naturalist* 155(2): 252–362.

Cooper, S.E., C.K. Nielsen & P.T. McDonald (2012). Landscape factors affecting relative abundance of gray foxes (*Urocyon cinereoargenteus)* at large scales in Illinois, USA. *Wildlife Biology* 18(4): 366–373. https://doi.org/10.2981/11-093

Cortés–Marcial, M., Y.M. Martínez Ayón & M. Briones–Salas (2014). Diversity of large and medium mammals in Juchitan, Isthmus of Tehuantepec, Oaxaca, Mexico. *Animal Biodiversity and Conservation* 37(1): 1–12. https://doi.org/10.32800/abc.2014.37.0001

Cunningham, S.C., L. Kirkendall & W. Ballard (2006). Gray fox and coyote abundance and diet responses after a wildfire in central Arizona. *Western North American Naturalist* 66(2): 169–180. https://doi.org/10.3398/1527-0904(2006)66[169:GFACAA]2.0.CO;2

Davis, M.L., M.J. Kelly & D.F. Stauffer (2011). Carnivore co-existence and habitat use in the Mountain Pine Ridge Forest Reserve, Belize. *Animal Conservation* 14(1): 56–65. https://doi.org/10.1111/j.1469-1795.2010.00389.x

Deuel, N.R., L.M. Conner, K.V. Miller, M.J. Chamberlain, M.J. Cherry & L.V. Tannenbaum (2017). Gray fox home range, spatial overlap, mated pair interactions and extra-territorial forays in southwestern Georgia, USA. *Wildlife Biology* https://doi.org/10.2981/wlb.00326

Donadio, E. & S.W. Buskirk (2006). Diet, morphology, and interspecific killing in carnivora. *American Naturalist* 167(4): 524–536. https://doi.org/10.1086/501033

Downey, P.J., E.C. Hellgren, A. Caso, S. Carvajal & K. Frangioso (2007). Hair snares for noninvasive sampling of felids in North America: do gray foxes affect success? *The Journal of Wildlife Management* 71(6): 2090–2094. https://doi.org/10.2193/2006-500

Elbroch, L.M. & M.L. Allen (2013). Prey indices and behaviors at a Gray Fox den in San Mateo County, California. *Western North American Naturalist* 73(2): 240–243. https://doi.org/10.3398/064.073.0215

Eriksson, C.E., K.M. Moriarty, M.A. Linnell & T. Levi (2019). Biotic factors influencing the unexpected distribution of a Humboldt marten (*Martes caurina humboldtensis*) population in a young coastal forest. *PLOS ONE* 14: e0214653. https://doi.org/10.1371/journal.pone.0214653

Farias, V., T.K. Fuller, R.K. Wayne & R.M. Sauvajot (2005). Survival and cause-specific mortality of gray foxes (*Urocyon cinereoargenteus*) in southern California. *Journal of Zoology* 266(3): 249–254. https://doi.org/10.1017/S0952836905006850

Farías, V., T.K. Fuller & R.M. Sauvajot (2012). Activity and distribution of Gray Foxes (*Urocyon cinereoargenteus*) in southern California. *The Southwestern Naturalist* 57(2): 176–181. https://doi.org/10.1894/0038-4909-57.2.176

Fedriani, J.M., T.K. Fuller, R.M. Sauvajot & E.C. York (2000). Competition and intraguild predation among three sympatric carnivores. *Oecologia* 125(2): 258–270. https://doi.org/10.1007/s004420000448

Fritzell, E. K. & K.J. Haroldson (1982). *Urocyon cinereoargenteus. Mammalian Species* 189: 1–8.

Fuller, T.K. & B. Cypher (2004). Gray Fox (*Urocyon cinereoargenteus*), pp. 92–97. In: Sillero-Zubiri, C., M. Hoffmann & D.W. Macdonald (eds). *Canids: Foxes, Wolves, Jackals, and Dogs—Status Survey and Conservation Action Plan*. IUCN/SSP Canid Specialist Group, Gland, Switzerland; and Cambridge, United Kingdom.

Gallina, S., P. Lopez-Colunga, C. Valdespino & V. Farias (2016). Relative abundance of the gray fox *Urocyon cinereoargenteus* (Carnivora: Canidae) in Veracruz central area, Mexico. *Revista De Biologia Tropical* 64(1): 221–233. https://doi.org/10.15517/rbt.v64i1.18237

Gehrt, S.D., S.P.D. Riley & B.L. Cypher (eds.) (2010). *Urban Carnivores: Ecology, Conflict, and Conservation*. The John Hopkins University Press, Baltimore, USA, 304pp.

Glenn, J.L.W., D.J. Civitello & S.L. Lance (2009). Multiple paternity and kinship in the gray fox (*Urocyon cinereoargenteus*). *Mammalian Biology* 74(5): 394–402. https://doi.org/10.1016/j.mambio.2008.10.003

Gompper, M.E. (2002). Top carnivores in the suburbs? Ecological and conservation issues raised by colonization of north-eastern North America by coyotes. *Bioscience* 52(2): 185–190. https://doi.org/10.1641/0006-3568(2002)052[0185:TCITSE]2.0.CO;2

Green, D.S., S.M. Matthews, R.C. Swiers, R.L. Callas, J.S. Yaeger, S.L. Farber, M.K. Schwartz & R.A. Powell (2018). Dynamic occupancy modelling reveals a hierarchy of competition among fishers, grey foxes and ringtails. *Journal of Animal Ecology* 87(3): 813–824. https://doi.org/10.1111/1365-2656.12791

Gómez-Ortiz, Y., O. Monroy-Vilchis & I. Castro-Arellano (2019). Temporal coexistence in a carnivore assemblage from central Mexico: temporal-domain dependence. *Mammal Research* 64(3): 333–342. https://doi.org/10.1007/s13364-019-00415-8

Greenberg, C.H. & M.R. Pelton (1994). Home range and activity patterns by Gray Foxes, *Urocyon cinereoargenteus* (Carnivorea: Canidae), in east Tennessee. *Brimleyana* 21: 131–140.

Haines, A.M., M.E. Tewes, L.L. Laack, J.S. Horne & J.H. Young (2006). A habitat-based population viability analysis for ocelots (*Leopardus pardalis*) in the United States. *Biological Conservation* 132(4): 424–436. https://doi.org/10.1016/j.biocon.2006.04.035

Harmsen, B.J., E. Sanchez, O.A. Figueroa, S.M. Gutierrez, C.P. Doncaster & R.J. Foster (2019). Ecology of a versatile canid in the Neotropics: gray foxes (*Urocyon cinereoargenteus*) in Belize, Central America. *Mammal Research* 64(3): 319–332. https://doi.org/10.1007/s13364-018-00413-2

Harrison, R.L. (1993). A survey of anthropogenic ecological factors potentially affecting gray foxes (*Urocyon cinereoargenteus*) in a rural residential area. *Southwestern Naturalist* 38(4): 352–356. https://doi.org/10.1656/058.011.0313

Harrison, R.L. (1997). A comparison of gray fox ecology between residential and undeveloped rural landscapes. *Journal of Wildlife Management* 61(1): 112–122. https://doi.org/10.2307/3802420

Harrison, R.L. (2002). Estimating gray fox home-range size using half-night observation periods. *Wildlife Society Bulletin* 30(4): 1273–1275.

Henke, S.E. & F.C. Bryant (1999). Effects of coyote removal on the faunal community in western Texas. *Journal of Wildlife Management* 63(4): 1066–1081.

Hody, J.W. & R. Kays (2018). Mapping the expansion of coyotes (*Canis*

latrans) across North and Central America. *Zookeys* 759: 81–97. https://doi.org/10.3897/zookeys.759.15149

Holmgren, M. & S.A. Schnitzer (2004). Science on the rise in developing countries. *PLoS Biology* 2(1): 10–13. https://doi.org/10.1371/journal.pbio.0020001

Hostetler, J.A., J.W. McCown, E.P. Garrison, A.M. Neils, M.A. Barrett, M.E. Sunquist, S.L. Simek & M.K. Oli (2009). Demographic consequences of anthropogenic influences: Florida black bears in north-central Florida. *Biological Conservation* 142(11): 2456–2463. https://doi.org/10.1016/j.biocon.2009.05.029

Jones, G.D. & J.K. Frey (2008). First record of the gray fox (*Urocyon cinereoargenteus*) on Texas Barrier Islands. *Texas Journal of Science* 60(3): 225–227.

Kapfer, J.M. & R.W. Kirk (2012). Observations of gray foxes (*Urocyon cinereoargenteus*) in a suburban landscape in the piedmont of North Carolina. *Southeastern Naturalist* 11(3): 507–516. https://doi.org/10.1656/058.011.0313

Karlin, M. & G. De La Paz (2015). Using camera-trap technology to improve undergraduate education and citizen-science contributions in wildlife research. *Southwestern Naturalist* 60: 171–179. https://doi.org/10.1894/SWNAT-D-14-00005.1

Kelly, T.R. & J.M. Sleeman (2003). Morbidity and mortality of red foxes (*Vulpes vulpes*) and gray foxes (*Urocyon cinereoargenteus*) admitted to the Wildlife Center of Virginia, 1993–2001. *Journal of Wildlife Diseases* 39: 467–469. https://doi.org/10.7589/0090-3558-39.2.467

Klymus, K.E., C.A. Richter, N. Thompson & J.E. Hinck (2017). Metabarcoding of environmental DNA samples to explore the use of uranium mine containment ponds as a water source for wildlife. *Diversity* 9: 54. https://doi.org/10.3390/d9040054

Kowalski, B., F. Watson, C. Garza & B. Delgado (2015). Effects of landscape covariates on the distribution and detection probabilities of mammalian carnivores. *Journal of Mammalogy* 96: 511–521. https://doi.org/10.1093/jmammal/gyv056

LeFlore, E.G., T.K. Fuller, J.T. Finn, S. DeStefano & J.F. Organ (2019). Wild canid distribution and co-existence in a natural-urban matrix of the pioneer valley of western Massachusetts. *Northeastern Naturalist* 26: 325–342. https://doi.org/10.1656/045.026.0208

Lesmeister, D.B., C.K. Nielsen, E.M. Schauber & E.C. Hellgren (2015). Spatial and temporal structure of a mesocarnivore guild in midwestern North America. *Wildlife Monographs* 191: 1–61. https://doi.org/10.1002/wmon.1015

Lombardi, J.V., C.E. Comer, D.G. Scognamillo & W.C. Conway (2017). Coyote, fox, and bobcat response to anthropogenic and natural landscape features in a small urban area. *Urban Ecosystems* 20: 1239–1248. https://doi.org/10.1007/s11252-017-0676-z

Lovell, C.D., B.D. Leopold & C.C. Shropshire (1998). Trends in Mississippi predator populations, 1980-1995. *Wildlife Society Bulletin* 26: 552–556.

Mahard, T.J., J.A. Litvaitis, P. Tate, G.C. Reed & D.J.A. Broman (2016). An evaluation of hunter surveys to monitor relative abundance of bobcats. *Wildlife Society Bulletin* 40(2): 224–232.

Markovchick-Nicholls, L., H.M. Regan, D.H. Deutschman, A. Widyanata, B. Martin, L. Noreke & T.A. Hunt (2008). Relationships between human disturbance and wildlife land use in urban habitat fragments. *Conservation Biology* 22: 99–109. https://doi.org/10.1111/j.1523-1739.2007.00846.x

Maxwell, D. & S. Jennings (2005). Power of monitoring programmes to detect decline and recovery of rare and vulnerable fish. *Journal of Applied Ecology* 42(1): 25–37. https://doi.org/10.1111/j.1365-2664.2005.01000.x

Mcalpine, D., J.D. Martin & C. Libby (2008). First occurrence of the grey fox, *Urocyon cinereoargenteus*, in New Brunswick: a climate-change mediated range expansion? *Canadian Field-Naturalist* 122: 169–171.

Mella-Méndez, I., R. Flores-Peredo, J. Pérez-Torres, S. Hernández-González, D.U. González-Uribe & B.D. Bolivar-Cimé (2019). Activity patterns and temporal niche partitioning of dogs and medium-sized wild mammals in urban parks of Xalapa, Mexico. *Urban Ecosystems* 22: 1061–1070. https://doi.org/10.1007/s11252-019-00878-2

Moore, J.E., (1952). The gray fox in Alberta. *Journal of Mammalogy* 33: 253–253.

Mueller, M.M., D. Drake & M.L. Allen (2019). Using citizen science to inform urban canid management. *Landscape and Urban Planning* 189: 362–371. https://doi.org/10.1016/j.landurbplan.2019.04.023

Mumme, R.L., S.J. Schoech, G.W. Woolfenden & J.W. Fitzpatrick (2000). Life and death in the fast lane: demographic consequences of road mortality in the Florida scrub jay. *Conservation Biology* 14: 501–512. https://doi.org/10.1046/j.1523-1739.2000.98370.x

Nickel, B.A., J. Suraci, M.L. Allen & C.C. Wilmers (2020). Human presence and human footprint have non-equivalent effects on wildlife spatiotemporal habitat use. *Biological Conservation* 241: 108383. https://doi.org/10.1016/j.biocon.2019.108383

O'Donnell, K. & J. delBarco-Trillo (2020). Changes in the home range sizes of terrestrial vertebrates in response to urban disturbance: a meta-analysis. *Journal of Urban Ecology* 6: 1–8. https://doi.org/10.1644/09-MAMM-A-312.1

Omernik, J.M. & G.E. Griffith (2014). Ecoregions of the conterminous United States: evolution of a hierarchical spatial framework. *Environmental Management* 54: 1249–1266. https://doi.org/10.1007/s00267-014-0364-1

Ordeñana, M.A., K.R. Crooks, E.E. Boydston, R.N. Fisher, L.M. Lyren, S. Siudyla, C.D. Haas, S. Harris, S.A. Hathaway, G.M. Turschak, A.K. Miles & D.H. van Vuren (2010). Effects of urbanization on carnivore species distribution and richness. *Journal of Mammalogy* 91: 1322–1331.

Pearman-Gillman, S.B., J.E. Katz, R.M. Mickey, J.D. Murdoch & T.M. Donovan (2020). Predicting wildlife distribution patterns in New England USA with expert elicitation techniques. *Global Ecology and Conservation* 21: e00853. https://doi.org/10.1016/j.gecco.2019.e00853

Perez-Solano, L.A., M. Gonzalez, E. Lopez-Tello & S. Mandujano (2018). Medium and large mammals associated with the tropical dry forest of central Mexico. *Revista De Biologia Tropical* 66: 1232–1243.

Peterson, R.L., R.O. Standfield, E.H. McEwen & A.C. Brooks (1953). Early records of the red and gray fox in Ontario. *Journal of Mammalogy* 34: 126–127.

Pineda-Guerrero, A., J.F. Gonzalez-Maya & J. Perez-Torres (2015). Conservation value of forest fragments for medium-sized carnivores in a silvopastoral system in Colombia. *Mammalia* 79: 115–119. https://doi.org/10.1515/mammalia-2013-0050

Reed, S.E. (2011). Non-invasive methods to assess co-occurrence of mammalian carnivores. *Southwestern Naturalist* 56: 231–240. https://doi.org/10.1894/F13-JKF-14.1

Rich, M., C. Thompson, S. Prange & V.D. Popescu (2018). Relative importance of habitat characteristics and interspecific relations in determining terrestrial carnivore occurrence. *Frontiers in Ecology and Evolution* 6: 1–13. https://doi.org/10.3389/fevo.2018.00078

Richmond, N.D. (1952). Fluctuations in gray fox population in Pennsylvania and their relationship to precipitation. *Journal of Wildlife Management* 16: 198–206. https://doi.org/10.2307/3796930

Riley, S.P.D. (2006). Spatial ecology of bobcats and gray foxes in urban and rural zones of a national park. *The Journal of Wildlife Management* 70: 1425–1435.

Riley, S.P.D., R.M. Sauvajot, T.K. Fuller, E.C. York, D.A. Kamradt, C. Bromley & R.K. Wayne (2003). Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California. *Conservation Biology* 17: 566–576. https://doi.org/10.1046/j.1523-1739.2003.01458.x

Roemer, G., B. Cypher & R. List (2016). *Urocyon cinereoargenteus*. *The IUCN Red List of Threatened Species 2016*: e.T22780A46178068.

Rota, C.T., M.A.R. Ferreira, R.W. Kays, T.D. Forrester, E.L. Kalies, W.J. McShea, A.W. Parsons & J.J. Millspaugh (2016). A multispecies occupancy model for two or more interacting species. *Methods in Ecology and Evolution* 7: 1164–1173. https://doi.org/10.1111/2041-210X.12587

Sawyer, D.T. & T.T. Fendley (1994). Seasonal habitat use by gray foxes on the Savannah River site. *Proceedings of the Forty-Eighth Annual Conference of the Southeastern Association of Fish and Wildlife Agencies* 162–172.

Schantz, V.S. (1950). The gray fox in North-Dakota. *Journal of Mammalogy* 31: 197–198.

Schuler, K.L., G.M. Schroeder, J.A. Jenks & J.G. Kie (2014). Ad hoc smoothing parameter performance in kernel estimates of GPS-derived home ranges. *Wildlife Biology* 20: 259–266. https://doi.org/10.2981/wlb.12117

Schwertner, T.W., M.J. Peterson & N.J. Silvy (2006). Multi-scale asynchrony and spatial structuring of mesopredator abundance trends in central Texas, 1978–2003. *Texas Journal of Science* 58: 155–168.

Sillero-Zubiri, C., M. Hoffmann & D.W. Macdonald (2004). Canids: foxes, wolves, jackals and dogs. *Status Survey and Conservation Action Plan*. IUCN/SSC Canid Specialist Group. Gland, Switzerland.

Swaisgood, R.R., D. Wang & F. Wei (2018). Panda downlisted but not out of the woods. *Conservation Letters* 11: e12355.

Temple, D.L., M.J. Chamberlain & L.M. Conner (2010). Spatial ecology, survival and cause-specific mortality of gray foxes (*Urocyon cinereoargenteus*) in a longleaf pine ecosystem. *The American Midland Naturalist* 163: 413–422. https://doi.org/10.1674/0003-0031-163.2.413

Trapp, G.R. (1978). Comparative behavioral ecology of ringtail and gray fox in southwestern Utah. *Carnivore* 1: 3–32.

Walk, J.W., M.P. Ward, T.J. Benson, J.L. Deppe, S. Lischka, S.D. Bailey & J.D. Brawn (2010). Illinois birds: a century of change. Illinois Natural History Survey Special Publication 31, Champaign, USA.

Walters, J.R., S.R. Derrickson, M.D. Fry, S.M. Haig, J.M. Marzluff & J.M., Wunderle Jr. (2010). Status of the California condor (*Gymnogyps californianus*) and efforts to achieve its recovery. *The Auk* 127: 969–1001. https://doi.org/10.1525/auk.2010.127.4.969

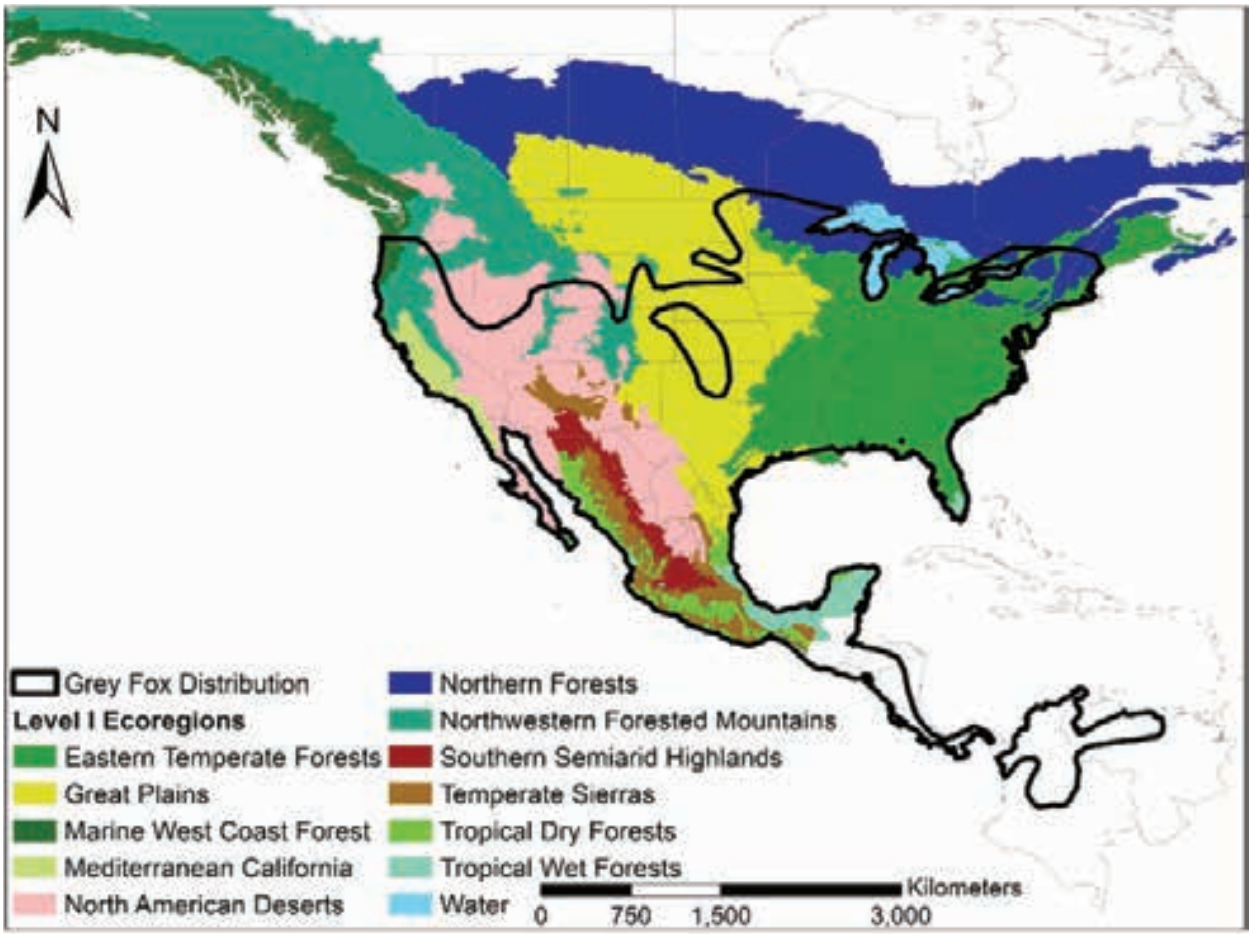
Walton, Z., G. Samelius, M. Odden & T. Willebrand (2017). Variation in home range size of red foxes *Vulpes vulpes* along a gradient of productivity and human landscape alteration. *PLoS ONE* 12: e0175291. https://doi.org/10.1371/journal.pone.0175291

Wang, Y., M.L. Allen & C.C. Wilmers (2015). Mesopredator spatial and temporal responses to large predators and human development in the Santa Cruz Mountains of California. *Biological Conservation* 190: 23–33. https://doi.org/10.1016/j.biocon.2015.05.007

Ward, R.J., R.A. Griffiths, J.W. Wilkinson & N. Cornish (2017). Optimising monitoring efforts for secretive snakes: a comparison of occupancy and N-mixture models for assessment of population status. *Scientific Reports* 7(1): 18074. https://doi.org/10.1038/s41598-017-18343-5

Weston, J.L. & I.L. Brisbin (2003). Demographics of a protected population of gray foxes (*Urocyon cinereoargenteus*) in South Carolina. *Journal of Mammalogy* 84: 996–1005. https://doi.org/10.1644/BOS-037

Zielinski, W.J., R.L. Truex, F.V. Schlexer, L.A. Campbell & C. Carroll (2005). Historical and contemporary distributions of carnivores in forests of the Sierra Nevada, California, USA. *Journal of Biogeography* 32: 1385–1407. https://doi.org/10.1111/j.1365-2699.2005.01234.x



Appendix 1. Level I ecoregions from Omernik & Griffith (2014) within our study area overlaid with the distribution of Grey Foxes (Roemer et al. 2016).

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SHORT COMMUNICATION

On the freshwater fish fauna of Krishna River, Sangli District, Maharashtra, India

Suresh M. Kumbar [1], Shrikant S. Jadhav [2], Swapnali B. Lad [3], Abhijit B. Ghadage [4], Satyawan S. Patil [5] & C. Shiva Shankar [6]

[1,3,4,5] Department of Zoology, Arts, Commerce and Science College, Vidyanagar, Tal. Palus, District Sangli, Maharashtra 416310, India.
[2,6] Zoological Survey of India, Freshwater Biology Regional Centre, Inner Ring Road, Attapur, Hyderguda, Hyderabad, Telangana 500048, India.
[1] smkumbar@rediffmail.com (corresponding author), [2] shrikantjadhavzsi@gmail.com, [3] swapnali5lad@gmail.com,
[4] abghadage82@gmail.com, [5] sspatilzoology@gmail.com, [6] cshivashankarchinna@gmail.com

Abstract: Freshwater fish fauna of Krishna River, Sangli district was studied from 2013 to 2017. A total of 73 species belonging to 10 orders, 22 families, and 49 genera were recorded, of which, 29 species are endemic to the Western Ghats and 11 species endemic to the Krishna River system. *Labeo kontius*, an endemic barb of the Cauvery River System was recorded for the first time from the Krishna River, Maharashtra. As per the IUCN Red List of Threatened Species, 54 species are assessed as 'Least Concern', four species as 'Near Threatened', three species as 'Vulnerable', five as 'Endangered', and two as 'Data Deficient'. The conservation status of two species has not yet been assessed. Fish fauna of the Krishna River within the study area is threatened as a result of alien species, and several anthropogenic stressors such as pollution from industrial as well as agricultural sources, human settlements, and overfishing. Since, this small study area harbours 28 endemic and eight threatened species, their conservation should be given high priority.

Keywords: Conservation, endemic species, fish diversity, threats, Western Ghats.

The Western Ghats of India is global biodiversity hotspot (Myers et al. 2000), known for its high level of endemism of taxonomic groups such as amphibians and freshwater fish. Around 320 species belonging to 11 orders, 35 families, and 112 genera are known from this region (Dahanukar & Raghavan 2013) and this number is certain to increase given the high number of species being discovered on a yearly basis. Krishna is one of the major perennial rivers of the northern Western Ghats. The river originates at Mahabaleshwar (17.988^{0}N; 73.637^{0}E), Satara District, Maharashtra, and traverses a distance of 290 km through Satara, Sangli, and Kolhapur districts in Maharashtra, thereafter flowing through the states of Karnataka and Telangana before emptying into the Bay of Bengal at Hamasaladeevi in Andhra Pradesh.

Earliest studies on the fish fauna of Deccan was carried out by Sykes (1839). Specific studies on the fish fauna of the Krishna River (in addition to the Godavari) were carried out by David (1963), but no separate 'river-wise' locations for the species collected, were provided. A major study on the fish fauna of Krishna River was also carried out by Jayaram (1995), but no separate list of fishes collected specifically from the tributaries in Sangli District was provided.

Previous studies on the fish fauna of Krishna River has largely focused on the tributaries in Satara District.

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Figure 1. Sampling sites in the Krishna River surveyed as part of the study

Annandale (1919) reported 18 species from the Yenna River at Medha, followed by Silas (1953) who studied the fish fauna of Mahabaleshwar and Wai and recorded 14 species. Arunachalam et al. (2002) recorded 14 species from Dhom reservoir, and subsequently Jadhav et al. (2011) reported 58 species from the Koyna tributary. More recently, Kharat et al. (2012) provided an updated checklist of the fish fauna of Krishna River at Wai and Dhom reservoir, and reported the presence of 51 species. The only published work on the freshwater fishes of the Krishna River in Sangli District is by Kumbar & Lad (2014) who recorded 13 species of catfishes. In the present paper, we provide a comprehensive checklist of the freshwater fishes of the Krishna River flowing through Sangli district in Maharashtra and identify possible threats so as build baseline data for future conservation action.

Methods

Field surveys were undertaken in the Krishna River, Sangli district, Western Maharashtra from the year 2013 to 2017. Fish specimens were collected from Bahe (17.1138°N & 74.2811°E), Borgaon (17.0808°N & 74.3691°E), Sangli (16.8591°N & 74.5577°E), Miraj (16.7877°N & 74.6291°E), and Mhaisal (16.7358°N & 74.6986°E) (Figure 1), with the help of local fishers using different mesh-sized gill nets and cast nets. Alternatively, fish samples were also procured from local fish markets.

Assuming that the fishing effort for a given type of net was constant, the relative abundance of the fish was grossly categorized following Dahanukar et al. (2012), namely abundant (76–100 % of total catch), common (51–75 % of total catch), moderate (26–50 % of total catch), and rare (1–25 % of total catch). Samples were preserved in 10% formalin and identified using the available literature (Menon 1987, 1992; Talwar & Jhingran 1991; Jayaram & Dhas 2000; Jayaram &

Sanyal 2003; Jayaram 1991, 2006, 2010) and relevant recent taxonomic literature related to different groups (Dahanukar et al. 2011; Keskar et al. 2015; Katawate et al. 2016; Lavoué et al. 2020; Sudasinghe et al. 2020). All identified specimens are deposited at the Department of Zoology, Arts, Commerce and Science College, Palus, Sangli District, Maharashtra, with accession numbers from ZID 01–73.

Results

We recorded a total 73 species of freshwater fish belonging to 10 orders, 22 families and 49 genera from the Krishna River in Sangli district (Table 1). Order Cypriniformes dominated with 42 species, followed by Siluriformes (18 species), Anabantiformes (three species), Synbranchiformes, Perciformes, & Beloniformes (two species each), and Cyprinodontiformes, Gobiiformes, Osteoglossiformes, & Cichliformes (one species each). Representative species of fish collected from Krishna River are shown in (Images 1, 2, 3 & 4). As per the IUCN Red List of Threatened Species, 54 species are assessed as 'Least Concern', four species as 'Near Threatened', three species as 'Vulnerable', five as 'Endangered', two as 'Data Deficient', and the conservation status of two species has not yet been assessed. Of the 73 species, 29 are endemic to the Western Ghats, and 11 are endemic to the Krishna River System (Table 1). Microlevel distribution of species along the upstream-downstream gradient showed that 56 species occurred in upper reaches, 28 species in middle stream, and 37 species in downstream respectively (Figure 1). Of the total fish collected, 15 species were found to be common, six abundant, 28 moderate and 24 rare.

Fish fauna of Krishna River is severely threatened by pollution from organic wastes particularly around the towns of Sangli and Miraj as well as from pollution due to agricultural runoff and sewage. Recently, sand mining has also increased significantly along the stretch of the river near Bahe and Borgaon, resulting in the loss of available habitats to the fish fauna of these areas. Similarly, overfishing, indiscriminate use of poison to collect fish in large numbers and using fine-meshed gill-nets, is a specific threat to species of the genera *Bangana, Tor, Hypselobarbus, Labeo, Cirrhinus, Opsarius, Salmostoma, Botia, Mystus, Cirrhinus*, and *Puntius*.

We also recorded seven non-native species—four transplanted: *Cirrhinus mrigala, Labeo rohita, Labeo catla, Labeo calbasu* in all sites and three alien invasive species: *Oreochromis mossambicus, Cyprinus carpio* and *Clarias gariepinus* at Sangli and Miraj. Studies in their entirety of Krishna River by Jayaram (1995) have recorded 10 invasive alien species, but interestingly Jadhav et al. (2011) could not record any alien species from Koyna tributary. However, Dahanukar et al. (2012) recoded seven introduced species from Indrayani River near Pune, and four species from Hiranyekeshi River by Kumkar et al. (2017).

Discussion

Krishna River harbours a number of endemic and threatened species. We collected *Glyptothorax* cf. *poonaensis* from Bahe near Islampur in moderate numbers. These specimens resemble *G. poonaensis* (Hora 1938), but differs considerably with the description provided in Dahanukar et al. (2011). It is therefore possible that this species might comprise a 'complex'. The population of Endangered and endemic *Bangana nukta* is declining drastically in the study area as per the local knowledge of fishers. Pollution, overfishing and the competition created by transplanted carps such as

Image 1. *Labeo kontius* collected from Krishna River near Miraj . Lateral view. After preservation. Scale= 10 mm. (Voucher No, ZID 26)

Table 1. List of Freshwater Fishes collected from the Krishna River, Sangli District, Maharashtra

	Order	Family	Species	Status	WGE	KRE	IUCN Red List
1	Anabantiformes	Channidae	*Channa gachua* (Hamilton, 1822)	M	-	-	LC
2			*Channa punctata* (Bloch, 1793)	M	-	-	LC
3			*Channa striata* (Bloch, 1793)	R	-	-	LC
4	Beloniformes	Belonidae	*Xenentodon cancila* (Hamilton, 1822)	R	-	-	LC
5		Hemiramphidae	*Hyporhamphus limbatus* (Valenciennes, 1847)	R	-	-	LC
6	Cichliformes	Cichlidae	*Oreochromis mossambicus* (Peters, 1852)	C	-	-	
7	Cypriniformes	Botiidae	*Botia striata* Rao, 1920	A	+	+	EN
8		Cobitidae	*Lepidocephalichthys thermalis* (Valenciennes, 1846)	A	-	-	LC
9		Cyprinidae	*Bangana nukta* (Sykes, 1839)	R	+	-	EN
10			*Cirrhinus reba* (Hamilton, 1822)	M	-	-	LC
11			*Cyprinus carpio* Linnaeus, 1758	R	-	-	
12			*Garra bicornuta* Rao, 1920	C	+	+	NT
13			*Garra mullya* (Sykes, 1839)	A	-	-	LC
14			*Gymnostomus ariza* (Hamilton, 1807)	R	-	-	LC
15			*Gymnostomus fulungee* (Sykes, 1839)	M	+	+	LC
16			*Hypselobarbus jerdoni* (Day, 1870)	M	+	-	LC
17			*Hypselobarbus kolus* (Sykes, 1839)	M	+	-	VU
18			*Hypselobarbus mussullah* (Sykes, 1839)	M	+	-	EN
19			*Labeo calbasu* (Hamilton, 1822)	M	-	-	LC
20			*Labeo catla* (Hamilton, 1822)	R	-	-	LC
21			*Labeo fimbriatus* (Bloch, 1795)	R	-	-	LC
22			*Labeo kontius* (Jerdon, 1849)	R	+	-	LC
23			*Labeo porcellus* (Heckel, 1844)	R	+	-	LC
24			*Labeo potail* (Sykes, 1839)	R	+	-	EN
25			*Labeo rohita* (Hamilton, 1822)	R	-	-	LC
26			*Osteobrama neilli* (Day, 1873)	R	+	+	LC
27			*Ostobrama peninsularis* Silas, 1952	M	+	-	DD
28			*Osteobrama vigorsii* (Sykes, 1839)	C	-	-	LC
29			*Parapsilorhynchus discophorus* Hora, 1921	R	+	-	VU
30			*Pethia sanjaymoluri* Katwate, Jadhav, Kumkar, Raghavan & Dahanukar, 2016	A	+	+	NE
31			*Puntius chola* (Hamilton, 1822)	M	-	-	LC
32			*Puntius sophore* (Hamilton, 1822)	C	-	-	LC
33			*Rohtee ogilbii* Sykes, 1839	M	+	+	LC
34			*Systomus sarana* (Hamilton, 1822)	C	+	-	LC
35		Danionidae	*Amblypharyngodon mola* (Hamilton, 1822)	R	-	-	NE
36			*Devario aequipinnatus* (McClelland, 1839)	C	-	-	LC
37			*Opsarius bendelisis* (Hamilton, 1807)	M	-	-	LC
38			*Rasbora daniconius* (Hamilton, 1822)	C	-	-	LC
39			*Salmostoma acinaces* (Valenciennes, 1844)	C	+	-	LC
40			*Salmostoma balookee* (Sykes, 1839)	C	-	-	LC
41			*Salmostoma bacaila* (Hamilton, 1822)	M	-	-	LC
42			*Salmostoma boopis* (Day, 1874)	A	+	-	LC
43			*Salmostoma novacula* (Valenciennes, 1838)	M	+	-	LC
44		Nemacheilidae	*Indoreonectes cf. evezardi* (Day, 1872)	R	-	-	LC
45			*Nemacheilus anguilla* Annandale, 1919	M	+	+	LC
46			*Nemachilichthys rueppelli* (Sykes, 1839)	M	+	+	LC
47			*Paracanthocobitis mooreh* (Sykes, 1839)	A			LC
48			*Schistura denisoni* (Day, 1867)	R	-	-	LC
49	Cyprinodontiformes	Aplocheilidae	*Aplocheilus lineatus* (Valenciennes, 1846)	R	-	-	LC
50	Gobiiformes	Gobiidae	*Glossogobius giuris* (Hamilton, 1822)	C	-	-	LC
51	Osteoglossiformes	Notopteridae	*Notopterus synurus* (Bloch & Schneider, 1801)	C	-	-	LC
52	Perciformes	Ambassidae	*Chanda nama* Hamilton, 1822	M	-	-	LC
53			*Parambassis ranga* (Hamilton, 1822)	M	-	-	LC

	Order	Family	Species	Status	WGE	KRE	IUCN Red List
54	Siluriformes	Ailiidae	*Proeutropiichthys taakree* (Sykes, 1839)	M	-	-	LC
55		Bagridae	*Hemibagrus maydelli* (Rossel, 1964)	M	+	+	LC
56			*Mystus bleekeri* (Day, 1877)	M	-	-	LC
57			*Mystus malabaricus* (Jerdon, 1849)	M	+	-	NT
58			*Mystus seengtee* (Sykes, 1839)	M	+	-	LC
59			*Mystus vittatus* (Bloch, 1794)	R	-	-	LC
60			*Rita gogra* (Sykes, 1839)	M	+	-	LC
61			*Rita kuturnee* (Sykes, 1839)	M	+	-	LC
62			*Sperata* cf. *aor* (Hamilton, 1822)	C	-	-	LC
63			*Sperata seenghala* (Sykes, 1839)	M	-	-	LC
64		Clariidae	*Clarias gariepinus* (Burchell, 1822)	C	-	-	
65		Heteropneustidae	*Heteropneustes fossilis* (Bloch, 1794)	M	-	-	LC
66		Horabagridae	*Pachypterus khavalchor* (Kulkarni, 1952)	R	+	+	DD
67		Pangasiidae	*Pangasius pangasius* (Hamilton, 1822)	R	-	-	LC
68		Siluridae	*Ompok bimaculatus* (Bloch, 1794)	C	-	-	NT
69			*Wallago attu* (Bloch & Schneider, 1801)	R	-	-	NT
70		Sisoridae	*Glyptothorax cf. poonaensis* Hora, 1938	R	+	+	EN
71			*Gagata itchkeea* (Sykes, 1839)	R	+		VU
72	Synbranchiformes	Mastacembelidae	*Macrognathus pancalus* (Hamilton, 1822)	M	-	-	LC
73			*Mastacembelus armatus* (Lacepede, 1800)	C	-	-	LC

A—Abundant | C—Common | M—Moderate | R—Rare | EN—Endangered | VU—Vulnerable | NT—Near Threatened | DD—Data Deficient | LC—Least Concern. Taxonomic status as per Fricke et al. (2020). Status for invasive alien species are not provided.

Cirrhinus mrigala, Labeo rohita, and *Labeo catla* may also be contributing to the population decline of *B. nukta* (Ghate et al. 2002; Kharat et al. 2003; Dahanukar et al. 2012). Similarly, *Hypselobarbus mussullah* assessed as 'Endangered' as per IUCN criteria (Dahanukar & Raghavan 2011) was collected in low numbers at Bahe. *Labeo potail,* a species that has been assessed as 'Endangered' due to population decline of 50–60 % in the last 10 years due to organic and inorganic pollution, exploitation and competition created by transplanted carps (Dahanukar 2011) was collected near Palus and Sangli. However, their numbers are declining rapidly due to pollution from domestic organic waste and effluents released heavily from industries situated on the river-bank. Another Krishna River endemic and threatened species, *Botia striata* (locally called 'waghmasa') (Image 3-22) was recorded from Bahe, Borgaon and Islampur. At Bahe and Borgaon, indiscriminate collection of this species by aquarium traders in the summer months is a major threat to the species. The species is however relatively abundant in the study area, and also in Koyna River (Jadhav *et al*. 2011).

Gagata itchkeea (Image 3-25) a species recorded previously from the Krishna River system (Kalwar & Kelkar 1956; Jayaram 1995; Kharat *et al*. 2003; Wagh & Ghate 2003; Chandanshive *et al*. 2007) was collected from Bahe in very low numbers. Other important endemic species such as *Garra bicornuta, Parapsilorhynchus discophorus, Pachypterus khavalchor* were also collected from various sampling sites.

We recorded *Labeo kontius* (Image 1) for the first time from the Krishna River system in, Maharashtra State, through samples from Miraj, thus extending its range to the northern part of the Western Ghats. *Labeo kontius* was described by Jerdon (1849) from Cauvery River and its tributaries. Currently, the species is also known to occur in the Bhavani and Moyar rivers and their tributaries (Rajan 1955; Manimekalan 1998), as well as in the main stretch of the Cauvery River (Jayaram et al. 1982; Jayaram & Dhas 2000).

Krishna River harbours a rich diversity of endemic and threatened fishes of Western Ghats. However, this fauna is threatened due to overfishing, introduced species, sand mining and organic and inorganic pollution. If the present anthropogenic impact continues, this might lead to a drastic decline of habitats and populations of fish species available in this region. It is therefore essential to declare some stretch of rivers as aquatic sanctuaries, particularly near Bahe and Miraj for protection and preservation of endemic and threatened species and mitigation of anthropogenic stress.

References

Annandale, N. (1919). Bombay streams fauna: notes on fresh water fish mostly from the Satara and Poona Districts. *Records of the Indian Museum* 16: 125–138.

Image 2. 1—*Systomus sarana* (Hamilton) | 2—*Pethia sanjaymoluri* Katwate, Jadhav, Kumkar, Raghavan & Dahanukar | 3—*Hypselobarbus jerdoni* (Day) | 4—*Puntius chola* (Hamilton) | 5—*Bangana nukta* (Sykes) | 6—*Hypselobarbus kolus* (Sykes) | 7—*Devario aequipinnatus* (McClelland) | 8—*Salmostoma bacaila* (Hamilton) | 9—*Salmostoma novacula* (Valenciennes) | 10—*Opsarius bendelisis* (Hamilton) | 11—*Osteobrama vigorsii* (Sykes) | 12—*Rohtee ogilbii* (Sykes) | 13—*Hypselobarbus mussullah* (Sykes) | 14—*Gymnostomus ariza* (Hamilton) | 15—*Xenentodon cancila* (Hamilton).

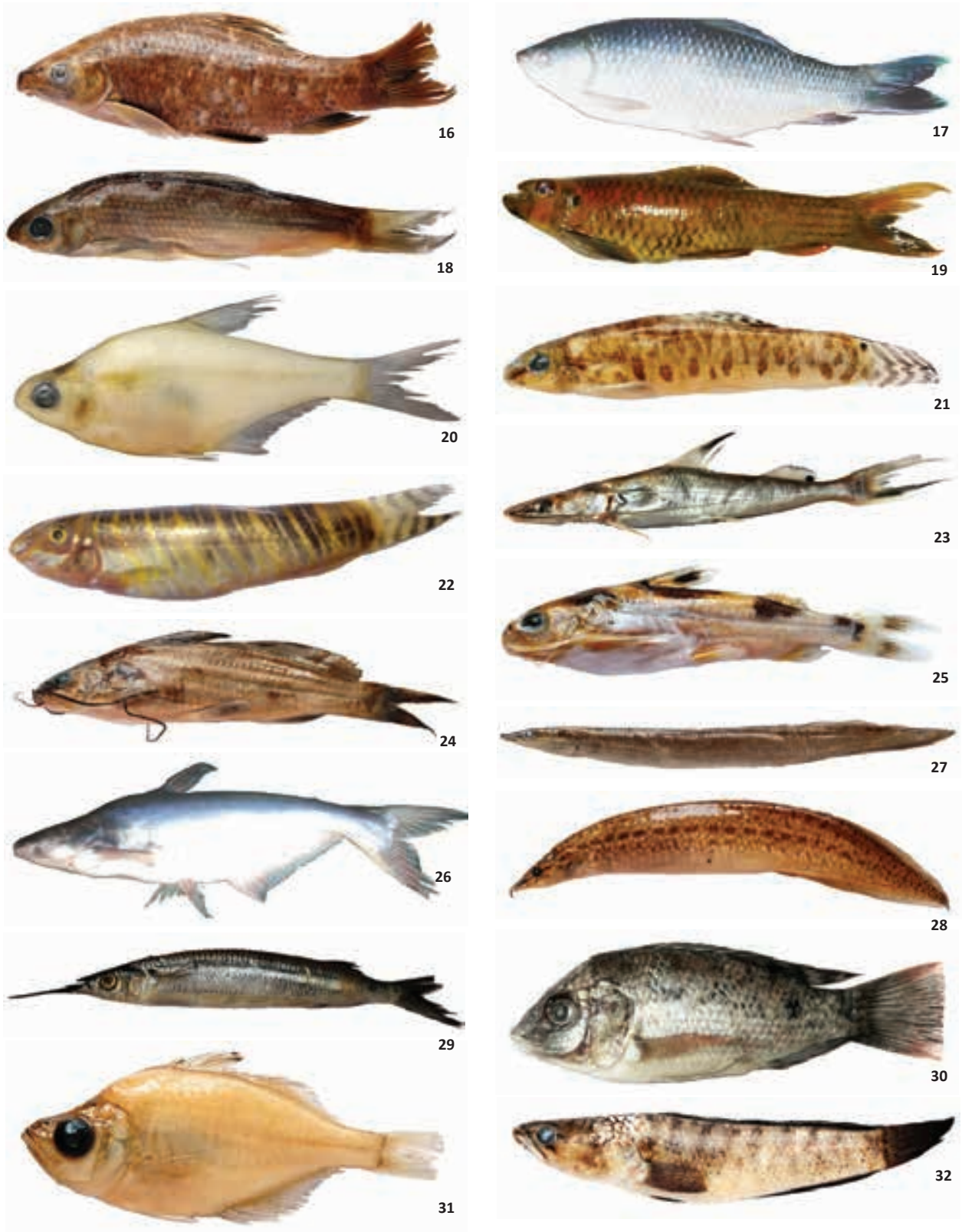

Image 3. 16—*Labeo fimbriatus* (Bloch) | 17—*Labeo rohita* (Hamilton) | 18—*Cirrhinus reba* (Hamilton) | 19—*Garra bicornuta* Rao | 20—*Osteobrama peninsularis* Silas | 21—*Paracanthocobitis mooreh* (Sykes) | 22—*Botia striata* Rao | 23—*Sperata seenghala* (Sykes) | 24—*Mystus vittatus* (Bloch) | 25—*Gagata itchkeea* (Sykes) | 26—*Pangasius pangasius* (Hamilton) | 27—*Mastacembelus armatus* (Lacepede) | 28—*Macrognathus pancalus* (Hamilton) | 29—*Hyporhamphus limbatus* (Valenciennes) | 30—*Oreochromis mossambicus* (Peters) | 31—*Parambassis ranga* (Hamilton) | 32—*Channa punctata* (Bloch).


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Image 4. 33—*Channa striata* (Bloch) | 34—*Channa gachua* (Hamilton) | 35—*Amblypharyngodon mola* (Hamilton) | 36—*Ompok bimaculatus* (Bloch).

Arunachalam, M., A. Sankaranarayanan, A. Manimekalan, R. Soranam, R. & J. A. Johnson (2002). Fish fauna of some streams and rivers in the Western Ghats of Maharashtra. *Journal of the Bombay Natural History Society* 99(2): 337–341.

Chandanshive, E.N., S. M. Kamble & B. E. Yadav (2007). Fish fauna of Pavana river of Pune, Maharashtra. *Zoos' Print Journal* 22(5): 2693–2694. https://doi.org/10.11609/JoTT.ZPJ.1481.2693-4

Dahanukar, N., M. Diwekar & M. Paingankar (2011). Rediscovery of threatened and Western Ghats endemic Sisorid Catfish *Glyptothorax poonaensis* (Teleostei: Siluriformes: Sisoridae). *Journal of Threatened Taxa* 3(7): 1885–1898. https://doi.org/10.11609/JoTT.o2663.1885-98

Dahanukar, N., M. Paingankar, R.N. Raut & S.S. Kharat (2012). Fish fauna of Indrayani River, northern Western Ghats, India. *Journal of Threatened Taxa* 4(1): 2310–2317. https://doi.org/10.11609/JoTT.o2771.2310-7

Dahanukar, N. & R. Raghavan (2013). Freshwater fishes of Western Ghats: Checklist v 1.0 August 2013. MIN - Newsletter of IUCN SSC/WI Freshwater Fish Specialist Group - South Asia and the Freshwater Fish Conservation Network of South Asia (FFCNSA) 1: 6–16.

Dahanukar, N. & R. Raghavan (2011). *Hypselobarbus mussullah*. The IUCN Red List of Threatened Species. Downloaded on 03 September 2020. https://doi.org/10.2305/IUCN.UK.2011-1.RLTS.T172446A6893728.en

Dahanukar, N. (2011). *Labeo potail*. The IUCN Red List of Threatened Species. Downloaded on 03 September 2020. https://doi.org/10.2305/IUCN.UK.2011-1.RLTS.T169627A6657573.en

David, A. (1963). Studies on the fish and fisheries of the Godavari and the Krishna River systems. Pt. I. *Proeedings of the Nature Acadamy of Science, India, Allahabad* B (2): 263–286.

Fricke, R., W.N. Eschmeyer & Van der Laan (eds.) (2020). Eschmeyers Catalogue of Fishes Genera, Species, References. Catalog of Fishes electronic version. http://research.calacademy.org/ichthyology/catalog/fishcatmain.asp Online version Downloaded on 3 August 2020.

Ghate, H.V., V.M. Pawar & B.E. Yadav (2002). Note on cyprinoid fish *Schismatorhynchos* (*Nukta*) *nukta* (Sykes) from the Krishna drainage, Western Ghats. *Zoos' Print Journal* 17(7): 830–831. https://doi.org/10.11609/JoTT.ZPJ.17.7.830-1

Hora, S.L. (1938). Notes on fishes in the Indian Museum. XXXVIII. On the systematic position of *Bagrus lonah* Sykes, with descriptions of and remarks on other glyptosternoid fishes from Deccan. *Records of Indian Museum* 40: 363–375.

Jadhav, B.V., S.S. Kharat, R.N. Raut, M. Paingankar & N. Dahanukar (2011). Freshwater fish fauna of Koyna River, northern Western Ghats, India. *Journal of Threatened* Taxa 3(1): 1449–1455. https://doi.org/10.11609/JoTT.o2613.1449-55

Jayaram, K.C., T. Venkateswaralu & M.B. Ragunathan (1982). *A survey of Cauvery river system with a major account of its fish fauna.* Records of the Zoological Survey of India, Occ. Paper No. 36, 115pp.

Jayaram, K.C. (1991). Revision of the Genus *Puntius* Hamilton from the Indian Region (Pisces: Cypriniformes: Cyprinidae: Cyprininae). Occasional Paper No. 135. Records of the Zoological Survey of India, Kolkata, 178pp.

Jayaram, K.C. (1995). *The Krishna River System: A Bioresources Study*. Occasional Paper No. 160. Records of Zoological Society of India, 167pp.

Jayaram, K.C. & J.J. Dhas (2000). *Revision of the Genus* Labeo *from Indian Region with A Discussion on its Phylogeny and Zoogeography*. Occasional Paper No. 183. Records of the Zoological Survey of India, Kolkata, 143pp.

Jayaram, K.C. & A. Sanyal (2003). *A Taxonomic Revision of the Fishes of the Genus* Mystus *Scopoli* (*Family: Bagridae*). Occasional Paper No. 207. Records of the Zoological Survey of India, Kolkata, 136pp.

Jayaram, K.C. (2006). *The catfishes of the Indian Region*. Narendra Publishing House, Delhi, 383pp.

Jayaram, K.C. (2010). *The Freshwater Fishes of the Indian Region*. Second Edition. Narendra Publishing House, Delhi, 616pp.

Jerdon, T.C. (1849). On the freshwater fishes of Souther India. *Madras. 1. Lit. Sci.,* 15: 302 346.

Kalawar, A.G. & C.N. Kelkar (1956). Fishes of Kolhapur. *Journal of the Bombay Natural History Society* 53(4): 669–679.

Katwate, U., S. Jadhav, P. Kumkar, R. Raghavan & N. Dahanukar (2016). *Pethia sanjaymoluri*, a new species of barb (Teleostei: Cyprinidae) from the northern Western Ghats, India. *Journal of Fish Biology* 88: 2027–2050. https://doi.org/10.1111/jfb.12980

Keskar, A., P. Kumkar, U. Katwate, A. Ali, R. Raghavan & N. Dahanukar (2015). Redescription of *Nemachilichthys rueppelli*, a senior synonym of *N. shimogensis* (Teleostei: Nemacheilidae). *Zootaxa* 4059(3): 555–568.

Kharat, S.S., N.Dahanukar, R. Raut & M. Mahabaleshwarkar (2003). Long term changes in freshwater fish species composition in north Western Ghats, Pune District. *Current Science* 84(6): 816–820.

Kharat, S.S., M. Paingankar & N. Dahanukar (2012). Freshwater fish fauna of Krishna River at Wai, northern Western Ghats, India. *Journal of Threatened Taxa* 4(6): 2644–2652. https://doi.org/10.11609/JoTT.o2796.2644-52

Kumbar, S.M. & S. Lad (2014). Diversity, threats and conservation of catfish fauna of the Krishna River, Sangli District, Maharashtra, India. *Journal of Threatened Taxa* 6(1): 5362–5367. https://doi.org/10.11609/JoTT.o3394.5362-7

Kumkar, P., S. S. Kharat, N. S. Sawant, U. Katwate & N. Dahanukar (2017). Freshwater fish fauna of Hiranyakeshi River, the northern Western Ghats, India. *Journal of Threatened Taxa* 9(5): 10178–10186. https://doi.org/10.11609/jott.3126.9.5.10178-10186

Lavoué, S., S. Z. Ghazali, J. A. F. Jamaluddin, S. A. M. Nor and K. M. Zain (2020). Genetic evidence for the recognition of two allopatric species of Asian bronze featherback *Notopterus* (Teleostei, Osteoglossomorpha, Notopteridae). *Zoosystematics and Evolution*, v. 96(2): 449–454.

Manimekalan, A. (1998). The fishes of Mudumalai Wildlife Sanctuary, Tamil Nadu, South India. *Journal of the Bombay Natural History Society* 95(3): 431–443.

Manimekalan, A. (2011). *Labeo kontius*. The IUCN Red List of Threatened Species. Downloaded on 04 September 2020. https://doi.org/10.2305/IUCN.UK.2011-1.RLTS.T172407A6885940.en

Menon, A.G.K. (1987). *The Fauna of India and Adjacent Countries, Pisces, Vol–4, Teleostei-Cobitoidea, Part–1, Homalopteridae*. Zoological Survey of India, Kolkata, 259pp.

Menon, A.G.K. (1992). *The Fauna of India and Adjacent Countries, Pisces, Vol–4, Teleostei-Cobitoidea, Part–2 Cobitidae*. Zoological Survey of India, Kolkata, 113pp.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. De Fonseca & J. Kent (2000). Biodiversity and hotspots for conservation priorities. *Nature* 403: 853–858. https://doi.org/10.1038/35002501

Rajan, S. (1955). Notes on a collection of fish from the headwaters of the Bhavani river, South India. *Journal of the Bombay Natural History Society* 53(1): 44–48.

Silas, E.G. (1953). Notes on fishes of Mahabaleshwar and Wai (Satara Dist., Bombay State) *Journal of the Bombay Natural History Society* 51: 579–589.

Sudasinghe, H., R. Pethiyagoda, R. Raghavan, N. Dahanukar, L. Rüber & M. Meegaskumbura (2020). Diversity, phylogeny and biogeography of *Systomus* (Teleostei, Cyprinidae) in Sri Lanka. *Zoologica Scripta*, 1–22. https://doi.org/10.1111/zsc.12445

Sykes, W.H. (1839). On the fishes of the Deccan. *Proceedings of the General Meetings for Scientific Business of the Zoological Society of London* 6: 157–165.

Talwar, P.K. & A.G. Jhingran (1991). *Inland Fishes of India and Adjacent Countries*. Oxford-IBH Publishing Co. Pvt. Ltd., New Delhi, 1158pp.

Wagh, G. K. & H.V. Ghate (2003). Freshwater fish fauna of the rivers Mula and Mutha, Pune, Maharashtra. *Zoos' Print Journal* 18(1): 977–981. https://doi.org/10.11609/JoTT.ZPJ.18.1.977-89

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SHORT COMMUNICATION

Diversity and distribution of the large centipedes (Chilopoda: Scolopendromorpha) in the Phia Oac - Phia Den National Park, Vietnam

Le Xuan Son [1], Nguyen Thi Tu Anh [2], Tran Thi Thanh Binh [3], Thu Anh T. Nguyen [4] & Anh D. Nguyen [5]

[1] Institute of Tropical Ecology, Vietnamese-Russian Tropical Center, 63 Nguyen Van Huyen Str., Cau Giay District, Hanoi, Vietnam.
[2,3] Faculty of Biology, Hanoi National University of Education, 136, Xuan Thuy Str., Caugiay District, Hanoi, Vietnam.
[4,5] Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology, 18, Hoangquocviet Rd., Cau Giay District, Hanoi, Vietnam.
[1] lesonenv86@yahoo.com (corresponding author), [2] nthuanh189@gmail.com, [3] binhttt@hnue.edu.vn, [4] tuanh30499@gmail.com, [5] ducanh.iebr@gmail.com

Abstract. The scolopendromorph fauna of the Phia Oac - Phia Den National Park, northernmost Vietnam has been studied. As a result, a total of 17 species in eight genera and three families have been recorded in five different types of habitats (wood forest, bamboo forest, wood-bamboo mixed forest, pine forest, and grassland-shrubs) and from three elevation range (<1,000 m, 1,000–1,600 m, and >1,600 m). Scolopendridae is the most diverse family with nine recorded species. Of the five habitats, most species have been found in wood forests and wood-bamboo mixed forests (11 species each habitat), and at the elevation range of 1,000–1,600 m (15 species). The research also recommended that this number does not reflect the true biodiversity of this region; more intensive surveys are needed to have a better understanding of the scolopendromorph diversity in the Phia Oac - Phia Den National Park.

Keywords. Biodiversity, bioinventory, Cao Bang Province, high mountains, scolopendromorphs.

Centipedes play an important role in soil ecosystems. They participate in decaying process, returning and cycling nutrients (Lewis 1981). Some large centipedes could be used as a traditional medicine (Pham et al. 2000; Yang et al. 2013; Ma et al. 2014). To date, about 3,150 centipede species in 400 genera, 24 families, and five orders have been reported worldwide, but it is estimated 8,000 species exist in nature (Minelli 2011).

In Vietnam, 73 species in 27 genera, 13 families, and four orders (Scolopendromorpha, Geophilomorpha, Lithobiomorpha, and Scutigeromorpha) have been recorded (Tran et al. 2013). Of the four orders, Scolopendromorpha has 35 species in 11 genera and three families. The data on their distribution is very limited as some of species have been known only in one or two locations. It is because there are not many studies on centipedes in Vietnam (Tran et al. 2013, 2019; Vu et al. 2020).

The Phia Oac - Phia Den National Park is located in Cao Bang Province, northernmost part of Vietnam. Its total area is about 10,593 ha including 8,146 ha of natural forests. This park has very complicated topology with high mountains (more than 1,000 m). The biodiversity of this park is very high and quite characteristic because of complicated combination of high mountains and geological & climatic conditions (Vietnam Administration of Forestry 2013). The recent report already recorded

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1,287 plant species in 786 genera, 202 families of six phyla, and 496 vertebrate species. Of which, 352 plants and 58 mammals are currently listed in the Vietnam Red Book (Pham 2014). Almost all field surveys have focused on only vertebrate animals, but not invertebrates, especially soil invertebrates including centipedes. Therefore, data on invertebrate fauna of the Phia Oac - Phia Den National Park is very limited, or even lacking. This work herein aims to provide the first preliminary data on centipedes including species diversity and distribution in the Phia Oac - Phia Den National Park.

Materials and Methods

Collecting fieldworks were conducted in July 2017, August 2018 and August 2019 in five different types of habitats in Phia Oac – Phia Den National Park (Cao Bang Province), including wood forest (WF), bamboo forest (BF), wood-bamboo mixed forest (WBF), pine forest (PF), and grassland-shrub (GS). Specimens were also searched in three elevation ranges following the classification of Vu Tu Lap (2012): below 1,000 m; 1,000–1,600 m; and above 1,600 m.

Centipede specimens were collected using pitfall trapping (Mesibov & Churchill 2003), leaf-sifting (Górny & Grum 1993) in five habitats. A total of 95 specimens were collected and preserved in 75% ethanol.

Centipedes were identified following Attems (1930, 1938, 1953), Schileyko (1992, 1995, 2007), and Minelli (2011).

Ecological indices including number of species, Shanon-Weaver H', uniformnity J' were calculated using the software Primer ver. 7.0 for each habitat type. Similarity index was calculated using the software R ver. 4.0.4.

Results

Species composition and taxon diversity

From 95 specimens collected in Phia Oac - Phia Den National Park, 17 species of eight genera, three families (Scolopendridae, Cryptopidae, and Scolopocryptopidae) were recorded in the national park (Table 1). Three species, *Tonkinodentus lestes*, *Asanada brevicornis*, and *Rhysida longipes,* were recorded for the first time in northern Vietnam. These species were previously found in central and southern Vietnam, and two species *A. brevicornis* and *R. longipes* has been widely distributed in southeastern Asia (Tran et al. 2013). In addition, the distribution of two species, *Otostigmus aculeatus* and *Otostigmus multidens*, was also expanded northward (Vu et al. 2020).

Table 1 indicates that, two habitats, WF and WBF, were the most diverse one in terms of number of species (11 for each habitat) and number of genera (six in WF and seven in WBF). The diversity reduced from BF habitat (8 species, 6 genera, 3 families) to PF (6 species, 4 genera, 2 families). The lowest number of species, genera and families were recorded in GS habitat (two species in one genus, one family).

Of 17 centipede species, three (*Asanada brevicornis, Cryptops spinipes*, and *Tokinodentus lestes*) were commonly found in four habitats; four (*Scolopendra subspinipes, Scolopendra cingulatoides, Scolopocryptops spinicaudus*, and *Scolopocryptops* sp.) were found in only three habitats; four (*Otostigmus aculeatus*, *Cryptops doriae*, *Cryptops* sp., and *Scolopocryptops rubiginosus*) were found in only two habitats; two species (*Alluropus demangei* and *Rhysida longipes*) were recorded only in WBF while other two (*Otostigmus voprosus* and *Otostigmus multidens*) were found only in PF habitat.

Regarding topological distribution, the highest species diversity was recorded in the elevation range of 1,000–1,600 m (15 species, 7 genera, 3 families) while other elevation ranges had lower diversity (11 species, 6 genera, 2 families in >1,600 m and 9 species, 3 genera, 2 families in <1,000 m). However, this result may not reflect the true diversity of centipedes in different elevation. This may depend on our collecting efforts, and it requires more intensive surveys in the elevation range of less than 1.000 m.

Three species (*Asanada brevicornis, Scolopendra cingulatoides*, and *Cryptops spinipes*) were found in all three elevation ranges; nine species were recorded at two elevation ranges and five species were found at only one elevation ranges.

Taxon diversity

Of three families, Scolopendridae was recorded with nine species (accounting for 58.82% of the total number of recorded species) in five genera (accounting for 62.5% of the total number of recorded genera); Cryptopidae had four species (23.53%) in two genera (25.0%); and lastly Scolopocryptopidae recorded three species (17.65%) in only one genus (12.5%) (Table 2).

It can be seen the remarkable diversity in terms of number of species and genus of the family Scolopendridae in Phia Oac - Phia Den NP. This is also consistent with the study of Nguyen et al. (2019) when they studied the order Scolopenromorpha in Hoang Lien National Park in which climatic characteristics and high mountainous terrain are similar to Phia Oac - Phia Den National Park. According to Nguyen et al. (2019), Scolopendridae is the most diverse family with high

Table 1. Species composition and distribution of Scolopendromorpha in the Phia Oac - Phia Den National Park.

		Habitat					Elevation range (m)		
		WF	WBF	BF	PF	GS	<1.000	1.000–1.600	>1.600
	Family Scolopendridae Pocock, 1895								
	***Genus Alluropus* Silvestri, 1912**								
1	*Alluropus demangei* Silvestri, 1912	-	+	-	-	-	-	+	-
	Genus *Asanada* Meinert, 1886								
2	*Asanada brevicornis* Meinert, 1886	+	+	+	+	-	+	+	+
	Genus *Otostigmus* Porat, 1876								
3	*Otostigmus aculeatus* Haase, 1887	-	-	+	+	-	+	+	-
4	*Otostigmus voprosus* Schileyko, 1992	-	-	-	+	-	-	+	-
5	*Otostigmus multidens* Schileyko, 1995	-	-	-	+	-	-	+	-
	Genus *Rhysida* Wood, 1862								
6	*Rhysida longipes* Newport, 1845		+	-	-	-	-	-	+
	***Genus Scolopendra* Linnaeus, 1758**								
7	*Scolopendra subspinipes* Leach, 1815	+	+	-	-	+	+	+	-
8	*Scolopendra dehaani* Brandt, 1840	+	-	-	-	-	-	+	+
9	*Scolopendra cingulatoides* Attems, 1938	+	+	-	-	+	+	+	+
10	*Scolopendra calcarata* Porat, 1876	-	-	+	-		+	-	-
	Family Cryptopidae Rausch, 1881								
	Genus *Cryptops* Leach, 1815								
11	*Cryptops spinipes* Pocock, 1891	+	+	+	+	-	+	+	+
12	*Cryptops doriae* Pocock, 1891	+	-	+	-	-	-	+	+
13	*Cryptops* sp.	+	+	-	-	-	-	+	+
	***Genus Tonkinodentus* Schileyko, 1992**								
14	*Tonkinodentus lestes* Schileyko, 1992	+	+	+	+	-	-	+	+
	Family Scolopocryptopidae Pocock, 1896								
	Genus *Scolopocryptops* Newport, 1844								
15	*Scolopocryptops spinicaudus* Wood, 1862	+	+	+	-	-	-	+	+
16	*Scolopocryptops rubiginosus* L. Koch, 1878	+	+	-	-	-	-	+	+
17	*Scolopocryptops* sp.	+	+	+	-		-	+	+
	Total number of individuals	**26**	**32**	**22**	**11**	**4**	**9**	**57**	**29**
	Total species	**11**	**11**	**8**	**6**	**2**	**6**	**15**	**11**

WF—Wood forest | WBF—Wood-bamboo mixed forest | BF—Bamboo forest | PF—Pine forest | GS—Grass-shrub | +—present | -—absent.

Table 2. Taxon diversity of Scolopendromorpha.

Classification rank	Genus		Species	
	Amount	Ratio (%)	Amount	Ratio (%)
Scolopendridae	5	62.5	10	58.82
Cryptopidae	2	25.0	4	23.53
Scolopocryptopidae	1	12.5	3	17.65
Total	**8**	**100**	**17**	**100**

Table 3. Diversity index and uniformity index by habitat.

Habitat	Amount		Index	
	Species	Individual	J'	H'
WF	11	26	0.94	2.25
WBF	11	32	0.76	1.81
BF	8	22	0.85	1.77
PF	6	11	0.86	1.54
GS	2	4	0.81	0.56

WF—Wood forest | WBF—Wood-bamboo mixed forest | BF—Bamboo forest | PF—Pine forest | GS—Grass-shrub.

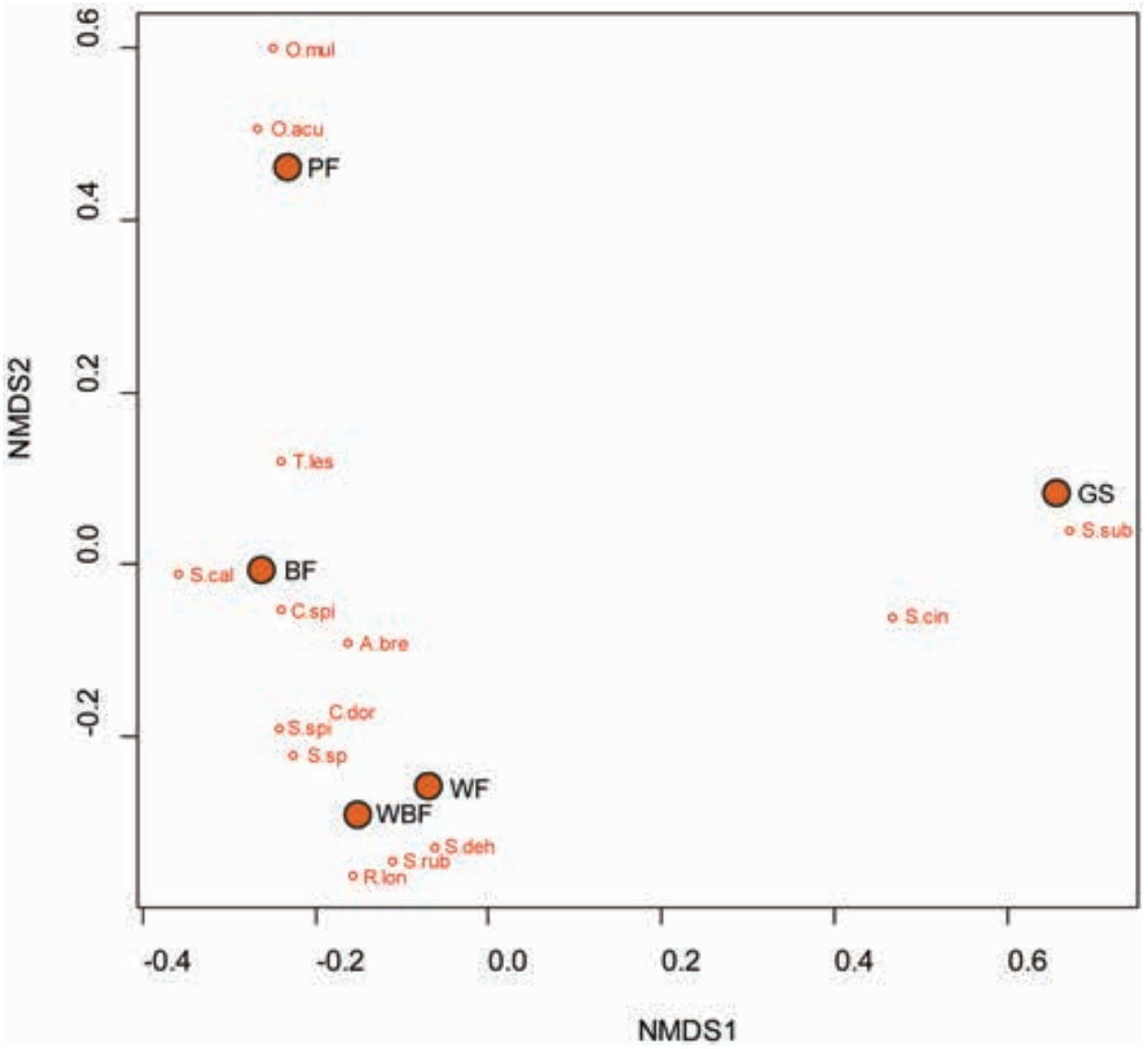

Figure 1. Non-metric multidimensional scaling (NMDS) analysis by habitat: S.cal—*Scolopendra calcarata* | S.sub—*Scolopendra subinosus* | S.cin—*Scolopendra cingulatoides* | S.deh—*Scolopendra dehaani* | S.rub—*Scolopocryptops rubiginosus* | S.spi—*Scolopocryptops spinicaudus* | O.acu—*Otostigmus aculeatus* | O.mul—*Otostigmus multidens* | C.spi—*Cryptops spinipes* | C.dor—*Cryptops doriae* | A.bre—*Asanda brevicornis* | R.lon—*Rhysida longipes* | T.les—*Tokinodentus lestes* | A.dem—*Alluropus demanhei*.

percentage of species (41.6%).

Biological indices

The species diversity index (H') is highest at WF (2.25), decreased to WBF (1.81), BF (1.77), PF (1.54), and lowest at GS (0.56). Similarly, the uniformity index (J') is also highest at WF (0.94), but lowest at WBF (0.76), and from 0.81 to 0.86 in other habitats (Table 3). The reversion between H' and J' indexes in two habitats (WF and WBF) indicates that there were several species with high individuals collected in WBF while species were collected in WF with relatively equal number of individuals.

As be seen, three habitats (WF, WBF, and BF) can be classified into a group which have the high similarity in the species composition; of which, WF is closer to WBF than to BF. This highly homologous group is also different from the other two habitats (PF and GS). In addition, there was a close association between recorded species and habitats such as *Scolopendra dehaani*, *Scolopocryptops rubiginosus*, *Rhysida longipes* in WF and WBF, *Scolopendra calcarata* in BF, *Otostigmus aculeatus* in PF, and *Scolopendra subspinipes* in GS.

Discussion

The Phia Oac - Phia Den NP has a higher number of scolopendromorphs in comparison with other northern mountainous region, such as Hoang Lien NP (12 species), Ta Xua (15 species), Thuong Tien (12 species), Xuan Nha (12 species) (Nguyen et al. 2018, 2019; Tran et al. 2018). This might be due to the high diversity of habitats, wide range of elevations and different climatic characteristics (Vu Tu Lap 2012). However, most centipede specimens were collected in rainy season (July and August), it is, therefore, recommended to have more species not to be recognized in this region. More intensive surveys should be conducted in different time to have a better understanding of the centipede diversity in the national park.

Almost all previous studies in Vietnam indicated that the genus *Otostigmus* usually has the highest number of recorded species (Nguyen et al. 2018, 2019, Tran et al. 2018; Le et al. 2017). However, this is not true for the Phia Oac - Phia Den National Park where the genus *Otostigmus* has only three species while *Scolopendra* has four species. It might be explained that the genus *Otostigmus* is tropically distributed, and not be familiar with high mountains and cool climatic condition. This was also observed and reported by Nguyen et al. (2019) in Hoang Lien National Park.

Two species, *Scolopocryptops spinicaudus* and *Scolopocryptops rubiginosus*, were previously recorded at the low elevations in China and Taiwan (Chao & Chang 2003; Song et al. 2004). These species were considered as temperate species inhabiting in cool climatic region. Therefore, they have been only found at the elevation range of more than 800 m, such as Hoang Lien National Park, Ta Xua Nature Reserve, Thach Nham (Le et al. 2017; Tran et al. 2018; Nguyen et al. 2019) and even more than 1,000 m in Phia Oac - Phia Den National Park

The species *Alluropus demangei* (Image 1) was originally described from Phu Ly, Ha Nam Province (Silvestri 1911), but it has never been recorded in other locations in Vietnam. All previous reports on this species were inherited from Silvestri (1911) (Schileyko 2007; Tran et al. 2013). Recently, Tran et al. (2018) reported this species from Ta Xua at the elevation range of 600–1,000 m. In this study, *Alluropus demangei* was also recorded in woody-bamboo forests at the elevation range of 1,000–1,600 m.

Conclusion

The scolopendromophs fauna of the Phia Oac - Phia Den was recognized with 17 species in eight genera and three families. More intensive surveys in different times are needed to reveal a better understanding of the scolopendromophs diversity in this park.

Image 1. ***Alluropus demangei.***

References

Attems, C. (1930). Myriopoda. 2. Scolopendromorpha. *Das Tierreich* 54: 1–308. (In German)

Attems, C. (1938). Die von Dr. C. Dawydoff in französisch-Indochina gesammelten Myriopoden. *Mémoires du Muséum National d'Histoire Naturelle* (N.S.) 6: 187–353. (In German)

Attems, C. (1953). Myriopoden von Indochina. Expedition von Dr. C Dawydoff (1938-1939). *Mémoires du Muséum National d'Histoire Naturelle* (Nouvelle Serie, Série A, Zoologie) 5(3): 133–230. (In German)

Chao, J.-L. & H.-W. Chang (2003). The scolopendromorph centipedes (Chilopoda) of Taiwan. *African Invertebrates* 44(1): 1–11.

Górny, M. & L. Grum (1993). *Methods in Soil Zoology*. Elsevier Science, 459pp.

Le, X.S., D.A. Nguyen, T.H. Vu, D.H. Nguyen, T.T.B. Tran (2017). Species diversity of the large centipedes (Chilopoda: Scolopndromorpha) in the Thach Nham protected forests, Kon Tum. *Journal of Science and Technology, Ministry of Agriculture and Rural Development* 13: 84–89. (In Vietnamese)

Lewis, J. (1981). The Biology of Centipedes. Cambridge University Press, Cambridge.

Ma, W., R. Liu, R. Qi & Y. Zhang (2014). Extracts of centipede *Scolopendra subspinipes mutilans* induce cell cycle arrest and apoptosis in A375 human melanoma cells. *Oncology letters* 8(1): 414–420. https://doi.org/10.3892/ol.2014.2139

Mesibov, R. & T.B. Churchill (2003). Patterns in pitfall captures of millipedes (Diplopoda: Polydesmida: Paradoxosomatidae) at coastal heathland sites in Tasmania. *Australian Zoologist* 32(3): 431–438. https://doi.org/10.7882/AZ.2002.021

Minelli, A. (2011). Class Chilopoda, Class Symphyla and Class Pauropoda. In: Zhang, Z.-Q. (Ed.), Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness. *Zootaxa* 3148: 157–158.

Nguyen, D.H., D.Q. Do, T.T.B. Tran, T.H. Vu, D.A. Nguyen & X.S. Le (2019b). Data on species composition and distribution of centipedes (Chilopoda: Scolopendromorpha, Scutigeromorpha) Hoang Lien National Park, Vietnam. *Journal of Hanoi National University of Education* 64(10A): 82–89. (In Vietnamese)

Nguyen, D.H., Q.T.C. Dang, T.T.H. Nguyen, X.S. Le & T.T.B. Tran (2019a). Diversity of centipedes (Chilopoda: Scolopendromorpha and Scutigeromorpha) in Xuan Nha Nature Reserve, Son La province, Vietnam. *Can Tho University Journal of Science* 11(3): 75–82. (In Vietnamese)

Nguyen, D.H., N.A. Hoang, D.Q.C. Tran & T.T.B. Tran (2018). Preliminary data on centipedes (Chilopoda: Scolopendromorpha, Scutigeromorpha) in Thuong Tien natural reserve, Hoa binh province. *The 3rd National Conference of Scientists on Biological Research and Teaching in Vietnam*: 533–540. (In Vietnamese)

Pham, H.H. (2014). A report on investigation and assessment of biodiversity status and natural resources for the scientific basis of Phia Oac - Phia Den National Park. *Vietnam Association for Conservation of Nature and Environment*. (In Vietnamese)

Pham, T., V.T. Le & X.C. Bui (2000). Medicinal plants, herbal remedies and brand-name drugs. Part II: Medicinal animals. Medical Publishing House. (In Vietnamese)

Schileyko, A.A. (1992). Scolopenders of Viet-Nam and some aspects of the system of Scolopendromorpha (Chilopoda: Epimorpha). Part 1. *Arthropoda Selecta* 1: 5–19.

Schileyko, A.A. (1995). The scolopendromorph centipedes of Vietnam (Chilopoda: Scolopendromorpha). Part 2. *Arthropoda Selecta* 4: 73–87.

Schileyko, A.A. (2007). The scolopendromorph centipedes (Chilopoda) of Vietnam, with contributions to the faunas of Cambodia and Laos. Part 3. *Arthropoda Selecta* 16: 71–95.

Silvestri, F. (1911). Descrizione di un nuovo genere di Scolopendridae (Chilopoda) del Tonkino. *Bollettino del Laboratorio di Zoologia Generale e Agraria della Regia Scuola Superiore d'Agricoltura* 6: 43–44.

Song, Z., D. Song & M. Zhu (2004). On a new species and a new record of the genus Scolopocryptops from China (Chilopoda: Scolopendromorpha: Scolopocryptopidae). *Hebei Nongye Daxue Xuebao* [*Journal of Agricultural University of Hebei*] 27: 80–95.

Tran, T.T.B, D.H. Nguyen, T.K.L. Ha & T.H. Vu (2018). Preliminary data on centipedes (Chilopoda: Scolopendromorpha and Scutigeromorpha) in Ta Xua Natural Reserve, Son La Province, Vietnam. *Academia Journal of Biology* 40(1): 100–107. (In Vietnamese)

Tran, T.T.B., T.T.H. Tran & L. Banato (2019). A new soil centipede from South-East Asia with a unique arrangement of ventral glands, and a revised synopsis of Gonibregmatidae (Chilopoda, Geophilomorpha). *Zookeys* 838: 111–132. https://doi.org/10.3897/zookeys.838.33131

Tran, T.T.B, X.S. Le & A.D. Nguyen (2013). An annotated checklist of centipedes (Chilopoda) of Vietnam. *Zootaxa* 3722(2): 219–244.

Vietnam Administration of Forestry (2013). *Vietnam National Parks*. La Ban Printing Joint Stock Company. (In Vietnamese)

Vu, T.L. (2012). *Vietnam Natural Geography (8th edition)*. National University of Education Publishing House, Hanoi. 340 pp. (In Vietnamese)

Vu, T.H., D.H. Nguyen, X.S. Le, K. Eguchi, A.D. Nguyen & T.T.B. Tran (2020). A review and notes on the phylogenetic relationship of the centipede genus *Otostigmus* Porat, 1876 (Chilopoda: Scolopendromorpha: Scolopendridae) from Vietnam. *Zootaxa* 4808(3): 401–438. https://doi.org/10.11646/zootaxa.4808.3.1

Yang, S., Y. Xiao, D. Kang, J. Liu, Y. Li, A.B.E. Undheim, K.J. Klint, Q.M. Rong, R. Lai & F.G. King (2013). Discovery of a selective NaV1.7 inhibitors from centipede venom with analgesic efficacy exceeding morphine in rodent pain models. *PNAS* 110(43): 17534–17539. https://doi.org/10.1073/pnas.1306285110

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SHORT COMMUNICATION

Diversity of ants in Aarey Milk Colony, Mumbai, India

Akshay Gawade [1] & Amol P. Patwardhan [2]

[1] B.N. Bandodkar College of Science, Thane 400601. Maharashtra. India.
[2] Department of Zoology, K.J. Somaiya College of Science and Commerce, Mumbai, Maharashtra 400077, India.
[1] akki.gawade2@gmail.com, [2] amolppatwardhan@gmail.com (corresponding author)

Abstract: Aarey Milk Colony (AMC) is 16km^2 of forested area, acts as a buffer to the Sanjay Gandhi National Park, Mumbai. It has gardens, lakes, recreation spots, and a nursery. It also harbors 32 cattle farms, animal husbandry centers. Apart from urbanization and forest degradation, this forest harbors great biodiversity which includes the leopard as a top predator and also lesser-known species of amphibians, reptiles, and arthropods. Considering ants as important bio indicators and the vulnerability of AMC to development plans, a study on the diversity of ants was conducted from January 2016 to May 2016. Four methods were used for data collection of ants—pitfall trap, line-transect, quadrate, and all-out search. A total of 35 species under 24 genera under six subfamilies– *Myrmicinae, Formicinae, Ponerinae, Dolichoderinae, Pseudomyrmecinae*, and *Cerapachyinae* were recorded during this study. The Simpson's diversity index (0.88) for the pit fall trap indicates that the diversity of ants in the AMC is fairly high. This increases the importance of this forest land which is presently facing a mass destruction of trees.

Keywords: Bio indicator, data collection, Maharashtra, Sanjay Gandhi National Park.

Aarey Milk Colony (AMC) was notified in 1949 which covers an area of 16km^2. It is situated on the southwestern boundary of Sanjay Gandhi National Park, Mumbai. The colony acts as a buffer zone for the densely forested national park. The colony faces heavy anthropogenic pressure such as illegal encroachment, change in land use, which converted it into a garden, nursery, picnic spots, restaurants, and milk processing units.

Among invertebrates, insects are the most abundant and diverse organisms on Earth, as most of the insects are highly mobile, their presence in an ecosystem may be temporary which limits their use to detect environmental changes (Khot et al. 2013). On the other hand, the ants being more local than other insects they can be efficiently used as a bio-indicator (Stephens & Wagner 2006; Underwood & Fisher 2006; Jonathan et al. 2007; Abril & Gomez 2013).

Andersen et al. (2002) suggested that ants can provide valuable information about the environment in which they occur and considerably more than could traditional wildlife (vertebrate) surveys. According to Wilson (1990) and Gadagkar et al. (1993), the biomass of ants is approximately four times greater than the biomass of all of the vertebrates. Due to their abundance, high species richness, occupancy of high topographic level and being highly responsive to environmental changes ants are considered as excellent bio-indicators (Jonathan 1983). According to Bharti (2011), there are 652 species/subspecies that are known to occur in India. Khot et al. (2012) recorded 28 species representing six subfamilies from Maharashtra Nature Park and Quadros et al. (2009) recorded 19 species of ants from IIT Bombay campus;

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163 species of ants, in 52 genera, were reported by Mathew & Tiwari (2000) from Meghalaya. Kharbani & Hajong (2009) recorded 28 species from 18 genera from the West Khasi hills, Meghalaya. Bharti et al. (2009) recorded 40 species of ants from eight genera from Punjab Shivalik.

The forest of AMC is of mixed moist deciduous type and is dominated by *Tectona grandis*, *Bombax ceiba*, *Butea monosperma*, *Pongamia pinnata*, *Cassia fistula*, *Ziziphus* sp., heavily intermixed with exotic/invasive species such as *Eucalyptus*, *Gliricidia sepium* as well as *Delonix regia* and *Lantana* sp. (Mirza & Sanap 2010). According to Mirza & Sanap (2010) the faunal diversity of AMC includes 13 species of amphibians, 46 species of reptiles, 76 species of avifauna, 16 species of mammals, 86 species of butterflies, five species of scorpions, and 19 families of spiders. There is no reported work on the ants of this area.

AMC (Image 1) is under immense anthropogenic pressure. Hence the study on ants might be helpful in throwing some light on the diversity of invertebrates that are about to get lost or displaced.

Material and Methods

The survey was carried out from January 2016 to May 2016.

Four sampling methods were deployed as follows.

1. Pitfall trap (n= 52): Transparent plastic glasses having 7.5 cm diameter and 7.5 cm height were used for pitfall traps buried at ground level. In each trap four plastic glasses were kept at the corner of 4 x 4 m quadrate. The traps were set up for 24 hr. The total area covered was 832 m^2. The trap was observed regularly to avoid predation on ants, if any. Ants were released from the trap after photo documentation.

2. Line transect (n= 9): Line transects of 100 m were plotted in the study site so that maximum area and different habitats were covered. This method was used three times a day (morning, afternoon, and evening). The total area covered by line transects was 1,800 m.

3. Quadrat method (n= 13): Four quadrates of 4 x 4 m were placed in the selected study site. Each quadrat was observed for 10 min.

4. All-out search method (n= 30): This method was used to collect data opportunistically.

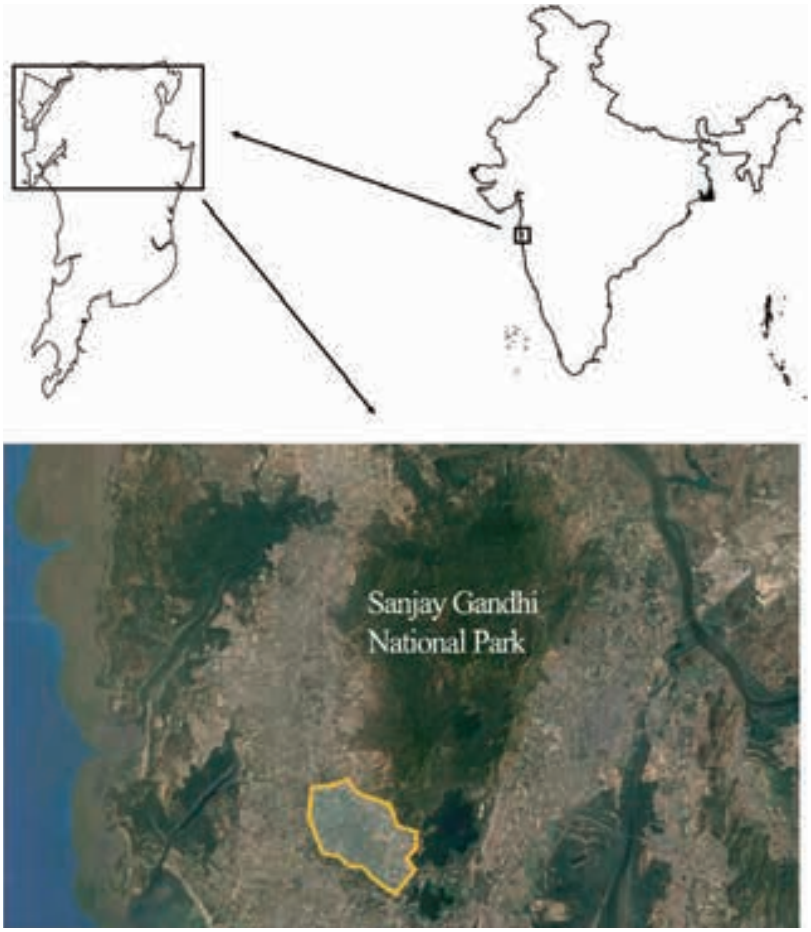

Image 1. Location of Aarey Milk Colony highlighted. (Courtsey: Google)

All the individuals recorded by the above four methods were photographed using Canon 600D camera body with a 90mm macro lens and identified using Bingham (1903), Narendra & Kumar (2006), antweb (http://antweb.org/), and antwiki (http://www.antwiki.org/wiki/).

To have a basic idea of richness, pit fall trap data was utilized for calculating Simpson's diversity index.

Results

A total of 35 species under 24 genera and six subfamilies were recorded from the study area (Table 1). Table 2 represents the dominance of the subfamilies. Myrmicinae (9 genera and 13 species) and Formicinae (6 genera and 11 species) were the most dominant subfamilies followed by Poneriane (5 genera and 6 species); Dolichoderinae (2 genera and 2 species), Pseudomyrmicinae (1 genus and 2 species), and Cerapachynae (1 species).

Pitfall trap, line transects, quadrate, and all-out search methods were used to collect this data (Table 3). *Solenopsis geminata, Crematogaster subnuda, Crematogaster ransonneti, Monomarium pharaonis, Camponotus compressus, Paratrechina longicornis, Polyrachis lacteipennis, Diacama rugosum*, and *Tapinoma melanocephalum* were recorded from all four sampling methods. *Oecophylla smaragdina, Anochetes graffei, Platythyrea sagei, Leptogenys chinensis, Leptogenys processionalis,* and *Cerapachys longitarsus* were recorded only by one of the methods.

A comparison of sampling methods (Table 4) suggests that the pitfall method was the most productive yielding 27 of 35 species recorded. All-out search method was the second most productive yielding 24 of 35 species which was high probably because a larger area was covered in opportunistic visits. Pitfall and all-out search methods shared 16 species in common. The line transact was substantially productive in terms of recording the number of individuals. This can be attributed to the foraging habits of the ants.

The Simpson's diversity index for pitfall trap data.

$D = 1 - \sum n(n-1)/N(N-1) = 1 - \sum 29292/250500 = 0.88$

The Simpson's diversity index of 0.88 indicates the diversity of ants on the higher side. Further, a long time assessment and detailed analyses of different sampling methods might reveal more comprehensive results.

Aarey colony is under pressure from human developmental activities hence further study is required so as to use ant as an effective indicator for highly disturbed forest habitats.

Table 1. Ant diversity in Aarey Milk Colony, Mumbai, Maharashtra.

	Species	Subfamily	Figure number
1	*Aphaenogaster beccarii*	Myrmicinae	2
2	*Cardiocondyla nuda*	Myrmicinae	3
3	*Cataulacus taprobanae*	Myrmicinae	4
4	*Crematogaster ransonneti*	Myrmicinae	5
5	*Crematogaster subnuda*	Myrmicinae	6
6	*Meranoplus bicolor*	Myrmicinae	7
7	*Monomorium criniceps*	Myrmicinae	8
8	*Monomorium pharaonis*	Myrmicinae	9
9	*Myrmicaria brunnea*	Myrmicinae	10
10	*Pheidole watsoni*	Myrmicinae	11
11	*Solenopsis geminata*	Myrmicinae	12
12	*Tetramorium smithi*	Myrmicinae	13
13	*Tetramorium walshi*	Myrmicinae	14
14	*Camponotus angusticollis*	Formicinae	15
15	*Camponotus compressus*	Formicinae	16
16	*Camponotus irritans*	Formicinae	17
17	*Camponotus parius*	Formicinae	18
18	*Camponotus sericeus*	Formicinae	19
19	*Oecophylla smaragdina*	Formicinae	20
20	*Paratrechina longicornis*	Formicinae	21
21	*Polyrhachis exercita*	Formicinae	22
22	*Polyrhachis lacteipennis*	Formicinae	23
23	*Polyrhachis rastellata*	Formicinae	24
24	*Camponotus angusticollis*	Formicinae	25
25	*Anochetus graeffei*	Ponerinae	26
26	*Brachyponera lutipes*	Ponerinae	27
27	*Diacamma rugosum*	Ponerinae	28
28	*Leptogenys chinensis*	Ponerinae	29
29	*Leptogenys processionalis*	Ponerinae	30
30	*Platythyrea sagei*	Ponerinae	31
31	*Tapinoma melanocephalum*	Dolichoderinae	32
32	*Technomyrmex albipes*	Dolichoderinae	33
33	*Tetraponera rufonigra*	Pseudomyrmicinae	34
34	*Tetraponera allaborans*	Pseudomyrmicinae	35
35	*Cerapachys longitarsus*	Cerapachyinae	36

Table 2. Family-wise diversity of ant species.

	Sub-families	Species	Percentage (%)
1	*Myrmicinae*	13	37
2	*Formicinae*	11	31
3	*Ponerinae*	6	17
4	*Dolichoderinae*	2	6
5	*Pseudomyrmicinae*	2	6
6	*Cerapachyinae*	1	3
	Total	**35**	100

Table 3. Sampling methods deployed for collecting data on ants. PT—Pitfall trap | LT—Line transect | Q—Quadrate | AO—All-out search.

	Species	PT	LT	Q	AL
1	*Aphaenogaster beccarii*	+	-	-	-
2	*Cardiocondyla nuda*	-	-	-	+
3	*Cataulacus taprobanae*	-	+	-	+
4	*Crematogaster ransonneti*	+	+	+	+
5	*Crematogaster subnuda*	+	+	+	+
6	*Meranoplus bicolor*	-	-	-	+
7	*Monomorium criniceps*	+	-	+	-
8	*Monomorium pharaonis*	+	+	+	+
9	*Myrmicaria brunnea*	+	-	+	-
10	*Pheidole watsoni*	+	+	+	+
11	*Solenopsis geminata*	+	+	+	+
12	*Tetramorium smithi*	+	-	-	+
13	*Tetramorium walshi*	-	+	+	-
14	*Camponotus angusticollis*	+	+	-	+
15	*Camponotus compressus*	+	+	+	+
16	*Camponotus irritans*	+	+	-	+
17	*Camponotus parius*	-	+	-	+
18	*Camponotus sericeus*	+	-	-	+
19	*Oecophylla smaragdina*	-	-	-	+
20	*Paratrechina longicornis*	+	+	+	+
21	*Polyrhachis exercita*	-	-	-	+
22	*Polyrhachis lacteipennis*	+	+	+	+
23	*Polyrhachis rastellata*	+	-	-	+
24	*Camponotus angusticollis*	+	+	-	+
25	*Anochetus graeffei*	+	-	-	-
26	*Brachyponera lutipes*	+	-	-	+
27	*Diacamma rugosum*	+	+	+	+
28	*Leptogenys chinensis*	+	-	-	-
29	*Leptogenys processionalis*	+	-	-	-
30	*Platythyrea sagei*	+	-	-	-
31	*Tapinoma melanocephalum*	+	+	+	+
32	*Technomyrmex albipes*	+	+	-	-
33	*Tetraponera rufonigra*	-	+	+	+
34	*Tetraponera allaborans*	+	+	-	+
35	*Cerapachys longitarsus*	+	-	-	-
	Total	**27**	**18**	**14**	**24**

Table 4. Species and total individuals recorded in sampling methods.

	Trapping method	Species recorded	Individuals recorded
1	Pitfall trap	27	501
2	Line transect	18	889
3	Quadrate	14	225
4	All-out search	24	534

Image 2. *Aphaenogaster beccarii* (Emery, 1887). © Akshay Gawade

Image 3. *Cardiocondyla nuda* (Mayr, 1866). © Akshay Gawade

Image 4. *Cataulacus taprobanae* (Smith, 1853). © Akshay Gawade

References

Abril, S. & C. Gomez (2013). Rapid assessment of ant assemblages in public pine forests of the central Iberian Peninsula. *Forest Ecology and Management* 293: 79–84.

Andersen, A., B.D. Hoffman, W.J. Muller & A.D. Griffiths (2002). Using

Image 5. *Crematogaster subnuda* (Mayr, 1879). © Akshay Gawade

Image 6. *Crematogaster ransonneti* (Mayr, 1868). © Akshay Gawade

Image 7. *Meranoplus bicolor* (Guerin-Meneville, 1844). © Akshay Gawade

Ants as Bioindicators in Land management: Simplifying Assessment of Ant Community Responses. *Journal of applied Ecology* 39(1): 8–17.

Bharti, H., Y.P. Sharma & A. Kaur (2009). Seasonal patterns of ants (*Hymenoptera*: *Formicidae*) in Punjab Shivalik. *Haltere* 1: 36–47.

Bharti, H. (2011). List of Indian Ants. *Halteres* 2: 79–87.

Bingham, C.T. (1903). *The Fauna of British India, including Ceylon and Burma. Hymenoptera, Vol. ll. Ants and Cuckoo-wasps.* London: Taylor and Francis, 506pp.

Gadagkar, R., P. Nair, C. Chandrashekhara & D.M. Bhat (1993). Ant species richness and diversity in some selected localities in Western Ghats, India. *Hexapoda* 5(2) : 79–94.

http://antweb.org/ (visited June 2016; Revisited 20th June 2020)

http://www.antwiki.org/ (visited June 2016; Revisited 20 June 2020)

Jonathan, D.M. (1983). Ants: Bio-indicators of minesite rehabilitation, land-use, and land conservation. *Environmental Management* 7(4): 375–383.

Jonathan, D.M., G. Oraby & L. Bisevac (2007). Ants (*Hymenoptera: Formicidae*) pass the bioindicator scorecard. *Myrmecological News* 10: 69–76.

Kharbani, H. & S.R. Hajong (2013). Seasonal patterns in ant (Hymenoptera: Formicidae) activity in a forest habitat of the West Khasi Hills, Meghalaya, India. Asian Myrmecology 5: 103–112.

Khot, K., G. Quadros & V.U. Somani (2013). Ant diversity in an urban garden at Mumbai, Maharashtra, pp. 121–125. Proceedings of the National Conference of Biodiversity: Status and Challenges in Conservation.

Mathew, R. & R.N. Tiwari (2000). *Insecta*: *Hymenoptera*: *Formicidae* Zoological Survey of India, State Fauna Series 4: Fauna of Meghalaya Part-7: 251–409pp.

Mirza, Z. & R. Sanap (2010). Biodiversity of Aarey Milk Colony and Film City (2007–2009). A report submitted to the Government of Maharashtra and the Forest Department of Maharashtra, 51pp.

Narendra, A. & M.S. Kumar (2006). *On Trail with Ants. A Handbook of the Ants of Peninsular India.* Self published, 193pp.

Quadros, G., G. Gurav, K. Bhagat, A. Chorghe, A. Dhamorikar, K. Khot & M. Nagarkar (2009). Report on the Study of the Biodiversity of Indian Institute of Technology Bombay Campus. By WWF-India MSO for IIT Bombay, 158pp.

Stephens, S.S. & M.R. Wagner (2006). Using Ground Foraging Ant (Hymenoptera: Formicidae) Functional Groups as Bioindicators of Forest Health in Northern Arizona Ponderosa Pine Forests. *Environmental Entomology* 35(4): 937–949

Underwood, E.C. & B.L. Fisher (2006). The role of ants in conservation monitoring: If, when and how. *Biological conservation* 132: 166–182.

Wilson, E.O. (1990). Success and Dominance in Ecosystems: The Case of the Social Insects. In: Kinne, O. (Ed.). *Excellence in Ecology.* Vol. 2. Ecology Institute, Oldendorf/Luhe, Germany, 104pp+15figs.

Image 8. *Monomorium criniceps* (Mayr, 1879). © Akshay Gawade

Image 9. *Monomorium pharaonis* (Linnaeus, 1758). © Akshay Gawade

Image 10. *Myrmicaria brunnea* (Saunders, 1842). © Akshay Gawade

Image 11. *Pheidole watsoni* (Forel, 1902). © Akshay Gawade

Image 12. Solenopsis geminata (Fabricius, 1804). © Akshay Gawade

Image 13. Tetramorium smithi (Mayr, 1879). © Akshay Gawade

Image 14. *Tetramorium walshi* (Forel, 1890). © Akshay Gawade

Image 15. *Anoplolepis gracilipes* (Smith, 1857). © Akshay Gawade

Image 16. *Camponotus angusticollis* (Jerdon, 1851). © Akshay Gawade

Image 17. *Camponotus compressus* (Fabricius, 1787). © Akshay Gawade

Image 18. *Camponotus irritans* (Smith, 1857). © Akshay Gawade

Image 19. *Camponotus parius* (Emery, 1889). © Akshay Gawade

Image 20. *Camponotus sericeus* (Fabricius, 1798). © Akshay Gawade

Image 21. *Oecophylla smaragdina* (Fabricius, 1775) (Queen). © Akshay Gawade

Image 22. *Paratrechina longicornis* (Latreille, 1802). © Akshay Gawade

Image 23. *Polyrhachis exercita* (Walker, 1859). © Akshay Gawade

Image 24. *Polyrhachis lacteipennis* (Smith, 1858). © Akshay Gawade

Image 25. *Polyrhachis rastellata* (Latreille, 1802). © Akshay Gawade

Image 26. *Anochetus graeffei* (Mayr, 1870). © Akshay Gawade

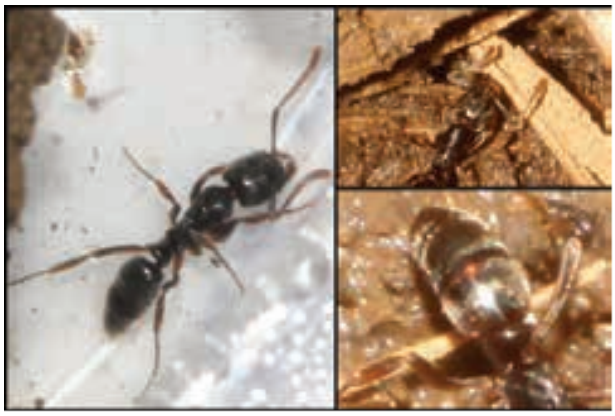

Image 27. *Brachyponera luteipes* (Mayr, 1862. © Akshay Gawade

Image 28. *Diacamma rugosum* (Le Guillou, 1842). © Akshay Gawade

Image 29. *Platythyrea sagei* (Forel, 1900). © Akshay Gawade

Image 30. *Leptogenys chinensis* (Mayr, 1870). © Akshay Gawade

Image 31. *Leptogenys processionalis* (Jerdon, 1851). © Akshay Gawade

Image 32. *Tapinoma melanocephalum* (Fabricius, 1793). © Akshay Gawade

Image 33. *Technomyrmex albipes* (Smith, 1861). © Akshay Gawade

Image 34. *Tetraponera allaborans* (Walker, 1859). © Akshay Gawade

Image 35. *Tetraponera rufonigra* (Jerdon, 1851). © Akshay Gawade

Image 36. *Cerapachys longitarsus* (Mayr, 1879). © Akshay Gawade

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SHORT COMMUNICATION

First record of ghost shrimp *Corallianassa coutierei* (Nobili, 1904) (Decapoda: Axiidea: Callichiridae) from Indian waters

Piyush Vadher [1], Hitesh Kardani [2], Prakash Bambhaniya [3] & Imtiyaz Beleem [4]

[1,2,3] Fisheries Research Station, Junagadh Agricultural University, Sikka, Jamnagar, Gujarat 361140, India.
[4] Office of the Superintendent of Fisheries, (Commissioner of Fisheries, Agriculture, Farmer Welfare and Co-operation Department) Fisheries harbour area, Mangrol, Gujarat 362226, India.
[1] vadherpiyush4@gmail.com, [2] hiteshkardani@gmail.com (corresponding author), [3] prakashbambhaniya72@gmail.com, [4] imtiyazbelim7@gmail.com

Abstract: A Callichiridae ghost shrimp species *Corallianassa coutierei* (Nobili, 1904) is recorded and described here for the first time from the Indian waters. Formerly, five species under the family Callichiridae were recorded from different coastal waters of India. In addition, *C. coutierei* was infested with several copepods. Additional description of *C. coutierei* with key characters and distribution status is given for this species. A comprehensive checklist of the infraorder Axiidea is prepared based on previous records from Indian waters.

Keywords: Checklist, copepods, new record, Goose reef, Gulf of Kachchh, Gujarat.

Axiidea de Saint Laurent, 1979, an infraorder of Decapoda is also known as ghost shrimp, mud shrimp or burrowing shrimp (Dworschak et al. 2012), although they are only distantly related to true shrimp, they are ecologically and morphologically adapted as burrowing forms (Dworschak 2015). Axiidea is the infaunal organisms that build complex burrows, found in marine and estuarine areas of bays (Golubinskay et al. 2016). Axiidea comprises a total of 11 valid families (WoRMS 2020a) dwelling in shallow water of intertidal or subtidal water (less than 200 m or 660 ft). Axiidea comprises 19 species belonging to five families and 16 genera, distributed in the Indian waters (Table 1). Family Callichiridae comprises of 96 species belonging to 17 genera worldwide (WoRMS 2020b).

The ghost shrimp genus *Corallianassa* was described by Manning in 1987 from America (family: Callianassidae Dana, 1852). The genus *Corallianassa* comprises 13 species in the World (WoRMS 2020c). A scrutiny of literature pertaining to ghost shrimps of Indian waters revealed that the genus *Corallianassa* is hitherto not reported from Indian waters. Therefore, the present taxon, including the genus is the first report from Indian waters.

Ghost shrimp can be the host for copepods. The cavity between the shell and body of the ghost shrimp can be a favourable site for these associated arthropods. Only a few accounts on the copepods of ghost shrimps have been described and recorded worldwide (Pillai 1959; Corsetti & Strasserm 2003; Kihara & Rocham 2013; Sepahvand et al. 2017a,b, 2019). From India Pillai (1959) had recorded and described two new species of *Clausidium* Kossmann, 1874 parasitic on

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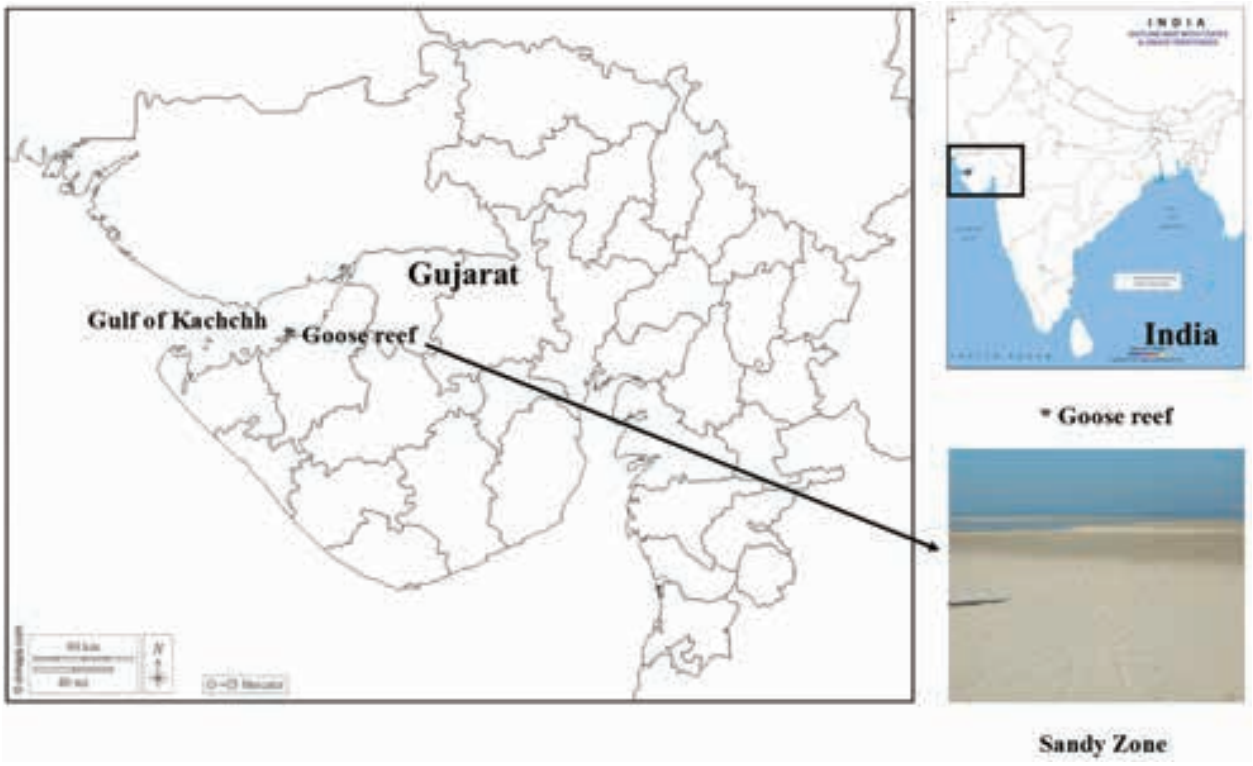

Image 1. Study area of the new find of the ghost shrimp *Corallianassa coutierei*.

Callianassa Leach, 1814 (in Leach, 1813–1815). Many researchers suggested their relationship as symbiont (Corsetti & Strasser 2003; Kihara & Rocha 2013) while many suggested them as parasites (Wilson 1935, 1937; Pearse 1947; Humes 1949; Pillai 1959). In this study, *C. coutierei* infested with copepods (*Clausidium* sp.) on the carapace region (Image 3b) can be either parasitic or symbiotic, although all the clausidiid copepods are categerised as parasitic upon different species of *Corallianassa* (Wilson 1935). Hence, this study reports *Corallianassa* genus infested with copepods for the first time from Indian waters.

Materials and Methods

The present study was carried out at Goose reef (22.498N & 69.808E) in the Gulf of Kachchh, Gujarat (Image 1). Intertidal area of the Island is having a sandy shore, rocky shore, and coral reefs. Goose reef is under tremendous anthropogenic pressure of various industries which have constructed their offshore terminals. A single live specimen was collected, which was hidden in the sandy zone of the island. The collected specimen was transferred to the laboratory of Fisheries Research Station, Junagadh Agricultural University, Sikka. Identification was carried out through standard literature of (Man 1905; Ngoc-Ho 2005; Dworschak 2018) and communication with experts.

Size of the specimen is indicated by carapace length (cl) measured from the tip of the rostrum to the midpoint of the posterodorsal margin of the carapace and the total length (tl) measured from the tip of the rostrum to the midpoint of the posterodorsal margin of the telson. A comprehensive checklist was compiled and prepared based on previous literatures and publications of an infraorder Axiidea from Indian waters (Table 1).

Results

We report the ghost shrimp *C. coutierei* (Nobili, 1904) along with an associated species of copepod *Clausidium* Kossmann, 1874 for the first time in Indian waters (Image 2c,d). A comprehensive checklist of an Infraorder Axiidea listed a total of 19 species belonging to five families and 16 genera with distribution status in Indian waters is provided (Table 1). Maximum species were reported belonging to the family Callichiridae (six genera, six species) followed by Axiidae (four genera, six species), Callianassidae (four genera, five species), Callianideidae (one genus, one species), and Callianopsidae (one genus, one species).

Systematics

Class: Malacostraca Latreille, 1802
Order: Decapoda Latreille, 1802
Infraorder: Axiidea De Saint Laurent, 1979
Family: Callichiridae Manning & Felder, 1991
Genus: *Corallianassa* Manning, 1987

***Corallianassa coutierei* (Nobili, 1904)** (Image 2 & 3)

Synonymy:

Callianassa (*Callichirus*) *coutierei* Nobili, 1904
Callianassa (*Callichirus*) *placida* de Man, 1905
Callianassa coutierei (Nobili, 1904)
Callianassa placida de Man, 1905
Callichirus placidus (de Man, 1905)
Corallichirus placidus (de Man, 1905)
Glypturus coutierei (Nobili, 1904)

Material examined

FRSACDA1, 04.i.2018, 1 male, tl 75mm, Goose reef (22.494N & 69.802E), Intertidal zone of sandy shore, coll. Prakash Bambhaniya.

Description

Dorsal oval shaped as long as carapace, rostrum with acute anterolateral carapace spine (Image 2b), shorter than eyestalk. Cornea large. Third maxilliped-merus-ischium with 2.2 times as long as wide, merus shorter than ischium, ischium with crista dentata mesially, propodus as wide as long, dactylus shorter than propodus width about 0.2 of propodus. Cheliped

Table 1. Checklist of the infraorder Axiidea of Indian waters.

	Infraorder	Family	Genus	Species	Author	Distribution
1	Axiidea	Axiidae	*Ambiaxius*	*Ambiaxius alcocki* (McArdle, 1900)	Radhakrishnan et al. 2012; Samuel et al. 2016	Southwestern coast of India
2			*Calaxiopsis*	*Calaxiopsis felix* (Alcock & Anderson, 1899)	Alcock & Anderson 1899; Radhakrishnan et al. 2012; Samuel et al. 2016	Indian coast
3			*Calocaris*	*Calocaris macandreae* Bell, 1846	Alcock & Anderson 1894	Laccadive Sea, India
4			*Eiconaxius*	*Eiconaxius andamanensis* (Alcock, 1901)	Rao 2010; Radhakrishnan et al. 2012; Samuel et al. 2016	Andaman & Nicobar Islands
5				*Eiconaxius kermadeci* Bate, 1888	Alcock & Anderson 1894	Laccadive Sea, India
6				*Eiconaxius laccadivensis* Alcock & Anderson, 1894	Radhakrishnan et al. 2012; Samuel et al. 2016	Lakshadweep Islands, India
7		Callianassidae	*Gilvossius*	*Gilvossius tyrrhenus* (Petagna, 1792)	Patel & Mahyavanshi 1974	Okha Port, Gujarat
8			*Paratrypaea*	*Paratrypaea bouvieri* (Nobili, 1904)	Sakai 1999	Gulf of Mannar
9				*Paratrypaea maldivensis* (Borradaile, 1904)	Pearson 1905	Gulf of Mannar
10			*Pugnatrypaea*	*Pugnatrypaea pugnatrix* (de Man, 1905)	Sakai 2005	Tharangambadi, Tamil Nadu
11			*Rayllianassa*	*Rayllianassa lignicola* (Alcock & Anderson, 1899)	Alcock & Anderson 1899; Rao 2010; Radhakrishnan et al. 2012; Samuel et al. 2016	Andaman & Nicobar Islands, Bay of Bengal
12		Callianideidae	*Callianidea*	*Callianidea typa* H. Milne Edwards, 1837	Rao 2010	Andaman & Nicobar Islands
13		Callianopsidae	*Callianopsis*	*Callianopsis caecigena* (Alcock & Anderson, 1894)	Alcock & Anderson 1894	Bay of Bengal, India
14		Callichiridae	*Audacallichirus*	*Audacallichirus audax* (de Man, 1911)	Rao & Kartha 1966; Sakai 1999, 2005; Dworschak 1992	Ratnagiri, Maharashtra; eastern coast of India; Kannur, Kerala
15			*Balsscallichirus*	*Balsscallichirus masoomi* (Tirmizi, 1970)	Sakai 1999, 2005; Sankolli 1971	Bombay, Maharashtra; Ratnagiri, Maharashtra
16			*Corallianassa*	*Corallianassa coutierei* (Nobili, 1904)	Present study	Goose reef, Gulf of Kachchh, Gujarat- India
17			*Karumballichirus*	*Karumballichirus karumba* (Poore & Griffin, 1979)	Sakai 1999, 2005	Chilka Lake, Odisha; Kayamkulam Lake, Kerala; Travancore, Tamil Nadu
18			*Michaelcallianassa*	*Michaelcallianassa indica* K. Sakai, 2002	Sakai 2005	Tharangambadi, Tamil Nadu
19			*Neocallichirus*	*Neocallichirus jousseaumei* (Nobili, 1904)	Beleem et al. 2019	Diu, India

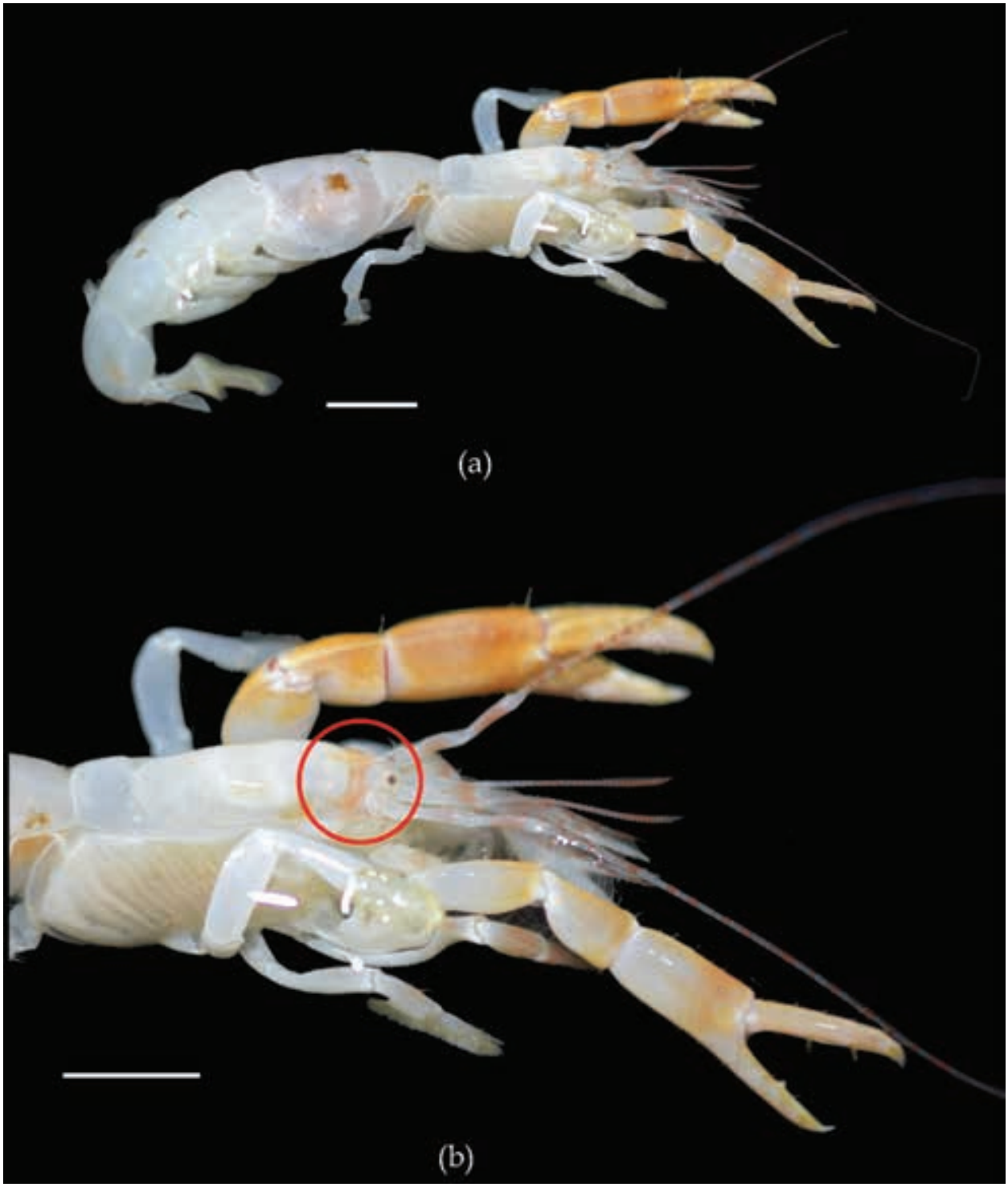

Image 2. a—entire view of *Corallianassa coutierei* (Nobili, 1904) | b—anterolateral carapace spine of C. coutierei (Bar represents= 1cm).

distinctly unequal in shape. Major cheliped massive, ischium unarmed anteriorly, lower margin possesses four teeth increasing gradually in size; merus having row of tubercles at lower margin; carpus broader than long; propodus smooth; cutting edge of fixed fingers sharp with small sharp triangular tooth proximally; dactylus longer than fixed finger, cutting edge sharp, unarmed. Minor cheliped relatively stout; ischium with four teeth distally increasing gradually in size, merus and carpus unarmed; propodus twice longer than carpus; cutting

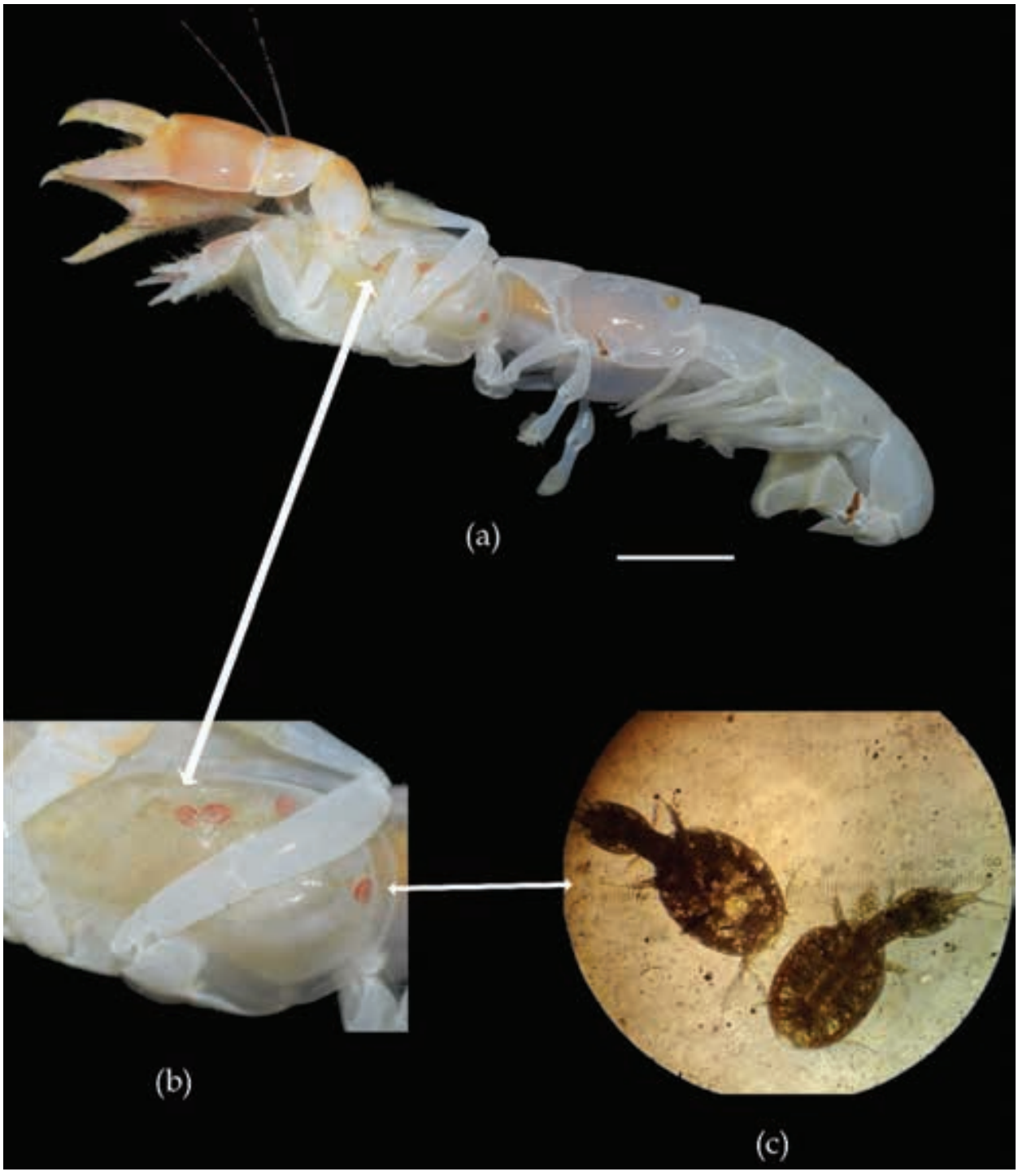

Image 3. a—lateral view of *C. coutierei* | b—copepods (*Clausidium* sp.) infested on carapace region of *C. coutierei* | c—female-male interlocking mechanism of copepods. (Bar size= 1cm). © Fisheries Research Station, Junagadh Agricultural University, Sikka.

edge of fixed finger with median small sharp tooth; dactylus slightly longer than fixed finger, cutting edge sharp, unarmed. Third pereopod as long as high. Telson trapezoid in shape as wide as long. Uropod, endopod oval shaped, longer than telson; uropodal exopod with strongly elevated dorsal plate, as long as endopod.

Colour

Entire animal whitish; carapace tinge of orange spots; chelipeds light brown with white blotches.

Habitat

Present species was found hidden in sandy shore of

Goose reef during low tide.

Distribution

Arabian Gulf (Ngoc-Ho 2005); Djibouti (Sakai 1999; Dworschak 2018); Fiji (Sakai 2005); French Polynesia (Ngoc-Ho 2005); Gilbert Islands (Sakai 1999); Hawaii (Edmondson 1944); Indonesia (Man 1905; Aguilera et al. 1986; Sakai 1999); Iran (Sepahvand et al. 2013); Madagascar (Sakai 1999; Ngoc-Ho 2005); Maldives (Borradaile 1904; Man 1928); Papua New Guinea (Dworschak 2018); Philippines (Sakai 1999; Dworschak 2018); Tahiti (Sakai 1999).

India: This species is reported from Goose reef, Gulf of Kachchh, Gujarat (present study).

Remarks

Taxonomical characters of the present specimen examined agree well with the detailed description given by Dworschak (2018). *C. coutierei* resembles *C. longiventris* (A. Milne-Edwards, 1870) but differentiated by the shape of major and minor chelipeds. Cheliped is slenderer in *C. longiventris* with triangular carpus, whereas the carpus is rectangular in *C. coutierei*. Sepahvand et al. (2017a) reported two species of copepods, *Clausidium makranensis* Sepahvand & Kihara, 2018 and *C. sarii* Sepahvand & Kihara, 2018 from *Neocallichirus natalensis* (Barnard, 1947) and *Corallianassa martensi* (Miers, 1884), respectively. This was observed in *C. coutierei* associated as *C. martensi* in this report, and it is also documented in other species *Corallianassa* (Pearse, 1947; Sephavand et al. 2017a).

Conclusion

From India, with regards to family Callichiridae, six species are recorded, namely, *Audacallichirus audax* (de Man, 1911), *Balsscallichirus masoomi* (Tirmizi, 1970), *Karumballichirus karumba* (Poore & Griffin, 1979), *Michaelcallianassa indica* K. Sakai, 2002, *Neocallichirus jousseaumei* (Nobili, 1904), and *Corallianassa coutierei* (Nobili, 1904) (present study) (Table 1). The present investigation reports the occurrence of *C. coutierei* in association with *Clausidium* for the first time from the Indian waters. The longer duration of their relationship inclines to assume that they might be in symbiotic association. Further detailed research is required to understand the relationship of copepods (either symbiotic or parasitic). Study is also required on ghost shrimps pertaining to diversity, life history, ecology which are still lacking in India. Molecular analysis of copepods and ghost shrimps can be performed to understand their range of extension towards the Indian waters.

References

Aguilera, J.L.H., I.L. Salgado & P.S. Hernandez (1986). Crustáceos estomatópodos y decápodos de Isla Clarión. Fauna Carcinologica insula de Mexico, I. *Investigaciones Oceanográficas Biologia* 3(1): 183–250.

Alcock, A. & A.R.S. Anderson (1894). Natural history notes from H.M. Royal Indian Marine Survey Steamer Investigator, Commander C.F. Oldham, R.N., commanding. Series II, No. 14. An account of a recent collection of deep-sea Crustacea from the Bay of Bengal and the Laccadive Sea. *Journal of the Asiatic Society of Bengal* 63(2): 141–185.

Alcock, A. & A.R.S. Anderson (1899). Natural History Notes from H.M. Royal Indian Marine Survey Ship Investigator, Commander T.H. Heming, R.N., commanding. Series III. No. 2. An Account of the deep-sea Crustacea dredged during the Surveying season of 1897-98. *Annals and Magazine of Natural History* 7(3): 287–290.

Beleem, I., P. Poriya & B. Gohil (2019). First record of the callianassid ghost shrimp *Neocallichirus jousseaumei* (Nobili, 1904) (Decapoda: Axiidea) from India. *Journal of Threatened Taxa* 11(3): 13402–13405. https://doi.org/10.11609/jott.3251.11.3.13402-13405

Borradaile, L.A. (1904). Marine Crustaceans. XIII. The Hippidea, Thalassinidea and Scyllaridea, pp. 750–754. In: Gardiner, J.S. (eds.). *The Fauna and Geography of the Maldive and Laccadive Archipelagoes.* Cambridge University Press, London, 805pp.

Corsetti, J.L. & K.M. Strasser (2003). Host selection of the symbiotic copepod *Clausidium dissimile* in two sympatric populations of ghost shrimp. *Marine Ecology Progress Series* 256: 151–159. https://doi.org/10.3354/meps256151

Dworschak, P.C. (1992). The Thalassinidea in the Museum of Natural History, Vienna; with some remarks on the biology of the species. *Annalen des Naturhistorischen Museums in Wien* 93(B): 189–238.

Dworschak, P.C. (2015). Methods collecting Axiidea and Gebiidea (Decapoda): a review. *Annalen des Naturhistorischen Museums in Wien* 117(B): 5–21.

Dworschak, P.C. (2018). Axiidea of Panglao, the Philippines: families Callianideidae, Eucalliacidae and Callichiridae, with a redescription of *Callianassa calmani* Nobili, 1904. *Annalen des Naturhistorischen Museums in Wien* 120(B): 15–40.

Dworschak, P.C., D.L. Felderand & C.C. Tudge (2012). Infraorders Axiidea de Saint Laurent, 1979 and Gebiidea de Saint Laurent, 1979 (formerly known collectively as Thalassinidea), pp. 109–219. In: Schram, F.R. & J.C.V.V. Klein, (eds.). *The Crustacea - Treatise on Zoology: Anatomy, Taxonomy and Biology*. Brill Publishers, Boston, 359pp.

Edmondson, C.H. (1944). Callianassidae of the central Pacific. *Bernice P. Bishop Museum* 18(2): 35–61.

Golubinskaya, D.D., O.M. Korn & E.S. Kornienko (2016). The seasonal dynamics and distribution of burrowing shrimp larvae of the infraorders Gebiidea and Axiidea in Amursky and Ussuriysky Bays, the Sea of Japan. *Russian Journal of Marine Biology* 42(3): 232–242. https://doi.org/10.1134/S1063074016030044

Humes, A.G. (1949). A new copepod (Cyclopoida: Clausidiidae) parasitic on mud shrimps in Louisiana. *Transactions of the American Microscopical Society* 68(2): 93–103. https://doi.org/10.2307/3223256

Kihara, T.C. & C.E.F. Rocha (2013). First record of *Clausidium* (Copepoda, Clausidiidae) from Brazil: a new species associated with ghost shrimps *Neocallichirus grandimana* (Gibbes, 1850) (Decapoda, Callianassidae). *ZooKeys* 335: 47–67. https://doi.org/10.3897/zookeys.335.5490

Man, J.G.D. (1905). Diagnoses of new species of macrurous decapod Crustacea from the "Siboga Expedition". *Tijdschrift Der Nederlandsche Dierkundige Vereeniging* 2(9): 587–614.

Man, J.G.D. (1928). A contribution to the knowledge of twenty-two species and three varieties of the genus *Callianassa* (Leach). *Capita Zoologica* 2(6): 1–56.

Manning, R.B. (1987). Notes on Western Atlantic Callianassidae (Crustacea: Decapoda: Thalassinidea), In: Kensley, B. (ed.).

Proceedings of the Biological Society of Washington, 19 May 1987. Washington, United States 100(2): 386–401.

Manning, R.B. (1992). A new genus for *Corallianassa xutha* Manning (Crustacea, Decapoda, Callianassidae). In: Robbins, C.B. (Ed.). *Proceedings of the Biological Society of Washington*, 15 Oct 1992. Washington, United States 105(3): 571–574.

Ngoc-Ho, N. (2005). Thalassinidea (Crustacea, Decapoda) from French Polynesia. *Zoosystema* 27(1): 47–83.

Patel, M.I. & I.N. Mahyavanshi (1974). Larva of *Callianassa tyrrhena* (Petagna) (Crustacea, Decapoda, Callianassidae), a new record from the Gulf of Kutch. *Journal of the Marine Biological Association of India* 16(1): 307–10.

Pearse, A.S. (1947). Parasitic copepods from Beaufort, North Carolina. *Journal of the Elisha Mitchell Scientific Society* 63: 1–16.

Pearson, J. (1905). Report on the Macrura collected by Prof. Herdman at Ceylon in 1902, pp. 65–92. In: Herdman, W.A. (ed.). *Report to the government of Ceylon on the Pearl oyster fisheries of the Gulf of Mannar.* The Royal Society, London, 326pp.

Pillai, N.K. (1959). On two new species of *Clausidium* (Copepoda: Cyclopoida) parasitic on the shrimp Callianassa. *Journal of the Marine Biological Association of India* 1(1): 57–65.

Radhakrishnan, E.V., V.D. Deshmukh, G. Maheshwarudu, J. Joseleen, A.P. Dineshbabu, K.K. Philipose, P.T. Sarada, S.L. Pillai, K.N. Saleela, R. Chakraborthy, G. Dash, C.K. Sajeev, P. Thirumilu, B. Sridhara, Y. Muniyappa, A.D. Sawant, G. Vadiya, R.D. Jhony, J.B. Verma, P.K. Baby, N.P. Unniakrishnan, A. Ramachandran, A. Variamani, A. Palanichany, M. Radhakriashnan & B. Raju (2012). Prawn fauna (Crustacea: Decapoda) of India - An annotated checklist of the Penaeoid, Sergestoid, Stenopodid and Caridean prawns. *Journal of the Marine Biological Association of India* 54(1): 50–72. https://doi.org/10.6024/jmbai.2012.54.1.01697-08

Rao, D.V. (2010). *Field Guide to Coral and Coral Associates of Andaman and Nicobar Islands*. Zoological Survey of India, Kolkata, 283pp.

Rao, P.V. & K.N.R. Kartha (1966). On the occurrence of *Callianassa (Callichirus) audax* de Man (Crustacea Decapoda-Callianassidae) on the southwest coast of India with a description of the male. Proceedings Symposium on Crustacea held at Ernakulam from January 12 to 15, 1965, Symposium Series 2, pt. 1(2), pp. 279–284. Marine Biological Association of India, Mandapam Camp, India.

Sakai, K. (1999). Synopsis of the family Callianassidae, with keys to subfamilies, genera and species, and the description of new taxa (Crustacea: Decapoda: Thalassinidea). *Zoologische Verhandelingen* 326: 1–152.

Sakai, K. (2005). Callianassoidea of the world (Decapoda, Thalassinidea). *Crustaceana Monographs* 4: 1–285.

Samuel, V.K.D., C.R. Sreeraj, P. Krishnan, C. Parthiban, V. Sekar, K. Chamundeeswari, T. Immanuel, P. Shesdev, R. Purvaja & R. Ramesh (2016). An updated checklist of shrimps on the Indian coast. *Journal of Threatened Taxa* 8(7): 8977–8988. https://doi.org/10.11609/jott.2628.8.7.8977-8988

Sankolli, K.N. (1971). The Thalassinoidea (Crustacea, Anomura) of Maharashtra. *Journal of the Bombay Natural History Society* 68(1): 94–106.

Sepahvand, V., A. Sari, H. Salehi, S.M.B. Nabavi & S.G. Ghorbanzadeh (2013). Littoral mud shrimps (Decapoda: Gebiidea & Axiidea) of the Persian Gulf and Gulf of Oman, Iran. *Journal of the Marine Biological Association of the United Kingdom* 93(4): 999–1008. https://doi.org/10.1017/S0025315412001361

Sepahvand, V., N. Rastegar–Pouyani & T.C. Kihara (2017a). Two new species of *Clausidium* copepods (Crustacea, Poecilostomatoida) associated with ghost shrimps from Iran. *Journal of the Marine Biological Association of the United Kingdom* 98(6): 1401–1409. https://doi.org/10.1017/S0025315417000303

Sepahvand, V., N. Rastegar-Pouyani, T.C. Kihara & F. Momtazi (2017b). A new species of *Clausidium* Kossmann, 1874 (Crustacea, Copepoda, Cyclopoida, Clausidiidae) associated with ghost shrimps from Iran. *Nauplius* 25: 1–16. https://doi.org/10.1590/2358-2936e2017018

Sepahvand, V., T.C. Kihara & G.A. Boxshall (2019). A new species of *Clausidium* Kossmann, 1874 (Copepoda: Cyclopoida) associated with ghost shrimps from the Persian Gulf, including female-male interlocking mechanisms and remarks on host specificity. *Systematic Parasitology* 96(2): 171–189. https://doi.org/10.1007/s11230-019-09839-x

Wilson, C.B. (1935). Parasitic Copepods from the Pacific Coast. *The American Midland Naturalist* 16(5): 776–797. https://doi.org/10.2307/2420107

Wilson, C.B. (1937). Two new semi-parasitic copepods from the Peruvian Coast. *Parasitology* 29(2): 206–211. https://doi.org/10.1017/S0031182000024744

WoRMS (2020a). World Register of Marine Species. Available from Axiidea. Accessed at: http://www.marinespecies.org/aphia.php?p=taxdetails&id=477324 on 30 March 2020.

WoRMS (2020b). World Register of Marine Species. Available from Callichiridae Manning & Felder, 1991. Accessed at: http://www.marinespecies.org/aphia.php?p=taxdetails&id=1397714 on 30 March 2020.

WoRMS (2020c). World Register of Marine Species. Available from Corallianassa Manning, 1987. Accessed at: http://www.marinespecies.org/aphia.php?p=taxdetails&id=246268 on 30 March 2020.

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SHORT COMMUNICATION

A preliminary checklist of dragonflies and damselflies (Insecta: Odonata) of Vakkom Grama Panchayath, Thiruvanthapuram District, Kerala, India

J. Arunima [1] & P.O. Nameer [2]

[1,2] Centre for Wildlife Studies, College of Forestry, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala 680656, India.
[1] arunima.bindhu@gmail.com, [2] nameer.po@kau.in (corresponding author)

Abstract: A one-year study was conducted at Vakkom Grama Panchayath, Thiruvananthapuram district, Kerala, to assess the diversity of odonates. We report 49 species, which include 31 species of Anisoptera (dragonflies) and 18 species of Zygoptera (damselflies). Among dragonflies, the family Libellulidae dominated with 26 species, while Coenagrionidae with 10 species was the dominant family among the damselflies. The odonate diversity of Vakkom Grama Panchayath accounted for 28% of the odonates in Kerala and 25% of the odonates of the Western Ghats. Vakkom Grama Panchayath also recorded the presence of *Mortonagrion varralli* which is an uncommon species in Kerala. This study provides some important baseline information on the odonates of one of the grama panchayaths in Kerala, India. An updated checklist of 57 species of odonates of Thiruvananthapuram district, Kerala is also provided.

Keywords: Biodiversity register, Biological Diversity Act, odonates.

Dragonflies and damselflies constitute an order of carnivorous insects. They are treated as an important component of aquatic ecosystems as well as biological indicators of environmental conditions (Clark & Samways 1996; Samways et al. 2010). There are 497 species of odonates in 154 genera and 18 families recorded from India (Joshi & Sawant 2020; Kalkman et al. 2020; Payra et al. 2020; Subramaniyan & Babu 2017, 2020); 196 species in 14 families and 83 genera have been documented from the Western Ghats (Subramanian et al. 2018); and 175 species from Kerala to date (Society for Odonate Studies 2021).

The studies on the odonates from human-dominated landscapes from Kerala part include Peter (1981) who reported 26 species of odonates from the Thiruvananthapuram district of Kerala, which was later updated by Emiliyamma & Radhakrishnan (2002) to 43 species. Emiliyamma (2005) recorded 31 species of odonates from Kottayam district, Kerala. Adarsh et al. (2014) reported 52 species of odonates from Kerala Agricultural University campus, Thrissur, Kerala and Chandran et al. (2021) reported 44 species of odonates from the Kole Wetlands in Thrissur and Malappuram districts, Kerala.

Documentation of regional biodiversity is important for the long-term conservation and management of different taxa. Thus, a study was conducted at Vakkom Grama Panchayat in Thiruvananthapuram district, Kerala, southern India from November 2018 to December 2019, and the results of the same are presented here.

Study Area

The Vakkom Grama Panchayath (VGP) is located 35 km north of Thiruvananthapuram city, in Chirayinkeezhu

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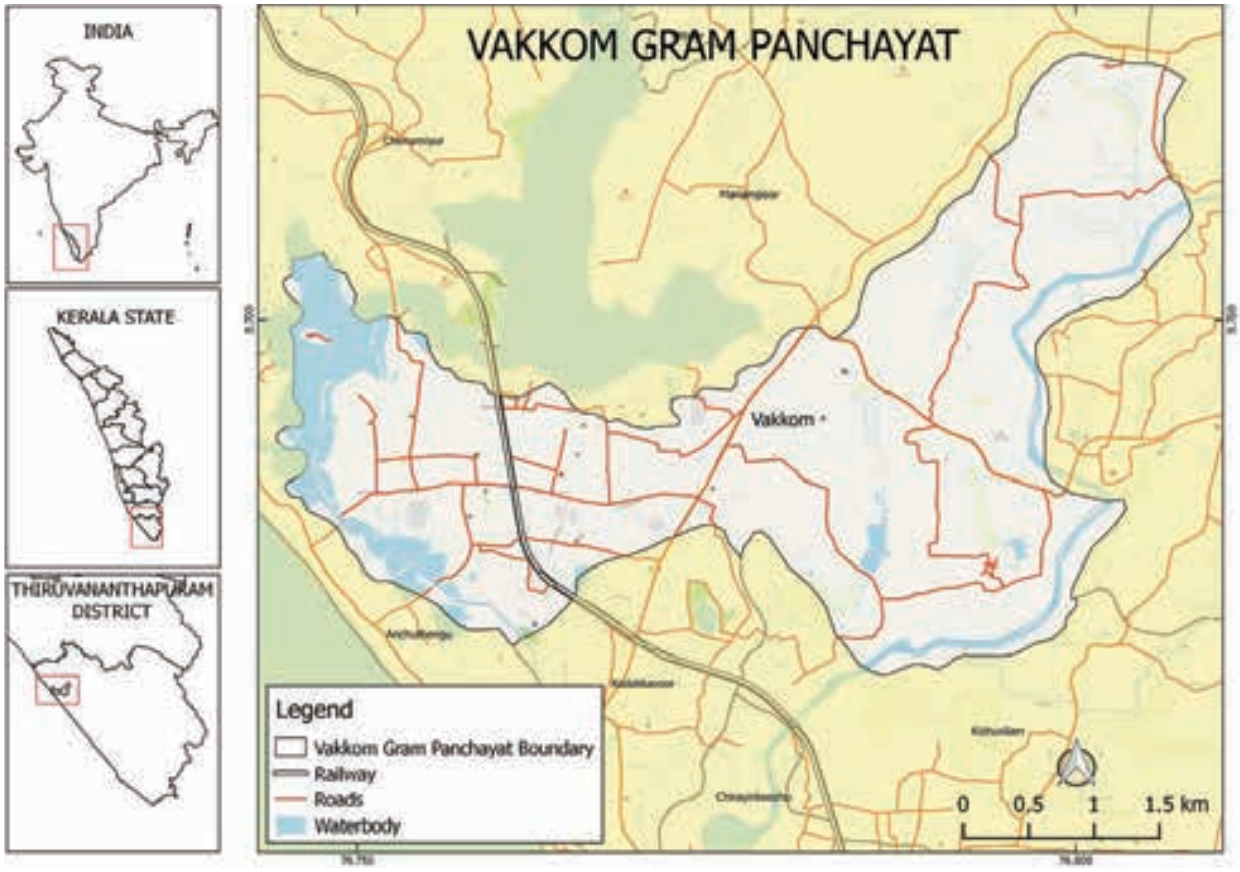

Figure 1. Location of Vakkom Grama Panchayath, Kerala.

Taluk (Figure 1). It is located between 8.69°N & 76.77°E and has a total area of 5.36 km^2. VGP is surrounded by backwaters and is an islet laced by Parvathiputhanar (ar= river) and Anchuthengu Kayal (kayal= backwater). The study area is enriched with various aquatic habitats like lakes, ponds, marshes, and backwaters.

Methods

The odonates of VGP were studied between November 2018 and December 2019. The visual encounter survey method was followed and most of the taxa were photo-documented. The major aquatic habitats of the VGP are ponds, backwaters, canals, and paddy fields. The study sites were visited at least once a month and the survey was undertaken for two hours in the morning and one hour in the evening. The odonates were identified using the field guides such as Subramanian (2009) and Kiran & Raju (2013). Taxonomy and nomenclature have been updated after Kalkman et al. (2020). Based on the frequency of sighting the odonates it was categorized as Very Common (VC) when they were sighted during 75–100% of the field outings, Common (CO) when the sighting was between 50–75%, Occasional (OC) when the sighting was only 25–50%, and Rare (RA) when the sighting was below 25%. The study period was categorised into three different seasons such as summer (February–May), monsoon (June–September), and post monsoon (October–January).

Results

A total of 49 species of odonates (18 species of damselflies and 31 species of dragonflies) belonging to eight families were recorded from VGP (Table 1). Family Libellulidae (26 spp.) dominated among the Anisoptera followed by Aeshnidae (3) and Gomphidae (2). Among Zygoptera, the dominant family was Coenagrionidae (10 spp.) followed by Lestidae (3), Calopterygidae (2), Platycnemididae (2), and Chlorocyphidae (1). The family-wise distribution of species is shown in Figures 2 & 3. Libellulidae (26) and Coenagrionidae (11) are two dominant families of Odonates at VGP.

The occurrence data during the study period shows that out of 49 species, six were found to be Very Common, 19 species were Common, 16 species found to be Occasional, while eight species were Rare. Among Zygoptera, *Agriocnemis pygmaea* (Rambur,

Table 1. The checklist of odonates of Vakkam Grama Panchayath, Thiruvananthapuram, Kerala and an updated checklist of odonates of Thiruvananthapuram District, Kerala.

	Common name	Family/Scientific name	Relative frequency class	IUCN Red List status	Image no.	Remarks
	ORDER ZYGOPTERA (DAMSELFLIES)					
	Spread Wing	**Family Lestidae**				
1	Emerald Spreadwing	*Lestes elatus* Hagen in Selys, 1862	OC	LC		***
2	Sapphire-eyed Spreadwing	*Lestes praemorsus* Hagen in Selys, 1862	OC	LC	1	**
3	Brown Spreadwing	*Lestes concinnus* Hagen in Selys, 1862	R	DD	2	**
	Glories	**Family Calopterygidae**				
4	Black-tipped Forest Glory	*Vestalis apicalis* Selys, 1873	OC	LC	3	***
5	Clear-winged Forest Glory	*Vestalis gracilis* (Rambur, 1842)	OC	LC	4	***
	Stream jewels	**Family Chlorocyphidae**				
6	Stream Ruby	*Heliocypha bisignata* (Hagen in Selys, 1853)		LC		*
7	Southern Heliodor	*Libellago indica* (Fraser, 1928)	R	NE	5	**
	Bush darts	**Family Platycneminidae**				
8	Wayand Bambootail	*Caconeura risi* (Fraser, 1931)		DD		*
9	Yellow Bush Dart	*Copera marginipes* (Rambur, 1842)	CO	LC		***
10	Blue Bush Dart	*Copera vittata* (Selys, 1863)	CO	LC		***
11	Black Bambootail	*Prodasineura verticalis* (Selys, 1860)				*
	Marsh Darts	**Family Coenagrionidae**				
12	Green-Striped Slender Dartlet	*Aciagrion occidentale* Laidlaw 1919	OC	LC	6	***
13	White Dartlet	*Agriocnemis pieris* Laidlaw, 1919	OC	LC	7	**
14	Pigmy Dartlet	*Agriocnemis pygmaea* (Rambur, 1842)	VC	LC	8	***
15	Kerala Dartlet	*Agriocnemis keralensis* Peters, 1981		LC		*
16	Splendid Dartlet	*Agriocnemis splendidissima* Laidlaw, 1919		LC		*
17	Orange-tailed Marsh Dart	*Ceriagrion cerinorubellum* (Brauer, 1865)	CO	LC	9	***
18	Coromandel Marsh Dart	*Ceriagrion coromandelianum* (Fabricius, 1798)	CO	LC	10	***
19	Orange Marsh Dart	*Ceriagrion rubiae* Laidlaw, 1916	OC	LC		**
20	Golden Dartlet	*Ischnura rubilio* Selys, 1876	OC	LC	11	***
21	Senegal Golden Dartlet	*Ischnura senegalensis* (Rambur, 1842)	CO	LC	12	***
22	Brown Dartlet	*Mortonagrion varralli* Fraser, 1920	OC	DD	13	***
23	Jungle Grass Dart	*Pseudagrion malabaricum* Fraser, 1924		LC		*
24	Blue Grass Dart	*Pseudagrion microcephalum* (Rambur, 1842)	VC	LC	14	**
25	Saffron-faced Grass Dart	*Pseudagrion rubriceps* Selys, 1876				*
	ORDER ANISOPTERA (DRAGONFLIES)					
	Darners	**Family Aeshnidae**				
26	Pale-spotted Emperor	*Anax guttatus* (Burmeister, 1839)	OC	LC	15	**
27	Blue Darner	*Anax immaculifrons* Rambur, 1842	R	LC		**
28	Brown Darner	*Gynacantha dravida* Lieftinck, 1960	CO	DD		**
	Clubtails	**Family Gomphidae**				
29	Common Clubtail	*Ictinogomphus rapax* (Rambur, 1842)	CO	LC	16	**
30	Common Hooktail	*Paragomphus lineatus* (Selys, 1850)	R	LC		**
	Skimmers	**Family Libellulidae**				
31	Trumpet Tail	*Acisoma panorpoides* Rambur, 1842	CO	LC	17	***
32	Scarlet Marsh Hawk	*Aethriamanta brevipennis* (Rambur, 1842)	R	LC	18	***

	Common name	Family/Scientific name	Relative frequency class	IUCN Red List status	Image no.	Remarks
33	Rufous-backed Marsh Hawk	*Brachydiplax chalybea* Brauer, 1868	CO	LC	19	***
34	Little Blue Marsh Hawk	*Brachydiplax sobrina* (Rambur, 1842)	OC	LC		**
35	Ditch jewel	*Brachythemis contaminata* (Fabricius, 1793)	CO	LC	20	***
36	Granite Ghost	*Bradinopyga geminata* (Rambur, 1842)	VC	LC	21	***
37	Ruddy Marsh Skimmer	*Crocothemis servilia* (Drury, 1773)	CO	LC	22	***
38	Ground Skimmer	*Diplacodes trivialis* (Rambur, 1842)	VC	LC	23	***
39	Amber-winged Marsh Glider	*Hydrobasileus croceus* (Brauer, 1867)	R	LC	24	**
40	Asiatic Blood-tail	*Lathrecista asiatica* (Fabricius, 1798)	R	LC	25	***
41	Fulvous Forest Skimmer	*Neurothemis fulvia* (Drury, 1773)	R	LC	26	**
42	Pied Paddy Skimmer	*Neurothemis tullia* (Drury, 1773)	VC	LC	27	***
43	Brown-backed Red Marsh Hawk	*Orthetrum chrysis* (Selys, 1891)	VC	LC	28,29	***
44	Tri-coloured Marsh Hawk	*Orthetrum luzonicum* (Brauer, 1868)	OC	LC	30	***
45	Crimson-tailed Marsh Hawk	*Orthetrum pruinosum* (Burmeister, 1839)	CO	LC	31	***
46	Green Marsh Hawk	*Orthetrum sabina* (Drury, 1770)	CO	LC	32	***
47	Wandering Glider	*Pantala flavescens* (Fabricius, 1798)	CO	LC	33	***
48	Yellow-tailed Ashy Skimmer	*Potamarcha congener* (Rambur, 1842)	OC	LC	34	***
49	Rufous Marsh Glider	*Rhodothemis rufa* (Rambur, 1842)	OC	LC	35	***
50	Common Picture Wing	*Rhyothemis variegata* (Linnaeus, 1763)	CO	LC	36	***
51	Coral-tailed Cloud Wing	*Tholymis tillarga* (Fabricius, 1798)	CO	LC	37	***
52	Black Marsh Glider	*Tramea limbata* (Desjardins, 1832)	OC	LC		***
53	Crimson Marsh Glider	*Trithemis aurora* (Burmeister, 1839)	CO	LC	38	***
54	Black Stream Glider	*Trithemis festiva* (Rambur, 1842)	OC	LC	39	***
55	Long-legged Marsh Glider	*Trithemis pallidinervis* (Kirby, 1889)		LC		*
56	Greater Crimson Glider	*Urothemis signata* (Rambur,1842)	CO	LC	40	**
57	Brown Dusk Hawk	*Zyxomma petiolatum* (Rambur, 1842)	CO	LC		***

LC—Least concern | NE—Not Evaluated | DD—Data Deficient | VC—Very common | CO—Common | OC—Occasional | R—Rare | *—Species listed in Emiliyamma & Radhakrishnan (2002) but not sighted from Vakkom GP | **—Addition to the odonates of Thiruvananthapuram district recorded during the present study | ***—Odonate species that are common in both checklists.

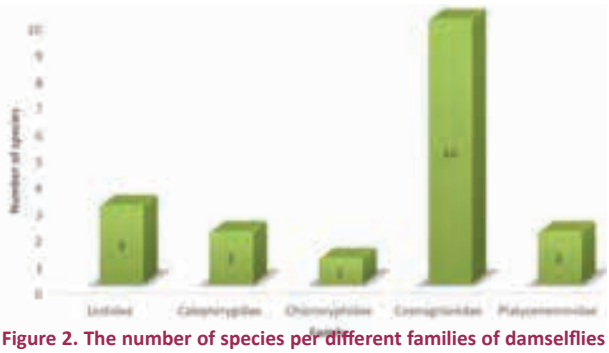

Figure 2. The number of species per different families of damselflies (Zygoptera) in Vakkam Grama Panchayath, Thiruvananthapuram, Kerala

1842) and *Pseudagrion microcephalum* (Rambur, 1842) were the most common species, whereas *Neurothemis tullia* (Drury, 1773) and *Bradinopyga geminata* (Rambur, 1842) were the most common species among Anisoptera. Monsoon season recorded the maximum number of species during the present study (Figure 4). Common species like *Neurothemis tullia* (Drury, 1773) and *Bradinopyga geminata* (Rambur, 1842) were found in almost all months during the study period. An updated checklist of 57 species of odonates of the Thiruvananthapuram district, Kerala is also presented in Table 1.

Discussion

The current study on odonates of VGP revealed the presence of 49 species which constitute 28.65% of the total species of odonates of Kerala state. The VGP reports 15 additional species of odonates than the previously known from the Thiruvananthapuram district, Kerala (Emiliyamma & Radhakrishnan 2002), however eight

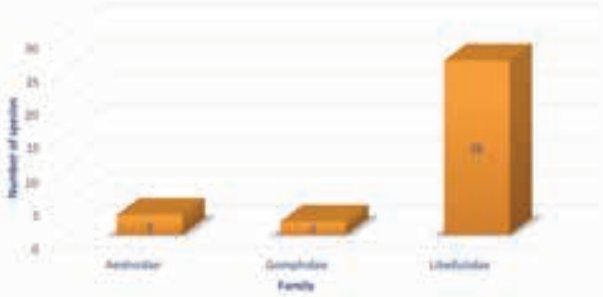

Figure 3. The number of species per different families of dragonflies (Anisoptera) in Vakkom Grama Panchayath, Thiruvananthapuram, Kerala.

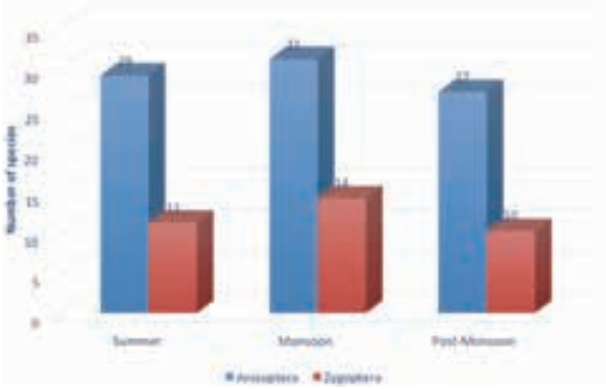

Figure 4. The seasonal variation in the species richness of odonates in Vakkom Grama Panchayath, Thiruvananthapuram, Kerala.

species previously reported from Thiruvananthapuram district could not be located from VGP. It is also interesting to note that a small grama panchayath (5.6 km^2) supports a high diversity of odonates.

Conclusion

This documentation becomes important in the light of the national Biological Diversity Act (2002) of the Government of India, and one of the mandates of which is the preparation of the local biodiversity registers at the Panchayath level across the country. The information gathered as part of this study could be useful in this backdrop and could even ensure the long-term conservation of these little-known taxa.

References

Adarsh, C.K., K.S. Aneesh & P.O. Nameer (2014). A preliminary checklist of odonates in Kerala Agricultural University (KAU) campus, Thrissur District, Kerala, Southern India. *Journal of Threatened Taxa* 6(8): 6127–6137. https://doi.org/10.11609/JoTT.o3491.6127-37

Chandran, A.V., S.K. Jose & S.V. Gopalan (2021). Dragonflies and damselflies (Insecta: Odonata) of the Kole Wetlands, Central Kerala, India. *Journal of Threatened Taxa* 13(3): 17963–17971. https://doi.org/10.11609/jott.5885.13.3.17963-17971

Clark, T.E. & M.J. Samways (1996). Dragonflies (Odonata) as indicators of biotope quality in the Kruger National Park, South Africa. *Journal of Applied Ecology* 33: 1001–1012.

Emilyamma, K.G. & C. Radhakrishnan (2002). Additions to the Odonata (Insecta) of Thiruvananthapuram district, Kerala. *Zoos' Print Journal* 17(10): 914-917. http://doi.org/10.11609/JoTT.ZPJ.17.10.914-7

Joshi, S. & D. Sawant (2020). Descripton of *Bradinopyga konkanensis* sp. nov. (Odonata: Anisoptera: Libellulidae) from the coastal region of Maharashtra, India. *Zootaxa* 4779(1): 065–078. https://doi.org/10.11646/zootaxa.4849.1.1

Kalkman, V.J., R. Babu, M. Bedjanič, K. Conniff, T. Gyeltshen, M.K. Khan, K.A. Subramanian, A. Zia & A.G. Orr (2020). Checklist of the dragonflies and damselflies (Insecta: Odonata) of Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. *Zootaxa* 4849(1): 001–084. https://doi.org/10.11646/zootaxa.4849.1.1

Kiran, C.G. & D.V. Raju (2013). *Dragonflies and Damselflies of Kerala (Keralathile Thumbikal).* Tropical Institute of Ecological Sciences, 156pp.

Peters, G. (1981). Trockenzeit-Libellen ausdem Indischen Tiefand. Deutsch Entomologische Zeitschrift (N.F.) 28: 93–108.

Payra, A., K.A. Subramanian, K. Chandra & B. Tripathy (2020). A first record of *Camacinia hartert* Karsch, 1890 (Odonata: Libellulidae) from Arunachal Pradesh, India. *Journal of Threatened Taxa* 12(8): 15922–15926. https://doi.org/10.11609/jot.4653.12.8.15922-15926

Society for Odonate Studies (2021). List of odonates of Kerala. https://odonatesociety.org/list-of-odonates-of-kerala/ Electronic version accessed on 6 May 2021.

Subramanian, K.A. (2009). *Dragonflies and Damselflies of Peninsular India - A Field Guide*. Vigyan Prasar, Noida, India, 168pp.

Subramanian, K.A. & R. Babu (2017). Checklist of Odonata (Insecta) of India. Version 3.0. Records of the Zoological Survey of India, Kolkata, 488pp.

Subramanian, K.A. & R. Babu (2020). Dragonfies and Damselfies (Insecta: Odonata) of India, pp. 29–45. In: Ramani, S., P. Mohanraj & H.M. Yeshwanth (eds.). *Indian Insects: Diversity and Science.* CRC Press, Taylor & Francis Group, London, 450pp.

Image 1. *Lestes praemorsus*

Image 2. *Lestes concinnus*

Image 3. *Vestalis apicalis*

Image 4. *Vestalis gracilis*

Image 5. *Libellago indica*

Image 6. *Acciagrion occidentale*

Image 7. *Agriocnemis pieris*

Image 8. *Agriocnemis pygmaea*

Image 9. *Ceriagrion coromandelianum*

Image 10.*Ceriagrion cerinorubellum*

Image 11. *Ischnura rubilio*

Image 12. *Ischnura senegalensis*

Image 13. *Mortonagrion varralli*

Image 14. *Pseudagrion microcephalum*

Image 15. *Anax guttatus*

Image 16. *Ictinogomphus rapax*

Image 17. *Acisoma panorpoides*

Image 18. *Aethriamanta brevipennis*

Image 19. *Brachydiplax chalybea*

Image 20. *Brachythemis contaminata*

Image 21. *Bradinopyga geminata*

Image 22. *Crocothemis servilia*

Image 23. *Diplacodes trivialis*

Image 24. *Hydrobasileus croceus*

Image 25. *Lathrecista asiatica*

Image 26. *Neurothemis fulvia*

Image 27. *Neurothemis tullia*

Image 28. *Orthetrum chrysis*

Image 29. *Orthetrum chrysis*

Image 30. *Orthetrum luzonicum*

Image 31. *Orthetrum pruinosum*

Image 32. *Orthetrum sabina*

Image 33. *Pantala flavescens*

Image 34. *Potamarcha congener*

Image 35. *Rhodothemis rufa*

Image 36. *Rhyothemis variegata*

Image 37. *Tholymis tillarga*

Image 38. *Trithemis aurora*

Image 39. *Trithemis festiva*

Image 40. *Urothemis signata*

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SHORT COMMUNICATION

Diversity pattern of butterfly communities (Lepidoptera) in different habitat types of Nahan, Himachal Pradesh, India

Suveena Thakur [1], Suneet Bahrdwaj [2] & Amar Paul Singh [3]

[1,2] Ministry of Environment, Forest and Climate Change, Indira Paryavaran Bhawan, Jorbagh Road, New Delhi 110003, India.
[3] Department of Animal Ecology and Conservation Biology, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248001, India.
[1] suv_uhf@rediffmail.com (corresponding author), [2] bhardwaj-suneet1979@gmail.com, [3] amarpaulsingh4@gmail.com

Abstract: Diversity and similarity of butterfly communities were assessed in three different habitat types in the mountains of Nahan, Himachal Pradesh, from May 2012 to April 2013. A total of 75 species and five families were reported. Proportion of species was highest in deciduous dry forest (49%), followed by *Shorea* (Saal) forest (34%), and *Pinus* (Cheer) forest (17%). Family Pieridae was dominant followed by Nymphalidae in all three habitat types. Cluster analysis revealed that Cheer forest stood out clearly from Dry and Saal forest which represents the different species composition. We found significant differences in butterfly diversity in the three forest types based on Shannon index, Simpson dominance index, and Buzas & Gibson's evenness. These differences may be attributable to variations in host and nectar plant distribution. Of the habitats surveyed, dry deciduous forest appeared to be the most suitable for butterfly conservation.

Keywords: Butterfly, diversity index, species composition, western Himalaya.

Insect diversity is influenced by available vegetation (DeVries 1992). The diversity of some moths and beetles are high in natural forests and low in secondary forests (Morse et al. 1988; Barlow & Woiwod 1989), but butterfly diversity has been found to usually be low in natural forests, moderate in disturbed forests and high in moderately disturbed forests (Blair & Launer 1997; Schulze et al. 2004) or near forest banks (Vu 2008, 2009).

Asian forests are under intense pressure from deforestation and forest degradation (Achard et al. 2002), which can have large effects on biodiversity. Climate change is another factor affecting biodiversity (Stange & Ayres 2010). Lepidoptera (moths and butterflies) are considered bioindicator species because of their sensitivity to climate change (Ronkay 2004). For example, recently some butterflies have shifted their distribution northwards in Europe and North America (Parmesan 1996; Parmesan et al. 1999; Sparks et al. 2007), and local species compositions have also been affected by climate change (Woiwod 1997).

Tropical butterfly assemblages have been observed to be largely dependent on closed-canopy forests (Collins & Morris 1985; Sutton & Collins 1991), which have a rich variety of vegetation (Erhardt 1985; Thomas & Mallorie 1985; Viejo 1989; Lawton et al. 1998). Such studies are important for determining patterns of tropical insect diversity in forest ecosystems (Brown 1991; DeVries et al. 1997). Various studies have been performed in Himachal Pradesh in order to document the diversity of butterflies on regional basis (Uniyal & Mathur 1998; Singh 2008; Arora et al. 2009; Bhardwaj & Uniyal 2009; Kumar 2009; Chandel et al. 2014). So far, no study has been performed to document the variation in butterfly diversity among

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different habitat types of Nahan, Himachal Pradesh. Therefore, the present study documented the seasonal (pre-monsoon, monsoon, post-monsoon, pre-winter, winter, and post-winter) variation of butterfly diversity among three different habitat types.

Material and Methods

Study was conducted in the three different forest types of Nahan town (30.55°N, 77.3°E) located in Sirmaur district of Himachal Pradesh with an elevation of 895 m. Nahan is situated in the Shivalik hills of western Himalaya. The town is surrounded by different forest patches, we conducted our study in *Shorea* (Saal) forest (30.554°N 77.293°E), deciduous dry forest (30.567°N 77.2852°E), and *Pinus* (Cheer) forest (30.563°N 77.314°E) (Figure 1).

Butterfly surveys were conducted from 8000 h to 1000 h and 1300 h to 1500 h in the afternoon, twice a month from May 2012 to April 2013. Butterflies were observed and identified in the field using a guide by Smetacek (2016) and doubtful species were collected using the sweep net method, identified & released immediately. We divided the data sets into six seasons: pre-monsoon (May–June), monsoon (June–July), post-monsoon (August–September), pre-winter (October–November), winter (December–January) and post-winter (February–March). Species diversity was calculated using:

Shannon index (Magurran 1988)

$H' = -\sum pi \ln pi$. (1)

pi= the proportion of the i^{th} species in the total sample.

Simpson dominance index (D)

$D = \text{sum}((n_i/n)^2)$ where n_i is number of individuals of taxon i,

and Buzas & Gibson's evenness= e^H/S

where H is the Shannon diversity index and S is the number of species.

Comparisons of butterfly species composition among different forest types was estimated using single linkage cluster analysis based on Bray-Curtis similarity.

Results and Discussion

Seventy-five species of butterflies were recorded (Table 1). In dry deciduous forest, species from five families were recorded: Pieridae (46%), Nymphalidae

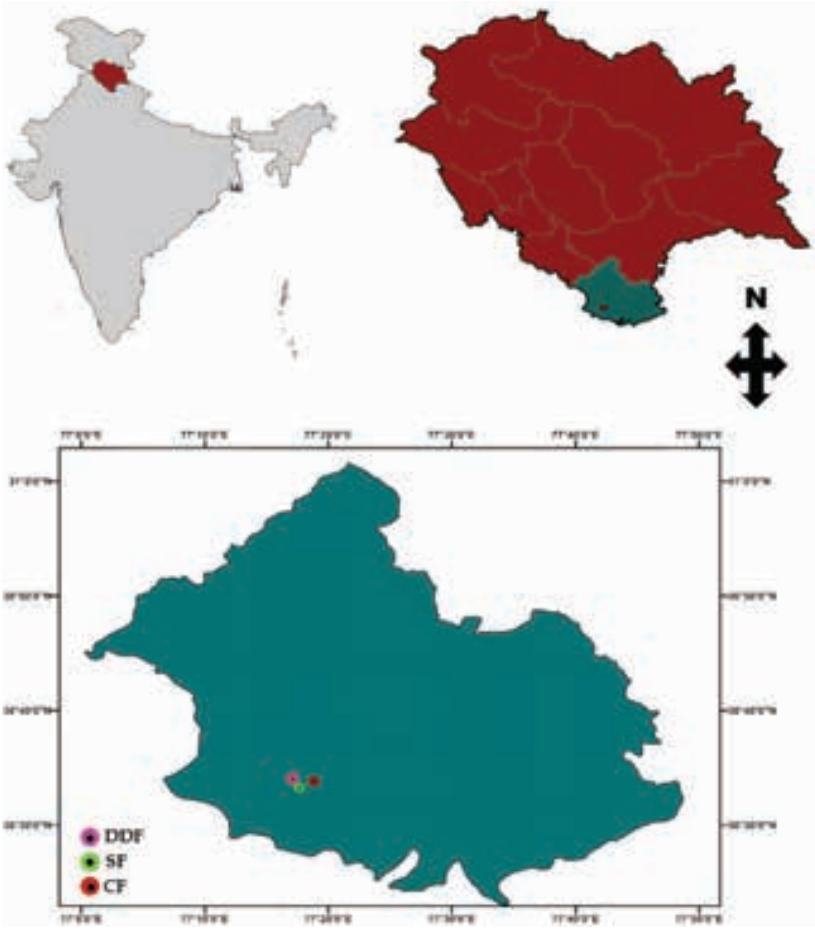

Figure 1. The three different habitat sites of Nahan town of Himachal Pradesh.

Table 1. Butterfly species reported in different forest types. DDF—Dry deciduous forest | SF—Saal forest | CF—Cheer Forest of Nahan.

	Family	Scientific name	Common name	DDF	SF	CF
1	Hesperiidae	*Sarangesa dasahara* (Moore, [1866])	Common Small Flat	4	18	7
2		*Suastus gremius* (Fabricius, 1798)	Oriental Palm Bob	1	0	0
3		*Pelopidas mathias* (Fabricius, 1798)	Small Branded Swift	1	0	0
4		*Pelopidas sinensis* (Mabille, 1877)	Chinese Branded Swift	0	3	0
5		*Notocrypta feisthamelii* (Boisduval, 1832)	Spotted Demon	4	7	0
6		*Taractrocera danna* (Moore, 1865)	White-Spotted Grass Dart	4	1	0
7		*Ochlodes brahma* (Moore, 1878)	Grey-Branded Darter	7	0	0
8	Lycaenidae	*Zizeeria karsandra* (Moore, 1865)	Dark Grass Blue	15	11	14
9		*Zizula hylax* (Fabricius, 1775)	Tiny Grass Blue	7	0	0
10		*Pseudozizeeria maha* (Kollar, [1844])	Pale Grass Blue	48	16	6
11		*Heliophorus sena* (Kollar, [1844])	Sorrel Sapphire	93	58	12
12		*Zizina otis* (Fabricius, 1787)	Lesser Grass Blue	28	20	11
13		*Lampides boeticus* (Linnaeus, 1767)	Pea Blue	65	59	1
14		*Acytolepis puspa* (Horsfield, [1828])	Common Hedge Blue	19	11	6
15		*Euchrysops cnejus* (Fabricius, 1798)	Gram Blue	5	0	0
16		*Arhopala rama* (Kollar, [1844])	Dark Oakblue	1	0	0
17		*Cyrestis thyodamas* Doyère, [1840]	Common Map	0	14	0
18		*Chilades pandava* (Horsfield, [1829])	Plains Cupid	3	11	4
19		*Talicada nyseus* (Guérin-Méneville, 1843)	Red Pierrot	2	2	0
20		*Leptotes plinius* (Fabricius, 1793)	Zebra Blue	1	1	0
21		*Castalius rosimon* (Fabricius, 1775)	Common Pierrot	3	0	0
22		*Catochrysops strabo* (Fabricius, 1793)	Forget-Me-Not	0	0	1
23		*Rapala selira* (Moore, 1874)	Himalayan Red Flash	1	0	0
24	Nymphalidae	*Tirumala limniace* (Cramer, [1775])	Blue Tiger	2	0	0
25		*Phalanta phalantha* (Drury, [1773])	Common Leopard	38	36	12
26		*Neptis hylas* (Linnaeus, 1758)	Common Sailer	24	10	20
27		*Aglais caschmirensis* (Kollar, [1844])	Indian Tortoiseshell	4	0	0
28		*Danaus chrysippus* Linnaeus, 1758	Plain Tiger	6	5	11
29		*Danaus genutia* Cramer, 1779	Common Tiger	6	0	2
30		*Danaus genutia* (Cramer, [1779])	Striped Tiger	9	0	0
31		*Parantica aglea* (Stoll, [1782])	Glassy Tiger	6	5	0
32		*Tirumala septentrionis* (Butler, 1874)	Dark Blue Tiger	1	0	0
33		*Junonia lemonias* (Linnaeus, 1758)	Lemon Pansy	156	145	20
34		*Junonia hierta* (Fabricius, 1798)	Yellow Pansy	3	6	0
35		*Junonia iphita* (Cramer, [1779])	Chocolate Pansy	18	29	12
36		*Vanessa indica* (Herbst, 1794)	Indian Red Admiral	12	3	0
37		*Kaniska canace* (Linnaeus, 1763)	Blue Admiral	0	2	0
38		*Vanessa cardui* (Linnaeus, 1758)	Painted Lady	13	4	0
39		*Kallima inachus* (Doyère, [1840])	Orange Oakleaf	1	0	0
40		*Ideopsis similis* (Linnaeus, 1758)	Blue Glassy Tiger	2	3	4
41		*Symphaedra nais* (Forster, 1771)	Baronet	0	8	0
42		*Mycalesis perseus* Fabricius, 1775	Common Bushbrown	2	1	1
43		*Melanitis leda* (Linnaeus, 1758)	Evening Bushbrown	2	0	0
44		*Melanitis phedima* (Cramer, [1780])	Dark Evening Brown	0	0	3

	Family	Scientific name	Common name	DDF	SF	CF
45		*Lethe rohria* (Fabricius, 1787)	Common Treebrown	2	0	0
46		*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown	1	0	0
47		*Hypolimnas bolina* (Linnaeus, 1758)	Great Eggfly	5	4	0
48		*Junonia hierta* (Fabricius, 1798)	Yellow Pansy	1	0	0
49		*Euthalia aconthea* (Cramer, [1777])	Common Baron	4	0	0
50		*Hypolimnas misippus* (Linnaeus, 1764)	Danaid Eggfly	2	2	0
51		*Ypthima asterope* (Klug, 1832)	Common Three Ring	7	0	0
52	Nymphalidae	*Ypthima baldus* (Fabricius, 1775)	Common Five Ring	4	0	0
53		*Papilio polytes* Linnaeus, 1758	Common Mormon	81	34	48
54		*Euploea core* (Cramer, [1780])	Common Crow	14	4	0
55		*Euploea mulciber* (Cramer, [1777])	Striped Blue Crow	2	2	0
56		*Ariadne ariadne* (Linnaeus, 1763)	Angled Castor	26	11	0
57		*Ariadne merione* (Cramer, [1777])	Common Castor	21	11	4
58		*Lethe confusa* Aurivillius, [1898]	Banded Treebrown	0	0	3
59		*Lasiommata schakra* (Kollar, [1844])	Common Wall	1	0	0
60		*Pachliopta aristolochiae* (Fabricius, 1775)	Common Rose	0	4	0
61	Papilionidae	*Papilio demoleus* Linnaeus, 1758	Lime Swallowtail	39	18	0
62		*Graphium nomius* (Esper, 1799)	Spot Swordtail	2	2	0
63		*Catopsilia pomona* (Fabricius, 1775)	Lemon Emigrant	188	186	119
64		*Eurema hecabe* (Linnaeus, 1758)	Common Grass Yellow	98	67	44
65		*Eurema brigitta* (Stoll, [1780])	Small Grass Yellow	30	23	9
66		*Cepora nerissa* (Fabricius, 1775)	Common Gull	88	5	0
67		*Delias belladonna* (Fabricius, 1793)	Hill Jezebel	0	2	0
68		*Pieris rapae* Linnaeus, 1758	Small Cabbage White	209	94	84
69	Pieridae	*Catopsilia pyranthe* (Linnaeus, 1758)	Mottled Emigrant	83	82	56
70		*Belenois aurota* (Fabricius, 1793)	Pioneer	13	4	0
71		*Pontia daplidice* (Linnaeus, 1758)	Bath White	2	0	0
72		*Eurema laeta* (Boisduval, 1836)	Spotless Grass Yellow	1	17	5
73		*Eurema blanda* (Boisduval, 1836)	Three Spot Grass Yellow	1	0	0
74		*Delias eucharis* (Drury, 1773)	Indian Jezebel	0	0	0
75		*Pieris brassicae* (Linnaeus, 1758)	Large Cabbage White	2	0	0

(31%), Lycaenidae (19%), Papilionidae (2.7%), and Hesperiidae (1.4%). Pieridae were also dominant in Saal forest (45%), followed by Nymphalidae (31%), Lycaenidae (19%), Hesperiidae (2.7%), and Papilionidae (2.3%). Pieridae were also dominant in Cheer forest (61%) followed by Nymphalidae (27%), Lycaenidae (11%), and Hesperiidae (1.4%); no Papilionidae were recorded from Cheer forest.

The composition of butterfly communities in different habitat types is summarized in Figure 2. Comparisons indicate that Cheer forest had a markedly different species composition than dry deciduous and Saal forests, while the latter two showed similar species composition.

Shannon index in DDF ranged from 1.772 to 3.182 (Mean= 2.50 ± Sd 0.48), in SF from 1.435 to 3.065 (mean= 2.27 ± sd 0.57) and in CF from 0.8902 to 2.538 (mean= 1.75 ± sd 0.61) (Table 2, Figure 3). Diversity analysis for dominance in DDF ranged from 0.05334 to 0.2588 (mean= 0.12 ± sd 0.07), in SF from 0.05853 to 0.3208 (mean= 0.15 ± sd 0.09) and in CF from 0.09383 to 0.5542 (mean= 0.24 ± sd 0.16) (Table 3, Figure 4). Diversity analysis for evenness in DDF ranged from 0.4895 to 0.8237 (mean= 0.59 ± sd 0.12), in SF from 0.525 to 0.8608 (mean= 0.63 ± sd 0.15) and in CF from 0.4871 to 0.8742 (mean= 0.73 ± sd 0.14) (Table 4, Figure 5).

Species distribution governs the local assemblages (Ranta & Tiainen 1982). In this study, we documented

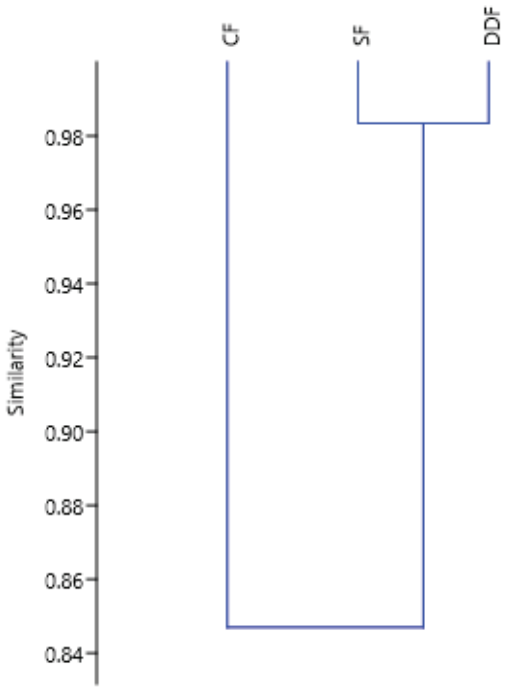

Figure 2. Similarity of species composition of butterfly families among different habitat types.

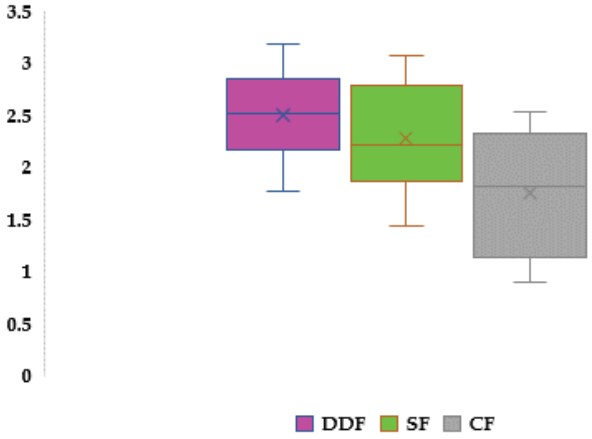

Figure 3. Box plot representing the difference of Shannon index between the forest types.

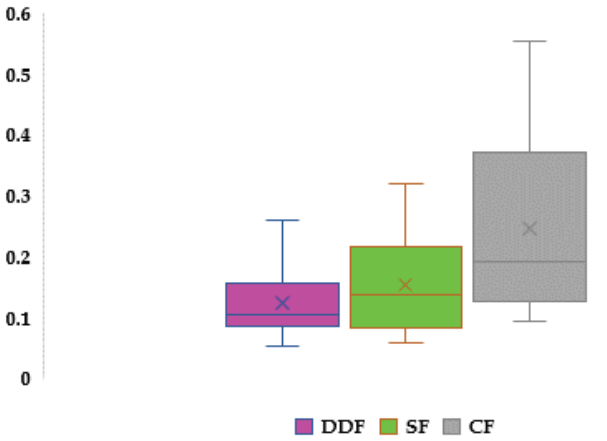

Figure 4. Box plot representing the difference of Simpson dominance index between the forest types.

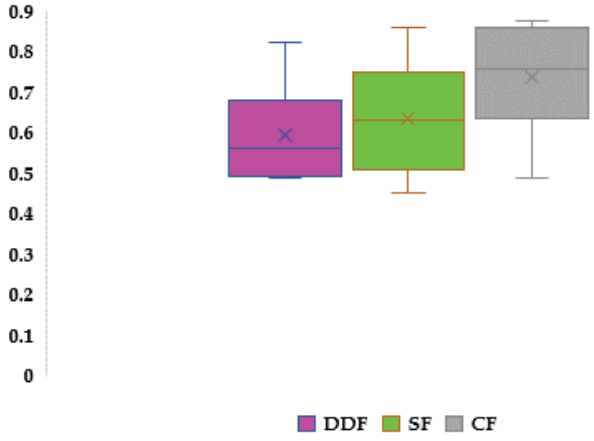

Figure 5. Box plot representing the difference of Buzas & Gibson's evenness index between the forest types.

the highest species diversity in DDF, followed by SF and CF. The habitat specificity of butterfly species is linked to the availability of host plants (Sarkar et al. 2011; Majumder et al. 2013), and in the present study species composition indicates the presence of host and nectar plants in particular areas and habitats. Family Pieridae was found dominant in all three forested habitats followed by Nymphalidae. Sarkar et al. (2011) also reported that the dominancy of Pieridae species correlates with the distribution of host plant species. On the other hand, high diversity of Nymphalidae directly indicates the high richness of host plants (Majumder et al. 2013). Nymphalidae species have a polyphagous nature, which allows them to inhabit vast habitats.

Bray-Curtis single linkage cluster analysis based on the similarity value revealed the percentage similarity between DDF and SF with a linkage of 99 % whereas CF has different species composition. We predicted that the *Pinus roxburghii* is the dominant plant species in cheer forest, which is why it has the lowest butterfly species diversity. Among all the habitats surveyed, the dry deciduous forest signified the most suitable habitat for butterfly diversity, which might be because of the habitat richness having the preferable nectar and host plant species.

Table 2. Two way ANOVA For Shannon diversty Index between seasons and forest type.

Source of variation	SS	Df	MS	F	P-value	F crit
Forest type	1.757115	2	0.878557	46.02805	9.03E-06	4.102821
Season	4.471064	5	0.894213	46.84824	1.28E-06	3.325835
Error	0.190874	10	0.019087			
Total	6.419053	17				

Tale 3. Two way ANOVA For Simpson's dominance index between seasons and forest type.

Source of variation	SS	df	MS	F	P-value	F crit
Forest type	0.049197	2	0.024598	8.719129	0.00643	4.102821
Season	0.178656	5	0.035731	12.66528	0.000462	3.325835
Error	0.028212	10	0.002821			
Total	0.256064	17				

Table 4. Two way ANOVA For Buzas & Gibson's evenness index between seasons and forest type.

Source of variation	SS	df	MS	F	P-value	F crit
Forest type	0.064756	2	0.032378	7.591687	0.009873	4.102821
Season	0.241155	5	0.048231	11.30879	0.000736	3.325835
Error	0.042649	10	0.004265			
Total	0.34856	17				

References

Achard, F., H.D. Eva, H.J. Stibig, P. Mayaux, J. Gallego, T. Richards & J.P. Malingreau (2002). Determination of deforestation rates of the world's humid tropical forests. *Science* 297: 999–1002. https://doi.org/10.1126/science.1070656

Arora, G.S., H.S. Mehta & V.K. Walia (2009). *Handbook on Butterflies of Himachal Pradesh*. Zoological Survey of India, Kolkata, 160pp.

Barlow, H.S. & I.P. Woiwod (1989). Moth diversity of a tropical forest in Peninsular Malaysia. *Journal of Tropical Ecology* 5(1): 37–50.

Bhardwaj, M. & V.P. Uniyal (2009). Assessment of butterflies in montane temperate forest of Allain-Duhaingan catchment in Kullu, Himachal Pradesh, India. Proposed Hydroelectric Project Site. *Indian Forester* 135(10): 1357–1366.

Blair, R.B. & A.E. Launer (1997). Butterfly diversity and human land use: species assemblages along an urban gradient. *Biological Conservation* 80(1): 113–125. https://doi.org/10.1016/S0006-3207(96)00056-0

Brown, K.S. Jr. (1991). Conservation of neotropical environments: insects as indicators, pp. 449–504. In: Collins, N.M. & J.A. Thomas (eds.). *The Conservation of Insects and Their Habitats*. Academic Press, London.

Chandel, S., V. Kumar, B.P. Sharma & R. Patiyal (2014). Butterfly Fauna of Shivalik Hills Areas of Kangra and Hamirpur districts of Himachal Pradesh in India. *Life Science Leaflets* 55: 25–38.

Collins, N.M. & M.G. Morris (1985). Threatened Swallowtail Butterflies of the World. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland, 21–26pp.

DeVries, P.J., D. Murray & R. Lande (1997). Species diversity in vertical, horizontal, and temporal dimensions of a fruit-feeding butterfly community in an Ecuadorian rainforest. *Biological Journal of the Linnaean Society* 62: 343–364.

DeVries, R.G. (1992). *Outlines of Entomology - 7th Edition*. Chapman & Hall/CRC, Boca Raton, Fla, USA, 420pp.

Erhardt, A. (1985). Diurnal Lepidoptera: sensitive indicators of cultivated and abandoned grassland. *Journal of Applied Ecology* 22: 849–861. https://doi.org/10.2307/2403234

Kumar, R. (2009). Biosystematics and ecological studies on butterflies from Himachal Pradesh. PhD Thesis, H.P. University, Shimla, India, 288pp.

Lawton, J.H., D.E. Bignell, B. Bolton, G.F. Bloemers, P. Eggleton, M. Hodda, R.D. Holt, T.B. Larsen, N.A. Mawdsley & N.E. Stork (1998). Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. *Nature* 391(6662): 72–76.

Magurran, A.E. (1988). *Ecological Diversity and Its Measurement*. Chapman & Hall, London, UK, X+179pp. https://doi.org/10.1007/978-94-015-7358-0

Majumder, J., R. Lodh & B.K. Agarwala (2013). Butterfly species richness and diversity in the Trishna wildlife sanctuary in South Asia. *Journal of Insect Science* 13: 79. https://doi.org/10.1673/031.013.7901

Morse, D.R., N.E. Stork & J.H. Lawton (1988). Species number, species abundance and body length relationships of arboreal beetles in Bornean lowland rain forest trees. *Ecological Entomology* 13(1): 25–37.

Parmesan, C. (1996). Climate and species range. *Nature* 382: 765–766. https://doi.org/10.1038/382765a0

Parmesan, C., N. Ryrholm, C. Stefanescu, J.K. Hill, C.D. Thomas, H. Descimon, B. Huntley, L. Kaila, J. Kullberg, T. Tammaru & W.J. Tennent (1999). Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature* 399: 579–583. https://doi.org/10.1038/2118.1

Ranta, E. & M. Tiainen (1982). Structure in seven bumblebee communities in eastern Finland in relation to resource availability. *Ecography* 5: 48–54. https://doi.org/10.1111/j.1600-0587.1982.tb01016.x

Ronkay, L. (2004). Jelenkorifaunaváltozások a Kárpát-

medencebelsőterületein: tények, jelenségekésértékelhetőségük. (Lepkék, elsősorban Macroheterocera) – Esettanulmány„ A globálisklímaváltozáshatásai Magyarországfaunájára" c. kérdéskörről. Kézirat, 22pp. [Current changes in the interior of the Carpathian Basin: facts, phenomena and their evaluability. (Butterflies, mainly Macroheterocera) - Case Study "The effects of global climate change on Hungary's fauna" c. issue]

Smetacek, P. (2016). *A Naturalist's Guide to the Butterflies of India*. Prakash Books India Private Limited, 176pp.

Sarkar, V.K., D.D. Sukumar, V.C. Balakrishnan & K. Kunte (2011). Validation of the reported occurrence of *Tajuria maculata*, the spotted royal butterfly (Lepidoptera: Lycaenidae), in the Western Ghats, southwestern India, on the basis of two new records. *Journal of Threatened Taxa* 3(3): 1629–1632. https://doi.org/10.11609/JoTT.o2645.1629-32

Schulze, C.H., I. Steffan-Dewenter & T. Tsharntke (2004). effects of land use on butterfly communities at the rain forest margin: a case study from Central Sulawesi, pp. 281–297. In: Gerold, G., M. Fremerey & E. Guhardja (eds.). *Land Use, Nature Conservation and The Stability of Rainforest Margins in Southeast Asia*. Springer, Berlin, Heidelberg, XXXI533pp.

Singh, A.P. (2008). Butterflies of Renuka Wildlife Sanctuary, Sirmaur District, Himachal Pradesh, India. *Indian Forester* 134(10): 1326–1338.

Sparks, T.H., R.L. Dennis, P.J. Croxton & M. Cade (2007). Increased migration of Lepidoptera linked to climate change. *European Journal of Entomology* 104(1): 139.

Stange, E.E. & M.P. Ayres (2010). Climate Change Impacts: Insects, pp. 1–7. In: Encyclopedia of Life Sciences (ELS). John Wiley & Sons, Ltd: Chichester. https://doi.org/10.1002/9780470015902.a0022555

Sutton, S.L. & P.J. Collins (1991). Insects and tropical forest conservation, pp. 405–424. In: Collins, N.M. & J.A. Thomas (eds.). *The Conservation of Insects and Their Habitats*. Academic Press, London, 450pp.

Thomas, C.D. & H.C. Mallorie (1985). Rarity, species richness and conservation: butterflies of the Atlas Mountains in Morocco. *Biological Conservation* 33: 95–117. https://doi.org/10.1016/0006-3207(85)90098-9

Uniyal, V.P. & P.K. Mathur (1998). Diversity of butterflies in the Great Himalayan National Park, Western Himalaya. *Indian Journal of Forestry* 21(2): 150–155.

Viejo, J.L. (1989). The importance of woodlands in the classification of butterflies (Lep.: Papilionoidea and Hesperoidea) in the centre of the Iberian Peninsula. *Biological Conservation* 48: 101–114. https://doi.org/10.1016/0006-3207(89)90029-3

Vu, L.V. (2009). Diversity and similarity of butterfly communities in five different habitat types at Tam Dao National Park, Vietnam. *Journal of Zoology* 277(1): 15–22. https://doi.org/10.1111/j.1469-7998.2008.00498.x

Vu, V.L. (2008). Biodiversity of butterflies (Lepidoptera: Rhopalocera) and ecological indicator role of some butterfly species in Tam Dao National Park, Vinh Phuc. PhD Thesis. Institute of Ecology and Biological Resources, Hanoi, Vietnam.

Woiwod, I.P (1997). Detecting the effects of climate change on Lepidoptera. *Journal of Insect Conservation* 1: 149–158.

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SHORT COMMUNICATION

Descriptions of the early stages of *Vagrans egista sinha* (Lepidoptera: Nymphalidae) with notes on its host plant *Xylosma longifolia* Clos from the western Himalaya of India

Pranav Gokhale [1] & **M.A. Yathumon** [2]

[1,2] Wildlife Institute of India, Post Box #18, Chandrabani, Dehradun, Uttarakhand 248001, India.
[1] pranav@wii.gov.in (corresponding author), [2] yadu@wii.gov.in

Abstract: Distribution, life history stages, and status of *Vagrans egista sinha* (Kollar, 1844) in western Himalaya are presented. It is for the first time that this butterfly is reported on X*ylosma longifolia* Clos from Dehradun, Uttarakhand (India).

Keywords: Life cycles, Vagrant butterfly, *Xylosma longifolia*

Vagrans egista (Cramer, 1780) (Lepidoptera: Nymphalidae) belonging to the monotypic genus *Vagrans* Hemming, 1934, is distributed from India to the South Pacific Islands (D'Abrera 1985; Corbet & Pendlebury 1992). The subspecies found in India, identified as *Vagrans egista sinha* (Kollar, 1844), is distributed from Uttarakhand to the eastern Himalaya, northeastern India, West Bengal, Odisha, and Assam (Bingham 1905; Evans 1932; Wynter-Blyth 1957; Sondhi & Kunte 2018). In the western Himalaya, *V. egista sinha* is known to be fairly common in the Garhwal part (Singh & Sondhi 2016). Recently, it has been found distributed westward and southward as far as Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, and Chhattisgarh (Kirti et al. 2016; Sisodia & Naidu 2019; Gokhale 2020; Kumar et al. 2020). It measures 64–70 mm in wing expanse; has tawny wings with characteristic brownish-black markings; forewing shaded with dusky brown near the base, costa, apex and outer margin while hindwing at the base, apex and outer margin; dull-yellow lunules border the outer margins of both wings and a short tail on the hindwing (Bingham 1905).

The early stages of *V. egista sinha* have been illustrated in part from Hong Kong and Malaysia (Johnston & Johnston 1980; Igarashi & Fukuda 1997; Bascombe et al. 1999), although these descriptions do not contain full details of its 1st and 5th instars. The immature stages *V. egista sinha* are reported to feed on *Dillenia* sp. (Dilleniaceae), *Flacourtia* sp., *Homalium* sp., *Xylosma* sp. (all Salicaceae) and *Maytenus* sp. (Celastraceae) (Johnston & Johnston 1980; Igarashi & Fukuda 1997; Bascombe et al. 1999; Vane-Wright & de Jong 2003; Robinson et al. 2010) although there are no specific reports on the early stages or the larval host plants of *V. egista sinha* in India. The early stages of *Vagrans egista propinqua* (Miskin, 1884) are briefly described from Australia (Orr & Kitching 2010; Sankowsky 2020), where it is known to lay eggs mostly on unoccupied spider webs, dead twigs, or dead leaves on and beneath a host

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plant, but not on the fresh foliage (Sankowsky 2014). Although *V. egista sinha* is a fairly common butterfly in its range of distribution, there is a paucity of information pertaining to the early stages and natural history of this subspecies from India. In this paper, attempts have been made to describe all the life history stages of *V. egista sinha* supplemented with images.

Materials and Methods

The eggs were field collected along with the leaves and reared in a closed container at room temperature (25–30 °C). Every day fresh leaves from the host plant were provided to the caterpillars. The larval frass and old remnants of leaves were taken out daily to keep the container clean. The egg, various instars, pupa, and freshly enclosed butterfly were photographed using a DSLR camera and macro lens. Natural history observations were also noted during butterfly watching in Dehradun, Uttarakhand, India.

Results and Observations

Field observations of butterfly behaviour: This butterfly is common in the Wildlife Institute of India Dehradun campus and the entire Dehradun valley. It is generally found to fly fast in open areas along trails, in gardens and forest edges visiting flowers of *Lantana camara* L. It is quite active rarely found resting except when feeding on flower nectar, bird droppings, and moist soil. Observations on the biology of this butterfly are given below.

Oviposition: The butterfly was observed laying eggs on the tender leaves of the host plant *Xylosma longifolia* Clos (Image 1) around the pond in a Sal *Shorea robusta* Gaertn. forest on the Wildlife Institute of India campus on 13 October 2019 at 1155 h (30.2862° N, 77.9744° E; 595 m above mean sea level). *X. longifolia* is an evergreen thorny tree when young; bark is grey-brown; leaves are simple, alternate and glabracent, and the margins are serrated. The eggs were laid singly on the tender leaves.

Eggs: The eggs were pale yellow in colour, dome shaped, and flat at the micropylar end, diameter 0.7–0.8 mm (Image 2). The surface of the eggs was marked with small numerous pits which are somewhat hexagonal around the micropyle and rectangular below.

Emergence of caterpillar: The young caterpillar emerged by eating away part of the eggshell at the micropylar end. This empty eggshell then became the first meal of the newly hatched caterpillar.

1st instar caterpillar: The 1st instar was 2–3 mm in length, pale yellow in colour covered in numerous fine-grey-coloured hairlike bristles (setae) emerging from tubercles over the entire body (Image 3). The thoracic and last abdominal segments turned grey as the caterpillar grew. The head capsule was brown in colour. The caterpillars fed along the margins of the tender leaves, which are typically reddish brown in colour.

2nd instar caterpillar: After moulting, the caterpillar became 4–5 mm long (Image 4a,b). The head capsule was pale yellow in colour with two black spots in the front. The thoracic and abdominal segments were grey except the last few abdominal segments which were reddish in colour. The tubercles were enlarged at the base of the setae and gave rise to three rows of branched processes on each side of the body: one dorso-laterally, one super-spiracularly and one that runs sub-spiracularly. The central axis of these processes was translucent grey in colour with 10–12 small black coloured projections attached at the nodes. A prominent white line runs between the super-spiracular and sub-spiracular processes on both sides.

3rd instar caterpillar: The caterpillar reached a length of 8–10 mm (Image 5). The head capsule and last 1-2 abdominal segments were yellow in colour while other body segments were brown. The dorso-lateral and super-spiracular processes were black in colour while the sub-spiracular process was translucent grey in colour. The processes were branched with 20–22 small black coloured projections at the nodes. The white line became much broader than in the 2nd instar.

4th instar caterpillar: The caterpillar was 18–20 mm in length (Image 6a,b,c). The head capsule was yellow in colour and the last few abdominal segments were pale brown in colour. The processes were longer than in the 3rd instar and much branched. The sub-spiracular processes turned black in colour. The appearance of small white spots was seen over the caterpillar's entire body.

5th instar caterpillar: The 5th instar was similar to the 4th instar but 30–32 mm in length (Image 7a,b) with only the white spots becoming more prominent. All body segments were brown in colour. In the late stage of the 5th instar, the body turned pale green in colour. The tubercles giving rise to the processes were sky blue in colour.

Prepupa: The caterpillar slowly stopped feeding and started wandering around. The length of caterpillar reduced to 25 mm (Image 8a,b). It then stopped on a twig of the host plant kept in the container where it started spinning a silk pad to hang vertically. The immobile prepupa suspended itself upside down from a silk pad. Caterpillars were also seen several times later in the field to pupate on nearby Sal trees.

Pupa: The pupa was 25 mm in length; pale green

Image 1—Female laying eggs on *Xylosma longifolia*. © M.A. Yathumon | Image 2–6—Early stages of *Vagrans egista sinha*: 2—Egg | 3—1st instar caterpillar | 4(a–b)—2nd instar caterpillar | 5—3rd instar caterpillar | 6(a–c)—4th instar caterpillar. © Pranav Gokhale.

in colour with five pairs of red, black-tipped processes running dorso-laterally (Image 9a,b). The second pair of processes from the anterior end was reduced. The base of each process was silver and sky blue coloured. In the late stage, the pupa turned orange in colour, and one day before eclosion (Image 11), the pupal skin turned translucent and the forewing of the pharate butterfly became visible (Image 10a,b).

Conclusion

This paper reports all the early stages of *V. e. sinha* from Dehradun, India. Most of the available published literature on this subspecies' larval host plants traces back to the original work done outside India (Corbet & Pendlebury 1992; Vane-Wright & de Jong 2003; Smetacek 2012; Kirti et al. 2016). The firm evidence of this subspecies using *Xylosma longifolia* as a local host plant in Dehradun, Uttarakhand has been reported in this paper. More work is needed to explore plants from the same or related families to know more about the

Image 7–11—Early stages of Vagrans egista Sinha | 7(a–b)—Early 5th instar caterpillar | 8(a–b)—Prepupa caterpillar | 9(a–b)—Pupa | 10(a–b)—Pupa before eclosion | 11—Eclosed butterfly drying its wings. © Pranav Gokhale.

caterpillars' food preferences. Unlike *V. e. propinqua* from Australia, *V. e. sinha* does not lay eggs on spider webs or off a host plant, but rather uses tender leaves of the host plant. The difference in the egg-laying behaviour (Sankowsky 2014) as well as the morphology of the early stages (Orr & Kitching 2010; Sankowsky 2020) highlights the variation/disparity between these subspecies. The study of a butterfly's juvenile biology across its full distribution range is essential in understanding the current scientific placement of the species.

References

Bascombe, M., F. Bascombe & G. Johnston (1999). *The Butterflies of Hong Kong*. Academic Press, London, 422pp.

Bingham, C.T. (1905). *The fauna of British India including Ceylon and Burma — butterflies. Vol I.* Taylor and Francis, London, 528pp.

Corbet, A.S. & H.M. Pendlebury (1992). *The Butterflies of the Malay Peninsula.* 4th edition revised by Eliot, J.N. Malayan Nature Society, Kuala Lumpur.

D'Abrera, B. (1985). *Butterflies of the Oriental Region, Part II. Nymphalidae, Satyridae & Amathusidae.* Hill House, Melbourne, 534pp.

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

Gokhale, P. (2020). *Vagrans egista* (Cramer, [1780]) – Vagrant. Kunte, K., S. Sondhi, & P. Roy (Chief Editors). *Butterflies of India, v. 2.88. Indian Foundation for Butterflies.*http://www.ifoundbutterflies.org/sp/908/Vagrans-egista. Electronic version accessed 8 July 2020.

Igarashi, S. & H. Fukuda (1997). *The Life Histories of Asian Butterflies. Vol. 1.* Tokai University Press, Tokyo, 572pp.

Johnston, G. & B. Johnston (1980). *This is Hong Kong: Butterflies*. Hong Kong Government Publication, 224pp.

Kirti, J.S., D. Mehra & A.K. Sidhu (2016). *Vagrans egista sinha* (Kollar, 1844) (Lepidoptera: Papilionoidea: Nymphalidae): range extension and an addition to the butterfly fauna of Himachal Pradesh, India. *Check List* 12(4): 1–3.

Kumar, A., S. Kushwaha & A. Namdev (2020). First record of Vagrant *Vagrans egista sinha* from Uttar Pradesh, India. Bugs R All #185, In: *Zoo's Print* 35(4): 12–14.

Orr, A. & R. Kitching (2010). *The Butterflies of Australia*. Allen & Unwin, Crows Nest, 336pp.

Robinson, G.S., P.R. Ackery, I.J. Kitching, G.W. Beccaloni & L.M. Hernández (2010). HOSTS - A Database of the World's Lepidopteran Hostplants. Natural History Museum, London.

Sankowsky, G. (2014). Unusual egg laying strategies of some Lepidoptera. *Metamorphosis Australia* (73): 17–21.

Sankowsky, G. (2020). *Field Guide to Butterflies of Australia*. New Holland Publishers, Sydeny, 400pp.

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

Sisodia, A. & R. Naidu (2019). Extension of the known distribution of the Vagrant butterfly *Vagrans egista* (Cramer, [1780]) (Lepidoptera: Nymphalidae) to Bastar, Chhattisgarh. *BIONOTES* 21(1).

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

Sondhi, S. & K. Kunte (2018). *Butterflies of Uttarakhand – A Field Guide*. Bishen Singh Mahendra Pal Singh (Dehradun), Titli Trust (Dehradun), National Centre for Biological Sciences (Bengaluru), and Indian Foundation for Butterflies (Bengaluru), 310pp.

Vane-Wright, R.I. & R. de Jong (2003). The butterflies of Sulawesi: annotated checklist for a critical island fauna. *Zoologische Verhandelingen* 343: 3–267.

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

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First photographic record of Mishmi Takin *Budorcus taxicolor taxicolor* and Red Goral *Nemorhaedus baileyi* from Kamlang Tiger Reserve, Arunachal Pradesh, India

Cheshta Singh [1] & **Deepti Gupta** [2]

[1] Divisional Forest Officer, Kamlang Tiger Reserve and Wildlife Sanctuary Division, Lohit, Arunachal Pradesh 792102, India.
[2] Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248001, India.
[1] singh.cheshta@gmail.com (corresponding author), [2] rics.deepti@gmail.com

The landscape of northeastern India is a highly diverse and a species-rich area. There are many species which are not systematically surveyed in this region. This has led to a far lesser number of records of species than what are actually present in this region. To overcome this, it is essential to increase the intensity of surveys and their scientific documentation. It will help in increasing the awareness of these species which is essential for saving them from the threats of habitat fragmentation, climatic changes, and risks faced through hunting cases. Over the last two-and-a-half decades, advancements of various noninvasive techniques such as camera trapping has strengthened the sampling procedure and approach to reliable scientific data with reduction of time, efforts, and cost. Camera traps have nowadays become very useful to study cryptic and elusive species.

Kamlang Tiger Reserve (KTR) (Figure 1), situated in southeastern part of Lohit District, Arunachal Pradesh was declared a tiger reserve in 2017. It is surrounded by the Kamlang Reserve Forest to the west and north, un-classed state forest (USF) to the east and Namdapha Tiger Reserve to the south. The total area of KTR is 783 km^2, which includes a core area of 696 km^2 and a buffer area of 87 km^2. Many perennial rivers like Lang, Lathi, Kamlang, Sinabarai, Tawa, and Lai flow from the reserve. Glaw lake is a perennial lake at an altitude of 1,168 m. The major indigenous communities inhabiting this region are the Digaru-Mishmi and Mizu-Mishmi.

The reserve has rugged terrain with an altitudinal gradient of 500–4,500 m. KTR represents one of the bio-diversity hotspots of India, Himalaya, which supports many elusive and rarely sighted mammals, birds, and other taxa. This area lacks systematic scientific surveys mainly due to extremely complex terrain and hence is very less known for its biodiversity. Kaul & Haridasan (1987) have classified forests of Arunachal Pradesh into six categories, viz., tropical, subtropical, temperate, alpine, subalpine, and secondary forest, out of which KTR contains tropical wet evergreen forests, tropical semi-evergreen forests, sub-tropical semi evergreen forests, moist bamboo forests, Himalayan moist temperate forests, and moist alpine scrub forest.

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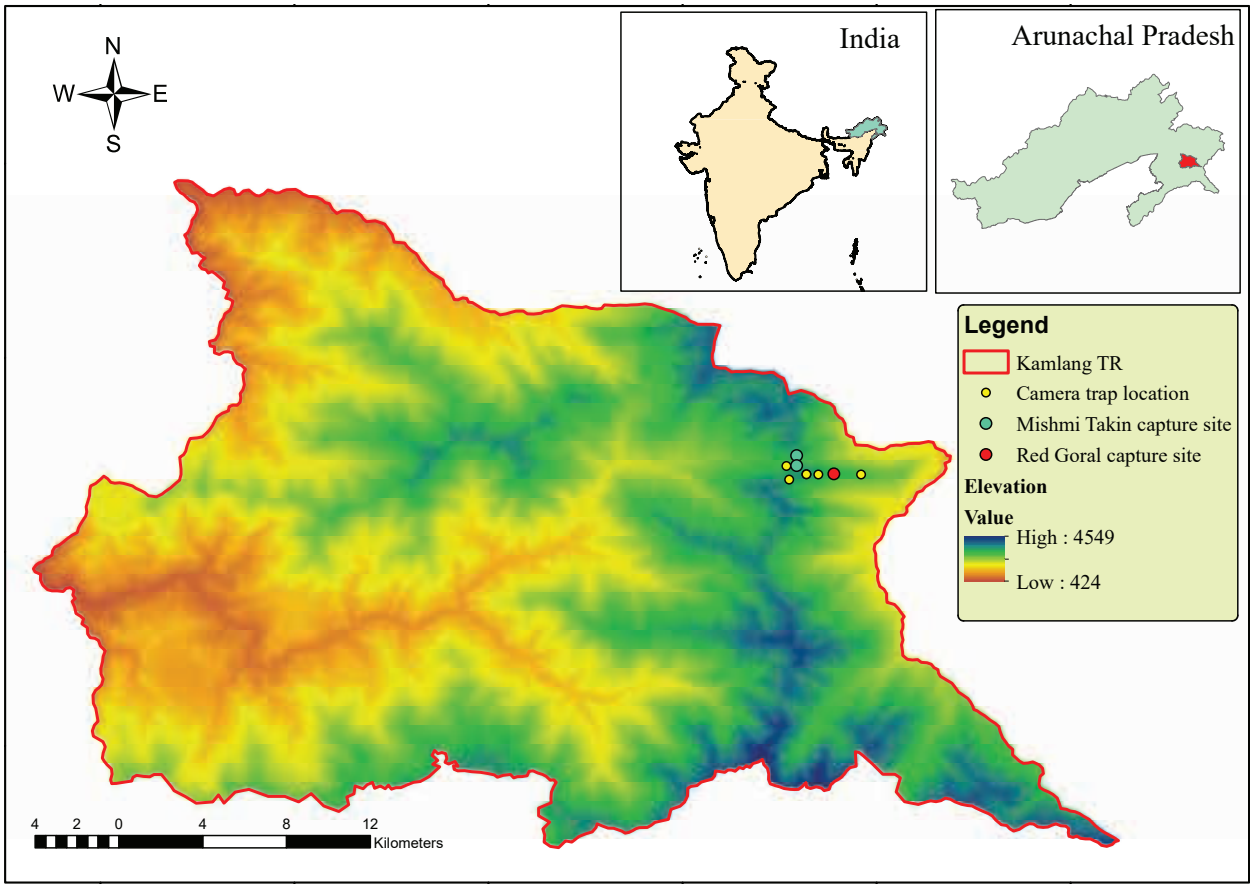

Figure 1. Camera trap locations in Kamlang Tiger Reserve.

A sign survey exercise was carried out for the first time in a particular region of KTR, which falls in Anjaw District, along the northeastern boundary of the reserve. Based on the inputs received from the local people and the results of sign survey, this region seemed to be diversity rich. We therefore carried out a camera trapping exercise for surveying this region. Nine Cuddeback camera traps were deployed over a period of 77 days (Total trap nights= 693), due to limitations of terrain accessibility and suitability of season. We considered a single trap night to be an occasion for example if an individual/group of animals was captured once in 24 hours it was counted as an occasion. We used occasion as a unit to avoid false count from the multiple capture of grazing herbivores. Our trap sites fall in the moist alpine scrub forest type. No camera traps had been previously deployed in this particular region. It was thus selected as a site for camera trap deployment to capture and understand the species that could be found here.

We captured a lesser known ungulate Red Goral *Nemorhaedus baileyi* (Bailey 1912) on two occasions in Anjaw District on a high-altitude ridge area (Image 2). On an occasion, a female was captured with fawn which is a sign of breeding range in the area. Red Goral has been categorized as a Vulnerable species in the IUCN red list with less than 10,000 mature individuals left worldwide. The presence of this species has been reported from Dibang, Changlang (Datta et al. 2008) and Lohit valley (Nijhawan 2020) before but no photographic records have been reported from KTR so far. The Red Goral remains poorly studied due to its narrow geographic range and low population estimates (Singh 2002). This species prefers a forested habitat, meadow, and scrublands with altitudinal range from 2,000 to 4,500 m. We captured its presence at an elevation of 3,410 m. The forest type is mainly sub-alpine in this area. This species continues to face threats due to habitat fragmentation, illegal hunting, and infrastructure developments (Sung et al. 1997) and hence, needs immediate attention for conserving its range. As KTR is being reported its breeding range, conservation practices should be focused in this region.

We also captured another lesser known species Mishmi Takin *Budorcas taxicolor taxicolor* (Image 1), which has been listed as vulnerable in IUCN Red List (Song

Table 1. Details of camera trapping in reference to the species captured during sampling.

	Species	Number of occasions on which species was captured	Total number of captures	Altitude (m)
1	Red Goral	2	8	3410
2	Mishmi Takins	16	165	3470
3	Barking Deer	1	1	3215
4	Yellow-throated Marten	7	8	3432
5	Hoary-bellied Squirrel	3	7	3248

Image 1. Mishmi Takin *Budorcas taxicolor taxicolor* captured in a camera trap.

Image 2. Red Goral *Nemorhaedus baileyi* (female) captured in a camera trap.

et al. 2008). It is distributed at the northeastern tip of India, however, precise geographic distribution in India is less known. It has been sighted and photographed by Singh (2002) and genome was sequenced using carcass tissue sample collected from Dibang Valley by Kumar et al. (2019). We captured 165 photographs on 16 trap occasions at an altitude of 3,470 m. Mishmi Takin was captured as solitary, as a group of two individuals and a group of three individual including a calf. Though this species is a group living animal, our solitary records may

be because of camera placements. We recorded species presence mostly from the Himalayan moist temperate forest. Its population trend is decreasing mainly because of hunting for bushmeat consumptions and habitat destructions (Wang et al. 2005) and considered rare in this region. Our findings represent KTR as an important breeding site for this species and demands more attention on this area for conservation efforts.

Apart from this, we captured Barking Deer *Muntiacus muntjak*, Yellow-throated Marten *Martes flavigula* and Hoary-bellied Squirrel *Callosciurus pygerythrus* from the camera traps deployed in this region of KTR (Table 1).

This document assembles a baseline by presenting photographic information on the presence of rare and elusive mammals present in the area. Eastern Himalaya are a great source of biodiversity but are extremely sensitive to climatic changes (Chettri et al. 2009). KTR is mostly inviolate due to inaccessibility and negligible biotic pressure. This protected area together with Namdapha National Park and Kamlang reserve forests forms a landscape for the conservation of large cats like Bengal Tiger, Common & Clouded Leopards, various mountain ungulates and other small mammals. Immediate conservation steps must be taken with necessary supply of resources in order to protect such remaining patches of habitats along with strict enforcement of ban on hunting. Population monitoring studies that provide strong scientific basis should be encouraged for effective conservation strategies.

References

Bailey, F.M. (1912). Journey through a portion of south-eastern Tibet and the Mishmi Hills. *The Geographical Journal* 39(4): 334. https://doi.org/10.2307/1778662

Chettri, N., M. Eriksson, F. Jing, P.K. Mool, E. Sharma, A.B. Shrestha & K. Tse-ring (2009). Climate Change Impacts and Vulnerability in the Eastern Himalayas. International Centre for Integrated Mountain Development (ICIMOD).

Datta, A., M.O. Anand & R. Naniwadekar (2008). Empty forests: large carnivore and prey abundance in Namdapha National Park, north-east India. *Biological Conservation* 141(5): 1429–1435. https://doi.org/10.1016/j.biocon.2008.02.022

Kaul, R.N. & K. Haridasan (1987). Forest types of Arunachal Pradesh-A preliminary study. *Journal of Economic and Taxonomic Botany* 9(2): 379–389.

Kumar, A., K.B. Gautam, B. Singh, P. Yadav, G.V. Gopi & S.K. Gupta (2019). Sequencing and characterization of the complete mitochondrial genome of Mishmi takin (Budorcas taxicolor taxicolor) and comparison with the other Caprinae species. *International Journal of Biological Macromolecules* 137: 87–94. https://doi.org/10.1016/j.ijbiomac.2019.06.201

Nijhawan, S. (2020). *Naemorhedus baileyi* (amended version of 2020 assessment). The IUCN Red List of Threatened Species 2020: e.T14294A179947455. Downloaded on 5 Jan 2021. https://doi.org/10.2305/IUCN.UK.2020-3.RLTS.T14294A179947455.en

Singh, D.N. (2002). Status and distribution of mountain ungulates in Arunachal Pradesh pp. 44–49. In: Sathyakumar, S. & Y. V. Bhatnagar (eds.). *Mountain Ungulates. ENVIS Bulletin: Wildlife and Protected Areas.* Wildlife Institute of India, Dehradun, 141pp.

Song, Y.-L., A.T. Smith & J. MacKinnon (2008). *Budorcas taxicolor*. The IUCN Red List of Threatened Species 2008: e.T3160A9643719. Downloaded on 5 Jan 2021. https://doi.org/10.2305/IUCN.UK.2008.RLTS.T3160A9643719.en

Sung, W., G. Jinhe, H. Defu, N. Luo, Z. Yongzu, W. Zongyi, Y. Rongsheng & C. Guiquan (1997). China pp. 148–172. In: Shackleton, M. (ed.). *Wild Sheep and Goats and their Relatives. Status Survey and Conservation Action Plan for Caprinae*. IUCN, Gland, Switzerland and Cambridge, UK.

Wang, X.Z., Y.L. Song, Z.G. Zeng, H.S. Gong & N.X. Zhao (2005). Characteristics of birth-site and early mother-infant relationship of the golden takin Budorcas taxicolor bedfordi. *Acta Zoologica Sinica* 51(4): 748–752.

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Utilisation of honey trap method to ensnare a dispersing sub-adult Bengal Tiger *Panthera tigris tigris* L. in a human dominated landscape

Gobind Sagar Bhardwaj [1], Balaji Kari [2] & Arvind Mathur [3]

[1] Rajasthan State Pollution Control Board, Institutional Area, Jhalana dungri, Jaipur, Rajasthan 302004, India.
[2] Udaipur North, Gulabh Bagh, Udaipur, Rajasthan 313001, India.
[3] Zoo, Ramniwas Bagh, Jaipur, Rajasthan 302004, India.
[1] gobindsagarbhardwaj@gmail.com (corresponding author), [2] balaji.kari1@gmail.com, [3] drarvindmathur69@gmail.com

Young tigers, as in all felids, typically disperse from their natal territory to find new areas to settle (Karanth 2001; Goodrich et al. 2010). In doing so they may encounter settlements and villages where the potential for cattle lifting exists. Here we present a case study of a sub-adult tiger in Sariska who had dispersed out of his natal territory into a human dominated landscape, and a novel technique was used to lure and trap him and release him back into a different site in Sariska where he settled down and fathered cubs.

Sariska Tiger Reserve (STR) is located in the Aravalli hill range and lies in the semi-arid biogeographic zone of Rajasthan (Rodgers & Panwar 1988). Covering an area of 1,213 km², the terrain of the landscape is undulating to hilly with large to narrow valleys, two large plateaus called Kiraska and Kankwari with large lakes, Silised, Mansarovar, & Somasagar are located in the reserve. The maximum altitude of Sariska is 777m. The vegetation of STR is tropical dry deciduous forests (Champion & Seth 1968). Earlier the local people had killed all the tigers in Sariska. Therefore this reserve is a dangerous place for tigers, due to adversarial attitudes of the local population.

For localizing the straying tiger, urine and feces of a tigress was collected from Nahargarh Zoological Park, Jaipur, for 10 days in the middle of June 2017. The 11-year old tigress had been observed to be in estrous, frequently vocalizing, growling, scent marking and other signs that she was ready to mate. For the collection of urine, a small layer of sterilized absorbent cotton ball embankment (2 inches) was made across the slope in the shelter where she rested. The urine was squeezed into a sterile 500 ml bottle and with the help of sterile syringes. This exercise was repeated for 10 days resulting in the collection of approximately 1 liter of urine. It was diluted to five litres by adding normal saline solution. Feces of the same tigress was mixed in the urine.

A track, observed to be continuously used by livestock, villagers, and by the male subadult tiger named ST13 was selected. A dummy trail was made by spraying a mixture of urine and feces using a spray pump at prominent points like large boulders lying along the track or at the trunks of large trees leading to an open area where ST13 could be darted. The immobilization team with Dan-inject syringe projector and necessary equipment was kept in a sheltered area. Within 30 hours of creating the dummy trail, ST13 came out into the open and was immobilized with 3.2–3.5 of ml of mixture

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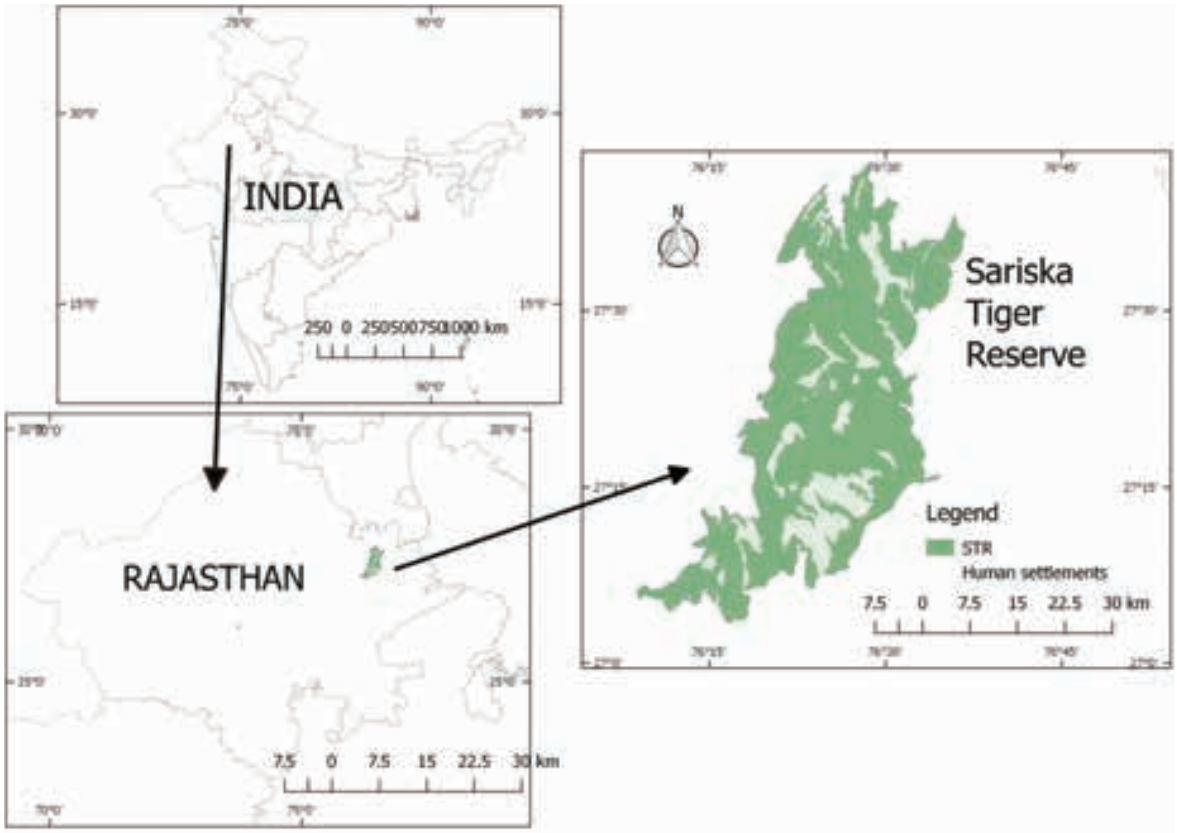

Figure 1. Map showing location of study area, Sariska Tiger Reserve.

Table 1. Table showing the area of occupancy (MCP) of ST13 during (pre-MI) and post-MI period.

Months	Area of occupancy (MCP) during pre-MI in km²	Months	Area of occupancy (MCP) during post-MI in km²
Aug 16	4.71*	Jul 17	174.09
Sep 16	5.23*	Aug 17	63.41
Oct 16	87.53	Sep 17	44.79
Nov 16	687.58	Oct 17	39.55
Dec 16	556.34	Nov 17	35.53
Jan 17	52.27	Dec 17	32.89
Feb 17	9.49	Jan 18	77.79
Mar 17	3.6	Feb 18	26.12
Apr 17	87.99	Mar 18	81.31
May 17	120.96	Apr 18	67.86
Jun 17	51.18**	May 18	121.73
		Jun 18	78.08
		Jul 18	73.11
		Aug18	57.96
Mean	166.2		69.6
SE	5.7		1.2

MCP—minimum convex polygon | pre-MI—pre-managerial intervention | post-MI—post managerial intervention | *—the time period when ST13 is in its natal area | **—the month of managerial intervention.

of Xylazine and Ketamine (500 mg + 400 mg, HBM). The transportation cage weighing 250 kg with dimensions (length 1.8m, breadth 1m and height 1.2m) fabricated with non-slip wooden planks at the bottom and angle iron frames on sides and top (Shankar et al. 2010) was used to transport him. ST13 was relocated on June 26, 2017 to an enclosure located in his natal area to follow a soft-release protocol. The translocated tiger (now radio-collared) was kept in a soft enclosure in Karnakawas beat for 24 hours. He was subsequently released in the same area by opening the gate of the enclosure on June 28, 2017. He was then monitored by a team of two persons until the end of 2018.

It was observed that after a small period of wandering in different areas, ST13 finally settled in the Talvriksh Range of the reserve. Table 1 shows the area occupancy of ST13 during post managerial intervention (post-MI). The tiger settled in the northern portion of CTH in Talvriksh Range of Sariska. The overlapping of its home range with those of female tigresses ST12 and ST10 resulted in siring of six cubs from ST12 in two subsequent litters of three each in 2018 and 2020; and one cub from ST10 in 2020, a net increase of seven tigers in STR. This is a case study of using a 'honey trap' to

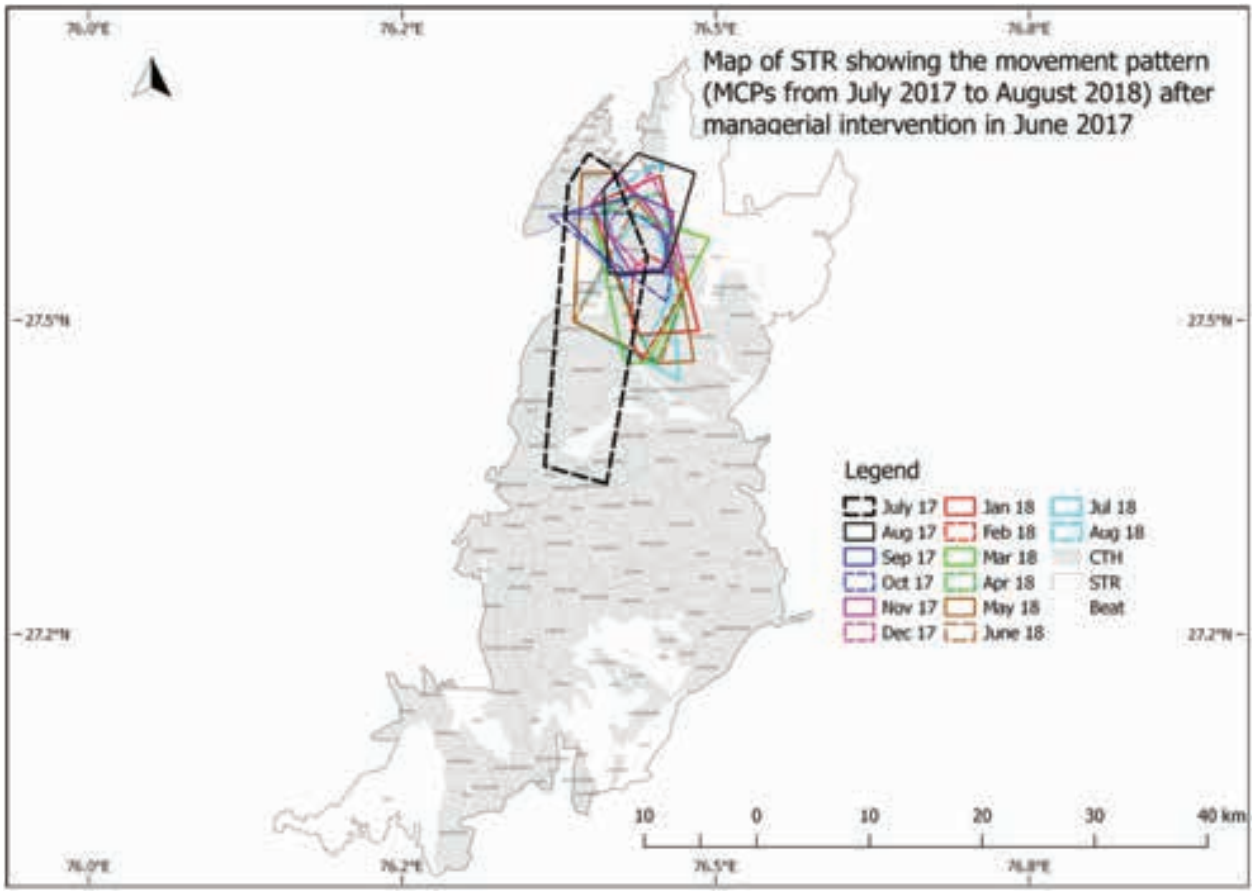

Figure 2. Map of Sariska Tiger Reserve showing the movement pattern of tiger ST13 (MCPs from July 2017 to June 2018).

successfully relocate a dispersing sub-adult tiger from a human dominated area to a section of the reserve.

References

Champion, H.G. & H.K. Seth (1968). *A revised survey of the forest type of India*. Government of India Press, Delhi, 404 pp.

Goodrich, J.M., D.G. Miquelle, E.N. Smirnov, L.L Kerley, H.B. Quigley & M.G. Hornocker (2010). Spatial structure of Amur (Siberian) Tigers (*Panthera tigris altaica*) on Sikhote–Alin Biosphere Zapovednik, Russia. *Journal of Mammalogy* 91(3): 737–748.

Karanth, K.U. (2001). *The Way of theTtiger*: *National History and Conservation of the Endangered Big Cat*. Hyderabad, India, 132pp.

Rodgers, W.A. & H.S. Panwar (1988). Planning wildlife protected area network in India Vol. I & II Wildlife Institute of Dehradun.

Sankar, K., Q. Qureshi, P. Nigam, P.K. Malik, P.R. Sinha, R.N. Mehrotra, R. Gopal, S. Bhattacharjee, K. Mondal & S. Gupta (2010). Monitoring of reintroduced tigers in Sariska Tiger Reserve, western India: preliminary findings on home range, prey selection and food habits. *Journal of Tropical Conservation Science* 3(3): 301–318.

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NOTE

First camera trap photographs of Indian Pangolin *Manis crassicaudata* (Mammalia: Pholidota: Manidae) from Pakistan

Misbah Bint Riaz [1], Faraz Akrim [2], Siddiqa Qasim [3], Syed Afaq Bukhari [4], Asad Aslam [5], Muhammad Waseem [6], Rizwana Imtiaz [7] & Tariq Mahmood [8]

[1,3,8] Department of Wildlife Management, PMAS Arid Agriculture University Rawalpindi 46300 Pakistan.
[2,4,5] Zoology Department, University of Kotli, Azad Jammu & Kashmir, Pakistan.
[6] WWF Pakistan, Ground Floor, Pakistan Academy of Sciences Building, Constitution Avenue, G-5, Islamabad, Pakistan.
[7] Punjab Wildlife and Parks Department, Loi Bher office Rawalpindi, Pakistan.
[1] misbahriaz750@gmail.com, [2] faraz.akrim@uokajk.edu.pk, [3] sqasim@gmail.com, [4] mafaq@hotmail.com, [5] asada@gmail.com, [6] mwaseem@wwf.org.pk, [7] rizwanazix@gmail.com, [8] tariqjanjua75@uaar.edu.pk (corresponding author)

The Indian Pangolin *Manis crassicaudata* is categorized as 'Endangered' by IUCN and also listed in the Appendix-I of the Convention on International Trade in Endangered Species of wild fauna and Flora (CITES) (Mahmood et al. 2019). The species is distributed across five range countries including Pakistan, India, Nepal, Sri Lanka, and Bangladesh (although its occurrence in Bangladesh is not confirmed by field evidence). The species population is declining across its range due to poaching and illegal killing for its scales which are traded in the international markets for making traditional medicines.

In Pakistan, the Indian Pangolin has been focused for ecological studies like its distribution, habitat, population density, and food habits (Akrim et al. 2017; Irshad et al. 2015; Mahmood et al. 2012, 2014, 2016, 2019; Waseem et al. 2020a,b) for last one decade, but no previous records exist for camera trapping of the species.

In the current study, we have camera trapped Indian Pangolin in the country providing very first camera trap photographs of the species from Pakistan. The species has been camera trapped from two sampling sites; one from Pothwar Plateau (Kallar Syedan site 33.465N & 73.409E, Rawalpindi District) and the other from Rolli Hills (33.486N & 73.902E), surrounding the University of Kotli (Image 1), Azad Jammu & Kashmir. For this purpose, we installed eight camera trap stations from January 2021 till June 2021. We collected a total of 131 pictures of Indian Pangolin from Kallar Syedan site and 25 pictures of the species from Rolli Hills site surrounding University of Kotli AJ&K (Image 2). At Kallar Syedan site we confirmed two pangolins (Image 3) (one male and one female) while the female being pregnant and gave birth (direct field observation) to a baby in the month of April.

References

Akrim, F., T. Mahmood, R. Hussain, S. Qasim & I.U. Zangi (2017). Distribution pattern, population estimation and threats to the Indian Pangolin Manis crassicaudata (Mammalia: Pholidota: Manidae) in and around Pir Lasura National Park, Azad Jammu & Kashmir,

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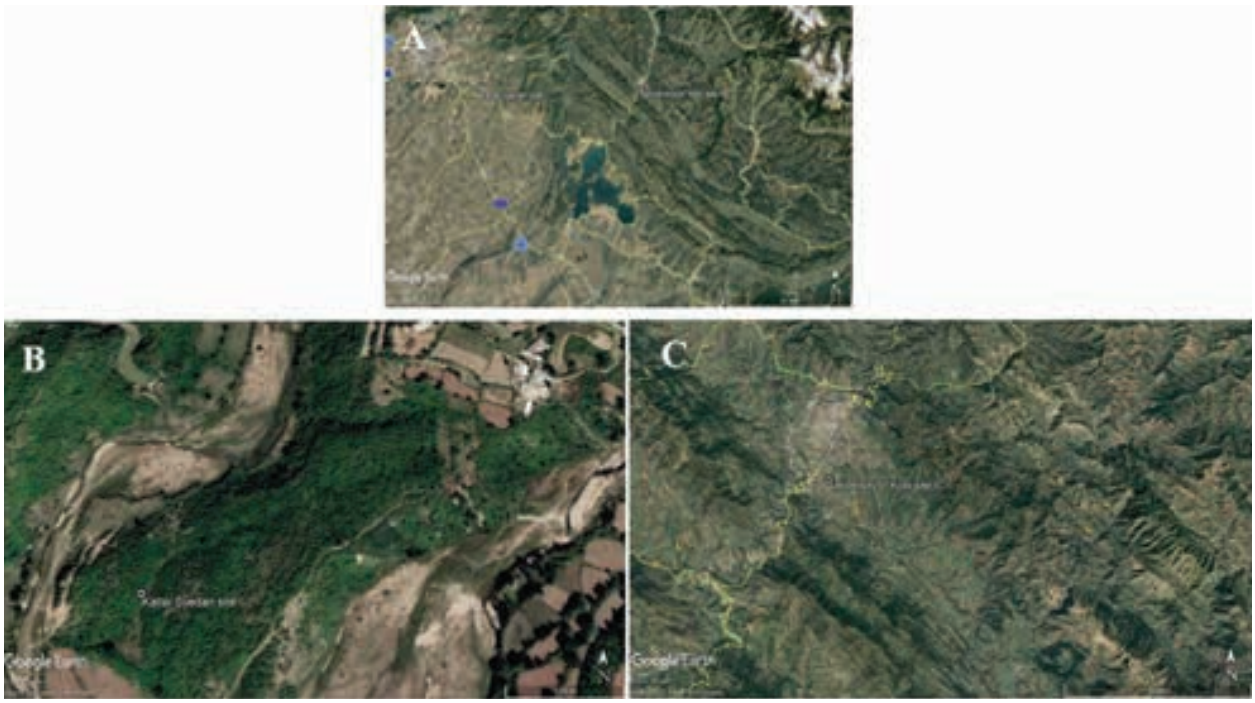

Image 1. A—Google earth map of the two sampling sites | B—Kallar Syedan site, Rawalpindi District | C—Rolli Hills University of Kotli AJ&K site.

Image 2. Camera trap photographs of the Indian Pangolin *Manis crassicaudata*. A&B—from Rolli Hills site, near University of Kotli | C&D—Kallar Syedan site Rawalpindi District.

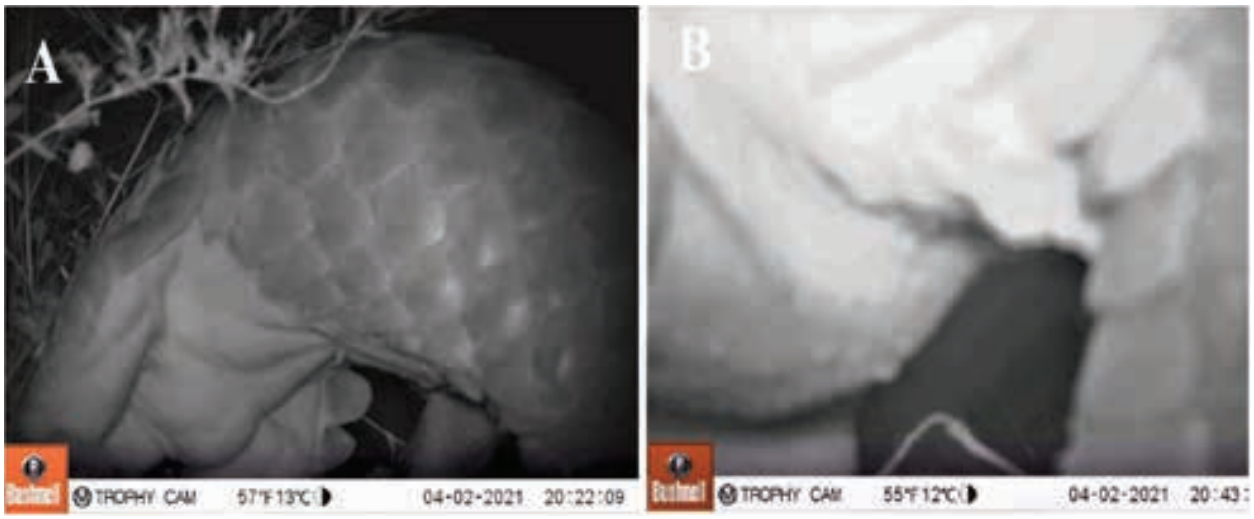

Image 3. A—camera trapped photograph of a male Indian Pangolin from Kallar Syedan site | B—a female Indian Pangolin.

Pakistan. *Journal of Threatened Taxa* 9(3): 9920–9927. https://doi.org/10.11609/jott.2914.9.3.9920-9927

Irshad, N., T. Mahmood, R. Hussain, & M. S. Nadeem (2015). Distribution, abundance and diet of the Indian Pangolin (*Manis crassicaudata*). *Animal Biology* 65(1): 57–71. https://doi.org/10.1163/15707563-00002462

Mahmood, T., F. Akrim, N. Irshad, R. Hussain, H. Fatima, S. Andleeb & A. Aihetasham (2019). Distribution and illegal killing of the Endangered Indian Pangolin *Manis crassicaudata* on the Potohar Plateau, Pakistan. *Oryx* 53(1): 159–164.

Mahmood, T., R. Hussain, N. Irshad, F. Akrim, & M.S. Nadeem (2012). Illegal mass killing of Indian Pangolin (*Manis crassicaudata*) in Potohar region, Pakistan. *Pakistan Journal of Zoology* 44(5): 1457–1461.

Mahmood, T., N. Irshad & R. Hussain (2014). Habitat preference and population estimates of Indian Pangolin (*Manis crassicaudata*) in district Chakwal of Potohar Plateau, Pakistan. *Russian Journal of Ecology* 45(1): 70–75. https://doi.org/10.1134/S1067413614010081

Mahmood, T., N. Irshad, R. Hussain, F. Akrim, I. Hussain, M. Anwar, M. Rais & M.S. Nadeem (2016). Breeding habits of the Indian Pangolin (*Manis crassicaudata*) in Potohar Plateau, Pakistan. *Mammalia* 80(2): 231–234. https://doi.org/10.1515/mammalia-2014-0153

Mahmood, T., R.K. Mohapatra, P. Perera, N. Irshad, F. Akrim, S. Andleeb, M. Waseem, S. Sharma & S. Panda (2019). Indian Pangolin *Manis crassicaudata* (Geoffroy, 1803), pp. 71–88. In: Challender, D.W.S., H.C. Nash & C. Waterman (eds.). Pangolins: Science, Society and Conservation. Elsevier, 658pp. https://doi.org/10.1016/B978-0-12-815507-3.00005-8

Waseem, M., B. Khan, T. Mahmood, H.S. Hussain, R. Aziz, F. Akrim, T. Ahmad, R. Nazir & M.N. Awan (2020a). Occupancy, habitat suitability and habitat preference of endangered Indian Pangolin (*Manis crassicaudata*) in Potohar Plateau and Azad Jammu and Kashmir, Pakistan. *Global Ecology and Conservation* 23: e01135. https://doi.org/10.1016/j.gecco.2020.e01135

Waseem, M., A. Raza, H. Aisha, M.N. Awan, T. Ahmad, R. Nazir & T. Mahmood (2020b). Scale of illegal killing and trade associated with Indian Pangolin (*Manis crassicaudata*) in Pakistan. *Pakistan Journal of Zoology* 52(1): 69–77. https://doi.org/10.17582/journal.pjz/2020.52.1.69.77

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Photographic record of Lesser Flamingo *Phoeniconaias minor* (Aves: Phoenicopteridae) in Ramganga river, Bareilly, India

Pichaimuthu Gangaiamaran [1], Aftab A. Usmani [2], G.V. Gopi [3], S.A. Hussain [4] & Khursid A. Khan [5]

[1–5] Wildlife Institute of India, Post Box No. 18 Chandrabani, 248001, Dehradun, Uttarakahnd, India
[1] bnhsgangai@gmail.com, [2] aftab.a.usmani@gmail.com, [3] gopigv@wii.gov.in, [4] hussain@wii.gov.in,
[5] khursid.amu@gmail.com (corresponding author)

India is one of the mega biodiversity countries consisting of 12.5% of the total avian diversity (Praveen et al. 2016). A total of 1,317 species of birds have been documented in India with high endemism (Praveen et al. 2020). The Phoenicopteridae family consists of six species of flamingos found worldwide and India possesses two of them, i.e., Lesser Flamingo *Phoeniconaias minor* and Greater Flamingo *Phoenicopterus roseus* (Jadhav & Parasharya 2004). The Lesser Flamingo is one of the smallest flamingo species distributed in eastern, southern, and western Africa, as well as in Pakistan and northwestern India (Zimmerman et al. 1996). In India, the breeding population is confined to the Little Rann of Kachchh in Gujarat, while nonbreeding, the population has restricted distribution and is mainly found along the western coast of the country in the state of Gujarat & Maharashtra (Tere 2008; Rameshchandra 2014) (Figure 1). The Lesser Flamingo can be differentiated from the Greater Flamingo based on smaller size, shorter leg & neck, smaller bill, prominent kinked, and dark red facial skin (Grimmett et al. 2011). It is one of the world's most numerous flamingoes estimated at one million individual birds throughout the world and classified as 'Near Threatened' by the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2020). It is also listed in the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) Action Plan (Childress et al. 2008). The Bonn Convention (CMS) and Convention on International Trade in Endangered Species (CITES) have enlisted this species in Appendix II, while it has been listed in Scheduled IV in Indian Wildlife (Protection) Act, 1972 (Tere 2008; Rameshchnadra 2014).

The Lesser Flamingo has been reported from Sewri mudflats and Thane Creek (Mumbai) (Vijayan et al. 2011; Nachane et al. 2014), Thol Lake Gujarat, Nalabana Bird Sanctuary in Chilika Lake Odisha (Balachandran et al. 2009), and several other coastal and inland freshwater wetlands in Gujarat (Jadhav & Parasharya 2004). Furthermore, all the recorded sightings of Lesser Flamingo indicate its northernmost distribution in Gurugram, Haryana, and National Chambal Sanctuary which seems to be approximately 248 km and 200 km far away from the current sighting (Figure 2). Its distribution in northern India is scarce and even the vagrant individuals have never been sighted in northern Uttar Pradesh and Uttarakhand. We have recorded a vagrant juvenile of Lesser Flamingo

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Competing interests: The authors declare no competing interests.

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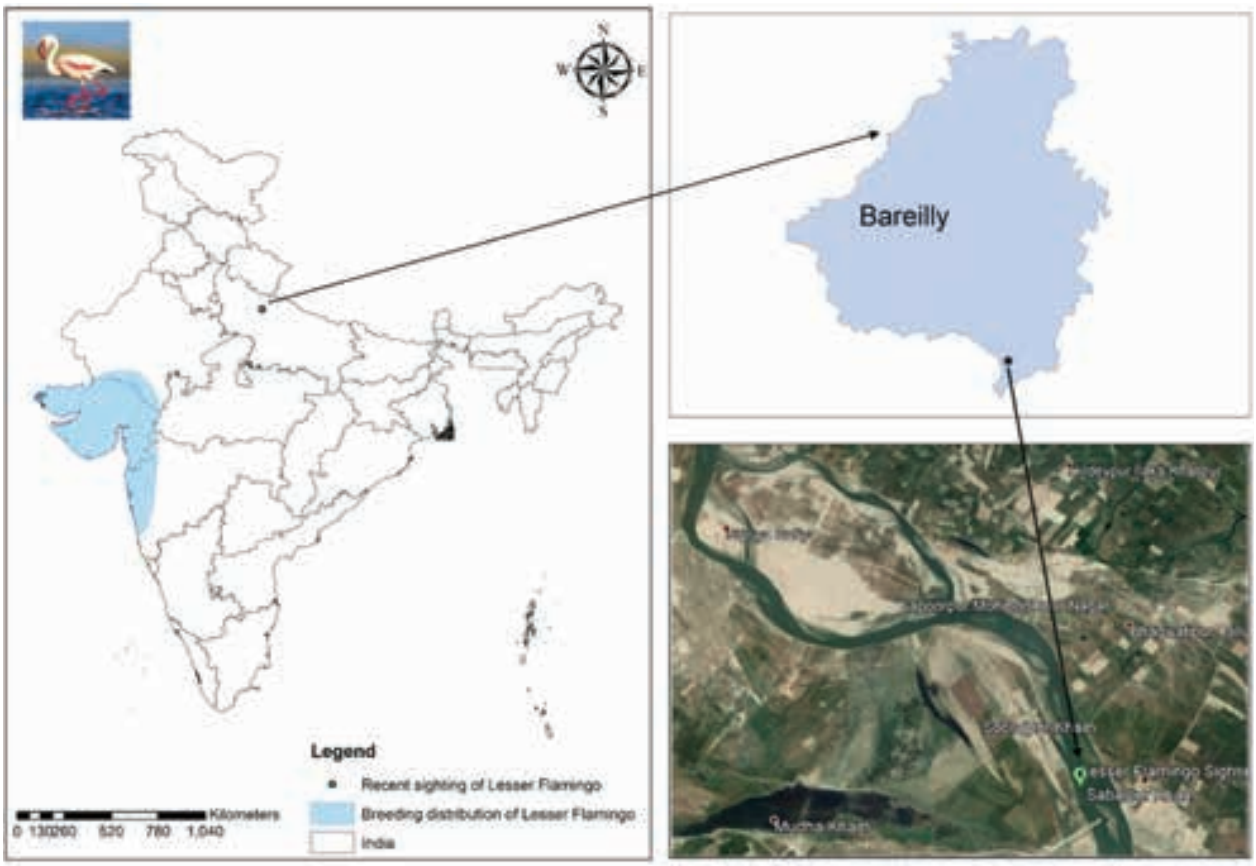

Figure 1. Breeding distribution of Lesser Flamingo and recent sighting in river Ramganga, Bareilly, Uttar Pradesh, India

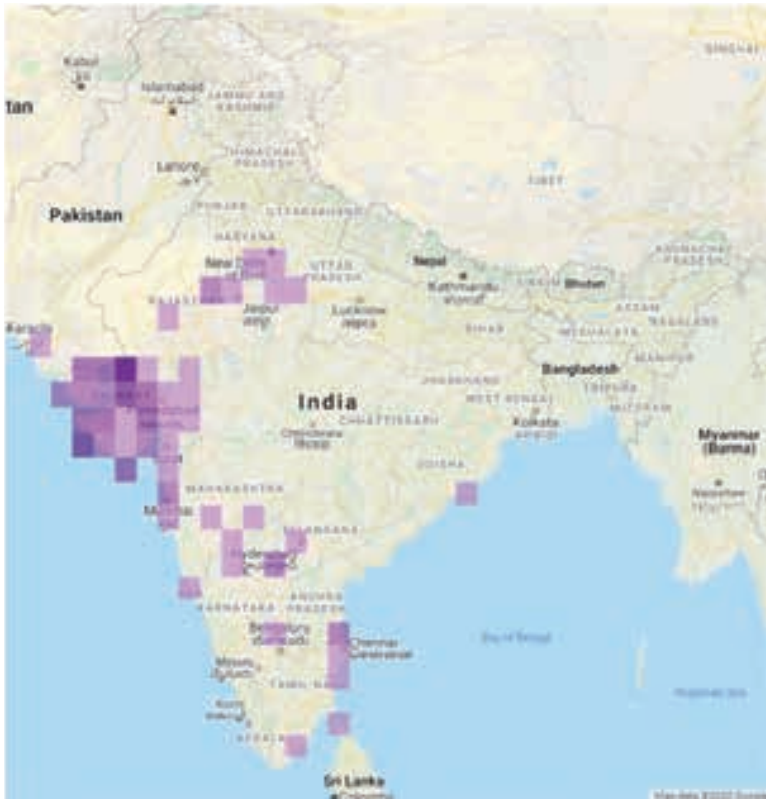

Figure 2. Sightings of Lesser Flamingo in India (ebird.com 2020).

Image 1–2. Lesser Flamingo feeding on shallow water in Ranganga River, Bareilly, Uttar Pradesh, India. © P. Gangaiamaran

Image 3. Lesser Flamingo in flight recorded at Ramganga River, Bareilly, Uttar Pradesh, India. © P. Gangaiamaran

feeding on shallow water on 24 February 2020 in river Ramganga near Kadarganj (28.1484°N, 79.466°E), Bareilly, Uttar Pradesh (Image 1–3) during the biodiversity survey of river Ramganaga. This survey was a part of biodiversity rejuvenation in River Ganges under the auspices of the National Mission for Clean Ganga. This record is one of the northernmost distribution known for the Lesser Flamingos in India.

The Lesser Flamingo is an itinerant species adapted to respond to changes in local environmental conditions by moving across a network of suitable wetland sites (Childress et al. 2007). Despite being numerous, the major threats the Lesser Flamingos face include predation pressure from medium-sized carnivores like Jackals & Hyenas and some birds, especially storks and eagles, which prey upon their young and eggs. Furthermore, the anthropogenic activities and infrastructure development in and around their distribution & nesting sites, flooding in their natural habitat, drought, and toxic load on the wetlands make them vulnerable to local extinction from the distribution ranges.

References

Balachandran, S., P. Sathiyaselvam & S. Panda (2009). *Bird atlas of Chilika*. *1st ed.* Bombay Natural History Society, Mumbai and Chilika Development Authority, Bhubaneshwar, 326 pp.

Childress, B., B. Hughes, D. Harper & W. van den Bossche (2007). East African flyway and key site network of the Lesser Flamingo (*Phoenicopterus minor*) documented through satellite tracking. *Ostrich* 78: 463–468.

Childress, B., S. Nagy & B. Hughes (Compilers) (2008). International Single Species Action Plan for the Conservation of the Lesser Flamingo (*Phoeniconaias minor*). CMS Technical Series No. 18, AEWA Technical Series No. 34. Bonn, Germany, 61pp.

ebird.com (2020). https://ebird.org/species/lesfla1 assessed on 02 May 2020.

Grimmett, R., C. Inskipp & T. Inskipp (2011). *Birds of the Indian Subcontinent. 2nd Edition.* Oxford University Press. New Delhi, India, 448pp.

IUCN (2020). https://www.iucnredlist.org/species/22697369/93611130. Accessed on 02 May 2020.

Jadhav, A. & B.M. Parasharya (2004). Counts of flamingos at some sites in Gujarat State, India. Waterbirds, 27(2): 141–146.

Nachane, A., A. Patil, S. More, P. Salunke & M. Indap (2014). A baseline study of habitat and abundance of Lesser Flamingo (*Phoeniconaias minor*) in sewri mudflats, Mumbai, India. Proceedings of the National Conference on Modern Trends in Zoological Research. Department of Zoology, St.Aloysius College, Elthuruth 25–26 March 2014.

Praveen, J., R. Jayapal & A. Pittie (2016). A checklist of the birds of India. *Indian BIRDS* 11 (5&6): 113–172.

Praveen, J., R. Jayapal, A. Pittie, V. Shankar, P. Gokhale & K. Kunte (2020). *Classification of Indian Birds*. In: Satose, V., V. Ramachandran, P. Roy & K. Kunte (chief editors). Birds of India, v. 2.14. Indian Foundation for Butterflies. Accessed on 05 May 2020.

Rameshchandra V.V. (2014). Studies on Lesser Flamingo *Phoeniconaias minor* with special reference to ecology threats and conservation management. Ph.D. Thesis. Maharaja Sayajirao University of Baroda, 213 pp.

Tere, A. (2008). Ecology of Greater Flamingo *Phoenicopterus roseus* and Lesser Flamingo *Phoenicopterus minor* on the wetlands of Gujarat. Ph.D. Thesis. Maharaja Sayajirao University of Baroda, 193 pp.

Vijayan, L., S. Somasundaram, A.P. Zaibin & B. Nandan (2011). Population and habitat of the Lesser Flamingo *Phoeniconaias minor* in Thane Creek, Mumbai, India. *Flamingo* 18: 58–61.

Zimmerman, D.A., D.A. Turner, D.J. Pearson, I. Willis & H.D. Pratt (1996). *Birds of Kenya and Northern Tanzania*. Princeton University Press, Princeton, USA, 576pp.

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Total length and head length relationship in Mugger Crocodiles *Crocodylus palustris* (Reptilia: Crocodilia: Crocodylidae) in Iran

Asghar Mobaraki [1], Elham Abtin [2], Malihe Erfani [3] & Colin Stevenson [4]

[1] Natural Environment Deputy, Wildlife Conservation and Management Bureau, Department of Environment, Tehran, Iran.
[2] Natural Environment Division, Department of Environment Office in Sistsan and Baluchestan Province, Zahedan, Iran.
[3] Department of Environmental Sciences, Faculty of Natural Resources, University of Zabol, Zabol, Iran.
[4] Crocodiles of the World, Burford Road, Brize Norton, Oxfordshire, OX18 3NX, UK.
[1] amobaraki@yahoo.com, [2] ala_saly@yahoo.co.uk, [3] maliheerfani@uoz.ac.ir (corresponding author), [4] coleosuchus@hotmail.com

A small population of around 500 Mugger crocodiles *Crocodylus palustris* in southeastern Iran occupies the western-most extreme of the species' global range (de Silva & Lenin 2010). This population is scattered across the region and individuals often come into close contact with local communities (Mobaraki 2015). The Mugger's habit of moving between different habitats depending on local climatic and seasonal conditions means that they often turn up in remote areas (Abtin & Mobaraki 2016). Because this population persists at the extreme edge of the species distribution, environmental limits or conditions are likely to affect its biology and population dynamics, as well as its susceptibility to potential threats (Mobaraki et al. 2019).

Like many other crocodilians around the world, monitoring of the *C. palustris* population in Iran has been based on day and night-time (spotlight) surveys. During surveys, crocodiles are usually partly submerged, with only the head exposed to observers. Where observers have considerable experience with carrying out surveys and capturing large numbers of different-sized crocodiles, estimating body length from size of the head comes somewhat naturally (C. Manolis, pers. comm. 2021). However, this is not the case in many situations, including that in Iran.

Researchers working on morphometric relationships of different species of crocodilians have invariably noted that head length (HL) relative to total length (TL) tends to change little across size classes (e.g., Webb & Messel 1978; Magnusson 1983; Webb et al. 1983; Montague 1984; Hutton 1987; Verdade 2000; Wu et al. 2006; Platt et al. 2011; Fukuda et al. 2013; Edwards et al. 2017). Whitaker & Whitaker (2008) examined the HL/TL ratio for a number of crocodilian species, and confirmed the average ratio to be around 1:7, but this ratio was found to be closer to 1:8 for large (>4 m TL) species such as *Crocodylus porosus*, due to ontogenic changes associated with the head with increasing body size (Webb & Messel 1978; Whitaker & Whitaker 2008; Britton et al. 2012; Fukuda et al. 2013). In this study, we aim to quantify the relationship between TL and HL for Iranian Muggers, as well as examining the ratio between these two morphometric measures.

Material and Methods: Natural and artificial ponds are

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the main Mugger habitats along or near the Bahoukalat River, the main part of which runs within the Gandou Protected Area. This area comprises 3,825km^2 (61.462E and 25.755N at central part), and was established in 1970 for the conservation of the crocodile population. Fifty-three Mugger crocodiles of varying sizes and sex were captured using fishing nets or ropes, during surveys or the translocation of nuisance specimens, in 2018 and 2019. Head length (HL) was measured from the anterior tip of the snout to the rear edge of the cranial platform (parietal bone). Total length (TL) was measured from the anterior tip of the snout to posterior tip of the tail along the back of the animal. Both measurements were taken using fiberglass tape, and the results rounded to the nearest cm. We excluded any specimens that were missing the tip of their tail. Sex was determined for 30 individual by examination of the cliteropenis, but as this sample size was considered small, the effect of sex was not examined further.

Statistical methods: The measurements were first tested for normality using Shapiro-Wilk (SW) and Kolmogorov-Smirnov (KS) tests. Linear regression analysis was used to examine the relationship between TL and HL, and between the TL/HL ratio and body size (TL and HL).

Results: Total length of the 53 Mugger crocodiles varied from 43 to 280 cm (average ± SD: 169 cm ± 63.7), and head length from 6 to 45 cm (average ± SD: 24.4 cm ± 9.93). Shapiro-Wilk and Kolmogorov-Smirnov tests (SW= 0.973 and p-value= 0.271, KS= 0.0758 and p-value= 0.200 for total length; and SW= 0.978 and p-value= 0.426, KS= 0.066 and p-value= 0.200 for head length) confirmed data normality, allowing parametric tests like linear regression. The linear regression relationship between TL and HL was highly significant, and is described as:

TL (cm) = 15.52 + 6.283HL (cm) (N= 53; SEE= 13.08; p= 0.00; r^2= 0.96) (Figure 1)

The mean TL/HL ratio was 7.03 (N=53; range 5.8 to 8.5; SD= 0.57). The linear regression relationships between TL/HL, and TL and HL, were significant, albeit highly variable and relatively low proportions of the variation explained by the regressions.

TL/HL = 7.55 - 0.003TL (cm) (N= 53; SEE= 0.54; p= 0.01; r^2= 0.12) (Figure 2)

TL/HL = 7.75 - 0.03HL (cm) (N= 53; SEE= 0.49; p= 0.00; r^2= 0.26) (Figure 3).

Discussion and Conclusion: As with other crocodilians, the relationship between HL and TL in Iranian Muggers was linear and thus provides a means to estimate size from heads/skulls found in the field or as museum specimens. The mean TL/HL ratio in this study (7.03) was similar to that obtained by Whitaker & Whitaker (2008) in their review of other crocodilian species. For all but perhaps the most longirostrine species, there appears a similarity in TL/HL ratio for crocodilians of moderate size.

The increasing TL/HL ratio with increasing size in our sample of Muggers merits further investigation, particularly with inclusion of data from larger Muggers (>3 m TL), since in some other species there is an increase in the TL/HL ratio in the largest crocodiles (Whitaker & Whitaker 2008; Fukuda et al. 2013). More

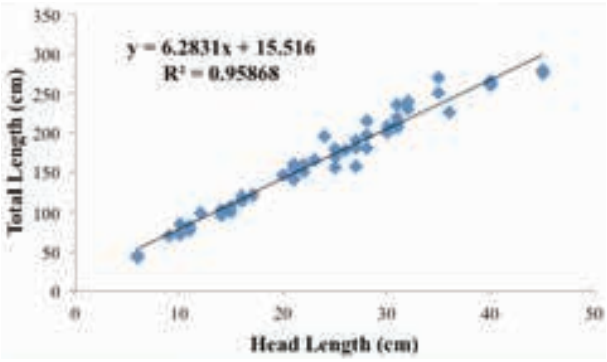

Figure 1. Linear regression between total length and head length for Mugger crocodiles.

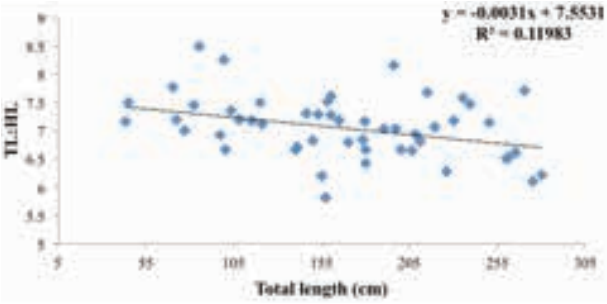

Figure 2. Linear regression relationship between TL/HL ratio and total length for Mugger crocodiles.

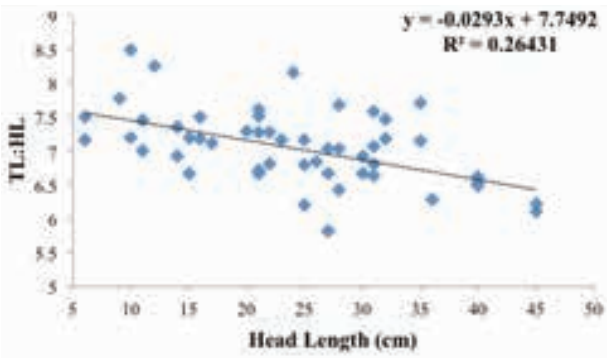

Figure 3. Linear regression relationship between TL/HL ratio and head length for Mugger crocodiles.

accurate data on additional head measurements (e.g., see Webb & Messel 1978) is likely to have provided more insights into how head shape changes with size in our sample of Muggers, and future work will take this into consideration.

In view of the relatively harsh environment in which Iranian Muggers occur, similar studies in other range states, namely Pakistan, Nepal, India, and Sri Lanka, may provide a clearer picture of potential morphometric differences across localities or populations for Muggers.

References

Abtin, E. & A. Mobaraki (2016). Gandou, Marsh Crocodile in Iran. Nashr-E-Talaie, Tehran, 144pp.

Britton, A., R. Whitaker & N. Whitaker (2012). Here be a dragon: exceptional size in a Saltwater Crocodile (*Crocodylus porosus*) from the Philippines. *Herpetological Review* 43(4): 541–546.

De Silva, A. & J. Lenin (2010). Mugger Crocodile *Crocodylus palustris*. pp. 94–98. In: Manolis, S.C. & C. Stevenson (eds.). *Crocodiles. Status Survey and Conservation Action Plan*. Third Edition. Crocodile Specialist Group, Australia.

Edwards, G.P., G.J. Webb, S.C. Manolis & A. Mazanov (2017). Morphometric analysis of the Australian freshwater crocodile (*Crocodylus johnstoni*). *Australian Journal of Zoology* 65(2): 97–111.

Fukuda, Y., K. Saalfeld, G. Lindner & T. Nichols (2013). Estimation of total length from head length of Saltwater Crocodiles (*Crocodylus porosus*) in the Northern Territory, Australia. *Journal of Herpetology* 47(1): 34–40.

Hutton, J.M. (1987). Morphometrics and field estimation of the size of the Nile crocodile. *African Journal of Ecology* 25: 225–230.

Magnusson, W.E. (1983). Size estimates of crocodilians. *Journal of Herpetology* 17(1): 86–88.

Mobaraki, A. (2015). Sustainable Management and Conservation of the Mugger Crocodile (*Crocodylus palustris*) in Iran. Msc thesis, International University of Andalusia, Spain, 58pp.

Mobaraki, A., M. Erfani, E. Abtin & F. Ataie (2019). Assessing habitat suitability of the mugger crocodile using maximum entropy. *Environmental Sciences* 16(4): 47–62.

Montague, J.J (1984). Morphometric analysis of *Crocodylus novaeguineae* from the Fly River Drainage, Papua New Guinea. *Australian Wildlife Research* 11(2): 395–414.

Platt, S.G., T.R. Rainwater, J.B. Thorbjarnarson & D. Martin (2011). Size estimation, morphometrics, sex ratio, sexual size dimorphism, and biomass of *Crocodylus acutus* in the coastal zone of Belize. *Salamandra* 47(4): 179–192.

Verdade, L.M. (2000). Regression equation between body and head measurement in the broad-snouted caiman (*Caiman latirostris*). *Revista Brasileira de Biologia* 60(3): 469–482.

Whitaker, R. & N. Whitaker (2008). Who's got the biggest? *Crocodile Specialist Group Newsletter* 27(4): 26–30.

Webb, G.J.W. & H. Messel (1978). Morphometric analysis of *Crocodylus porosus* from the north coast of Arnhem Land, northern Australia. *Australian Journal of Zoology* 26: 1–27.

Webb, G. J. W., R. Buckworth, and S. C. Manolis (1983). *Crocodylus johnstoni* in the McKinlay River area, NT. III. Growth, movement and population age structure. *Australian Wildlife Research* 10: 383–401.

Wu, X.B., H. Xue, L.S. Wu, J.L. Zhu & R.P. Wang (2006). Regression analysis between body and head measurements of Chinese alligators (*Alligator sinensis*) in captive population. *Animal Biodiversity and Conservation* 29(1): 65–71.

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NOTE

First record of the hoverfly genus *Spilomyia* Meigen (Diptera: Syrphidae) for Pakistan

Muhammad Asghar Hassan [1], Imran Bodlah [2], Riaz Hussain [3], Azan Karam [4], Fazlullah [5] & Azaz Ahmad [6]

[1] Department of Entomology, China Agricultural University, Beijing 100193, China.
[2,3] Department of Entomology, Pir Mehr Ali Shah Arid Agricultural University, Rawalpindi, Pakistan.
[4] Department of Zoology, Government Post Graduate Jahanzeb College Swat, Khyber Pakhtunkhwa, Pakistan.
[5] Centre for Agriculture and Bioscience International (CABI), Rawalpindi, Pakistan.
[6] Department of Entomology, University of Agriculture, Peshawar, Khyber Pakhtunkhwa, Pakistan.
[1] kakojan112@gmail.com (correspondent author), [2] imranbodlah@gmail.com, [3] riazsodaywa@gmail.com, [4] iazankhan4@gmail.com, [5] insectfauna@gmail.com, [6] azazahmad@aup.edu.pk

The genus *Spilomyia* Meigen, 1803 is a Holarctic genus, which currently includes 38 described species with a few representatives from the Neotropics and the Oriental regions (Wachkoo et al. 2019; Van Steenis 2000). The adults prefer to live in open areas having flowers with nectar (Thompson & Rotheray 1998) and their larvae are associated with damp, rotten timber in hollow trees and the decaying heartwood of deciduous trees (Maier 1982; Copeland 1989).

The species of the genus *Spilomyia* bear morphological and behavioral resemblance to social wasps in the field and can easily be differentiated from the other members of family Syrphidae by the presence of the following combination of characters: brown color pattern on eyes, apicoventral spur on hind femur and wing with cell R1 open (Van Steenis 2000).

Despite their widespread distribution, only three species of this genus, viz., *Spilomyia manicata* (Rondani, 1865), *S. saltuum* (Fabricius, 1794), and *S. sulphurea* Sack, 1910 are from Afghanistan and one species, *S. manicata* (Rondani) have been reported from India (Bańkowska 1968; Ghorpadé 2014; Wachkoo et al. 2019). The aim of the present study is to provide the distribution map of *Spilomyia manicata* (Rondani) from Pakistan and neighboring countries.

Material and Methods: The observation of this species took place on agricultural land having mixed grasses and wild flowers in Khyber Pakhtunkhwa province of Pakistan at an elevation of 760 m. The specimen was identified using Van Steenis (2000) and Watchkoo et al. (2019). The distribution map was updated after Watchkoo et al. (2019) and current data. The specimen was photographed using an Olympus SZX7 stereomicroscope with a Sony CCD digital camera attached. The identified specimen is deposited at the National Insect Museum, Islamabad, Pakistan (reg. no: 105).

Results: The first record of *Spilomyia manicata* (Rondani, 1865) from Pakistan is reported herein along with its distribution map, diagnostic characters, and images provided for quick identification.

Family Syrphidae

Genus *Spilomyia* Meigen, 1803

Diagnosis: Head, face without keel, brown color

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pattern on eyes; wings, radio-medial cross-vein on top half, often 1/3 of discal cell, vein R4+5 without distinct sinuate; legs, conical tooth at apicoventral anterolateral on hind femora; abdomen, with yellow and black bands (Van Veen 2010).

***Spilomyia manicata* (Rondani, 1865)**

Milesia manicata Rondani, 1865: 132.

Spilomyia integra Kuntze, 1913: 549.

Spilomyia boschmai Lucas, 1964: 206.

Material examined: Registration no: (105), 11.ix.2019, 1 male, Pakistan: Khyber Pakhtunkhwa Province, Swat District, 35.054092° N, 72.564847° E, 760 m, leg. A. Karam.

Diagnosis: Face yellow with black median strip (Image 1C), frons yellow with broad black triangular spot above antennae, ocellar triangle black, the triangle between anterior ocellus and the eyes yellow (Image 1C). Legs brownish except for all coxae which are yellow-brown to black, with basal yellowish hairs and distinct apico-ventral black setae; trochanter brownish-black; ventral with short black hairs; front tibia black on apical ¼–2/3; protarsus black except yellowish-brown 5th tarsomeres; legs with short yellowish setae except ventral sides of femora with distinct black bristly hairs; spur on hind femora narrowly concave (Images 1A–C). Thorax; color black except posterior half of humerus, posterior anepisternum, proepimeron, posterodorsal 1/5th of katepisternum, basal half of katepimeron, nearly all katatergite and macula (in front of scutellum semicircular) yellow; scutellum yellow on posterior 1/4–1/3; proepisternum, anterior anepisternum, anterior anepimeron, meron and metasternum black; the yellow spots having yellowish hairs; meron bare, katepisternum having distinct patch of hairs on apicodorsal and ventral (Images 1A–B). Wings, weakly brownish along anterior margins to hyalinous, r-m cross-vein strongly oblique, vein R4+5 narrowly bend into r4+5 cell, halters yellow; calypters whitish (Image 1E).

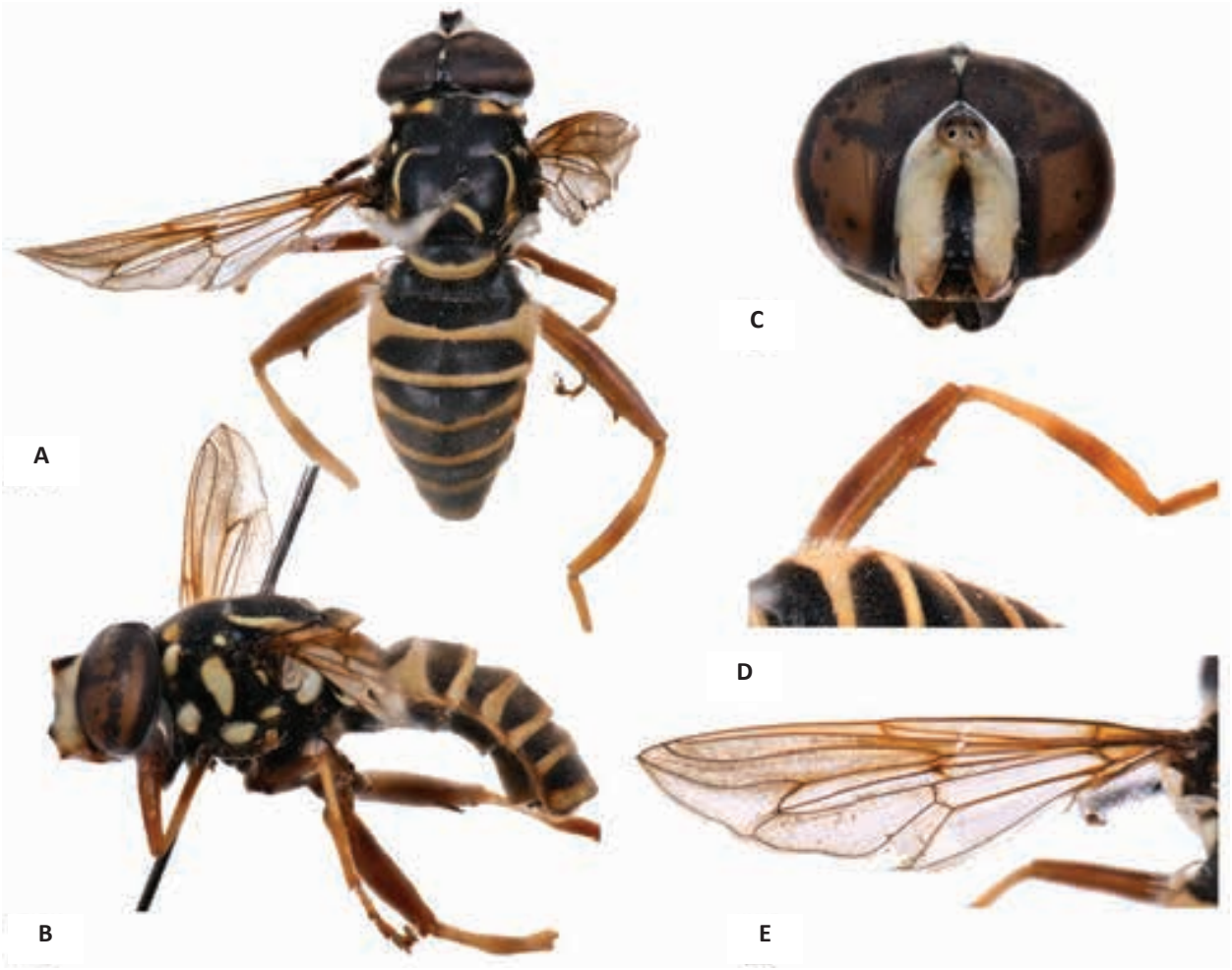

Image 1. *Spilomyia manicata* (Rondani, 1865), habitus of male: A—dorsal habitus | B—lateral habitus | C—frontal view | D— hind femora | E—left-wing © M.A. Hassan

Image 2. Distribution of *Spilomyia manicata* in India, Pakistan, and Afghanistan.

Abdomen, the anteromedial and posterior yellow fascia on abdominal tergites II–IV completed not separated in the middle. Sternites I–IV with black rectangular spots, sternum I wider than long, I–II with long white hairs and II–IV with short appressed black setae (Image IA,B).

Distribution: Central and southern Europe (Van Veen 2010), Afghanistan, and India (Wachkoo et al. 2019).

Discussion: Species of the genus *Spilomyia* Meigen, 1803 are widely distributed around the world with a few representatives from the Neotropics and Oriental regions. Despite their worldwide distribution, there are only a few recent records from most parts of its range. It is probably a threatened species or may be facing a high risk of threat in the future (Vujič et al. 2001; Speight 2013). *Spilomyia manicata* (Rondani, 1865) is recently reported from the Himalayas (India), i.e.; Kashmir Valley in northwestern Himalaya and western Himalayan state of Himachal Pradesh to the southern slopes of the Hindu Kush Mountains in the northeastern parts of Afghanistan (Wachkoo et al. 2019). The importance is that the discovery of this very rare species from the eastern Hindu Kush Mountains in Swat Valley extends the range of this species from the Himalaya to Hindu Kush ranges from India, Pakistan to Afghanistan (Image 2).

References

Bańkowska, R. (1968). Materialien zur Kenntnis der Syrphidae von Afghanistan. *Fragmenta Faunistica* 14: 195–207 (in German). [Materials for the knowledge of the Syrphidae (Diptera) of Afghanistan].

Fabricius, J.C. (1794). Entomologia Systematica emendata et aucta. Secundum classes, ordines, genera, species, adjectis synonimis, locis observationibus, descriptionibus. Tome 4. C.G. Proft (in Latin), Copenhagen, Denmark, 670pp.

Ghorpadé, K. (2014). An updated checklist of the hover-flies (Diptera—Syrphidae) recorded in the Indian subcontinent. *Colemania.* 44: 1–30.

Kuntze, A. (1913). Dipterologische Sammelreise in Korsika des Herrn W. Schnuse in Dresden im Juni und Juli 1899. Deutsche Entomol Zeitschr 1913: 544–567 (in German).

Lucas, J.A.W. (1964). A new species of *Spilomyia* from Sicily (Diptera, Syrphidae). *Zoologische Mededelingen.* 39: 206–208.

Meigen, J.W. (1803). Versuch einer neuen Gattungs-Eintheilung der Europaischen zweiflugligen Insekten. Mag Insektenkd 2: 259–281 (in German).

Rondani, C. (1865). Diptera Italica non vel minus cognita descripta vel annotate observationibus nonnullis additis. Fasc. I. Oestridae-Syrphidae-Conopidae; Fasc. II. Muscidae. Atti della Società Italiana di Scienze Naturali, Milano 8: 127–146 (in Latin).

Speight, M.C.D. (2013). Species Accounts of European Syrphidae (Diptera), Vol. 72. Syrph the Net Publications, Dublin, Ireland, 317 pp.

Steenis, J.V. (2000). The West-Palaearctic species of *Spilomyia* Meigen (Diptera: Syrphidae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft.* 73: 143–168.

Thompson, F.C. & G.E. Rotheray (1998). Family Syrphidae. In: Papp, L. & Darvas, B. (eds.). *Contributions to a Manual of Palaearctic Diptera* 3. Science Herald, Budapest, 81–139pp.

Van Veen, M.P. (2010). Hoverflies of Northwest Europe: Identification keys to the Syrphidae. KNNV Publishing, Utrecht, 248pp.

Vujič, A., S. Šimic & S. Radenkovič (2001). Endangered species of hoverflies (Diptera: Syrphidae) on the Balkan peninsula. *Acta Entomol Serb.* Expand 5: 93–105.

Wachkoo, A.A., J. van Steenis, Z.A. Rather, J. Sengupta & D. Banerjee (2019). First record of the genus *Spilomyia* (Diptera, Syrphidae) from the Oriental region. *Turkish Journal of Zoology* 43(2): 239–242.

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NOTE

Rediscovery of Watson's Demon *Stimula swinhoei swinhoei* (Elwes & Edwards, 1897) (Lepidoptera: Hesperiidae: Hesperiinae) in Meghalaya, India after 60 years

Suman Bhowmik [1] & **Atanu Bora** [2]

[1] Lepidoptera Conservation and Research Division, Wild Tripura Foundation, Agartala, Tripura, 799007, India.
[2] Department of Zoology, Moran College, Moranhat, Assam, 785670, India.
[1]sumanbhowmikwildlife@gmail.com, [2]atanubora2019@gmail.com (corresponding author)

The monotypic genus *Stimula* is represented by a single species Watson's Demon *Stimula swinhoei* (Varshney & Smetacek 2015). *Stimula swinhoei* was first introduced as *Watsonia swinhoei* by Elwes & Edwards in 1897 through the type specimens of Col. Swinhoei. Later, this species was treated as *Stimula swinhoei* (Evans 1932, 1949). Altogether two subspecies occur: *Stimula swinhoei swinhoei* – Khasi Hills, Sikkim, Assam, Sadon, northern Myanmar, and North Shan State and *Stimula swinhoei disca* – Myanmar, northern Thailand, Laos, and Yunnan. The Indian subspecies was last recorded by Cantlie from Khasi Hills, Meghalaya in 1956 (Cantlie 1956). Since then, there is no record of the species in Meghalaya (Radhakrishnan et al. 1989; Alfred 1999; Hatter et al. 2004; Kunte et al. 2012; Sondhi et al. 2013). The subspecies *swinhoei* is, however, recently recorded from Panbari Reserve Forest, Assam (Gogoi 2013). This observation discusses the rediscovery of the Indian subspecies after a gap of 60 years for Meghalaya along with small note on its identification and current habitat of the butterfly in the state (Image 1).

The present rediscovery is based on an opportunistic survey in Khasi hills as a part of the butterfly inventory and monitoring programme of northeastern India. On 20 February 2016 at about 1245 h, one of the authors, Atanu Bora photographed a skipper butterfly feeding on bird droppings adjacent to a hill stream in Riwai village (25.196N & 91.900E; at approximately 430m), Meghalaya. The butterfly exactly matched the original description of the underside of *Stimula swinhoei* in the published literature (Elwes & Edwards 1897; Evans 1949).

Stimula swinhoei is identical to *Ancistroides nigrita* but differs in the following characters (Elwes & Edwards 1897; Evans 1932, 1949):

1. *Stimula swinhoei*: The marginal third of only forewing paler. Additionally, large pale area on the dorsum of upperside forewing (hidden in the documented photographs). Underside hindwing uniformly dark brown (Image 3).

2. *Ancistroides nigrita*: The marginal third of both wings paler. Underside forewing dorsum not pale brown unlike *Stimula swinhoei* (Image 3).

Stimula swinhoei was last recorded by Cantlie from Khasi Hills of Meghalaya in 1956. However, none of the authors has recorded this species in Meghalaya afterwards. This rediscovery indicates that a population of the butterfly still exists in some restrictive habitats of Khasi hills. Currently, no information is available on

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Image 1. Locality where *Stimula swinhoei swinhoei* was recorded in Meghalaya.

Image 2. Photographic record of *Stimula swinhoei swinhoei* in Riwai village, Meghalaya.

ecology of the species in India. Our observation suggests that *Stimula swinhoei* can be found perching on the hill streams inside forest (Image 4). During daytime, the species can be found puddling on rocks, wet patches and bird droppings nearby hill streams or waterfalls. Additional records in future surveys will help to map the distribution of this species in the Indian subcontinent. The species might have been overlooked in the past historic works because of its close similarity with *Ancistroides nigrita*. We strongly hope that our observation will help Lepidopterists and butterfly enthusiast across the country in identification of the species and the habitat information can be used for proper monitoring of this butterfly in future.

References

Alfred J.R.B. (1999). *Fauna of Meghalaya-Part* 6. Insecta (Diptera and Lepidoptera). ZSI, Calcutta, I-IV, 537pp.

Cantlie, K. (1956). Hesperiidae of Khasi and Jaintea Hills. *Journal of the Bombay Natural History Society* 54: 212– 215.

Elwes, H.J. & J. Edwards (1897). A Revision of the Oriental Hesperiidae. *Transaction of Zoological Society London* 14(4): 101–324.

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

Evans, W.H. (1949). *A Catalogue of the Hesperiidae from Europe, Asia and Australia in the British Museum (Natural History).* London, 502pp.

Gogoi, M.J. (2013). Notes on some skipper butterflies (Lepidoptera: Hesperiidae) from Panbari Forest and its adjoining areas, Kaziranga-Karbi Anglong, upper Assam, India. *Journal of Threatened Taxa* 5(13): 4759–4768. https://doi.org/10.11609/JoTT.o3340.4759-68

Hatter, S.J.S., N. Sen, M. Rosamma & S. Sharma (2004). Faunal Diversity of Saipung Wild Life Sanctuary / Narpuh Reserve Forest, Jaintia Hills, Meghalaya. Conservation Area Series 21. Zoological Survey of India, Kolkata, 66pp.

Image 3. Side wise comparison between (a) *Stimula swinhoei swinhoei* and (b) *Ancistroides nigrita diocles.*

Image 4. A view of the habitat in Riwai village where *Stimula swinhoei swinhoei* was recorded in Meghalaya.

Kunte, K., S. Sondhi, B. Sangma, R. Lovalekar, K. Tokekar & G. Agavekar (2012). Butterflies of the Garo Hills of Meghalaya, northeastern India: their diversity and conservation. *Journal of Threatened Taxa* 4(10): 2933–2992. https://doi.org/10.11609/JoTT.o2945.2933-92

Radhakrishnan, C., J.R.B. Alfred & M.R. Rynth (1989). *Butterflies of Shillong and Its Environs*. Science & Technology Cell, Govt of Meghalaya, Shillong, 70pp.

Sondhi, S., K. Kunte, G. Agavekar, R. Lovalekar & K. Tokekar (2013). *Butterflies of the Garo Hills*. Samrakshan Trust (New Delhi), Titli Trust (Dehradun) and Indian Foundation for Butterflies (Bengaluru), xvi+200pp.

Varshney, R.K. & P. Smetacek (2015). *A Synoptic Catalogue of the Butterflies of India*. Butterfly Research Centre, Bhimtal and Indinov Publishing, New Delhi, ii+261pp+8pl.

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A record of *Ourapteryx dierli* Inoue, 1994 (Lepidoptera: Geometridae: Ennominae) from the Garhwal Himalaya, India

Arun P. Singh [1] & **Lekhendra** [2]

[1&2] Entomology Branch, Forest Protection Division, Forest Research Institute, P.O. New Forest, Dehradun, Uttarakhand 248006, India.
[1] ranoteaps@gmail.com (corresponding author), [2] lekhendrasahu750@gmail.com

Ourapteryx dierli Inoue, 1994 was described from central Nepal (Inoue 1994) with specimens collected during June (holotype and paratypes of this species were collected on various dates in vi.1973) between 2,500–2,600 m from central Nepal (Inoue 1994, 1995). Later, *O. dierli* was recorded from western Nepal at 1,000 m on 25.vii.1996 (Stüning 2000). Recently, Sondhi et al. (2020) reported it from Sarmoli village (23.v.2019; 2,200 m; 30.079°N & 80.235°E) near Munsiari in Pithoragarh district of Kumaon in Uttarakhand, India. Hence the known distribution range of *O. dierli* was noted as eastern Kumaon in Uttarakhand, India to western and central Nepal (Sondhi et al. 2020).

During the course of surveys carried out on insects infesting the western Himalayan oaks, the authors recorded one individual of this species (Figure 1) in the Chakrata hills. The individual was attracted to a CFL light on 08.vi.2020 at Kanesar Range Chowki (2,238 m; 30.714°N & 77.859°E; 20:31h; Temp: 17.8°C; RH 77%), Chakrata Forest Division, Dehradun District of Uttarakhand, India. The forest habitat around the site is 12/C1a Ban oak forest (Champion & Seth 1968) with *Quercus leucotrichophora* being the dominant tree species along with associates like Deodar *Cedrus deodara*, Moru Oak *Q. floribunda*, Horse Chestnut *Aesculus indica*, Blue Pine *Pinus wallichiana*, Alder *Alnus nepalensis*, *Rhododendron arboretum*, Bhamora *Cornus capiatata*, *Pyrus pashia*, and Dwarf Bamboo *Arundinaria falcata.* The earlier record from Uttarakhand by Sondhi et al. (2020) of this species was also in a similar forest habitat, altitude and season (pre-monsoon), which suggests the preference by this species for habitat, altitude, and season.

This finding further extends the western most limit in the distribution range of this species in the Himalaya to the Chakrata hills of Garhwal, Uttarakhand, India. This site of record lies in the Jaunsar region near the state of Himachal Pradesh to its west, and is ~250 km from the nearest known earlier record from Munsiari in Kumaon, India.

References

Champion, H.G. & S.K. Seth (1968). *A Revised Forest Types of India*. Manager of Publications, Government of India, Delhi.

Inoue, H. (1994). Descripton of a new species of *Ourapteryx* Leach (Geometridae: Ennominae) from central Nepal. *Tinea* 14(1): 10–12.

Inoue, H. (1995). The genera *Abraxas* and *Ourapteryx* from Nepal (Geometridae, Ennominae), pp. 119–139. In: Haruta, T. (ed.). (1995). *Moths of Nepal*. Part 4. TINEA. Vol. 14 (Supplement 2). The Japan Heterocerists' Society, Tokyo, 206pp+32pls.

Sondhi, S., D.N. Basu & K. Kunte (2020). First record of *Ourapteryx dierli* Inoue, 1994 (Lepidoptera: Geometridae: Ennominae) from India. *Journal of Threatened Taxa* 12(13): 16916–16919. https://doi.org/10.11609/jot.5524.12.13.16916-16919

Stüning, D. (1994). On the identity of *Ourapteryx ebuleata* Guenee, 1857, *O. multstrigaria* Walker, 1866, and *O. caschmirensis* Bastelberger, 1911, with description of two new species (Lepidoptera: Geometridae, Ennominae). *Nachrichten des Entomologischen Vereins Apollo* (NF) 15: 109–134.

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Image 1. *Ourapterya dierli* Inoue, 1994 photographed at Kansar Range Chowki (2,238 m), Chakrata Forest Division, Dehradun District of Uttarakhand, India.

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NOTE

Report of *Bradinopyga konkanensis* Joshi & Sawant, 2020 (Insecta: Odonata) from Kerala, India

Muhammed Haneef [1], B. Raju Stiven Crasta [2] & A. Vivek Chandran [3]

[1] Department of Botany, Government Brennen College, Thalassery, Kannur, Kerala 670106, India.
[2] Holy Family Aided Senior Basic School, Kumbla post, Kasaragod, Kerala 671321, India.
[3] Department of Geology and Environmental Science, Christ College, Irinjalakuda, Thrissur, Kerala 680125, India.
[1] haneefmangad@gmail.com, [2] rajukidoor@gmail.com, [3] avivekchandran2@gmail.com (corresponding author)

Bradinopyga konkanensis Joshi & Sawant, 2020 is a newly described species of dragonfly in the family Libellulidae reported from the western region of Peninsular India. It is the fourth species described in the genus *Bradinopyga* Kirby, 1893 (Schorr & Paulson 2020) and is believed to be a Western Ghats endemic associated with lateritic coastal habitats. It was described based on specimens from three localities in Sindhudurg, Ratnagiri, and Thane districts of Maharashtra, India. All additional records are from coastal areas of Maharashtra. The authors had predicted its occurrence in other coastal areas of the Western Ghats, especially in the Konkan region of Goa and Karnataka (Joshi & Sawant 2020). We report this species from Kidoor village, Kasaragod district, Kerala, India.

Kidoor is a village under Kumbla grama panchayat, Kasaragod district in northern Kerala, southern India (Figure 1). It has lateritic formations near the coast, paddy fields and patches of forest adjoining human habitations. The lateritic region has many natural ponds which attract odonates (Image 1). The common species encountered here are *Brachydiplax sobrina, Crocothemis servilia, Indothemis carnatica, Orthetrum sabina, Agriocnemis pygmaea, Ceriagrion rubiae*, and *Ischnura rubilio*. On 18 July 2020, BRSC photographed a dragonfly that resembled *Bradinopyga geminata,* but with distinct brown colouration at the bases of hindwings (Image 2). On 20 July 2020, additional field photographs were taken from Kidoor and a specimen was collected. The specimen was studied under a stereo microscope (Olympus SZ61 with MAGCAM DC-5 CMOS 5 MP camera) and deposited in the collections of the Department of Zoology, Government Brennen College, Thalassery. All field photographs were taken using a Canon 600 D camera with 55–250 lens. Taxonomic terminology follows Garrison et al. (2006).

Material examined: GBCT.ENT.O23, 1 male, Kidoor (12.633°N, 74.981°E, 32m), 20.v.2020, coll. Muhammed Haneef.

Description: Abdomen: 27 mm, hindwing: 33 mm. Face mostly black, eyes dark greyish-brown, median ocellus dark brown, vertex elevated, ending in a pair of pointed tubercles (Image 3). Prothorax and thorax dark blue and pruinosed, covered with fine brown hair. Wings hyaline with the bases tinted brown as follows: In the forewings, small portion of costal space, half of first cell of subcostal space, 1/10th of median space, half of cubito-anal space and 1/4th of first cell of anal anterior

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Acknowledgements: We thank the Society for Odonate Studies (SOS), Kerala for encouraging us to undertake field studies on odonates. The first author would like to thank Dr. V.S. Anilkumar, head of the Department, Botany, Government College, Kasaragod for permitting to use laboratory equipment for the study.

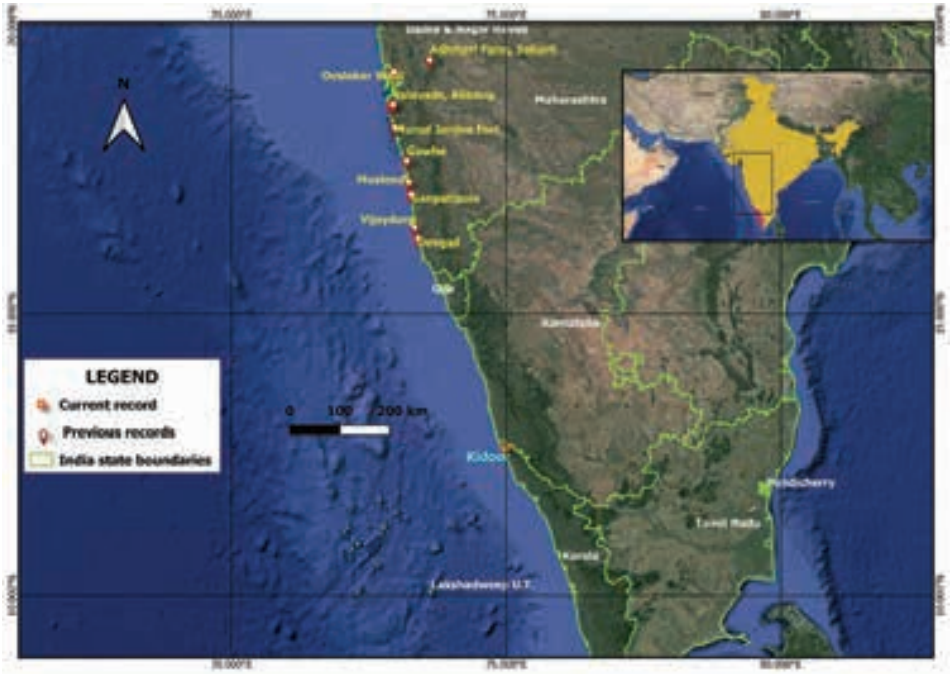

Figure 1. Observations of *Bradinopyga konkanensis*.

space. In the hindwings, small portion of costal space, 3/4th of subcostal space, first cell of cubito-anal space extending just slightly into the second cell, and triangular marking encompassing 7–8 cells of anal anterior space, extending into neighbouring cells. Medially, two rows of cells present between: i) IRP2 & Rspl, ii) RP3+4 & MA, and iii) MP & CuA. Pterostigma bicoloured, central region black with dark brown on both sides (Image 4). Abdomen black, pruinosed bluish (Image 5). Secondary genitalia: Anterior hamuli with a base, a posteriorly facing lobe ending with sharply curved, hook-like, pointed end. Posterior hamuli with margins straight, rounded at apices, covered with thick brown hair (Image 6). Cerci pale brown with darker brown apices, conical, broader at base and pointed apically, covered with whitish hair. Epiproct dark brown, black at base and apices, curved slightly upwards (Images 7, 8, 9).

There are three other species of odonates—*Bradinopyga geminata* (Rambur, 1842), *Indothemis carnatica* (Fabricius, 1798) and *Indothemis limbata* (Selys, 1891)—which co-occur in the region and look similar to *B. konkanensis*, but they can be separated by clear distinguishing features (Fraser 1936; Joshi & Sawant 2020). We have tabulated the differences to aid precise identification of these species during field surveys (Table 1). We report *Bradinopyga konkanensis* from Kidoor village in Kerala, 450 km away from its nearest record (Devgad, Maharashtra). Kidoor is at a distance of 6 km from the sea and falls within the range

Image 1. A natural pond in the lateritic region of Kidoor Village. © B. Raju Stiven Crasta.

Image 2. Bradinopyga konkanensis in its lateritic habitat. © B. Raju Stiven Crasta.

Table 1. Differences between *Bradinopyga konkanensis* and closely similar species (males).

Species / Feature	*Bradinopyga konkanensis*	*Bradinopyga geminata*	*Indothemis carnatica*	*Indothemis limbata*
No. of cell rows (medially) between: IRP_2 & Rspl RP3+4 & MA MP & CuA	Two	Two	One	One
Basal wing colouration	Brown tint up to anal anterior space in forewings and extending to neighbouring cells of anal anterior space in hindwings	Hyaline (no colour)	Small point of amber yellow in hindwings	Dark mahogany brown, reaching the first antenodal nervure in forewings and second antenodal & arc in hindwings
Pterostigma	Bicolorous, black at the centre & brown at the sides	Bicolorous, black at the centre & white at the sides	Bright ochreous between thick black nervures	Ochreous, paler along posterior border, bordered with a thick black nervure anteriorly & a thin one posteriorly
Thorax	Dark blue	Dirty pale yellow, marbled and peppered with black irregularly (like granite)	Blackish-brown	Black
Abdomen	Black, pruinosed bluish	Black marbled with yellow	Blackish-brown with yellow markings obscurely showing through	Black with yellow markings forming a broken lateral stripe

Image 3. Head of *Bradinopyga konkanensis*. © Muhammed Haneef.

Image 4. Wings of *Bradinopyga konkanensis*. © Muhammed Haneef.

Image 6. *Bradinopyga konkanensis*: lateral view of secondary genitalia. © Muhammed Haneef.

Image 5. *Bradinopyga konkanensis* habitus showing black abdomen with blue pruinescence. © Muhammed Haneef.

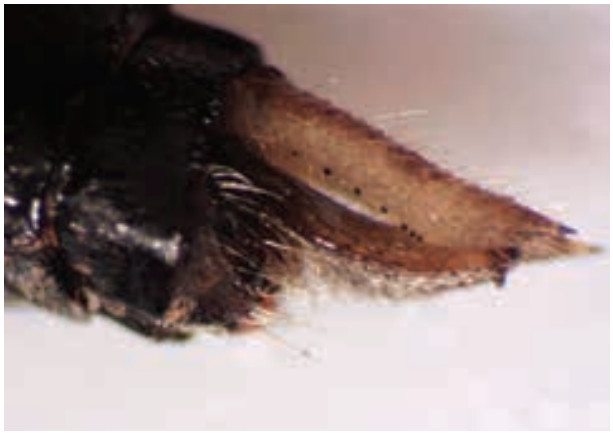

Image 7. *Bradinopyga konkanensis*: lateral view of caudal appendages. © Muhammed Haneef.

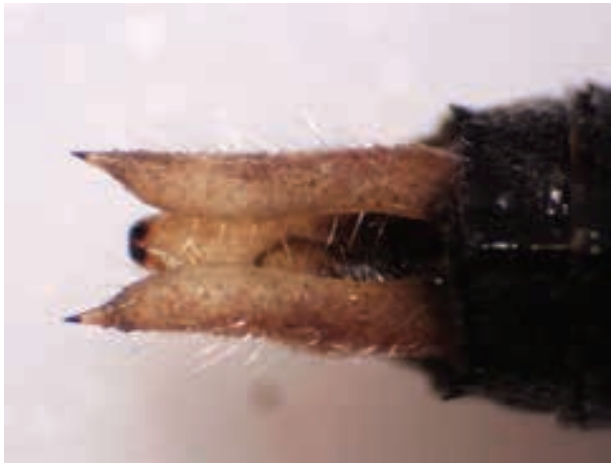

Image 8. *Bradinopyga konkanensis*: dorsal view of caudal appendages. © Muhammed Haneef.

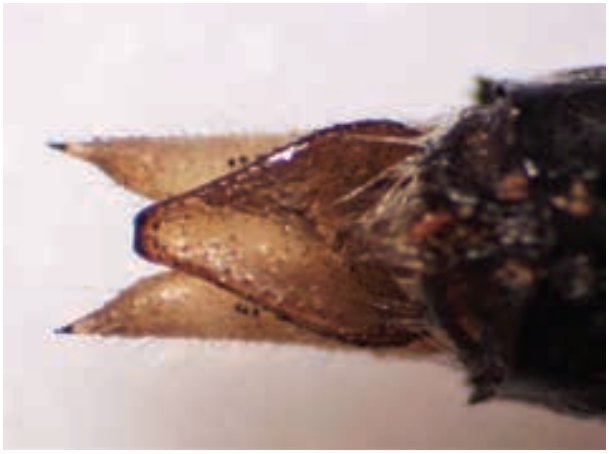

Image 9. *Bradinopyga konkanensis*: ventral view of caudal appendages. © Muhammed Haneef.

of distances from sea recorded earlier for the species (0–89 km). The observation adds credence to the opinion of the authors of the species that it could be found in lateritic coastal habitats in Goa and Karnataka. A survey of similar habitats in the coastal region of Kerala could also yield additional records.

References

Fraser, F.C. (1936). *The Fauna of British-India including Ceylon and Burma, Odonata. Vol. III*. Taylor and Francis Ltd., London, 461pp.

Garrison, R.W., N. von Ellenreider & J.A. Louton (2006). *Dragonfly genera of the New World: An Illustrated and Annotated Key to the Anisoptera*. The Johns Hopkins University Press, Baltimore, 368pp.

Joshi, S. & D. Sawant (2020). Description of *Bradinopyga konkanensis* sp. nov. (Odonata: Anisoptera: Libellulidae) from the coastal region of Maharashtra, India. *Zootaxa.* 4779: 65–78. https://doi.org/10.11646/zootaxa.4779.1.4

Schorr, M. & D. Paulson (2020). World Odonata List. https://www.pugetsound.edu/academics/academic-resources/slater-museum/biodiversity-resources/dragonflies/world-odonata-list2/Electronic version accessed on 26 July 2020.

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NOTE

A new distribution record of *Bianor angulosus* (Karsch, 1879) (Araneae: Salticidae) from Kerala, India

Nishi Babu [1], John T.D. Caleb [2] & G. Prasad [3]

[1,3] Department of Zoology, University of Kerala, Kariavattom, Thiruvanandthapuram, Kerala 695581, India.
[2] No. 27, Saravana Nagar, Manigantapuram, Thirumulliavoyal, Chennai, Tamil Nadu 600062, India.
[1] nishibabu510@gmail.com, [2] caleb87woodgate@gmail.com, [3] probios1@gmail.com (corresponding author)

Abbreviations: CP—central epigynal pocket | PLE—posterior lateral eyes | RTA—retrolateral tibial apophysis.

Globally, the salticid fauna is represented by 6,334 species under 659 genera (World Spider Catalog 2021) and the Indian diversity by 275 species under 99 genera (Caleb & Sankaran 2021). The cosmopolitan genus *Bianor* was established by Peckham & Peckham (1885) with *Scythropa maculata* Keyserling, 1883 as its type species. At present, this genus includes 27 species (World Spider Catalog 2021) of which eight are known from India (Caleb & Sankaran 2020). The present paper deals with the description and first distributional record of *Bianor angulosus* (Karsch, 1879) from Kerala.

The study was conducted at Kainakary (9.52^{0}N, 76.39^{0}E) in Kuttanad, Kerala. Collection and observations were made early morning from the paddy fields in both rabi and kharif crop seasons. The duration of the study was from July 2019 to August 2020. Specimens were photographed while alive, then collected either by hand or using a sweeping net and preserved in 70% alcohol. Detailed examination was done using a stereozoom microscope (Magnus, MS 24). The epigynum was dissected, cleared in 10% KOH and mounted on a temporary slide and observed under a compound microscope (Leica DM1000 LED) at both 10X and 20X magnifications to study the internal structures. Male left palp was removed and observed. All the measurements are in millimeters (mm). The studied specimens are deposited in the Zoological Museum of the Department of Zoology, University of Kerala, Kariavattom.

Genus *Bianor* Peckham & Peckham, 1886

Bianor angulosus (Karsch, 1879) (Images 1–6)

Ballus angulosus Karsch, 1879: 553

Bianor angulosus Żabka, 1988: 442, figs. 56–58; Logunov, 2001: 231, figs. 47–74; Logunov, 2019: 101, figs. 1–3, 5–10

Bianor hotingchiehi Żabka, 1985: 210, figs. 1–15

Bianor simoni Żabka, 1985: 204, figs. 30–34

For a complete list of taxonomic references refer the World Spider Catalog (2021).

Material examined: KUDZEN2021.I.01a, 28.viii.2019, 2 females from Kainakary, Kuttanad (9.52°N, 76.39°E), coll. Nishi Babu; KUDZEN2021.I.01b, 15.ix.2020, 2 males,

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same data as of females.

Description: Female—total length: 5.05, cephalothorax length: 2.04, width: 2.20. Abdomen length: 3.01, width: 2.15. Clypeus height 0.15. Morphometry of legs given in Table 1. Cephalothorax dark brownish, covered with straw colored hairs medially; broadest at PLE. Eye field trapezoid, distinctly broader posteriorly; posterior thoracic slope steep, almost vertical (Image 2). Clypeus densely covered with small white hairs. Chelicerae with single retromarginal tooth and two promarginal teeth. Sternum oval, reddish-brown, covered with white hairs. Maxillae, labium and chelicerae brownish. Leg formula 1342. Leg I stronger and longer than rest. Leg I brown, legs II-IV yellowish. Palp brown, covered with tiny white hairs. Abdomen elongated oval. Dorsally brown, covered with white and yellow hairs (Image 2). Posterior medial region with rows of black and white hairs. Epigyne ventrally with well-developed fossae and copulatory openings on either side of CP; internal structures with long, coiled insemination ducts; spermathecae tubular and elongated with fertilization ducts set apically (Images 3, 4). Spinnerets brown.

Male—total length: 5.08, Cephalothorax length: 2.45, width: 2.03. Abdomen length: 2.63, width 1.36. Clypeus height 0.10. Morphometry of legs given in Table 2. Cephalothorax punctured reticulate, shining, russet, covered with white elongate scales forming bright white patches behind posterior lateral eyes and white marginal stripes (Image 1). Clypeus brown with row of long white hairs. Sternum brownish-yellow covered with white hairs. Maxillae, labium and chelicerae yellowish-brown. Leg formula 1342. Leg I brown, legs II--IV yellowish. Palps brownish; small and broad cymbium; embolus thin, needle-like emerging from the proximal region of the bulb and tapering toward the tip; a membraneous region present at 3 o' clock position; RTA thick, broad at its base and slightly curved and pointed at the tip (Images 5, 6). Abdomen dorsally brown in colour with three pairs of white spots or a pair of longitudinal white stripes (Image 1). Sides and ventral region yellow. Spinnerets yellowish-brown. Rest of the characters are same as in female.

Distribution: India: Assam, Bihar, Himachal Pradesh, Karnataka, Kerala (present study), Odisha, Punjab, and West Bengal (Caleb 2019) (Image 7). The species is widespread throughout South and Southeast Asia from India, Sri Lanka, Bhutan, Bangladesh, China, Myanmar, Vietnam, Thailand, Malaysia, and Indonesia (World Spider Catalog 2021).

Habitat: The specimens were collected from a foliage of paddy as indicated in the previous study (Logunov 2001). The species constructs sac like webs and takes shelter in them.

Table 1. Leg measurements of female (KUDZEN2021.I.01a).

	Leg I	Leg II	Leg III	Leg IV
Femur	1.48	1.18	1.54	1.44
Patella	0.82	0.66	0.73	0.60
Tibia	1.28	0.79	0.68	0.75
Metatarsus	0.72	0.54	0.71	0.88
Tarsus	0.60	0.45	0.50	0.43
Total	**4.90**	**3.62**	**4.16**	**4.10**

Table 2. Leg measurements of male (KUDZEN2021.I.01b).

	Leg I	Leg II	Leg III	Leg IV
Femur	1.46	1.16	1.51	1.40
Patella	0.80	0.60	0.72	0.59
Tibia	1.13	0.75	0.64	0.81
Metatarsus	0.70	0.50	0.72	0.88
Tarsus	0.60	0.43	0.50	0.40
Total	**4.69**	**3.44**	**4.09**	**4.08**

Note: The species appears to exhibit a wide range of variations in coloration, size and morphology (Logunov 2001: 234). Our samples fall within one of the variations already illustrated for the species and its synonyms. The abdominal pattern of the male with a pair of longitudinal white stripes is similar to that illustrated by Logunov (cf. Image 1 with fig. 62 in Logunov 2001). The shape of RTA is identical to the samples from Sumatra and Vietnam (cf. Image 6 with fig. 64 in Logunov 2001 and fig. 2 in Żabka 1985). The epigyne with slanted central pocket appears similar to specimen from Vietnam and the internal structures are also identical with the same (cf. Images 3, 4 with figs. 8, 11 in Żabka 1985).

References

Caleb, J.T.D. (2019). *An Annotated checklist of jumping spiders (Araneae: Salticidae) of India*. AkiNik Publications, New Delhi, 75pp.

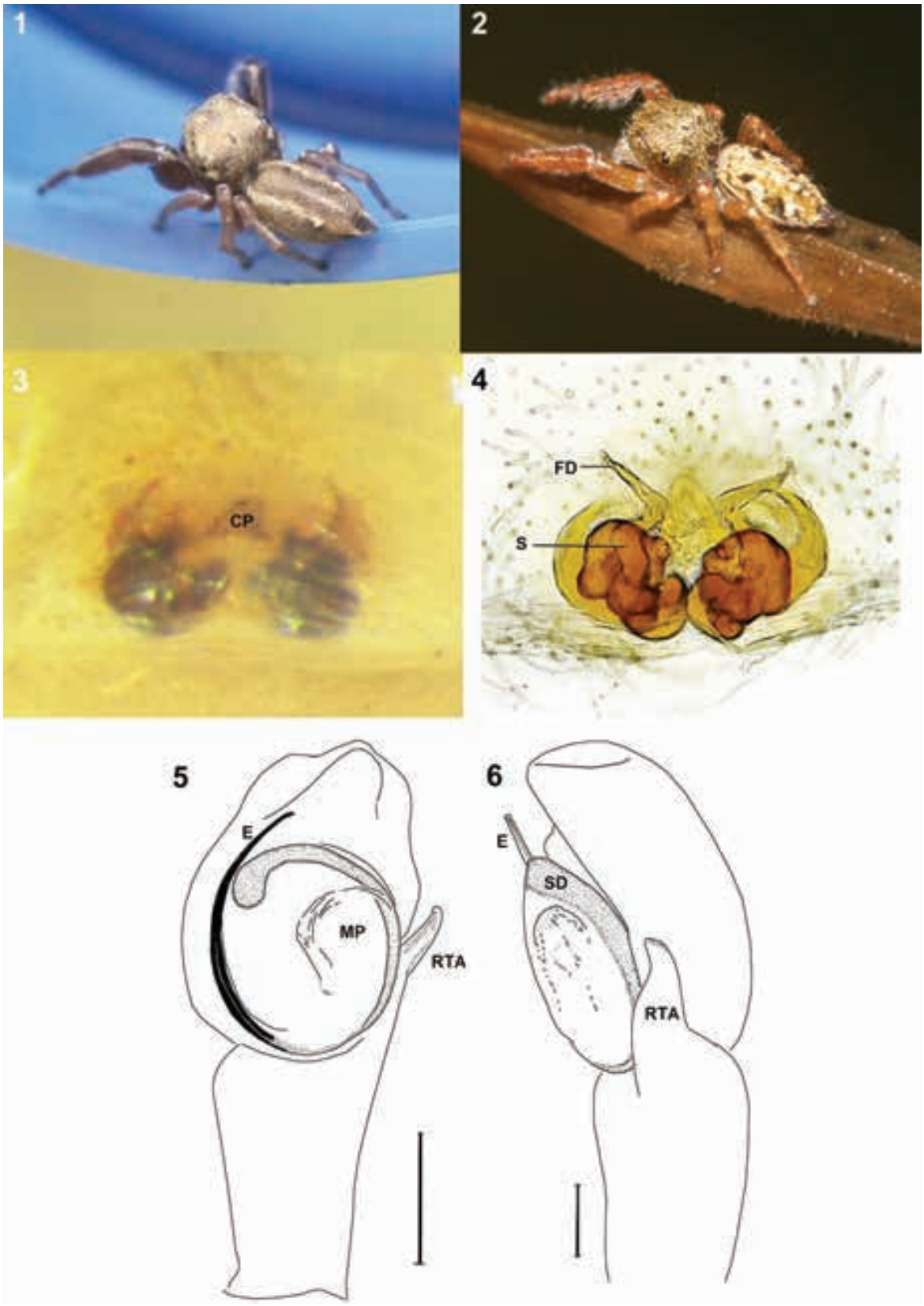
Caleb, J.T.D. & P.M. Sankaran (2021). Araneae of India. Version 2021, online at http://www.indianspiders.in (accessed on 5 January 2021).

Karsch F. (1879). Arachnologische Beitrage. *Zeitschriff fur die Gesammten Naturwissenschaften* 52: 534–562.

Logunov, D.V. (2001). A redefinition of the genera *Bianor* Peckham & Peckham, 1885 and *Harmochirus* Simon, 1885, with the establishment of a new genus *Sibinor* gen. n. (Aranei: Salticidae). *Arthropoda Selecta* 9(4): 221–286.

Logunov, D.V. (2019). Taxonomic notes on the Harmochirina Simon, 1903 from South and South-East Asia (Aranei: Salticidae). *Arthropoda Selecta* 28(1): 99–112.

Peckham, G.W. & E.G. Peckham (1885). Genera of the family Attidae: with the partial synonymy. *Transactions of the Wisconsin Academy*



Images 1–6. 1—*Bianor angulosus* male habitus (dorsal view) | 2—female habitus (dorsal view) | 3—female epigynum, ventral view | 4—vulva, dorsal view | 5—male palp, ventral view | 6—same, retrolateral view. Abbreviations: CP—central epigynal pocket | E—embolus | FD—fertilization duct | MP—membraneous patch | RTA—retrolateral tibial apophysis | S—spermatheca | SD—sperm duct. Images 3 & 4 not to scale. Scale bars: 5—0.2mm, 6—0.1mm. © 1, 3 & 4 Nishi Babu; 2 Binish Roopas.

Image 7. New collecting locality of *Bianor angulosus* is shown in yellow circle. Red circles represent previous distribution records in India.

of Science, Arts and Letters 6: 225–342.

World Spider Catalog (2021). World Spider Catalog. Natural History Museum Bern, online at http://wsc.nmbc.ch, version, 22. Accessed on 18 February 2021.

Żabka, M. (1985). Systematic and zoogeographic study on the family Salticidae (Araneae) from Viet-Nam. *Annales Zoologici, Warszawa* 39: 197–485.

Żabka, M. (1988). Salticidae (Araneae) of Oriental, Australian and Pacific regions, III. *Annales Zoologici, Warszawa* 41: 421–479.

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NOTE

Notes on lectotypification of the Assam Ironwood *Mesua assamica* (King & Prain) Kosterm. (Calophyllaceae)

Prantik Sharma Baruah [1], Sachin Kumar Borthakur [2] & Bhaben Tanti [3]

[1–3] Department of Botany, Gauhati University, Guwahati, Assam 781014, India.
[1] Present Address: Department of Botany, Nowgong College (Autonomous), Nagaon, Assam 782001, India.
[1] prantik1610@gmail.com, [2] skbgu1@gmail.com, [3] btanti@gauhati.ac.in (corresponding author)

Mesua assamica (King & Prain) Kosterm., commonly known as 'Sia- Nahor' in Assamese is a slow-growing, large, evergreen tree belonging to the family Calophyllaceae. Leaves are simple, opposite, ovate in shape, light to dark green in colour and coriaceous in texture. Leaf apex is acuminate, base rounded with entire margin, and petiolate. Venation is semi-craspedodromous in nature, distally forming distinct loops with bold inter-secondary veins. Flowers are small, white or creamy white, bisexual, fragrant and coriaceous bearing numerous golden yellow coloured stamens and a 4-fid stigma. Fruit is 1-seeded and globose. Flowering occurs in the months of April–May (Baruah et al. 2017). It is distributed in India, Myanmar and the Malay Peninsula (www.catalogueoflife.org/col.). In India, the plant is, however, confined only to the sub-montane forests of both Lakhimpur and Dhemaji districts of Assam (Kanjilal et al. 1934; Sharma et al. 1993; Baruah et al. 2016, 2020). Although the species has not been assessed by IUCN yet, it is reported as Endangered at a regional level based on its small restricted population (Choudhuri 2007).

The species was reported for the first time by Barker from the foot hills of the North Lakhimpur district of Assam and the specimens were submitted to the Forest School at Dehra Dun in October 1886 for identification, but having received no definite reply he sent a flowering material to the Calcutta Herbarium (CAL). Prain (1901) commented that Barker's specimen was not sufficient enough to identify the species but opined that the specimen belonged to the same natural order as that of *Mesua* in the genus *Kayea*. Further, King & Prain described the species as *Kayea assamica* based on two sets of specimens (fruiting and flowering) collected by H.G. Young and Mr. Barker from the erstwhile Dibrugarh district of Assam, India (Prain 1901).

Out of the set of fruiting specimens available for the species, three of them are housed in Central National Herbarium (CAL), Kolkata, India (CAL 47574; CAL 47575; CAL s.n.); one in Conservatoire et Jardin Botaniques ville de Geneva (G) (G00355757) labelled as Syntype by P.F. Sturn in 1975. All those specimens belonging to the collection of Young bear the same date and place of collection, i.e., December 1899 and Dibrugarh, Assam, India. Moreover, there is a fruiting specimen collected by Young with the same date and place of collection, i.e., December 1899 and Dibrugarh, Assam, India housed

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at Kew (K000677304). Another specimen collected by Young on December 1899 from Dibrugarh bearing only leaves has been housed at Natural History Museum, London (BM000611295) which had been designated as Isosyntype by P.F. Stevens in 1985. Among the flowering specimens available, one of them (CAL 47573) housed in CNH, Kolkata, India is without any date of collection and collector's details, whereas there is an attached illustration of the reproductive parts drawn by King & Prain with the specimen. It evident from the letter of Young to David Prain dated 6 December 1899 and a confirmation slip that remained attached with the above voucher specimen. While the other flowering specimen (K000677305) has been housed in Royal Botanic Gardens, Kew (K) collected by Young from Dibrugarh but with a date of collection of 29 June 1900 and labelled as Isosyntype by P.F. Sturn in 1985. The whereabouts of the specimen of Barker referred to by Prain (1901) could not be ascertained as there are nine materials presently housed at Herbarium of the Forest School at Dehradun (DD) (DD 69649; DD 70659; DD 70660; DD 76170; DD 76171; DD 85505; DD 85506; & DD 85507 together with a collection of H.G. Young from Dibrugarh dated 06.xii.1899). Out of the voucher specimens housed at DD, there is only one collection of Young from Dibrugarh in 1899. As no types were designated specifically to *Mesua* (whereas, P.F. Sturn designated the types twice for the species, under the genus *Kayea*, once referring fruiting material in 1975 and flowering material in 1985), lectotypification is therefore necessary in this study (Deka et al. 2018). Kostermans (1969) while transferring the species *Kayea assamica* to *Mesua* mentions specimens of both Young and Barker housed at BM, G, and K, but he or any of the subsequent workers did not designate any of these specimens as Lectotype.

Out of the five specimens collected by H.G. Young

Figure 1. Lectotype of *Mesua assamica* (King & Prain) Kosterm., H.G.Young (K000677304), © The Board of Trustees of the Herbarium of Royal Botanic Gardens, Kew (K).

Table 1. List of all specimens examined.

	Herbarium	Collector	Studied material
1	CAL	-	s.n. (47573, CAL)
		H.G. Young	Assam, Dibrugarh, December, 1899, H.G. Young (47574, CAL)
			Assam, Dibrugarh, December, 1899, H.G. Young (47575, CAL)
			Assam, Dibrugarh, December, 1899, H.G. Young (s.n., CAL)
2	G	H.G. Young	Assam, Dibrugarh, December, 1899, H.G. Young (G00355757, G)
3	BM	H.G. Young	Assam, Dibrugarh, December, 1899, H.G. Young (BM000611295, BM)
4	K	H.G. Young	Assam, Dibrugarh, December, 1899, H.G. Young (K000677304, K)
			Assam, Dibrugarh, 06.xii.1899, H.G. Young (DD)
			Assam, Dibrugarh, 24.vi.1900, H.G. Young (K000677305, K)
5	DD	Range officer, Tinsukia Range	Assam, Lakhimpur dist., loc. Dibru Reserve, Tinsukia Range, Range officer, 70659 (DD)
			Assam, Lakhimpur dist., loc. Dibru Reserve, Tinsukia Range, 21.ix.1935, Range officer, 70660 (DD)
		Range officer, North Lakhimpur Range	Assam, North Lakhimpur Range, December, 1937, Range officer, 76170 (DD)
			Assam, North Lakhimpur Range, December, 1937, Range officer, 76171 (DD)
			Assam, North Lakhimpur Range, Range officer, 85505 (DD)
			Assam, North Lakhimpur Range, Range officer, 85506 (DD)
		S.K. Dutta	Assam, North Lakhimpur, 26.v.1940, S.K. Datta, 85507 (DD)
6	ASSAM	U. Kanjilal	Assam, Lakhimpur dist., loc. Dulong Reserve Forest, 24.iii.1914, Alt. 310 ft., U. Kanjilal, 3678 (ASSAM)
			Assam, Lakhimpur dist., loc. Dulong Reserve Forest, 24.iii.1914, Alt. 310 ft., U. Kanjilal, 3678 (ASSAM)
			Assam, Lakhimpur dist., loc. Dulong Reserve Forest, 24.iii.1914, Alt. 310 ft., U. Kanjilal, 69649 (DD)
			Assam, Lakhimpur dist., loc. Dirju, 06.iv.1914, Alt. 300 ft., U. Kanjilal, 4398 (ASSAM)
			Assam, Lakhimpur dist., 18.vii.1932, U. Kanjilal, 10256 (ASSAM)
		N. Odyuo & D.K. Roy	Assam, North Lakhimpur, loc. Kakoi Reserve Forest, Block Nala Hill top, 11.ii.2011, Alt. 196 m., N. Odyuo & D.K. Roy, 121241 (89633, ASSAM)
			Assam, North Lakhimpur, loc. Kakoi Reserve Forest, Block Nala Hill top, 11.ii.2011, Alt. 196 m, N. Odyuo & D.K. Roy, 121241(89634, ASSAM)
		N. Odyuo	Assam, North Lakhimpur, loc. Dullung Reserve Forest, Ghokor 2, 07.v.2011, Alt. 250 m., N. Odyuo, 122387 (89648, ASSAM)
			Assam, North Lakhimpur, loc. Dullung Reserve Forest, Ghokor 2, 07.v.2011, Alt. 250 m., N. Odyuo, 122387 (89649, ASSAM)
			Assam, North Lakhimpur, loc. Dullung Reserve Forest, Ghokor 2, 07.v.2011, Alt. 250 m., N. Odyuo, 122387 (89650, ASSAM)
		D.K. Roy & N. Odyuo	Assam, North Lakhimpur, loc. Dullung Reserve Forest, Pathalipam, 17.ix.2011, D.K. Roy & N. Odyuo, 123113 (89647, ASSAM)
		N. Odyuo & R. Daimary	Assam, North Lakhimpur, loc. Dullung Reserve Forest, Ghokor 1, 21.v.2012, Alt. 120 m., N. Odyuo&R. Daimary, 126669 (89635, ASSAM)
			Assam, North Lakhimpur, loc. Dullung Reserve Forest, Ghokor 1, 21.v.2012, Alt. 120 m., N. Odyuo & R. Daimary, 126669 (89636, ASSAM)
		P. Sharma Baruah	Assam, North Lakhimpur, loc. Dullung Reserve Forest, Pathalipam, 23.iv.2016, P. Sharma Baruah, 1(92897, ASSAM)
			Assam, North Lakhimpur, loc. Dullung Reserve Forest, Pathalipam, 23.iv.2016, P. Sharma Baruah, 1(92898, ASSAM)
			Assam, North Lakhimpur, loc. Dullung Reserve Forest, Pathalipam, 23.iv.2016, P. Sharma Baruah, 1(92899, ASSAM)

Abbreviations: CAL—Central national Herbarium/Calcutta Herbarium | G—Geneva Herbarium | BM—The Natural History Museum | K—Kew Herbarium | DD—Herbarium of the Forest Research Institute, Dehra Dun | ASSAM—Eastern Regional Centre, Shillong, BSI (Botanical Survey of India).

from Dibrugarh on 06.xii.1899, one specimen presently housed at Kew (K000677304), three specimens are housed at CAL (CAL 47574; CAL 47575; and CAL s.n.) and one specimen housed at DD (DD s.n.). Further, the flowering specimen presently housed at CAL (CAL 47573) was supposed to be used while describing the species, but is presently in a dilapidated condition except the illustration attached to it. Even after rigorous search we were unable to locate Barker's specimens. Therefore, after consulting the protologues and study

of all the original specimens examined by King & Prain, the fruiting specimen of the taxa housed at Kew (K000677304) collected by H.G. Young from Dibrugarh in 06.xii.1899 agreed with the description provided in the protologue and hence selected as the lectotype and specimens housed at CAL (CAL 47574; CAL 47575; & CAL s.n.) and the specimen housed at DD (DD s.n.) have been selected as isolectotypes.

Lectotypification: *Mesua assamica* (King & Prain) Kosterm., *Reinwardtia*, 7: 426 (1969).

Lectotype (designated here): INDIA. Assam: Dibrugarh, December 1899, H.G. Young (K000677304); isolectotypes (CAL 47574; CAL 47575; CAL s.n.; & DD s.n.).

References

Baruah, P.S., S.K. Borthakur & B. Tanti (2016). Conservation of *Mesua assamica* (King and Prain) Kosterm-an endangered plant of Assam. *NeBIO* 7(1): 17–22.

Baruah, P.S., K. Deka, B. Sarma, P. Das, S.K. Borthakur & B. Tanti (2017). Assessment of few unexplored RET plant wealth of Assam, India. *Journal of Advanced Plant Sciences* 9(2): 10–15.

Baruah, P.S., S.K. Borthakur & B. Tanti (2020). Preventing extinction and improving conservation status of *Mesua assamica* (King & Prain) Kosterm. - An endangered plant of Assam, India. *Acta Ecologica Sinica* 40: 185–189.

Chaudhuri, A.B. (2007). *Endangered Medicinal Plants*. Daya Publishing House, Delhi, 323pp.

Deka, K., S.K. Borthakur, C. Nepi & B. Tanti (2018). Lectotypification of *Calamus nambariensis* (Arecaceae). *Nordic Journal of Botany* 36(10): e01953. https://doi.org/10.1111/njb.01953

Kanjilal, U.N., P.C. Kanjilal, A. Das & C. Purakayastha (1934). *Flora of Assam*. Vol-1. Bishen Singh Mohendra Pal Singh, Dehradun, India, 113pp.

Kostermans, A.J.G.H. (1969). *Kayea* Wall. and *Mesua* L. (Guttiferae). *Reinwardtia* 7: 426–431.

Prain, D. (1901). A new Assam Timber Tree. *The Indian Forester* 27(2): 61–62.

Sharma, B.D., M. Sanjappa & N.P. Balakrishnan (1993). *Flora of India*. Vol. 3. Botanical Survey of India, Kolkata, 639pp.

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NOTE

On the rediscovery of a rare root parasite *Gleadovia ruborum* Gamble & Prain (Orobanchaceae) from Uttarakhand, western Himalaya, India

Amit Kumar [1], Navendu V. Page [2], Bhupendra S. Adhikari [3], Manoj V. Nair [4] & Gopal S. Rawat [5]

[1,2,3,5] Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248002, India.
[4] Lal Bahadur Shastri National Academy of Administration, Mussoorie, Uttarakhand 248179, India.
[1] amit@wii.gov.in, [2] navendu@wii.gov.in, [3] adhikaribs@wii.gov.in (corresponding author), [4] manojnair74@gmail.com, [5] rawatg@wii.gov.in

The family Orobanchaceae Vent. comprising ca. 2,060 species under 90 genera are distributed across all continents except Antarctica (McNeal et al. 2013). Commonly known as the broomrape family, Orobanchaceae includes holoparasites (non-photosynthetic) that depend on their hosts and hemi-parasites (photosynthetic), most of which were earlier kept in Scrophulariaceae. *Pedicularis* L. with ca. 600 species (Li et al. 2019) followed by *Euphrasia* L. (250–300 species), *Castilleja* Mutis ex L.f. (200–210 species), *Buchnera* L. (130–140 species), and *Orobanche* L. (80–100 species) are the largest genera under this family (POWO). The genus *Gleadovia* Gamble & Prain, a member of Orobanchaceae is native to the western and eastern Himalaya in India and southwestern Yunnan to western Hunan, China. Described by J.S. Gamble and D. Prain in 1900, *Gleadovia* is currently represented by four species namely *G. ruborum* Gamble & Prain (type species; Uttarakhand in western Himalaya, India and China: 1900), *G. mupinensis* Hu (China: 1939), *G. banerjiana* Deb (Manipur, India: 1957) and *G. konyakianorum* Odyuo, D.K. Roy & Aver. (Nagaland, India: 2017).

During a recent floristic exploration (June–July 2020) in and around Surkanda in the outer Himalayan range of Uttarakhand, western Himalaya, an interesting plant species of family Orobanchaceae was observed. Detailed study of the characters observed in the field, scrutiny of literature (Gamble & Prain 1900; Issar 1966; Wu & Raven 1998; Agarwal 2017; Roy 2017) and examination of online herbarium specimens at Kew (J.S. Gamble, 26949K! (K000999865 and K000999866)) and DD (Osmaston, 23093; Charlton Thomas, 20794) revealed that the taxon is a rare root parasite, *Gleadovia ruborum*, a species previously known only from three localities (Figure 1). The species was originally collected by M.F. Gleadov in 1898 and later described by J.S. Gamble and D. Prain in 1900 from Bodyar (Budher) near Chakrata, Uttarakhand. The species was recollected from the same locality by Osmaston in 1900. Later, it was also collected by Charlton Thomas in 1951 from Balate valley in eastern Almora (now in Pithoragarh district), Kumaon and Ramesh Bedi in 1964 (GKV 1234) from Yamuna Forest Division, Garhwal (Issar 1966).

The plant specimen of *G. ruborum* along with roots of the host, *Rubus pedunculosus* has been preserved (wet specimen) following standard methods and deposited at the herbarium of the Wildlife Institute of India, Dehradun (WII). Detailed information on the distribution range,

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known host, habitat, elevation range and phenology of *Gleadovia* species are provided in Table 1.

Gleadovia ruborum Gamble & Prain, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 69(2): 489 (1900).

Type: Northwestern Himalaya. Bodyar Jaunsar, 2,500–3,000 m; on the northern slopes in very shady forest of Fir and Deodar on the roots of wild Raspberry *Rubus niveus*; very scarce, Gleadov! Gamble! Duthie! Duthie's collectors!

Lectotype (Roy 2017): India. Erstwhile Uttar Pradesh Hills (now Uttarakhand): northwestern Himalaya, Jaunsar, Bodyar (on the northern slopes in very shady woods of Fir and Deodar), 2,500–3,000 m, June 1898, J.S. Gamble 26949-K! (K000999865); Isolectotypes-K! (K000999866); CAL! (Acc. No. 329959).

Fleshy, root-parasitic herb 10–18 cm high. Rootstock bulbous and swollen at the point of attachment with the host root. Stem largely sub-terranean, with ovate scales; lower scales rounded, upper oblong and sometimes bifid. Flowers in dense corymbose or paniculate inflorescences at the end of stem. Pedicel stout ca. 0.8cm long. Bracts solitary, ca. 1.5 cm long, sheathing, rounded; bracteoles two, 1.5–2.5 cm long, spatulate, acute, concave. Calyx 2.5–3 cm long, light red, tubular, somewhat inflated, equally five-lobed, lobes rounded, divided to less than half the tube length. Corolla up to 5 cm long, white at the base, reddish towards the apex, with dark longitudinal veins; tube much longer than the calyx, slightly curved, two-lipped; upper lip of two connate, rounded, lobes; lower lip of three narrow, acute lobes. Stamens 4; filaments bent at point of insertion; anthers spurred, connectives produced beyond the anther lobes, 3-fid at the apex. Ovary one-celled, ovate. Style shorter than the filaments; stigma of two fleshy, semi-orbicular lobes depressed in the centre; placenta 2 pairs, free below and above, confluent in the middle; ovules numerous. Seeds numerous, minute.

Etymology: Genus *'Gleadovia'* is dedicated to M.F. Gleadov who was first to discover it in 1898 and *'ruborum'* refers to red corolla with darker veins.

Specimen examined: 22201 (WII, wet collection of flowers), 20.vi.2020, India, Uttarakhand, Surkanda hill

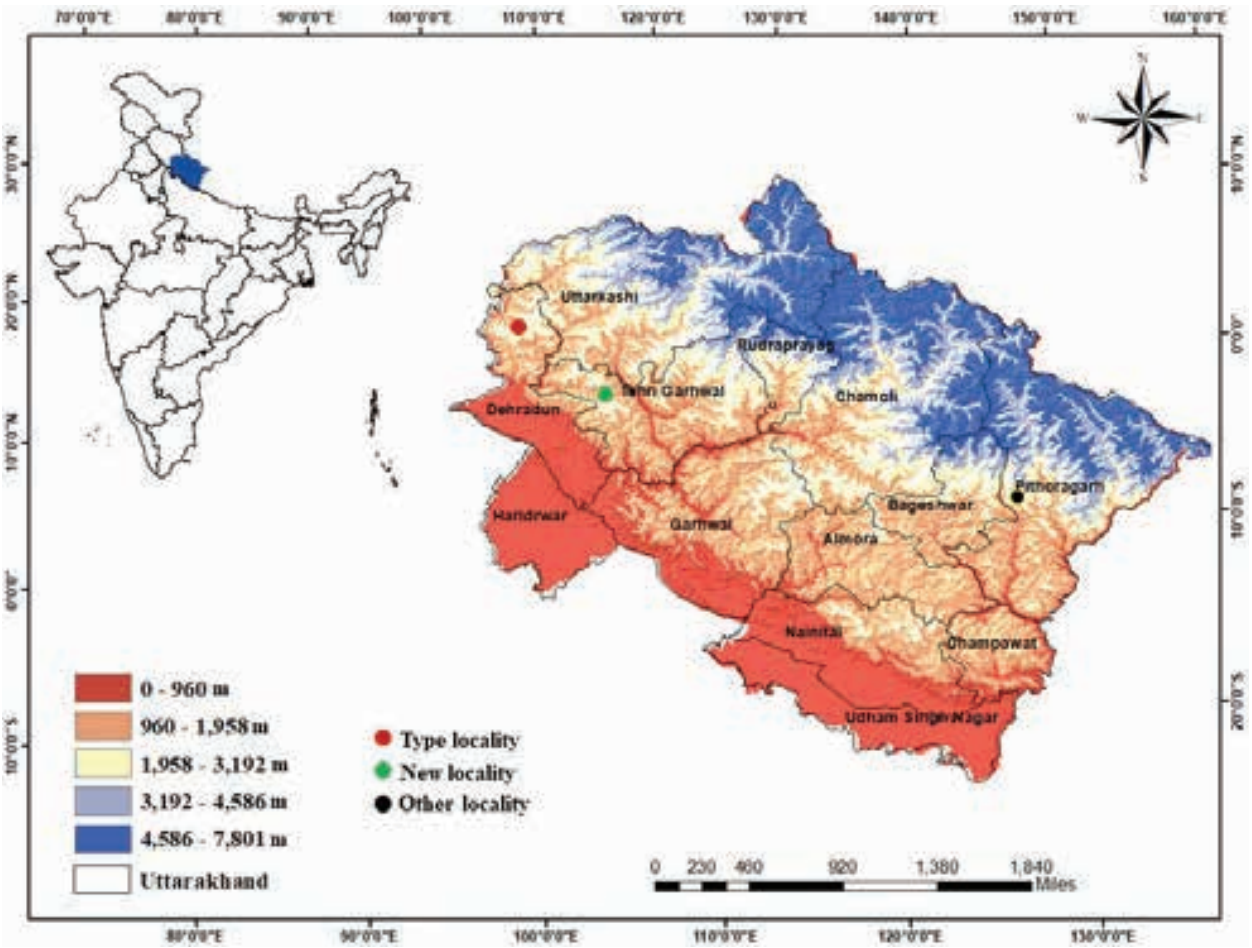

Figure 1. Map showing distribution of *Gleadovia ruborum* in Uttarakhand, India.

Table 1. Distribution range, habitat, host, elevation range, and phenology of *Gleadovia* species.

Species	Distribution range	Habitat	Host	Elevation (m)	Flowering (fl.) and fruiting (fr.)	Reference
Gleadovia ruborum	Chakrata (Budher) and Mussoorie hills (Surkanda) in Uttarakhand, western Himalaya, India	Northern slopes in very shady *Cedrus deodara - Abies pindrow* and *Abies pindrow - Quercus floribunda* forests	Roots of wild raspberry, *Rubus pedunculosus*	2,500–3,000	Jun–Jul (fl.), Jul–Aug (fr.)	Gamble & Prain (1900), Issar (1966), Agarwal (2017), Roy (2017), present study
	Southwestern Yunnan to western Hunan, China	Temperate rainforest under bamboo; humid places in forests or thickets	Not ascertained	900–3,500	Apr–Aug (fl.), Aug–Oct (fr.)	Gamble & Prain (1900), Wu & Raven (1998)
Gleadovia mupinensis	Southcentral and Southeastern China	Roadsides, forests and humid places	Not ascertained	3,000–3,500	Apr–Jul (fl.)	Hu (1939), Wu & Raven (1998)
Gleadovia banerjiana	Koubru hill, Manipur, India	-	Roots of *Strobilanthes discolor*	1,800–2,000	-	Deb (1956)
Gleadovia konyakianorum	Nagaland, India	Semi-evergreen forest	Roots of *Strobilanthes* sp.	1,500–1,600	Apr (fl)	Odyuo et al. (2017)

near Mussoorie of Tehri Garhwal district, 30.415^{0}N, 78.280^{0}E, 2,450 m, coll. N. Page, A. Kumar, B.S. Adhikari & G.S. Rawat; 22202 (WII, wet collection of the fruiting specimen along with rootstock of host plant), 08.vii.2020, India, Uttarakhand, Surkanda hill near Mussoorie of Tehri District, 30.415^{0}N, 78.280^{0}E, 2,450m, coll. N. Page, A. Kumar, B.S. Adhikari & G.S. Rawat (Image 1).

Distribution range, host, and habitat: *G. ruborum* was first recorded in shady forest at Bodyar or Budher in Jaunsar, Dehradun district at 2,500 m above mean sea level by M.F. Gleadov in 1898 (Gamble & Prain 1900). Interestingly, it shows disjunct distribution as it has also been reported in northern Guangxi, Hubei, western Hunan and southwestern Yunnan areas of China (Hu 1939; eflora China). Notably, it has not been recorded anywhere else from India and China (Agarwal 2017). Issar (1966), Roy (2017), and Osmaston (1900) had recorded *Glaedovia ruborum* on the roots of *Rubus pedunculosus* (*R. niveus* Wall. ex. Hook; Agarwal 2017). Agarwal (2017) studied the flora of Chakrata hills in detail but he could not locate populations of *G. ruborum* in its type locality despite best efforts. In Surkanda (the new locality), all the four individuals were recorded on the roots of *Rubus pedunculosus* in *Abies pindrow-Quercus floribunda* forest at 2,450 m on northern slopes. The common species recorded in the vicinity (314 m^2) of *Gleadovia* were *Quercus floribunda, Abies pindrow, Viburnum cotinifolium, Daphne papyracea, Salix denticulata, Rosa macrophylla, Hypericum oblongifolium, Senecio rufinervis, Roscoea purpurea*, and *Geranium wallichianum.*

Conservation status: *G. ruborum* has been assessed as 'rare' and 'extremely rare' by Issar (1966) and Agarwal (2017), respectively. The IUCN conservation status of this species is yet to be assessed.

In the current communication, we report a new locality of *G. ruborum* at 2,450 m in Surkanda near Mussoorie of Tehri Garhwal district, Uttarakhand. The present collection marks the rediscovery of the species after a gap of 57 years from a new locality in the Uttarakhand, western Himalaya. The new location is approximately 60km from the type locality. Intensive surveys in the right season, in temperate and sub-alpine shady moist forests with a dense undergrowth of *Rubus pedunculosus* may yield more distributional records and better understanding of its distributional range.

REFERENCES

Agarwal, S.K. (2017). *Flora of Jaunsar-Bawar (Chakrata Hills, Western Himalaya): with ethno-botanical notes*. Bishen Singh Mahendra Pal Singh, Dehradun, 1001pp.

Deb, D.B. (1957). A new species of *Gleadovia* Gamble et Prain from Manipur. *Journal of the Bombay Natural History Society* 54(3): 799–801.

Gamble, J.S. & D. Prain (1900). Description of a new Himalayan genus of Orobanchaceae. *Journal of the Asiatic Society of Bengal* 69(2): 488–489.

Hu, H.H. (1939). On the genus *Gleadovia* in China. *Sunyatsenia* 4(1–2): 1–9.

Issar, R.K. (1966). A note on the occurrence of *Gleadoviaruborum* a rare Himalayan genus. *The Indian Forester* 92(2): 131–132.

Li, X., H. Wang, L. De-Zhu & Y. Wen-Bin (2019). Taxonomic and nomenclatural notes on *Pedicularis* (Orobanchaceae): I. One new species from north-west Yunnan, China. *Phytokeys* 130: 205–215. https://doi.org/10.3897/phytokeys.130.35258

McNeal, J.R., J.R. Bennett, A.D. Wolfe & S. Mathews (2013). Phylogeny and origins of holoparasitism in Orobanchaceae. *American Journal of Botany* 100(5): 971–983.

Plants of the World Online (POWO). Available from https://www.plantsoftheworldonline.org (accessed 1 April, 2021).

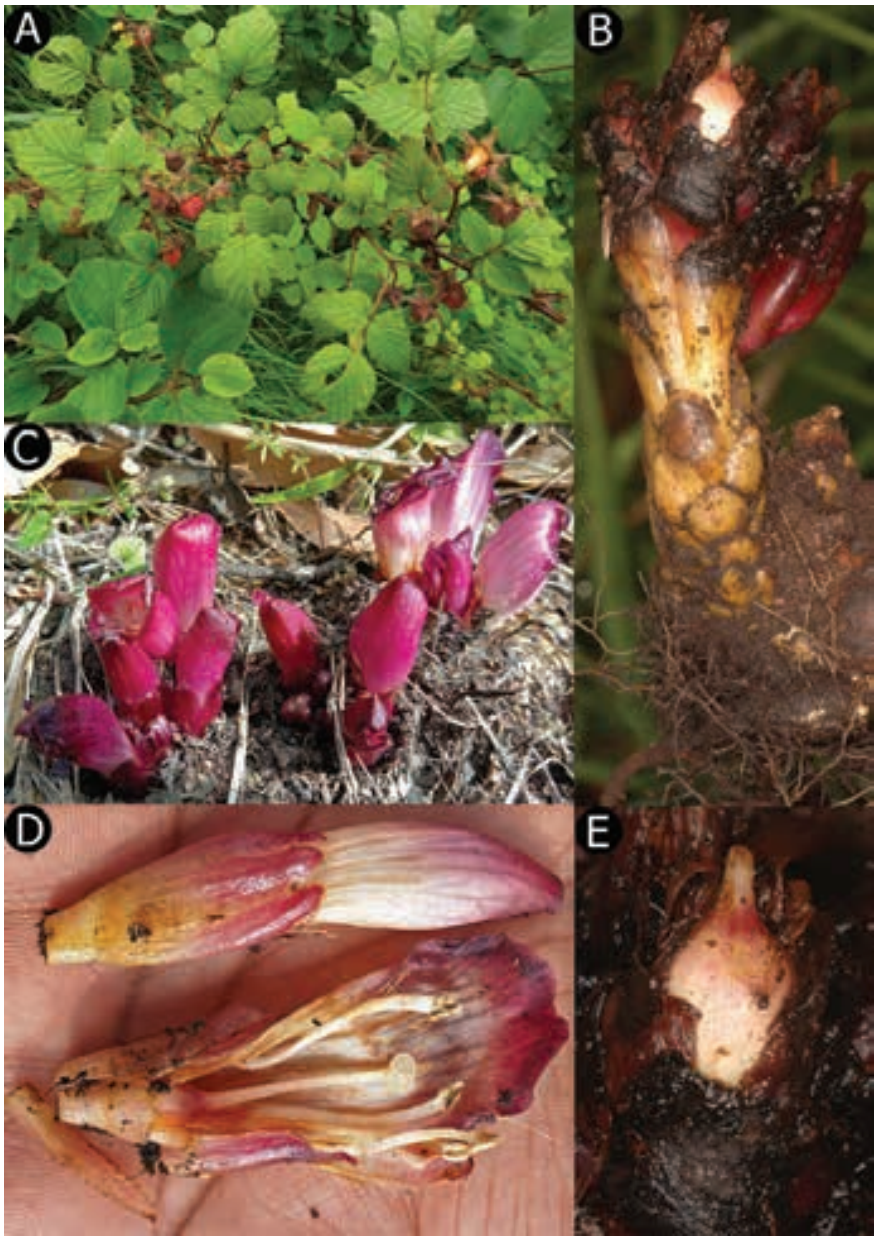

Image 1. Host and habit of *Gleadovia ruborum*: A—*Rubus pedunculosus* - the host species (© Amit Kumar) | B—Habit showing scales on the stem (© Navendu Page) | C—Inflorescences and flowers (© B.S. Adhikari) | D—Section of the corolla showing the stamens, stigma and the ovary (© Navendu Page) | E—Close-up of fruit (© Navendu Page).

Roy, D.K. (2017). Lectotypification of the name *Gleadoviaruborum* Gamble & Prain (Orobanchaceae). *Phytotaxa* 323(2): 197–198. https://doi.org/10.11646/phytotaxa.323.2.9

Wu, Z.Y. & P.H. Raven (eds.) (1998). *Flora of China (Scrophulariaceae through Gesneriaceae).* Science Press, Beijing and Missouri Botanical Garden Press, St. Louis, 241pp.

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NOTE

Occurrence of vivipary in *Ophiorrhiza rugosa* Wall. (Rubiaceae)

Birina Bhuyan [1] & Sanjib Baruah [2]

[1,2] Department of Botany, Bodoland University, Kokrajhar, Assam 783370, India.
[1] birinabhuyan305@gmail.com, [2] sanjibbaruah9@gmail.com (corresponding author)

Ophiorrhiza rugosa Wall. (Family Rubiaceae), a highly valuable medicinal herb and a potential source of Campothecin (CPT) used as an anticancer alkaloid producing plant (Gharpure et al. 2010). There are many natural varieties of *O. rugosa* Wall., which are now considered as strong candidates for the CPT (Hsiang et al. 1985; Vineesh et al. 2007).

Vivipary is the process-by which seeds germinate within the fruits followed by embryo development before the seeds are dispersed from the parent plant. Vivipary has been considered as a precocious germination, relatively unusual phenomenon in angiosperms (Farnsworth 2000).

Here, we report an unusual occurrence of the viviparous germination of seeds of *Ophiorrhiza rugosa* in the wild. This rare phenomenon was observed during the field visit to Karbi Anglong District, Assam in the last week of May 2019. The sites were located in 25.954^{0}N and 92.603^{0}E, at 128m. The rainy season in this area is with 90% of the rainfall during April–June (60–70 days). On an average, the area receives 1,400–2,000 mm of rainfall; and the soil is clayey loam.

The authors observed an occurrence of the true viviparous germination in the plant growing on hill slopes (Image 1). The plant is fully grown and contains the mature capsules. The capsules of the plant contain two halves and the seedlings were growing within the halves. The germination of seeds was epigeal and one capsule contains an average of 4–5 seedlings (Image 2D). Of the total seeds in a capsule, 75% showed viviparous germination. The species which show viviparous germination were collected during a period of almost continuous rainfall in the region. The location of plant was along the sloppy mountain where splash water could easily accommodate the capsule which might be triggered the germination inside the capsule. We presume that due to continuous precipitation and splashing of water from the stream resulting in inducing vivipary in the species. It has been suggested that vivipary is a specialized feature of evolutionary and biological importance that ensures survival of plant (Cota-Sanchez 2004). The results may be useful in large-scale propagation to meet increasing CPT demand and conservation of this valuable medicinal herb.

References

Cota-Sanchez, J.H. (2004). Vivipary in the Cactaceae: Its taxonomic occurrence and biological significance. *Flora - Morphology Distribution Functional Ecology of Plants* 199(6): 481–490. https://doi.org/10.1078/0367-2530-00175

Farnsworth, E. (2000). Ecology and Physiology of Viviparous and RecalcitrantSeeds. *Annual Review of Ecology and Systematics* 31: 107–138. https://doi.org/10.1146/annurev.ecolsys.31.1.107

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Image 1. The collection site of the plant.

Gharpure, G., B. Chavan, U. Lele, A. Hastak, A. Bhave, N. Malpure, R. Vasudeva & A. Patwardhan (2010). Camptothecin accumulation in *Ophiorrhizarugosa* var. *prostrata* from northern Western Ghats. *Current Science* 98(3): 302–304.

Hsiang, Y.H., R. Hertzberg, S. Hecht & L.F. Liu (1985). Camptothecin induces protein-linked DNA breaks via mammalian DNA topoisomerase I. *Journal of Biological Chemistry* 260(27): 14873–14878.

Vineesh, V.R., P.V. Fijesh, C.J. Louis, V.K. Jaimsha & J. Padikkala (2007). In vitro production of camptothecin (an anticancer drug) through albino plants of *Ophiorrhizarugosa* var. *decumbens*. *Current Science* 92(9): 1216–1218.

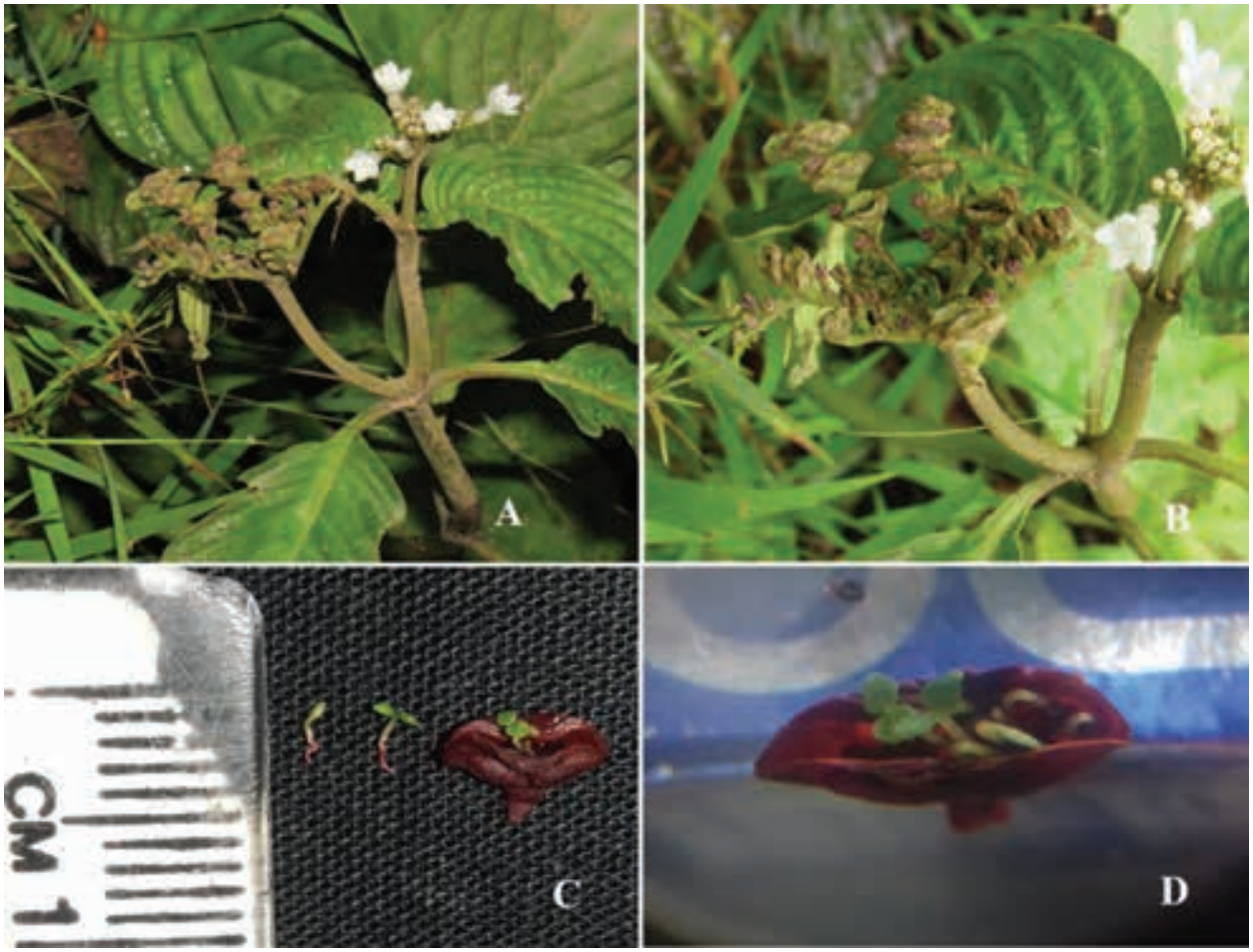

Image 2. Viviparous germination in *Ophiorrhiza rugosa* Wall: A—plant with inflorescence | B—fruits with viviparous germination | C—viviparous seedlings | D—viviparous seedlings arising from single capsule. © Birina Bhuyan.

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