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Cover: Giant Oceanic Manta Ray *Mobula birostris* in ink on acrylic wash by Elakshi Mahika Molur adapted from scientific illustration by Roger Hall.

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ARTICLE

Nesting habitat and nest directionality of the Indian Giant Squirrel *Ratufa indica maxima* (Schreber, 1784) (Mammalia: Rodentia: Sciuridae) in the Nelliyampathy Reserve Forest, Western Ghats, Kerala, India

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Abstract: The information on selection of nesting habitat and nest directionality for arboreal species is crucial in developing conservation and management plan for the species. We studied the factors which affect the nesting habitat selection and the nest orientation by using the quadrat sampling method in Nelliyampathy Reserve Forest, Kerala. A total of 119 nest sites were observed on 26 different tree species in four different habitat types. Around 56.30% and 36.13% of the nests were sighted in contiguous forests and plantation with native tree shade, respectively. Of the 119 nests, 112 were in trees of height up to 30 m. *Cullenia exarillata, Mesua ferrea*, *Actinodaphne malabarica*, and *Schleichera oleosa* accounted for 45.4% of the nest with 15.9%, 11.8%, 9.2% and 8.4% nests, respectively. About 24.4% of the nests were directed towards the north-east direction (n = 29) whereas least preferred direction was the south (n = 05). This shows that the nests are oriented towards sun rise and to avoid wind and rainfall of monsoon which is foreseen from the south-west direction.

Keywords: Arboreal, behavior, conservation, ecology, forest fragmentation, native tree plantation, nest orientation, nest tree selection, rain avoidance, sunlight preference.

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Author contributions: KM - conceived the idea and collected the data; KM, JJE, MS - analyzed the data; KM, JJE, MS - wrote the article.

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INTRODUCTION

An understanding of the costs and benefits of choosing a certain nest site and placing a nest entrance in a specific direction in arboreal mammals is still in its inception. Nest sites chosen based on specific criteria, most often improve concealment, which may increase nesting success by lowering the risk of predation (Pradhan et al. 2017). Young individuals are highly sensitive to environmental factors, and by reducing environmental extremes in the nest, adults are likely to improve the survival rate of their infants, and their own fitness (Murphy 1983; Webb & King 1983; Bekoff et al. 1987; Webb 1987; Martin 1988; Martin & Roper 1988). It is predicted that most nests are orientated in response to environmental conditions such as wind, precipitation, and in particular sun radiation (Haggerty 1995; Burton 2007).

Avian nesting sites have shown that there is a wide range of nest orientation and pattern among species and/or nesting guilds (e.g., open cup, domed nest, primary/secondary cavity nest). Although some studies have found little to no pattern in nest orientation (Albano 1992; Rendell & Robertson 1994; Tarvin & Smith 1995; Mennill & Ratcliffe 2004), many groups representing a variety of nest architectures do show considerable preferences in the orientation of their nests (Austin 1974; Walsberg 1981; Martin & Roper 1988; Bergin 1991; Hooge et al. 1999; Mezquida 2004). Most often, researchers have discovered that nest orientation is related to either prevailing winds (Norment 1993; Mezquida 2004) or sun exposure (Viñuela & Sunyer 1992; With & Webb 1993; Yanes et al. 1996; Rauter et al. 2002; Hartman & Oring 2003; Burton 2006), both of which may have an immediate impact on the microclimate of the nest (Hartman & Oring 2003; Ardia et al. 2006). In hot habitats near the equator, animals would be predicted to orient their nests to optimize shade during the day, when the sun and thus temperatures are at their maximum (Maclean 1984). Mid-latitude nests commonly face eastward since it may be less important to avoid the mid-day or afternoon sun there. Nests that face east rather than west may warm up more quickly in the morning (Nelson & Martin 1999), lessening the potential effects of low overnight temperatures on embryos and young. Nests may be pointed towards the equator at the highest latitudes to benefit from the greater insolation and warmth coming from that direction and lessen the consequences of a cold climate (Ojedat et al. 2021). But due to variations in nest-site parameters at any given latitude, there may be a significant difference in the preferred nest orientations within species. Hence, nest site and orientation are crucial elements of bird reproduction that may have an impact on embryonic development, hatching success, nestling growth (Austin 1974; Viñuela & Sunyer 1992; Lloyd & Martin 2004; Burton 2006) and overall nesting success (Martin & Roper 1988; Filliater et al. 1994; Rauter et al. 2002). With the context of avian nesting sites, we would like to investigate the nesting orientation of the Indian Giant Squirrel as well.

The Indian Giant Squirrel (IGS; *Ratufa indica maxima*) is a diurnal and arboreal species which is found only in peninsular India (Agrawal & Chakraborty 1979; Corbet & Hill 1992). Despite being widely distributed within its range, it is found in severely fragmented populations (Molur et al. 2005). The ecology of squirrels in Asian countries has received less focus, and available research is scarce (Pradhan et al. 2012; Borges 2015). It is a solitary species that only appears in pairs during the breeding season. During a single breeding season, it usually builds more than one nest, or drey. Recent studies on nesting tree selection in the IGS have shown that the most common and abundantly available tree species in the forest were preferred for nesting over random tree species (Rathod et al. 2022). The nests made of leaves and twigs are large, globular in shape with a lateral opening which are built on tall, profusely branched trees in the higher canopy (Ramachandran 1988; Borges 1989; Datta & Goyal 1996; Kumara & Singh 2006; Pradhan et al. 2017). The nesting trees were comparably taller species with interlinking crowns which allowed easy access and movement in the canopy, probably to avoid predators (Ramachandran 1988; Datta

Image 1. The Indian Giant Squirrel *Ratufa indica maxima*

& Goyal 1996). At the landscape level, the nest trees were found predominantly in the contiguous forests of evergreen, moist-deciduous and deciduous forests with abundant availability of food resources, and away from the agricultural fields.

Factors that influence nest-site selection, nest design, nest orientation, and the inter- and intra-specific variation of these behaviours in IGS are scarce. As a result, we investigated nest-site selection and nest orientation patterns in the IGS. Our goals were to find out (1) the nesting preferences of IGS, and (2) whether there is any directionality to its nest entrance.

MATERIALS AND METHODS

Study area

We carried out this study in Nelliyampathy Range of Nelliyampathy Reserve Forest (10.41–10.30 N & 76.58–76.75 E), Nemmara Forest Division in the Western Ghats in Palakkad District of Kerala (Figure 1). It covers an area of about 157 km^2 (Erinjery et al. 2018) with a vegetation of evergreen, semi-evergreen and moist deciduous forests with interspersed tea, coffee and cardamom plantations (Ramachandran & Suganthasakthivel 2010). The altitude ranges 500–1,633 m. The average rainfall is about 3,378 mm over a period of 10 years. The forest mainly consists of *Cullenia*, *Mesua* and *Palaquim*s species (Pascal 1988; Ramachandran & Suganthasaktivel 2010; Erinjery et al. 2015). Some of the arboreal species which belong to family Sciuridae found here are the Western Ghats Striped Squirrel *Funambulus tristriatus* Waterhouse, 1837, the Dusky Striped Squirrel *Funambulus sublineatus* Waterhouse, 1838., the Indian Giant Flying Squirrel *Petaurista philippensis* Elliot, 1839, Travancore Flying Squirrel *Petinomys fuscocapillus*, and the Indian Giant Squirrel (Ramachandran & Suganthasakthivel 2010; Kumara & Suganthasakthivel 2011; Babu et al. 2015).

Data collection

The habitat of the IGS nests was broadly divided into four different types namely contiguous forest (45 km^2, >60% canopy cover, dominated by evergreen and dry deciduous forest trees), fragmented forest (8 km^2, evergreen/dry deciduous forest patches are divided between open plantation), plantation with native tree shade (25 km^2, 30–60% canopy cover, mainly included coffee, cardamom plantations with native trees) and plantation with monoculture tree shade (17 km^2, >30% canopy cover, dominated by monoculture Teak and Silver Oak). The categorization of the habitat was derived from the high-resolution vegetation type and land-use map with accuracy >85% developed from Sentinel2 MSI 10 m spectral bands and Sentinel1 SAR bands, NDVI and Textural layers (Erinjery et al. 2018). We obtained the data on IGS nesting by Quadrat sampling method (Heltshe & Forrester 1983). The study area was divided into quadrats of 0.5 x 0.5 km^2. Based on the average home range of the IGS, the observer walked randomly in each quadrat looking for the nests of the IGS, and made sure that 75% of the pre-defined habitat types in the quadrat was sampled without overlapping. We did not conduct surveys in habitats such as open plantations, rocky mountains and grasslands as these habitat structures did not consist of any tree species. Thus, a total of 95 km^2 was only sampled and considered for the analysis. Only active IGS nest was considered for the analysis. It is difficult to differentiate between active and non-active nests of the IGS unless an individual is sighted using the nest. Active nests are the ones which are freshly built nests of lush green in colour and are highly dense and compact in structure, which makes it difficult to sight as they camouflage with the tree canopy. Over a period as twigs of the nest dry, it becomes easier to identify due to variation in the nest and canopy colour. Non-active nest consists only of dry leaves and twigs and the walls of the nest are very loosely arranged and mostly worn out. Nest location was recorded by using handheld GPS (Montana 650). Data on nesting tree species (the trees in which nests are constructed), height of the tree and height of the nest from the ground was recorded by using the laser range finder (HAWKE LRF 900). We collected data on nesting direction for which nest orientation readings was recorded by holding a compass directly below the nest and orienting it with the nest entrance. A statistical test was performed to know the independent variable which is contributing to the habitat selection between the above mentioned habitat types by chi square test followed by Marascuilo's post hoc test. The alpha level for all statistical tests was kept at 0.05. The average was represented as mean±standard deviation (SD) to understand the true variation of the data using SPSS 20.

RESULTS

Nest tree selection

A total of 119 nests (Table 1) of IGS were located on 26 tree species (Table 2). There were more than one or two nests in a single tree. The tree species with multiple nests were *Culenia exarillata, Artocarpus heterophyllus and Mesua ferrea.* The number of nests in contiguous

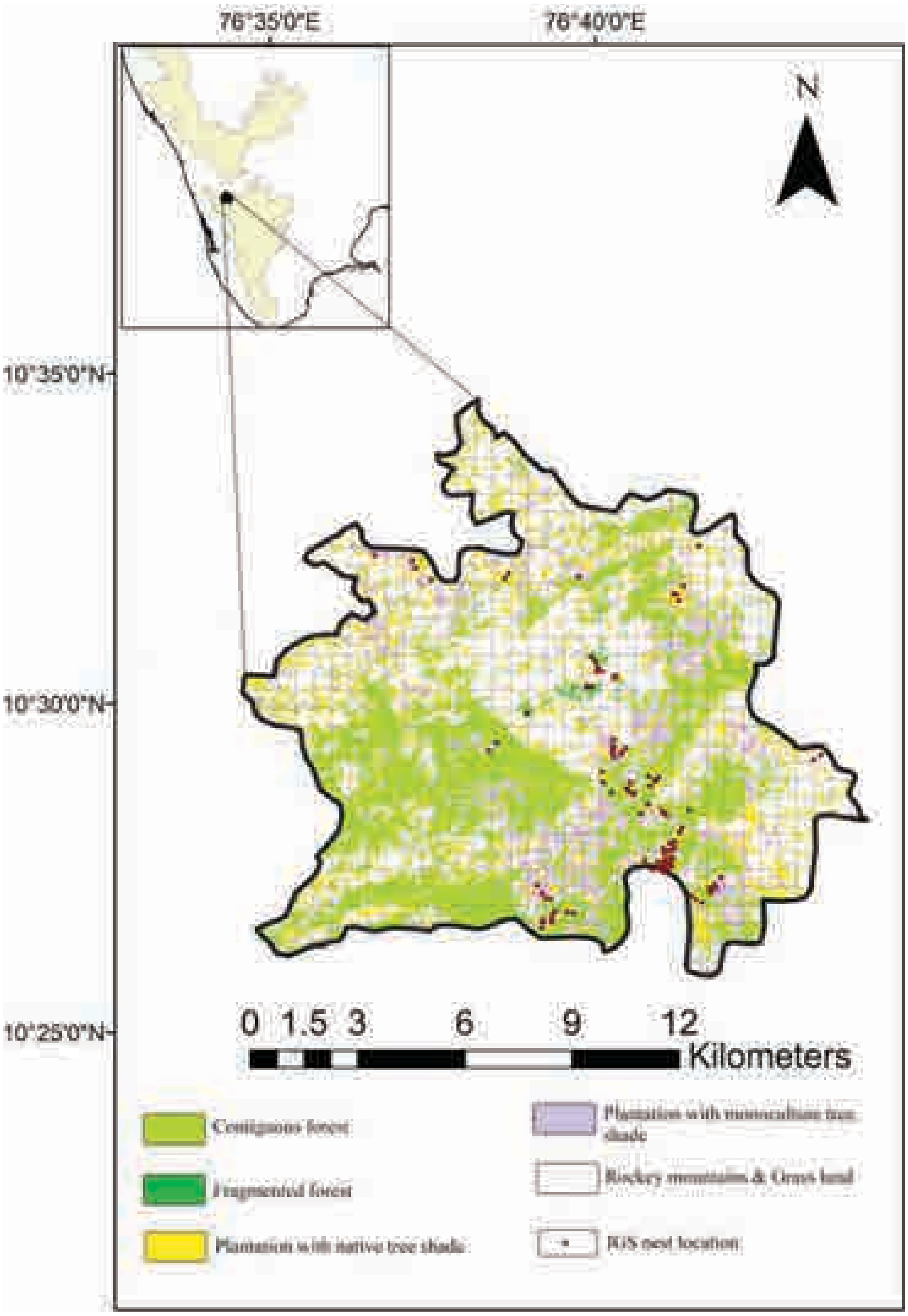

Figure 1. The study locality.

forests, fragmented forests, plantation with native tree shade and plantation with monoculture tree shade was 67, 4, 43, and 5, respectively, and the density of 1.48 nests/km^2, 0.5 nests/km^2, 1.72 nests/km^2, and 0.29 nests/km^2, respectively in these habitat types varied significantly ($\chi^2 = 45.9$ df = 3 p <.01). Plantation with native tree shade and contiguous forest accounted for 81% of the nests. IGS were observed to nest on 26 tree species (Table 2) and the number of nests per tree species varied

Table 1. Preferred habitat types of the Indian Giant Squirrel for nesting.

Habitat type	Number of nests	Density of the nest per sq. km.	Percentage (%)
Contiguous forest	67	1.48	56.30
Fragmented forest	04	0.5	3.36
Plantation with native tree shade	43	1.72	36.13
Plantation with monoculture tree shade	05	0.29	4.20

Table 2. Tree species and nesting height preference by Indian Giant Squirrel.

	Tree species	Tree height (m ± SD)	Nest height (m ± SD)	Percentage (%)
1	*Actinodaphne malabarica*	25 ± 9.98	24 ± 9.45	9.24
2	*Aglaia bourdillonii*	40 ± 0	38 ± 0	0.84
3	*Aglaia malabarica*	24.66 ± 1.52	22.33 ± 1.52	2.52
4	*Artocarpus heterophyllus*	18 ± 3.03	17.5 ± 2.42	5.04
5	*Cedrela toona*	25.5 ± 4.24	22.12 ± 2.69	6.72
6	*Cinnamomum malabatrum*	18 ± 0	17 ± 0	0.84
7	*Cordia gharaf*	22 ± 0	21 ± 0	0.84
8	*Cullenia exarillata*	23.12 ± 4.96	21.73 ± 5.69	15.96
9	*Drypetes malabarica*	16 ± 3.46	13.66 ± 4.93	2.52
10	*Dysoxylum malabaricum*	15 ± 4.24	13.5 ± 4.94	1.68
11	*Ficus beddomei*	16 ± 0	13.5 ± 0.70	1.68
12	*Ficus racemosa*	20.66 ± 4.61	19.66 ± 3.78	2.52
13	*Ficus talbotii*	25.33 ± 4.61	23.66 ± 4.16	2.52
14	*Garcinia gummi-gutta*	18 ± 0	18 ± 0	0.84
15	*Holoptelea integrifolia*	17 ± 4.24	15.5 ± 3.53	1.68
16	*Macaranga peltata*	16 ± 3.46	14.33 ± 3.05	2.52
17	*Mangifera indica*	18 ± 0	16 ± 1.41	1.68
18	*Mesua ferrea*	22.57 ± 7.77	21 ± 7.22	11.76
19	*Myristica dactyloides*	20.5 ± 5	19 ± 4.83	3.36
20	*Neolitsea scrobiculata*	23 ± 0	21 ± 0	0.84
21	*Palaquium ellipticum*	23 ± 10.39	20 ± 8.12	3.36
22	*Persea macrantha*	22.6 ± 3.43	21.6 ± 2.88	4.20
23	*Pleurostylia opposita*	20.8 ± 4.60	19.6 ± 4.03	4.20
24	*Polyalthia longifolia*	23.75 ± 6.13	21.25 ± 6.13	3.36
25	*Schleichera oleosa*	21.3 ± 5.33	19.2 ± 5.63	8.40
26	*Vernonia monosis*	21 ± 7.81	18.33 ± 7.23	2.52

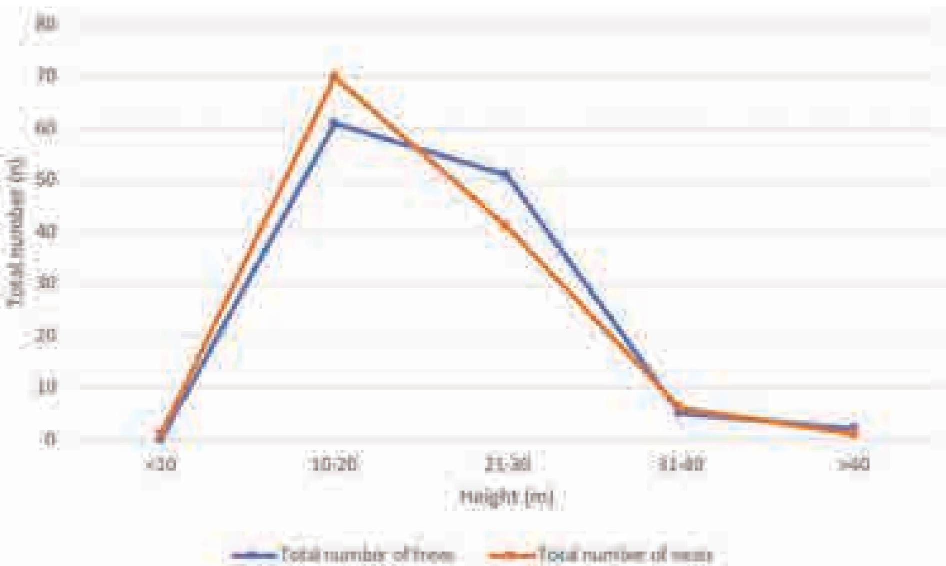

Figure 2. Different height class of nesting trees and Indian Giant Squirrel nests.

significantly (χ^2 = 95.07 df = 25 p <.01). However, only four tree species including *Culenia exarillata, Mesua ferrea*, *Actinodaphne malabarica*, and *Schleichera oleosa* accounted for 45.36% of the nests with 15.96%, 11.76%, 9.24%, and 8.40% nests, respectively (Table 2). Table 2 shows the frequency in various class height on which nests were observed. The squirrels made nests in trees of height classes of <10 m, 10–20 m, 21–30 m, 31–40 m, and >40 m with a frequency of 0, 61, 51, 5, and 2, respectively, which differed significantly (χ^2 = 117.89 df = 3 p <.01). Likewise, the number of nests in nest height categories of <10 m, 11–20 m, 21–30 m, 31–40 m, and >40 m was 1, 70, 41, 6, and 1, respectively, which significantly varied (χ^2 = 121.71 df = 4 p <.01). The tree height and the nest height correlated significantly (Pearson r = 0.96 N = 5 p <.01) (Figure 2) showing that most nests were in trees of height up to 30 m with similar nest height numbers indicating that the nests were towards the tree canopies.

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Nest characteristics

The IGS builds globular nests out of green leaves, twigs, and branches. The nests were either round or oval in shape with a lateral opening. The nests were usually constructed away from the tree trunk where the canopies were interlocked with the neighboring tree canopies. The entry of the nest was placed horizontal to the ground. Most of the nests were constructed by using the tender leaves of the nesting trees itself. However, squirrels also used the leaves of other plant species such as *Mallotus tetracoccus* and *Pouteria campechiana* in the construction of the nests. The number of nests in different directions (Figure 3) varied significantly (χ^2 = 27.06 df = 7 p <.01). Most of the nests sighted in the study area were observed facing towards the north-east direction (n = 29) followed by east (n = 23), and south-west (n = 17) whereas least preferred direction was towards the south (n = 05) (Figure 3). Nests were very often found at the highest point on the tree (Table 2).

DISCUSSION

Preference for nesting habitat could depend on factors such as access to nesting material, nest safety, branching pattern of the tree species, and availability

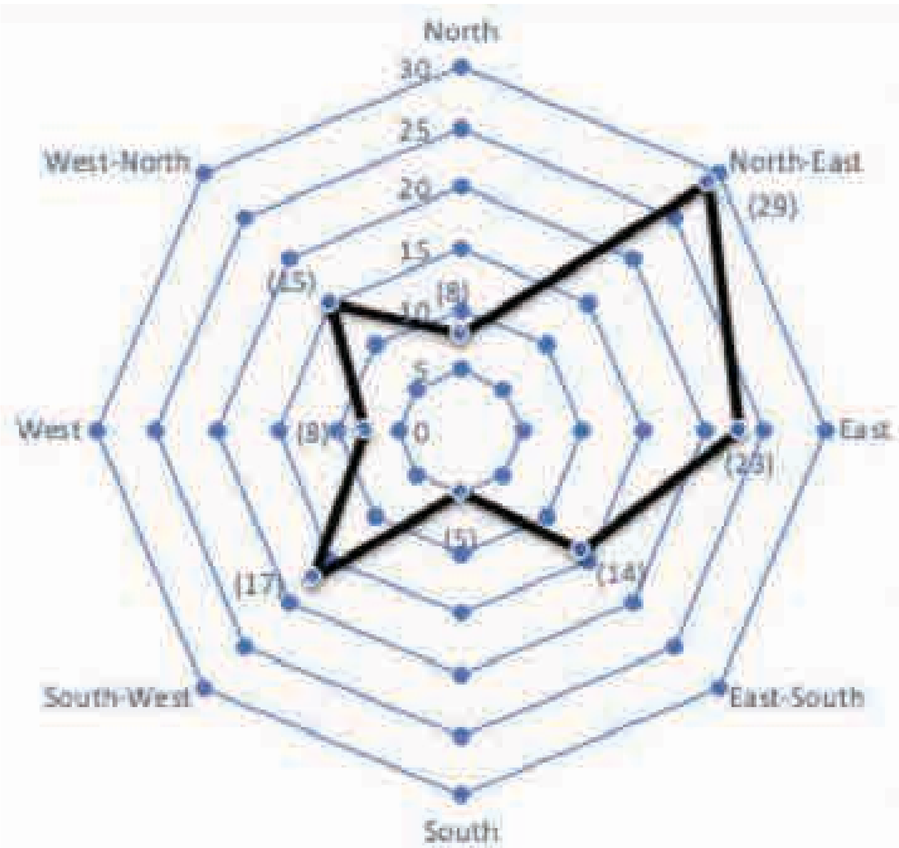

Figure 3. Directionality of the Indian Giant Squirrel nests in the Nelliyampathy Reserve Forest.

of food. A total of 26 tree species were recognized as nesting trees of the IGS in Nelliyampathy Reserve Forest of which *Culenia exarillata, Mesua ferrea*, *Actinodaphne malabarica*, and *Schleichera oleosa* were highly preferred for nesting. The high preference of these species maybe because of the dense canopy and higher canopy height which facilitates the IGS for easy movement from the nest in all directions (Ramachandran & Suganthasakthivel 2010). There is also the major advantage to escape from predators and to move to other parts of the home range for foraging and other activities through the canopy (Datta & Goyal 1996; Arockianathan 2020). In addition to that, most of the species of trees which is preferred for nesting accounts for the major diet of the IGS as well. Given the fact that the IGS prefers to feed as soon as they get out of the nests in the dawn and to feed before entering the nests in the dusk (Ramachandran 1988), they prefer mostly to build nests in the same trees which they feed on frequently. This helps them to reduce the time and energy spent on locomotion and foraging activities and in turn helps in conserving energy for other activities.

Most of the nests were sighted in the plantation with native tree shade and contiguous forest, maybe because of the availability and more abundance of the preferred nesting trees with highest parts of canopies and canopy contiguity, and the presence of food throughout the year in these habitat structures. Fragmented forests and plantation with monoculture tree shade were less preferred because they are more open and exposed habitat types where the probability of encountering predators is more, and as they consist less diverse tree species composition, the food choices are also limited. We observed that the nests were built towards the tree tops, but these were not built on the extreme top of the canopy, as the squirrels sought cover above the nest. Such cover might help to avoid direct heat from the sun and serve as hiding from birds of prey (Datta 1998; Pradhan et al. 2012). We observed that majority of the nests were built by using the same foliage of the tree in which the nests were built but, in some instances, they were using different foliage than the nesting tree species. We could not comprehend the reason behind this kind of behavior and hence, more specific study is required for knowing as to why some trees are used for nesting but its leaves are not used for nest building.

We found evidence to support the hypothesis that the nest orientation is mostly towards the north-east and east directions. This shows that the species has the cognitive ability to identify different directions and they preferred to orient most of the nests towards the sun rise. As the temperature in these forests becomes low in the nights, the animal receives the early morning sun light from the easterly direction for the warmth. Further, this region gets its rains primarily from the south-west monsoons in which the heavy winds and the rains are received from the west. The easterly direction of the nests therefore helps avoid direct exposures to winds and heavy monsoon rains.

REFERENCES

Agrawal, V.C., & S. Chakraborty (1979). Catalogue of mammals in the Zoological Survey of India. Rodentia. 1. Sciuridae. *Records of the Zoological Survey of India* 74(4): 333–481.

Albano, D.J. (1992). Nesting mortality of Carolina Chickadees breeding in natural cavities. *The Condor* 94(2): 371–382. https://doi.org/10.2307/1369210

Ardia, D.R., J.H. Pérez & E.D. Clotfelter (2006). Nest box orientation affects internal temperature and nest site selection by tree swallows. *Journal of Field Ornithology* 77(3): 339–344. https://doi.org/10.1111/j.1557-9263.2006.00064.x

Arockianathan, S. (2020). Nesting Behavior of Indian Giant Squirrel (*Ratufa indica* Erxleben, 1777) in Mudumalai Tiger Reserve, Western Ghats, Southern India, pp. 1–13. In: Loth, S.M. (ed.). *Rodents*. IntechOpen, 80 pp. https://doi.org/10.5772/intechopen.83079

Austin, G.T. (1974). Nesting success of the Cactus Wren in relation to nest orientation. *Condor* 76(2): 216–217. https://doi.org/10.2307/1366737

Babu, S., H.N. Kumara & E.A. Jayson (2015). Distribution, abundance and habitat signature of the Indian Giant Flying Squirrel *Petaurista philippensis* (Elliot, 1893) in the Western Ghats, India. *Journal of the Bombay Natural History Society* 112(2): 65–71.

Bekoff, M., A.C. Scott & D.A. Conner (1987). Non-random nest-site selection in Evening Grosbeaks. *The Condor* 89(4): 819–829. https://doi.org/10.2307/1368530

Bergin, T.M. (1991). A comparison of goodness-of-fit tests for analysis of nest orientation in Western Kingbirds (*Tyrannus verticalis*). *The condor* 93(1): 164–171. https://doi.org/10.2307/1368619

Borges, R.M. (1989). Resource heterogeneity and the foraging ecology of the Malabar Giant Squirrel *Ratufa indica*. PhD Thesis, University of Miami.

Borges, R.M. (2015). The Indian Giant Squirrel *Ratufa indica*, pp. 483–500. In: Johnsingh, A.J.T. & N. Manjrekar (eds.). *Mammals of South Asia*. Vol. 2. University Press, Hyderabad, India.

Burton, N.H. (2006). Nest orientation and hatching success in the Tree Pipit *Anthus trivialis*. *Journal of Avian Biology* 37(4): 312–317. https://doi.org/10.1111/j.2006.0908-8857.03822.x

Burton, N.H. (2007). Intraspecific latitudinal variation in nest orientation among ground-nesting passerines: a study using published data. *The Condor* 109(2): 441–446. https://doi.org/10.1093/condor/109.2.441

Corbet, G.B. & J.E. Hill (1992). *The Mammals of the Indomalayan Region: A Systematic Review* (Vol. 488). Oxford University Press, Oxford.

Datta, A. & S.P. Goyal (1996). Comparison of forest structure and use by the Indian Giant Squirrel (*Ratufa indica*) in two riverine forests of Central India. *Biotropica* 28(3): 394–399. https://doi.org/10.2307/2389203

Datta, A. (1998). The anti-predatory response of the Indian Giant Squirrel *Ratufa indica* to predation attempts by the Crested Hawk Eagle *Spizaetus cirrhatus limnaetus*. *Journal of the Bombay Natural History Society* 95: 332–335.

Erinjery, J.J., T.S. Kavana & M. Singh (2015). Food resources, distribution and seasonal variations in ranging in Lion-tailed Macaques, *Macaca* *silenus* in the Western Ghats, India. *Primates* 56: 45–54. https://doi.org/10.1007/s10329-014-0447-x

Erinjery, J.J., M. Singh & R. Kent (2018). Mapping and assessment of vegetation types in the tropical rainforests of the Western Ghats using multispectral Sentinel-2 and SAR Sentinel-1 satellite imagery. *Remote Sensing of Environment* 216: 345–354. https://doi.org/10.1016/j.rse.2018.07.006

Filliater, T.S., R. Breitwisch & P.M. Nealen (1994). Predation on Northern Cardinal nests: Does choice of nest site matter? *The Condor* 96(3): 761–768. https://doi.org/10.2307/1369479

Haggerty, T.M. (1995). Nest-site selection, nest design and nest-entrance orientation in Bachman's Sparrow. *The Southwestern Naturalist* 40(1): 62–67.

Hartman, C.A. & L.W. Oring (2003). Orientation and microclimate of Horned Lark nests: the importance of shade. *The Condor* 105(1): 158–163. https://doi.org/10.1093/condor/105.1.158

Heltshe, J.F. & N.E. Forrester (1983). Estimating diversity using quadrat sampling. *Biometrics* 39(4): 1073–1076. https://doi.org/10.2307/2531340

Hooge, P.N., M.T. Stanback & W.D. Koenig (1999). Nest-site selection in the Acorn Woodpecker. *The Auk* 116(1): 45–54. https://doi.org/10.2307/4089452

Kumara, H.N. & M. Singh (2006). Distribution and relative abundance of giant squirrels and flying squirrels in Karnataka, India/Distribution et abondance relative des espèces d'écureuils géants et volants à Karnataka, Inde. *Mammalia* 70(1–2): 40–47. https://doi.org/10.1515/MAMM.2006.006

Kumara, H.N. & R. Suganthasakthivel (2011). Predicting the potential distribution and conservation needs of Travancore Flying Squirrel, *Petinomys fuscocapillus*, in Peninsular India and Sri Lanka, using GARP. *Tropical Conservation Science* 4(2): 172–186.

Lloyd, J.D. & T.E. Martin (2004). Nest-site preference and maternal effects on offspring growth. *Behavioral Ecology* 15(5): 816–823. https://doi.org/10.1093/beheco/arh085

Maclean, G.L. (1984). Avian adaptations to the Kalahari environment: a typical continental semi-desert. *Koedoe* 27(2): 187–193. https://doi.org/10.4102/koedoe.v27i2.579

Martin, T.E. (1988). Nest placement: implications for selected life-history traits, with special reference to clutch size. *The American Naturalist* 132(6): 900–910. https://doi.org/10.1086/284896

Martin, T.E. & J.J. Roper (1988). Nest predation and nest-site selection of a western population of the Hermit Thrush. *The Condor* 90(1): 51–57. https://doi.org/10.2307/1368432

Mennill, D.J. & L.M. Ratcliffe (2004). Nest cavity orientation in Black-capped Chickadees *Poecilea tricapillus*: do the acoustic properties of cavities influence sound reception in the nest and extra-pair matings? *Journal of Avian Biology* 35(6): 477–482. https://doi.org/10.1111/j.0908-8857.2004.03351.x

Mezquida, E. T. (2004). Nest site selection and nesting success of five species of passerines in a South American open Prosopis woodland. *Journal of Ornithology* 145(1): 16–22. https://doi.org/10.1007/s10336-003-0002-9

Molur, S., C. Srinivasulu, B. Srinivasulu, S. Walker, P.O. Nameer & L. Ravikumar (2005). Status of South Asian non-volant small mammals: Conservation Assessment and Management Plan (C.A.M.P) Workshop Report. Zoo Outreach Organization/CBSG-South Asia, Coimbatore, India, 618 pp.

Murphy, M.T. (1983). Nest success and nesting habits of Eastern Kingbirds and other flycatchers. *The Condor* 85(2): 208–219. https://doi.org/10.2307/1367258

Nelson, K.J. & K.A.T.H.Y. Martin (1999). Thermal aspects of nest-site location for Vesper Sparrows and Horned Larks in British Columbia. *Studies in Avian Biology* 19: 137–143.

Norment, C.J. (1993). Nest-site characteristics and nest predation in Harris' Sparrows and White-crowned Sparrows in the Northwest Territories, Canada. *The Auk* 110(4): 769–777. https://doi.org/10.2307/4088632

Ojeda, V., A. Schaaf, T.A. Altamirano, B. Bonaparte, L. Bragagnolo, L. Chazarreta & N. Politi (2021). Latitude does not influence cavity entrance orientation of South American avian excavators. *The Auk* 138(1): ukaa064. https://doi.org/10.1093/ornithology/ukaa064

Pascal J.P. (1988). Wet evergreen forests of the Western Ghats of India: Ecology, structure, floristic composition and succession. Institut de Francais de Pondicherry, Pondicherry.

Pradhan, A.K., S. Shrotriya & S.D. Rout (2012). Observation on nest–site selection by Indian Giant Squirrel in Karlapat Wildlife Sanctuary, Odisha. *Zoo's Print Journal* 4(2): 12–13.

Pradhan, A.K., S. Shrotriya, S.D. Rout & P.K. Dash (2017). Nesting and feeding habits of Indian Giant Squirrel (*Ratufa indica*) in Karlapat wildlife sanctuary, India. *Animal Biodiversity and Conservation* 40(1): 63–69. https://doi.org/10.32800/abc.2017.40.0063

Ramachandran, K.K. (1988). Ecology and behaviour of Malabar Giant Squirrel (*Ratufa indica maxima*) Schreber. Kerala Forest Research Institute Report No. 55, Peechi.

Ramachandran, K.K. & R. Suganthasakthivel (2010). Ecology and behaviour of the arboreal mammals of the Nelliyampathy forests. Kerala Forest Research Institute Report No. 382, Peechi.

Rathod, G., E. Bharucha & K. Yardi (2022). Population density and nesting behaviour of Indian Giant squirrel *Ratufa indica* (Erxlebeln, 1777) in Bhimashankar wildlife sanctuary, Western Ghats of Maharashtra, India. *Journal of Threatened Taxa* 14(9): 21786–21796. https://doi.org/10.11609/jott.7816.14.9.21786-21796

Rauter, C.M., H.U. Reyer & K. Bollmann (2002). Selection through predation, snowfall and microclimate on nest-site preferences in the Water Pipit *Anthus spinoletta*. *Ibis* 144(3): 433–444. https://doi.org/10.1046/j.1474-919X.2002.00013.x

Rendell, W.B. & R.J. Robertson (1994). Cavity-entrance orientation and nest-site use by secondary hole-nesting birds (Orientación de la Entrada de Cavidades y UsoSecondario de lasMismaspor Aves que no lasExcavan). *Journal of Field Ornithology* 65(1): 27–35.

Tarvin, K.A. & K.G. Smith (1995). Microhabitat factors influencing predation and success of suburban Blue Jay *Cyanocitta cristata* nests. *Journal of Avian Biology* 26(4): 296–304.

Viñuela, J. & C. Sunyer (1992). Nest orientation and hatching success of Black Kites *Milvus migrans* in Spain. *Ibis* 134(4): 340–345. https://doi.org/10.1111/j.1474-919X.1992.tb08013.x

Walsberg, G.E. (1981). Nest-site selection and the radiative environment of the Warbling Vireo. *The Condor* 83(1): 86–88. https://doi.org/10.2307/1367612

Webb, D.R. & J.R. King (1983). An analysis of the heat budgets of the eggs and nest of the White-crowned Sparrow, *Zonotrichia leucophrys,* in relation to parental attentiveness. *Physiological Zoology* 56(4): 493–505.

Webb, D.R. (1987). Thermal tolerance of avian embryos: a review. *The Condor* 89(4): 874–898. https://doi.org/10.2307/1368537

With, K.A. & D.R. Webb (1993). Microclimate of ground nests: the relative importance of radiative cover and wind breaks for three grassland species. *The Condor* 95(2): 401–413. https://doi.org/10.2307/1369363

Yanes, M., J. Herranz & F. Suárez (1996). Nest microhabitat selection in larks from a European semi-arid shrub-steppe: the role of sunlight and predation. *Journal of Arid Environments* 32(4): 469–478. https://doi.org/10.1006/jare.1996.0040

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ARTICLE

Impact of human activities on wild ungulates in Nagarjunsagar Srisailam Tiger Reserve, Andhra Pradesh, India

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Abstract: Human activities affect wildlife in several ways, ungulates tend to avoid areas of high human use and alter their behavior to avoid human activity. We used remote camera traps to quantify the relative abundance and activity of wild ungulates in high and low human use areas within Nagarjunasagar Srisailam Tiger Reserve (NSTR). Major human activity in NSTR included collection of forest produce and fuel wood, and livestock grazing. Poaching for bush-meat and the use of hunting dogs was also prevalent, but could not be quantified. The relative abundance of wild ungulates was high in low human-use areas except for chital and wild pigs, which require flat terrain and water found in prime areas for settlements. Diurnal ungulates like Chital and Nilgai substantially altered their activity in response to human activity, as did nocturnal species like Sambar and Mouse Deer. The demographic response of ungulates in NSTR has been poor compared to other tiger reserves that have been made free of human use. Our research highlights the importance of having human-free protected areas so as to achieve the desired conservation objectives of harbouring viable populations of large carnivores that require high prey abundance.

Keywords: Activity pattern, camera traps, human impacts, NSTR, relative abundance.

Telugu abstract: మానవులు అడవులలో చేసే కార్యకలాపాలు అనేక విధాలుగా వన్యప్రాణులను ప్రభావితం చేస్తాయి మరియు మానవ సంచారం ఎక్కువగా వుండే ప్రాంతాలలో వారికి ఎదురుపడకుండా శాఖాహార జంతువులు వాటి అలవాట్లను మరియు ప్రవర్తనను మార్చుకుంటున్నాయి. నాగార్జునసాగర్ శ్రీశైలం టైగర్ రిజర్వ్ (NSTR) పరిధిలోని ఎక్కువ మరియు తక్కువ మానవ సంచారం మరియు వినియోగం వుండే ప్రాంతాలలో అడవి జంతువుల లభ్యత, కదలికలు మరియు కార్యకలాపాలను లెక్కించడానికి మేము రిమోట్ కెమెరా ట్రాప్‌లను ఉపయోగించాము. (NSTR) లో అటవీ ఉత్పత్తులు మరియు వంటచెరుకు, కలప సేకరణ మరియు పశువులను మేపడం, మాంసం కోసం వేటాడటం మరియు వేట కుక్కల వాడకం లాంటి ప్రధానమైన మానవ కదలికలు. కానీ దీనికి సంభంధించి సరైన గణాంకాలు లెక్కించబడలేదు. తక్కువ మానవ సంచారం వున్న ప్రాంతాలలో చితల్ మరియు అడవి పందులను మినహాయించి ఇతర శాఖాహార వన్యప్రాణుల యొక్క లభ్యత ఎక్కువగా ఉంది, చితల్ మరియు అడవి పందుల వంటి జీవులకు చదునైన భూభాగం మరియు నివాస ప్రాంతాలలో నీరు అవసరం అవి మన నివాస ప్రాంతాలకు దగ్గరగా నివసిస్తుంటాయి . సాంబార్ మరియు మౌస్ డీర్ వంటి నిశాచర జాతుల మాదిరిగానే చితాల్ మరియు నీల్‌గాయ్ వంటి పగటి పూట సంచరించే జీవులు మానవ కార్యకలాపాలకు ప్రతిస్పందనగా తమ కదళికలను గణనీయంగా మార్చుకున్నాయి. మానవ కదళికలను నిషేదించిన ఇతర టైగర్ రిజర్వ్‌లతో పోలిస్తే NSTRలో శాఖాహార జీవుల జనాభా ప్రతిస్పందన పేలవంగా ఉంది. మా పరిశోధ పెద్ద మాంసాహారుల యొక్క జనాభాను కాపాడటం కోసం ఎంత మొత్తంలో వేటాడబడే జీవులు సమృద్ధిగా వుండాలో తెలిపే అంశాలను గుర్తించడం మరియు మానవ-రహిత రక్షిత అటవీ ప్రాంతాలను కలిగి ఉండటం యొక్క ప్రాముఖ్యత లాంటి పరిరక్షణ అంశాలను స్పష్టంగా తెలియజేస్తుంది.

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INTRODUCTION

Global biodiversity declines are being driven by the direct and indirect effects of anthropogenic actions (Hooper et al. 2012). India supports an extremely high diversity of wildlife (inside and outside designated PAs); most of these species are found in higher densities here than elsewhere across their range (Srivathsa et al. 2023). Remarkable species richness can be found among herbivores, which are primary consumers at the base of many food chains (Putman 1989). Human activities including fuelwood extraction, fodder collection, cattle grazing, consumption of bush meat, and infrastructure development in natural areas can influence herbivore populations, habitat, behaviour, and relationships negatively (Meyer et al. 2013; Frey et al. 2017). In places where wild animals co-occur with humans and space is limiting, animals may minimize contact with humans by separating themselves in time and/or space (Kronfeld-Schor & Dayan 2003), often at a cost to their fitness. These activity shifts in wild animals have been studied using advanced monitoring tools such as GPS-satellite collars (Berger et al. 2003; Ungar et al. 2005) and camera traps (Edwards et al. 2020).

The time and activity budgets of species under different ecological conditions can provide insights into factors that influence predation, competition, metabolic requirements, and others (Aschoff 1989; Hayward & Hayward 2012; Kasiringua et al. 2017). Camera traps have been used as a tool for animal population estimation (Karanth

& Nichols 1998; Rowcliffe & Carbone 2008), inventorying rare and elusive species (O'Brien et al. 2003), monitoring illegal activities (Jenks 2012; Hossain et al. 2016), and studying animal behaviour (Wegge et al. 2004). For species where direct observation is difficult, camera trap data has been used to study animal activity patterns (Rowcliffe & Carbone 2008; Frey et al. 2017). For species that cannot be individually recognized from coat patterns, camera trap-based encounter rates are used to compute a relative abundance index (RAI) that is often correlated with independent density estimates (Carbone et al. 2001; Rovero & Marshall 2009).

Nagarjunsagar Srisailam Tiger Reserve (NSTR) forms part of the Nallamala Hills of the Eastern Ghats in Andhra Pradesh. Despite being the largest tiger reserve in the country (area 3,728 km^2; Jhala et al. 2015), there is little ecological data available from the reserve (Srinivasulu 2001). Two forest-dwelling communities, the Lambadas and Chenchus, inhabit the core area of the Tiger Reserve. Impacts of humans and their animals on wild ungulates can be due to: 1) direct hunting, 2) hunting by free-ranging dogs, 3) competition with livestock, and 4) disturbance/competition caused by extraction of forest produce. These impacts may influence the demography of ungulates (decreased abundance and slow growth rates) changes in habitat use, and behavioural changes in time-activity patterns to avoid human activity periods (Madhusudan & Karanth 2002; Karanth et al. 2009; Dave & Jhala 2011; Ohashi et al. 2013; Ritchie at al. 2013).

Due to human-related activities, the animal density in NSTR seems to be low (Srinivasulu 2001). Yet, earlier studies from this site indicates that ungulate sightings were common in the early morning hours close to waterbodies (Bhargav et al. 2009). But due to livestock grazing and hunting pressure the detection of prey was very low and hence proper density estimates were not obtained (Bhargav et al. 2009; Jhala et al. 2011, 2015, 2020).

Due to the presence of armed militant groups in NSTR until recently, few studies could be conducted and therefore information on ungulate densities in this area were lacking. The objective of tiger reserves in India is to use the charismatic tiger as an umbrella species to protect ecosystems. A demographically viable tiger population requires space for a minimum of 20 breeding female tigers (Chapron et al. 2008; Bisht et al. 2019) which translates to an area of about 1,000 km^2 with an average of 50 km^2 as a female breeding territory in Indian forests. This area should support ~450 medium sized ungulates per tiger, and the minimum requirement for a breeding population of tigers is around 34,000 (Jhala et al. 2021). The All India Tiger Estimation Report (Jhala et al. 2020) reports that there were 38 unique tigers captured in the study area resulting in a density estimate of 0.91 tigers per 100 km^2 (SE ± 0.14) and due to low prey sighting on transects the prey density was not estimated (Jhala et al. 2020). NSTR is the only tiger reserve in the state of Andhra Pradesh that has a reasonable number of tigers, and when combined with the tiger reserve of Amrabad in the state of Telangana can potentially accommodate more tigers in the future.

High-density tiger populations and humans do not mix well. To create space for a source population of tigers while providing better livelihoods for forest-dwelling people, a scheme of incentivized voluntary relocation of human settlements from the core areas of tiger reserves is implemented by the National Tiger Conservation Authority (Jhala et al. 2021). The relocation incentive scheme (currently INR 15,00,000 or ~ 20,000 US$ per adult) was not applicable to the tribal communities of Lambadas and Chenchus since their presence in NSTR was not considered to be detrimental for tiger conservation due to the perception that tribal communities lived in harmony with nature and for the utilitarian reason that they were useful as labour for reserve maintenance and management (E.g., patrolling & protection, habitat management activities, and forest fire management activities) since bringing labour from outside is expensive. Also, owing to presence of armed militant groups, the implementation of human resettlement scheme was difficult as militants depended on local forest dwellers for resources and did not permit them to relocate. Now that militancy in the area has been subdued, the administration can initiate incentivized voluntary relocation of all interior settlements to outside of the tiger reserve for better livelihood options and for creating space for wildlife (Pandey et al. 2013; Jhala et al. 2021).

The present study is a first of its kind in the Eastern Ghats landscape that evaluates relative abundance of wild herbivores, their activity patterns, and their behavioural responses to human-related activities. Our study was constrained by the large size of the protected area and the low abundance of ungulates (Kothari et al. 1995; Karamsi 2010; Jhala et al. 2015), making traditional robust approaches like distance sampling impractical due to the large amount of effort required, compounded by low detections of skittish ungulates. Under conditions where ungulates are traditionally hunted, the use of line transect-based distance sampling can be biased, since wild ungulates are extremely vigilant and would likely detect the observer before they can be detected and flee, thus potentially be unavailable for sampling.

To understand the ecology of a wild ungulate species, the factors that influence the dynamics of its population or the ecosystem it represents are crucial. Our a priori hypotheses were that ungulate abundances would be lower in areas of high human use, and that ungulates would adjust their activity to avoid periods of high human activity. With this ecological understanding in mind, our study aims to: a) estimate the relative abundance of wild ungulates in the park using camera traps and b) quantify the impact of human activities on the abundance & behaviour of wild ungulates. This study would help us to better understand the low densities and slow recovery of ungulate populations in NSTR and provide recommendations for management interventions.

MATERIALS AND METHODS

Study Area

NSTR is the largest tiger reserve in the country (3,728 km^2), demarcated as core and buffer administrative units of 2,444 km^2 and 1,284 km^2, respectively. It is located in the southern Eastern Ghats (15.88333-16.71666 N, 78.50000-79.46666 E) in the state of Andhra Pradesh. Our study area covered 2,500 km^2 within two administrative units, namely, Markapur and Atmakur divisions, including the extended Tiger Reserve core area constituted by Gundala Brahmeswaram Wildlife Sanctuary (GBM), Velgode, and Bairlutty ranges (Image 1).

The terrain of NSTR can broadly be classified as hills, plateaus, valleys, gorges, and escarpments. The vegetation type is southern tropical dry deciduous, tropical moist deciduous, and tropical thorn forests (Champion & Seth 1968). Forest contributed to (84%) of land cover in the study area which is mostly deciduous and scrub/degraded forest followed by agricultural land (1%), waste land (12%), water bodies (2%), and built up (1%). In total, forest covers 84% of the study area. These data were calculated using Arc GIS (v.10.1*)* (ESRI 2011).

The major portion of rainfall is received from the south-west monsoon that commences from the second half of June and continues up to the first week of October. Then there is a short dry spell for a month. The north-east monsoon is active from November to the first half of December, mainly on the eastern slopes of Nallamala Hills. The mean annual rainfall ranges from 590–760 mm (Jhala et al. 2020). NSTR supports large carnivores like the Tiger *Panthera tigris*, Leopard *Panthera pardus*, Dhole *Cuon alpinus*, Wolf *Canis lupus*, Striped Hyena *Hyena hyena*, Golden Jackal *Canis aureus*, and Sloth Bear *Melursus ursinus*. Wild ungulates found in NSTR are Chital *Axis axis*, Sambar *Rusa unicolor*, Blackbuck *Antelope cervicapra*, Mouse Deer *Moschiola meminna*, Nilgai *Boselaphus tragocamelus*, Chousingha *Tetracerus quadricornis*, and Wild Boar *Sus scrofa* (Pandey et al. 2013).

The study area encompasses 15 major villages that were home to two scheduled tribes (Subramanyachary 2013), the Chenchus and Lambadas, with few other scheduled castes and their livestock, mainly composed of cattle, buffalos, and goats & sheep. Location of human settlements is mostly determined by proximity to perennial water and productive flat lands, which are also prime habitat for wildlife (pers. obs.).

Andhra Pradesh is home to 12 primitive tribal groups (PTGs), with Chenchu being one of the PTGs recognized

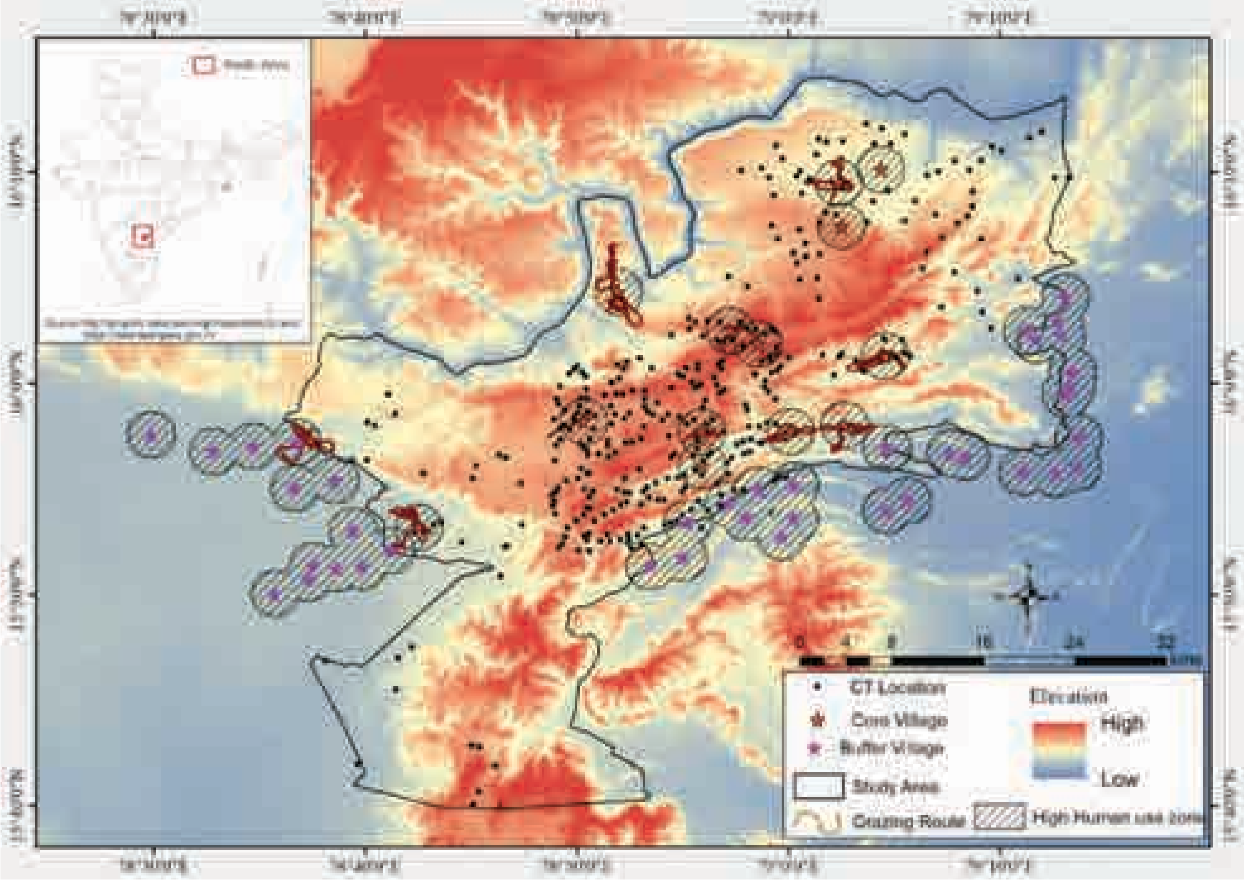

Image 1. Map showing camera trap locations within Nagarjunsagar Srisailam Tiger Reserve (NSTR). Cameras within the maximum grazing radius of livestock from villages/cattle sheds were considered to in the high human impact zone. DEM based on Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global courtesy of the U.S. Geological Survey (https://earthexplorer.usgs.gov/ The map inset shows the location of NSTR within the state of Andhra Pradesh, India (http://projects.datameet.org/maps/districts) and (https://data.telangana.gov.in). The map was created by authors using Arc GIS 10.1.

by the Indian government. Later in 2006, the Indian government proposed renaming the primitive tribal group as primitive and vulnerable for 75 tribal groups in India based on their dependency on hunting, gathering food from the forest, growth of their population, and literacy level. The purpose of this classification was to provide assistance so as to uplift the tribal community in different sectors like education, health, livelihood, skilled labour, agriculture, housing, while retaining their culture (Ministry of Tribal Affairs 2015). These communities are mostly confined to the foothills and low-lying areas of Nallamalla Hills covering Prakasam, Kurnool, Mahaboobnagar, Rangareddy, Guntur Nalgonda districts of both Andhra Pradesh and Telangana states (Raju et al. 2009).

Historically, Chenchus were nomadic hunters and food gatherers inhabiting forested areas, where they ate honey and tubers, and hunted wildlife for food (Murty 1981). Most Chenchus now live in permanent settlements called gudem or pentas, which are a cluster of huts made from bamboo and grass, however, they continue to engage in collecting honey, grass, fruits, nuts, and leaves as supplements to their livelihood (Suryakumari et al. 2008). Chenchus still carry traditional bows and arrows when they move inside the forest that can be used for hunting.

Lambada tribes are called by different names, such as Sugalis and Banjaras in other parts (Lal 2015). These tribes spread across Andhra Pradesh and Telangana states in southern India (Vaditya 2019). They live in exclusive settlements of their own called ‘Thandas’ (Shankar 2016). Present day occupation of majority of Lambadas in general is cultivation and pastoralism (Karamsi 2010).

Inside the core area of NSTR, there are around 5,650 households, with a total population of more than 25,000 people and 2,977 cattle, while another 69 villages with 1,26,000 cattle are present in the buffer zone of the tiger reserve (Bhargav et al. 2009; Mathur et al. 2018). The entire tribal population within the tiger reserve depends on forest resources for survival, which are shared with wildlife (Srinivasulu 2001; Sudeesh & Sudhakar 2012).

Data Collection

Estimation of wild ungulate density

The smallest administrative unit, i.e., forest beats, were used to systematically distribute line transects (n = 142) to survey the study area. The length of each line transect was between 1.5 to 3 km. Each transect was walked once during the early morning (0600–0800 h) between December to February of 2014 and 2016. All sightings of animals, the group size, radial distance to the centre of the group and bearing were manually recorded on a datasheet**.** Radial distances to animals were measured using a hand-held range finder (Bushnell RX1000). Bearings were recorded using a hand-held compass (Suunto KB 20).

Relative Abundance of Wild ungulates

Sampling using camera traps was done across the study area between January to July 2014 in an area covering 713 km^2. A total of 345 camera locations were sampled, with a double camera unit (Cuddeback attack 1149, Cuddeback ambush 1194) deployed at each location for about 40 days. Since this exercise's primary objective was to obtain a population estimate of tigers, camera placement was mostly on game trails, dry stream beds, and dirt roads to maximize photo captures of carnivores. However, we believe that the photo capture data on ungulates to address our study's objectives and comparisons with other sites would remain unbiased as placement locations were similarly selected across the study area and in other tiger reserves across India (Jhala et al. 2021). We checked cameras every 3–7 days to download data and check battery status. All photographs were segregated to species, and information on time, date, and coordinates, recorded for each image.

Livestock were not free-ranging in NSTR, but taken out to graze by herders from corrals in each settlement every morning and brought back by dusk. Herders were often accompanied by dogs. Since livestock movement was constrained by the distance they could move from their corrals and from water sources, human, dog, and livestock activity was mostly concentrated within a certain radius from settlements. Cattle, buffalo, goat, and sheep escorted by herders were accompanied by the first author from early morning when they left the corrals to late evening when they returned to their corrals. A hand-held GPS unit was used by the first author to record the daily grazing circuit from villages in the winter and summer of 2014 and 2015. The grazing circuit was mapped using ArcGIS (v. 9.3), the average displacement distance of livestock herds from settlements/villages was computed, and each settlement was buffered by the 95% upper bound of this distance to delineate a zone of high human use. A total count of all livestock in each season was done for each village and cattle shed across NSTR at a time when livestock were corralled to determine the total livestock population.

Data analysis

Wild ungulate density estimation

Analysis was done using the conventional distance sampling approach in Program DISTANCE (v. 6.0) (Buckland et al. 2004). Due to low detection of ungulate species in NSTR on line transects we pooled observations from three sampling periods (Jhala et al. 2011 & 2015 and sampled by first author in 2016) from NSTR and used line transect observation data from seven other sites in the country (Table S1, S2) which have the similar habitat type to NSTR for fitting species detection functions in program DISTANCE to estimate effective strip width. Shape criteria were examined for heaping, and any outliers were right-hand truncated where necessary (Buckland et al. 2004). Three key functions (Half normal and hazard rate all with cosine and Hermite polynomial series adjustment) were considered for analysis. Model selection was evaluated using Akaike's information criteria (AIC), while Kolmogorov–Smirnov statistics were used to assess the goodness of fit of each model (Buckland et al. 2004). Subsequently, this pooled effective strip width was used to obtain year wise density estimates of ungulate species in NSTR.

Relative Abundance of Wild ungulates

Relative abundances of the wild ungulates in the study area were estimated from 2014 camera trap data, as photo capture rates which were computed by summing independent photo-captures of each species and dividing this sum by the camera trap operational days. We defined an independent photo-capture event as follows 1) consecutive photographs of different species or different individuals of the same species; 2) Consecutive photographs of individuals of the same species taken more than 30 minutes apart (O'Brien et al. 2003); and, 3) non-consecutive photos of individuals of the same species.

We used independent photographs of species to calculate relative abundance index (RAI) from camera trap images. RAI was computed as the number of independent photo captures of a species in 100 trap nights (Carbone et al. 2001). The total effort invested was determined by multiplying total camera operation day. Camera traps were segregated into two strata based on their location as i) within the high human - use areas and ii) those outside this zone as low human impact areas. RAI of ungulates was also computed separately for these two zones. We hypothesised that RAI values of ungulates would be lower in high human impact areas and RAI values of human disturbances (photocaptures of humans, domestic dogs, and livestock) would be higher in high human impact areas.

The RAI was computed for each camera trap location for each species in both high and low human use zones, for testing if RAI differed between high and low human use zones we used non-parametric Mann-Whitney U-test (Zar 2022).

Camera trap-based data collection overcomes biases induced by the skittish nature of wild ungulates which can result in non-availability for sampling on line transects, but unfortunately RAI does not allow for rigorous inference on absolute abundance. To test the hypothesis that RAI is a reliable index of absolute density we regressed the RAI values of Chital and Sambar (species with a reasonable sample size of observations) with absolute density estimates of these species obtained from line transect distance sampling from other similar forest types where absolute density estimates from distance sampling were also available (Jhala et al. 2020). A significant positive relationship between RAI and absolute density would lend support to the hypothesis.

Temporal peak activity pattern

We used camera trap images and their associated information from the metadata of the images like date, time of the photograph to understand the temporal activity of six wild ungulate species in NSTR. The time of the photo capture was used to create a 24-hour activity pattern graph as well as analysis using Oriana software (v. 4.0). Oriana uses circular statistics to enumerate the dispersions such as mean vector length (r) along with confidence intervals. The mean vector has two properties: direction and length of the mean or angle, and the mean vector length (r) denotes the clusters of observation around the mean, which ranges from 0 to 1, where 1 is the frequency of observations very close to the mean and 0 is when observations are scattered across the study. In the rose plot the arc on the outer edge extending to either side of the mean represents the 95% confidence limits Oriana software (v.4). The output provided activity clustering along with mean peak activity time for wild ungulates and human related activities factors within a 24-hour cycle, facilitating a quantitative statistical comparison of their temporal activity.

Activity pattern and temporal overlap

We estimated the proportion of time active and activity pattern of ungulates across the day from camera trap data using the Activity package (v1.3.1) (Rowcliffe 2022) in Program R (v. 1.4). This provided information on how much time an ungulate species remains active in a day while the activity pattern describes the distribution of activity across the 24-hour period. Analysis of data was done separately for the two human impact strata. We hypothesised that ungulates in high human impact zones would alter their active behaviour and activity to avoid peak human associated activity periods (human, dog, and livestock activity peaks). Temporal overlap of ungulate activity with anthropogenic disturbances using different packages like Overlap (v. 0.3.3) (Ridout & Linkie 2009) and ggplot2 (v 3.3.3) in Program R (v 1.4.) software was estimated. We used the overlap coefficient (Δ), ranging from 0 – no overlap to 1 – complete overlap (Ridout & Linkie 2009) to estimate the overlap for each wild ungulate species in both high and low human-use areas with human related activities. Since samples used for overlap analysis were more than 75 independent photo-captures for most of the wild ungulate species in both high and low human impact areas we used D-hat 4 estimator for all species (Ridout & Linkie 2009).

RESULTS

Livestock Population and Grazing radius

The total livestock population in NSTR was 4,403 in summer and 3,934 in winter. The livestock population comprised of 44.5% goats, 31.4% cattle, & 24.0% buffalo during summer and 35.8% goats, 35.4% cattle, & 28.8% buffalo during winter. Average livestock grazing circuit was 4.0 (SE ± 0.12) km. Livestock ranged more in summer 4.6 (SE ± 0.22) km than in winter 3.5 (SE ± 0.23) km. The average foraging radius combined for both seasons was 1.8 (SE ± 0.07) km. The 99% upper bound on the foraging radius was 2.01 km. Camera traps within a buffer of this maximum foraging radius (2.01 km) around each human settlement / cattle shed were considered to be within high human activity zone (Image 1).

Wild ungulate density

Detection of all ungulates was low in NSTR. Density estimation for Chousingha, Mouse Deer, and Nilgai was not meaningful to report due to very few detections on transect surveys, and therefore density estimates of Chital at 1.8 (SE ± 0.0.52) individuals / km^2, Sambar at 0.72 (SE ± 0.24) / km^2, and Wild Boar at 0.48 (SE ± 0.15) / km^2, are reported (Table 1).

Relative Abundance Indices

We obtained 35,306 usable photographs with an effort of 10,681 trap nights. Humans were photo-captured the most (Table 2). Wild ungulates constituted 37% of this data. The highest number of captures were of Sambar (38%) followed by Chital (26%), Wild Boar (18%), Chousingha (9%), Mouse Deer (5%), and Nilgai (4%). RAI was highest for Wild Boar (10.0), while it was lowest was for Nilgai (1.5) (Table 2). Human impact was recorded throughout NSTR (in the form of human, livestock, and domestic dog photo-captures), and was similar across the reserve for humans and domestic dogs since RAIs of humans and domestic dogs were not significantly different near settlements and away from settlements (Table 2, Figure S1). Livestock RAI was significantly higher in the proximity of settlements (Figure S1). Amongst wild ungulates only Chousingha and Nilgai had significantly higher RAI in low human use areas while Wild Boars had significantly higher RAI in high human use areas (Table 2, Figure S1).

In support of our hypothesis, the regression between absolute density and RAI was asymptotically linear with a reasonably good fit for both Chital (Table S1, Figure S2; R^2 = 0.86; P = <0.001) and Sambar (Table S2, Figure S6; R^2 = 0.69; P = <0.01).

Temporal Activity Patterns

All wild ungulates except Chousingha showed bimodal activity. Chousingha were diurnal, Chital and Nilgai were

Table 1. Density estimates of ungulates in Nagarjunsagar Srisailam Tiger Reserve based on line transect distance sampling.

Species	Observations	Model	Density (SE)	%CV	Group density (DS)- (S.E)	%CV	ESW	Detection probability (P^)	Chi P-value
Chital	22	Hazard rate/Hermite polynomial	1.80 (0.52)	29	0.52 (0.13)	26.46	50.9	0.42	0.66
Sambar	17	Hazard rate/Hermite polynomial	0.72 (0.24)	33	0.49 (0.15)	31.82	41.9	0.41	0.72
Wild Boar	13	Uniform/Cosine	0.48 (0.15)	33	0.37 (0.10)	28.36	41.7	0.41	0.90

DS—Group density | ESW—Effective strip width | SE—Standard error | %CV—Coefficient of variation.

Table 2. Relative abundance of wild ungulates, livestock, domestic dogs, and humans in Nagarjunasagar Srisailam Tiger Reserve as estimated from relative abundance index (RAI) from camera trap data.

Species	Total number of photographs	Total number of independent photographs	Overall RAI	RAI in the high human-use zone	RAI in the low human-use zone	Overall % time active	% Time active in high human- use zone	% Time active in low human- use zone
Sambar	5003	923	8.6	6.7	9.2	45	37	47
Chital	3443	859	8.0	12.1	6.9	29	28	28
Wild Boar	2356	1073	10.0	14.4	8.7	47	53	41
Chousingha	1152	383	3.6	1.9	4.1	30	31	30
Mouse Deer	665	380	3.6	1.5	4.1	36	23	35
Nilgai	387	158	1.5	0.5	1.8	43	28	36
Humans	14033	4117	38.5	50.1	35.2	38	34	36
Livestock	7127	821	7.7	13.3	6.1	36	28	27
Domestic dog	1140	264	2.5	2.4	2.5	39	41	34

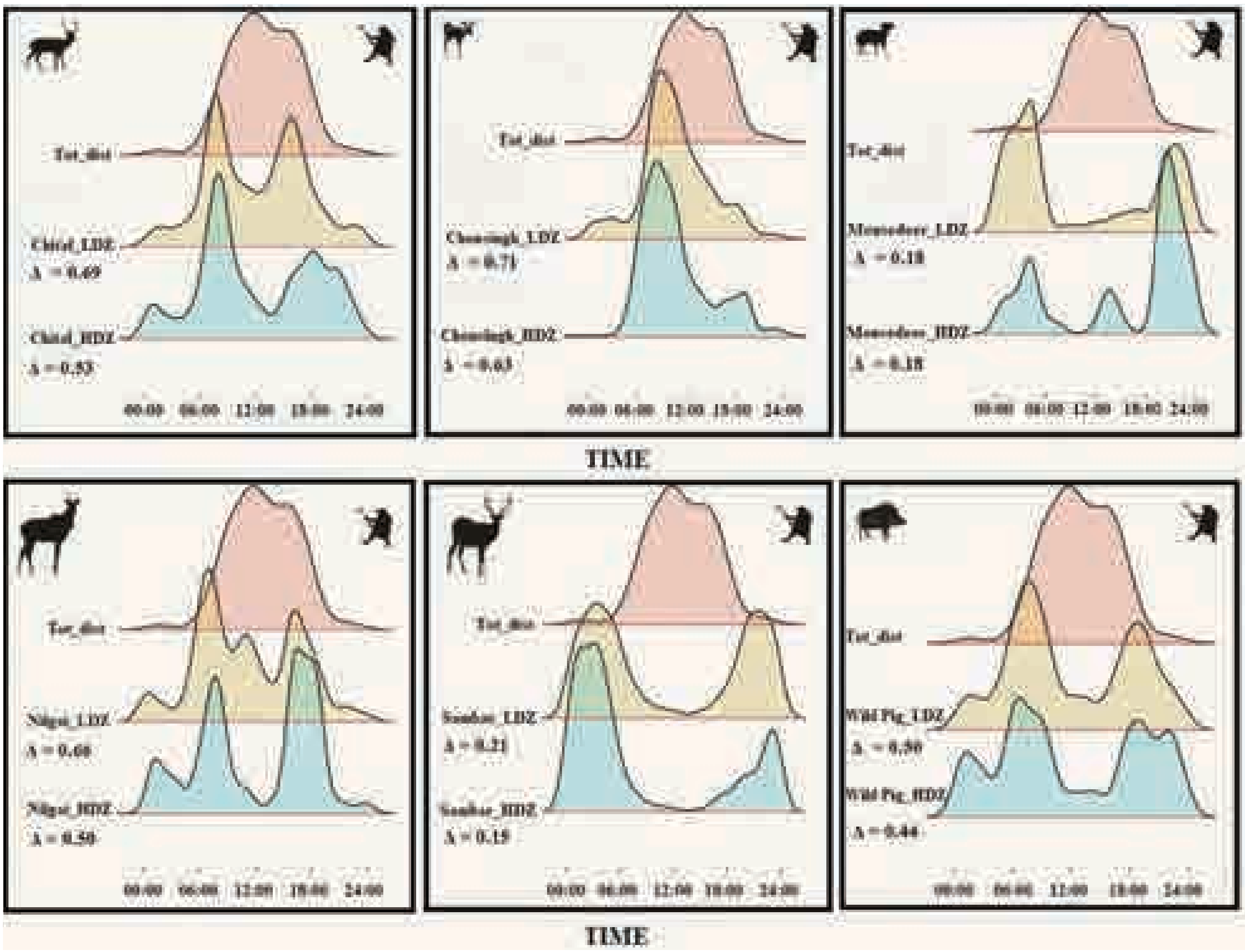

Figure 1. Temporal overlap depicted as kernel density functions of wild ungulate activity with combined anthropogenic disturbances ((Tot_dist= photo captures of humans, livestock, and domestic dogs) in areas of high human impacts (HDZ, in proximity to settlements) and low human impacts (LDZ, away from settlements). Δ – is the coefficient of overlap between human activity and ungulate activity in Nagarjunsagar Srisailam Tiger Reserve.

crepuscular and diurnal, Sambar and Mouse Deer were primarily nocturnal, while Wild Boars showed activity at night and in the forenoon (Figure S3). All human related activity (humans, domestic dogs, and livestock) were diurnal, beginning late mornings and extending into late evening (Figure 1, Figure S3). In agreement with our a priori hypothesis, within the constraints of some ungulates being diurnal, wild ungulates avoided all forms of human activities (Figure 1; Figure S3). The 95% confidence intervals of wild ungulate activities (except Chital) did not overlap any of the human related activities (humans, livestock, and domestic dogs; Figure S3). Chital activity in low human use areas overlapped only with the 95% confidence intervals of livestock active periods (Table 3, Figure S3). Overlap of ungulate activity with anthropogenic activities within the high-human impact zone was found to be higher for Chousingha (63%) and the lowest for Sambar (15%) (Figure S4). For species like Chital, Chousingha, and Nilgai in the low human impact zone, the overlap with various anthropogenic disturbance factors, such as humans, dogs, and livestock activities combined, was found to be more than (60%) for Chital and least for Mouse Deer (18%), respectively (Figure 1).

DISCUSSION

In the Anthropocene, exclusive space for biodiversity is one of the most limiting factors for conservation (Kipkeu 2014). Many protected areas set aside for wildlife conservation have people residing within them (Kothari et al. 1995). NSTR has 15 villages with human population of 5,650 families with a population of ~18,000 (Lal 2015), and a livestock population of ~4,500 within the tiger reserve. In addition to the resident settlements, NSTR is

Table 3. Temporal activity pattern of wild ungulates, livestock, domestic dogs, and humans in Nagarjun Sagar Srisailam Tiger Reserve. Mean vector length (r) denotes the clusters of observation around the mean, which ranges from 0 and 1 where 1 is the frequency of observations very close to the mean and 0 is when observations are scattered. The 95% confidence limit of the mean, overlap between HDZ (high human use zone) and LDZ (low human use zone) 95% CI signifies no statistical shift in peak activity between the two zones.

Species/zone	No. of observations	Mean vector (μ)	Length of mean vector (r)	SE mean	95% C.I
Chital HDZ	1569	10:37	0.143	00:28	09:41–11:32
Chital LDZ	1881	11:57	0.343	00:10	11:36–12:18
Sambar HDZ	664	01:38	0.659	00:08	01:22–01:54
Sambar LDZ	4085	00:47	0.51	00:04	00:38– 00:56
Chousingha HDZ	121	09:45	0.601	00:21	09:02– 10:27
Chousingha LDZ	981	10:27	0.581	00:08	10:11–10:42
Mouse Deer HDZ	50	22:19	0.612	00:33	21:14– 23:24
Mouse Deer LDZ	615	00:51	0.556	00:10	00:30–01:12
Wild Boar HDZ	839	02:12	0.134	00:41	00:50– 03:33
Wild Boar LDZ	1515	08:41	0.115	00:36	07:30– 09:52
Livestock HDZ	3257	12:14	0.697	00:03	12:07– 12:21
Livestock LDZ	3863	12:22	0.624	00:03	12:15– 12:29
Humans HDZ	4096	13:22	0.689	00:03	13:16– 13:28
Humans LDZ	9597	13:04	0.619	00:02	12:59– 13:08
Domestic dogs HDZ	469	12:34	0.597	00:11	12:12–12:56
Domestic dogs LDZ	668	13:48	0.693	00:07	13:33– 14:03

also used by humans and their livestock from peripheral villages (Image 1). Human and livestock photo-captures outnumber all other species in NSTR (Table 2), which should be reason for concern.

Human-related activities contributed 63% of total independent photo-captures. Photo-captures of humans were high, followed by livestock and domestic dogs which were all primarily restricted to daylight hours. However, except for livestock, the presence of humans and domestic dogs was recorded across the protected area, suggestive of high impacts of human activities within NSTR and not limited to near the settlements. Though we found that wild ungulates avoided active periods of humans we found no statistical differences in relative abundance or activity for most wild ungulates between areas closer to human settlements (high human use) and further from settlements (low human use) suggesting a pernicious impact of humans across NSTR.

In a comparative scenario, in Kuno Wildlife Sanctuary with similar dry deciduous forest like NSTR, the Chital population was found to recover from a density of 4.6 km^{-2} (Banerjee 2005) to ~40 km^{-2} (Jhala et al. 2015) after human habitations were relocated from Kuno and protection from poaching enhanced. Subsequent to the data collection for this study, we obtained photo-capture of local communities indulging in hunting activities (Image S1). Wild Boar abundance was not in agreement with our a priori predictions since they had higher abundance in high human use areas. This was likely since human habitations were located in flatter productive terrain (Image 1) which is also the only habitat for Chital and Wild Boars as these species tend to avoid hilly areas.

Earlier studies on temporal activity of sambar in India (Schaller 1967; Shea et al. 1990; Lahkar et al. 2020) and on greater mousedeer from Borneo (Ross et al. 2013) report these species to be nocturnal. Our data confirm these inherent biological patterns of Sambar and Mouse Deer becoming active well after darkness and continuing their activity into dawn hours (Lahkar et al. 2020). By being nocturnal, both species avoid periods of high human activities. However, in human-free areas, Sambar are recorded to show activity during daylight hours as well (Griffiths & Schaik 1993). Though there were no totally human free areas in NSTR, we did observe greater daytime activity for Sambar in low human impact zone (Figure 1).

More significantly, the overall active period of Sambar reduced in high human use areas (Table 2), thereby reducing the duration available for foraging and other vital activities. At NSTR, chital were reported to be widely dispersed and to form small herds (Srinivasulu

2001), which contrasts with our observations, since we found all ungulates to be very skittish, Chital in particular, were at very low densities and mostly observed as solitary or in very small groups, a major deviation from observations in other protected areas where chital tend to be the most abundant wild ungulate, often occurring in large herds. Chital have been reported as being diurnal with a bimodal activity at dawn and dusk (Schaller 1967) our results conform to this pattern.

A shift in the activity of Chital (though not statistically significant) was observed between high and low human-use areas of NSTR (Figure 1), with the evening peak of activity being less pronounced and more spread out into the late evening and early night in high human-use areas. High and low human-use areas actually differed only in terms of livestock use, with human and domestic dog usage being recorded across NSTR with no statistical difference across zones.

Livestock is sympatric with wild ungulates in most forested areas of India (Kothari et al. 1989), where they potentially compete for essential resources like food and water. Even though livestock grazes Indian forests to varying extents, their impact on wild native ungulates is less understood (Madhusudan 2004). Understanding the interaction between wild ungulates and livestock is complex and varied under different ecological conditions (Sankar 1994; Dave & Jhala 2011). Though we segregate our camera traps into high and low human impact zones we caution that human activity was recorded across NSTR and therefore we find little differences between low and high human impact zones in terms of timing of activity as well as active duration, these differences would likely have been more pronounced if compared between total human impact free areas and human use areas.

More importantly, our data show that all ungulates across NSTR avoided time periods having high human activities. Often diseases like foot and mouth can get transmitted between livestock and sambar (Johnsingh & Manjrekar 2015). NSTR has a large resident cattle population and during the monsoon an additional large number of cattle migrate from nearby villages to graze (Bhargav et al. 2009).

Presence of domestic dogs in protected areas shifts wildlife temporally or permanently from the available space they have (Banks & Bryant 2007). Our results show that domestic dogs were very active (41%) in high human use areas and domestic dogs usually accompanied humans (Table 2). Domestic dogs have been traditionally used by forest dwelling communities to hunt bushmeat. Even the odour of dog urine or faeces can trigger wild animals to avoid an area (Hennings 2016). Since domestic dogs occur at densities higher than natural predators, the frequency of attacks on wild prey species is also likely high, especially in and around protected areas (Ritchie et al. 2013).

We found that free-ranging dogs often accompany tribesmen armed with bow and arrows who move around unhindered inside the protected area on the pretext of collecting non-timber forest products. While conducting fieldwork AK witnessed incidents where dogs accompanied by local tribal communities chased Chital. Temporal activity pattern revealed that activity of dog's overlap more than 60% of the activity of Chital, Nilgai, and Chousingha. These ungulates being diurnal are limited in their ability to change their activity to avoid dog activity periods (that are only diurnal). Thus human impacts and predation through dogs would affect these diurnal species the most. Domestic dogs were often used for hunting wildlife by local tribal communities and their impact were likely significant in depressing ungulate densities as also reported (Madhusudan & Karanth 2002).

Many wildlife species face extinction because of human impacts; therefore, a prevailing belief is that many species cannot co-exist with people (Carter et al. 2012). Any human-related activity can disturb wildlife; one such significant depressant is hunting. Carnivore assemblages may be affected by direct poaching or through poaching of their prey. Diverse methods, including domestic dogs, bow and arrows, traps, and smoking of fossorial mammals, were traditionally used for hunting (Datta & Naniwadekar 2019). It is recognized that continued overhunting lowers animal densities and subsequently leads to local, regional, and overall species extinction (Diamond 1989; Rabinowitz 1995). A study from Nagarahole Tiger Reserve mentions that 78% of local communities interviewed preferred to hunt Mouse Deer by using domestic dogs (Madhusudan & Karanth 2002).

In NSTR mousedeer has the least overlap with domestic dog activity (Figure S5) possibly to avoid predation. Hunting also changes the behaviour of wildlife as seen in Sika Deer in Bialowieza National Park where they became more diurnal once the park management restricted tourism and hunting (Kamler et al. 2007). Hunting influenced Wild Boar activity patterns where it was more diurnal during the non-hunting season in central Japan (Ohashi et al. 2013). The NSTR management acknowledges that the resident Chenchu tribals, who always carry a bow and arrows and are accompanied by domestic dogs whenever they move inside the forest, do hunt birds and monitor lizards (Pandey et al. 2013). The Lambada tribe, are reported to occasionally hunt small mammals during festive season (Bhargav et al. 2009). Despite the fact that we were unable to quantify ungulate poaching as a cause of their low densities, based on observations and camera trap photographs of such actions, poaching, combined with high livestock densities, and domestic dog related stress was most likely to be responsible for NSTR's low wild ungulate densities.

CONCLUSIONS

Our findings suggest that RAI estimates can help index abundance and can be used to estimate trends in wild ungulate populations. Our data and inferences show that impacts of human activities alter wild ungulate abundance and behaviour, as also demonstrated previously (Gaynor et al. 2018) The tropical dry deciduous forests are among the most impacted habitats by anthropogenic activities and are vulnerable to degradation (Chundawat et al. 1999). The forests near human settlements were more disturbed than those away from settlements. In the short-term, we recommend active removal of free-ranging dogs, control of poaching, and minimizing livestock grazing, for wildlife population revival.

Most forest dwellers prefer to relocate when given a genuine opportunity, since living within protected areas is difficult due to limited access to basic amenities like electricity, roads, health care, education, and markets. While within protected areas, their crops are raided by wild ungulates, and large carnivores often kill their livestock and sometimes humans (Madhusudan & Mishra 2003; Chapron et al. 2008). However, people rights activists argue that human resettlement from protected areas is unethical and is not required since forest-dwelling communities live in harmony with nature and forest resource use by them is sustainable (Rangarajan & Shahabuddin 2006; Dattatri 2010). In certain instances, relocation results in transformation of the 'way of living' since relocation usually results in changing nomadic hunter-gatherer or pastoral communities to a more settled livelihood based on agriculture or labour.

Several communities such as Gujjars in Uttarakhand, Sahariyas in Madhya Pradesh, and Maldharis in Gujarat face a challenging transition that is often difficult to make (Rangarajan & Shahabuddin 2006). In line with this argument, the forest-dwelling tribes of NSTR (Chenchus and Lambadas) have not been offered the NTCA incentive of voluntary relocation. Thus, without any genuine feasible option to move out of the core area of NSTR, human settlements continue to grow within the tiger reserve, and their impact on forest resources remains unabated and increasing with time. To achieve the conservation objectives of the tiger reserve, i.e., to establish a long-term viable population of tigers that act as a flagship and umbrella species for the conservation of the ecosystem, higher abundance of wild ungulates is required, for this it seems important to mitigate the current human impacts in NSTR.

We propose that the incentivized voluntary relocation package of INR 1.5 million per adult (~ USD 20,000) (NTCA 2021) be made available to the forest-dwelling communities of NSTR. This would open an option for potentially better livelihoods and lifestyles to these people outside of the tiger reserve and benefit both people and wildlife simultaneously. Future studies should be carried out by camera trap based monitoring each year, keeping the present study as a baseline, to understand the status and trends of carnivore and herbivore abundance after human impacts are reduced/removed within NSTR. Such monitoring should conclusively prove the depressant effects of humans on wildlife and document the recovery of the wild ungulate populations (Anonymous 2009).

REFERENCES

Anonymous (2009). The state of forest report, forest survey of India, Ministry of Environment and Forests, Government of India. New Delhi 54–57.

Aschoff, J. (1989). Temporal orientation: circadian clocks in animals and humans. *Animal Behaviour* 37 (4): 881–896. https://doi.org/10.1016/0003-3472(89)90132-2

Banerjee, K. (2005). Estimating the ungulate abundance and developing the habitat-specific effective strip width models in Kuno Wildlife Sanctuary, Madhya Pradesh. M.Sc. Thesis. Forest Research Institute, Dehradun.

Banks, P., & J. Bryant (2007). Four-legged friend or foe? Dog walking displaces native birds from natural areas. *Biology Letters* 3: 611-613. https://doi.org/10.1098/rsbl.0374:1–4

Berger, A., K.M. Scheibe, S. Michaelis & W. Streich (2003). Evaluation of living conditions of free-ranging animals by automated chronobiological analysis of behavior. *Behavior Research Methods, Instruments, & Computers* 35(3): 458–466.

Bhargav, P., S. Dattatri & A. Desai (2009). A Rapid Appraisal report on Nagarjunasagar Srisailam Tiger Reserve-Andhra Pradesh. National Tiger Conservation Authority, 31 pp.

Bisht, S., S. Banerjee, Q. Qureshi & Y. Jhala (2019). Demography of a high-density tiger population and its implications for tiger recovery. *Journal of Applied Ecology* 56(7): 1725–1740. https://doi.org/10.1111/1365-2664.13410

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers & L. Thomas (2004). Advance Distance Sampling*: Estimating abundance of biological populations,* Oxford, Oxford University Press, 33–47 pp.

Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J.R. Ginsberg & W.N. Shahruddin (2001). The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation* 4(1): 75–79. https://doi.org/10.1017/S1367943001001081

Carter, N.H., B.K. Shrestha, J.B. Karki, N.M.B. Pradhan & J. Liu (2012). Coexistence between wildlife and humans at fine spatial scales. *Proceedings of the National Academy of Sciences* 109(38): 15360–15365. https://doi.org/10.1073/pnas.1210490109

Champion, H.G., & S.K. Seth (1968). *A Revised Survey of Forest Types of India*. Natraj Publishers, Dehradun, 404 pp.

Chapron, G., D.G. Miquelle, A. Lambert, J.M. Goodrich, S. Legendre & J. Clobert (2008). The impact on tigers of poaching versus prey depletion. *Journal of Applied Ecology* 45(6): 1667–1674. https://doi.org/10.1111/j.1365-2664.2008.01538.x

Chundawat, R.S., N. Gogate & A.J.T. Johnsingh (1999). Tigers in Panna: preliminary results from an Indian tropical dry forest. *Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes.* Cambridge University Press, 378 pp.

Cumming, D.H.M. & G.S. Cumming. (2003). Ungulate community structure and ecological processes: body size, hoof area and trampling in African Savannas. *Oecologia* (134): 560–568.

Datta, A. & R. Naniwadekar (2019). Hunting for answers: the scale and impacts of hunting, and the importance of listening to hunters. *Mongabay* (Electronic Version) https://india.mongabay.com/2019/11/commentary-hunting-for-answers-the-scale-and-impacts-of-hunting-and-the-importance-of-listening-to-hunters/ Accessed on 21 January 2021.

Dattatri, S. (2010). The Myth of Harmonious Co-existence. *Conservation India.* https://www.conservationindia.org/articles/the-tribal-bill-the-myth-of-harmonious-co-existence-2 Electronic Version accessed on 21 January 2021

Dave, C. & Y. Jhala, (2011). Is competition with livestock detrimental for native wild ungulates? A case study of chital (Axis axis) in Gir Forest, India. *Journal of Tropical Ecology* 27(03): 239–247. https://doi.org/10.1017/S0266467410000738

Diamond, J.M. (1989). The present, past and future of human-caused extinctions. *Philosophical Transactions of the Royal Society of London. Biological Sciences* 325(1228): 469–477.

Edwards, S., J. Noack, L. Heyns & D. Rodenwold. (2020). Are camera traps a reliable method for estimating activity patterns? A case study comparing technologies for estimating brown hyaena activity curves. *Remote Sensing in Ecology and Conservation* 7(2): 129–138. https://doi.org/10.1002/rse2.175

ESRI (2011). ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Frey, S., J.T. Fisher, A.C. Burton & J.P. Volpe (2017). Investigating animal activity patterns and temporal niche partitioning using camera-trap data: challenges and opportunities. *Remote Sensing in Ecology and Conservation* 3(3): 123–132. https://doi.org/10.1002/rse2.60

Gaynor, K.M., C.E. Hojnowski, N.H. Carter & J.S. Brashares (2018). The influence of human disturbance on wildlife nocturnality. *Science* 360(6394): 1232–1235. https://doi.org/10.1126/science.aar7121

Gompper, M.E. (2013). The dog-human-wildlife interface: assessing the scope of the problem. *Free-Ranging Dogs and Wildlife Conservation*. Oxford University Press, 342–351 pp.

Griffiths., M. & C.P.V. Schaik (1993). The Impact of Human Traffic on the Abundance and Activity Periods of Sumatran Rain Forest Wildlife. *Conservation Biology* 7(3): 623–626.

Hayward., M.W. & M.D. Hayward (2012). Waterhole use by African fauna. *South African Journal of Wildlife Research* 42: 117–127.

Hennings, L. (2016). The impacts of dogs on wildlife and water quality: A literature review- Technical Report. Metro Park and Nature-Metro Regional Government. Oregon-Portland, 109 pp.

Hooper, D.U., E.C. Adair, B.J. Cardinale, J.E. Byrnes, B.A. Hungate, K.L. Matulich & M.I. O'Connor (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature* 486(7401): 105–108.

Hossain, A.N.M., A. Barlow, C.G. Barlow, A.J. Lynam, S. Chakma & T. Savini (2016). Assessing the efficacy of camera trapping as a tool for increasing detection rates of wildlife crime in tropical protected areas. *Biological Conservation* 201: 314–319.

Jenks, K.E. (2012). Distributions of Large Mammal Assemblages in Thailand with a Focus on Dhole (Cuon alpinus) Conservation. Ph.D Dissertation. University of Massachusetts Amherst, United States.

Jhala Y.V., R. Gopal, V.B. Mathur, P. Ghosh, H.S. Negi, S. Narain, S.P. Yadav, M. Amit, R. Garawad & Q. Qureshi (2021). Recovery of tigers in India: Critical introspection and potential lessons. *People and Nature* 3(2): 281–293. https://doi.org/10.1002/pan3.10177

Jhala, Y.V., Q. Qureshi & R. Gopal (2015). The status of Tigers, Co-predators & Prey in India 2014 (eds) 2015. No. TR2015/021pp. 218–220. National Tiger Conservation Authority, New Delhi & Wildlife Institute of India, Dehradun.

Jhala, Y.V., Q. Qureshi, R. Gopal & P.R. Sinha (2011). Status of the Tigers, Co-predators, and Prey in India, 2010. No. TR 2011/003 pp-302. National Tiger Conservation Authority, Govt. of India, New Delhi, and Wildlife Institute of India, Dehradun.

Jhala, Y.V., Q. Qureshi & A.K. Nayak (2020). *Status of Tigers Co-Predators and Prey in India*. National Tiger Conservation Authority Government of India, New Delhi, and Wildlife Institute of India, Dehradun.

Johnsingh, A. & N. Manjrekar (2015). *Mammals of South Asia, 1st edition*. Universities Press (India) Private Limited, Hyderabad, Telangana, 392 pp.

Karamsi, S.R. (2010). "Deconstructing the Caste Hegemony –Lambada Oral Literature" *Journal of Alternative Perspectives in the Social Sciences* 2(1): 455–467.

Kamler, J.F., B. Jędrzejewska & W. Jędrzejewski (2007). Activity patterns of red deer in Białowieża National Park, Poland. *Journal of Mammalogy* 88(2): 508–514.

Karanth, K.U. & J.D. Nichols (1998). Estimation of Tiger densities in India using photographic captures and recaptures. *Ecology* 79(8): 2852-2862. https://doi.org/10.1890/0012-9658(1998)079

Karanth, K.K., J.D. Nichols, J.E. Hines, K.U. Karanth & N.L. Christensen (2009). Patterns and determinants of mammal species occurrence in India. *Journal of Applied Ecology* 46(6): 1189–1200. https://doi.org/10.1111/j.1365-2664.2009.01710

Kasiringua, E., G. Kopij, & S. Proches (2017). Daily activity patterns of ungulates at water holes during the dry season in the Waterberg National Park, Namibia. *Russian Journal of Theriology* 16(2): 129–138. https://doi.org/1015298/rusjtheriol.16.2.02

Kipkeu, M.L. (2014). Understanding community participation in wildlife conservation in Amboseli ecosystem, *IOSR Journal of Environmental Science, Toxicology and Food Technology* 8(4): 68–75.

Kothari, A., P. Pande, S. Singh, & D. Variava (1989). Management of National Parks and Wildlife Sanctuaries in India. A status report. Indian Institutes of Public Administration, New Delhi, 298 pp.

Kothari, A., S. Suri & N. Singh (1995). Conservation in India: A New Direction. *Economic and Political Weekly* 30(43): 2755–2766.

Kronfeld-Schor, N. & T. Dayan (2003). Partitioning of Time as an Ecological Resource. *Annual Review of Ecology, Evolution, and Systematics* 34(6) 153-181. https://doi.org/10.2307/30033773

Lahkar, D., M.F. Ahmed, R.H. Begum, S.K. Das & A. Harihar (2020). Responses of a wild ungulate assemblage to anthropogenic influences in Manas National Park, India. *Biological Conservation* 243: 108425. https://doi.org/10.1016/j.biocon.2020.108425

Madhusudan, M.D. & K.U. Karanth (2002). Local Hunting and the Conservation of Large Mammals in India. *Ambio* 31(1): 49–54. https://doi.org/10.2307/4315210

Madhusudan, M. & C. Mishra (2003). Why big, fierce animals are threatened: conserving large mammals in densely populated landscapes, pp. 31–55. In: Saberwal, V.K. & M. Rangajaran (eds.). *Battles Over Nature: Science and The Politics of Wildlife Conservation*. Permanent Black, 430 pp.

Madhusudan, M. (2004). Recovery of wild large herbivores following livestock decline in a tropical Indian wildlife reserve. *Journal of Applied Ecology* 41(5): 858–869.

Mathur, V.B., A.K. Nayak & N.A. Ansari (2018). Fourth Cycle of

Management Effectiveness Evaluation (MEE) of Tiger reserves in India. National Tiger Conservation Authority and Wildlife Institute of India, Ministry of Environment, Forest and Climate Change, Government of India, 134 pp.

Meyer, S.M.B., S.R.Jnawali, J.B. Karki, P. Khanal, S. Lohani, B. Long, D.I. MacKenzie, B. Pandav, N.M.B. Pradhan, R. Shrestha, N. Subedi, G. Thapa, K. Thapa & E. Wikramanayake (2012). Influence of prey depletion and human disturbance on tiger occupancy in Nepal: Nepal tiger occupancy. *Journal of Zoology* 289(1): 10–18. https://doi.org/10.1111/j.1469-7998.2012.00956.x

Murty, M.K. (1981). Hunter-gatherer ecosystems and archaeological patterns of subsistence behaviour on the south-east coast of India: An ethnographic model. *World Archaeology* 13(1): 47–58. https://doi.org/10.2307/124212

Ministry of Tribal Affairs (2015). Revised Scheme of "Development of Particularly Vulnerable Tribal Groups (PVTGs) http://tribal.gov.in/writereaddata/Schemes/4-5-NGO. Electronic version accessed on 16 January 2023.

National Tiger Conservation Authority (NTCA) (2021). Enhancement of funding assistance for voluntary village relocation.https://ntca.gov.in/assets/uploads/guidelines/Village_Relocation_Order.pdf Electronic version accessed 16 January 2023.

O'Brien, T.G., Kinnaird, M.F., & Wibisono, H.T. (2003). Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation* 6(2): 131–139. https://doi.org/10.1017/S1367943003003172

Ohashi, H., M. Saito, R. Horie, H. Tsunoda, H. Noba & Y. Hoshino (2013). Differences in the activity pattern of the wild boar Sus scrofa related to human disturbance. *European Journal of Wildlife Research* 59(2): 167–177. https://doi.org/10.1007/s10344-012-0661-z

Oriana Version 4- User's Manual. (2011). Kovach Computing Services, Pentraeth, Wales, U.K., 175 pp. Available online at https://www.kovcomp.co.uk/oriana

Pandey, R., C. Saravanan, D. Mydeen & K. Valli (2013). Tiger Conservation Plan- Nagarjunsagar Srisailam Tiger reserve (for the period 2013-2014 to 2022-2023 Andhra Pradesh Forest Department, 68–79 pp.

Prakash, V., D. Pain, A. Cunningham, P. Donald, N. Prakash & A. Verma (2003). Catastrophic collapse of Indian white-backed Gyps bengalensis and long-billed Gyps indicus vulture populations. *Biological Conservation* (109): 381–390. https://doi.org/ 10.1016/S0006-3207(02)00164-7

Putman, R. (1989). *The Natural History of Deer*, Cornell University Press, 680–681 pp.

R Development Core Team (2018). A language and environment for statistical computing, version 3.5.0. R Foundation for Statistical Computing, Vienna, Austria. Available online at https://www.R-project.org

Rabinowitz, A. (1995). Helping a species go extinct: The Sumatran rhino in Borneo. *Conservation Biology* 9(3): 482–488.

Raju, P.S., C. Sudhakar & C.H. Umamohan (2009). Chenchus and Social Transformation: A Study of a Primitive Tribe in Kurnool District of Andhra Pradesh. *The Anthropologist* 11(3): 167–172. https://doi.org/10.1080/09720073.2009.11891098

Rangarajan, M. & G. Shahabuddin (2006). Displacement and Relocation from protected Areas: Towards a Biological and Historical Synthesis. *Conservation and Society* 4(3): 359–378.

Ridout, M.S. & M. Linkie (2009). Estimating overlap of daily activity patterns from camera trap data. *Journal of Agricultural, Biological, and Environmental Statistics* 14(3): 322–337. https://doi.org/10.1198/jabes.2009.08038

Ritchie, E.G., C.R. Dickman, M. Letnic, & A.T. Vanak (2013). Dogs as predators and trophic regulators pp. 55–68. In: Gompper, M.E. (ed.). *Free-Ranging Dogs and Wildlife Conservation*. Oxford University Press, 336 pp. https://doi.org/10.1093/acprof:osobl/9780199663217.003.0002

Ross, J., A.J. Hearn, P.J. Johnson, & D.W. Macdonald (2013). Activity patterns and temporal avoidance by prey in response to Sunda clouded leopard predation risk: Activity of Sunda clouded leopards and their prey. *Journal of Zoology* 290(2): 96–106. https://doi.org/10.1111/jzo.12018

Rovero, F., & A.R. Marshall (2009). Camera trapping photographic rate as an index of density in forest ungulates. *Journal of Applied Ecology* 46(5): 1011–1017.

Rowcliffe, J.M. (2022). Animal Activity Statistics. https://Cran.r-Project.Org/Web/Packages/Activity/Activity.Pdf (1.3.2): 24.

Rowcliffe, J.M., & C. Carbone (2008). Surveys using camera traps: are we looking to a brighter future? *Animal Conservation* 11(3): 185–186.

Sankar, K. (1994). The Ecology of three Large Sympatric Herbivores (Chital, Sambar, Nilgai) with Special Reference for Reserve Management in Sariska Tiger Reserve, Rajasthan. PhD Thesis. University of Rajasthan, Rajasthan, 120–128 pp.

Schaller, G.B. (1967). *The deer and the tiger: a study of wildlife in India*. University of Chicago Press, Chicago, 411–413 pp.

Shankar, A. (2016). Socio political pattern of banjaras-a study of Warangal district of Telangana State. *Indian Journal of Society & Politics* 3(3): 10–16.

Shea, S., L. Flynn, R. Marchinton & J. Lewiss (1990). Part II. Social behaviour, movement ecology and food habits. In Ecology of Sambar Deer on St Vincent National Wildlife Refuge, Florida. *Tall Timbers Research Station* 7(25): 13–62.

Srinivasulu, C. (2001). Chital (Axis axis Erxleben, 1777) herd composition and sex ratio on the Nallamala Hills of Eastern Ghats, Andhra Pradesh, India. *Zoos' Print Journal* 16(12): 655–658. https://doi.org/10.11609/JoTT.ZPJ.16.12.655-8

Srivathsa, A., D. Vasudev, T. Nair, S. Chakrabarti, P. Chanchani, R. DeFries, A. Deomurari, S. Dutta, D. Ghose, V.R. Goswami, R. Nayak, A. Neelakantan, P. Thatte, S. Vaidyanathan, M. Verma, J. Krishnaswamy, M. Sankaran & U. Ramakrishnan (2023). Prioritizing India's landscapes for biodiversity, ecosystem services and human well-being. *Nature Sustainability* 6: 568–577. https://doi.org/10.1038/s41893-023-01063-2

Subramanyachary, P. (2013). Status of schedule tribes in Andhra Pradesh. *The Dawn Journal* 2(1): 336–343.

Sudeesh, S., & C.R. Sudhakar (2012). Vegetation and Land Cover Mapping of Nagarjunasagar-Srisailam Tiger Reserve, Andhra Pradesh, India using Remote Sensing and GIS. *People International Journal of Geomatics and Geosciences* 2(4): 953–963.

Suryakumari, D., K.B. Rao & C.Vasu (2008). Connecting Lives-Establishing Linkages with Other Players Towards Sustainable Livelihoods in Community Forestry Initiatives. *Centre for People's Forestry*. 7–9 pp.

Ungar, E.D., Z. Henkin, M. Gutman, A. Dolev, A. Genizi & D. Ganskopp (2005). Inference of animal activity from GPS collar data on free-ranging cattle. *Rangeland Ecology & Management* 58(3): 256–266.

Vaditya, V. (2019). Cultural Changes and Marginalisation of Lambada Community in Telangana, India. *Tribal Intellectual Collective India* 31 (2): 13-19

Wegge, P., C.P. Pokheral & S.R. Jnawali (2004). Effects of trapping effort and trap shyness on estimates of tiger abundance from camera trap studies. (7) 251–256. Presented at the Animal Conservation Forum, Cambridge University Press.

Zar, J.H. (2022). *Bio-statistical analysis 5th edition.* Pearson, Norther Illinois University, 255 pp.

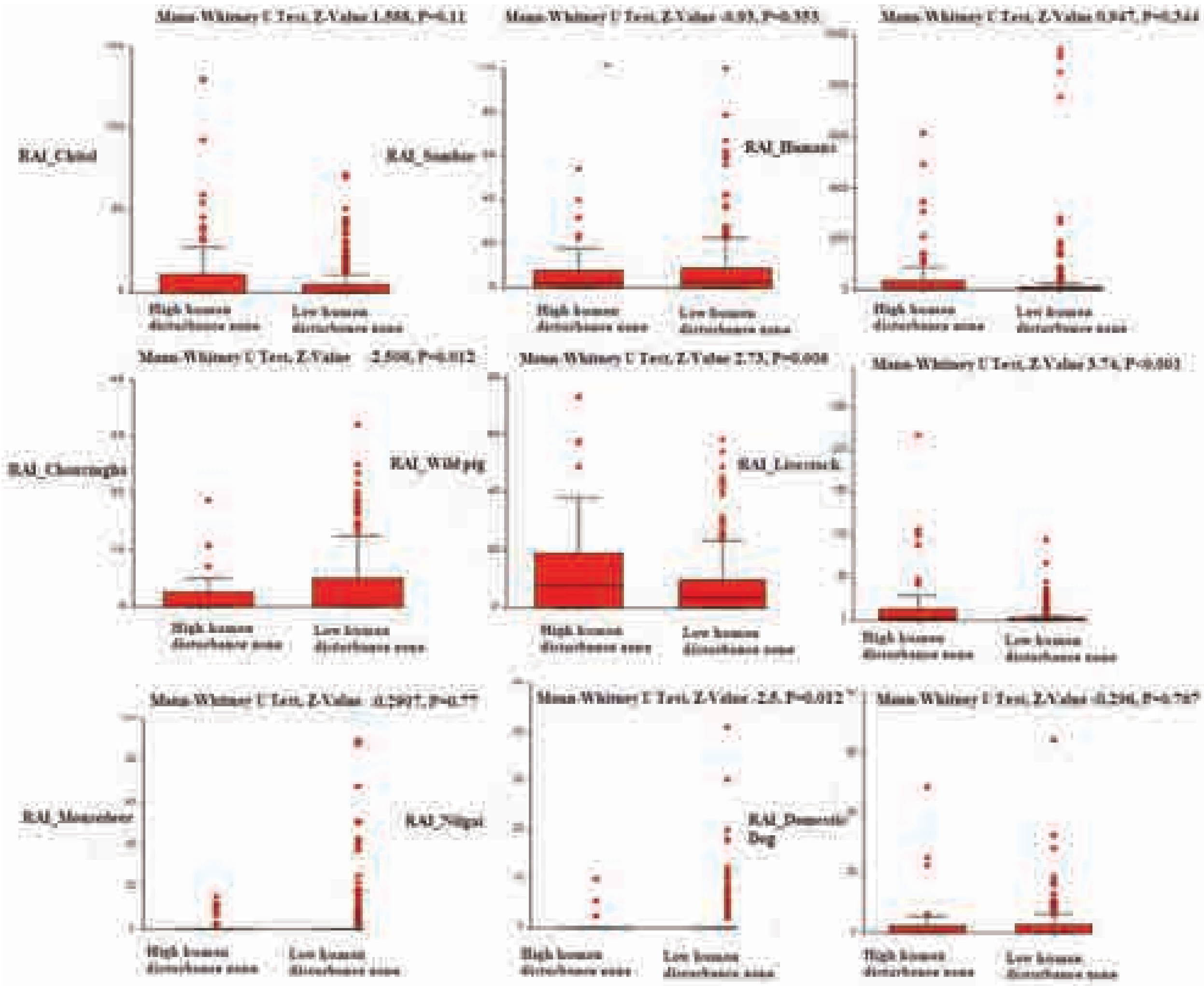

Figure S1. Box plots of relative abundance index (RAI) for wild ungulates as well as humans, domestic dogs, and livestock in proximity to settlements (high human activity zone) and further from settlements (low human activity zone). Mann-Whitney U-Test were done to compare the two RAI's as data were not normally distributed.

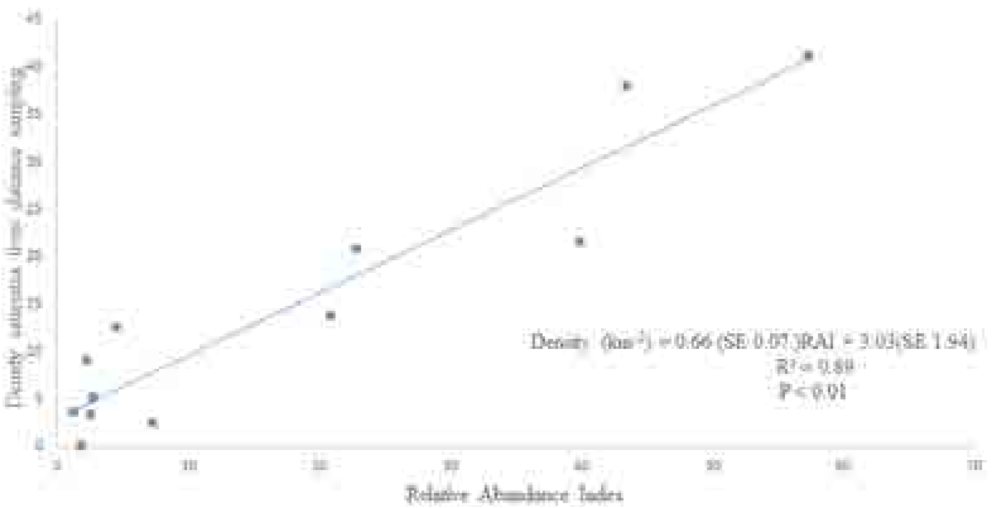

Figure S2. Scatter plot and correlation between distance sampling based density estimates for Chital with relative abundance index (RAI) from camera trap data.

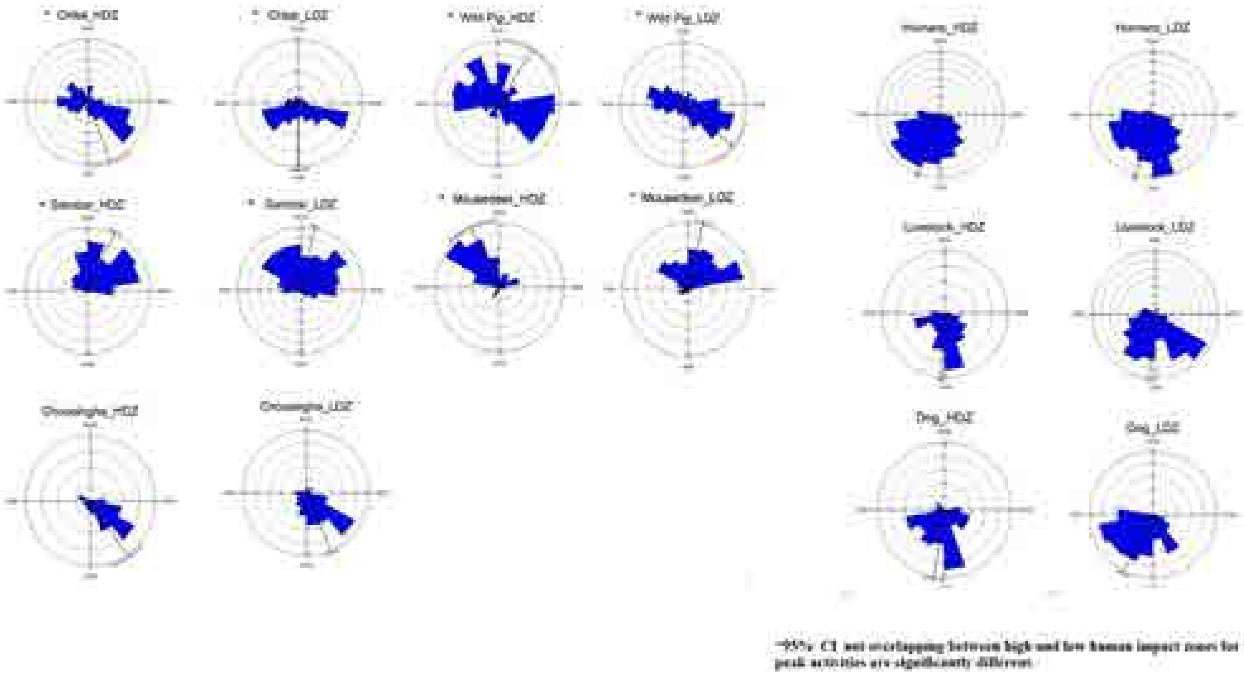

Figure S3. Temporal activity pattern of wild ungulates, in Nagarjunasagar Srisailam Tiger Reserve. Circular rose plot for 24 hours. Activity relative frequency of records of each hour. Red-line running from the center to the outer edge represents the mean angle of the data. The arc extending to either side represents the 95% confidence limit of the mean showing a more significant clustering of data around that hour.

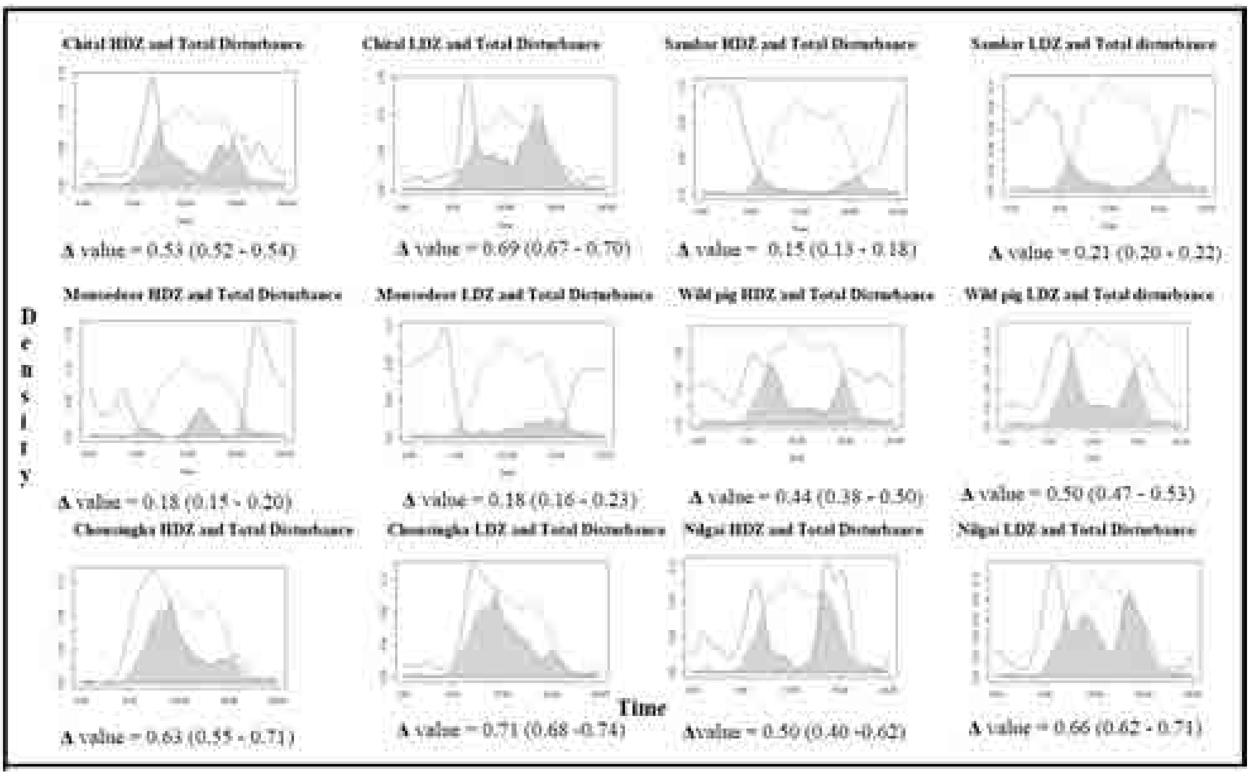

Figure S4. Temporal overlap depicted as kernel density functions of wild ungulate (bold line) activity with combined anthropogenic disturbances (photo-captures of humans, livestock and dogs as dotted line) in areas of high human impacts (HDZ, in proximity to settlements) and low human impacts (LDZ, away from settlements). Overlap was defined as the area under the curve formed by taking the minimum of the two activity patterns at each point in time (denoted in grey) (Δ – Coefficient of overlap, confidence interval in brackets) in Nagarjunsagar Srisailam Tiger Reserve.

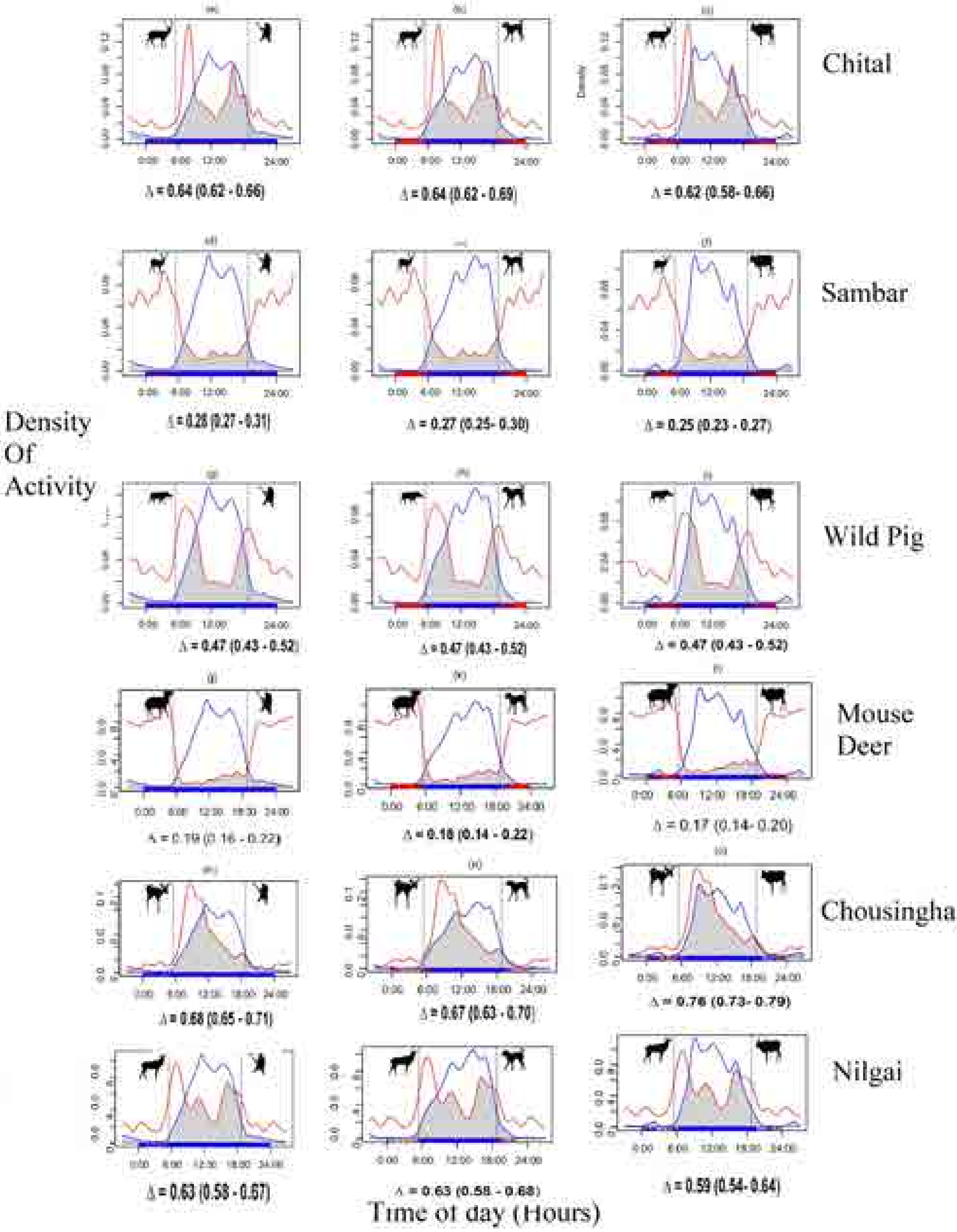

Figure S5. Overall temporal overlap of wild ungulate activity with different anthropogenic disturbance factors. Activity patterns of various anthropogenic disturbances shown as blue lines and of wild ungulates (red lines) depicted as kernel density functions. Overlap was defined as the area under the curve formed by taking the minimum of the two activity patterns at each point in time (denoted in grey) (Δ – Coefficient of overlap; confidence interval in brackets).

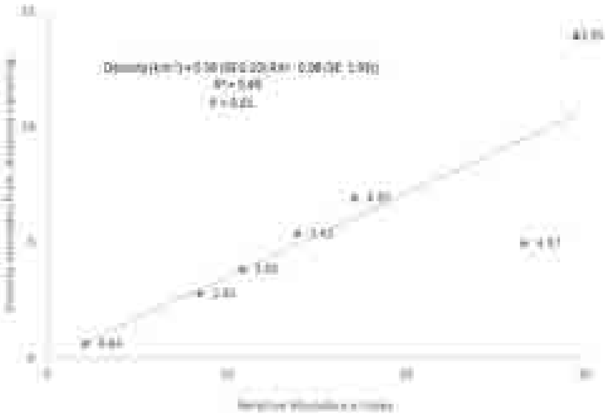

Figure S6. Scatter plot and correlation between distance sampling based density estimates for Sambar with relative abundance index (RAI) from camera trap data.

Image S1. Camera trap image of hunting by local communities in this landscape.

Table S1. Distance sampling based density estimates for Chital and relative abundance index (RAI) Jhala et al. (2020) obtained from camera trap data for habitats similar to Nagarjunasagar Srisailam Tiger Reserve.

Site	Density #/ km^2 (SE)	RAI
Nagarjunsagar Srisailam Tiger Reserve		8.0
Panna Tiger Reserve	13.78 (2.77)	20.89
Achanakmar Tiger Reserve	12.62 (1.78)	4.54
Nawegaon Nagzira Tiger Reserve	5.16 (1.16)	2.74
Pench Tiger Reserve (Maharashtra)	20.87 (4.36)	22.84
Ranthambore Tiger Reserve	21.66 (3.34)	39.90
Bandhavgarh Tiger Reserve	41.36 (4.09)	57.30
Kanha Tiger Reserve	38.14 (5.04)	43.46

Table S2. Distance sampling based density estimates for Sambar and relative abundance index (RAI) (Jhala et al. 2020) obtained from camera trap data for habitats similar to Nagarjunasagar Srisailam Tiger Reserve.

Site	Density #/ km^2 (SE)	RAI
Nagarjunsagar Srisailam Tiger Reserve		8.6
Panna Tiger Rserve	4.97	26.58
Achanakmar Tiger Reserve	0.64	2.15
Nawegaon Nagzira Tiger Reserve	2.81	8.51
Pench Tiger Reserve (Maharashtra)	5.41	13.98
Ranthambore Tiger Reserve	13.95	29.43
Bandhavgarh Tiger Reserve	3.85	10.89
Kanha Tiger Reserve	6.95	17.14

Threatened Taxa

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ARTICLE

Diversity, distribution, and conservation status of fish species in Kallar Stream, Achankovil River, Western Ghats of Kerala, India

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Abstract: The current study presents the findings of fish species inventories conducted at 12 locations in 'Kallar', the perennial tributary of the undammed Achankovil River that flows through the Achankovil Reserve Forest in Kerala State. A new checklist of ichthyofauna is prepared, by adding the updated scientific names, which comprises 35 species from 27 genera, 13 families, and eight orders. In order of abundance, *Opsarius bakeri*, *Salmostoma boopis*, and *Garra surendranathanii* were the most prevalent species in the Kallar tributary. Eight of the total species documented are listed as threatened on IUCN Red List. The study reports the presence of a poorly known smiliogastrin cyprinid, *Dawkinsia lepida* for the first time in the Achankovil River as well as the range expansion of the threatened catfish, *Batasio travancoria,* and the Malabar Spiny Eel *Macrognathus guentheri* to the Kallar tributary. The study also reports a species of *Balitora* from Kallar, distinct from its congeners in several morphometric and meristic characteristics. The absence of any non-native fish species in the study area revealed the pristine nature of the stream habitat. A comparison of diversity indices with the available pre-flood study revealed that the fish species composition in Kallar stream has not altered as a result of the 2018 catastrophic flood. The main existing threat is the practice of destructive fishing at high levels by local communities adjacent to but outside the forest area during the dry season by damming the streamlets and then applying plant-based piscicides. It is recommended that fishing be banned during dry season because this is the time of year when the majority of the upstream fishes breed. The existing environment and fisheries acts should also be strictly enforced. For the sake of future conservation, the competent authorities should see to it that the last remaining natural forest cover in the Kanayar and Kallar ranges are safeguarded from being converted to forest plantations.

Keywords: Fish species inventory, flood, forest cover, habitat heterogeneity, lepida barb, non-native fish, rheophily, river linking.

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Author contributions: VA— field sampling, collection of data, analysis and preparation of manuscript; ML— collection of data, photography, analysis and preparation of manuscript; JT- field sampling, photography and preparation of manuscript; PM- statistical analysis of data and interpretation; AA- field sampling, preparation of manuscript, reviewing and editing.

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INTRODUCTION

Documenting fish faunal diversity at periodic intervals, even within fluviatile systems inside the protected forests facilitates informing conservation status, designing specific management strategies, assessing the impacts of recent or ongoing natural hazards like flash floods and landslides, and forewarning the effects of proposed river interlinking projects and dams. Achankovil forest division, part of the Agathyamala Biosphere Reserve in Western Ghats, India has been recognised as a site that requires immediate attention in order to set up mechanism for inclusion into the protected area network by the Critical Ecosystem Partnership Fund Program (CEPF 2007). Although home to large number of native Western Ghats species, this area suffers considerable levels of forest degradation and conversion (Vijayan et al. 2021). As part of the Government of India's mega project- India Interlinking of Rivers (IIR), the Pamba-Achankovil-Vaippar water transfer link initiative, covering a portion of the forest area is proposed (NWDA 1995; Rani et al. 2016). Although, multiple researches on fish diversity of the Achankovil River have been undertaken, the main tributary, the Kallar, where the project proposed to be implemented, lacks a thorough account on the diversity and micro-level distribution of fish species.

Previous studies on the fish diversity of the Achankovil River, have either focused on the mid and downstream sections or were fractional surveys (Swapna 2009; Johnson & Arunachalam 2009). Species inventory studies pertaining to the upstream areas of Achankovil River have also either concentrated on the main Achankovil stream (Varghese 1994), or without covering all the streamlets of Kallar (Radhakrishnan 2006; Baby et al. 2011; Sabu el al. 2013), the major and the only perennial tributary inside the Achankovil Reserve Forest (ARF). Moreover, no research on the diversity of fish species has been done in the Achankovil River's headwaters following the devastating flood of 2018 to determine the effects. The current study aims to analyse the diversity and distribution pattern of ichthyofauna in Kallar Stream and prepare an updated checklist (by adding the revised scientific names) and photographic atlas, in order to address future conservation initiatives. The study also seeks to determine whether the devastating flood of 2018 had any effects on the diversity of fish species.

MATERIALS AND METHODS

Study Area

Achankovil River, originates from two Western Ghats hill ranges: Kottavasal (by streams from Pasukkidai Mettu, Rishi Malai, and Ramakkal Teri) at an elevation of 700 m in Kollam District and Devarmalai at an elevation of +1,200 m in Pathanamthitta District (Image I). The rocky, undulating, and extremely rough Achankovil forest area is located on the western face of the Western Ghats (Hosagoudar et al. 2010). Two distinct and prominent valleys are found within the study area: (1) Kallar and (2) Achankovil valleys. The tract's southernmost portion is drained by the Achankovil Stream, while its northernmost portion is drained by the Kallar Stream, which eventually unites to form the Achankovil River at Mukkadamuzhi. The Kallar Stream is the principal tributary of the Achankovil River; the name is derived from the rocky nature of its bed (Pillai & Muhammad 2007). After its origin at Devarmalai, Kallar flows for 30 km in east-west direction before taking a southern turn to join the Achankovil Stream. During summer, the Achankovil tributary, which flows from Kumbhavurutty and Manalar is left with no water, while the perennial Kallar tributary remains to be the only stream to feed water to the Achankovil River. Also, the Kallar and its associated streams originate from a greater elevation compared to the Achankovil tributary. Considering all these above factors, the perennial Kallar tributary flowing through the Achankovil Reserve Forest (ARF) was selected for investigating the ichthyofaunal diversity. Sites for species inventory and diversity were chosen to cover the maximum streamlets adjoining the mainstream as well as stream mesohabitats associated with it. Accordingly, 12 sites (Table 1; Image 1) were fixed in the mainstream and streamlets; commencing from Mukkadamuzhi (54 m), the lower elevation site to Kattikkuzhi (331 m), the higher elevation site. Among the sites, Mangala, Pulikkayam, Aramba muzhi, and Mukkadamuzhi were the sites at the confluence points of streamlets. The maps for denoting the sites for species inventory were prepared using QGIS Version 3.24 (Image 1).

Fish Species Inventory

Species inventory was carried out through rapid sampling following Abd et al. (2009) by effectively deploying possible fishing contrivances and covering possible mesohabitats in order to minimize the costs and logistics for multiple sampling over a lengthy period. The sampling was resorted to one time at each site;

Image 1. Sampling sites in Kallar Stream inside Achankovil Reserve Forest, Kerala.

sites I to VII were covered in January and sites VIII to XII were covered in April 2019, due to logistical constraints. At each site, experimental fishing operations were performed over a distance of 100–150 m using a diverse array of fishing gears such as cast net (length 3 m, mesh size 2.5 cm, nylon webbing, lead weight 4k g), seine net (length 25 m, depth 1.63 m, mesh size 1 cm, nylon webbing, plastic floats, and lead sinkers), mosquito net of standard size, scoop net (60 x 30 cm with stainless steel frame and nylon/mosquito netting material) and hook & lines alone or in combination. Immediately after capture, fishes were counted and identified to species level following Jayaram (1999) and taxon-specific revisions (Jayaram 2006; Silva et al. 2010; Knight et al. 2015; Katwate et al. 2020). The species names and their conservation status adhere to Eschmeyer's 'Catalogue of Fishes' (Fricke et al. 2022) and IUCN (2021), respectively. Individuals of all species were photographed in the field while still alive. After being anaesthetized with clove oil, representative specimens were first fixed in 10% neutral buffered formalin and then moved to 70% ethanol for long-term storage. Specimens of each species are catalogued with voucher numbers for accession in the museum collection of the Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi. Single specimen of each species was taken for preservation and genetic analysis and rest of the individuals were released back into the stream. The vernacular names of fishes were obtained from tribal communities and staff of the forest department. Identification and terminology of stream mesohabitats, follow Armantrout (1998).

Diversity Indices

Community structure analysis indices such as Margalef richness (d) Pielou's evenness (J'), Shannon diversity (H'log2), and Simpson dominance (λ), for the 12 sites were evaluated using Primer 6, following Clarke & Gorley (2006). Correlation between altitude of sampling stations and species diversity as well as richness was analysed using simple linear regression model.

RESULTS

A total of 1,808 individual fish specimens of 35 species belonging to 27 genera, 13 families, and eight orders were obtained during the study period from the Kallar Stream (Table 2 & Images 2–13 (1–35)). Of these, 27 (77%) fish species are found to be endemic to the Western Ghats, including eight species strictly restricted to streams and rivers of Kerala (Table 2). Three species reported, viz., *Rasbora dandia*, *Pseudetroplus maculatus*, and *Aplocheilus lineatus* are endemic to the brackish and freshwaters of India and Sri Lanka. *Opsarius bakeri*

Table 1. Geomorphological and habitat features of samling stations in Kallar tributary of Achankovil River, Kerala.

	Sampling station number, name, & coordinates	Elevation (m)	Stream width (m)	Mesohabitat type	Substrate and cover type
1	Site I- Kattikuzhi 9.1361 N 77.2007 E	331	29	Deep pools, cascades	Bedrock, boulders, and cobbles
2	Site II- Vazhaperiyar 9.1267 N 77.1915 E	275	28	intermittent slow to fast flowing riffles and pool- riffles	Cobble, pebble, gravel and sand with intermittent patches of shrubs in the main stream channel
3	Site III- Cheriya Minmutty 9.1421 N 77.1773 E	306	18	Cascades, pool- riffles	Boulders, cobbles and pebbles with thick canopy cover
4	Site IV- Mangala 9.1262 N 77.1694 E	214	30	Cascades, run, glides, slow and fast flowing riffles, deep pools	Cobbles, pebbles and gravel in the fast flowing habitats and silt and sand with leaf litter in the pool habitats. Canopy cover in pool areas and shrub patches in the fast flowing habitats.
5	Site V- Chittar Manjappara 9.1429 N 77.1469 E	214	25	Slow flowing riffle	Cobbles and pebbles as substrates with leaf litter deposition along the banks
6	Site VI- Pulikkayam 9.1363 N 77.1469 E	169	44	Wide streamlet with shallow to moderately deep pools	Silt, sand and silt covered bedrocks and boulders as substrates with large wooden logs across the stream and leaf litter along the shoreline. Luxuriant canopy cover along both banks
7	Site VII – Anakuthi 9.1302 N 77.1324 E	158	36	Moderate to deep pool habitats	Silt and sand as substrates with leaf litter deposition
8	Site VIII - Koottakkal 9.1488 N 77.092 E	141	26	Pool – riffle, run	Cobbles and pebbles
9	Site IX - Aramba muzhi 9.1444 N 77.0975 E	131	58	Glide, run, Pool- riffle, cascades, shallow-moderately deep pools	Bedrock, cobbles and boulders in the main stream course and silt plus sand along the banks and pools
10	Site X - Manakkayam 9.1366 N 77.0914 E	114	35	Rapids and fast flowing riffles	Bedrock, boulders and cobbles
11	Site XI – Pekkuzhi 9.1328 N 77.0711 E	93	38	Cascades, pool- riffles, glides and run	Bedrock, boulders and cobbles
12	Site XII – Mukkadamuzhi 9.1196 N 77.0645 E	54	76	Moderate to deep pool with extensive shallow marginal area at both the banks	sandy and silty substrata and leaf litters

was found to be the most common species found in almost all the sites, whereas *Channa gachua* (1), *Ompok malabaricus* (1), and *Systomus sarana* (3) were the rare species obtained from single sites.

Taxon wise, order Cypriniformes (60 %) dominated in Kallar Stream with 21 species in 15 genera, seven subfamilies and four families; followed by Siluriformes (14.2%) with five species in four genera and three families (Figure 1). Among Cypriniformes, family Cyprinidae dominated with 11 species (53%) followed by Danionidae with six species (29%) and Balitoridae with four species (19%). At subfamilial level, Smiliogastrinae dominated with seven species (41%) followed by Chedrinae (17%), Danioninae (12%), Labeoninae (12%), Torinae (12%), and Rasborinae (6%).

Number-wise, Cypriniformes constituted 90% of the total catch followed by Siluriformes (6.5%), Cyprinodontiformes (1.1%) and the rest by other five orders. Among Cypriniformes, family Danionidae contributed the most (42.6%) and out of which *Opsarius bakeri* marked the highest abundance with 287 individuals followed by *Salmostoma boopis* (254), *Opsarius gatensis* (89), *Devario malabaricus* (60), *Rasbora dandia* (48), and *Laubuka fasciata* (33). Family Cyprinidae represented 40% of the fish sampled, dominated by *Garra surendranathanii* (150), *G. mullya* (117), *Dawkinsia denisonii* (106), and *D. lepida* (103).

Community structure analysis indices for the 12 sampling sites (Table 3) revealed that site VI has the highest species richness (d) value of 4.13, followed by Site XII having a value of 4.07. Pielou's evenness index research revealed that Site III had the maximal value (0.96), followed by Sites V and X, but Site VII had the lowest value of 0.67 due to the uneven distribution of

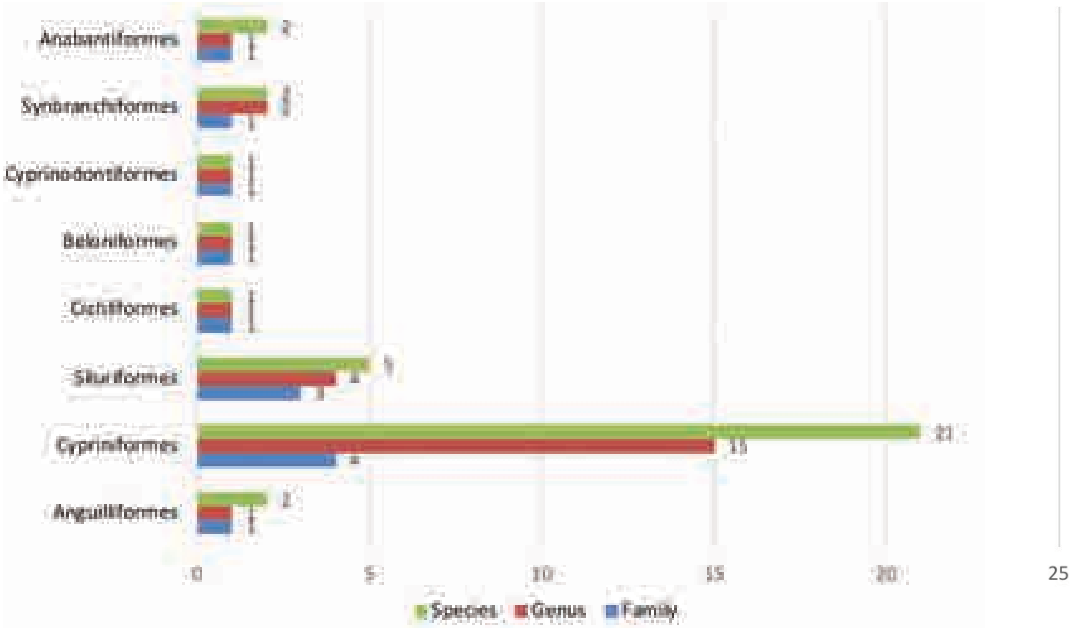

Figure 1. Taxon-wise fish species diversity in Kallar Stream.

nine species. The highest species diversity (H'(log)2) was recorded at Site XI, followed by Site VI, and Site IX, whereas Site I had the lowest value. Site VII had the highest Simpson dominance index of value 0.31, followed by Site I (0.30), and the lowest for Site XI. The results of the regression analysis (Figure 4a, b) revealed significant relationships with diversity and altitude (r = 0.59, t = 2.32, p = 0.0427) and species richness and altitude (r = 0.62, t = 2.5, p <0.0317).

Comparing the diversity indices with the previous study by Sabu et al. (2013) revealed that diversity, as far as Shannon index is considered, has increased in the current study except at two sites. Mean Shannon diversity index value of 3.12 ±0.61 recorded during the present study showed an increasing trend in comparison (2.43±0.69) with Sabu et al. (2013). Though the maximum number of species and individuals were collected from Arampamoozhi (Site IX) the diversity values were low due to the dominance of *Salmostoma boopis* (n = 138) and *Dawkinsia denisonii* (n = 60). A maximum Shannon diversity index of 3.79 was recorded in Site XI, which belongs to the lower elevation zone. Whereas, rest of the higher diverse areas follow the river confluence points such as Site VI (3.76) and Site IX (3.70).

Evenness has increased in the current study except for two locations in comparison with the previous report by Sabu et al. (2013). Overall Margalef species richness seems to decline along the Kallar stream when comparing with the previous study (Sabu et al. 2013) and is prominent in two sites such as Site VII and Site X.

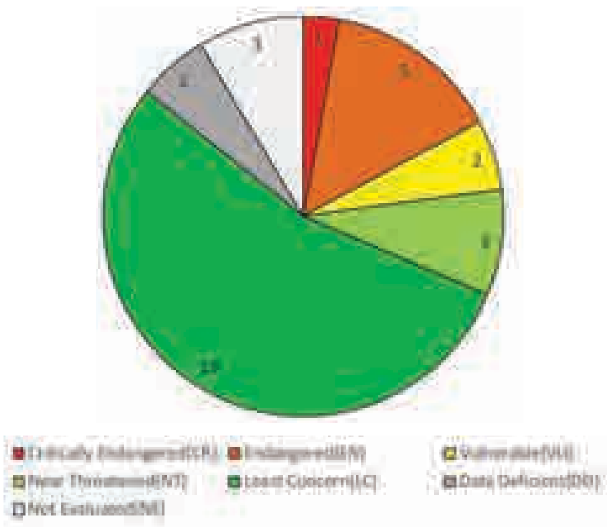

Figure 2. Conservation status of fish species in Kallar Stream (number).

Simpson's dominance index showed that the dominance of certain species has increased in the current study especially in Site VII (Anakuthy) showing a higher value (λ = 0.31) when compared to previous records (Sabu et al. 2013). The higher dominance value of Site VII is mainly due to the higher number of *Salmostoma boopis* (n = 48) in the specified area.

Of the 35 species encountered, eight species (22.9 %) belong to IUCN threatened categories (Table 2; Figure 2) with one Critically Endangered (CR) (*Mesonoemacheilus herrei*); five Endangered (EN) (*Dawkinsia chalakudiensis*,

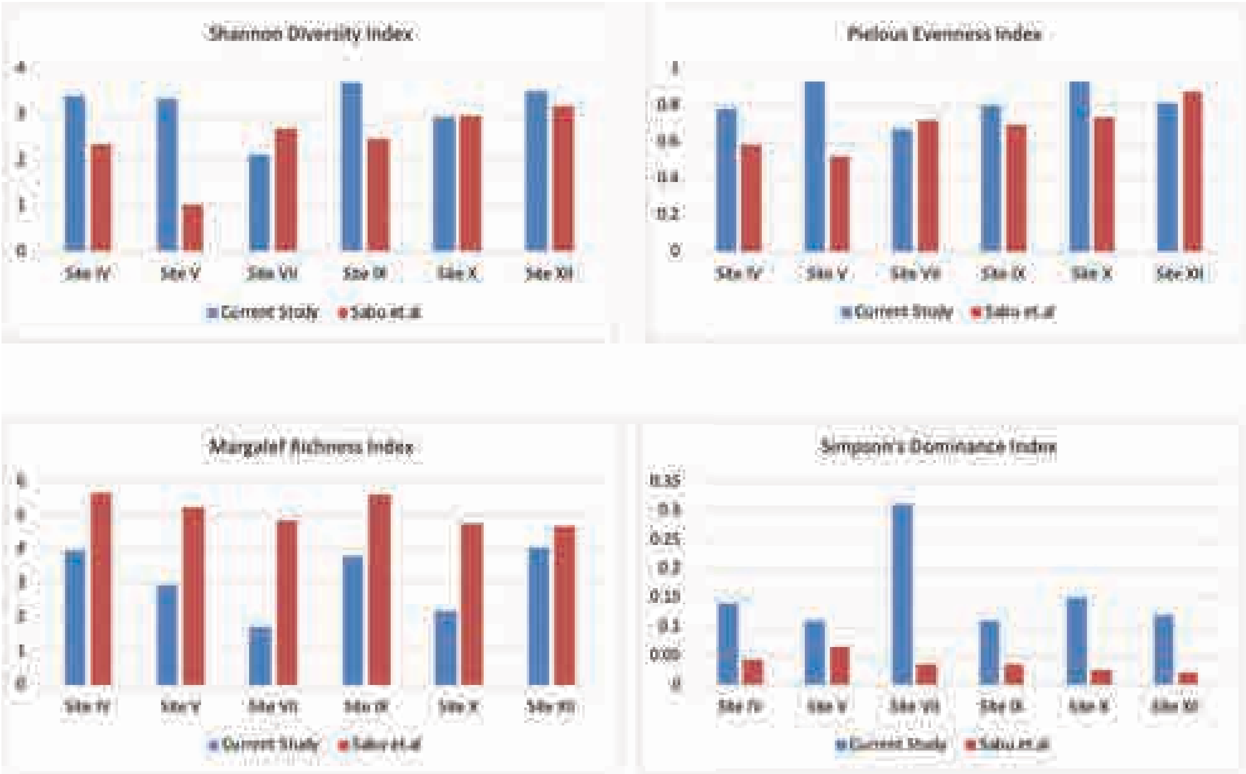

Figure 3. Comparison of diversity indices with the previous study (Sabu et al. 2013) in Kallar Stream.

D. denisonii, Garra surendranathani, Tor malabaricus, and *Glyptothorax anamaliensis*), and two Vulnerable (VU) (*Laubuka fasciata* and *Batasio travancoria*) species. Distribution of *Mesonemachrilus herrei* was found to be restricted to Pulikkayam (Site VI) and Arambamuzhi (Site IX); while the two species of the genus *Dawkinsia (D. denisonii* and *D. chalakkudiensis*) were co-occurring and distributed abundantly in seven sites with good population frequency (Table 2). Despite being gathered from five sites, the Endangered bagrid catfish, *Batasio travancoria* had a comparatively weak population compared to the good population of endangered mahseer, *Tor malabaricus*, at six sites. Among the Endangered species, *Laubuka fasciata* was the second most restricted species found only at two sites (Table 2).

The study reports the presence of the poorly known Lepida Barb *Dawkinsia lepida* for the first time from Achankovil River and is the second report of the endangered Chalakudy Redline Torpedo Barb *D. chalakudiensis*. The current study verifies the existence of *Macrognathus guentheri*, *Anguilla bicolor*, and *Batasio travancoria* in greater elevation gradients of the Achankovil River, despite the fact that these species had previously only been recorded by researchers from the mid and downstream areas of the river.

One positive result experienced was the absence of any records of *Oreochromis mossambicus*, an alien cichlid, from Kallar tributary including the site Mukkada, where the species had previously been reported. The major threat observed during the study period was the practice of destructive fishing at intense level by local communities during dry season, in streams very adjacent to but outside the forest area, by damming the channel including shallow pools followed by the application of plant-based piscicides.

DISCUSSION

Except 10 low land tolerant fish species including two catadromous eels—*Anguilla bicolor*, *A. bengalensis*, *Channa pseudomarulius*, *Puntius mahecola*, *Rasbora dandia*, *Dawkinsia filamentosa*, *Pseudetroplus maculatus*, *Macrognathus guentheri*, *Systomus sarana* and *Xenontodon cancila*—rest of the species were of intolerant fluviatile forms ranging from extreme rheophily with attachment organs in the form of oral adhesive disc (*Garra* sp.), thoracic friction pad (*Glyptothorax* sp.); without attachment organs but, with, really depressed body (*Bhavania* sp., *Balitora*

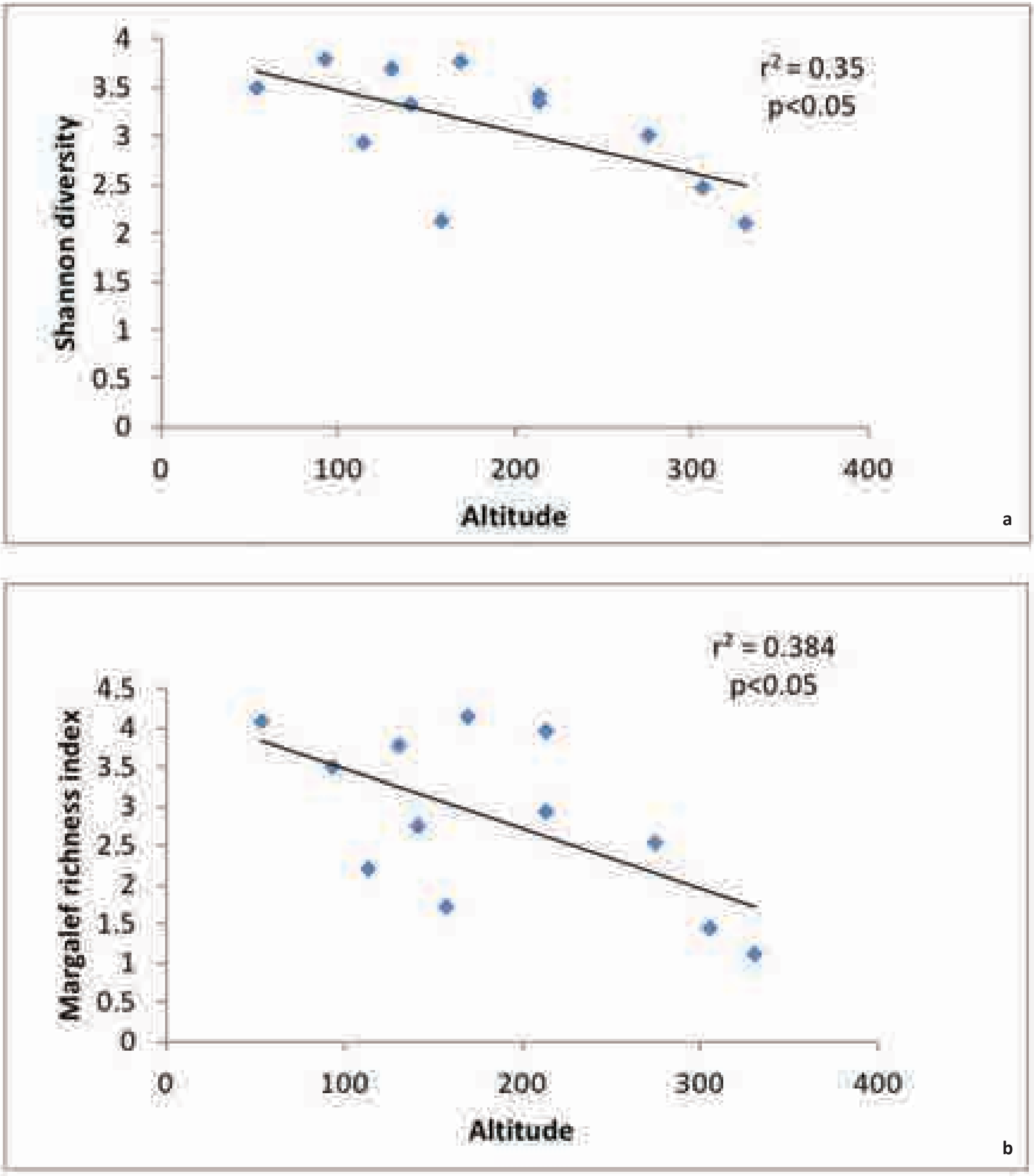

Figure 4. Regression plot of, a—species richness vs altitude (r = 0.50, t = 2.32, p = 0.0427) and | b—species diversity vs altitude (r = 0.62, t = 2.5, p = 0.0317) among the sampling stations in Kallar Stream.

sp.); elongate, anguilliform body (*Mesonoemacheilus* sp., *Mastacembelus* sp.) and compressed - high body (*Hypselobarbus kurali* and *Tor malabaricus*) (Lujan & Conway 2015; Arunachalam 2000).

From six sampling sites distributed along the inundated to elevated zones of the Achankovil River, including one site in the Achankovil tributary inside the ARF, Varghese (1994) recorded a total of 64 species, including 48 primary and 16 secondary freshwater forms, belonging to 43 genera, 28 families, and 10 orders. With the exception of *Channa striata*, all of the species recorded by Varghese (1994) have been reported from Kallar tributary under the current inventory, along with 19 additional species. In summary, of the 48 principal freshwater fish species found in the entire Achankovil River as reported by Varghese (1994), 24 species as well as 11 additional species have been found in the upstream Kallar tributary.

Radhakrishnan (2006) reported 49 fish species, while carrying out an exhaustive ichthyofaunal inventory in 23 sites ranging from the potamonic to rhithronic zones of Achankovil River including three upstream sites-

Table 2. List and details of fish species recorded from Kallar tributary of Achankovil River, Kerala.

	Scientific name	Common name	Vernacular name (Malayalam)	IUCN Red List status	Sites of occurrence & total number of individuals observed	Previous studies which haven't recorded the species	Endemism	Voucher numbers
	Order: Anguilliformes							
	Family: Anguillidae							
1	*Anguilla bengalensis* (Gray, 1831)	Indian Mottled Eel	നെടുമീൻ	NT	IV, VI, IX, XI, XII (5)	1,3,4,5,6	WD	KUFOS.2019.04.A.32
2	*Anguilla bicolor* McClelland, 1844	Indonesian Shortfin Eel	നെടുമീൻ	NT	IV, VI, IX, XI, XII (5)	2,3,4,5,6	WD	KUFOS.2019.04.A.33
	Order: Cypriniformes							
	Family: Danionidae							
	Subfamily: Chedrinae							
3	*Opsarius bakeri* (Day, 1865)	Baker's Baril	ചാലൻ	LC	All sites (287)	Recorded by all previous authors	KL	KUFOS.2019.04.A.1
4	*Opsarius gatensis* (Valenciennes, 1844)	Emerald Baril	ചാലൻ	LC	II, IV, V, VI, VIII, IX, XI, XII (89)	1,6	WG	KUFOS.2019.04.A.2
5	*Salmostoma boopis* (Day, 1874)	Boopis Razorbelly Minnow	പരവൽ	LC	IV, V, VII, IX, X, XI, XII (254)	2	WG	KUFOS.2019.04.A.12
	Subfamily: Danoninae							
6	*Devario malabaricus* (Jerdon, 1849)	Malabar Danio	വാലാട്ടി	LC	I, II, IV, V, VI, VIII, IX, XI (60)	1	WG	KUFOS.2019.04.A.5
7	*Laubuka fasciata* (Silas, 1958)	Malabar Leaping Barb	പരവൽ	VU	VI, VII (33)	1,2,3,5,6	KL	KUFOS.2019.04.A.9
	Subfamily: Rasborinae							
8	*Rasbora dandia* (Valenciennes, 1844)	Black Line Rasbora	തുപ്പല്കൊത്തി	LC	IV, V, VI, VII, VIII, IX, XI (48)	1,2,3,4,5	SIS	KUFOS.2019.04.A.16
	Family: Cyprinidae							
	Subfamily: Smiliogastrinae							
9	*Dawkinsia lepida* (Day, 1868)	Lepida Barb	പൂവാലി	NE	II, IV, V, VI, VIII, IX, X, XI, XII (103)	1,2,3,4,5,6	WG	KUFOS.2019.04.A.3
10	*D. filamentosa* (Valenciennes, 1844)	Filament Barb	പൂവാലി	LC	III, IV, V, VI, IX, XI, XII (19)	Recorded by all previous authors	WG	KUFOS.2019.04.A.4
11	*Sahyadria denisonii* (Day, 1865)	Denison's Redline Torpedo Barb	ചെങ്കണിയാൻ	EN	IV, VI, VIII, IX, X, XI, XII (106)	Recorded by all previous authors	WG	KUFOS.2019.04.A.11
12	*Sahyadria chalakkudiensis* (Menon, Rema Devi & Thobias 1999)	Chalakudy Redline Torpedo Barb	ചെങ്കണിയാൻ	EN	IV, VI, VIII, IX, X, XI, XII (58)	1,2,3,5,6	KL	KUFOS.2019.04.A.10
13	*Haludaria melanampyx* (Day, 1865)	Melon Barb	വാഴയ്ക്കാവരയൻ	DD	II, V, VIII, IX, XI (61)	1	KL	KUFOS.2019.04.A.8
12	*Puntius mahecola* (Valenciennes, 1844)	Mahe Barb	ഉരുളൻ പരൽ	DD	XII (8)	1,2,3,4,5	KL	KUFOS.2019.04.A.34
13	*Systomus sarana* (Hamilton, 1822)	Olive Barb	കുറുവ	LC	IX (3)	3,5,6	WG	KUFOS.2019.04.A.13
	Subfamiy: Labeoninae							
16	*Garra mullya* (Sykes, 1839)	Striped Stone Sucker	കല്ലേമുട്ടി, കൈപ്പ	LC	I, II, III, IV, V, VIII, IX, XI, XII (117)	Recorded by all previous authors	WG	KUFOS.2019.04.A.6
17	*Garra surendranathanii* Shaji, Arun & Easa, 1996	Surendran's Stone Sucker	കല്ലേമുട്ടി, കൈപ്പ	EN	I, II, IV, V, VI, VIII, IX, XI, XII (150)	1,3,6	KL	KUFOS.2019.04.A.7
	Subfamily: Torinae							
18	*Hypselobarbus kurali* Menon & Rema Devi, 1995	Kurali Barb	കൂരൽ	LC	I, III, VII, VIII, XI (47)	1,2,3,4,5	WG	KUFOS.2019.04.A.15
19	*Tor malabaricus* (Jerdon, 1849)	Malabar Mahaseer	കററി	EN	I, II, IV, VI, VIII, IX (42)	1,2,3,4,5,6	WG	KUFOS.2019.04.A.14
	Family: Balitoridae (stone loaches)							
	Subfamily: Balitorinae							
20	*Balitora* sp.	Slender stone loach	കല്ലട്ട	NE	II, IV, IX, XI (23)	1,2,3,4,5,6	KL	KUFOS.2019.04.A.20

	Scientific name	Common name	Vernacular name (Malayalam)	IUCN Red List status	Sites of occurrence & total number of individuals observed	Previous studies which haven't recorded the species	Endemism	Voucher numbers
21	*Bhavania australis* (Jerdon, 1849)	Bhavani Stone Loach	കല്ലട്ട, കൽനക്കി	LC	III, IV, VI, X (25)	1,3	WG	KUFOS.2019.04.A.17
	Family: Nemacheilidae							
22	*Mesonoemacheilus herrei* Nalbant & Bănărescu, 1982	Anamalai Loach	മണലാരി	CR	VI, IX (6)	1,2,3,4,5,6	WG	KUFOS.2019.04.A.19
23	*Mesonoemacheilus triangularis* (Day, 1865)	Zodiac Loach	മണലാരി	LC	II, III, IV, V, VI, VIII, IX, XI, XII (84)	1,2,6	WG	KUFOS.2019.04.A.18
	Order: Siluriformes							
	Family: Sisoridae							
24	*Glyptothorax anamalaiensis* Silas, 1952	Anamalai Mountain Catfish	കൽക്കൂരി, നെയ്കൂരി	EN	VI, IX, X, XI, XII (29)	2,3,6	WG	KUFOS.2019.04.A.24
25	*Glyptothorax annandalei* Hora, 1923	Annandale's Mountain Catfish	കൽക്കൂരി, നെയ്കൂരി	LC	II, III, IV, V, VI, VIII, IX, X (48)	1,3,4,6	WG	KUFOS.2019.04.A.25
	Family: Siluridae							
26	*Ompok malabaricus* (Valenciennes, 1840)	Malabar Butter Catfish	ചൊട്ടാവാള	LC	IV (1)	1,2,4,6	WG	KUFOS.2019.04.A.23
	Family: Bagridae							
27	*Batasio travancoria* Hora & Law, 1941	Travancore Batasio	നീലകൂരി	VU	VI, VII, IX, XI, XII (13)	1,2,3,4,5	KL	KUFOS.2019.04.A.22
28	*Mystus malabaricus* (Jerdon, 1849)	Malabar Mystus	ചില്ലാൻ കൂരി	NT	IV, VI (26)	2,5,6	WG	KUFOS.2019.04.A.21
	Order: Cichliformes							
	Family: Cichlidae							
	Subfamily: Etroplinae							
29	*Pseudetroplus maculatus* (Bloch, 1795)	Orange Chromide	പള്ളത്തി	LC	XII (15)	Recorded by all previous authors	IS	KUFOS.2019.04.A.30
	Order: Beloniformes							
	Family: Belonidae							
30	*Xenentodon cancila* (Hamilton, 1822)	Needle Fish	കോലാൻ	LC	VI, VII, IX, XII (4)	6	WD	KUFOS.2019.04.A.26
	Order: Cyprinodontiformes							
	Family: Aplocheilidae							
31	*Aplocheilus lineatus* (Valenciennes, 1846)	Striped Panchax	പൂഞ്ഞാൻ, നെററിയേപൊട്ടൻ	LC	XII (20)	Recorded by all previous authors	IS	KUFOS.2019.04.A.31
	Order: Synbranchiformes							
	Family: Mastacembelidae							
32	*Macrognathus guentheri* (Day, 1865)	Malabar Spiny Eel	ആരൽ, മണലാരകൻ	LC	VI,VII (2)	2,3,4,5,6	WG	KUFOS.2019.04.A.27
33	*Mastacembelus armatus* (Lacepède, 1800)	Zig-Zag-Eel	ആരൽ, പനയാരകൻ	LC	II, V, VI, VII, IX, X, XII (10)	6	WD	KUFOS.2019.04.A.28
	Order: Anabantiformes							
	Family: Channidae							
34	*Channa gachua* (Hamilton, 1822)	Dwarf Snakehead	വട്ടോൻ	LC	XII (1)	2,3,5,6	WD	KUFOS.2019.04.A.35
35	*Channa pseudomarulius* (Günther, 1861)	Giant Snakehead	വാക	NE	XI, XII (7)	6	PI	KUFOS.2019.04.A.29

CR—Critically Endangered | EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concern | DD—Data Deficient | NE—Not Evaluated | WD—Wide Distribution | KL—Kerala | WG—Western Ghats | SIS—Southern India and Sri Lanka | IS—India and Sri Lanka | PI—Peninsular India | 1—Varghese (1994) | 2—Radhakrishnan (2006) | 3—Swapna (2009) | 4—Baby et al. (2011) | 5—Sabu et al. (2013) | 6—Johnson & Arunachalam (2009).

Table 3. Diversity indices of fishes recorded from the study area.

Sites	S	N	d	J'	H'(log2)	λ
Site I	6	85	1.13	0.81	2.09	0.3
Site II	12	76	2.54	0.84	3	0.16
Site III	6	32	1.44	0.96	2.48	0.19
Site IV	21	158	3.95	0.78	3.41	0.14
Site V	12	42	2.94	0.93	3.34	0.11
Site VI	24	261	4.13	0.82	3.76	0.1
Site VII	9	103	1.73	0.67	2.12	0.31
Site VIII	14	111	2.76	0.87	3.32	0.12
Site IX	25	565	3.79	0.8	3.7	0.11
Site X	9	38	2.2	0.93	2.93	0.15
Site XI	20	230	3.49	0.88	3.79	0.09
Site XII	20	107	4.07	0.81	3.5	0.12

S—Number of species from each site | N—Total number of individuals from each site | d—Margalef richness index | J'—Pielou's evenness index | H' (log2)—Shannon diversity index | Lambda (λ)—Simpson dominance index.

Vazhaperiyar and Kallar in Kallar Stream and a third site in the neighbouring Achankovil Stream. All but three of the 15 species listed by Radhakrishnan (2006) (five from Kallar, seven from Achankovil, and four shared by both the streams) were collected under the current inventory. The possible reason for the absence of three rheophilic species - *Barbodes carnaticus*, *Garra hughi*, and *Pristolepis marginata* in the current study might be attributed to their restricted distribution within the Achankovil stream, which is supported by Baby et al. (2011). The current study added nine species additionally to the fish faunal list of Achankovil prepared by Radhakrishnan (2006).

Swapna (2009) reported 52 species belonging to five orders and 18 families from four sampling locations spread along the low and midland areas of Achankovil River. Although Swapna (2009) regarded the station 'Thura' (9.124N, 77.042E) as a high land area, the altitude was below that of the lowest elevation site (54 m) fixed for sampling in the present study. In the current investigation, the Kallar tributary was found to contain 23 of the species listed by Swapna (2009), 12 additional species, including nine rheophilic forms. Among these 12 species, except *Anguilla bicolor*, *A. bengalensis*, and *Channa gachua* all other species were typical rheophilic forms. The reasons for the non-record of other species in the current study which were reported by Swapna (2009) might be attributed to the potamonic or secondary freshwater affinity, as these species are mostly reported from lowland inland waters in Kerala (Renjithkumar et al. 2011).

Johnson & Aruncahalam (2009) recorded 17 species of fishes from a single location in the downstream area outside the ARF including new record of *Batasio travancoria* from Achankovil River. Except for three species (*Aplocheilus panchax*, *Puntius arenatus*, and *P. dorsalis*) reported by Johnson & Arunachalam (2009), all other species including *B. travancoria* were obtained in the current study. The three species might very well be misidentified with other species of the corresponding genera in Achankovil River.

Baby et al. (2011) prepared a checklist of fishes of ARF to consist of 46 species of freshwater fishes, belonging to 17 families and 31 genera, after sampling seven and four sites in the main Achankovil and Kallar streams, respectively. Seven species—*Angilla bicolor*, *A. bengalensis*, *Macrognathis guentheri*, *Batasio travancoria*, *Glyptothorax annandalei*, *Dawkinsia lepida*—and an unidentified *Balitora* species that were not reported by Baby et al. (2011) from the Achankovil Reserve Forest were collected in the current study from Kallar Stream. Also, six species—*Labuka fasciata*, *Hypselobarbus kurali*, *Aplocheilus lineatus*, *Channa gachua*, *Mystus malabaricus*, and *Ompok malabaricus*—that Baby et al. (2011) described from only the Achankovil Stream were also reported in the current study. Through repeated sampling in all the stations with maximum efforts in terms of time and number of fishing operations, the current study failed to obtain individuals of *Barbodes carnaticus* and *Pristolepis* *marginata*, inferring the restricted distribution of these species to the Achankovil tributary.

Sabu et al. (2013) reported 32 species of fish at 10 locations inside the Achankovil Reserve Forest as part of an ichthyofaunal survey. Eight of the 10 locations sampled by Sabu et al. (2013) belonged to the Kallar tributary and these sites are also investigated in the present study. The site with maximum elevation sampled by Sabu et al. (2013) was Kanayar (170 m), but the current study covered five additional sites >170 m. A comprehensive comparison on tributary as well as site-wise distribution of fish species was not possible with the findings of Sabu et al. (2013) as the researchers had not provided any detailed information. The current study failed to record five species recorded by them, viz., *Puntius vittatus*, *Mystus vittatus*, *M. cavasius*, *Pseudopshromenus cupanus*, and *Carinotetraodon travancoricus*; but reported 11 species additionally. The existence of those species in the Kallar tributary needs to be confirmed as Sabu et al. (2013) did not provide the stream-wise distribution of the fish species inside the ARF.

Swapna (2007) and Kurup et al. (2004) reported *Balitora brucei* Gray, a species endemic to northern and northeastern India from the Achankovil River. Radhakrishnan (2006) reported this species as *B. mysorensis* from two localities in Kallar tributary, viz., Chittar and Pulikkayam. Swapna (2009) reported the species as *B. mysorensis* from two localities outside the Achankovil Reserve Forest. The current study could obtain this species of *Balitora* from four locations in Kallar Stream inside the ARF. On detailed examination, the species was found to differ from all extant species of *Balitora* from peninsular India as well as from *B. brucei* in several morphomeristic aspects. Hence, we tentatively consider it as an undescribed species of *Balitora* in the fish species list presented here. The previously known records of the Lepida Barb *Dawkinsia lepida* are from Bhavani River in Tamil Nadu, Chalakudy, and Muvattupuzha drainages in Kerala (Katwate et al. 2020) and the current study confirms the presence of this species in Kallar tributary of Achankovil River and it may be inferred that the species enjoys a wide distribution range and may occur beyond south of Achankovil River.

The ichthyofaunal diversity in the upstream areas of Achankovil, especially the Kallar tributary within the ARF is rich and comparable to other protected areas in Kerala in terms of the number of species reported (N) such as the Neyyar (N = 38) and Idukki (N = 40) wildlife sanctuaries (Thomas et al. 2000a); Chinnar Wildlife Sanctuary (N = 20) (Thomas et al. 1999); Chimmony (N = 34) and Peechi-Vazhani (N = 35) wildlife sanctuaries (Thomas et al. 2000b); Parambikulam National Park (N = 41) (Biju et al. 1999) and Aralam Wildlife Sanctuary (N = 33) (Shaji et al. 1995). The number of species recorded in the current study (N = 35) was equal to or higher than those encountered in several protected areas in Kerala, necessitating the conservation significance of the perennial Kallar tributary.

The lowest diversity was found at higher altitudes, and the same trend followed in Margalef richness confirmed the hypothesis of Reves-Gavilan et al. (1996), that diversity and species richness declines with increasing altitude, and was also matching with results of previous researches made in rivers of Western Ghats (Raghavan et al. 2008; Johnson & Arunachalam 2009). Fluctuations in evenness may be due to disturbances resulted by the flood. The increased number of fish species in the confluence points are attributed to the high habitat diversity or habitat heterogeneity and the observation is in agreement with Arunachalam (2000); Johnson & Arunachalam (2009).

The comparison of diversity indices with Sabu et al. (2013), revealed that the fish faunal composition has not altered due to the 2018 catastrophic flood and this might be attributed to the non-significant alterations caused due to the 2018 catastrophic flood on stream bed substrata and canopy cover in the head waters within forest areas (Raghavan 2019) as compared to large scale multiple negative consequences occurred in the downstream areas (Pereira 2018). Among the forest ranges encompassing the headwaters of Achankovil River (Achankovil, Kallar, Kanayar, and Mannarathara), Kallar and Kanayar are the ones that retain the remaining natural forest cover in the Achankovil River basin, the other two forest jurisdictions have been widely converted into teak plantations (Vijayan et al. 2021). These patches of forest might have minimised the effects of the flash flood-assisted landslides, fish habitat loss, and species displacement to a great extent in the catchment areas of the Kallar sub-basin as against the multiple adverse impacts caused in the mid and downstream areas of the Achankovil River basin and other river basins in Kerala (Pereira 2018; Cheriyan & Oommen 2020). Resistance and resilience are recognised as two crucial elements of fish species assemblage stability (Pearsons & Lamberti 1992). The current study's findings are in line with those of other studies (Meffe & Minckley 1987; Pearsons & Lamberti 1992), which have highlighted the importance of meso- and micro-habitat heterogeneity as playing a critical role in the ability of fish in streams' headwaters to withstand flash floods. Forested streams offer distinctive microhabitats for many endemic rheophilic species and it can be presumable that the degradation or conversion of riparian vegetation can lead to biotic homogenization that may reduce species diversity and ecosystem services (Casatti et al. 2012).

The absence of any kind of non-native fish species including transplanted and exotic fish species from the study area, in contrast to the records of such species from other protected areas in Kerala including Periyar National Park (Biju et al. 1999; Radhakrishnan & Kurup 2010; Thomas et al. 2000a,b), revealed the pristine nature of the habitat within ARF and the efficacy of aquatic habitat conservation under forest protection. Though the presence of Mozambique Tilapia *Oreochromis mossambicus* has been reported by Baby et al. (2011) from Mukkadamuzhi, our detailed sampling with multiple fishing contrivances failed to obtain a single individual of the species from any of the sampling stations in Kallar tributary. Also, the indigenous Etroplin Cichlid *Pseudeptroplus maculatus* is found abundant (with plenty of juveniles being cared by parents) in the stream stretch at Mukkadamuzhi. The flood may have a positive impact on the displacement of tilapias to lower elevation zones, as evidenced by the reports of increased landing of tilapias from the downstream areas (Raghavan et al. 2019). The absence of non-native fish species qualifies Kallar Stream, as a reference site for future ecosystem health assessments using fish-based index of biotic integrity (IBI) for Achankovil River as used in temperate and tropical aquatic systems (Angermeier & Karr 1986; Ganasan & Hughes 1998).

Though a large share of the population of the species including threatened ones are protected within the reserve forest area, destructive fishing practices employed by the local people outside the forest area targeting mainly the migratory and nocturnal fish species such as the catadromous anguillid eels, spiny eels, and catfishes may certainly result in disruption of proper recruitment to the stock and subsequent population decline. Moreover, this type of fishing practice may have a serious negative impact on the breeding and recruitment of non-targeted species; as the majority of the hill stream fishes including most of the threatened fishes are known to breed during the post monsoon months of November to February (Ali & Prasad 2007; Thampy 2009; Solomon et al. 2011). Hence, there is an urgent need for declaring a fishing ban or closed season during these months for protecting the breeding populations and ensure proper recruitment. Also, such destructive fishing practices need to be monitored and regulated with the provisions of the Kerala Inland Fisheries and Aquaculture Act 2010, and the Environmental Protection Act 1986, Government of India. Awareness has to be created among local communities on the negative impacts of fishing during the dry season and the protection of stream habitats.

In the context of the past reduction of protected forest area in the catchment areas of Achankovil River basin by 53% from 1978 to 2015 (Vijayan et al. 2021), forest-associated habitat heterogeneity in streams supporting a rich fish diversity, conservation status and endemism of the species inhabiting, and other numerous functions offered by the riparian vegetation; the remaining natural forest cover, specifically in the Kanayar and Kallar ranges need to be protected as such from being converted to forest plantations. Also, construction of a concrete dam across the Kallar tributary (3 km upstream from the confluence point of Kallar tributary) has been envisaged in the proposed Pamba-Achankovil-Vaippar link project (NWDA 1995; Rani et al. 2016), for diverting surplus water in Pamba and Achankovil rivers in central Kerala to the deficit Vaippar in Tamil Nadu State. The location of the dam and the tunnel that is proposed to be built within the Kallar tributary includes three most species-diverse sites (Pulikkayam, Pekkuzhi, and Mukkadamuzhi) housing populations of seven threatened species, including five 'Endangered' (*Dawkinsia denisonii*, *D. chalakudiensis*, *Glyptothorax anamalaiensis*, *Garra surendranathathanii*, and *Tor malabaricus*) and two 'Vulnerable' (*Batasio travancoria* and *Laubuca fasciata*) species. The implementation of the proposed project could have negative effects on the natural forest cover and its dependent biodiversity, especially in the catchment areas of Kallar, which is also the type locality for the 'Critically Endangered' Tuberous Geophyte *Arisaemia sarracenioides* and the only known location outside the type locality for the endemic orchid species *Denrobium kallarensis* (Mathew et al. 2016). Considering the warning on 'the complete loss of natural forest cover within near future as the current conversion continues at the present scale' (Vijayan et al. 2021), proper environmental and ecological impact assessment studies have to be carried out prior to consideration. Given the ecological significance of the forest area associated with the Kallar tributary in relation to the endemism and threat status of the fauna and flora inhabiting it, the livelihood support that the specific forest provides to the tribal community, and the fact that the study area harbour the only remaining natural forest cover in the Achankovil River basin, the water diversion project should be abandoned.

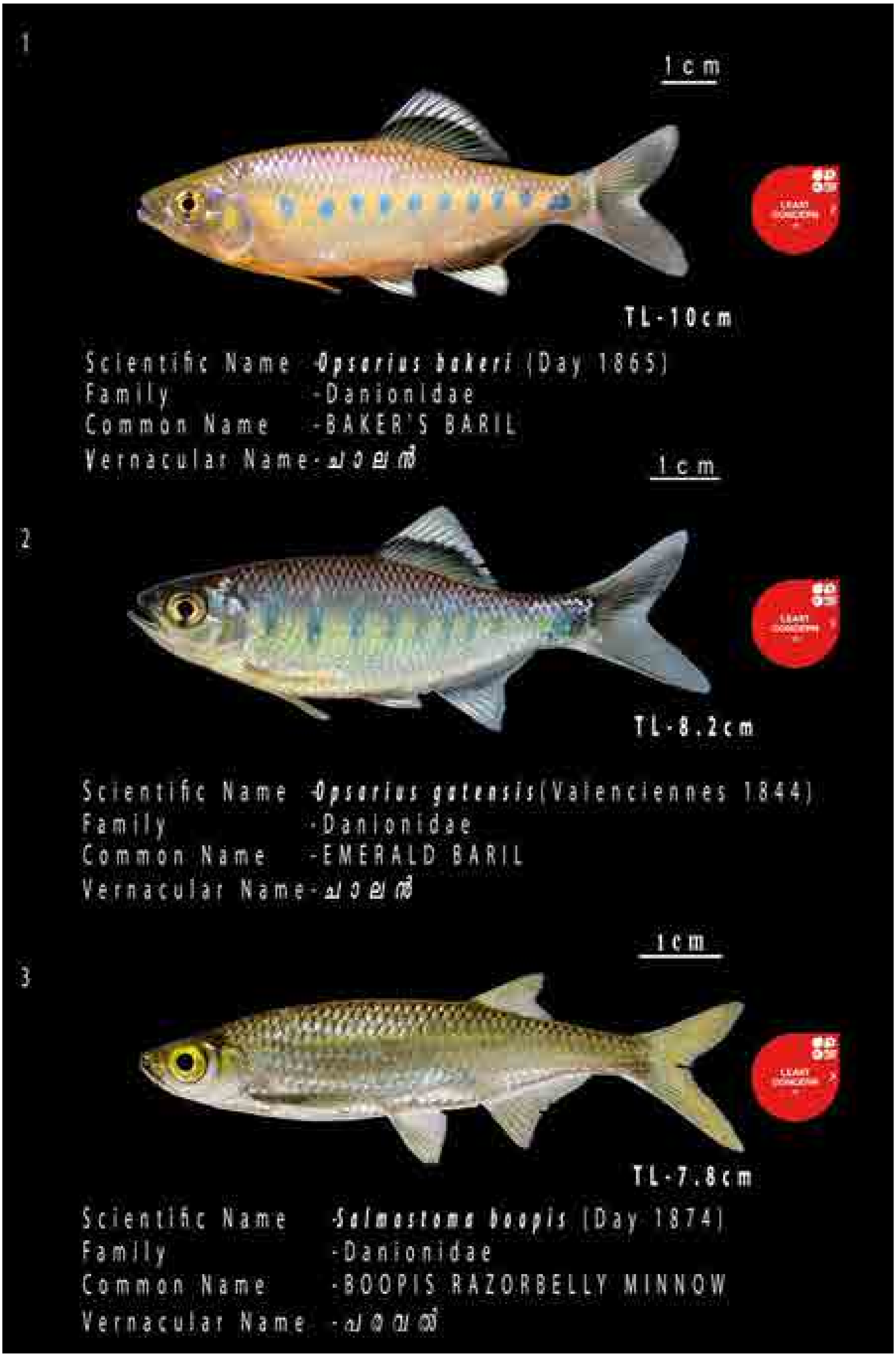

Image 2. Fish specimens from the Kallar Stream. © Melbin Lal.

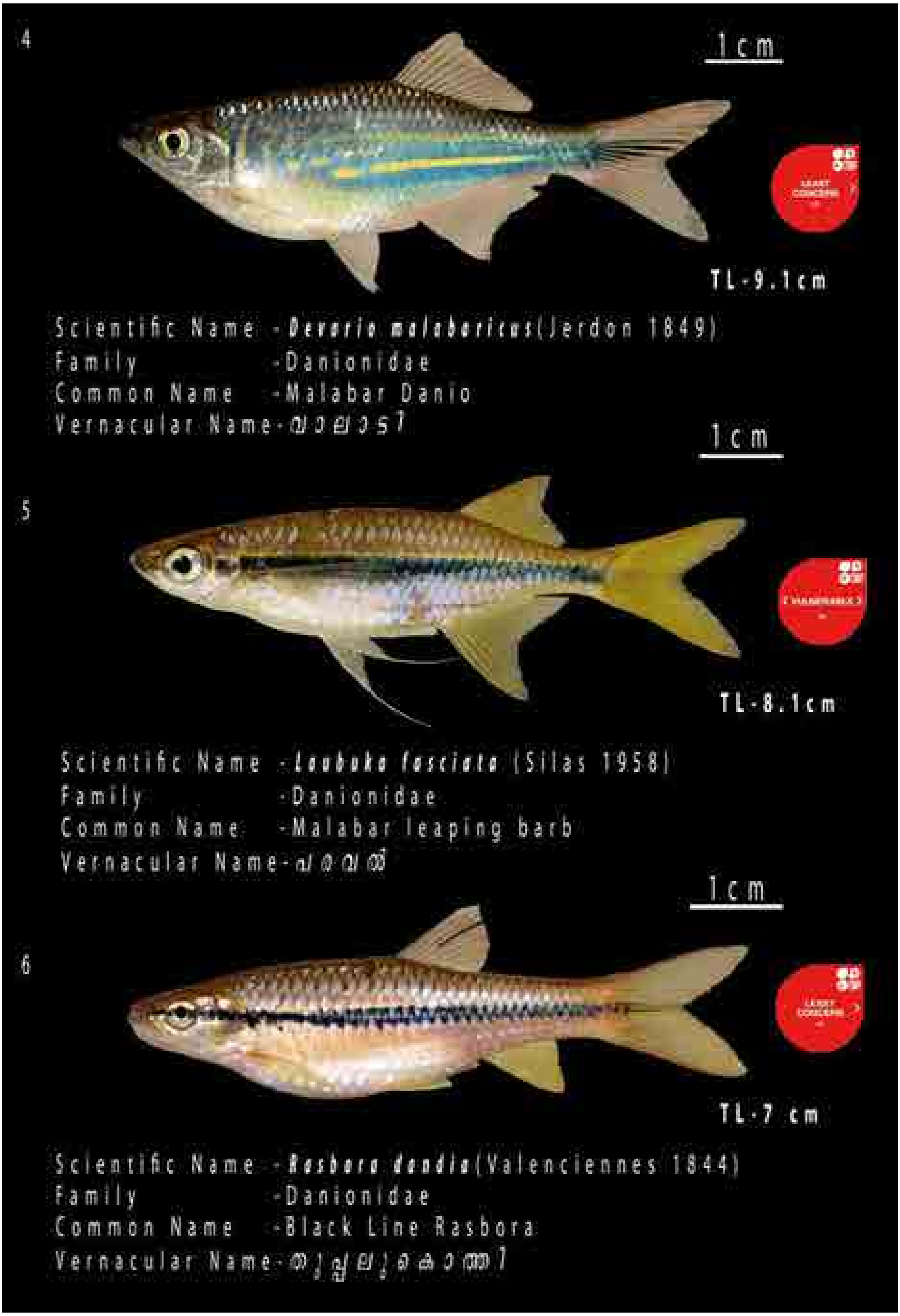

Image 3. Fish specimens from the Kallar Stream. © Josin Tharian.

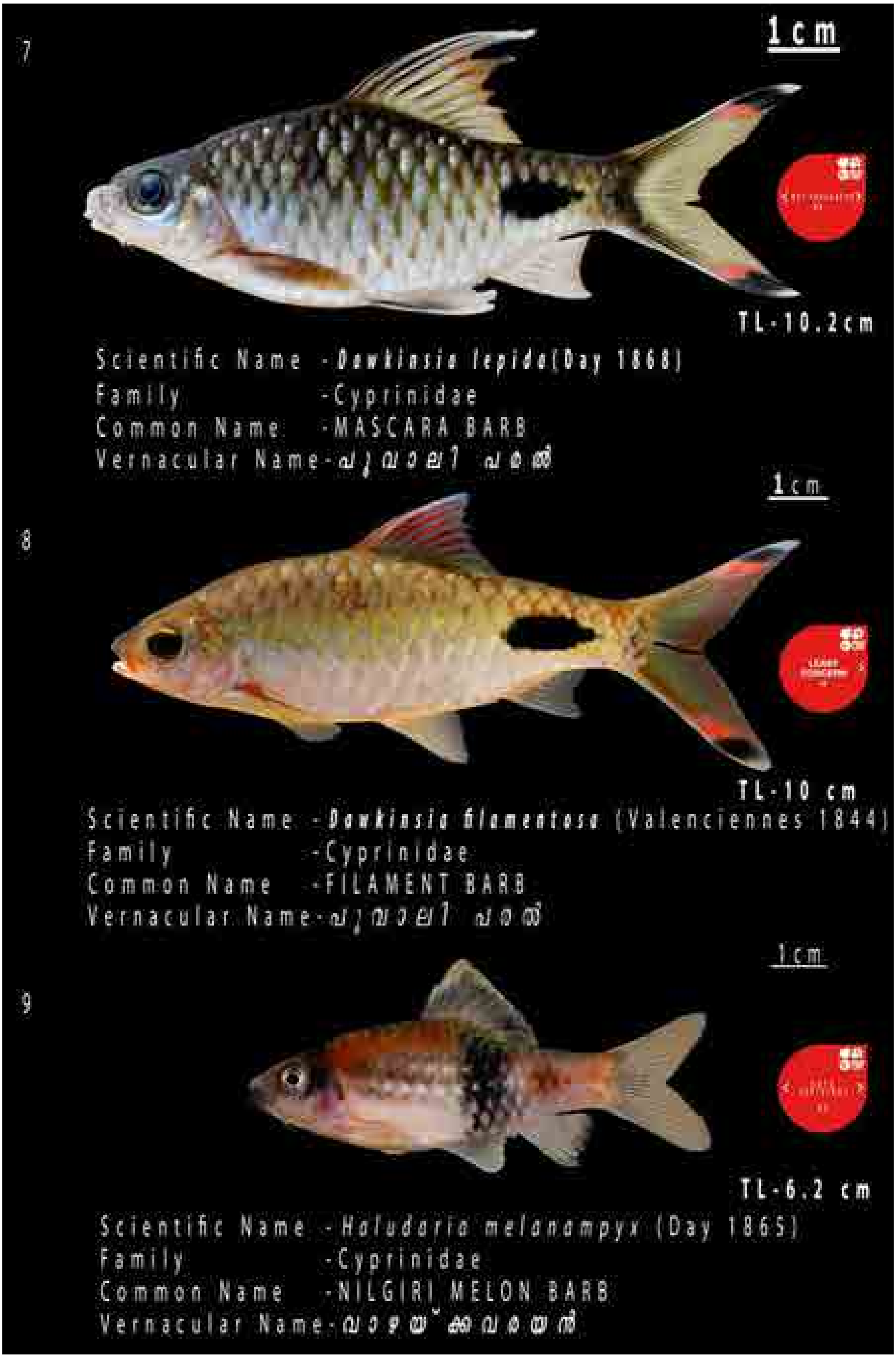

Image 4. Fish specimens from the Kallar Stream. © Josin Tharian.

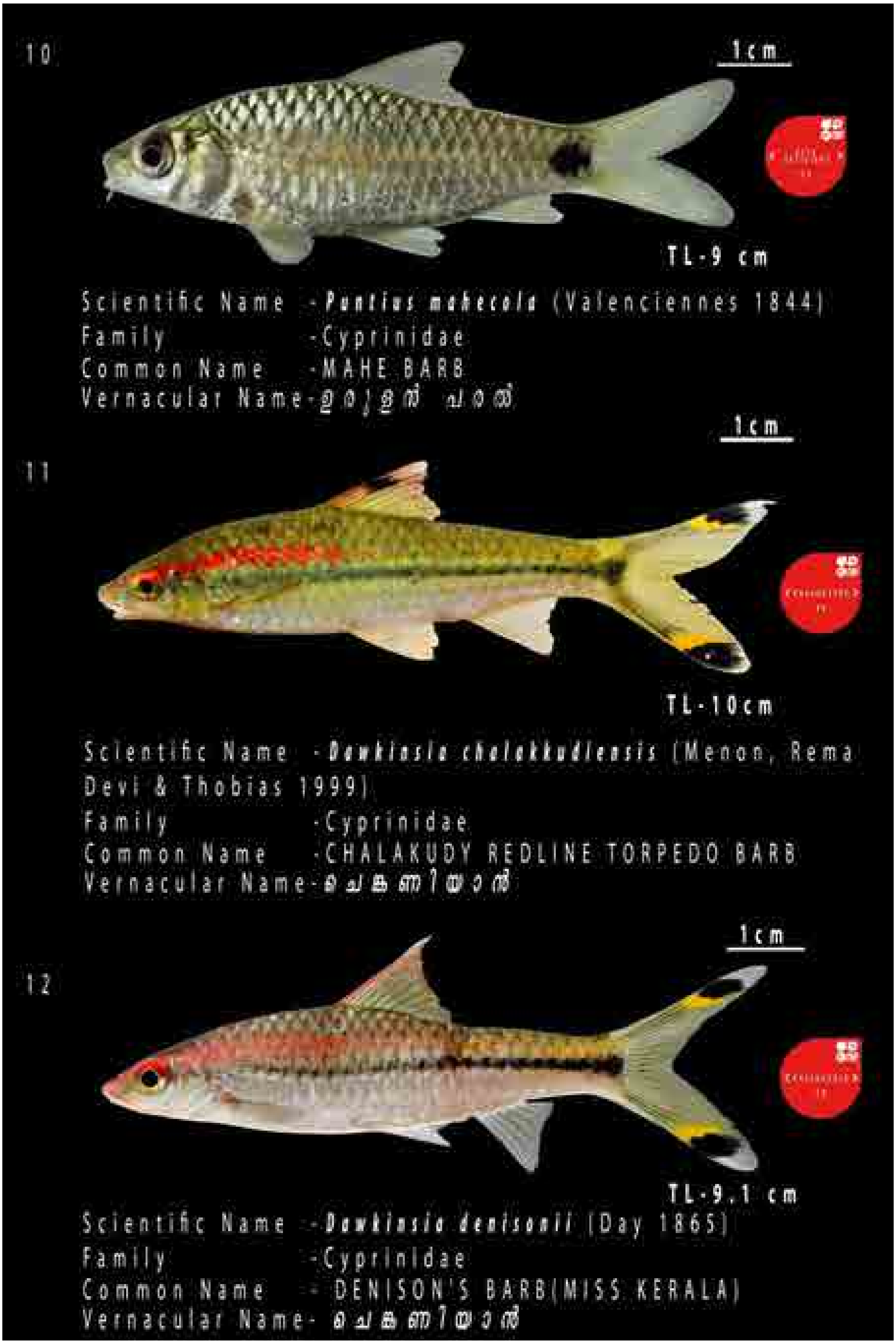

Image 5. Fish specimens from the Kallar Stream. © Josin Tharian.

Image 6. Fish specimens from the Kallar Stream. © Josin Tharian.

Image 7. Fish specimens from the Kallar Stream. © Josin Tharian.

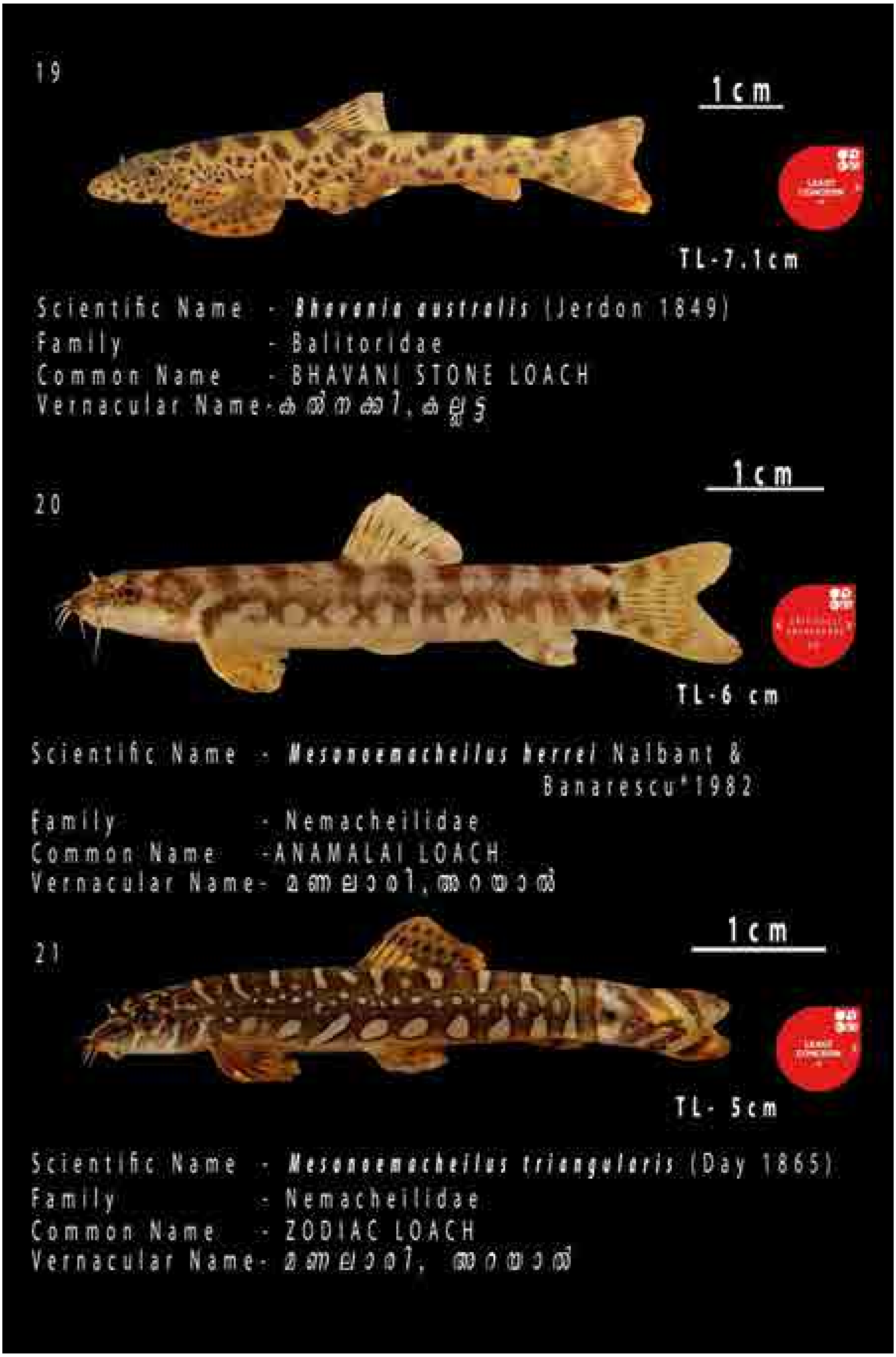

Image 8. Fish specimens from the Kallar Stream. © Melbin Lal.

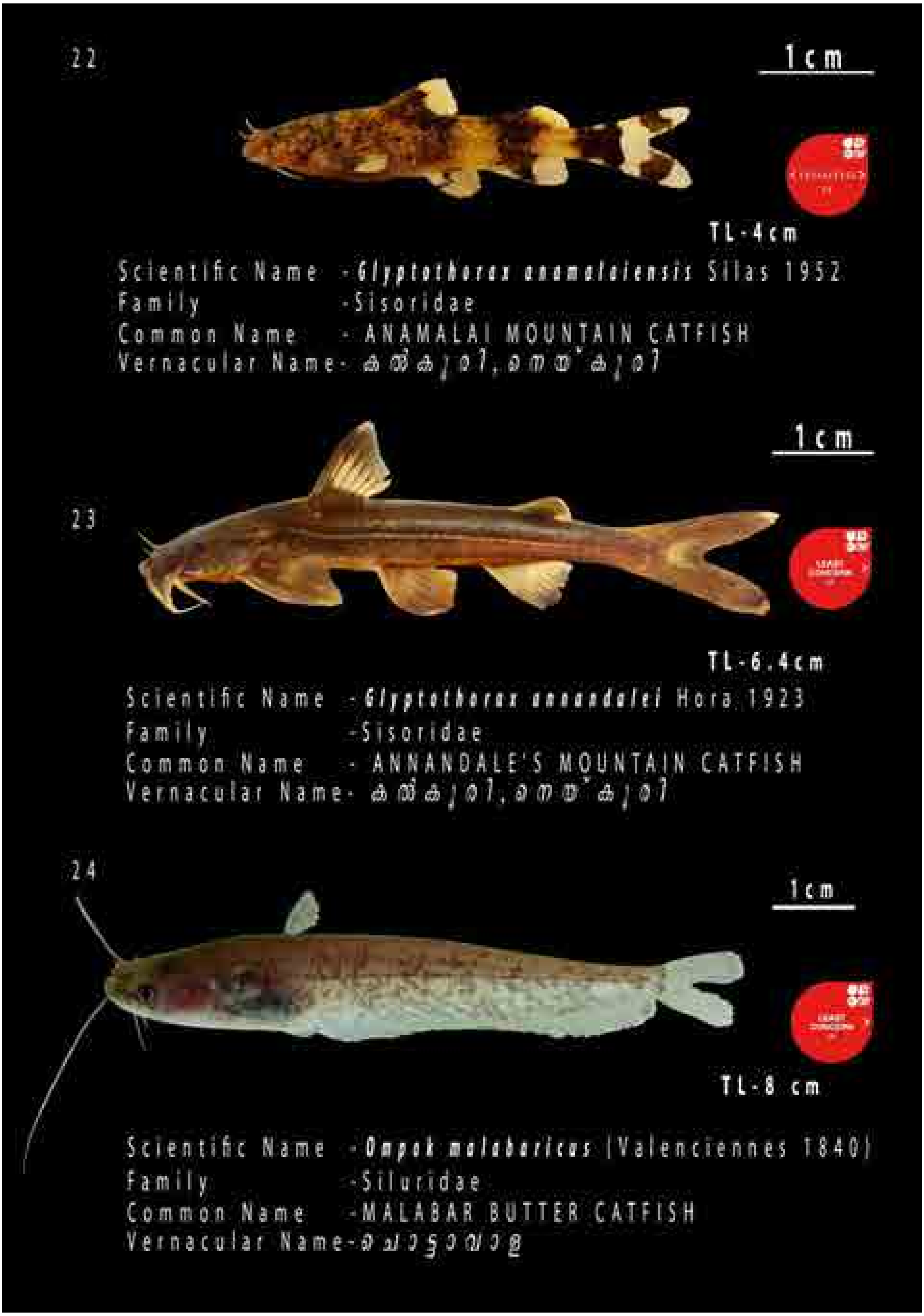

Image 9. Fish specimens from the Kallar Stream. © Melbin Lal.

Image 10. Fish specimens from the Kallar Stream. © Josin Tharian.

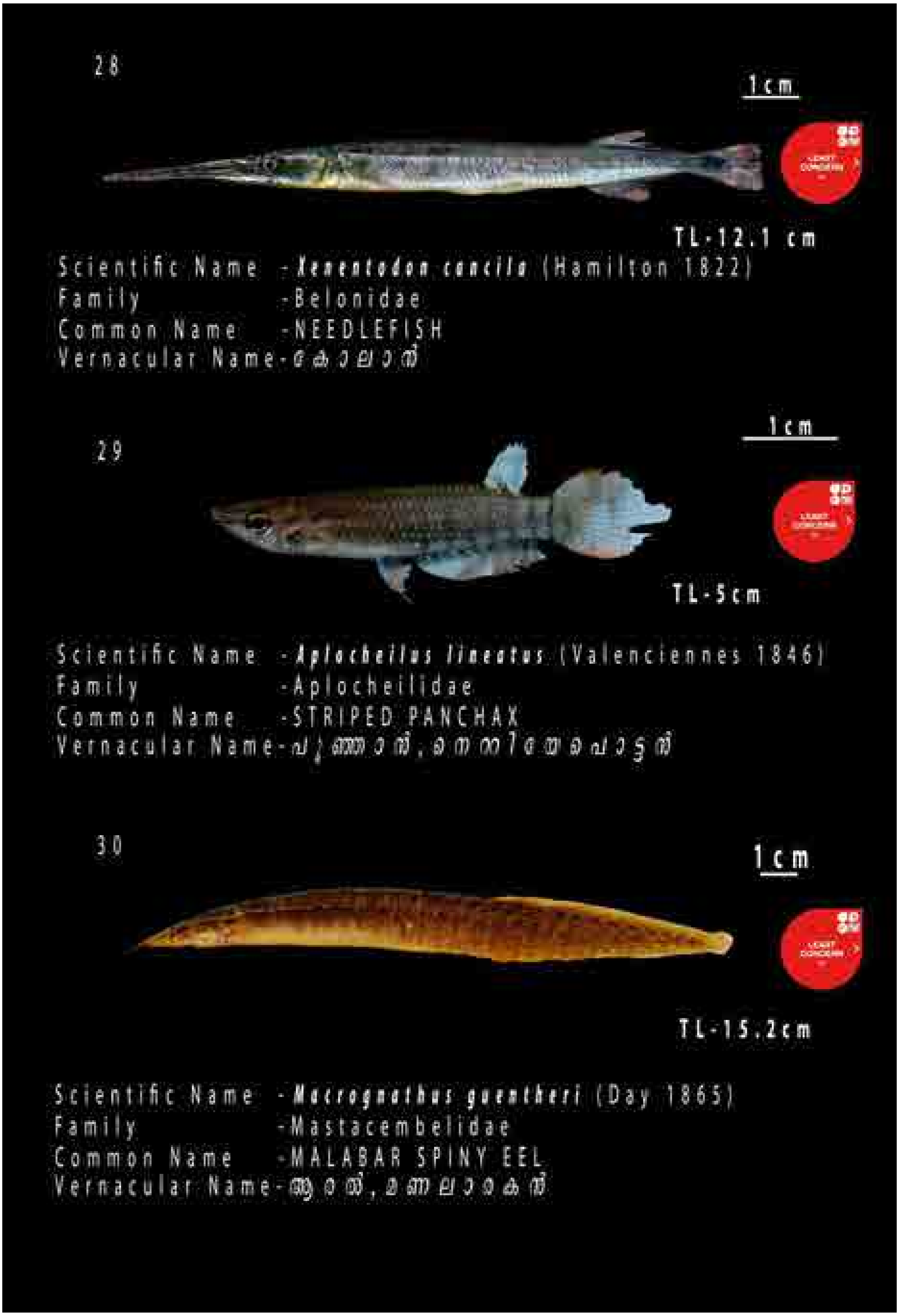

Image 11. Fish specimens from the Kallar Stream. © Melbin Lal.

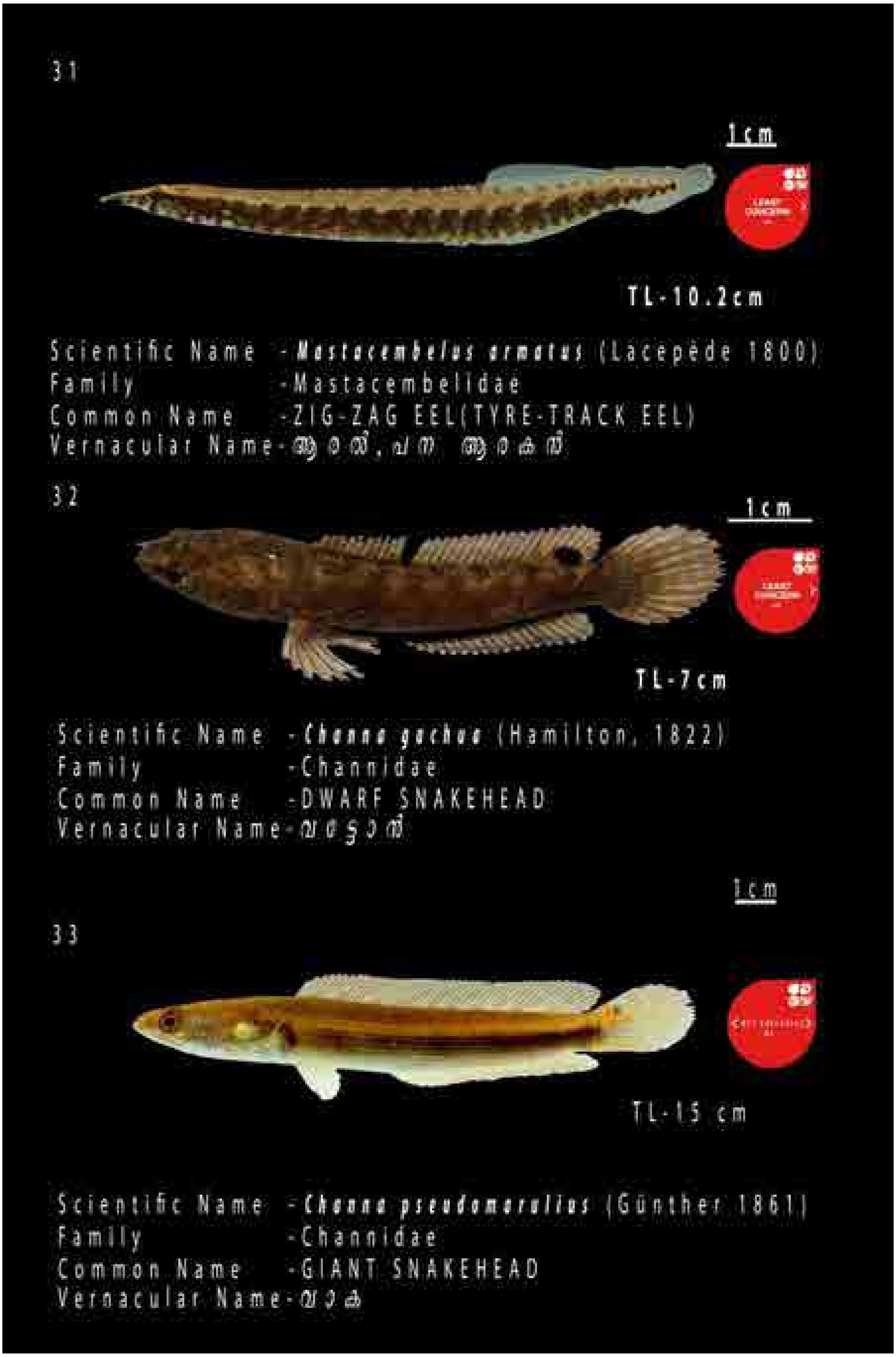

Image 12. Fish specimens from the Kallar Stream. © Melbin Lal.

Image 13. Fish specimens from the Kallar Stream. © Anvar Ali.

REFERENCES

Abd, I., C. Rubec & B. Coad (2009). Key Biodiversity Areas: Rapid assessment of fish fauna in southern Iraq. *BioRisk* 3: 161–171. https://doi.org/10.3897/biorisk.3.15

Ali, P.H.A. & G. Prasad (2007). Bionomics of a critically endangered and endemic catfish, *Horabagrus nigricollaris* from its type locality in Kerala. *Journal of the Bombay Natural History Society* 104: 165–169.

Angermeier, P.L. & J.R. Karr (1986). Applying an index of biotic integrity based on stream-Fish communities: considerations in sampling and interpretation. *North American Journal of Fisheries Management* 6(3): 418–429. https://doi.org/10.1577/1548-8659(1986)6<418:AAIOBI>2.0.CO;2

Armantrout, N.B. (1998). *Glossary of aquatic habitat inventory terminology*. American Fisheries Society, 150 pp.

Arunachalam, M. (2000). Assemblage structure of stream fishes in the Western Ghats (India). *Hydrobiologia* 430: 1–31. https://doi.org/10.1023/A:1004080829388

Baby, F., J. Tharian, S. Philip, P.H.A. Ali & R. Raghavan (2011). Checklist of the fishes of the Achankovil forests, Kerala, India with notes on the range extension of an endemic cyprinid *Puntius chalakkudiensis*. *Journal of Threatened Taxa* 3(7): 1936–1941. https://doi.org/10.11609/JoTT.o2674.1936-41

Biju, C.R., K.R. Thomas & C.R. Ajithkumar (1999). Fishes of Parambikulam Wildlife Sanctuary, Palakkad District, Kerala. *Journal of the Bombay Natural History Society* 96: 82–87.

Casatti, L., F.B. Teresa, T. Gonçalves-Souza, E. Bessa, A.R. Manzotti, C.D.S. Gonçalves & J.D.O. Zeni (2012). From forests to cattail: how does the riparian zone influence stream fish? *Neotropical Ichthyology* 10(1): 205–214. https://doi.org/10.1590/S1679-62252012000100020

Cherian, L.P. & M. Oommen (2020). Post–flood changes in the fish fauna of Meenachil River, Kerala South India. *Journal of Aquatic Biology & Fisheries* 8: 53–61.

Clarke, K.R. & R.N. Gorley (2006). *PRIMER v6: User Manual/Tutorial*. Plymouth Marine Laboratory. Plymouth: PRIMER - E, 192 pp.

CEPF (2007). Critical Ecosystem Partnership Fund *Ecosystem Profile: Western Ghats and Sri Lanka Biodiversity Hotspot* - Western Ghats region, 95 pp

Fricke, R., W.N. Eschmeyer & R. Van der Laan (2022). Eschmeyer's Catalog of Fishes: Genera, Species, references. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp. Electronic version accessed 4 January 2022.

Ganasan, V. & R.M. Hughes (1998). Application of an index of biological integrity (IBI) to fish assemblages of the rivers Khan and Kshipra (Madhya Pradesh), India. *Freshwater Biology* 40(2): 367–383. https://doi.org/10.1046/j.1365-2427.1998.00347.x

Hosagoudar, V.B., P.J. Robin & B. Shivaraju (2010). Foliicolous fungi from the Achankovil forests in Kollam District of Kerala State, India. *Journal of Threatened Taxa* 2(3): 760–761. https://doi.org/10.11609/JoTT.o2323.760-1

IUCN (2021). The IUCN Red List of Threatened Species. Version 2021.3. https://www.iucnredlist.org. Downloaded on 11 January 2022.

Jayaram, K.C. (1999). *The freshwater fishes of the Indian region*. Narendera Publishing House, New Delhi (India), 551 pp.

Jayaram, K.C. (2006). *Catfishes of India*. Narendera Publishing House, New Delhi, 383 pp.

Johnson, J.A. & M. Arunachalam (2009). Diversity, distribution and assemblage structure of fishes in streams of southern Western Ghats, India. *Journal of Threatened Taxa* 1(10): 507–513. https://doi.org/10.11609/JoTT.o2146.507-13

Katwate, U., J.D.M. Knight, V.K. Anoop, R. Raghavan & N. Dahanukar (2020). Three new species of filament barbs of the genus *Dawkinsia* (Teleostei: Cyprinidae) from the Western Ghats of India. *Vertebrate Zoology* 70(2): 207–233. https://doi.org/10.26049/VZ70-2-2020-08

Knight, J.D.M., A. Rai, R.K.P. D'Souza & B. Vijaykrishnan (2015). *Barilius ardens* (Teleostei: Cyprinidae), a new species from the Western Ghats, India, with redescription of *B. malabaricus* and *B. canarensis*. *Zootaxa* 3926(3): 396–412.

Kurup, B.M., K.V. Radhakrishnan & T.G. Manojkumar (2004). Biodiversity status of fishes inhabiting rivers of Kerala (S. India) with special reference to endemism, threats and conservation measures, pp. 163–182. In: Wellcome, R.L. & T. Petr (eds.). Proceedings of LARS2. 2nd Large Rivers Symposium, Phnom Penh, Cambodia. 11–14 February 2003.

Lujan, N.K. & K.W. Conway (2015). Life in the fast lane: a review of rheophily in freshwater fishes, pp. 107–136. In: Riesch, R., M. Tobler & M. Plath (eds.). *Extremophile Fishes.* Springer, Cham.

Mathew, J., K.V. George & R. Yohannan (2016). Rediscovery of *Arisaema sarracenioides* (Araceae)–a rare and endemic species from Achankovil forests, part of southern Western Ghats. *Webbia: Journal of Plant Taxonomy and Geography* 71(1): 117–119. https://doi.org/10.1080/00837792.2015.1119405

Meffe, G.K. & W.L. Minckley (1987). Persistence and stability of fish and invertebrate assemblages in a repeatedly disturbed Sonoran Desert stream. *American Midland Naturalist* 117(1): 177–191.

NWDA (1995). Feasibility report of Pamba-Achankovil-Vaippar Link Project. National Water Development Agency, New Delhi.

Pearsons, T.N., H.W. Li & G.A. Lamberti (1992). Influence of habitat complexity on resistance to flooding and resilience of stream fish assemblages. *Transactions of the American Fisheries* Society 121(4): 427—436. https://doi.org/10.1577/1548-8659(1992)121<0427:IOHCOR>2.3.CO;2

Pereira, F.G.B. (2018). Assessment of native and exotic ichthyodiversity status and pesticide level of River Bharathapuzha, Periyar, Pamba. Report submitted to the Kerala State Biodiversity Board, 82 pp.

Pillai, P.R. & P.P. Muhammad (2007). Working Plan, Achankovil Forest Division, Forest and Wildlife department, Government of Kerala. Report submitted to Kerala Forest & Wildlife Department, 240 pp.

Radhakrishnan, K.V. (2006). Systematics, germplasm evaluation and pattern of distribution and abundance of freshwater fishes of Kerala (India). PhD Thesis. Cochin University of Science and Technology, Kochi, 518 pp.

Radhakrishnan, K.V. & B.M. Kurup (2010). Ichthyodiversity of Periyar Tiger Reserve, Kerala, India. *Journal of Threatened Taxa* 2(10): 1192–1198. https://doi.org/10.11609/JoTT.o2350.1192-8

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, 21 pp.

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

Rani, D., D.K. Srivastava & T.R. Gulati (2016). A set of linked optimization models for an inter-basin water transfer. *Hydrological Sciences Journal* 61(2): 371–392. https://doi.org/10.1080/02626667.2014.986484

Renjithkumar, C.R., M. Harikrishnan & B.M. Kurup (2011). Exploited fisheries resources of the Pampa River, Kerala, India. *Indian Journal of Fisheries* 58(3): 13–22.

Reves-Gavilan, F.G., R. Garrido, A.G. Nicieza, M.M. Toledo & F. Brana (1996). Fish community variation along physical gradients in short streams of northern Spain and the disruptive effect of dams. *Hydrobiologia* 321(2): 155–163. https://doi.org/10.1007/BF00023171

Sabu, K., T.M. Binumon & G. Prasad (2013). Physicochemical characteristics and fish species richness in hill stream tributaries of Achenkovil River, Achenkovil Reserve Forest, Kerala, India, pp. 393–398. In: Kumar, K.G., R. Subramanian, R. Poduval & I. Anitha (eds). Proceedings 23rd Swadeshi Science Congress, Mahatma Gandhi University, Kottayam. 6–8 November 2013.

Shaji, C.P., P.S. Easa & S.C. Basha (1995). Fresh water fish diversity in Aralam Wildlife Sanctuary, Kerala, South India. *Journal of the Bombay Natural History Society* 92: 360–363.

Silva, A., K. Maduwage & R. Pethiyagoda (2010). A review of the genus *Rasbora* in Sri Lanka, with description of two new species (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwaters* 21(1): 27–50.

Solomon, S., M.R. Ramprasanth, F. Baby, B. Pereira, J. Tharian, P.H.A. Ali & R. Raghavan (2011). Reproductive biology of *Puntius denisonii*, an endemic and threatened aquarium fish of the Western Ghats and its implications for conservation. *Journal of Threatened Taxa* 3(9): 2071–2077. https://doi.org/10.11609/JoTT.o2608.2071-7

Swapna, S. (2007). Assessment of production potential and environmental degradation in the Achankovil River in Central Kerala. PhD Thesis. Mahatma Gandhi University, Kottayam, 307 pp.

Swapna, S. (2009). Fish Diversity in Achenkovil River, Kerala, India. *Journal of the Bombay Natural History Society* 106: 104–106.

Thampy, S. (2009). Bionomics, cryopreservation of gametes and captive breeding behaviour of threatened hillstream cyprinid, *Garra surendranathanii* Shaji, Arun & Easa 1996. PhD Thesis. Cochin University of Science & Technology, Kochi, 177 pp.

Thomas, K.R., C.R. Biju & C.R. Ajithkumar (1999). Additions to the Fish Fauna of Pambar River, Kerala. *Journal of the Bombay Natural History Society* 96: 332–334.

Thomas, K.R., C.R. Biju, C.R. Ajithkumar & M.J. George (2000a). Fish Fauna of Idukki and Neyyar Wildlife Sanctuaries Southern Kerala, India. *Journal of the Bombay Natural History Society* 97: 443–446.

Thomas, K.R., C.R. Biju, C.R. Ajithkumar & M.J. George (2000b). Fishes of Chimmony and Peechi -Vazhani Wildlife Sanctuaries, Kerala, India. *Journal of the Bombay Natural History Society* 97: 289–292.

Varghese, J.G. (1994). Studies on the fish assemblages in the Achenkovil River system with special reference to their niche segregation and habitat usage. PhD Thesis. Mahathma Gandhi University, Pathanamthitta, 138 pp

Vijayan, D., H. Kaechele, R. Girindran, S. Chattopadhyay, M.C. Lukas & M. Arshad (2021). Tropical forest conversion and its impact on indigenous communities Mapping forest loss and shrinking gathering grounds in the Western Ghats, India. *Land Use Policy* 102: 105–133. https://doi.org/10.1016/j.landusepol.2020.105133

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ARTICLE

Effect of ecological factors on the grass dynamics at Point Calimere Wildlife Sanctuary, India

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Abstract: Grass dynamics play a major role in the density and diversity of grazing mammals. To understand the drivers of grass quality and quantity, we assessed the height, cover, soft-texture, green leaves, and reproductive phase of grass species in relation to 13 ecological covariates belonging to climate, vegetation, human disturbance, and wild herbivores at Point Calimere Wildlife Sanctuary, southern India during November 2018–September 2020. From the 1,024 quadrates, we recorded 22 grass species and 10 sedges. The grass parameters varied significantly among habitats and between seasons. The grass height and grass cover were more in open scrub, while the soft-textured green grasses were more in grasslands. All the grass parameters except reproductive stage were highest during the wet season. The general linear model (GLM) based analysis on the covariate effect on grass quantity and quality demonstrated that among the 13 covariates compared, *Prosopis*, an alien invasive species, is the major driver, with negative influence on both grass quantity; the cover, and grass quality; soft-texture and greenness of grass. The feral horse, an alien invasive, negatively influenced grass height. Earlier studies have also shown the devastating effects of these exotics on native flora and fauna at Point Calimere, and measures suggested by these studies are recommended to safeguard natural communities in the area.

Keywords: Dry evergreen, grasslands, grass quality, greenness of grass, invasive threat, open scrub, soft-textured grass, southern India, species composition, Tamil Nadu.

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Author contributions: SS—data collection and analyses, draft preparation. SA—data collection, pruning, and analyses and draft preparation. NB—conceptualizing, supervising, data analyses, and final draft preparation.

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INTRODUCTION

In grassland environment grass phenology regulates the life cycles of grasses, which has a direct impact on biodiversity and trophic levels associated to herbivory (Auken 2009; Fischer et al. 2013). Phenology of grass species such as fledgling grass, soft shoots, soft, and green leaves determine herbivore nutrients (Hughes et al. 1993). Leaf length, leaf size, and spruce growth are unique features of each species (Ahsan et al. 2010; Huijser & Schmid 2011; Wang et al. 2011). The growth rate depends on the life cycle of the grass species. At the vegetative phase, cellulose and hemicellulose are present in large quantities for energy supply (Islam et al. 2003; Hussain & Durrani 2009). The budding, flowering, fruiting to seed dispersal stages are the reproductive phases (Sherry et al. 2011). Many factors, including rainfall, soil type, season, access to water, and the availability of open habitat play a role in determining the quantity and quality of grass that can grow (Ganskopp & Bohnert 2001; Sawyer et al. 2005; Hagenah et al. 2008; Hussain & Durrani 2009; Zeng et al. 2010).

Grasslands are significant global reservoirs of biodiversity and important food sources for herbivores (Jing et al. 2014; White et al. 2000; Bardgett et al. 2021). Natural grasslands are also vital to climate and water regulation, and to biogeochemical cycles like carbon balance, hence their degradation has serious consequences (White et al. 2000; O'Mara 2012; Cai et al. 2015). Natural grasslands cover regions with sufficient precipitation for grass to grow. Climatic, human-caused, and other environmental factors influence grasslands and alter grass phenology (Boval & Dixon 2012). Worldwide, grasslands have been disappearing for the greater part of a century (Egoh et al. 2016). In a short amount of time, grassland can be negatively affected by a shift in land use. Specifically, a major issue with grasslands is the growth and succession of forests (Liu et al. 2013).

This study focuses on the grass species of Point Calimere Wildlife Sanctuary, which acts as the major food source to the Blackbuck, an iconic species of the reserve, and other ungulates. Multiple pressures, from the invasion of *Prosopis* to over-grazing by cattle and feral horse on the grasslands habitat, would result in decline in grass biomass needed to support the Blackbuck population in the study area (Baskaran et al. 2016; Arandhara et al. 2020, 2021). Although grasses have wide ecological amplitude and several adaptations to withstand trampling, grazing, fire, food, and drought, they face severe competition for light and nutrients from aggressive wood species and invasive plants in tropical forests (Ashokkumar et al. 2021). This study assessed grass species parameters representing quantity: height & cover, and quality: grass soft-texture, green grass, & reproductive phase, across three habitats and two seasons between 2018–2020 to identify the ecological drivers of grass quantity and quality.

METHODS

Study area

The research was carried out at the Point Calimere Wildlife Sanctuary in Tamil Nadu, which is located between 10.30–79.85 ^{0}N and 10.35–79.42 ^{0}E at the confluence of the Bay of Bengal and the Palk Strait, near Nagapattinam (Figure 1). The reserve encompasses 30 km^2 of dry evergreen forest, grassland, open scrub, sandy coastline, salt marshes, and backwaters (Ali 2005). The grasses in the sanctuary's southernmost region cover 17% (4.49 km^2) of the total sanctuary area. The sanctuary's native and flagship species of Blackbuck live in grasslands that also serve as a foraging ground for other herbivores like feral horses, Chital, and domestic cattle. The average annual rainfall in Point Calimere is 1,366 mm, with temperatures ranging 23–37 ºC. The grasslands are especially vulnerable to invasion by *Prosopis juliflora*. Anthropogenic pressures on the sanctuary include firewood collection, fishing, and cattle grazing.

Data collection

Assessment of Grass dynamics and other variables: Data were collected between November 2018 and October 2020 covering two seasons (dry season: February–August and wet season: September–January) and three habitats (Dry evergreen, open scrub, and grasslands). The study area was overlaid with 1 km^2 grids and placed with a 1-km line transect at each grid. The grass availability and parameters were evaluated on a monthly interval. Four 1 m^2 quadrates were placed at 5 m intervals on the north, south, east, and west directions at every 250 m interval along these transects. Quadrates of this size have previously been widely used in studies of grass abundance (Menut & Ceaser 1979; Hacker 1984; Sivaganesan 1991). In total, 1,024 quadrates were laid (dry evergreen—453, open scrub—272, and grasslands—299) (Image 1). All grass dynamic parameters were recorded in each quadrat following methods described in Table 1 Grass specimens were collected and preserved in order to create herbariums for each grass species for species identification and confirmation (Rangel et al. 1999; Shaw 2008; Shankar & Shashikala 2010). The vouchered

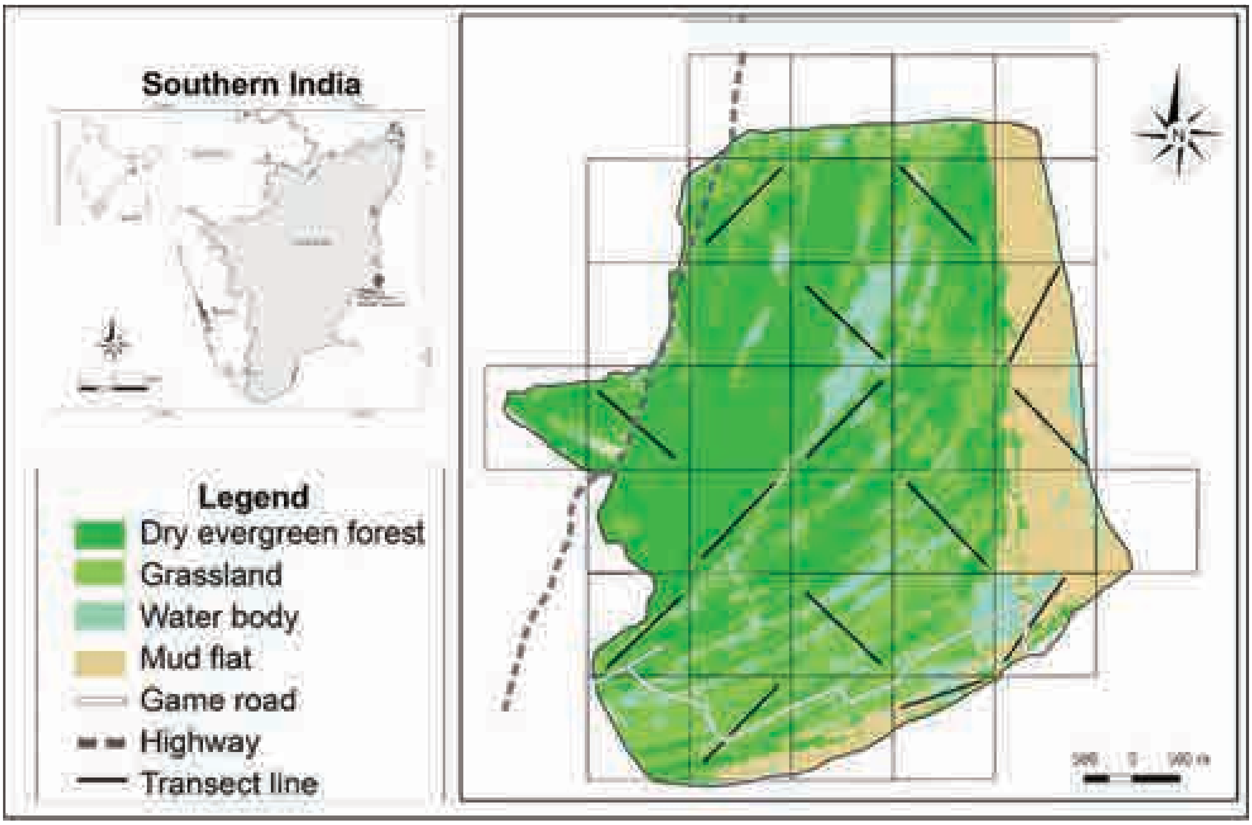

Figure 1. Map showing the study area at Point Calimere Wildlife Sanctuary, India.

Image 1. Grassland at Point Calimere Wildlife Sanctuary, India.

herbarium was deposited at mammalian biology lab, department of Zoology in A.V.C. College (Autonomous).

Data analysis

Statistical analysis: Prior to performing a detailed analysis, the compiled data were examined for normality and variance homogeneity. The Kolmogorov-Smirnov (KS) test used on grass parameter such as, height (KS: 0.35; p = <0.05), cover (KS: 0.19; p = <0.05), soft texture (KS: 0.23; p = <0.05), green leaves (KS: 0.16; p = <0.05), and reproductive phase (KS: 0.37; p = <0.05) of grass species was neither normal, nor could be transformed to normal with four different transformations (Arsin, Log10 (LG10), Inverse log, and Exponential). Therefore, the difference in the selection of this species between seasons were tested using non-parametric Mann-Whitney U-test and Kruskal-Wallis H test. SPSS V.23 software package was used for the statistical test and the general linear model (GLM) was used to identify the covariates influencing on grass dynamics characteristics and all parameter models were ranked by their small-sample Akaike information criterion (AICc) and inferences were taken from models with ΔAICc ≤ 2. However, in results are comprehensively shows that top two models of lowest ΔAICc. Model comparison were calculated by the *R* package 'MuMIn' (Barton et al. 2018) by in R Library, in R Software Version 3.3.3 (R Core Team 2019). This model was ranked first due to lowest AIC. Also, the proportion of the total predictive power found in the model was sorted to be the highest at weight value. The analysis was carried out for each grass parameter separately.

RESULTS

In total, the study identified 22 grass species and 10 species of sedges at Point Calimere (Table 2). The grass species dominated the stand in all parameters studied compared to sedges. *Aeluropus lagopoides* had the highest mean height, percentage of cover, soft texture, and green leaves. *Chloris barbata* had the highest percentage of reproductive phase. *Dactyloctenium aegyptium* was the second highest in terms of cover, soft texture green leaves, followed by *Cyperus compressus*.

Variation in grass parameters between season and among habitats

The grass parameters varied significantly among the three habitats: grassland, open-scrub, and dry evergreen. Among the five grass parameters, grass height, percentage cover, and reproductive phase were significantly more in open-scrub followed by grasslands and dry evergreen (Figure 2). On the other hand, soft-textured grass and green leaves were significantly higher in grasslands than the other two habitats. In relation to season, grass height, percentage cover, soft texture, and green leaves were significantly higher in the wet compared to dry season. While the reproductive stage was significantly higher during dry compared to wet season (Table 3).

Influence of covariates on grass parameter - GLM Model

Grass height: GLM to test the influence of covariates on grass height showed a model with covariates viz feral-horse density, *P. juliflora* cover, rainfall, spotted deer density, shrub % cover, and distance from water bodies turned out as the best model with lower delta AIC and higher weightage, influencing the grass height (Table 4). However, the covariates, viz., feral-horse with negative influence and rainfall with positive influence were alone turned out to be the significant predictors of grass height (Table 5).

Grass cover: Although the GLM showed that covariates with feral-horse density, grasslands, *P. juliflora* cover, rainfall and distance from water bodies entered as the best model with lower delta AIC and higher weightage influencing the grass cover (Table 4), covariates, viz., feral-horse, P. *juliflora* cover, distance from water with negative influence, and rainfall and wet season with positive influence turned out to be the significant predictors of grass cover (Table 5).

Grass soft-texture: A model with open habitat, *P. juliflora* density, rainfall and distance from shade entered as the best model with lower delta AIC and higher weightage influenced the soft-texture of grass (Table 4). Interestingly, all the four covariates had significant effect on the soft-texture with rainfall, open habitat, and distance from shade were having positive influence, while the *P. juliflora* density had negative influence (Table 5).

Grass green leaves: Although a model with blackbuck density, open habitat, *P. juliflora* density, and rainfall entered as the best model with lower delta AIC and higher weightage influencing the green leaves availability (Table 4), covariates, viz., density of *P. juliflora* and blackbuck with negative effect and open habitat with positive effect were alone significantly influencing the percentage of green leaves in the grass species (Table 5).

Grass reproductive phase: Although a model with covariates such as feral-horse density, open habitat extent, P. *juliflora* density, and rainfall entered as the

Table 1. Details of grass dynamics parameters and covariates sampled at Point Calimere Wildlife Sanctuary, India.

	Grass dynamics parameters	Description
Dependent variables		
1	Grass height (cm)	Grass height was measured using a measuring scale, from the ground level to the highest leaf blade bend, at five points (one each at four corners and one at the center) of the quadrate.
2	Grass cover/m^2	Assessed visually assuming 100% for the entire quadrat and estimating the proportion of area within a quadrat covered by each grass.
3	Soft texture (%)	Examined crushing the leaves by hands, if leaf's structure could be squashed into a ball—proportion of such leaves for a given grass species in quadrat was rated in % rating.
4	Green leaves (%)	Assessed visually quantifying the proportion of leaves in a given species with green grass, assuming 100% for all the leaves of the same species.
5	Reproductive phase (%)	Evaluated visually quantifying the proportion of a given grass with flowers and fruits in % rating.
Covariates		
6	Open habitat extent (km^2)	At every plot laid, habitat visibility on all four directions of north, south, east, and west.
7	Distance to water (m)	Measured as the distance from a given quadrate to the water source using a rangefinder or obtained from land-use land-cover map.
8	Distance to shade (m)	Measured as the distance from a given quadrat to the nearest canopy cover area using a rangefinder.
9	Distance to road (m)	Measured as the distance from a given quadrat location to the nearest road or obtained from land-use land-cover map.
10	Ambient temperature (°C)	Measured using a generic digital thermometer-cum-hygrometer device (model: HT01) at each observation at the feeding site.
11	Humidity (Relative %)	As described above.
12	Weather	Recorded visually as cloudy or sunny weather at the start of each feeding site examination.
13	Rainfall (mm)	Rainfall data arrived from the secondary sources (https://www.soda-pro.com/web-services/meteo-data/merra)
14	*Prosopis juliflora* cover/25 m^2	*Prosopis* density were arrived from 5 x 5 m quadrates in the study area
15	*Prosopis juliflora* density/25 m^2	*Prosopis* cover were obtained from 5 x 5 m quadrates in the study area
16	Blackbuck density	Density was obtained by the line transect survey method in the study area.
17	Feral horse density	As described above
18	Chital density	As described above.

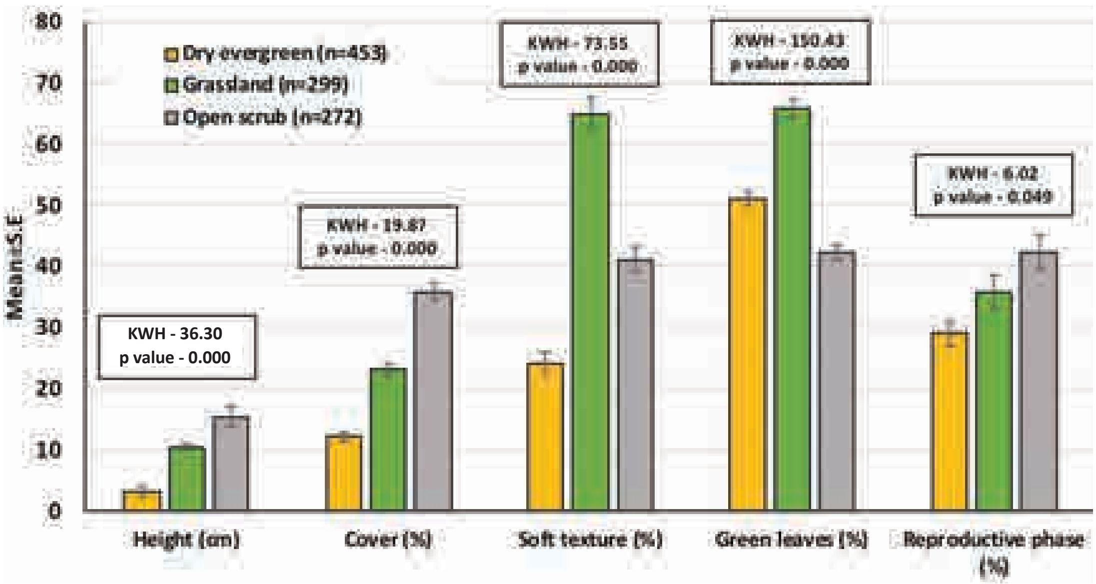

Figure 2. Variation in grass dynamics parameters among the habitats at Point Calimere Wildlife Sanctuary, India.

best model with lower delta AIC and higher weightage influencing the reproductive phase of the grass (Table 4), covariates, viz., *P. juliflora* density and open-scrub with positive effect and rainfall with negative effect had significant influence on the amount of grass reproductive phase (Table 5).

Table 2. Overall list of grass and sedge species and their parameter recorded at Point Calimere Wildlife Sanctuary, India.

	Grass and sedge species	Height (cm)	Cover (%)	Soft texture (%)	Green leaves (%)	Reproductive phase (%)
Grasses						
1	*Aeluropus lagopoides* (L.)	**13.2 ± 0.9**	**20.3 ± 1.5**	**20.3 ± 1.5**	**20.4 ± 1.5**	6.1 ± 0.4
2	*Aristida adscensionis* (L.)	1.0 ± 0.4	0.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	0.3 ± 0.1
3	*Aristida setacea* (Retz.)	1.4 ± 0.4	1.3 ± 0.4	1.3 ± 0.4	1.2 ± 0.4	0.0 ± 0.0
4	*Brachiaria ramosa* (L.) Stapf.	2.4 ± 0.4	3.8 ± 0.6	3.8 ± 0.6	3.8 ± 0.6	1.3 ± 0.2
5	*Cenchrus ciliaris* (L.)	1.5 ± 0.6	0.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	1.4 ± 0.6
6	*Chloris barbata* Sw.	**10.6 ± 1.2**	7.6 ± 0.9	7.5 ± 0.9	7.4 ± 0.9	**13.0 ± 1.5**
7	*Chrysopogon aciculatus* (Retz.) Trin.	4.8 ± 1.1	1.7 ± 0.4	1.7 ± 0.4	1.7 ± 0.4	4.6 ± 1.1
8	*Chrysopogon fulvus (Spreng.) Chiov.*	2.6 ± 0.8	1.1 ± 0.3	1.1 ± 0.3	1.0 ± 0.3	2.9 ± 0.9
9	*Cynodon dactylon* (L.) Pers.	0.1 ± 0.1	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.2	0.3 ± 0.2
10	*Cyrtococum trigonum* (Retz.) A.Camus	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.3	0.6 ± 0.3
11	*Dactyloctenium aegyptium* (L.) Willd.	5.8 ± 0.5	**12.4 ± 1.2**	**12.6 ± 1.2**	**12.8 ± 1.2**	**12.2 ± 1.1**
12	*Dichanthium annulatum* (Forssk.) Stapf	3.6 ± 1.1	1.1 ± 0.3	1.1 ± 0.3	1.1 ± 0.3	0.6 ± 0.2
13	*Digitaria longiflora* (Retz.) Pers.	1.2 ± 0.3	1.2 ± 0.3	1.2 ± 0.4	1.3 ± 0.4	1.9 ± 0.5
14	*Eragrostiella bifaria* (Vahl) Bor.	0.6 ± 0.2	0.6 ± 0.2	0.6 ± 0.2	0.6 ± 0.2	0.9 ± 0.4
15	*Eriochloa procera* (Retz.) C.E.Hubb.	0.7 ± 0.3	0.8 ± 0.3	0.8 ± 0.3	0.8 ± 0.3	0.9 ± 0.3
16	*Hemarthria compressa* (L.f.) R.Br.	0.6 ± 0.4	0.3 ± 0.2	0.3 ± 0.2	0.3 ± 0.2	0.3 ± 0.2
17	*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.	2.7 ± 1.3	0.4 ± 0.2	0.4 ± 0.2	0.4 ± 0.2	0.3 ± 0.1
18	*Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs, 2003	1.9 ± 0.8	0.7 ± 0.3	0.7 ± 0.3	0.7 ± 0.3	0.6 ± 0.2
19	*Oplismenus composites* (L.) P. Beauv.	1.9 ± 0.5	1.6 ± 0.4	1.5 ± 0.4	1.5 ± 0.4	3.1 ± 0.8
20	*Paspalum paspaloides* (L.)	1.3 ± 0.6	0.5 ± 0.2	0.5 ± 0.2	0.5 ± 0.2	0.0 ± 0.0
21	*Perotis indica* (L.)	**10.0 ± 1.6**	4.1 ± 0.7	4.0 ± 0.7	4.0 ± 0.6	9.0 ± 1.5
22	*Trachys muricata* (L.) Pers.	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.3
Sedges						
23	*Bulbostylis barbata* (Rottb.) C.B.Clarke	2.9 ± 0.5	3.8 ± 0.6	3.8 ± 0.6	3.8 ± 0.6	6.2 ± 1.0
24	*Cyperus compressus* (L.)	5.5 ± 0.6	**10.2 ± 1.0**	**10.2 ± 1.0**	**10.1 ± 1.0**	5.6 ± 0.6
25	*Cyperus kyllingia* (L.)	1.8 ± 0.3	3.3 ± 0.6	3.4 ± 0.6	3.4 ± 0.6	1.2 ± 0.2
26	*Cyperus polystachyos* Rottb.	2.4 ± 0.4	3.3 ± 0.6	3.2 ± 0.6	3.2 ± 0.6	2.5 ± 0.4
27	*Cyperus rotundus* (L.)	0.9 ± 0.3	1.3 ± 0.4	1.4 ± 0.4	1.4 ± 0.4	0.3 ± 0.1
28	*Cyperus squarrosus* (L.)	1.2 ± 0.3	1.8 ± 0.4	1.8 ± 0.4	1.8 ± 0.4	0.6 ± 0.1
29	*Fimbristylis cymosa* R.Br.	8.9 ± 1.1	6.9 ± 0.8	7.0 ± 0.9	7.0 ± 0.9	**11.3 ± 1.4**
30	*Fimbristylis ovata* (Burm.f.) J.Kern	0.3 ± 0.1	0.6 ± 0.3	0.6 ± 0.3	0.6 ± 0.3	0.6 ± 0.3
31	*Fimbristylis triflora* (L.) K.Schum.	3.0 ± 0.6	2.2 ± 0.5	2.2 ± 0.5	2.2 ± 0.5	4.6 ± 1.0
32	*Kyllinga nemoralis* (J.R.Forst. & G.Forst.) Dandy ex Hutch. & Dalziel	4.9 ± 0.7	4.9 ± 0.7	4.9 ± 0.7	5.0 ± 0.7	6.8 ± 1.0

DISCUSSION

This study observed 22 species of grasses and 10 sedges in the study area, similar to what Arandhara et al. (2021) and Frank et al. (2021) reported for the same area. On the basis of cover, species such as *A. lagopoides*, *D. aegyptium,* and *C. compressus* are the three dominant grasses recorded in the coastal habitats, open-scrub, and dry-evergreen in this study. These findings also support earlier studies elsewhere for *A. lagopoides* (Khan & Gulzar 2003; Ahmed et al. 2013), *D. aegyptium* (Rojas-Sandoval 2016), and *C. compressus* (Ravi & Mohanan 2002; Bryson & Carter 2008).

Table 3. Seasonal variation among the grass parameter at Point Calimere Wildlife Sanctuary, India.

Grass dynamics parameters	Wet season (n = 592)	Dry season (n = 432)	Mann-Whitney U	p
Height (cm)	13.4 ± 1.43	10.1 ± 0.26	17224	0.000
Cover (%)	24.7 ± 0.78	21.6 ± 0.89	40389	0.000
Soft texture (%)	67.1 ± 1.75	47.6 ± 1.58	24379	0.000
Green leaves (%)	75.7 ± 0.80	37.6 ± 0.82	69701	0.000
Reproductive phase (%)	36.4 ± 1.82	43.5 ± 2.24	31091	0.001

Table 4. Top two best models extracted from GLM to characterize relationship among the grass parameter and the covariates sorted according to AIC.

Dependent variables	Model	df	Log *L*	AICc	ΔAICc	weight
Grass height (cm)	Feral-horse density + *Prosopis juliflora* cover + rainfall + Spotted deer density + Shrub percentage cover + Distance from water bodies	5	-3258	6527	0.00	0.099
	Feral-horse density + Spotted deer density + Shrub percentage cover	4	-3259	6527	0.20	0.090
Grass cover (%)	Feral-horse density + Grassland habitat + *Prosopis juliflora* cover + rainfall + Distance from water bodies	8	-4544	9105	0.00	0.091
	Feral-horse density + Grassland habitat + *Prosopis juliflora* cover + rainfall + Shrub percentage cover + Distance from water bodies	9	-4543	9106	0.28	0.079
Grass soft texture (%)	Open habitat availability+ *Prosopis juliflora* density + rainfall + Distance from shade	5	-4995	10001	0.00	0.996
	Open habitat availability+ *Prosopis juliflora* density + rainfall	4	-5002	10013	1.51	0.002
Grass green leaves (%)	Blackbuck density + Open habitat availability + *Prosopis juliflora* density + rainfall	6	-5496	11004	0.00	0.650
	Blackbuck density + Open habitat availability + *Prosopis juliflora* density	5	-5498	11006	1.60	0.292
Grass reproductive phase (%)	*Prosopis juliflora* cover + rainfall + Open-scrub	5	-4965	11098	0.00	0.880
	Prosopis juliflora cover + rainfall + Open-scrub	4	-4910	11088	1.04	0.652

Independent factors influencing the grass parameters

Rainfall, wet season, open habitat availability, distance from shade, and open-scrub habitat all had a positive impact on the grass parameters measured at Point Calimere. In contrast, *Prosopis juliflora*, the density of feral horse and Blackbuck, and the distance from water negatively influenced the grass parameters studied.

Predictors of grass height

The density of feral horses, a non-ruminant bulk feeder (Arandhara et al. 2020), had the greatest negative effect on grass height among the 13 covariates compared. According to Maron & Crone (2006), the effects of herbivory on grassland are more severe than those on woodland. Rainfall, widely regarded as the most effective factor in promoting plant growth, was a major predictor influencing positively on height of the grass species (Derner & Hart 2007; Parton et al. 2012). Increased rainfall during the growing season has been shown to improve soil water use, which in turn promotes healthy root development and grasses as well as other plant growth (Wan et al. 2002).

Predictors of grass cover

The study showed that percentage of grass cover decreased with feral horse density, *P. juliflora* cover and distance from the waterbody. The feral-horse is a large herbivore with predominant grazing nature and a bulk-feeder (Baskaran et al. 2019; Arandhara et al. 2020). Their intensive grazing pressure is thus negatively influencing the grass cover, as grazing mostly occurs during the growing season (Hao & He 2019). In this study, a decrease in grass cover was observed with the *Prosopis* cover. *Prosopis* is an alien invasive species at Point Calimere, which grow taller and tap the sunlight at canopy level. Sunlight is an essential factor for the photosynthesis of all plants including grass species and thus the increase in *Prosopis* cover reduces the intensity of sunlight available to the grass species found at the ground level. Therefore, grass cover decreased with *Prosopis* cover (Baskaran et al. 2019; Murugan et al. 2019; Arandhara et al. 2021). Like the sunlight, soil nutrient, soil moisture is also another important factor influences the plant growth and productivity and moisture in the soil is required during the wet season to promote CO_2 absorption and plant growth (Morgan et al. 2016). Therefore, the grass

Table 5. The best model showing the relationship between each grass variable and the significant covariates.

Dependent variable	Covariate	Estimate ± S.E.	z value	Pr(>|z|)
Grass height (cm)	(Intercept)	10.6 ± 0.59	17.95	0.000
	Feral horse density	-0.0 ± 0.01	3.28	0.001
	Rainfall	0.1 ± 0.00	0.64	0.022
Grass cover (%)	(Intercept)	42.2 ± 0.02	251.41	0.000
	Feral horse density	-0.0 ± 0.00	11.40	0.000
	P. juliflora cover	-0.0 ± 0.01	14.65	0.000
	Rainfall	0.0 ± 0.02	3.21	0.001
	Wet season	0.1 ± 0.01	4.28	0.000
	Distance from water	-0.0 ± 0.02	2.80	0.005
Grass soft texture (%)	(Intercept)	4.0 ± 1.79	223.28	0.000
	Rainfall	0.0 ± 0.02	4.97	0.000
	P. juliflora density	-1.1 ± 0.12	-9.70	0.000
	Open habitat availability	0.0 ± 0.02	3.83	0.000
	Distance from shade	0.0 ± 0.02	-3.80	0.000
Grass green leaves (%)	(Intercept)	4.0 ± 0.02	223.64	0.000
	Rainfall	0.0 ± 0.02	4.16	0.000
	P. juliflora density	-1.0 ± 0.12	-8.62	0.000
	Open habitat availability	0.0 ± 0.02	3.52	0.000
	Blackbuck density	-512 ± 179.3	-2.86	0.004
Grass reproductive phase (%)	(Intercept)	39.4 ± 5.29	7.44	0.000
	P. juliflora cover	0.82 ± 0.33	2.46	0.013
	Rainfall	-0.10 ± 0.01	-6.25	0.000
	Open scrub	1.8 ± 0.89	0.04	0.048

cover increased significantly with rainfall and during wet season compared to dry season as reported elsewhere (Wan et al. 2002; Zhang et al. 2020; Xu et al. 2021). Since soil moisture decreases with increase in distance from waterbody, the grass cover decreased significantly with distance from the waterbody.

Predictors of soft-texture and green grass

The study showed that grass soft-texture increased with rainfall, open habitat, and distance from the shade, but it decreased with *Prosopis* density. Similarly, the green grass availability increased with rainfall, and open habitat, but it decreased with *Prosopis* and blackbuck densities. Studies have shown that rainfall by increasing the soil moisture, triggering the growth of fresh, and green grasses (Hermance et al. 2015; Moore et al. 2015; Morgan et al. 2016; Post & Knapp 2020). The fact that fresh grown plants parts are softer than the old-grown parts due to low fiber and cellulose content (de Jong 1995; Treydte et al. 2011; Kunwar et al. 2016). Thus, rainfall increases significantly both soft-texture and green leaves of grasses. The open habitat provides the ideal sunlight intensity and temperature for promoting photosynthesis in grass species (Solofondranohatra et al. 2018) and thus the soft-textured green grasses increased significantly with extent of open habitats. In contrast, with increase in *Prosopis* density, which exploits both sunlight at canopy level and the available soil moisture more efficiently (Shiferaw et al. 2021), reduces the soft-texture and greenness of the grass species through reduced growth. The negative effect of shade on grass soft-texture also follows the above concept as explained for *Prosopis*. Blackbucks are a species of ruminant that is known for eating the tips of young, tender grass leaves, which are richer nutrients and water content (Jhala 1997; Baskaran et al. 2016) and thus green grass availability decreases with the density of blackbucks.

Predictors of grass reproductive phase

The study shows that the grass species reproductive phase increased with *P. juliflora* cover and open-scrub. As stated in earlier studies that the open-scrub predominantly with woody plants that are typically less than 3 m tall and relatively open, offers excellent support for grasses and plants that are shorter than them (Wardle 1971; Solofondranohatra et al. 2018). Likewise, *P. juliflora* is the most common woody plant in open-scrub at Point Calimere (Arandhara et al. 2021). Since, grazers are unable to access the grass species found between and beneath the bushes, the grazing intensity is lower in open-scrub compared to grasslands. Thus, the grass species with less grazing pressure in the open-scrub or with more density of *Prosopis*, with better growth as found in this study, had more reproductive phases than that of in grasslands. These findings are similar to earlier study that states the grass species in the open-scrub were shielded from overgrazing (Popay & Field 1996). As a result, the grass species reaches its maximum potential for growth and reproduction. As the mean annual precipitation across space increased, flowering time pushed back for most grass species, as documented by Munson & Long (2017).

CONCLUSIONS AND RECOMMENDATIONS

Point Calimere supports grasses and sedges which provide ideal food sources for mammalian grazing communities. Both grass species quantity and quality varied among habitats and between seasons. Among the 13 covariates compared, *Prosopis*, an alien invasive species, is the major driver that negatively influences on both grass quantity and quality. The feral horse, an alien invasive, negatively affected grass height. The devastating effect of these exotics on native flora and fauna at Point Calimere have been already documented by various studies (Ali 2005; Baskaran et al. 2019; Arandhara et al. 2020, 2021). Thus, to safeguard the natural communities of plants and animals of Point Calimere, effective measures are needed as suggested by earlier studies.

REFERENCES

Ahmed, M.Z., T. Shimazaki, S. Gulzar, A. Kikuchi, B. Gul, M.A. Khan, H.W. Koyro, B, Huchzermeyer & K.N. Watanabe (2013). The influence of genes regulating transmembrane transport of Na+ on the salt resistance of *Aeluropus lagopoides*. *Functional Plant Biology* 40(9): 860–871.

Ahsan, N., T. Donnart, M.Z. Nouri & S. Komatsu (2010). Tissue-specific defense and thermo-adaptive mechanisms of soybean seedlings under heat stress revealed by proteomic approach. *Journal of Proteome Research* 9(8): 4189–4204.

Ali, R. (2005). Field studies for the conservation and management of Point Calimere Complex. Foundation for ecological research, advocacy and learning. A Report for the Tamil Nadu Forest Department, 40 pp.

Arandhara, S., S. Sathishkumar & N. Baskaran (2020). Modelling the effect of covariates on the detectability and density of native Blackbucks and invasive feral-horse using multiple covariate distance sampling at Point Calimere Wildlife Sanctuary, Southern India. *Mammalian Biology* 100(2): 173–186.

Arandhara, S., S. Sathishkumar, S. Gupta & N. Baskaran (2021). Influence of invasive *Prosopis juliflora* on the distribution and ecology of native blackbuck in protected areas of Tamil Nadu, India. *European Journal of Wildlife Research* 67(3): 1–16.

Ashokkumar, M., S. Swaminathan & R. Nagarajan (2021). Grass species composition in tropical forest of southern India. *Journal of Threatened Taxa* 13(12): 19702–19713. https://doi.org/10.11609/jott.7296.13.12.19702-19713

Auken, O.W. (2009). Causes and consequences of woody plant encroachment into western North American grasslands. *Journal of Environmental Management* 90(10): 2931–2942.

Bardgett, R.D., J.M. Bullock, S. Lavorel, P. Manning, U. Schaffner, N. Ostle, M. Chomel, G. Durigan, L. Fry, D. Johnson & J.M. Lavallee (2021). Combatting global grassland degradation. *Nature Reviews Earth & Environment* 2(10): 720–735.

Barton, H., G. Mutri, E. Hill, L. Farr & G. Barker (2018). Use of grass seed resources c. 31 ka by modern humans at the Haua Fteah cave, northeast Libya. *Journal of Archaeological Science* 99: 99–111.

Baskaran, N., K. Ramkumaran & G. Karthikeyan (2016). Spatial and dietary overlap between blackbuck (*Antilope cervicapra*) and feral horse (*Equus caballus*) at Point Calimere Wildlife Sanctuary, southern India: Competition between native versus introduced species. *Mammalian Biology* 81(3): 295–302.

Baskaran, N., S. Arandhara, S. Sathishkumar & S. Gupta (2019). Assessing the changes in land use and land cover by invasive species and its influence on native flora & ungulates in selected protected areas of Tamil Nadu, India using GIS and remote sensing. Technical report submitted to SERB, Government of India.

Boval, M & R.M. Dixon (2012). The importance of grasslands for animal production and other functions: A review on management and methodological progress in the tropics. *Animal* 6(5): 748–762.

Bryson, C.T. & R. Carter (2008). The significance of Cyperaceae as Weeds, pp. 15–102. In: Naczi, R.F.C. & B.A. Ford (eds.). *Sedges: Uses, Diversity, and Systematics of the Cyperaceae, 1st ed*. Missouri Botanical Garden Press, 298 pp.

Cai, H., X. Yang & X. Xu (2015). Human-induced grassland degradation/restoration in the central Tibetan Plateau: the effects of ecological protection and restoration projects. *Ecological Engineering* 83: 112–119.

De Jong, T.J. (1995). Why fast-growing plants do not bother about defence. *Oikos* 74(3): 545–548.

Derner, J.D. & R.H. Hart (2007). Grazing-induced modifications to peak standing crop in northern mixed-grass prairie. *Rangeland Ecology & Management* 60(3): 270–276.

Egoh, B.N., J. Bengtsson, R. Lindborg, J.M. Bullock, A.P. Dixon & M. Rouget (2016). The importance of grasslands in providing ecosystem services: opportunities for poverty alleviation, pp. 421–441. In: Routledge handbook of ecosystem services, Routledge.

Fischer, L.K., M. von der Lippe & I. Kowarik (2013). Urban grassland restoration: which plant traits make desired species successful colonizers*? Applied Vegetation Science* 16(2): 272–285.

Frank, S.J.D., G.V. Gopi, K. Sankar & S.A. Hussain (2021). Dry season resource selection among sympatric ungulates in a tropical coastal landscape: implications for conservation and management. *Tropical Ecology* 62(3): 418–426.

Ganskopp, D & D. Bohnert (2001). Nutritional dynamics of 7 northern Great Basin grasses. *Rangeland Ecology & Management/Journal of Range Management Archives* 54(6): 640–647.

Hacker, J.B. (1984). Genetic variation in seed dormancy in *Digitaria milanjiana* in relation to rainfall at the collection site. *Journal of Applied Ecology* 21: 947–959.

Hagenah, N., H. Munkert, K. Gerhardt & H. Olff (2008). Interacting effects of grass height and herbivores on the establishment of an encroaching savanna shrub, pp. 189–202. In: Valk, A.K. (ed.). Herbaceous Plant Ecology. Recent Advances in Plant Ecology.

Springer, 367+VII pp. https://doi.org/10.1007/978-90-481-2798-6

Hao, Y. & Z. He (2019). Effects of grazing patterns on grassland biomass and soil environments in China: A meta-analysis. *PloS One* 14(4): p.e0215223. https://doi.org/10.1371/journal.pone.0215223

Hermance, J.F., D.J. Augustine & J.D. Derner (2015). Quantifying characteristic growth dynamics in a semi-arid grassland ecosystem by predicting short-term NDVI phenology from daily rainfall: a simple four parameter coupled-reservoir model. *International Journal of Remote Sensing* 36(22): 5637–5663.

Hughes, L., M. Westoby & A.D. Johnson (1993). Nutrient costs of vertebrate-and ant-dispersed fruits. *Functional Ecology* 54-62 pp.

Huijser, P. & M. Schmid (2011). The control of developmental phase transitions in plants. *Development* 138(19): 4117–4129.

Hussain, F. & M.J. Durrani (2009). Nutritional evaluation of some forage plants from Harboi rangeland, Kalat, Pakistan. *Pakistan Journal of Botany* 41(3): 1137–1154.

Islam, M.R., C.K. Saha, N.R. Sharkar, M. Jahilil & M. Hasanuzzamam (2003). Effect of variety on proportion of botanical fraction and nutritive value of different Napier grass (*Pennisetum puporeum*) and relationship between botanical fraction and nutritive value. *Asian-Australasian Journal of Animal Sciences* 16: 177–188.

Jhala, Y.V. (1997). Seasonal effects on the nutritional ecology of blackbuck Antelope cervicapra. *Journal of Applied Ecology* 34(6): 1348–1358.

Jing, Z., J. Cheng, J. Su, Y. Bai & J. Jin (2014). Changes in plant community composition and soil properties under 3-decade grazing exclusion in semiarid grassland. *Ecological Engineering* 64: 171–178.

Khan, M.A. & S. Gulzar (2003). Light, salinity and temperature effects on the seed germination of perennial grasses. *American Journal of Botany* 90: 131–134.

Kunwar, A., R. Gaire, K.P. Pokharel, S. Baral & T.B. Thapa (2016). Diet of the four-horned antelope *Tetracerus quadricornis* (De Blainville, 1816) in the Churia hills of Nepal. *Journal of Threatened Taxa* 8(5): 8745–8755. https://doi.org/10.11609/jott.1818.8.5.8745-8755

Liu, L., S. Bestel, J. Shi, Y. Song & X. Chen (2013). Paleolithic human exploitation of plant foods during the last glacial maximum in North China. *Proceedings of the National Academy of Sciences* 110(14): 5380–5385.

Maron, J.L. & E. Crone (2006). Herbivory: effects on plant abundance, distribution and population growth. *Proceedings of the Royal Society B: Biological Sciences* 273(1601): 2575–2584.

Moore, L.M., W.K. Lauenroth, D.M. Bell & D.R. Schlaepfer (2015). Soil water and temperature explain canopy phenology and onset of spring in a semiarid steppe. *Great Plains Research* 25(2): 121–138.

Morgan, J.A., W. Parton, J.D. Derner, T.G. Gilmanov & D.P. Smith (2016). Importance of early season conditions and grazing on carbon dioxide fluxes in Colorado shortgrass steppe. *Rangeland Ecology & Management* 69(5): 342–350.

Morgan, J.W., J.M. Dwyer, J.N. Price, S.M. Prober, S.A. Power, J. Firn, J.L. Moore, G.M. Wardle, E.W. Seabloom, E.T. Borer & J.S Camac (2016). Species origin affects the rate of response to inter-annual growing season precipitation and nutrient addition in four Australian native grasslands. *Journal of Vegetation Science* 27(6): 1164–1176.

Munson, S.M. & A.L. Long (2017). Climate drives shifts in grass reproductive phenology across the western USA. *New Phytologist* 213(4): 1945–1955.

Murugan, R., I. Djukic, K. Keiblinger, F. Zehetner, M. Bierbaumer, S. Zechmeister-Bolternstern & R.G. Joergernsen (2019). Spatial distribution of microbial biomass and residues across soil aggregate fractions at different elevations in the Central Austrian Alps. *Geoderma* 339: 1–8.

O'Mara, F.P. (2012). The role of grasslands in food security and climate change. *Annals of Botany* 110(6): 1263–1270.

Parton, W., J. Morgan, D. Smith, S. Del Grosso, L. Prihodko, D. LeCain, R. Kelly & S. Lutz (2012). Impact of precipitation dynamics on net ecosystem productivity. *Global Change Biology* 18(3): 915–927.

Popay, I. & R. Field (1996). Grazing animals as weed control agents. *Weed Technology* 10(1): 217–231.

Post, A.K. & A.K. Knapp (2020). The importance of extreme rainfall events and their timing in a semi-arid grassland. *Journal of Ecology* 108(6): 2431–2443.

Rangel, A.A., D.D. Rockemann, F.M. Hetrick & S.K. Samal (1999). Identification of grass carp haemorrhage virus as a new genogroup of aquareovirus. *Journal of General Virology* 80(9): 2399–2402.

Ravi, N. & N. Mohanan (2002). Common Tropical and Sub-tropical Sedges and Grasses. *Science Publishers*, Inc., Enfield, New Hampshire

Rojas-Sandoval, J. (2016). *Dactyloctenium aegyptium* (crowfoot grass). Invasive Species Compendium, 19321 pp.

Sawyer, H., F. Lindzey & D. McWhirter (2005). Mule deer and pronghorn migration in western Wyoming. *Wildlife Society Bulletin* 33(4): 1266–1273.

Shankar, N.B. & J. Shashikala (2010). Diversity and structure of fungal endophytes in some climbers and grass species of Malnad region, Western Ghats, Southern India. *Mycosphere* 1(4): 265–274.

Shaw, R.B. (2008). *Grasses of Colorado*. University Press of Colorado, Boulder, CO, 650 pp.

Sherry, R.A., X. Zhou, S. Gu, J.A. Arnone III, D.W. Johnson, D.S. Schimel, P.S. Verburg, L.L. Wallace & Y. Luo (2011). Changes in duration of reproductive phases and lagged phenological response to experimental climate warming. *Plant Ecology & Diversity* 4(1): 23–35.

Shiferaw, H., T. Alamirew, S. Dzikiti, W. Bewket, G. Zeleke & U. Schaffner (2021). Water use of Prosopis juliflora and its impacts on catchment water budget and rural livelihoods in Afar Region, Ethiopia. *Scientific Reports* 11(1): 1–14.

Sivaganesan, N. (1991). The ecology of the Asian Elephant in Mudumalai Wildlife Sanctuary, with special reference to habitat utilization. Unpublished PhD Thesis. Bharathidasan University, Tiruchirapalli.

Solofondranohatra, C.L., M.S. Vorontsova, J. Hackel, G. Besnard, S. Cable, J. Williams, V. Jeannoda & C.E. Lehmann (2018). Grass functional traits differentiate forest and savanna in the Madagascar central highlands. *Frontiers in Ecology and Evolution* 6: 184.

Treydte, A.C., J.G. van der Beek, A.A. Perdok & S.E. van Wieren (2011). Grazing ungulates select for grasses growing beneath trees in African savannas. *Mammalian Biology* 76(3): 345–350.

Wan, C., I. Yilmaz & R.E. Sosebee (2002). Seasonal soil-water availability influences snakeweed root dynamics. *Journal of Arid Environments* 51: 255–264.

Wang, T., X. Jin, Z. Chen, M. Megharaj & R. Naidu (2011). Green synthesis of Fe nanoparticles using eucalyptus leaf extracts for treatment of eutrophic wastewater. *Science of the Total Environment* 466: 210–213.

Wardle, J. (1971). The forests and shrublands of the Seaward Kaikoura Range. *New Zealand Journal of Botany*, 9: 269–292

White, R.P., S. Murray, M. Rohweder, S.D. Prince & K.M. Thompson (2000). *Grassland Ecosystems*. World Resources Institute, Washington, DC, 81 pp.

Xu, W., X. Deng, B. Xu, J.A. Palta & Y. Chen (2021). Soil Water Availability Changes in Amount and Timing Favor the Growth and Competitiveness of Grass Than a Co-dominant Legume in Their Mixtures. *Frontiers in Plant Science* 12: 723839.

Zeng, D.H., L.J. Li, Z.Y. Yu, Z.P. Fan & R. Mao (2010). Soil microbial properties under N and P additions in a semi-arid, sandy grassland. *Biology and Fertility of Soils* 46(6): 653–658.

Zhang, Y., Q. Wang, Z. Wang, Y. Yang & J. Li (2020). Impact of human activities and climate change on the grassland dynamics under different regime policies in the Mongolian Plateau. *Science of the Total Environment* 698: 134304.

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COMMUNICATION

Current populations of *Colobus vellerosus* (Geoffory, 1834) & *Cercopithecus lowei* (Thomas, 1923) and land-use, land cover changes in Boabeng-Fiema Monkey Sanctuary, Ghana

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Abstract: Background and Research aim: This study evaluated the density of two primate species *Colobus vellerosus* and *Cercopithecus lowei* and the change in land-use types in Boabeng-Fiema Monkey Sanctuary in Ghana, from 2007 to 2019. Method: Total counts of individual monkeys were done in all six patches of forest in the Sanctuary in 2019. Using Landsat imagery, land-cover maps of the study area were examined to evaluate the change that has occurred over a nine-year period between 2010 and 2019. Results: A total of 602 individuals of *C. vellerosus* were counted in 34 groups (0.58 group/ha). Group locations were: 15 at Boabeng (0.12 groups/ha), five at Fiema (0.08 group/ha), three at Bomini (0.09 group/ha), four at Busuyna (0.13 group/ha), three at Bonte (0.06 group/ha), and four at Akrudwa (0.11 group/ha). *C. lowei* was only encountered at Boabeng and Fiema, with a total of 351 individuals distributed in 26 groups. In 2010, forest covered a land area of 1,540.08 ha, and it was estimated to have increased to 2,643.12 ha in 2019. Farmlands covered 5,069.07 ha in 2010, and in 2019 were estimated to cover 4,155.03 ha. Built-up areas in 2010 covered an area of 433.89 ha, and in 2019 had declined to 244.89 ha. Conclusion: The monkey populations have increased and spread to occupy all patches in the Monkey Sanctuary. On LULCC, 72% increase, 18% reduction, and 44% reduction in forest cover, farmland and built-up areas were observed respectively. Implications for conservation: There is a blend of traditional and conventional conservation efforts contributing to the increase in primate population, the occupancy of previously 'empty' forest patches and change in areas of land-use types.

Keywords: Endangered species, forest patches, human activities, indigenous knowledge, landscape, population dynamics, primates, protected areas, satellite imagery.

Abstract in Akan: Onipa dasani ase retrɛ ama nwuram moadoma ase reshe nanso Boabeng-Fiema Monkey Sanctuary ye baabi a wɔde amamre ne gyidi abɔ Efoɔ (Colobus vellerosus)ne Kwakuo (Cercopithecus lowei) ho ban besi nɛ. Saa nsroboa yi ase reyɛ atore wo yɛ man ne wiase nyinaa. Enti yɛ kenkan saa mmoa yi dodoɔ ɛna yesan whɛɛ senea ɔmanfoɔ nso de asaase no redi dwuma. Yɛ nyaa Efoɔ dodo oha-nsia ne mienu (602) a na wote akuo akuo aduasa-anan (34), a na wotete kwaewa nsia a ɛwowɔ hɔ no mu. Kwakuo no nso na wɔyɛ ahasa-aduonum-baako (351) a wote akuo akuo aduonu-nsia (26) wo kwaewa ɛwɔ Boabeng ne Fiema. Afei yɛ hunuu sɛ omanfoɔ no de asaase no ye kwae, afuo, ne adansie. Ye de toto mfie dumienu a atwam no a, ye hu se mmoa no ase atrɛ akɔ kwaewa a ɛwɔ ho no nyinaa mu na omanfoɔ no nso kwae no atre ama asaase a wode ye afuo ne nea ode si dan no deɛ ɛso ate.

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INTRODUCTION

Human population growth has had significant impact both directly and indirectly on the dynamics and structure of biological communities. This is because of the extension, growth, and dispersal of human populations, which have been greatly influenced by both the agricultural and industrial revolutions. Nonhuman primates are not exempt from problems associated with human population growth (Cowlishaw & Dunbar 2000). Early in the 1950s, it was discovered that the Red Colobus *Procolobus waldroni* was imperiled due to habitat loss and poaching, and Booth (1956) expressed the opinion that its extinction in the Gold Coast (now Ghana) in the near future could be considered to be a possibility. Booth therefore asked for effective laws that would safeguard the species as well as its habitats, but it is now likely to be extinct (Oates et al. 2000). Recent studies have clarified the realities that other related primates have probably now been extirpated from most protected areas (Wiafe 2021) or a few groups occur where enforcement against poaching has been intensified (Wiafe 2016).

In addition, Oates et al. (2000) attributed the recent extinction of primates to complacency, since primates in general have received much attention from conservation measures and are regarded as one of the few large orders of mammals not to have lost a taxon in the 20th century (Mittermeier et al. 1997). Oates et al. (2000), however, warned that such complacency may allow taxa that could have been saved by more vigorous and timely action to become extinct. The danger could be particularly acute in the case of taxa that have received little attention and live in parts of the world where biologists and conservationists focus less. Also, reports indicate that population trends for animals are more favorable in nations with higher development rankings (Barnes et al. 2016).

Other reports reveal that more than 50% of protected areas that contained *Colobus vellerosus* in the 1970s no longer contain it, and on average an 87% reduction in encounter rates of this species in six forest reserves in the last 30 years has been estimated (Matsuda-Goodwin et al. 2019). This suggests an equivalent reduction in population size in recent times. On the contrary, as of 2007, Boabeng-Fiema Monkey Sanctuary (BFMS) in Ghana harbored 365 individuals *C. vellerosus* (Kankam & Sicotte 2013) and has consistently been a site for a stable population of this endangered primate. Between 2007 and 2019 (about 12 years), no systematic census from the sanctuary has been published, probably because the population appears to be stable. However, the accelerated unwanted factors like deforestation, over-exploitation of resources, invasive species, human population increase, and weak legislation may have a great toll on the stable populations and therefore a regular census is required (Ntiamoa-Baidu 1995; Attuquayefio & Fobil 2005).

Land-use and land-cover change (LULCC) has been observed to be dynamic and accelerated in recent times, influenced by factors such as farming, estate development and mining, and aggravated by climate change impacts and adaptation. Bamford et al. (2001) echoed that LULCC is a major driving force of habitat modification and has important implications for the distribution of wildlife in ecosystems. The need to regularly analyze LULCC cannot be over-emphasized, as it can be used to predict changes in ecological systems and species population changes, as well as examine the factors responsible for such changes. In the Masai Mara ecosystem (Kenya), a 30-year LULCC indicated that a rapid land conversion had a drastic decline on a wide range of wildlife species (Mundia & Murayama 2009). In a study at BFMS in Ghana, Amankwa et al. (2021) concluded from a 26-year LULCC analysis of six-year intervals that the rapid changes were attributed to human population growth and associated activities.

The objectives of this study were to determine the species densities in the forest patches; examine the population growth rate of the primates and determine the relationship between the species densities and patch sizes. We also assessed the change that has happened in land-use and land-cover over a decade.

METHODS

Study Area

This study took place at Boabeng-Fiema Monkey Sanctuary (BFMS) which comprises forest patches in the villages of Boabeng — 128 ha, Fiema — 62 ha, Bomini — 30.6 ha, Bonte — 33.5 ha, Busuyna — 54.1 ha, Akrudwa (Panin) — 32.2 ha, Kwaase — 4.9 ha, Tankor — 6.8 ha, Senya — 74.9 ha, and Akrudwa (Kuma) — 3.2 ha (Kankam & Sicotte 2013). BFMS is a community-based conservation area situated in the Bono-East Region of Ghana located on with 7.666N to 7.669N and 1.629W to 1.700W. The 499.2 ha Sanctuary is located in the Nkoranza North District on a flat terrain. BFMS is a dry semi-deciduous forest which lies in the savanna transition zone (Figure 1). The vegetation type is dominantly a primary mosaic forest (Hall & Swaine 1981; Fargey 1991). BFMS has two distinct seasons: rainy season between March and October and dry season between November and February with the mean annual rainfall of 1,250

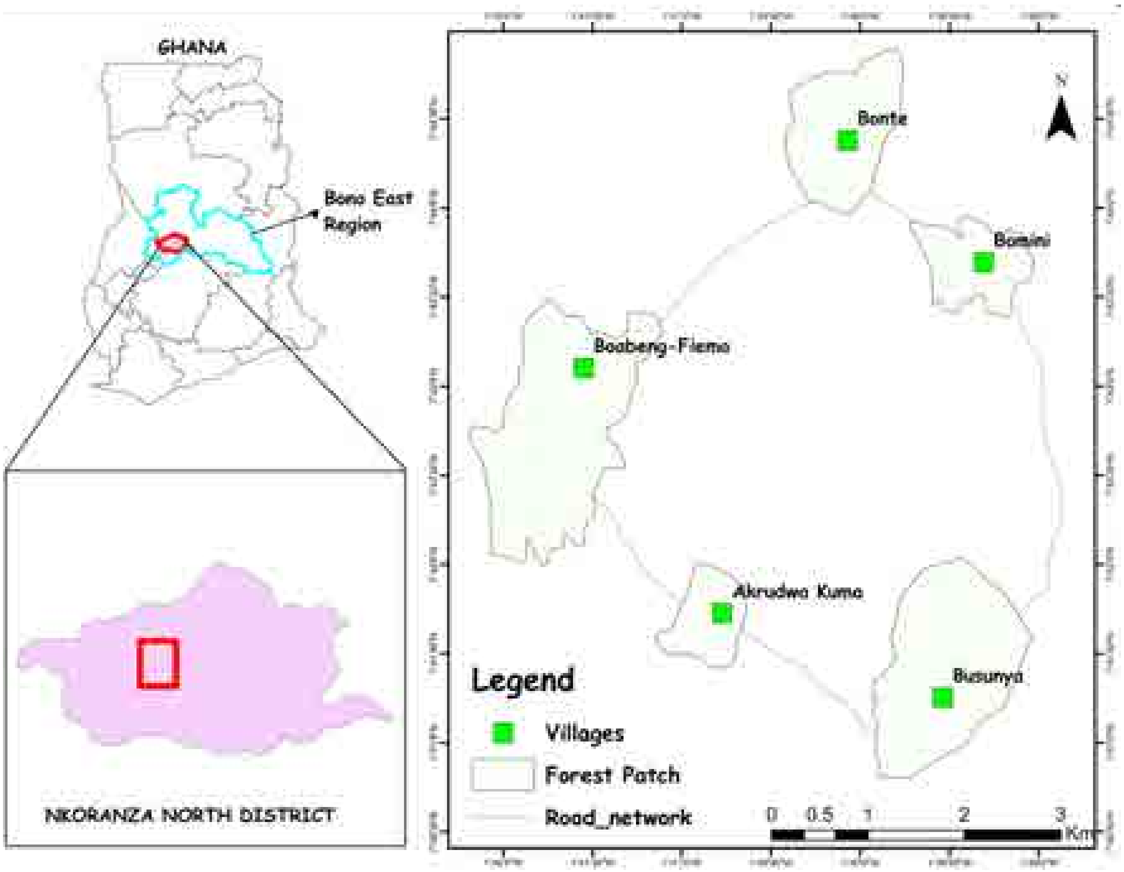

Figure 1. Study area (BFMS) showing villages and road linking the villages.

mm (Fargey 1991). The sanctuary is developed from the traditional belief of the local people, where hunting and killing of a primate is perceived as a taboo (Fargey 1991; Ntiamoa-Baidu 1995; Attuquayefio & Fobil 2005). The sanctuary is noted as a community-based conservation area with the community members in charge of managing its activities. *C. vellerosus* and *C. lowei* are the two primates in the sanctuary (Fargey 1991; Kankam 1997) with over 3,700 human inhabitants (G.S.S. 2010). The community members cultivate cashew, maize, yam, groundnut, cassava, and oil palm (Wiafe & Arku 2012).

Study species

Colobus vellerosus White-thighed Colobus and *Cercopithecus lowei* Lowe's monkey are two distinct primate species living sympatric in Boabeng-Fiema Monkey Sanctuary (BFMS) (Kankam & Sicotte 2013).

Known to be highly arboreal, *C. vellerosus* at BFMS has been found to intermittently travel on the ground (Schubert 2011). The diet has been observed to be mostly leaves, fruits, seeds, and flowers (Wong et al. 2006). This species has been reported in other protected areas in Ghana such as Kakum National Park, Cape Three Points Forest Reserve, Mole National Park, and Atewa Range Forest Reserve (Wiafe 2016, 2019, 2021). It is also reported to occur in Côte d'Ivoire's Bandama-Sassandra interfluvial zone (Gonedelé Bi et al. 2014), Togo's Togodo Faunal Reserve, (Segniagbeto et al. 2017), and Benin's Lama and Kikele Forest Reserves (Campbell et. al. 2008). It is currently classified as critically endangered on the IUCN (International Union for Conservation of Nature) Red List of Threatened Species (Matsuda-Goodwin et al. 2019) (Image 1).

C. lowei is usually found in primary, secondary, and gallery/riverine forest, and it is observed to be active in the lower forest strata and on the ground (Wiafe 2016; Wiafe et al. 2019). The diet of *C. lowei* includes mainly fruits but is supplemented with insects (Wiafe 2015). *C. Lowei* are also distributed in some parts of Ghana including Kakum Conservation Area, Cape Three Points, and Atewa Range Forest reserves (Oates et al. 2000; Wiafe 2016, 2021), and Côte d'Ivoire's Soko and Guelitapia forests (Gonedelé Bi et al. 2014). It is currently classified as vulnerable on the IUCN red list of species (Wiafe et al. 2019) (Image 2).

Image 1. A White-thighed Colobus *Colobus vellerosus* at B.F.M.S. © Wiafe E.D.

Image 2. Lowe's Monkey *Cercopithecus lowei* at B.F.M.S. © Wiafe E.D.

Survey design

The study included the existing patches of forest stands where the management of the sanctuary confirmed that those patches harbored monkeys for the past five years. The management also informed us that forest patches of Akrudwa (Kuma) and Akrudwa (Panin) have been merged as Akrudwa. Therefore, we surveyed in the following forests patches with respective sizes: Boabeng — 128 ha, Fiema — 62 ha, Bomin — 30.6 ha, Bonte — 33.5 ha, Busuyna — 54.1 ha, and Akrudwa — 37.4 ha (Figure 1). The vegetation type of the six patches has been described by Kankam & Sicotte (2013) as open forest mixed with savanna woodland. The already existing trails (tourist trails) were used for the study, and only accessible paths were used to assess the patches because the team decided not to disturb or destroy the vegetation in the area by creating new paths. To equalize sampling intensity, we used 17 transects of varying lengths ranging from 500–1,000 m to count monkeys in all the patches of forests. In total, 71,050 m of transect walks were made in specific patches as follows: Boabeng = 14,300 m, Fiema = 10,650 m, Bomini = 11,200 m, Busunya = 12,450 m, Bonte = 11,200 m, and Akrudwa = 11, 250 m.

Using Landsat Imagery, a land-cover map of the study area was made to examine the change that has occurred over a nine-year period between 2010 and 2019 (The image with less cloud was obtained in 2010 instead of years around 2007).

Data Collection

Primate Species Enumeration

Six selected patches were visited to identify and count the two sympatric primates through visual observation of primate presence. Primate species censuses were carried out within the six patches simultaneously by three people in one group (18 people total). In each group, two members served as observers while one member served as a recorder of the observations. Every team was led by a Sanctuary staff member who was conversant with the territory of every primate group. The team walked through the existing trails in the patches to search for the primates with the help of binoculars used for scanning the canopy of the vegetation. When primates were spotted, the species were identified and counted, and the locations recorded. When a group of primates was spotted, GPS coordinates were noted at the center of the group spread. The process started at 06:00 GMT till they enumerated all the groups.

The census was done two times to cross-check whether all the subjects were encountered. To reduce observer bias, the start and end times of the census were clearly stated to all team members, and team members were also reshuffled between groups so that an area with species was not counted twice by the same group at the second time. The numbers were estimated based on 'good visibility' counts (Baker et. al. 2009).

Land-Cover Changes

To verify how the land-cover has undergone changes and its possible effect on the primate distribution, satellite images of the study area between 2010 and 2019 were analyzed. This study acquired a time frame series of two Satellite Landsat Images: Landsat 7 ETM (Enhanced Thematic Mapper), representing the year 2010, and Landsat 8 OLI (Operational Land Imager), representing the year 2019. These two images were all acquired through the Google Earth Engine platform which serves as a cloud-based system that houses several satellite images for earth observation analysis. The image resolution was 30 m which was quite good for image analysis. To select the best image, we considered images within the whole year with least cloud cover. The chances were that the resolution of the images from the dry season (December–March) was quite high, so images from December 2010 and December 2019 were used.

Data Analysis

Primate Density Calculations

The number of groups and individuals were tallied and totaled for each transect and patch.

The line transect method has been widely used and is considered the most accurate method of conducting wildlife surveys to study animal populations and calculate species density (Whitesides et al. 1988; Plumptre 2000; Buckland et al. 2001), and the commonly used software package DISTANCE has also been used for data analysis. However, the use of this method requires certain criteria or assumptions in order for the mathematical model to be applicable to the data (Buckland et al. 2001). Unfortunately, several constraints prevented use of this method. First, most of the time the monkeys detected the observer and started moving before the observer could detect them. Second, there was poor visibility in the forest which prevented the clear detection of the animals for accurate distance and angle measurements as well as lesser number of sightings than 40.

As the mathematical models associated with line transects model could not be applied to calculate densities, primate density was calculated by the ratio of number of group of monkeys or total individuals encountered to size of the forest patch or length of transect (Collinson 1985; Ellis 2003; Wiafe 2016).

Statistical analysis involved the use of 'R' statistical software version 4.2.1 (R Core Team, 2021). The Shapiro-Wilk normality test was used to check the normality of the abundances of *C. vellerosus* (response variable), and the result indicated that the response variable was not normally distributed ($W = 0.68949$, $p < 0.001$). Therefore, Marasquilo's test was used to get an overall Chi square to compare medians of abundance of *C. vellerosus* among all the six patches and pairwise comparisons of the abundance of *C. vellerosus* in any two different forest patches. The *C. lowei* was encountered in only two nearby patches (Boabeng and Fiema) and because of this we did not do any further statistical analysis. The *C. vellerosus* density change rate was calculated as follows:

$$\text{Growth rate} = \frac{Nt - No}{No}$$

Where:
Nt = density at current time (2019)
No = density at the beginning of the period (2007)
Since the time lag between the first and the second densities was 12 years the population growth rate per annum was calculated by dividing the growth rate by 12. For the *C. lowei*, there was no known published previous population to serve as basis to determine the change in population of the species, within the period.

Remote sensing analysis on land-cover

We preprocessed both images (Satellite Landsat images) in Google Earth Engine. The preprocessing steps include the following: (1) filtering of the image by the region of interest which was an extent of the area created as a feature; (2) filtering by the date ('2010-01-01', '2010-12-31') for 2010 and ('2019-01-01', '2019-12-31') for 2019; and (3) filtering by least cloud cover and a median composite of all the bands for the respective years.

A supervised land-cover classification was then performed by first creating training samples of the respective classes (forest, villages/communities, and agricultural fields). The training samples were created with the help of high-resolution images from Google Earth Imagery in comparison with other literature studies on classification and knowledge of the study area. With the training samples as inputs for the classification, we used a Classification and Regression Tree (CART) classification algorithm which is a predictive model that explains how outcome variables' values can be predicted based on other values in the Google Earth Engine that was used to classify the satellite images into the land-cover classes listed above. This procedure was validated as well with Google Earth Imagery again and other sources of literature (Allotey & Wiafe 2015) on classification within the same study area. A change detection table was generated where the area in terms of percentage and hectares of land-cover between 2010 and 2019 was generated to assess the changes that took place over time.

RESULTS

Population Densities of Primates

C. vellerosus were encountered and distributed in all the six patches of forest at BFMS: Boabeng, Fiema, Bomini, Busuyna, Bonte, and Akrudwa. In all, a total of 602 individuals were counted in 34 groups. These were made up of 15 groups of 315 individuals at Boabeng; five groups of 73 individuals at Fiema; three groups of 54 individuals at Bomini; four groups of 58 individuals at Busuyna; three groups of 36 individuals at Bonte and four groups of 66 individuals at Akrudwa. In terms of density per patch size, Boabeng recorded 2.46 individual/ha, 1.18 individual/ha at Fiema, 1.59 individual/ha at Bomini, 1.87 individual/ha at Busunya, 0.67 individual/ha at Bonte, and 3.88 individual/ha at Akrudwa (Table 1).

The *C. lowei* were only encountered at Boabeng and Fiema, and in total, 351 individuals were distributed over 26 groups. In Boabeng, 18 groups were encountered with a total of 236 individuals, and eight groups of 115 individuals were encountered at Fiema (Table 2).

Further analysis indicated that the densities of *C. vellerosus* encountered in Boabeng differ significantly from that of all the other five patches (Fiema, Bomini, Busunya, Bonte, Akrudwa). On the contrary, the densities of *C. vellerosus* in all other forest patches were found not to be significantly different. (Marascuilo's test: Overall χ^2=37.97 df-5 p<.001: For pairwise comparisons – BBG-FM χ^2 = 12.59, df = 1, p<.02; BBG-BON χ^2 = 30.91, df = 1, p <.01; BOS-BON χ^2 = 12.14, df = 1, p <.03; BON-AKR χ^2 = 11.83, df = 1, p <.03); Likewise, Marascuilo's test for BBG-FM for C. vellerosus χ^2 = 0.001, df = 1, p <.98)

Table 1. Densities of *C. vellerosus* enumerated in the forest patches of BFMS (BBG—Boabeng | FM—Fiema | BOM—Bomini | BUSU—Busunya | BONTE—Bonte | AKRU—Akrudwa.

Forest patch	Number of groups	Number of animals	Area (ha)	Number of groups/ha	Density/ ha
BBG	15	315	128	0.12	2.46
FM	5	73	62	0.08	1.18
BOM	3	54	34	0.09	1.59
BUSU	4	58	31	0.13	1.87
BONTE	3	36	54	0.06	0.67
AKRU	4	66	37	0.11	1.78
Total	34	602	346	0.09	1.74

Table 2. Densities of *C. lowei* enumerated in the forest patches of BFMS.

Forest patch	Number of groups	Number of animals	Area (ha)	Number of groups/ha	Density/ ha
BBG	18	236	128	0.14	1.84
FM	8	115	62	0.13	1.85
BOM	0	0	34	0	0
BUSU	0	0	31	0	0
BONTE	0	0	54	0	0
AKRU	0	0	37	0	0
Total	26	351	346	0.07	1.01
	26	351	190	0.14	1.84

From the year 2007 to 2019 the densities of the *C. vellerosus* in the entire sanctuary increased by 70.0 % over 12 years at an average growth rate of 5.8% per annum. There was, however, variation in the growth rate in different forest patches as shown in Table 3.

Land-cover and Land-use Changes

The classification approach yielded two land-cover maps within the area from 2010–2019 (Image 3). In 2010, forest covered a land area of 1,540.08 ha, representing 21.87%, but the area was estimated to be 2,643.12 ha in 2019, representing 37.53%. (Forested area has increased by 1,103.04 ha, representing 15.66%). Farmlands (agricultural lands) on the other hand covered 5069.07 ha (71.97%) in 2010, but in 2019 these were estimated to cover 4155.03 ha (59.00%) (a reduction of 914.04 ha or 12.97%). Villages or built-up areas in 2010 covered an area of 433.89 ha (6.16%), but 244.89 ha (3.48%) in 2019 (a reduction of 189 ha or 2.68%) (Table 4).

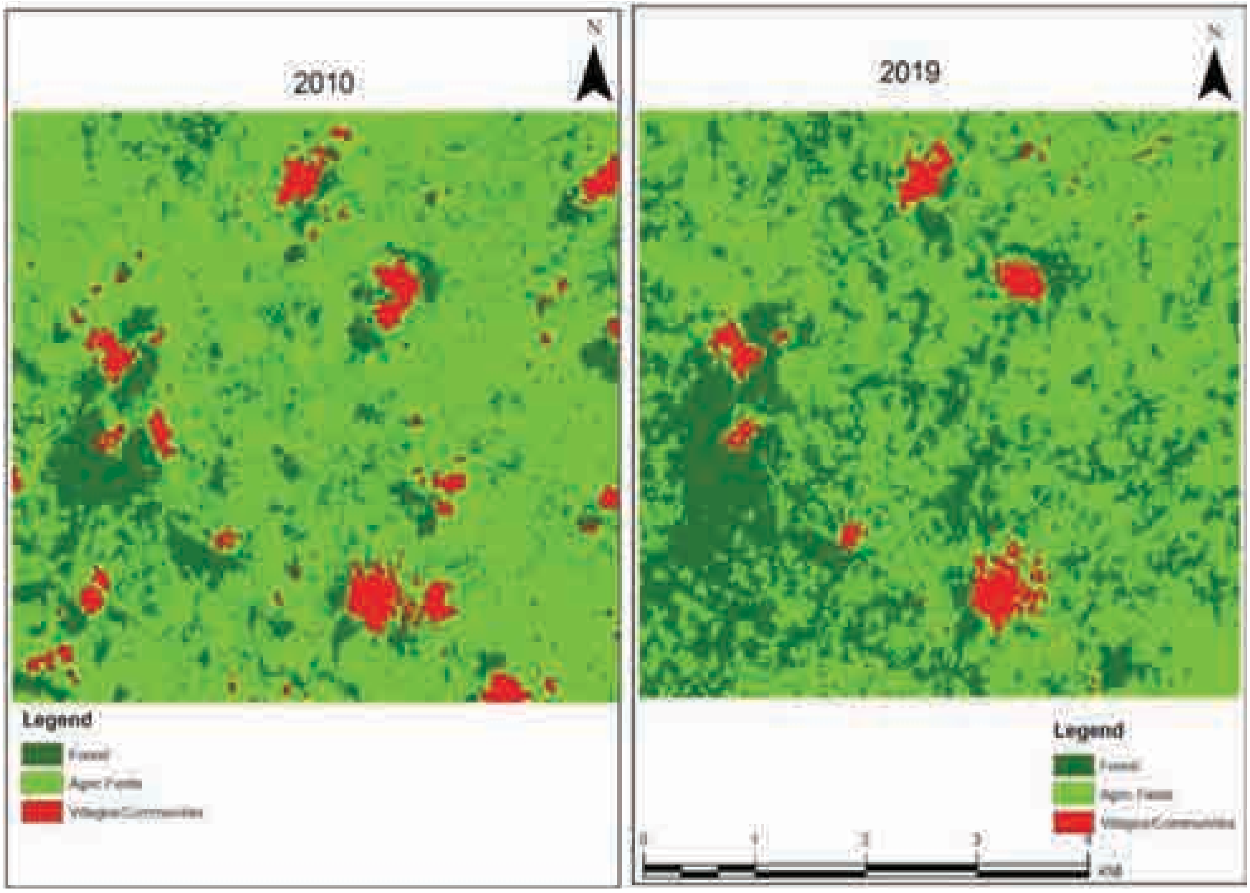

Image 3. Land cover changes in the study area (BFMS).

Table 3. Growth rates of densities of *C. vellerosus* in the six patches of forest in BFMS.

Forest patch	Density of 2019 (This study)	Density of 2007 (Kankam & Sicotte 2013)	Growth rate (%) in 12 years	Av. Growth/ annum (%)
BBG	2.46	1.63	50.98	4.25
FM	1.18	1.08	9.02	0.75
BOM	1.59	0.72	120.59	10.05
BUSU	1.87	0.13	1339.21	111.60
BONTE	0.67	0.44	51.52	4.29
AKRU	1.78	0.50	256.76	21.40
Total	7.68	4.50	1828.08	-
Average	1.28	0.75	304.68	-

Table 4. Classification table on land cover changes.

	2010		2019	
Class Names	Area (ha)	Area (%)	Area (ha)	Area (%)
Forest	1540.08	21.87	2643.12	37.53
Farm/Agric Lands	5069.07	71.97	4155.03	59.00
Villages/Communities	433.89	6.16	244.89	3.48
Total Area	**7043.04**	**100**	**7043.04**	**100**

DISCUSSION

The conservation of primates in BFMS has solely depended on traditional knowledge and belief until the early parts of 1970s when the government intervened to support the management of the sanctuary. Since then, the sanctuary has been combining the use of taboos and conventional law enforcement to prohibit hunting of the primates in the sanctuary (Attuquayefio & Fobil 2005; Saj et al. 2005, 2006; Wong & Sicotte 2005; Kankam & Sicotte 2013). Conservation education and other interventions such as eco-tourism, tree planting, and eco-friendly agriculture have been intensified since 2010. It could be deduced that within the six patches, *C. vellerosus* and *C. lowei* were not evenly distributed. Both were mostly concentrated at Boabeng and Fiema. This concentration could be attributed to historical distribution, the traditional belief of not hunting or killing primates, and the unsuitable nature of the other patches. The study area is a forest-savannah transition zone; thus, the unsuitable nature of some patches is the result of the limited number of trees, alongside the presence of some invasive species such as *Chromolaena odorata* (E.D. Wiafe, 2019 pers. obs.) which suppresses the growth of native plant species that might have been essential food sources for the primates. Due to the savanna dominated nature of a patch such as Bonte of size 33.5 ha (Table 4), it is mostly shrub and grassland with few trees. Thus, such an area becomes less attractive to the two species.

It was observed that *C. lowei* did not travel out of the patches of Boabeng and Fiema areas. This could be attributed to the fact that the local people of Boabeng and Fiema use human food to feed *C. lowei*, as the people believe that the primates are their ancestors (Wiafe & Arku 2012). This behavior of the people providing food for the primates may have increased the availability of feed for *C. lowei* to limit them in Boabeng and Fiema patches. The *C. lowei* further forages on crops cultivated by humans which usually causes antagonistic relationships. However, the people of Boabeng and Fiema have resolved to coexist and tolerate the destructive activities of the monkeys to some extent as opposed to the people of other patches. Notwithstanding, the *C. lowei's* absence in other patches is likely due to the natural dispersal pattern of the species as (compared to *C. vellerosus*). In *C. vellerosus* both sexes disperse, which makes it very easy for new groups to form and spread (Teichroeb et al. 2009, 2011), but in *C. lowei*, females are philopatric (Cowlishaw & Dunbar 2000). This means that new groups can only form by the fission of very large existing groups and these new groups of females would all have to find their way to a new fragment together. That is much more difficult and less likely than single colobus making the journey, and making it far easier for new groups to be created and to spread than for the female philopatric cercopethecines.

On the other hand, *C. vellerosus* were found in all the six patches, and this is not different from the report of previous studies by Kankam (1997), Saj et al. (2005), and Wong et al. (2006). In 2003, Wong and colleagues confirmed the presence of *C. vellerosus* at Bonte and Akrudwa in addition to Boabeng, Fiema, Bomini and Akrudwa, just as Kankam's report in 1997 and Kankam & Sicotte (2013). It has been reported that Bonte has two groups of *C. vellerosus* in the area with only one resident group (Kankam & Sicotte 2013).

Over the past decades, *C. vellerosus* population in western Africa has experienced drastic decline resulting from habitat loss and bush meat trade. Several studies (Fargey 1991; Kankam 1997; Wong & Sicotte 2005; Kankam & Sicotte 2013) at BFMS have shown that *C. vellerosus* population has been increasing. As reported by Wong & Sicotte (2005), this increment within the sanctuary can be related to the movement from the small patches (within the study area) with less food resources available to the larger patches which provide adequate resources for primates' survival.

Comparing the current census to the last census of 2007 (Kankam & Sicotte 2013), the total number of groups of *C. vellerosus* has increased from 29 to 34 (Table 1) as follows: Boabeng has increased from 13 to 15; Fiema has reduced from six to five; Bomini has increased from one to three; Bonte from two to three; Busunya from three to four; and Akrudwa from two to four. Note that Kankam & Sicotte (2013) reported one group at Konkrompe, but the sanctuary managers negated their current presence. The average density in 2007 was 0.75 perha and in the present study (2019) it was 1.28 per ha (Table 3). Comparative analysis indicated that the population growth is 70% spread over 12 years at an average growth rate of 5.9% per annum (though there were specific variations in growth at the patch level) (Table 3). This comparison must be viewed with caution since different surveyors and different data analysis methods were used.

As a community-based conservation area in the central Ghana, the people have consciously made efforts to increase forest cover through planting of trees in the villages, roadsides, and alongside agricultural crops in the farmlands. Also, the decline in the cover of the villages (build-up) indicates that more trees have been planted in the villages and that the people have promoted natural regeneration of forests in previous opened areas. Comparing this study's results to the last land-cover analysis done in 2007, Allotey & Wiafe (2015) reported that settlement expansion due to the increasing human population in the area led to a 22.4% decline of the forest cover. Meanwhile, agricultural land-use yielded a 54.5% increase in land-cover, and build-up 23.1%. Tree harvesting has not been reported to have caused a change in forest cover in the area. This is probable because primate habitats are prohibited for human use in the sanctuary, but Amankwa et al. (2021) recently reported charcoal and lumber production in the surrounding areas. The results of this study showed increases in forest cover by 71.62%, 18.03% reduction in farmland, and 43.56% reduction built up areas. This improvement in forest cover creates better conditions for *C. vellerosus* groups to disperse to occupy all patches in the nearby communities.

IMPLICATIONS FOR CONSERVATION

BFMS is the only conservation area harboring such endangered primates amidst human activities such as agriculture and settlement expansion. Therefore, both traditional and conventional knowledge have been necessary to put human activities under control, which has allowed for the regeneration of the forest cover in the study area. This creates a good impression about the forest cover, hence a good condition for *C. vellerosus* group dispersal to occupy all patches in the proximity. Also, the population of the *C. vellerosus* has increased and more than doubled within the 12-year period, showing that when species are protected against hunting and habitat destruction, their population will increase (Wiafe 2016). The community members support the conservation of the primates and protect their habitats to promote primate tourism, and as a result contribute to the population stabilization and increase in the area of distribution and occupancy. At present, habitat destruction, habitat degradation, overexploitation, and poaching of wild animals, as well as climate change have been identified as the major threats to wildlife in the world (Hogue & Breon 2022). In that case, any efforts to reduce the impacts must be embraced and supported.

The results of this study do not conform to the totality of the notion that small patches of habitat support smaller populations and if individuals are unable to migrate to other suitable habitat areas, the population becomes isolated, putting them at risk of extinction. However, with the institution of the combination of traditional and conventional conservation intervention in highly fragmented environments (as shown in this study), conserving parts of acceptable primate habitats (forest patches) and prohibiting hunting have allowed the primates to migrate between these different locations, occupy the previous 'empty' patches as well as increased their populations. Existing evidence suggests that some primate species, such as Chimpanzees *Pan troglodytes* (McLennan 2008), Orangutans *Pongo* spp. (Spehar & Rayadin 2017), and Samango monkeys *Cercopithecus albogularis labiatus* (Nowak et al. 2017), have extremely high behavioral flexibility, allowing them to survive in human-modified landscapes. Additional evidence is the forest patches in Belize's Community Baboon Sanctuary in which Steinberg (1999) found that a population of Black Howler monkeys *Alouatta pigra* increased by 138% over 13 years when forest buffer strips along property boundaries and strips of forest across large cleared areas were maintained. As a result, the population grew from 840 to over 2,000 individuals (138 %), indicating that they have a high level of behavioral plasticity that allows them to survive in human-modified environments.

We therefore recommend that the government should prioritize the protection of the sanctuary and channel resources to support the conservation of the two species in the sanctuary. Regular population monitoring at short intervals should be carried out by the Sanctuary Management Authority in collaboration with the research institutions in order to predict the dynamics of population growth and events that can affect the primates' population. In addition, a land-use change monitoring regime should be implemented in the area so as to invest resources in the land-use type that favor both the human and non-human primates.

REFERENCES

Allotey, A.N.M. & E.D. Wiafe (2015). Effect of land use dynamics on habitat of two sympatric primates in Boabeng-Fiema monkey sanctuary, Ghana. *Ghana Journal of Science* 55(1): 3–14.

Amankwa, A.A., J.A. Quaye-Ballard, B. Koomson, R.K. Amankwa, A. Awotwi, B.O.Kankam, N.Y.Opuni-Frimpong, D.S. Baah & S. Adu-Bredu (2021). Deforestation in forest-savannah transition zone of Ghana: Boabeng-Fiema Monkey Sanctuary. *Global Ecology and Conservation* 25: 1–14.

Attuquayefio D.K. & J.N. Fobil (2005). An overview of biodiversity in Ghana: Challenges and Prospects. *West African Journal of Ecology* 7: 1–18.

Baker, L.R., A.A. Tanimola, O.S. Olubode & D.L. Garshelis (2009). Distribution and abundance of sacred monkeys in Igboland, Southern Nigeria. *American Journal of Primatology* 71: 574–586.

Bamford, A., J.L. Moore, T. Brookes, N. Burges, L.A. Hansen, P. Williams & C. Rahbeck (2001). Conservation conflicts across Africa. *Science* 291(5513): 2626–2619. https://doi.org/10.1126/science.291.5513.2616

Barnes, M. D., I.D. Craigie, L.B. Harrison, J. Geldmann, B. Colle, S. Whitmee, A. Balmford, N.D. Burgess, T. Brooks, M. Hockings & S. Woodle (2016). Wildlife population trends in protected areas predicted by national socio-economic metrics and body size. *Nature Communications* 7: 12747. https//:doi.org/10.1038/Ncomms12747

Booth, A.H. (1956). The distribution of Primates in the Gold Coast. *Journal of the West African Science Association* 2: 122–133.

Buckland, S. T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers & L. Thomas (2001). *Introduction to Distance Sampling: Estimating Abundance of Biological Populations.* Oxford University Press, London, 432 pp.

Campbell, G., J. Teichroeb & J.D. Paterson (2008). Distribution of diurnal primate species in Togo and Bénin. *Folia Primatologica* 79(1): 15–30.

Collinson, R.F.H. (1985). Selecting wildlife census techniques. Monograph 6. Institute of Natural Resources. University of Natal, Pitermariztburg, South Africa, 83 pp.

Cowlishaw, G. & R. Dunbar (2000). *Primate Conservation Biology*. The University of Chicago Press, Chicago and London, 498 pp.

Ellis, A.M. (2003). An assessment of estimation methods for forest ungulates. A Master of Science Thesis. Rhodes University, 89 pp.

Fargey, P.J. (1991). Assessment of the conservation status of the Boabeng-Fiema Monkey Sanctuary. Report submitted to the Flora and Fauna Preservation Society.

Hall, J.B. & M.D. Swaine (1981). *Distribution and Ecology of Vascular Plants in a Tropical Rain Forest: Forest Vegetation in Ghana.* The Hague, Dr W Junk Publishers, 392 pp.

Hogue, A.S. & K. Breon (2022). The greatest to species. *Conservation Science and Practice* 2022; 4:e12670. https://doi.org/10.1111/csp2.12670.

Gonedelé Bi, S., A. Bitty, K. Ouatara, & W.S. McGraw (2014). Primate surveys in Côte d'Ivoire's Sassandra–Bandama interfluvial region with notes on a remnant population of black-and-white colobus. *African Journal of Ecology* 52(4): 491–498.

G.S.S. (2010). Population and housing census: national analytical report. Accra-Ghana: Ghana Statistical Service. https://www2.statsghana.gov.gh/nada/index.php/catalog/51

Kankam, B.O. (1997). The population of black-and-white colobus (*Colobus polykomos*) and the mona monkeys (*Cercopithecus mona*) at the Boabeng-Fiema Monkey Sanctuary and surrounding villages. University of Science and Technology, Kumasi (Ghana), 71 pp.

Kankam, B.O. & P. Sicotte (2013). The Effect of Forest Fragment Characteristics on Abundance of *Colobus vellerosus* in the Forest-Savanna Transition Zone of Ghana. *Folia Primatologia* 84: 74–86.

Matsuda-Goodwin, R., S. Gonedelé Bi, G. Nobimè, I. Koné, D. Osei, G. Segniagbeto & J.F. Oates (2019). *Colobus vellerosus*. The IUCN Red List of Threatened Species 2019: e.T5146A17944551. https://doi.org/10.2305/IUCN.UK.20193.RLTS.T5146A17944551.en Date of download is 13th October, 2019.

McLennan, M.R. (2008). Beleaguered chimpanzees in the agricultural district ofHoima, Western Uganda.*Primate Conservation* 23: 45–54.

Mittermeier, R.A., A.B. Rylands, A.E. Eudey, A.E. Rodriguez-Dina & T. Butynski (1997). Specialist group reports: Primate Specialist Group. *Species* 28: 56–57.

Mundia, C.N. & Y. Murayama (2009). Analysis of land use/cover changes and animal population dynamics in a wildlife sanctuary in East Africa. *Remote Sensing* 2009(1): 952–970.

Nowak K., K. Wimberger, S.A. Richards, R.A. Hill & A. le Roux (2017). Samango monkeys (*Cercopithecus albogularis labiatus*) manage risk in a highly seasonal, human-modified landscape in Amathole Mountains, South Africa. *International Journal of Primatology* 38: 194–206.

Ntiamoa-Baidu, Y. (1995). *Indigenous verses introduced biodiversity conservation strategies: The case of Protected Area systems in Ghana*. Biodiversity Support Programme (Issues in African Biodiversity No.1), Washington D.C., 20 pp.

Oates, J.F., M. Abedi-Lartey, M. McGraw, T.T. Struhsaker & G.H. Whitesides (2000). Extinction of a West African Red Colobus. *Conservation Biology* 14(5): 1526–1532.

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Plumptre, A.J. (2000). Monitoring mammal populations with line transect techniques in African forests. *Journal of Applied Ecology* 37(2): 356–368.

Saj, T.L., J.A. Teichroeb & P. Sicotte (2005). The population status of the ursine colobus (*Colobus vellerosus*) at Boabeng-Fiema, Ghana. *Commensalism and conflict: the human primate interface* (Paterson, J.D.& J. Wallis eds.). American Society of Primatologists, Norman, OK, 350, 375 pp.

Saj, T.L., C. Mather & P. Sicotte (2006). Traditional taboos in biological conservation: the case of *Colobus vellerosus* at the Boabeng-Fiema Monkey Sanctuary, Central Ghana. *Social Science Information* 45(2): 285–310.

Schubert, R.L. (2011). The conservative nature of primate positional behavior: testing for locomotor and postural variation in Colobus vellerosus and Cercopithecus campbellilowei at Boabeng-Fiema Monkey Sanctuary, Ghana (Doctoral dissertation, The Ohio State University).

Ségniagbeto, G.H., D. Assou, K.D. Koda, E.K G. Agbessi, K.H. Atsri, D. Dendi, L. Luiselli, J. Decher & R.A. Mittermeier (2017). Survey of the status and distribution of primates in Togo (West Africa). *Biodiversity*18(4): 137–150.

Spehar S.N. & Y. Rayadin (2017). Habitat use of Bornean orangutans (*Pongo pygmaeusmorio*) in an industrial forestry plantation in East Kalimantan, Indonesia. *International Journal of Primatology* 38: 358–384.

Steinberg, M.K. (1999). Timber, Tourists, and Temples. Conservation and Development in the Maya Forest of Belize, Guatemala, and Mexico. *Economic Botany* 53: 88. https://doi.org/10.1007/BF02860797.

Teichroeb, J., E. Wikberg & P. Sicotte (2009). Female dispersal patterns in six groups of ursine colobus (*Colobus vellerosus*): infanticide avoidance is important. *Behaviour* 146(4–5): 551–582.

Teichroeb, J. A., P. Sicotte & E.C. Wikberg (2011). Dispersal in male ursine colobus monkeys (*Colobus vellerosus*): influence of age, rank and contact with other groups on dispersal decisions. *Behaviour* 148(7): 765–793.

Whitesides, G.H., J.F. Oates, S.M. Green & R.P. Kluberdanz (1988). Estimating primate densities from transects in a West African rain forest: a comparison of techniques. *Journal of Animal Ecology* 57(2): 345–367.

Wiafe, E.D. & F.S. Arku (2012). Victims Perspectives of Lowe's Monkeys' (*Cercopithecus campbelii lowei*) crop raiding events in Ghana: A case of Boabeng-Fiema Monkey Sanctuary. *Journal of Biodiversity and Environmental Sciences* 2(2): 1–8.

Wiafe, E.D. (2015). Nutrient contents of three commonly consumed fruits of Lowe's monkey (*Cercopithecus campbelli lowei*). *Springer Plus* 4(1): 44.

Wiafe, E.D. (2016). Population studies of Lowe's monkey (Mammalia: Primates: Cercopitecidae: *Cercopithecus lowei* Thomas, 1923) in Kakum Conservation Area, Ghana. *Journal of Threatened Taxa* 8(2): 8434–8442. https://doi.org/10.11609/jott.2193.8.2.8434-8442

Wiafe, E.D. (2019). Encounter rates and group sizes of diurnal primate species of Mole National Park, Ghana. *Journal of Threatened Taxa* 11(5): 13523–13530. https://doi.org/10.11609/jott.4026.11.5.13523-13530

Wiafe, E.D. (2021). Distribution and population density of endangered primate species in Ghana`s forest reserves. *Forestist* 71: 238–247.

Wiafe, E., J.F. Oates, S. Gonedelé Bi, I. Koné, R. Matsuda-Goodwin & D. Osei (2019). *Cercopithecus lowei*. *The IUCN Red List of Threatened Species* 2019. https://www.iucnredlist.org/species/136931/92373680

Wong, S.N.P. & P. Sicotte (2005). Population size and density of *Colobus vellerosus* at the Boabeng-Fiema Monkey Sanctuary and surrounding forest fragments in Ghana. *American Journal of Primatology* 68: 465–476.

Wong, S.N.P., T.L. Saj & P. Sicotte (2006). Comparison of habitat quality and diet of *Colobus vellerosus* in forest fragments in Ghana. *Primates* 47: 365–373.

Threatened Taxa

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COMMUNICATION

Roadkill records of two civet species on National Highway 715 passing through Kaziranga-Karbi Anglong landscape complex, Assam, India

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Abstract: This study was conducted on a continuous 64-km stretch of National Highway (NH) 715, which bifurcates the Kaziranga-Karbi Anglong landscape complex, with Kaziranga National Park on its southern side and North Karbi Anglong Wildlife Sanctuary on the northern side. The survey was carried out from October 2017 to September 2018 via two-way journeys three days a week, with two observers using a motor vehicle at a steady speed of 25–35 km/hour. Roadkill reports of one Large Indian Civet *Viverra zibetha* and six Small Indian Civets *Viverricula indica* were collected. Both the species are solitary and nocturnal, and prefer to inhabit secondary landscapes intermingled with human habitation. This stretch of NH 715 forms a crucial passage for wildlife foraging and breeding, and this study reflects the impacts of roads causing wildlife-vehicle collision for two civet species.

Keywords: Large Indian Civet, mortality, Small Indian Civet, *Viverra zibetha, Viverricula indica,* wildlife-vehicle collision.

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Author contributions: SS—conceptualization, methodology, validation, investigation, resources, data curation, writing - original draft, review & editing. PKS—supervision, conceptualization, validation, writing, review & editing. MKS—supervision, resources, writing, review & editing.

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INTRODUCTION

Roadways can pose substantial threats to the movement of local wildlife when they pass through protected areas (Gokula 1997; Selvan 2011). Roads are often concrete and permanent features of any landscape, and a road in the wrong place can have devastating consequences for the environment (Laurance et al. 2001). Also, roads in pristine areas like forest covers or patches are environmentally challenging (Laurance et al. 2001). The effect of roads and highways on animals and their environment ranges from habitat alteration and modification (Carr & Fahrig 2001) to disruption of animal distribution and movement (Desai & Baskaran 1998). This can affect breeding density (Reijnen et al. 1995), heterozygosity, genetic polymorphism (Reh & Seitz 1990), and survival due to mortality from vehicular collisions (Shwiff et al. 2007). Thus, with the demandingly growing road network, animals get forced to cross roads to meet with their routine necessities and hence are killed by vehicular collisions (Hourdequin 2000). The ecological effects of roads and traffic have been reported in various studies that date back to the beginning of the 20th century with a rapid increase in studies since the 1980s when road ecology became recognised as a scientific discipline (Linsdale 1929; Laursen 1981; Raman 2011; Samson et al. 2016; Jegannathan et al. 2018; Miranda et al. 2020).

With an estimated total population of 1.3 billion people and 2.4% of an annual rate of change (The World Factbook 2020), India has the second largest road system in the world as per the National Highway Authority of India. The network covers approximately 5.89 million km of road stretch, which in length is after the USA. Enormous growth in road network is expected and predicted in the upcoming years (Indian Road Industry Report 2020). Considering this vast network of roads in concoction with the incessant anthropogenic factors like habitat alteration, alien species invasions, and climatic change, the impact of roads on wildlife cannot be overlooked (Erritzoe et al. 2003; Glista et al. 2008).

This study found (Sur et al. 2022) roadkill of various species of amphibia, reptiles, birds, and other small mammals, but here we primarily focus on the roadkill of two civet species. The Large Indian Civet *Viverra zibetha* of the Viverridae family is a solitary and terrestrial nocturnal animal, categorized as 'Least Concern' by the IUCN Red List (Timmins et al. 2016). The Indian population is listed on CITES Appendix III, as there is an increasing decline in its population. The Small Indian Civet *Viverricula indica* is also categorized as 'Least Concern' by the IUCN Red List (Choudhury et al. 2015), with a stable population trend, widespread geographical distribution, and habitat use, it is commonly found in India, Sri Lanka, and Bangladesh (Choudhury 2013; Mudappa 2013). *V. zibetha* is known to prefer forests, grasslands, & scrubs intermingled with human habitats and is a good climber. *V. indica* is nocturnal and terrestrial, known to occur in healthy populations in agricultural & secondary landscapes and is highly adaptable in degraded & open habitats (Su 2005). As only a single study of reptilian roadkill has been reported from this area (Das et al. 2007), this is the first documentation of civet roadkill in this stretch of the highway and thereby depicts the need and urgency of similar research work in relation to roads and their effects on wildlife in NH 715.

METHODS

This study was conducted on a continuous 64 km stretch of the paved NH 715 (26.5669–26.7669 N & 93.1336—93.6002 E), which was earlier known as the NH 37, and runs parallel to the southern boundary of Kaziranga National Park (KNP) dividing the landscape into south and north (Figure 1). The Kaziranga-Karbi Anglong landscape is located in the northeastern state of Assam spreading over an 25,000 km^2 south of the Brahmaputra River in Assam, touching the neighbouring states of Meghalaya and Nagaland. The landscape includes KNP, North Karbi Anglong Wildlife Sanctuary (NKAWS), East Karbi Anglong Wildlife Sanctuary (EKAWS), river Brahmaputra, and NH-715. River Brahmaputra divides the state into northern and southern halves, and the NH 715 runs between KNP and NKAWS. The landscape covers the districts of Golaghat, Nagaon, Sonitpur, and Karbi Anglong. This stretch of the road bisects two protected areas, with KNP to the north and NKAWS to the south, thus making it a crucial passage for wildlife.

Wildlife movement across the NH 715 is vital, since during the wet season, when there are floods the animals migrate from the low-lying floodplains of KNP to the elevated Karbi Anglong hills. Movement also takes place during the dry season when the animals cross move to meet their breeding and feeding necessities. This paved road passes through various habitats including tea gardens, human habitations, paddy fields, teak plantations, wetlands, swamps, and marshy areas besides forest habitats of KNP at Panbari, Haldibari, Kanchanjuri, and Gorakati. All these habitats are potential sites and corridors for animal movement,

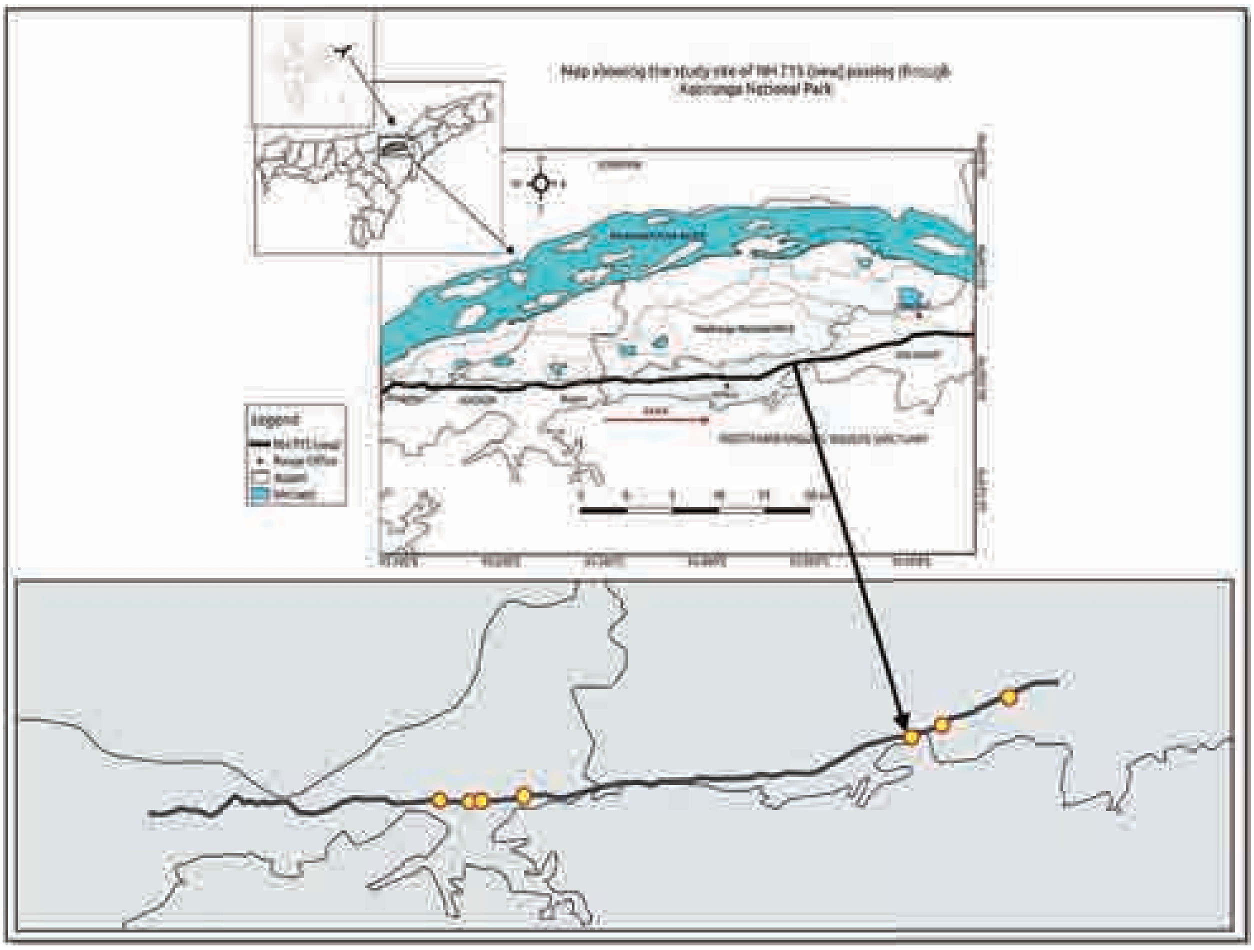

Figure 1. Map showing study area (upper map) along with the location of civet roadkill (dots in lower map).

typically between KNP and Karbi Anglong Hills, and therefore more susceptible to collisions due to moving traffic and vehicles when the animal crosses the 7.5m paved width of the road.

The survey was conducted for a period of one year from October 2017 to September 2018. Data were collected by two observers at 0700 h during the winter and at 0500 h in the summer, depending upon visibility, in both directions from Bokakhat to Amguri, using a motor vehicle at a steady speed of 25–35 kmph, for three days a week. Thereby, a total of 144 systematic surveys were conducted from starting to end point, for the entire study period, approximating to 128 km for every instance. On encountering a civet roadkill, the number of individual roadkill, their status, and nearby habitat characteristics were recorded along with geo-location (Figure 1). The animal carcasses encountered were photographed for identification and were removed from the road to avoid double counting (Glista et al. 2008). The animals were identified by their distinguishing tail pattern, spots, body colour, and size (Images 2, 3) using a field guide (Menon 2014).

RESULTS

Here we report the roadkill of one *V. zibetha* near Gauri Shankar Shantidevi School, Diphloo, on NH 715 and six *V. indica* at different locations (Table 1). The roadkills were found in a dry and deformed condition (Image 1,2).

V. zibetha roadkill was observed in March which is the pre-monsoon season, and the *V. indica* roadkill were observed in March (n = 2), June (n = 1), August (n = 1), and December (n = 2) which falls under pre-monsoon, monsoon and winter seasons respectively. Immediate habitat of the incident sites were tea plantations, scattered human settlements, agricultural fields, open lands, scrublands, and waterbodies (Table 1).

Table 1. List of individual civet kills with their kill status surrounding landscape characters and geolocation.

	Date	Species	Status	Landscape Characteristics	Longitude (N)	Latitude (E)
1.	09.iii.2018	Large Indian Civet	Fresh	Tea Plantation/ Human Habitat	93.5504	26.6333
2.	01.xii.2017	Small Indian Civet	Fresh	Tea Plantation/ Human Habitat	93.5531	26.6344
3.	07.xii.2017	Small Indian Civet	Fresh	Open Area/ Open Area	93.4937	26.6116
4.	08.iii.2018	Small Indian Civet	Fresh	Tea Plantation/ Scrubland	93.5122	26.6172
5.	12.iii.2018	Small Indian Civet	Fresh	Agriculture field/ Agriculture field	93.2055	26.5754
6.	15.v.2018	Small Indian Civet	Fresh	Agriculture field/ Scrubland	93.2327	26.5747
7.	23.viii.2018	Small Indian Civet	Fresh	Agriculture field/ Waterbody	93.2247	26.5747

DISCUSSION

Most of the civet roadkills occurred in areas nearby or in close association with human settlements. The presence of these civets near human habitations could be attributed to the easy availability of food sources (Prater 1971). Since civets are nocturnal species, they were possibly killed during the night hours while crossing the road, as they get blinded by the vehicle headlights (Baskaran & Boominathan 2010).

The roadkill reports for these species might seem to be insignificant, and could be an underestimate of the actual road related mortality, but this loss is unlikely to be balanced by the equivalent birth rate in the current population of the species (Bennett 1991). Nonetheless such trivial loss is intolerable and raises concern, considering the animal's unique nature, uncertain distribution, population stability, and density (Bennett 1991).

V. zibetha face various anthropogenic threats, which is leading to its population decline. Hunting for bush meat and scent glands is the main threat to this species in southeastern Asia (Lynam et al. 2005). Furthermore, habitat modifications and alterations are also a major cause for declining population records of *V. zibetha*. Additionally, anthropogenic activities like clearing and burning of forest understory could also drive their presence (Bista et al. 2012). Another less recognized threat faced by them is the effect of linear intrusions like roads and rails, leading to direct mortality due to vehicular collisions. A large array of studies worldwide has reported the kill of civets due to vehicular collisions (Behera & Borah 2010; Seshadri & Ganesh 2011; Selvan 2011; Mahananda & Jelil 2017; Jeganathan et al. 2018; Jamhuri et al. 2020). However, this elusive species has been little studied in terms of its distribution, ecology, and threats, particularly in the state of Assam and northeastern India, hence needs more research, to ascertain its actual status and position. *V. indica* are known to face various anthropogenic threats in terms of hunting for bush meat and medicines. *They are* subjected to little-controlled poaching and other forms of encroachment.

CONCLUSION

Linear infrastructures such as roads, railways, power lines, and pipelines may serve as barriers, conduits, habitats, sinks, or sources in the environment they bisect or traverse (Burel & Baudry 2003). Roads are one of the most crucial and critical components of human life since civilization and urbanization began (Demir 2007). Roads are considered to be the major man-made components that induces anthropogenic modifications in the natural environment (Keshkamat 2011). Therefore, these infrastructure constructions are degrading natural areas & environments and are eventually paving the way for quasi urbanization. Reduction of natural habitats is considered a global threat to biodiversity conservation (Geneletti 2003). Therefore, road designs and locations should be framed such that it should have low environmental cost and high socioeconomic costs.

It is thereby crucial to understand the interaction between roads and railways and wildlife, which have been intruded inside their habitat; it is certainly our responsibility to create and provide them with safe passage thus leading to peaceful coexistence and a long-term sustained effort to reduce such mortality of lesser-studied species.

REFERENCES

Baskaran, N. & D. Boominathan (2010). Road kill of animals by highway traffic in the tropical forests of Mudumalai Tiger Reserve,

Image 1. Carcass of Large Indian Civet *Viverra zibetha* from vehicle collision.

Image 2. Carcasses of Small Indian Civet *Viverricula indica* from vehicle collisions.

southern India. *Journal of Threatened Taxa* 2(3): 753–759. https://doi.org/10.11609/JoTT.o2101.753-9

Behera, S. & J. Borah (2010). Mammal mortality due to road vehicles in Nagarjunasagar-Srisailam Tiger Reserve, Andhra Pradesh, India. *Mammalia* 74: 427–430.

Bennett, A.F. (1991). Roads, roadsides and wildlife conservation: a review. In: Saunders, D.A. & R.J. Hobbs (eds.) *Nature Conservation 2: The Role of Corridors* 99–116 pp.

Bista, A., P. Chanchani, R. Warrier, R. Mann, M. Gupta & J. Vattakavan (2012). Detection of Large Indian Civet *Viverra zibetha* in camera-trap surveys in and around Dudhwa National Park in the Terai Region of North India. *Small Carnivore Conservation* 47: 54–57.

Burel, F. & J. Baudry (2003). *Landscape Ecology: Concepts, Methods, and Applications.* Science Publishers, Inc. Enfield, NH, USA, 357 pp.

Carr, L.W. & L. Fahrig (2001). Effect of road traffic on two amphibian species of differing vagility. *Conservation Biology* 15: 1071–1078.

Choudhury, A. (2013). *The mammals of North east India.* Gibbon Books and the Rhino Foundation for Nature in NE India, Guwahati, Assam, India, 432 pp.

Choudhury, A., J.W. Duckworth, R. Timmins, W. Chutipong, D.H.A. Willcox, H. Rahman, Y. Ghimirey & D. Mudappa (2015). *Viverricula indica*. The IUCN Red List of Threatened Species 2015. Accessed on 24 April 2020. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T41710A45220632.en

Das, A., M.F. Ahmed, B.P. Lahkar & P. Sharma (2007). A pre-liminary report of reptilian mortality on road due to vehicular movement near Kaziranga National Park, Assam, India. *Zoos' Print Journal* 22(7): 2742–2744. https://doi.org/10.11609/JoTT.ZPJ.1541.2742-4

Demir, M. (2007). Impacts, management and functional planning criterion of forest road network system in Turkey. *Transportation Research Part A* 41(1): 56–68. https://doi.org/10.1016/j.tra.2006.05.006

Desai, A.A. & N. Baskaran (1998). Ecology of Malabar Giant Squirrel (*Ratufa indica)* in Mudumalai Wildlife Sanctuary, South India. Technical Report. Bombay Natural History Society, Bombay.

Erritzoe, J., T. Mazgajski & L. Rejt (2003). Bird casualties on European roads–a review. *Acta Ornithologica* 38: 77–93.

Geneletti, D. (2003). Biodiversity Impact Assessment of roads: an approach based on ecosystem rarity. *Environmental Impact Assessment Review* 23(3): 343–365. https://doi.org/10.1016/S0195-9255(02)00099-9

Glista, D.J., T.L. Devault & J.A. Dewoody (2008). Vertebrate road mortality predominantly impacts amphibians. *Herpetological Conservation and Biology* 3(1): 77–87.

Gokula, V. (1997). Impact of vehicular traffic on snakes in Mudumalai Wildlife Sanctuary. *Cobra* 27: 26.

Hourdequin, M. (2000). Ecological effect of roads. Special section. *Conservation Biology* 14(1): 16–17.

Indian Road Industry Report (2020). https://www.ibef.org/archives/industry/roads-reports/indian-roads-industry-analysis-january-2020. Downloaded on 1 May 2020.

Jamhuri, J., M.A. Edinoor, K. Norizah, A.M. Lechner, A. Ashton-Butt & B. Azhar (2020). Higher mortality rates for large- and medium-sized mammals on plantation roads compared to highways in Peninsular Malaysia. *Ecology and Evolution* 10: 12049–12058.

Jeganathan, P., D. Mudappa, M.A. Kumar & T.R.S. Raman (2018). Seasonal variation in wildlife roadkills in plantations and tropical rainforest in the Anamalai Hills, Western Ghats, India. *Current Science* 114(3): 619–626.

Keshkamat, S.S. (2011). The road less travelled: Scale in the assessment and planning of highways. PhD Thesis. University of Twente, The Netherlands, x+264 pp.

Laurance, W.F., M.A. Cochrane, S. Bergen, P.M. Fearnside, P. Delamonica, C. Barber, S. D'Angelo & T. Fernandes (2001). The future of the Brazilian Amazon. *Science* 291: 438–439.

Laursen, K. (1981). Birds on roadside verges and the effect of mowing on frequency and distribution. *Biological Conservation* 20: 59–68.

Linsdale, J.M. (1929). Roadways as they affect bird life. *Condor* 31: 143–145. https://doi.org/10.2307/1362978

Lynam, A.J., M. Maung, S.H.T. Po & J.W. Duckworth (2005). Recent records of Large-spotted Civet *Viverra megaspila* from Thailand and Myanmar. *Small Carnivore Conservation* 32: 8–11.

Mahananda P. & S. Jelil (2017). A report on a road kill of Viverricula indica from Guwahati, Assam. *Zoo's Print* 32(1): 26–28.

Menon, V. (2014). *Indian Mammals: A Field Guide.* Hachette Book Publishing India Pvt Ltd. 528 pp.

Miranda, J.E.S., F.R. de Melo & R.K. Umetsu (2020). Are roadkill hotspots in the Cerrado equal among groups of vertebrates? *Environmental Management*. 65: 565–573.

Mudappa, D. (2013). Herpestids, viverrids and mustelids, pp. 471–498. In: Johnsingh, A.J.T. & N. Manjrekar (eds.). *Mammals of South Asia: Ecology, Behaviour and Conservation, Vol. 1*. Universities Press, Hyderabad, India.

Raman, T.R.S. (2011). Framing Ecologically sound Policy on Linear Intrusions Affecting Wildlife Habitats, Background paper. National Board for Wildlife, Ministry of Environment and Forests, India.

Reh, W. & A. Seitz (1990). The influence of land use on the genetic structure of populations of the common frog *Rana temporaria*. *Biological Conservation* 54: 239–49.

ROADS - Statistical Year Book India (2018). http://www.mospi.gov.in/statistical-year-book-india/2018/190. Downloaded on 1 May 2020.

Reijnen, R., R. Foppen, C.T. Braak & J. Thissen (1995). The effects of car traffic on breeding bird populations in woodland III: Reduction of density in relation to the proximity of main roads. *Journal of Applied ecology* 32: 187–202.

Samson, A., B. Ramakrishnan, A. Veeramani, P. Santhoshkumar, S. Karthick, G. Sivasubramanian, M. Ilakkia, A. Chitheena, J.L. Princy & P. Ravi (2016). Effect of vehicular traffic on wild animals in Sigur Plateau, Tamil Nadu, India. *Journal of Threatened Taxa* 8: 9182–9189. https://doi.org/10.11609/jott.1962.8.9.9182-9189

Selvan, K.M. (2011). Observation of road kills on Kambam-Kumily Road (NH 220) in Tamil Nadu. *Zoo's Print* XXVI(3): 25–26.

Seshadri, K.S. & T. Ganesh (2011). Faunal mortality on roads due to religious tourism across time and space in protected areas: a case study from south India. *Forest Ecology and Management* 262: 1713–1721.

Shwiff, S.A., H.T. Smith, R.M. Engeman, R.M. Barry, R.J. Rossmanith & M. Nelson (2007). Bioeconomic analysis of herpetofauna road-kills in a Florida State Park. *Ecological Economics* 64: 181–85.

Su, S. (2005). Small carnivores and their threats in Hlawga Wildlife Park, Myanmar. *Small Carnivore Conservation* 33: 6–13.

Sur, S., P.K. Saikia & M.K. Saikia (2022). Speed thrills but kills: A case study on seasonal variation in roadkill mortality on National Highway 715 (new) in Kaziranga-Karbi Anglong Landscape, Assam, India. In: Santos S, C. Grilo, F. Shilling M. Bhardwaj & C.R. Papp (eds.). Linear Infrastructure Networks with Ecological Solutions. Nature Conservation 47: 87–104. https://doi.org/10.3897/natureconservation.47.73036

The World Factbook (2020). https://www.cia.gov/the-world-factbook/ countries/ india/ #people-and society. Downloaded on 1 May 2020.

Timmins, R.J., J.W. Duckworth, W. Chutipong, Y. Ghimirey, D.H.A. Willcox, B. Rahman & A. Choudhury (2016). *Viverra zibetha*. The IUCN Red List of Threatened Species 2016: e.T41709A45220429. Accessed on 24 April 2020. https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T41709A45220429.en

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COMMUNICATION

Evaluating the influence of environmental variables on fish abundance and distribution in the Singhiya River of Morang District, eastern Nepal

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Abstract: Monitoring the impact of fishing pressure on the Singhiya River is critical for resource development and sustainability, and the present situation is alarming and causing critical concern among the public. This study aimed to identify fish community trends over time and space in the river, and to investigate the impact of environmental variables on fish abundance and dispersion. Monthly fish sampling was performed from October 2020 to September 2021 from the 5th to 10th of each month. We used three cast nets of various mesh sizes (0.5, 2, & 4 cm) and monofilament gill nets with mesh sizes of 6, 8, & 10 cm. A total of 7,593 fish were collected, representing 61 species from seven orders, 20 families, and 37 genera. Similarity percentage (SIMPER) analysis revealed 78.8% similarity among six stations, with the primary contributing species: *Puntius chola* (28.2%), *Puntius sophore* (13.5%), *Pethia ticto* (5.33%), *Chagunius chagunio* (3.76%), *Barbonymus gonionotus* (3.69%), *Puntius terio* (3.46%), *Opsarius shacra* (2.2%), and *Opsarius bendelisis* (2.1%). Analysis of variance (ANOVA) on canonical correspondence analysis revealed that four of the seven selected environmental variables had significant relationship with the fish assemblage such as water parameters velocity, temperature, pH, and hardness. Overfishing and direct discharge of industrial waste into water resources may be the primary causes for the decline in fish diversity in Singhiya River.

Keywords: ANOVA, assemblage structure, cast nets, fish diversity, fish ecology, habitat variable, time-space.

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INTRODUCTION

Freshwater bodies are vulnerable to habitat fragmentation, human encroachment, climate change, pollution, and biological invasions (Radinger et al. 2019). The combined effects of environmental pollution, unprecedented rates of biodiversity change, hydrological alteration, dam construction, and disconnection between the rivers and their lakes are possibly the largest threats to freshwater fish biodiversity (Huang & Li 2016). The diversity of the natural population is partially dependent on the environmental variables which always affect the competing populations (Chowdhury et al. 2011; Hossain et al. 2012). The factors influencing fish assemblages involve the environmental variables which are spatially heterogeneous and temporally variable and biotic interactions such as competition and predation (Harvey & Stewart 1991; Grossman et al. 1998). The environmental variables such as water velocity (Li et al. 2012; Adhikari et al. 2021; Limbu et al. 2021b), water depth (Kadye et al. 2008; Li et al. 2012; Mia et al. 2019; Chaudhary & Limbu 2021), substrate (Vlach et al. 2005; Yan et al. 2010), water temperature (Hossain et al. 2012; Nsor & Obodai 2016), and dissolved oxygen (Guo et al. 2018) all have been found to affect fish abundance and distribution in the rivers and streams.

In Nepal, few studies have looked at fish diversity and its link with environmental factors (Mishra & Baniya 2016; Limbu et al. 2020). Information on the relationship between fish community structure and environmental variables can aid in the preservation and management of aquatic biodiversity in the face of human-caused problems such as pollution and global climate change (Li et al. 2012). The Singhiya River has been altered due to several human encroachments such as settlements, factories, embankments, sand mining, electrofishing, damping and agriculture. To date, the space and time pattern of low-land, Terai region remains relatively unknown. Moreover, the details on fish community structure relating to their anthropogenic activities is also scanty. Facts about the relationship between fish community structure and environmental conditions can help us retain and lead aquatic biodiversity away from human-caused challenges like pollution and global climate change (Li et al. 2012).

The present study aimed to detect fish community patterns in the Singhiya River through time and space, as well as to evaluate the impact of environmental variables on fish abundance and dispersion. The current study expected that during the annual dry season, when water current and volume are reduced, fish abundance in the Singhiya River would be increased. We also hypothesized that the structure of fish assemblages will vary according to seasonal fluctuation defined by environmental variables.

MATERIALS AND METHODS

Study area

Singhiya River is situated in the Morang district of Eastern Nepal (Figure 1). It is a perennial river that originates from the periphery of Hattimuda, Dulary, and Sundar Haraicha and surges through the Budiganga Municipality and Biratnagar Sub-metropolitan, and from the Buddhanagar it crosses the border of India. It lies in the latitude and longitude coordinates of 26.913^{o} N & 87.157^{o} E, respectively. The water of this river is mainly used for irrigation. The vegetation bordering the river is mixed, mostly consisting of bamboo and coniferous forest and the dominant river substrata consist of cobbles, pebbles, gravel, and sand. In total, six sampling stations were set up to gather fish. Residents settled along the entire river in the catchment, and numerous small and large factories were established in stations 1, 2, 3, & 4 whereas, stations 6 & 7 were set up close to the city.

The Singhiya River region experiences mostly sunny weather, with occasional clouds, and the water is muddy due to increased anthropogenic activities near the area of human settlement but crystal clear in its origin parts. The study area for this research includes 22 km of river basin starting from Hattimuda to Buddhanagar of Morang District.

Data collection, Identification, and Preservation

From October 2020 to September 2021, fish samples were taken every month. Sample collection started on the 5th and continued to the 10th of the selected month, i.e., October, November, December (2020), January, February, March, April, May, June, July, August, and September (2021). We made 72 samples at six stations, namely, (S1) Hattimudha, (S2) Puspalal Chowk, (S3) near Hanuman Mandir, (S4) Hatkhola, (S5) Jahda Bridge, and (S6) Buddhanagar, with fish sampling carried out between 0070 h and 0090 h. We employed three cast nets of various sizes, one with a mesh size of 0.5 cm, diameter of 5 m, and a weight of 2 kg, and another with a mesh size of 2 cm, diameter of 5 m, and a weight of 4 kg. A cast net with a diameter of 4 cm, a length of 7 meters, and a weight of 7 kg was also utilized. Cast netting was used to cover 150 m to 200 m across each

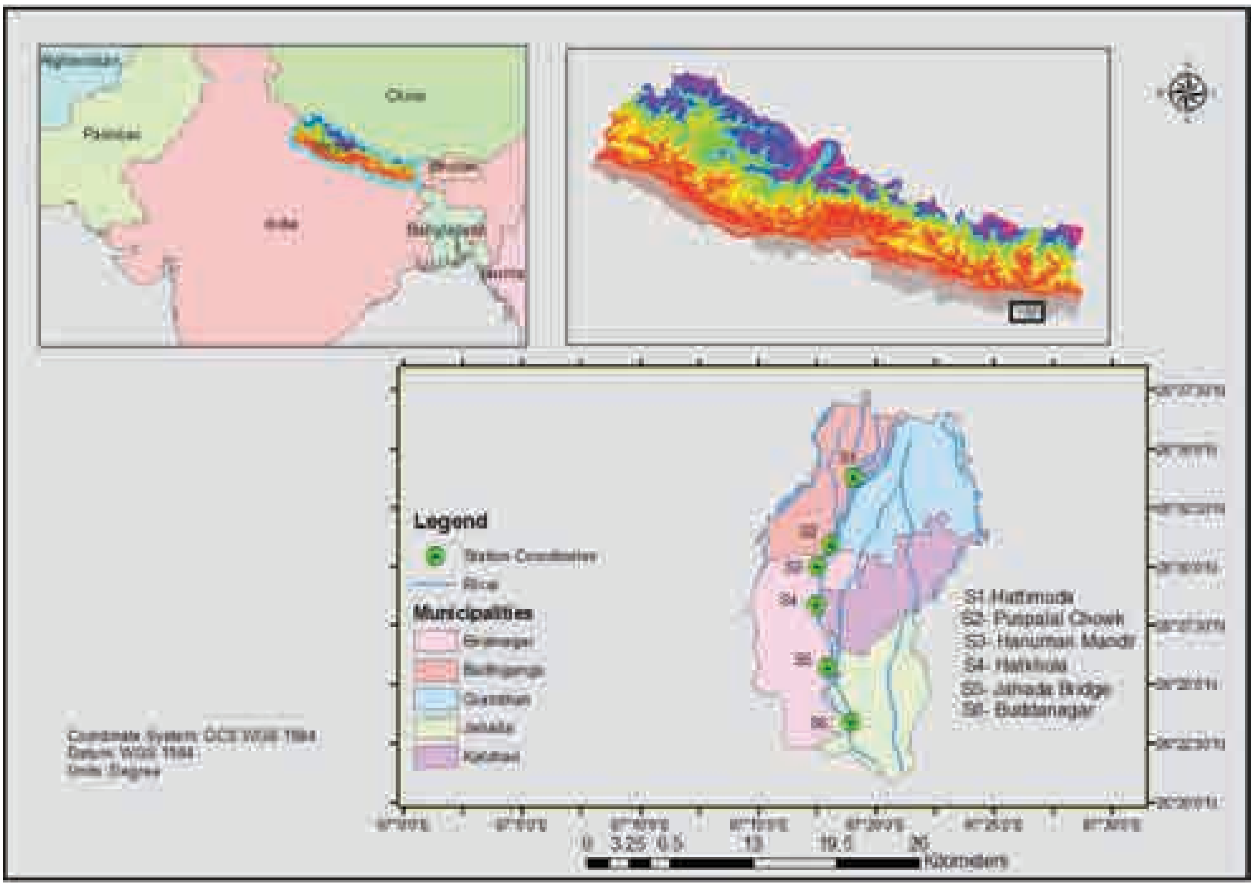

Figure 1. Map of study area showing sampling stations in Singhiya River, Nepal.

station, ensuring that all conceivable habitats were covered (Limbu et al. 2021b). For each cast net, a total of 10 throws were made over one hour. The fish were also caught using monofilament gill nets with mesh sizes of 6, 8, & 10 cm. Nine-gill nets were left late in the evening (1700h–1800 h) and pulled out early in the morning (0600h–0700 h) at a sample distance of 150–200 m at each station

Fish sampled were photographed and identified in the field, and unidentified specimens were preserved in 10% formalin for later identification. The remaining samples were released to their original habitat after the photography. Standard fish taxonomy literatures (Talwar & Jhingran 1991; Jayaram 2010; Shrestha 2019; Fricke et al. 2021) and other available standard literature were used to identify the fish. During field visits environmental variables such as water temperature, dissolved Oxygen (DO), pH, total hardness, water velocity, alkalinity, and free carbon dioxide (CO) were investigated using the American Public Health Association's standard methodology (APHA 2012). A digital thermometer was placed in the water at a depth of 1 foot to measure the water temperature (°C). The Winkler titrimetric method was used to determine DO (mg/l). A pH meter was used to determine the pH (HI 98107, HANNA Instrument). The EDTA titrimetric technique was used to evaluate total hardness (mg/l). With the help of a stopwatch, a small ball and a measuring tape, water velocity (m/s) was determined using the float method. The alkalinity (mg/l) was measured using the titration method. The titrimetric method was used to detect free carbon dioxide (mg/l) using phenolphthalein as an indicator.

Data analysis

To examine potential variation over space and time a one-way analysis of variance (ANOVA) was used for temperature, pH, dissolved oxygen, hardness, and water velocity. To determine which means were significantly different at the 0.05 level of probability, a posthoc Tukey HSD test was used (Spjøtvoll & Stoline 1973). In the first step of data processing, the diversity of the fish assemblage was quantified, and then a statistical comparison was performed. Data on fish abundance were subjected to various diversity indices (Shannon, Simpson dominance, evenness, and species richness). All of the diversity indices were created using data from

12 months (each month, six samples were taken, S1–S6) and the data were used directly in the analysis, according to Magurran (1988) for each fish community sample. The Shannon diversity index (Shannon & Weaver 1963) takes into account both the number of species and the distribution of individuals within species.

The Shannon diversity was calculated using the following formula:

$$H = \sum_{i=1}^{S} Pi * logPi \quad (1)$$

Where S is the total number of species and *Pi* is the relative proportion of i_{th} of species.

The Simpson index (Harper 1999) is a dominance index which gives more weight to common or dominant species.

The Simpson dominance index was calculated by using following formula:

$$D = \sum_i \left(\frac{ni}{n}\right)^2 \quad (2)$$

Where n_i is number of individuals of species *i*.

The Evenness index (Pieleu 1966) measures how evenly or uniformly the relative abundances Pi (i=1..,S) are distributed across the S different species, irrespective of the value of S and the Evenness index was determined by the following equation:

$$E = H'/\log S \quad (3)$$

Where, H' = Shannon diversity index

S = Total number of species in the sample.

In the multivariate analysis, rare species (<1%) were excluded in the analysis as they tend to affect multivariate analyses (Gauch 1982). Samples by species and environmental variables were analyzed through a multivariate analysis tool. Detrended correspondence analysis (DCA) (Hill & Gauch 1983) was performed to determine whether redundancy correspondence analysis (RDA) or canonical correspondence analysis (CCA) would be the most appropriate model to describe the association between species and environmental variables. The value of first axis length (3.14) and eigen value (0.53) obtained from DCA suggested that the uni-model associated with canonical correspondence analysis (CCA) (Ter Braak 1986) was more applicable. Therefore, a direct multivariate ordination method (Legendre & Legendre 1998) based on a linear response of species to environmental gradients was applied. Collected fish abundance and determined environmental variables were used directly in the multivariate analysis (Yan et al. 2010; Hossain et al. 2012; Vieira & Tejerina-Garro 2020; Tumbahangfe et al. 2021).

The one-way permutational multivariate analysis of variance (perMANOVA) (Clarke 1993) was used to determine whether there was a significant difference between the spatial and temporal scales of the collected fish data. A similarity percentage (SIMPER) (Clarke 1993) analysis was used to visualize the major contributing species in both space and time. Furthermore, Individual rarefaction analyses (Colwell et al. 2012), was performed across stations and months. All the statistical analysis were performed in R software (R Core Team 2019), 2.5-6 version.

RESULTS

Fish community structure

A total of 7,593 fish were collected, representing 61 species belonging to seven orders, 20 families, and 37 genera (Table 1). The three main orders that represented 84% of the total species count included Cypriniformes (32 species), Siluriformes (11 species), and Anabantiformes (8 species). Synbranchiformes and Perciformes each contained four species and the rest contributed less than 2% to the total species counts. At the family level, the Danionidae family included the most species (16), followed by Cyprinidae (11), Ambassidae (4), Bagridae (4), Channidae (4), Mastacembelidae (3), Cobitidae (2), Siluridae (2), Ailiidae (2), Anabantidae (2), Osphronemidae (2), Psilorhynchidae (1), Nemacheilidae (1), Botiidae (1), Sisoridae (1), Clariidae (1), Heteropneustidae (1), Synbranchidae (1), Mugilidae (1), and Gobiidae (1). The four most abundant species comprised 56% of the total catch, i.e., *Puntius chola* (27%), *Puntius sophore* (18%), *Pethia ticto* (6.3%), and *Barbonymus gonionotus* (5.3%). Considerable differences in fish abundance and diversity were observed among sampling stations and monthly samplings.

The highest number of fish was collected during October (1,707 specimens), followed by the months of November > December > February > January > September > April > March > August > June > July > May (Figure 2a). The highest fish diversity in the study area was calculated during October (42 species), followed by September (41 species), November (38 species), August (36 species), December, February, & April (34 species in each month), March & July (33 species each in each month), May (32 species), January (31 species), and June (29 species). The highest numbers of fish were collected at station (S6), followed by S5>S4>S3>S2>S1 (Figure 2b). According to similarity percentage (SIMPER) analysis (Table 2), 79% similarity was found between the stations, and the primary contributing species were: *Puntius chola* (28%), *Puntius sophore* (14%), *Pethia ticto* (5.3%), *Chagunius chagunio* (3.8%), *Barbonymus gonionotus* (3.7%), *Puntius terio* (3.5%), *Opsarius shacra* (2.2%), and

Table 1. Coding of the Singhiya River, Morang District, Nepal by order, family, and species.

Order / Family	Code	Species	IUCN status
Cypriniformes			
Cyprinidae	C1	*Chagunius chagunio* (Hamilton 1822)	LC
Cyprinidae	C2	*Cirrhinus mrigala* (Hamilton 1822)	LC
Cyprinidae	C3	*Cirrhinus reba* (Hamilton 1822)	LC
Cyprinidae	C4	*Labeo gonius* (Hamilton 1822)	LC
Cyprinidae	C5	*Tariqilabeo latius* (Hamilton 1822)	LC
Cyprinidae	C6	*Puntius chola* (Hamilton 1822)	LC
Cyprinidae	C7	*Puntius sophore* (Hamilton 1822)	LC
Cyprinidae	C8	*Puntius terio* (Hamilton 1822)	LC
Cyprinidae	C9	*Pethia ticto* (Hamilton 1822)	LC
Cyprinidae	C10	*Barbonymus gonionotus* (Bleeker 1849)	LC
Cyprinidae	C11	*Systomus sarana* (Hamilton 1822)	LC
Danionidae	C12	*Barilius barila* Hamilton 1822	LC
Danionidae	C13	*Opsarius bendelisis* Hamilton, 1822	LC
Danionidae	C14	*Opsarius shacra* Hamilton 1822	LC
Danionidae	C15	*Opsarius vagra* Day 1878	LC
Danionidae	C16	*Opsarius barna* Hamilton 1822	LC
Danionidae	C17	*Cabdio morar* (Hamilton 1822)	LC
Danionidae	C18	*Cabdio jaya* (Hamilton 1822)	LC
Danionidae	C19	*Danio rerio* (Hamilton 1822)	LC
Danionidae	C20	*Devario devario* (Hamilton 1822)	LC
Danionidae	C21	*Chela cachius* (Hamilton 1822)	LC
Danionidae	C22	*Esomus danrica* (Hamilton 1822)	LC
Danionidae	C23	*Amblypharyngodon mola* (Hamilton 1822)	LC
Danionidae	C24	*Rasbora daniconius* (Hamilton 1822)	LC
Danionidae	C25	*Bengala elanga* (Hamilton 1822)	LC
Danionidae	C26	*Salmostoma acinaces* (Valenciennes 1844)	LC
Danionidae	C27	*Salmostoma phulo* (Hamilton 1822)	LC
Psilorhynchidae	C28	*Psilorhynchus sucatio* (Hamilton 1822)	LC
Nemacheilidae	C29	*Paracanthocobitis botia* (Hamilton 1822)	LC
Cobitidae	C30	*Canthophrys gongota* (Hamilton 1822)	LC
Cobitidae	C31	*Lepidocephalichthys guntea* (Hamilton 1822)	LC
Botiidae	C32	*Botia lohachata* Chaudhuri 1912	NE
Siluriformes			
Bagridae	C33	*Mystus bleekeri* (Day 1877)	LC
Bagridae	C34	*Mystus cavasius* (Hamilton 1822)	LC
Bagridae	C35	*Mystus tengara* (Hamilton 1822)	LC
Bagridae	C36	*Mystus vittatus* (Bloch 1794)	LC
Siluridae	C37	*Ompok bimaculatus* (Bloch 1794)	NT
Siluridae	C38	*Wallago attu* (Bloch & Schneider 1801)	VU
Ailiidae	C39	*Ailia coila* (Hamilton 1822)	NT
Ailiidae	C40	*Clupisoma montanum* Hora 1937	LC
Sisoridae	C41	*Pseudolaguvia ribeiroi* (Hora 1921)	LC
Clariidae	C42	*Clarius magur* (Hamilton 1822)	EN
Heteropneustidae	C43	*Heteropneustes fossilis* (Bloch 1794)	LC
Synbranchiformes			
Synbranchidae	C44	*Ophichthys cuchia* (Hamilton 1822)	LC
Mastacembelidae	C45	*Macrognathus aral* (Bloch & Schneider 1801)	LC
Mastacembelidae	C46	*Macrognathus pancalus* Hamilton 1822	LC
Mastacembelidae	C47	*Mastacembelus armatus* (Lacepède 1800)	LC
Perciformes			
Ambassidae	C48	*Chanda nama* Hamilton 1822	LC
Ambassidae	C49	*Parambassis baculis* (Hamilton 1822)	LC
Ambassidae	C50	*Parambassis lala* (Hamilton 1822)	NT
Ambassidae	C51	*Parambassis ranga* (Hamilton 1822)	LC
Anabantiformes			
Anabantidae	C52	*Anabas cobojius* (Hamilton 1822)	DD
Anabantidae	C53	*Anabas testudineus* (Bloch 1792)	LC
Osphronemidae	C54	*Trichogaster fasciata* Bloch & Schneider 1801	LC
Osphronemidae	C55	*Trichogaster lalius* (Hamilton 1822)	LC
Channidae	C56	*Channa barca* (Hamilton 1822)	DD
Channidae	C57	*Channa gachua* Bloch & Schneider 1801	VU
Channidae	C58	*Channa striata* (Bloch 1793)	LC
Channidae	C59	*Channa punctata* (Bloch 1793)	LC
Mugiliformes			
Mugilidae	C60	*Minimugil cascasia* (Hamilton 1822)	LC
Gobiformes			
Gobiidae	C61	*Glossogobius giuris* (Hamilton 1822)	LC

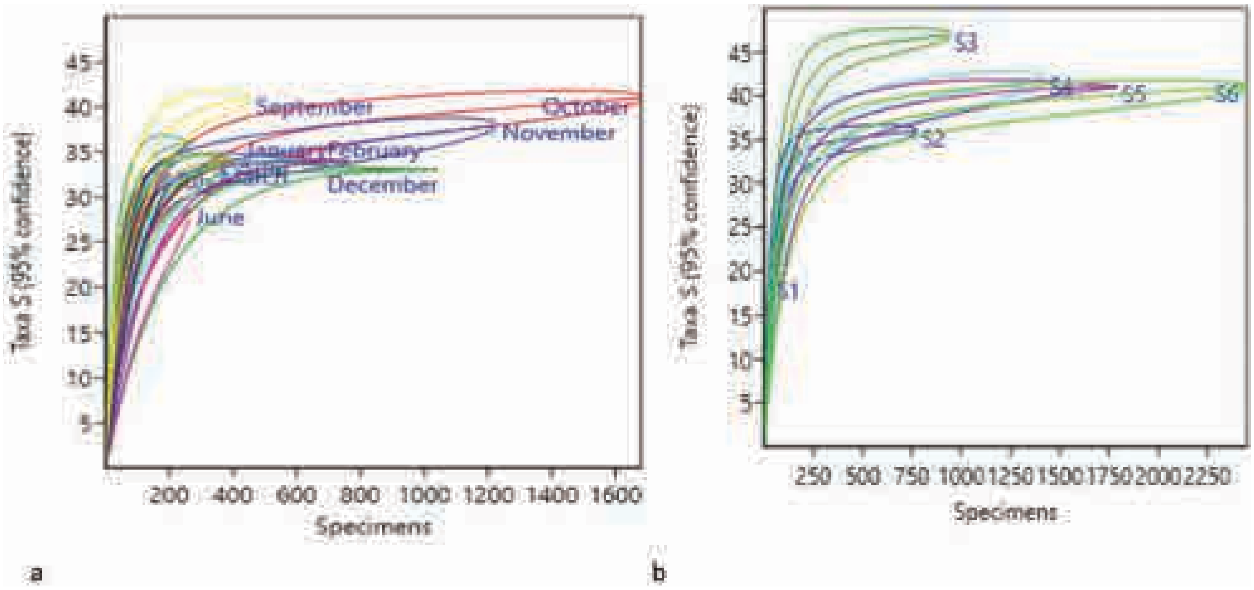

Figure 2. a—Individual rarefaction analysis plot based on months | b— Individual rarefaction analysis plot based on stations.

Table 2. Average similarity (%) and discriminating fish species in the Singhiya River, Morang District, Nepal, by month and station using SIMPER analysis.

Code	Species	Station Contribution (%)	Code	Species	Months Contributions (%)
C6	*Puntius chola*	28.2	C6	*Puntius chola*	26.58
C7	*Puntius sophore*	13.51	C7	*Puntius sophore*	13.78
C9	*Pethia ticto*	5.33	C9	*Pethia ticto*	5.7
C1	*Chagunius chagunio*	3.76	C10	*Barbonymus gonionotus*	3.81
C10	*Barbonymus gonionotus*	3.69	C8	*Puntius terio*	3.59
C8	*Puntius terio*	3.46	C1	*Chagunius chagunio*	3.51
C14	*Opsarius shacra*	2.2	C14	*Opsarius shacra*	2.24
C13	*Opsarius bendelisis*	2.1	C13	*Opsarius bendelisis*	2.15

Opsarius bendelisis (2.1%); 77.5% similarity was found between months, and the top contributing species were as listed above.

Diversity status

Tables 3 & 4 show the results of diversity indices. The highest Shannon diversity index (2.79) was found at station 2 (S2) and in the month of August (2.94) whereas the lowest (1.76) was found at station 1 (S1) and in June (1.51). Analysis of variance (ANOVA) testing for both time and space revealed a significant (P <0.05) difference across six stations, but no significant (P >0.05) difference for the Shannon diversity index over twelve months. The highest Simpson dominance index (0.91) was found at station 2 (S2) and in the month of August (0.93) while the lowest Simpson index value (0.67) was found at station 6 (S6) and in the month of June (0.61). There was no significant (P >0.05) difference in the Simpson dominance index across the six sampling points and months. Similarly, the highest Evenness index (0.59) was at stations 1 & 2 and the month of August (0.59) whereas the lowest value (0.44) was found at stations 5 & 6 respectively, and the month of June (0.42). There was also no significant (P >0.05) difference in the Evenness index between the six stations and months. On the other hand, the highest Species richness value was observed at station 6 (S6) and in the month of October (36) while the lowest value was found at station 1 (S1) and the month of June (21). The species richness index differed significantly (P <0.05) between the six sampling

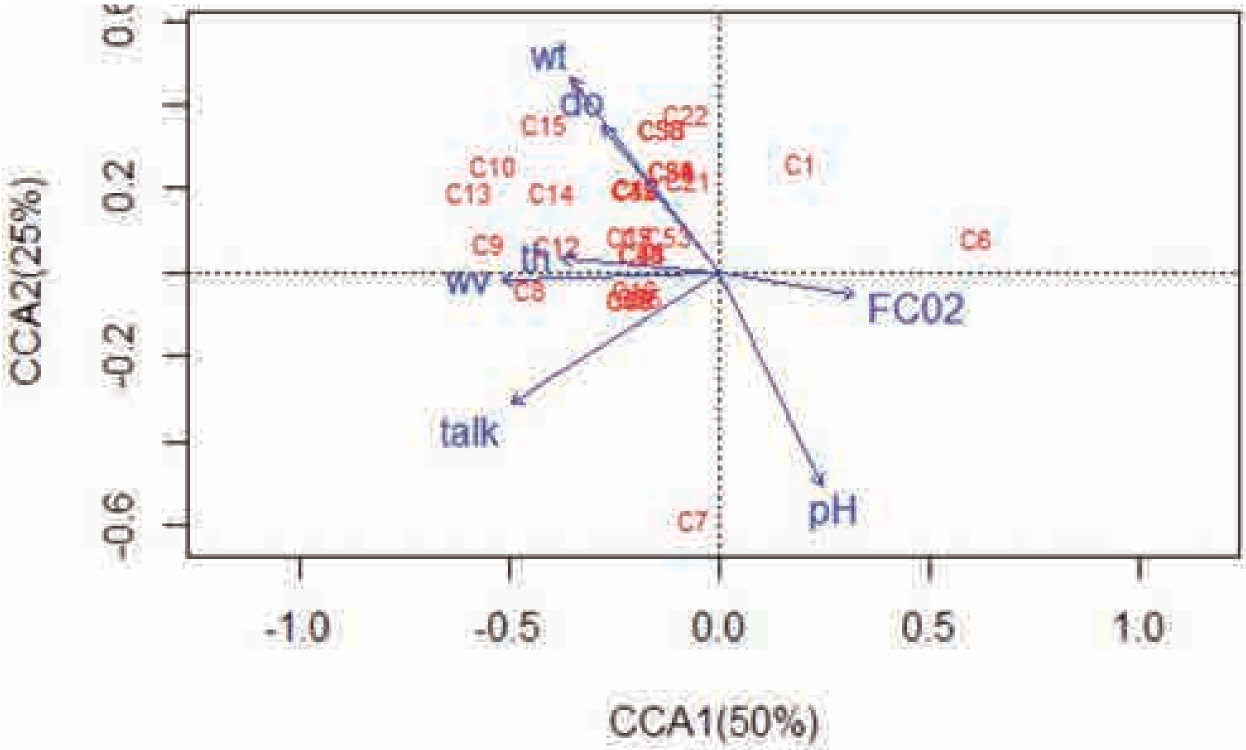

Figure 3. Canonical correspondence analysis ordination between fish community structure and environmental variables (for species code refer to table 1): talk—total alkalinity | do—dissolved oxygen | wv—water velocity | th—total hardness | wt—water temperature | FCO2—free carbon-dioxide.

Table 3. Diversity indices for the Singhiya River, Morang District, Nepal at six stations.

Stations	Shannon index	Simpson dominance index	Evenness index	Species richness
S1	1.76±0.7	0.9±0.14	0.59±0.93	18.44±3.88
S2	2.79±0.5	0.91±0.05	0.59±0.03	27±4.92
S3	2.37±0.64	0.8±0.14	0.51±0.09	31.4±4.77
S4	2.3±0.9	0.77±0.22	0.49±0.13	33.23±4.43
S5	1.87±0.8	0.68±0.2	0.44±0.12	34.51±4.07
S6	1.93±0.74	0.67±0.22	0.44±0.12	35.41±3.91

locations and months.

Environmental factors vs fish community structure

The results obtained after the canonical correspondence analysis are plotted in Figure 3. The first (CCA1) and second (CCA2) axis of the CCA accounted for 50% and 25%, respectively. The CCA biplot indicates the relationship between species and environmental variables. The fish species of *Puntius sophore* (C7), *Puntius terio* (C8), *Opsarius barna* (C16), *Salmostoma acinaces* (C26), and *Mystus tengara* (C35) are positively related to total alkalinity and water velocity but species of *Chagunius chagunio* (C1) and *Puntius chola* (C6) are negatively related to water velocity and total alkalinity. Fish species of *Pethia ticto* (C9), *Barbonymus gonionotus* (C10), *Barilius barila* (C12), *Opsarius bendelisis* (C13), *Opsarius shacra* (C14), *Opsarius vagra* (C15), *Cabdio morar* (C17), *Chela cachius* (C21), *Esomus danrica* (C22), *Mystus bleekeri* (C33), *Wallago attu* (C38), *Heteropneustes fossilis* (C43), and *Chanda nama* (C48) are positively related to water temperature, dissolved oxygen, and total hardness but negatively related to free carbon dioxide and pH. An analysis of variance (ANOVA) on canonical correspondence analysis suggested that water parameters of water velocity, water temperature, total alkalinity, pH and total hardness are the major

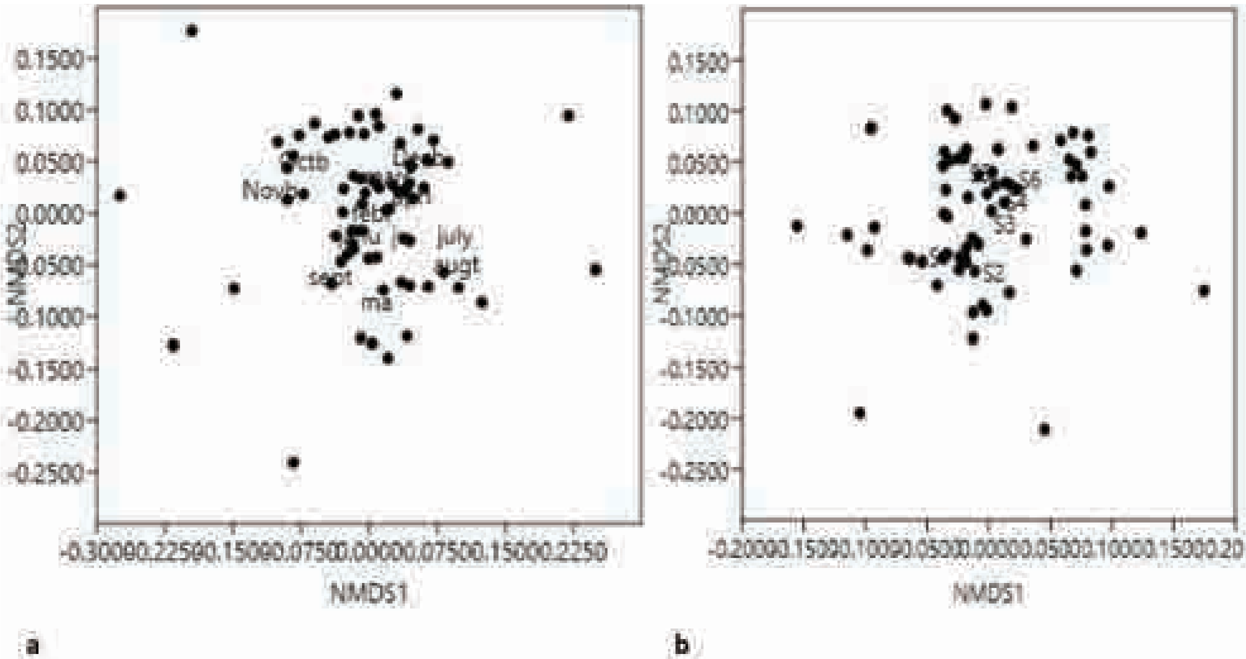

Figure 4. a—NMDS ordination of time variation of fish community structure in the Singhiya River | b—NMDS ordination of space variation fish community structure in the Singhiya River.

influencing factors (*P* <0.05) to determine the fish abundance and distribution.

In addition, one-way permutational multivariate analysis of variance (perMANOVA) on the Non-multidimensional Scaling (NMDS) showed no significant (*P* >0.05) difference between station 3, 4, 5, & 6, but station 1 & 2 showed significant (*P* <0.05) difference (Figure 4b). The fish community structure in October showed a significant (*P* <0.05) difference between January, February, March, April, May, June, July, August, & September but no significant (*P* >0.05) difference was found with November and December (Figure 4a).

DISCUSSION

This is the first study to describe the spatial and temporal fluctuation of fish community structure in a Nepalese low-land river. The outcomes of this study will improve our understanding of the variance in fish communities for the benefit of Nepalese low-land river conservation, which recorded a total of 7,593 individuals, represented by 61 species belonging to seven orders, 20 families, and 37 genera. This suggests that the Singhiya River provides a significant source of livelihood and food to local fisherman and communities. The representation of Cypriniformes, Siluriformes, and Anabantiformes orders found in this study is consistent with the information reported in the other river systems of Nepal such as the Mechi River (Adhikari et al. 2021), Ratuwa River (Rajbanshi et al. 2021), and Phewa Khola (Limbu et al. 2021b).

The present findings revealed that the maximum number and diversity of fish species were collected in October, September, and November. During June and July, water velocity was found to be low and the water temperature was found to be high in the current study. Because of the low water velocity, the fishermen could do the most of the fishes. River discharge and water temperature have a much greater impact on the amount and diversity of fish (Kriauciuniene et al. 2019). Overfishing, industrial discharges, and sand mining may have impacted the amount and diversity of fish in the Singhiya River. Furthermore, essential aquatic ecosystem measurements such as species richness and diversity indices are influenced by changes in abiotic parameters such as river discharge and water temperature (Crane & Kapuscinski 2018; Parker et al. 2018).

According to local fisherman, populations of *Cirrhinus mrigala, Cirrhinus reba, Labeo gonius, Systomus sarana, Danio rerio*, *Devario devario, Amblypharyngodon mola*, *Rasbora daniconius*, *Bengala elanga*, *Salmostoma acinaces*, *Salmostoma phulo*, *Psilorhynchus sucatio*, *Lepidocephalichthys guntea*, *Botia lohachata*, *Heteropneustes fossilis*, *Ophichthys cuchia*, *Macrognathus aral*, *Macrognathus pancalus*,

Table 4. Diversity indices for the Singhiya River, Morang District, Nepal over 12 months.

Months	Shannon index	Simpson dominance index	Evenness index	Species richness
Oct	2.33±0.27	0.84±0.03	0.52±0.01	35.97±7.61
Nov	2.34±0.9	0.82±0.14	0.51±0.09	32.98±5.89
Dec	1.9±0.79	0.75±0.16	0.49±0.11	30.35±5.59
Jan	2.26±0.84	0.83±0.15	0.54±0.1	30.48±6.58
Feb	2.08±1.19	0.71±0.32	0.46±0.21	30.42±5.53
Mar	1.99±0.68	0.74±0.2	0.48±0.13	27.94±6.44
Apr	2.12±0.93	0.72±0.27	0.47±0.17	30.17±5.45
May	2.38±0.53	0.84±0.12	0.56±0.08	26.31±6.04
Jun	1.51±0.91	0.61±0.29	0.42±0.2	20.66±7.31
Jul	1.91±0.48	0.72±0.15	0.47±0.1	26.26±7.13
Aug	2.94±0.59	0.93±0.05	0.59±0.03	33.01±6.65
Sep	2.91±0.2	0.91±0.04	0.56±0.03	34.92±6.98

Mastacembelus armatus, *Trichogaster fasciata*, *Trichogaster lalius*, *Channa barca*, *Channa orientalis*, *Channa striata*, *Minimugil cascasia*, and *Glossogobius giuris* have significantly reduced, with less than five individuals recorded for each over the 12-month study period. Many studies have suggested that ongoing road development, river corridor engineering, dams and water diversion, aquatic habitat loss and fragmentation, deforestation, riparian loss, overfishing, climate change, and direct discharge of industrial waste into water resources are the primary causes of Nepalese fish population reduction (Limbu et al. 2021a,b; Tumbahangfe et al. 2021). River output appears to be influenced by water level variations caused by climate change and water management, as well as fishing pressure (Halls 2015). Monitoring the impact of fishing pressure on the Singhiya River's exploited fish population is critical for resource development and sustainability. The present situation in the Singhiya River is still sounding the alarm and causing critical concern among the public. As the biodiversity of freshwater fish keeps on decreasing mainly due to anthropogenic impacts, it is apparent that there has been a serious lack of scientific basis and truly ecological action for sound river basin management (Li et al. 2012). The populations of *Labeo catla, Bagarius* spp., *Chitala chitala, Sisor* spp., and *Notopterus notopterus* have declined significantly and are not represented in the present study. Only *Cirrhinus* spp., *Channa* spp., *Labeo* spp., *Ophichthys cuchia, Heteropneustes fossilis, Macrognathus* spp., *Mastacembelus armatus, Clarius magur, Opsarius bendelisis, Chagunius chagunio,* and *Salmostoma* spp. are highly preferred fish species by the local community in the Singhiya River basin.

The Shannon diversity index takes into account the richness and proportion of each species, while the evenness and dominance indices reflect the relative number of individuals and the proportion of common species, respectively (Hossain et al. 2012; Yang et al. 2021). The highest Shannon diversity index (2.79) was identified at station 2 and in August (2.94), while the lowest (1.76) was discovered at station 1 and in June (1.51). A high Shannon diversity index is linked to a small number of individuals, whereas a low Simpson's diversity index is linked to a large number of individuals (Hossain et al. 2012; Temesgen et al. 2021). A biodiversity index seeks to categorize a sample's diversity (Magurran 1988) and is easily influenced by the number of specimens, sample size, and environmental factors (Leonard et al. 2006). The highest Simpson dominance index (0.91) was found at station 2 and the month of August (0.93), while the lowest Simpson index value (0.67) was obtained at station 6 and the month of June (0.61). Similarly, the highest evenness index (0.59) was observed at stations 1 and 2 and in August (0.59), while the lowest value (0.44) was recorded at stations 5 and 6 and in June (0.42). The maximum species richness (35.31) value was found at station 6 and the months of October (35.97), while the lowest (18.44) value was recorded at station 1 and the month of June (20.66). The species richness index varies considerably (P <0.05) between the six sampling locations and months. Overall, stations 2, 3, 4, 5, & 6 and the months of October, January, February, May, August, & September were likely to be rich with richness and diversity, because these sections were deeper and larger in terms of water depth and surface cover than station 1 section within the system. The river width and depth may be important for resting and hiding (Li et al. 2012) and for variable habitats for lotic water inhabiting fish such as *Cirrhinus* spp., *Mystus* spp., *Ailia coila*, *Ompok bimaculatus*, & *Wallago attu*

The information on the interaction between environmental variables and fish community structure can assist us in maintaining and managing aquatic biodiversity in the face of human-caused problems such as pollution, global climate change, and so on (Li et al. 2012). The influence of environmental variables on fish abundance, diversity, and distribution was checked by canonical correspondence analysis. In the current study, water velocity, water temperature, total alkalinity, pH, and total hardness are the major influencing factors (P <0.05) to determine the fish diversity, abundance, and distribution of the Singhiya River. Water velocity (Yu & Lee 2002; Yan et al. 2010; Adhikari et al. 2021), water temperature (Kadye et al. 2008; Temesgen et al. 2021), total alkalinity (Edds 1993; Pokharel et al. 2018), pH (Pokharel et al. 2018; Limbu et al. 2021b; Rajbanshi et al. 2021), and total hardness (Rajbanshi et al. 2021; Shrestha et al. 2021) have also been found to be influencing factors to shape the fish assemblage structure.

CONCLUSION

The Singhiya River exhibits a good ichthyofaunal diversity, represented by 61 species of fish belonging to seven orders, 20 families, and 37 genera. Of 61 species, *Puntius chola*, *Puntius sophore*, *Pethia ticto*, and *Barbonymus gonionotus* were the dominant fish species recorded in Singhiya River. However, commercially important species such as *Labeo catla, Bagarius* spp., *Chitala chitala, Sisor* spp., and *Notopterus notopterus* were not recorded during the study period. Thus, conservation of these species has become urgent in Singhiya River. Overfishing and direct discharge of industrial waste into water resources may be the primary causes for the decline in fish diversity in Singhiya River. Therefore, practices like dumping of industrial waste, overfishing, and sand mining should be minimized, monitored, and if required, prohibited to protect the Singhiya River's aquatic flora and fauna and natural ecology. The canonical correspondence analysis suggested that an important environmental variables in structuring the fish community in the Singhiya River were water velocity, temperature, pH, and hardness. Lastly, the current study, in conjunction with the preceding examination, could serve as a baseline scenario for future analysis of the Singhiya River and other connected water bodies in the coming decades.

REFERENCES

Adhikari, A., J.H. Limbu, & S. Pathak (2021). Fish diversity and water quality parameters of Mechi River, Jhapa, Province No. 1, Nepal. *Borneo Journal of Resources Science and Technology* 10(2): 24–34. https://doi.org/10.33736/bjrst.2954.2021

APHA (2012). Standard Methods for Examination of Water and Waste water. 22nd Edition. American Public Health Association, Washington DC, USA, 1220 pp.

Chowdhury, M.S.N., M. S. Hossain, N.G. Das & P. Barua (2011). Environmental variables and fisheries diversity of the Naaf River Estuary, Bangladesh. *Journal of Coastal Conservation* 15(1): 163–180. https://doi.org/10.1007/s11852-010-0130-3

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117–143. https://doi.org/10.1111/j.1442-9993.1993.tb00438.x

Colwell, K.K., A. Chao, N.J. Gotelli, S.L. Lin, C.X. Mao, R.L. Chazdon & J.T. Longino (2012). Models and estimators linking individual-based and samples-based rarefaction, extrapolation and comparison of assembales. *Journal of Plant Ecology* 5: 3–21.

Crane, D.P. & K.L. Kapuscinski (2018). Capture efficiency of a fine mesh seine in a large river: implications for abundance, richness, and diversity analyses. *Fisheries Research* 205: 149–157. https://doi.org/10.1016/j.fishres.2018.04.018

Edds, D.R. (1993). Fish assemblage structure and environmental correlates in Nepal's Gandaki River. *Copeia* 1993(1): 48–60. https://doi.org/10.2307/1446294

Fricke, R., W.N. Eschmeyer & R. Van der Laan (2021). Eschmeyer's catalog of fishes: genera, species, references: Electronic version. Accessed on 08 Aug 2019. http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp

Gauch, H. (1982). *Multivariate Analysis in Community Ecology*. Cambridge University Press, x+298pp. https://doi.org/10.1017/CBO9780511623332

Guo, Q., X. Liu, X. Ao, J. Qin, X. Wu & S. Ouyang (2018). Fish diversity in the middle and lower reaches of the Ganjiang river of China: Threats and conservation. *PLoS ONE* 13(11): e0205116. https://doi.org/10.1371/journal.pone.0205116

Halls, A. (2015). Lake Nasser Fisheries: recommendations for management, including monitoring and stock assessment Program Report. WorldFish, Penang, Malaysia, 51 pp.

Harvey, B.C. & A.J. Stewart (1991). Fish size and habitat depth relationship in headwater streams. *Oecologia* 87: 336–342. https://doi.org/10.1007/BF00634588

Hill, M.O. & H.G. Gauch (1980). Detrended correspondence analysis: an improved ordination technique. *Vegetatio* 42: 47–58. https://doi.org/10.1007/BF00048870

Hossain, M.S., N.G. Das, S. Sarker & M.Z. Rahaman (2012). Fish diversity and habitat relationship with environmental variables at Meghna River estuary, Bangladesh. *The Egyptian Journal of Aquatic Research* 38: 213–226. https://doi.org/10.1016/j.ejar.2012.12.006

Huang, L. & J. Li (2016). Status of freshwater fish biodiversity in the Yangtze River Basin, China, pp. 13–30. In: Nakano S., T. Yahara & T. Nakashizuka (eds.). *Aquatic Biodiversity Conservation and Ecosystem Services*. Ecological Research Monographs. Springer, Singapore, 135 pp. https://doi.org/10.1007/978-981-10-0780-4_2

Jayaram, K.C. (2010). *The Freshwater Fishes of Indian Region*. Narendra Publishing House, Delhi, India, 614 pp.

Kadye, W.T., C.H.D. Magadza, N.A.G. Moyo & S. Kativu (2008). Stream fish assemblages in relation to environmental factors on a montane plateau. *Environmental Biology of Fishes* 83: 417–428. https://doi.org/10.1007/s10641-008-9364-4

**Kriauciuniene, J., T. Virbickas, D. Sarauskiene, D. Jakimavičius, J. Kažys, A. Bukantis, V. Kesminas, A. Povilaitis, J. Dainys, V. Akstinas, A. Jurgelėnaitė, D. Meilutytė-Lukauskienė & A. Tomkevičienė

(2019). Fish assemblages under climate change in Lithuanian rivers. *Science of the Total Environment* 661: 563–574.

Legendre, P. & L. Legendre (1998). *Numerical Ecology*, Second Edition. Elsevier, Amsterdam, Netherlands, 853 pp.

Leonard, D.R., K.R. Clarke, P.J. Somerfield & R.M. Warwick (2006). The application of an indicator based on taxonomic distinctness for UK marine biodiversity assessments. *Journal of Environmental Management* 78(1): 52–62. https://doi.org/10.1016/j.jenvman.2005.04.008

Li, J.H., L.L. Huang, L.M. Zou, Y. Kano, T. Sato & T. Yahara (2012). Spatial and temporal variation of fish assemblages and their associations to habitat variables in a mountain stream of north Tiaoxi River, China. *Environmental Biology of Fishes* 93: 403–417.

Limbu, J.H., B. Bhurtel, A. Adhikari, G.C. Punam, M. Maharjan & S. Sunuwar (2020). Fish community structure and environmental correlates in Nepal's Andhi Khola. *Borneo Journal of Resources Science and Technology* 10(2): 85–92. https://doi.org/10.33736/bjrst.2510.2020

Limbu, J.H., J.K. Gurung, S. Subba, N. Khadka, A. Adhikari, & C.B. Baniya (2021a). An Impact Assessment of Betani irrigation dam on fish diversity of Damak municipality, Jhapa, Nepal. *Egyptian Journal of Aquatic Biology and Fisheries* 25(2): 163–175. https://doi.org/10.21608/ejabf.2021.161363

Limbu, J.H., S. Subba, J.K. Gurung, J. Tumbahangfe & B.R. Subba (2021b). Correlation of fish assemblages with habitat and environmental variables in the Phewa Khola stream of Mangsebung rural municipality, Ilam, Nepal. *Journal of Animal Diversity* 3(1): 27–36. https://doi.org/10.52547/JAD.2021.3.1.5

Magurran, A.E. (1988). *Ecological Diversity and its Measurement*. Princeton University Press, Princeton, 179 pp.

Mia, M.J., J. Naher, M.G. Azom, M.S.R. Sabuz, M.H. Islam & M.R. Islam (2019). Spatiotemporal variations in finfish assemblage and diversity indices in relation to ecological indicators of the Atrai River, Dinajpur, Bangladesh. *Egyptian Journal of Aquatic Research* 45: 175–182. https://doi.org/10.1016/j.ejar.2019.06.001

Mishra, A.R. & C.B. Baniya (2016). Ichthyofaunal diversity and physico-chemical factors of Melamchi River, Sind-upalchok, Nepal. *Journal of Institute of Science and Technology* 21(1): 10–18. https://doi.org/10.3126/jist.v21i1.16031

Nsor, C.C. & E.A. Obodai (2016). Environmental determinants influencing fish community structure and diversity in two distinct seasons among wetlands of Northern region (Ghana). *International Journal of Ecology* 2016: 1–10. https://doi.org/10.1155/2016/1598701

Pokharel, K.K., B.B. Khadga, C.M. Trilok & C.B. Chitra (2018). Correlations between fish assemblage structure and environmental variables of the Seti Gandaki River Basin. Nepal. *Journal of Freshwater Ecology* 33(1): 31–43. https://doi.org/10.1080/02705060.2017.1399170

R Core Team (2019). R: Alinguage and environment for statistical computing. R foundation for statistical computing, Vienna, Austria. https:/www.R-project.org/

Radinger, J., J. Britton, J.R. Carlson, S.M. Magurran, A.E. Alcaraz-Hernández, J.D. Almodóvar, A. Benejam, L. Fernández-Delgado, C. Nicola, G.G. Oliva-Paterna, F.J. Torralva & E. García- Berthou (2019). Effective monitoring of freshwater fish. *Fish and Fisheries* 20(4): 729–747. https://doi.org/10.1111/faf.12373

Rajbanshi, D., J.H. Limbu, N. Khadka, P. Kumar, J.K. Gurung, & D.K. Limbu (2021). Fish community structure along an altitudinal gradient with relation to environmental variables in Ratuwa River of eastern Nepal. *Our Nature* 19(1): 70–81. https://doi.org/10.3126/on.v19i1.41217

Shannon, C.E. & W. Weaver (1963). *The Mathematical Theory of Communication*. The University of Illinois Press, Urbana, pp. 1–117.

Shrestha, S., J.H. Limbu, D. Rajbanshi, & D.K. Limbu (2021). Relationships between environmental conditions and fish assemblages in the Lohore River of Dailekh, Western Nepal. *Our Nature* 19(1): 18–26. https://doi.org/10.3126/on.v19i1.41265

Shrestha, T.K. (2019). *Ichthyology of Nepal, a study of fishes of the Himalayan waters*. Prism Color Scanning and Press Supportive Pvt. Ltd, Kathmandu, Nepal, 400 pp.

Spjøtvoll, E. & M.R. Stoline (1973). An extension of the T-Method of multiple comparison to include the cases with unequal sample sizes. *Journal of the American Statistical Association* 68(344): 975–978. https://doi.org/10.1080/01621459.1973.10481458

Talwar, P.K. & A.G. Jhingran (1991). *Inland Fisheries of India and Adjacent Countries.* Volume I and II. Oxford and IBH Publishing Co. India, 1158 pp.

Temesgen, B., Z. Tadesse & M. Temesgen (2021). Diversity, distribution and abundance of fish species in upper Awash River Basin, West Showa Zone, Ethiopia. *Cogent Food and Agriculture* 7(1): 1–13. https://doi.org/10.1080/23311932.2021.1974181

Ter Braak, C.F. (1986). Canonical correspondence analysis: A review eigenvector technique for multivariate direct gradient analysis. *Ecology* 67: 1167–1179.

Tumbahangfe, J., J.H. Limbu, A. Prasad, B.R. Subba & D.K. Limbu (2021). Ichthyofaunal diversity with relation to environmental variables in the snow-fed Tamor River of eastern Nepal. *Journal of Threatened Taxa* 13(14): 20190–20200. https://doi.org/10.11609/jott.7554.13.14.20190-20200

Vieira, T.B. & F.L. Tejerina-Garro (2020). Relationships between environmental conditions and fish assemblages in Tropical Savanna Headwater streams. *Scientific Reports* 10(1): 1–13. https://doi.org/10.1038/s41598-020-59207-9

Vlach, P., J. Dusek, M. Svatora & P. Moravec (2005). Fish assemblage structure, habitat and microhabitat preference of five species in a small stream. *Folia Zoologica* 54: 421–431.

Yan, Y., H.E. Shan, C.H.U. Ling, X. Xiuying, J.I.A. Yanju, T.A.O. Juan & C. Yifeng (2010). Spatial and temporal variation of fish assemblages in a subtropical small stream of the Huangshan Mountain. *Current Zoology* 56(6): 670–677. https://doi.org/10.1093/czoolo/56.6.670

Yu, S.L. & T.W. Lee (2002). Habitat preference of the stream fish, *Sinogastromyzon puliensis*. *Zoological Studies* 41: 183–187.

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COMMUNICATION

Three new records of odonates (Insecta: Odonata) from Sindhudurg District, Maharashtra, India

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Abstract: Genus *Indolestes* Fraser, 1922 and *Dysphaea* Selys, 1853 were previously known from Goa, Kerala, Karnataka, Tamil Nadu, parts of Gujarat, and eastern India. In this paper, we report the first confirmed records of *Indolestes gracilis davenporti* Fraser, 1930 and *Dysphaea ethela* Fraser, 1924 based on a specimen collected from Sindhudurg District, Maharashtra, India. We have also provided additional records of *Macrodiplax cora* (Brauer, 1867) from Maharashtra based on photographic evidence from Sindhudurg District.

Keywords: Damselfly, *Dysphaea*, Euphaeidae, *Indolestes*, Lestidae *Macrodiplax,* Western Ghats.

Marathi Abstract: *Indolestes*, Fraser, 1922 and *Dysphaea* Selys, 1853 या टाचणीच्या दोन जाती आधी गोवा, केरळ, कर्नाटक, तमीळनाडू, गुजरात राज्याचा काही भाग आणि ईशान्य भारत येथुन ज्ञात होत्या. आम्ही या पेपरमध्ये महाराष्ट्र राज्यातुन *Indolestes gracilis davenporti* Fraser, 1930 या उपप्रजातीची आणि *Dysphaea ethela* Fraser, 1924 या प्रजातीची सिंधुदूर्ग जिल्ह्यातुन गोळ्या करण्यात आलेल्या नमुन्यांच्या आधारे निश्चित नोंद करत आहोत. तसेच *Macrodiplax cora* (Brauer, 1867) या प्रजातीच्या सिंधुदुर्ग जिल्ह्यातुन घेतलेल्या छायाचित्रांच्या आधारावर महाराष्ट्रातील अतिरिक्त नोंदी देत आहोत.

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Author contributions: AD wrote the manuscript and collected data in the field by surveying odonates at three different locations. YK photographed *Macrodiplax cora* from one of the localities. RT assisted AD during the collection of *Dysphaea ethela* and helped in collecting the data during field work.

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INTRODUCTION

The Sindhudurg District of Maharashtra is well-known for numerous new discoveries of faunal species as a result of extensive surveys carried out by researchers across the country (Biju & Bossuyt 2009; Mirza et al. 2014; Padhye 2014; Gower et al. 2016; Pati et al. 2016; Sayyed et al. 2016; Joshi & Sawant 2019, 2020; Praveenraj & Thackeray 2020; Sulakhe et al. 2020; Sayyed & Sulakhe 2020; Bhosale et al. 2021; Joshi et al. 2022). The district harbours mixed types of vegetation including moist deciduous, dry deciduous, and semi-evergreen forests (Kulkarni 1988; Sawant et al. 2023). It also has a diverse range of habitats, including grassland, open lateritic plateaus, wetlands, mangroves, and freshwater swamps (Satose et al. 2018; Sreedharan & Indulkar 2018). Recent documentation of Odonata diversity of the Sindhudurg District resulted in more than 90 species of odonates documented from Amboli & Chaukul village, recognised as one of the most biodiverse regions of Maharashtra State (Tiple & Koparde 2015; Sawant et al. 2022, 2023). Ten out of them resulted in the new records to the state of Maharashtra. Koli & Dalvi (2021), Koli et al. (2021), and Dalvi & Koli (2022) reported a total of five Odonata species from Sindhudurg District, all of which are first confirmatory records to the state of Maharashtra. In this paper, we report three new records of odonates from Maharashtra, India, and their distribution maps are provided.

MATERIAL AND METHODS

We surveyed Amboli-Chaukul and Dodamarg region of Sindhudurg District, Maharashtra from May 2022 to December 2022. One of the records is based on previous surveys conducted outside of this study area in the year 2020. The details including study localities are provided in Table 1. Specimens were photographed and collected from non-protected areas for identification purpose. All the specimens are deposited at the Zoological Survey of India (ZSI), Pune, Maharashtra, India (Table 1). All field photographs were taken with Canon 760D DSLR camera 100 mm F/2.8 macro lens & Nikon D5300 70–300 mm f/4.5–6.3G. Specimens were Identified with the help of Fraser (1933, 1934, 1936) Kosterin (2015), and Subramanian et al. (2018).

Abbreviations used in the text: S1–S10 = abdominal segments 1–10.

Morphological terms are referring to Garrison et al. (2010). Distribution maps are based on the data given by Subramanian et al. (2018) and Anonymous (2023a,b,c). Maps are created using QGIS v3.10.2.

RESULTS AND DISCUSSION

1. *Indolestes gracilis davenporti* Fraser, 1930

Akshay Dalvi & Yogesh Koli first observed *I. gracilis davenporti* at Bordhangarwadi stream (15.86528N, 74.09833E) on 15th May 2022 (Table 1, Image 4b). One male specimen was found perching on a tree branch at about two feet above the ground. Despite multiple visits to the same locality, only one male specimen was observed at this site. It is a medium sized damselfly, brown in its immature form and turns pale blue later. Male can be identified with two triangular spots on posterior lobe of prothorax, pterothorax with brownish black antihumeral stripes, wavy in its lower side, S9 is black whereas S10 is completely blue (Image 1a, b). In dorsal view, cerci are slightly rounded in shape, directed inwards and meet at the apices with protruding end, twice as long as S10 with robust spines on its outer border (Image 1c). Paraprocts short, broader at the base with blunt apices. Genus *Indolestes* Fraser, 1922 globally includes 36 species (Paulson et al. 2022). *I. indicus* Fraser, 1922, *I. assamicus* Fraser, 1930, and *I. cyaneus* (Selys, 1862) are endemic to India, found in northern Eastern Ghats. *I. gracilis* (Hagen in Selys, 1862) consists of two subspecies, mainly *I. gracilis gracilis* (Hagen in Selys, 1862) which is endemic to Sri Lanka whereas *I. gracilis davenporti* along with *I. pulcherrimus* Fraser, 1924 are endemic to the Western Ghats (Subramanian et al. 2018; Kalkman et al. 2020; Anonymous 2023a). Previous records of *I. gracilis davenporti* are confined to Kerala, Karnataka, and Tamil Nadu states (Image 5b). Here we report first confirmed

Table 1. Details of survey locations and deposition codes.

	Species Name	Location	Latitude & Longitude	Specimen deposited at ZSI, Pune	Altitude (in meter)
01	*Indolestes gracilis davenporti* (male)	Kegad (Bordhangarwadi)	15.8652N & 74.0983E	ZSI, WRC, Ent. 4/2990	784
02	*Dyspha ethela* (male)	Bambarde	15.9191N & 74.1213E	ZSI, WRC, Ent. 4/2991	89

record of this species to Maharashtra, India (Image 5a,b).

2. *Dysphaea ethela* Fraser, 1924

Akshay Dalvi first observed and photographed this species at Bambarde (15.91917 N, 74.12139 E) on 22 May 2022 (Table 1, Image 2). Two male specimens were observed along the side of a hill stream perching on a small shrub *Homonia repira*, locally known as 'Sherni' (Image 4a). *Dysphaea ethela* is the only species of the genus found in the Western Ghats Biodiversity Hotspot, which can be easily identified by its entire black colouration, transparent wings, and yellow stripes on the body (Image 2a). Cerci are deeply concave inside, widely separated at base, apices flattened inside and meet to an end; paraprocts very short, not visible dorsally (Image 2b,c). The genus *Dysphaea* Selys, 1853, constitutes a total of nine species distributed in Asia. Out of these, *D. gloriosa* Fraser, 1938 and *D. walli* Fraser, 1927 are found in northeastern and eastern India respectively whereas *D. ethela* is a widely spread species found in the Eastern and Western Ghats as well as in central India (Subramanian 2014; Subramanian & Babu 2017). However, Kalkman (2020) excluded *D. walli* from Indian Odonata checklist because current records are only based on photographic evidence and there are no voucher specimens available to confirm its validity. Within Western Ghats, *Dysphaea ethela* were earlier recorded from Goa, Kerala, Karnataka, Tamil Nadu, parts of Gujarat state (Anonymous 2023b) (Image 5c). Here we provide first confirmed record of this species to Maharashtra State, India (Image 5a,c).

3. *Macrodiplax cora* (Brauer, 1867)

Akshay Dalvi first observed and photographed female of this species on Chipi plateau (15.999533N, 73.526062E) on 5 January 2020 (Image 3b). Successively, Yogesh Koli observed and photographed male specimen perching on a wooden stick particularly in an obelisk position near Oros budruk dam (16.127627N, 73.72221E)

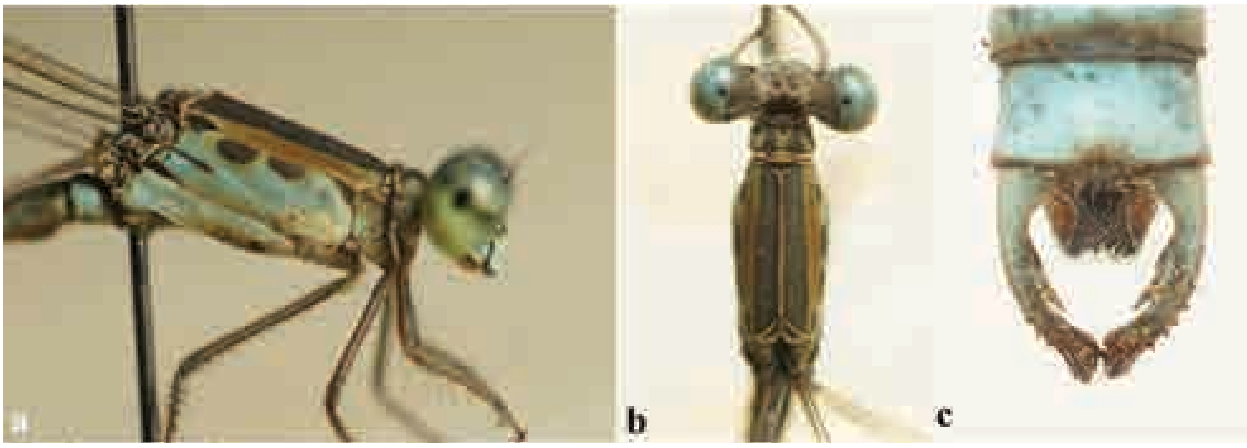

Image 1. *Indolestes gracilis davenporti* Fraser, 1930, male: a—thorax, lateral view | b—thorax, dorsal view | c—caudal appendages, dorsal view. © Yogesh Koli.

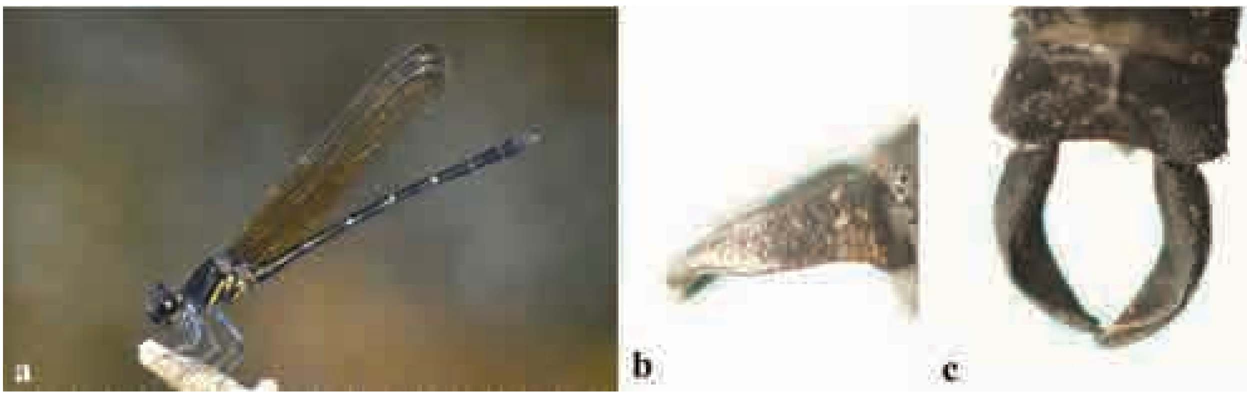

Image 2. *Dysphaea ethela* Fraser, 1924, male: a—habitus, lateral view | b—caudal appendages, lateral view | c—caudal appendages, dorsal view. © a—Akshay Dalvi | b, c— Yogesh Koli

Image 3. *Macrodiplax cora* (Brauer, 1867), male: a—habitus | b—female, habitus. © a—Yogesh Koli | b—Akshay Dalvi.

on 30 February 2020 (Image 3a). It is a red coloured dragonfly (Golden yellow in its immature stage) and can be easily identified by dumbbell shaped markings on dorsal side of S1–S10. Genus *Macrodiplax* Brauer, 1868 constitutes only one species within Indian limits. Within India, this species has been reported from Kerala, Odisha, Tamil Nadu, and West Bengal (Subramanian et al. 2018) (Image 5d). Sawant et al. (2022) added *M. cora* into the checklist of Maharashtra based on photographic evidence available at 'Odonata of India' (Joshi et al. 2017). Here we provide some additional records of this species to the Maharashtra State based on photographic evidence from Oros dam and Chipi plateau, Sindhudurg District (Image 5a).

This paper fills the gap of the disjunct distribution of the genus *Dysphaea* into the northern and central Western Ghats. Sawant et al. (2022) provided an annotated checklist of 93 Odonata species from Amboli-Chaukul and Parpoli region with the addition of total six species to the state of Maharashtra. In that, apart from these six species, Dattaprasad Sawant has mentioned the record of *D. ethela* from Hadpid, Devgad Taluka based on his personal observations (Image 5a). Here we provide the first confirmed record of this species to the state of Maharashtra based on a specimen collected from Bambarde Village. Hence the updated Odonata checklist of Maharashtra has 153 species from 13 families.

Perennial mountain streams originating in the Chandigarh Taluka, Kolhapur District, flows through the Bambarde Village, Dodamarg Taluka, Sindhudurg District and meets Tilari River later. All these are potential breeding places for the *D. ethela*. Habitat of *I. gracilis davenporti* is a small seasonal mountain stream which almost dries up after the monsoon. Both of these areas are quite inaccessible to some extent but can be surveyed extensively in future to document the species diversity in these regions. However, increasing pressure of human activities and habitat loss are already affecting the species diversity in Amboli-Dodamarg region. Hence, constant awareness among local people, and scientific studies are needed in order to formulate conservation plans in the near future.

REFERENCES

Anonymous (2023a). *Indolestes gracilis* Hagen in Selys, 1862 — Mountain Reedling. In: Joshi, S., P. Dawn, P. Roy, & K. Kunte (eds.). *Odonata of India, v. 1.57*. Indian Foundation for Butterflies. Accessed on 05 April 2023. http://www.indianodonata.org/sp/204/Indolestes-gracilis

Anonymous (2023b). *Dysphaea ethela* Fraser, 1924 — Black Torrent Dart. In: Joshi, S., P. Dawn, P. Roy& K. Kunte (eds.). *Odonata of India, v. 1.57*. Indian Foundation for Butterflies. Accessed on 05 April 2023. http://www.indianodonata.org/sp/275/Dysphaea-ethela

Anonymous (2023c). *Macrodiplax cora* (Brauer, 1867) — Estuarine Skimmer. In: Joshi, S., P. Dawn, P. Roy, & K. Kunte (eds.). *Odonata of India, v. 1.57*. Indian Foundation for Butterflies. Accessed on 05 April 2023. http://www.indianodonata.org/sp/599/Macrodiplax-cora

Bhosale A.R., A.J. Saadi, C.M. Wade, T. Thackeray, A.S. Tamboli, S.K. Kadam, D.V. Muley & D.C. Raheem (2021). *Varadia*, a new helicarionoidean semi-slug genus from India's Western Ghats (Stylommatophora: Helicarionoidea). *European Journal of Taxonomy* 757: 50–79. https://doi.org/10.5852/ejt.2021.757.1413

Biju, S.D. & F. Bossuyt (2009). Systematics and phylogeny of *Philautus* Gistel, 1848 (Anura, Rhacophoridae) in the Western Ghats of India, with descriptions of 12 new species. *Zoological Journal of the Linnean Society* 155(2): 374–444. https://doi.org/10.1111/j.1096-3642.2008.00466.x

Dalvi, A. & Y. Koli (2022). New records of odonates (Insecta: Odonata), *Archibasis oscilans* Selys, 1877 and *Merogomphus tamaracherriensis* Fraser, 1931 from Maharashtra, India. *Journal of Threantened Taxa* 14(2): 20648–20653. https://doi.org/10.11609/jott.7672.14.2.20648-20653

Fraser, F.C. (1933). *The Fauna of British India including Ceylon and Burma, Odonata. Vol. I.* Taylor and Francis Ltd., London, 436 pp.

Fraser, F.C. (1934). *The Fauna of British India including Ceylon and Burma, Odonata. Vol. II.* Taylor and Francis Ltd., London, 442 pp.

Fraser, F.C. (1936). *The Fauna of British India including Ceylon and Burma, Odonata. Vol. III*. Taylor and Francis Ltd., London, 461 pp.

Garrison, R.W., N. von Ellenrieder & J.A. Louton (2010). *Damselfly*

Image 4. Habitat: a—Bambarde hill stream, Dodamarg | b—Kegad hill stream, Sawantwadi | c—Chipi plateau, Vengurla | d—Oros budruk dam. © a, b, c—Akshay Dalvi | d—Bhupendra Kochrekar.

genera of the New World: an illustrated and annotated key to the Zygoptera. The Johns Hopkins University Press, Baltimore, 490 pp.

Gower, D., V. Giri, A. Captain & M. Wilkinson (2016). A reassessment of *Melanophidium* Günther, 1864 (Squamata: Serpentes: Uropeltidae) from the Western Ghats of peninsular India, with the description of a new species. *Zootaxa* 4085(4): 481–503. https://doi.org/10.11646/zootaxa.4085.4.2

Joshi, S. & D. Sawant (2019). *Ceriagrion chromothorax* sp. nov. (Odonata: Zygoptera: Coenagrionidae) from Sindhudurg, Maharashtra, India. *Journal of Threatened Taxa* 11(7): 13875–13885. https://doi.org/10.11609/jott.4753.11.7.13875–13885

Joshi, S. & D. Sawant (2020). Description of *Bradinopyga konkanensis* sp. nov. (Odonata: Anisoptera: Libellulidae) from the coastal region of Maharashtra, India. *Zootaxa* 4779(1): 65–78. https://doi.org/10.11646/zootaxa.4779.1.4

Joshi, S., D. Sawant, H. Ogale & K. Kunte (2022). *Burmagomphus chaukulensis*, a new species of dragonfly (Odonata: Anisoptera: Gomphidae) from the Western Ghats, Maharashtra, India. *Zootaxa* 5133: 413–430. https://doi.org/10.11646/zootaxa.5133.3.6

Joshi, S., P. Koparde, K.A. Subramanian & P. Roy (eds.) (2017). Odonata of India, v. 1.00. Indian Foundation for Butterflies. Electronic version accessed on 1 March 2023. https://www.indianodonata.org/home

Kalkman, V., 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: 1–84. https://doi.org/10.11646/zootaxa.48491.1

Koli, Y. & A. Dalvi (2021). A new distribution record of *Melanoneura bilineata* Fraser, 1922 (Insecta: Odonata) from India. *Journal of Threatened Taxa* 13(9): 19380–19382. https://doi.org/10.11609/jott.7536.13.9.19380-19382

Koli, Y., A. Dalvi & D. Sawant (2021). New records of *Agriocnemis keralensis* Peters, 1981 and *Gynacantha khasiaca* MacLachlan, 1896 (Insecta: Odonata) from Maharashtra, India. *Journal of Threatened Taxa* 13(7): 18908–18919. https://doi.org/10.11609/jott.6801.13.7.18908-18919

Kosterin, O.E. (2015). Taxonomical notes on *Indolestes* Fraser, 1922 (Lestidae, Zygoptera). 1. *Indolestes gracilis expressior* ssp. nov. from eastern Cambodia. International Dragonfly Fund (IDF) - Report 81: 1–11.

Kulkarni, B.G. (1988). *Flora of India - Series 3. Flora of Sindhudurg*. The Botanical Survey of India, Kolkata, xx+560 pp.

Sayyed, A., R. Pyron & R. Dileepkumar (2018). Four new species of the genus *Cnemaspis* Strauch, 1887 (Sauria: Gekkonidae) from the northern Western Ghats, India. *Amphibian and Reptile Conservation* 12(2): 1–29 (e157).

Mirza, Z.A., R.V. Sanap & H. Bhosale (2014). Preliminary review of Indian Eumenophorinae (Araneae: Theraphosidae) with description of a new genus and five new species from the Western Ghats. *PLoS One* 9(5): e98084. https://doi.org/10.1371/journal.pone.0087928

Padhye, A.D., N. Modak & N. Dahanukar (2014). *Indirana chiravasi*, a new species of Leaping Frog (Anura: Ranixalidae) from Western Ghats of India. *Journal of Threatened Taxa* 6(10): 6293–6312. https://doi.org/10.11609/JoTT.o4068.6293-312

Pati, S.K., T. Thackeray & A. Khaire (2016). Five new species of freshwater crabs of the genera *Ghatiana Pati* & Sharma, 2014, and *Gubernatoriana Bott*, 1970 (Crustacea, Decapoda, Brachyura: Gecarcinucidae Rathbun, 1904) from the Western Ghats, India. Zootaxa 4083(4): 569–586. https://doi.org/10.11646/zootaxa.4083.4.7

Paulson, D., M. Schorr, J. Abbott, C. Bota-Sierra, C. Deliry, K.D. Dijkstra & F. Lozano (2022). World Odonata List. https://www. pugetsound.

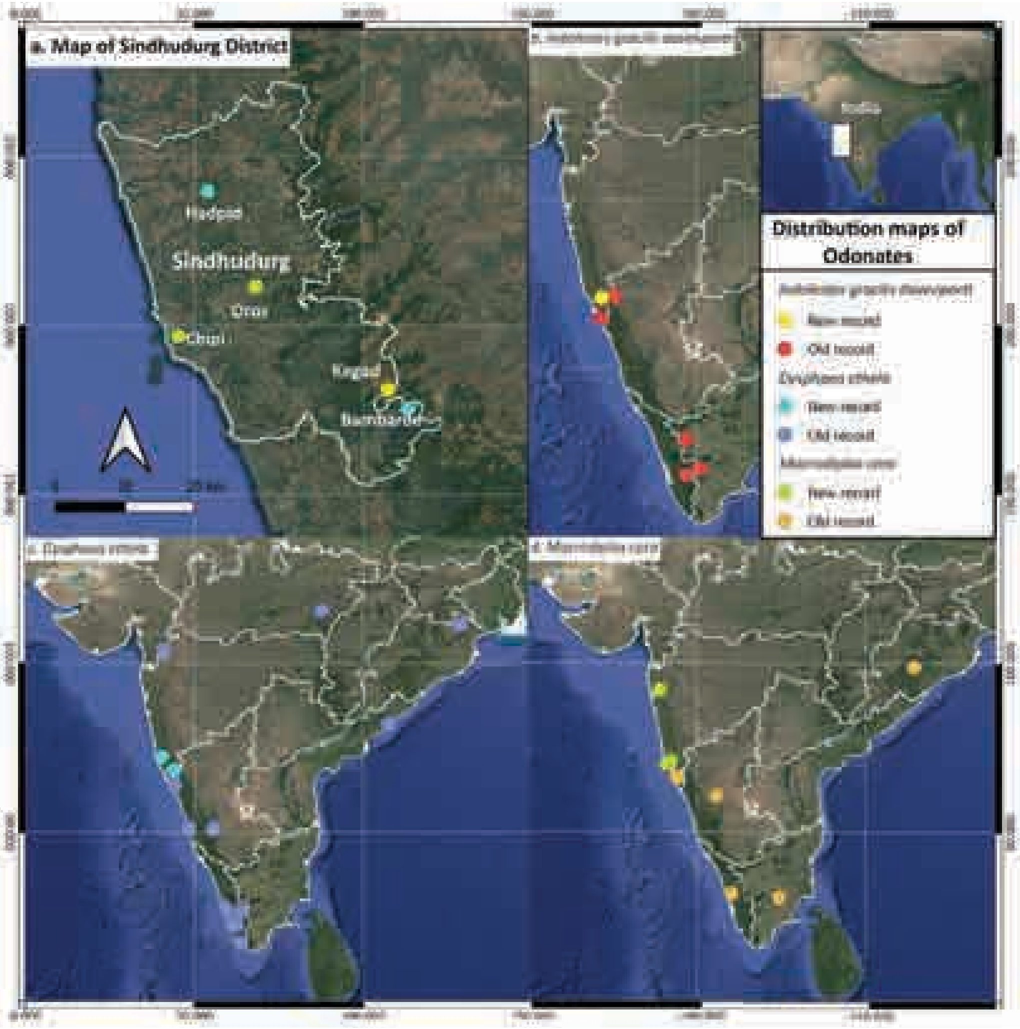

Image 5. Distribution maps: a—New records in Sindhudurg District | b—*Indolestes gracilis davenporti* | c—*Dysphaea ethela* | d—*Macrodiplax cora*. Maps are created using QGIS v3.10.2. ©Akshay Dalvi.

edu/academics/academic-resources/slater-museum/ biodiversity-resources/dragonfies/world-odonata-list2/ (Accessed on 10 January 2023). https://doi.org/10.48580/dfqz-75rv

Praveenraj, J., T. Thackeray & S. Balasubramanian (2020). *Schistura hiranyakeshi* a new loach (Cypriniformes: Nemacheilidae) from Maharashtra, northern Western Ghats, India. *Aqua International Journal of Ichthyology* 26(2): 49–56.

Satose, V., V. Choursiya, R. Deulkar & S. Menon (2018). Avian fauna of Amboli Ghat, Sindhudurg District, Maharashtra State, India. *Journal of Threatened Taxa* 10(13): 12805–12816. https://doi.org/10.11609/jott.2886.10.13.12805-12816

Sawant D., R. M. Deulkar, S. Ogale & H. Ogale (2023). Four new records of dragonflies (Insecta, Odonata) from Amboli region of Western Ghats, Maharashtra, India. *ENTOMON* 48(1): 99–106. https://doi.org/10.33307/entomon.v48i1.850

Sawant, D., H. Ogale & R.M. Deulkar (2022). An annotated checklist of odonates of Amboli-Chaukul-Parpoli region showing new records for the Maharashtra State, India with updated state checklist. *Journal of Threatened Taxa* 14(11): 22164–22178. https://doi.org/10.11609/jott.7715.14.11.22164–22178

Sayyed, A. & S. Sulakhe (2020). A new *Cnemaspis* Strauch, 1887 (Squamata: Gekkonidae) from the northern Western Ghats, Maharashtra, India. *Zootaxa* 4885: 83–98. https://doi.org/10.11646/zootaxa.4885.1.5

Sayyed, A., R.A. Pyron & N. Dahanukar (2016). *Cnemaspis flaviventralis*, a new species of gecko (Squamata: Gekkonidae) from the Western Ghats of Maharashtra, India. *Journal of Threatened Taxa* 8(14): 9619–9629. https://doi.org/10.11609/jott.2599.8.14.9619-9629

Sreedharan, G. & M. Indulkar (2018). New distributional record of the northernmost Myristica swamp from the Western Ghats of Maharashtra. *Current Science* 115: 1434–1436.

Subramanian, K., G. Emiliyamma, R. Babu, C. Radhakrishnan & S. Talmale (2018). *Atlas of odonata (Insecta) of Western Ghats, India*. Zoological Survey of India, Kolkata, 417 pp.

Subramanian, K.A. & R. Babu (2017). Checklist of Odonata (Insecta) of India, Version 3.0. http://www.zsi.gov.in. Accessed 01 December 2019.

Subramanian, K.A. (2014). A Checklist of Odonata of India. Zoological Survey of India, Kolkata. Version 2.0. http://www.zsi.gov.in. Accessed 01 December 2019.

Sulakhe, S., N. Dandekar, A. Padhye & D. Bastawade (2020). Two new cryptic species of Isometrus (Scorpiones: Buthidae) from the northern Western Ghats, India. *Euscorpius* 305: 1–24.

Tiple, A.D. & P. Koparde (2015). Odonata of Maharashtra, India with notes on species distribution. *Journal of Insect Science* 15(1): 1–10. https://doi.org/10.1093/jisesa/iev028

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COMMUNICATION

A first report of dung beetle *Garreta smaragdifer* (Walker, 1858) attending the faecal matter of Northern Plain Gray Langur *Semnopithecus entellus* (Dufresne, 1997) with range extension and a checklist of the genus *Garreta* Janssen, 1940

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Abstract: Genus *Garreta* Janssens, 1940 is an Afrotropical and of Oriental origin, consisting of 25 species and two subspecies from the world, eight species from India and two species from Maharashtra. Out of eight Indian species two are endemic to India. The present report is the first report of feeding of *Garreta smaragdifer* (Walker, 1858) on the faecal matter of Northern Plain Gray Langur *Semnopithecus entellus* (Dufresne, 1997) and also its range extension from central India to Maharashtra.

Keywords: Gautala-Autramghat Wildlife Sanctuary, primate, Satmala and Ajanta Hill ranges.

Marathi: सार: गॅरेटा जॅन्सेन्स, 1940 ही अफ्रोट्रोपिकल आणि ओरिएंटल वंशाची आहे, ज्यामध्ये जगातील 25 प्रजाती आणि दोन उपप्रजाती, भारतातील आठ प्रजाती आणि महाराष्ट्रातील दोन प्रजाती आहेत. आठ भारतीय प्रजातींपैकी दोन भारतासाठी स्थानिक आहेत. हा लेख नॉर्दर्न प्लेन ग्रे लंगूर सेम्नोपिथेकस एंटेलस (डुफ्रेस्ने, 1997) च्या विष्ठेवरील, गॅरेटा स्मारागडिफर (वॉकर, 1858) च्या आहाराचा व मध्य भारतापासून महाराष्ट्रापर्यंतच्या विस्ताराचा पहिला अहवाल आहे.

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Competing interests: The authors declare no competing interests.

Author details: Aparna Sureshchandra Kalawate (ASK) and M.J. Palot (MJP) are scientist working in Zoological Survey of India, Western Regional Centre, Pune. ASK is an entomologist and her interest groups are moths and scarab beetles. She has more than 68 research papers published in peer reviewed journals and holds an Indian Patent in the field of wood preservative chemical. MJP works on mammals, reptiles, birds and butterflies. He has more than 100 research papers published in peer reviewed journals.

Author contributions: ASK formulated the study, identified the beetle, dissected genetalia, taken photos, prepared map, written MS. MJP written the identification part of the Hanuman Langur, identified the Langur and helped in compilation, taken photo of Langur.

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INTRODUCTION

The genus *Garreta* Janssens, 1940, is widely distributed in Afrotropical and Oriental regions (Davis & Deschodt 2018) and is known by 25 extant species and two subspecies (Morrtto & Génier 2015; Schoolmeesters 2017; Davis & Deschodt 2018; Pokorny & Zídek 2018; Zídek 2018) from the world including 8 from India (Mittal 2011; Chandra & Gupta 2014). The Asian species of this genus have been revised by Pokorny & Zidek (2016) and the African species by Pokorny & Zidek (2018). In their revision, they clearly state that describing species in this genus based on the colours is not valid. The colour changes in this group are due to the temperature induced effect, they further state that the species distributed in the warmer regions are greenish-bluish in temperate regions and coppery in intermediate climatic conditions.

The species in this genus look similar and to delineate the species, recently in Afrotropical species, the micro-sculpture of the exoskeleton was used as an important character for differentiation by Moretto & Génier (2015) who divided some species into two species groups based on micro-sculpture and geographical distribution, i.e., *Garreta laetus* group and included three species, namely: *G. caffer* Fåhraeus, 1857, *G. laetus* (Hope, 1842), and *G. nyassicus* (Kolbe, 1897). In *Garreta nitens* group *G. nitens* (Olivier, 1789), *G. rutilans* (Castelnau 1840), and *G. wahlbergi* (Fåhraeus, 1857) have been included. The other species have not been included in any species group so far. In the present study, two infraspecific taxa, namely, *G. laetus laetus* (Hope, 1842) and *G. laetus olivaceus* (Quedenfeldt, 1884) have been considered valid (see Moretto & Génier 2015).

MATERIAL AND METHODS

The observation taken on the *G. smaragdifer* was opportunistic from the Gautala-Autramghat Wildlife Sanctuary, Maharashtra during a faunistic survey tour to the region from 9–18 August 2021. A few specimens were collected for identification in the laboratory. The specimens were hand-picked and kept in a vial of 70 percent ethyl alcohol. Leica EZ4E stereomicroscope with photographic facility was used for examining the specimens. The specimen was identified using available literature (Chandra & Gupta 2014; Pokorny & Zidek 2016). The distribution and the type locality data have been verified from Janssens (1940), Chandra & Gupta (2014), Pokorny & Zídek (2018), and Zídek (2018). The map of the collection locality was prepared using open, free access QGIS software version 3.16 (Figure 1). The material examined was deposited in the national repository of Zoological Survey of India, Western Regional Centre, Pune, Maharashtra, India (ZSI-WRC).

RESULTS AND DISCUSSION

Taxonomic account
Family Scarabaeidae Latreille, 1802
Subfamily Scarabaeinae Latreille, 1802
Tribe Gymnopleurini Lacordaire, 1856
Genus *Garreta* Janssen, 1940
1803. *Gymnopleurus* llliger (ex parte), *Mag. Ins.*, II: 199.
1897. *Paragymnopleurus* Shipp (ex parte), Entom., XXX: 166.
1940. *Garreta* Janssen, *Verh Kon Nat Mus Belg Brussel* 2(18): 22.
Type species: *Ateuchus azureus* Fabricius, 1801 (= *Garreta azureus* (Fabricius, 1801)), Natural History Museum, London, UK (BMNH).

Garreta smaragdifer **(Walker, 1858)**
(Image 1B–D)

1858. *Gymnopleurus smaragdifer* Walker, *Ann. Mag. Nat. Hist*. (3) II: 208.

1931. *Gymnopleurus smaragdifer* Arrow, *Fauna British India including Ceylon & Burma*, *Coleoptera, Lamellicornis*, III : 60–61, pl. III, fig. 13.

1940. *Garreta smaragdifer*, Janssens, *Verh. Kon. Nat. Mus. Belg.*, 2 (18): 29, pl. I, fig. 2.

1963. *Gymnopleurus* (*Garreta*) *smaragdifer*, Balthasar, *Mon. Scarab. Aphod. Palae. Ori. Reg.*, *(Coleoptera: Lamellicornia), Coprinae*, I: 226.

2014. *Garreta smaragdifer* Chandra & Gupta, *Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci*., (B) 84 (2):317–330.

2016. *Garreta smaragdifer*, Pokorný & Zidek, *Insecta Mundi*, 0483: 1–8.

Type locality: Sri Lanka?

Material examined: ZSI-WRC Ent-1/4123, 12.viii.2021, 5 examples, Kedarkund (20.311N & 74.971E; 409m), Jalgaon, Maharashtra, India, coll. A.S. Kalawate.

Distributon: India (Chhattisgarh, Madhya Pradesh, Maharashtra (in this study range extended), southern India), Sri Lanka.

Gautala-Autramghat Wildlife Sanctuary, Maharashtra, India lies in the Satmala and Ajantha hill ranges. During our field survey tour of the sanctuary, we came across many *G. smaragdifer* adults, busy rolling in fresh primate faecal matter of the Northern Plain

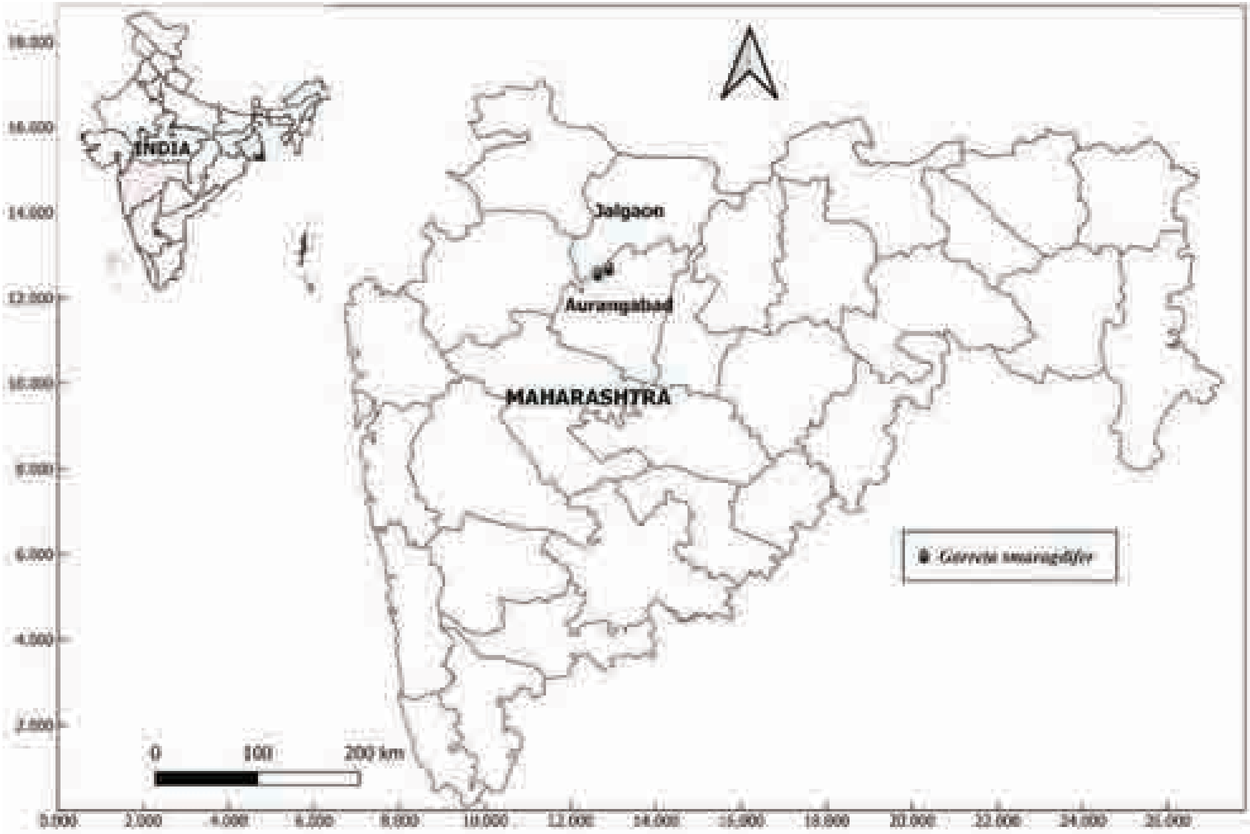

Figure 1. The study locality.

Gray Langur *Semnopithecus entellus* (Dufresne, 1997). Large troops of the langur were seen hopping on the *Hardwickia binata* Roxb. trees present in the Patnadevi part of the sanctuary and around the Bhaskaracharya Forest Guest house during the day time. Near the guest house it was observed that the fresh dung of the langur was rolled and carried by the large number of *G. smaragdifer*, who were busy in rolling and fighting for the dung in the day time. The langur was identified by the mammal expert and the second author. Some of the beetles were collected and brought to the laboratory for further study and to our surprise it was identified as *G. smaragdifer*, a new record for Maharashtra whose range extended from central India to Maharashtra. The aim of this paper is to provide a first report of the Dung Beetle *G. smaragdifer* attending the faecal matter of a primate species from India and also its range extension from Maharashtra.

First instance, on 12 August 2021, we observed a large troop of langurs near the Kedarkund area (20.309N & 74.967E; 447 m) very close to the water falls, about 4 km from the Bhaskaracharya Forest Rest House (Figure 1). The entire forest floor was covered with the shiny bluish-green dung beetles, either rolling or devouring the faecal matters of the langur (Image 1). As many as 80 beetles were counted during the survey. The next day, a similar emergence of dung beetles was noticed all along within the campus of the Bhaskracharya Forest Rest House (20.318N & 74.975E; 468 m), where a small roost of about 15 langurs was seen. A total of more than 100 beetles were encountered during the period. All were actively rolling the very meagre faecal matters underneath the tree. Some of them were fighting for the dung balls. This is a common practice where male dung beetles fight for the dung pad with other males. Both the days were exceptionally wet and the weather was slightly overcast with a light drizzle.

Various reports suggest that a dung ball is rolled away from the dung for brood construction by a single beetle, or by a pair and buried in the soil (Prasse 1957). An egg is laid at its base, and is covered with dung in the chamber making a brood. This brood is then coated with a mixture of soil and dung to prevent fungal attack (Scholtz et al. 2009). The *Garreta* brood is generally oval in shape. We also noticed slightly oval shaped brood balls all along the locality.

The other primate species observed during the survey was the Rhesus Macaque *Macaca mulatta*

Zimmermann, 1780, which are found in small numbers at the locality. Major herbivorous animals observed from the Gautala-Autramghat Sanctuary were Nilgai *Bosephalus tragocamelus* (Pallas, 1766), Indian Gazelle *Gazella bennettii* (Sykes, 1831), Sambar *Rusa unicolor* (Kerr, 1792), Spotted Deer *Axis axis* (Erxleben, 1777), Barking Deer *Muntiacus muntjac* (Zimmermann, 1780), and Wild Boar *Sus scrofa* Linnaeus, 1758. Carnivorous animals like Leopard *Panthera pardus* (Linnaeus, 1758), Tiger *Panthera tigris* (Linnaeus, 1758), and Jungle Cat *Felis chaus* Schreber, 1777 were also found during the survey. It was observed in the field that faecal matters of these animals were not attended to by *G. smaragdifer*.

Most scarabs prefer to feed on herbivore faecal matter, which are largely undigested plant matter, rather than carnivore faecal matters, which hold very little nutritional value for insects (Hadley 2021). According to Al-Houty & Musalam (1997) the faecal matter of herbivorous mammals was more preferred than the carnivores. There are many studies on the dung beetles attending on the dungs of elephants (Sabu et al. 2006), Gaur (Vinod & Sabu 2007), cattle species (Tonelli et al. 2021) from India. There are reports of dung beetles attending on the scats of carnivorous animals too (Al-Houty & Musalam 1997). Even though studies were reported on the faecal matters of primates from other countries (Estrada & Coates-Estrada 1991) so far there were none from India. Hence, the present report forms the first instance of dung beetles on the dungs of primate species from India and also reporting the beetle species *G. smaragdifer* for *the* first time from Maharashtra State.

The extant species of the genus *Garreta* Janson, 1940 (modified from Moretto & Génier 2015 and Zídek 2018).

1. *Garreta australugens* Davis & Deschodt, 2018.

Garreta australugens Davis & Deschodt, *Zootaxa*, 4450(2): 242–248.

Type Locality: Wildlife College, South Africa; SANC (South Africa, Gauteng, Pretoria, South African National Collection of Insects).

Distribution: Southern Africa.

2. *Garreta azureus* (Fabricius, 1801)

1801. *Ateuchus azureus* Fabricius, *Syst. Eleuth*., I: 57.

Type Locality: Guinea [Ghana]; ZMUC (Zoological Museum of Copenhagen University, Denmark).

Distribution: Africa.

3. *Garreta bechynei* (Pokorny & Zidek, 2018)

2018. *Garreta bechynei* Pokorny & Zidek, *Folia Heyrovskyana*, A, 26(1): 96.

Type Locality: N Zérékoré, se. Guinea; NMPC (National Museum (Natural History), Prague, Czech Republic).

Distribution: Guinea.

4. *Garreta caffer* (Fahraeus, 1857)

1857. *Gymnopleurus caffer* Fahraeus, in Boheman, Ins. Caffr., II: 181.

Type Locality: Caffraria; NHRS (Naturhistoriska Riksmuseet, Stockholm, Sweden).

Distribution: Angola, South Africa.

5. *Garreta crenulatus* (Kolbe, 1895)

1895. *Gymnopleurus crenulatus* Kolbe*, Stett. Ent. Zeits., LVI* : 333.

Type Locality: N of Lake Albert (Uganda?); MNHB (Museum für Naturkunde Leibniz-Institut, Berlin, Germany).

Distribution: Republic Democratic Congo.

6. *Garreta dejeani* (Castelnau, 1840)

1840. *Gymnopleurus dejeani* Castelnau, *Hist. Nat. Col.,* II: 70.

Type Locality: Not known; MNHN? (Muséum National d'Histoire Naturelle, Paris, France).

Distribution: India (Chhattisgarh, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Uttarakhand), Nepal, Pakistan.

7. *Garreta diffinis* (Waterhouse, 1890)

1890. *Gymnopleurus diffinis* Waterhouse, *Ann. Mag. Nat. Hist*. (6), V: 372.

Type Locality: Senegambia; BMNH (Natural History Museum, London, UK).

Distribution: Gabon, Gambia, Senegal, sw. DRC (Kuilu=Kwilu River).

8. *Garreta fastiditus* (Harold, 1867)

1867. *Gymnopleurus fastiditus* Harold, *Col. Hefte*, I : 74.

Type Locality: Cape of Good Hope MNHN (Muséum National d'Histoire Naturelle, Paris, France).

Distribution: Zimbabwe, Mozambique, South Africa.

9. *Garreta gilleti* (Garreta, 1914)

1914. *Gymnopleurus gilleti* Garreta, *Bull. Soc. Ent. Fr*.: 412.

Type Locality: Saigon, Cochinchine; MNHN (Muséum National d'Histoire Naturelle, Paris, France).

Distribution: India (Uttar Pradesh) Thailand, Vietnam.

10. *Garreta laetus* (Hope, 1842)

1842. *Gymnopleurus laetus* Hope, *Ann. Mag. Nat. Hist*., IX: 494.

Type Locality: Liberia: environs de cap Palmas [=Cape Palmas, Liberia]; OXUM (Oxford University Museum of Natural History, UK).

Distribution: Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Eritrea, Ethiopia, Ghana, Guinea, Ivory Coast, Kenya, Liberia, Niger, Nigeria, Democratic Republic of Congo, Senegal, Sierra Leone, Tanzania, Togo, and Uganda.

11. *Garreta laetus laetus* (Hope, 1842)

1895. *Gymnopleurus cupreovirens* Kolbe, *Stettiner entomologische Zeitung*, 56 (10-12): 333.

Type Locality: Liberia: environs de cap Palmas [=Cape Palmas, Liberia]; OXUM (Oxford University Museum of Natural History, UK).

Distribution: Cape Palmas.

12. *Garreta laetus olivaceus* (Quedenfeldt, 1884)

1884. *Gymnopleurus olivaceus* Quedenfeldt, *Berliner entomologische Zeitschrift*, 28 (2): 269.

Type Locality: Malange [Angola]; (MNHN) (Muséum National d'Histoire Naturelle, Paris, France).

Distribution: Angola, Congo, Malawi, Mozambique, Republic Democratic Congo, Tanzanie, and Zimbabwe.

13. *Garreta lugens* (Fairmaire, 1891)

1891. *Gymnopleurus lugens* Fairmaire, *Ann. Soc. Ent. Belg*., XXXV: 284.

Type Locality: Somalia; NHMW (Naturhistorisches Museum, Vienna, Austria).

Distribution: Botswana, Ethiopia, Kenya, Mozambique, South Africa, Somalia, and Tanzania.

14. *Garreta malleolus* Kolbe, 1895

1895. *Gymnopleurus malleolus* Kolbe, *Stett. Ent. Zeits*., LVI: 334.

Type Locality: Tanganyika. Lac Victoria [=East of Lake Tanganyika]; MNHB (Museum für Naturkunde Leibniz-Institut, Berlin, Germany).

Distribution: Republic Democratic Congo, Ruanda, Mozambique, Uganda, Urundi, and Zimbabwe.

15. *Garreta matabelensis* Janssens, 1938

1938. *Gymnopleurus* (*Paragymnopleurus*) *matabelensis* Janssens, *Mission de Witte, Pare National Albert*, 21: 44.

Type Locality: Matabele, Zimbabwe; ISNB (Institut Royal des Sciences Naturelles, Brussels, Belgium).

Distribution: Zimbabwe.

16. *Garreta mombelgi* (Boucomont, 1929)

1929. *Gymnopleurus mombelgi* Boucomont, *Lingn. Sc. Journ*. 7 : 760.

Type Locality: Sichuan, Yunnan, China; MNHN (Muséum National d'Histoire Naturelle, Paris, France).

Distribution: China.

17. *Garreta morosus* (Fairmaire, 1886)

1886. *Gymnopleurus morosus* Fairmaire, *Ann. Soc. Ent. Fr.* (6), VI: 319.

Type Locality: Sichuan, Yunnan, China; MNHN (Muséum National d'Histoire Naturelle, Paris, France).

Distribution: China.

18. *Garreta mundus* (Wiedemann, 1819)

1819. Gymnopleurus mundus Wiedemann, *Zool. Mag*., I, 3: 162.

Type Locality: the type destroyed.

Distribution: India (Bihar, Chhattisgarh, Himachal Pradesh, Kashmir, Madhya Pradesh, Punjab, Uttarakhand), Pakistan, southwestern China.

19. *Garreta namalugens* Davis & Deschodt, 2018

2018. *Garreta namalugens* Davis & Deschodt, *Zootaxa*, 4450 (2): 242–248.

Type Locality: NamibRand Nature Reserve, southern Africa; SANC (South Africa, Gauteng, Pretoria, South African National Collection of Insects).

Distribution: Southern Africa.

20. *Garreta nitens* (Olivier, 1789)

1789. *Scarabaeus nitens* Olivier, *Ent. I, Scharab*.:159, pl. 7, fig. 55.

Type Locality: Senegal; MNHN (Muséum National d'Histoire Naturelle, Paris, France).

Distribution: Senegal, Burkina Faso, Cameroon, Ivory Coast, Benin, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Chad, Togo, Central African Republic, Sierre Leone, Angola, Republic Democratic Congo, Ethiopia, Eritrea, Ruanda, Zambia, Malawi, Zimbabwe, Mozambique, Namibia, Botswana, Kenya, and South Africa.

21. *Garreta opacus* (Redtenbacher, 1848)

1848. *Gymnopleurus opacus* Redtenbacker, in Hugel, *Kaschmir*, IV, 2 : 516.

Type Locality: Punjab during British India? type lost; NHMW (Naturhistorisches Museum, Vienna, Austria).

Distribution: India: (Himachal Pradesh, Jammu &

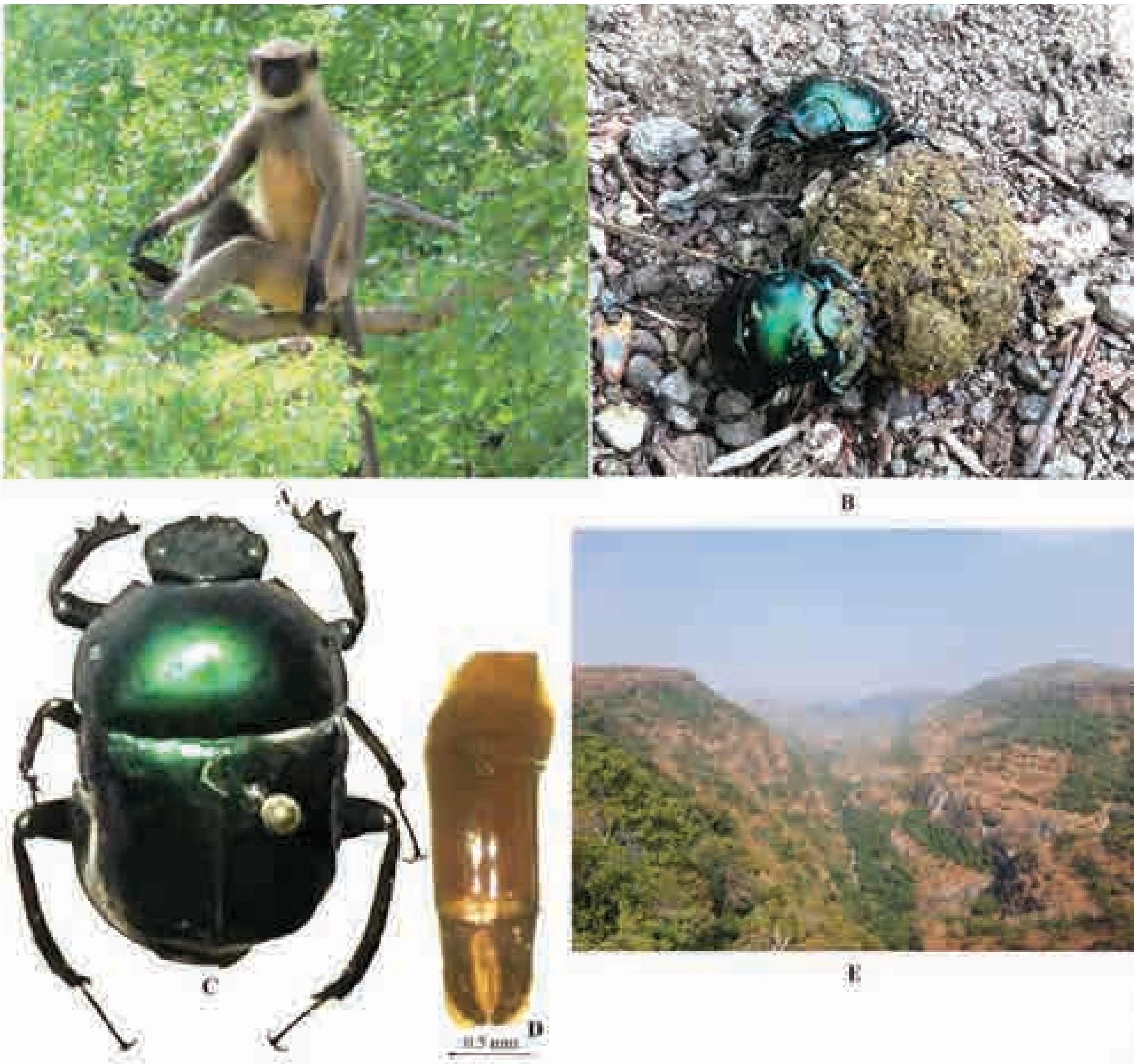

Image 1. A—Northern Plain Gray Langur *Semnopithecus entellus* (Dufresne, 1997) sitting on *Hardwickia binata* Roxb. Tree | B—*Garreta smaragdifer* rolling the faecal matter | C—Adult *Garreta smaragdifer*, dorsal view | D—male genitalia | E—Collection site. © Aparna S. Kalawate

Kashmir, Uttarakhand) and Nepal.

22. *Garreta ruficornis* (Motschulsky, 1854)

1854. *Gynmopleuru ruficornis* Motschulsky, *Etudes Ent*., III: 63.

Type Locality: Not known.

Distribution: India (Assam, Himachal Pradesh, Punjab, Uttarakhand), Afghanistan, China, Myanmar, and Thailand.

23. *Garreta rutilans* (Castelnau, 1840)

1840. *Gymnopleurus rutilans* Castelnau, *Duménil, Paris*. 38: 71.

Type Locality: Sennaar, Sudan; MNHN (Muséum National d'Histoire Naturelle, Paris, France).

Distribution: Botswana, eastern South Africa, Sudan, and Zimbabwe.

24. *Garreta smaragdifer* (Walker, 1858)

1858. *Gymnopleurus smaragdifer* Walker, *Ann. Mag. Nat. Hist*. (3), II: 208.

Type Locality: Not known; BMNH (Natural History Museum, London, UK).

Distribution: India (Chhattisgarh, Madhya Pradesh, Maharashtra (reported in this study), southern India) and Sri Lanka.

25. *Garreta sylvestris* Mittal, 2011

2011. *Garreta sylvestris* Mittal, *Journal of Entomological Research* 35(3): 297.

Type Locality: Haryana; INPC (National Pusa Collections, New Delhi, India).

Distribution: India (Haryana).

Remark: Endemic to India.

26. *Garreta unicolor* (Fahraeus, 1857)

1857. *Gymnopleurus unicolor* Fahraeus, in Boheman, Ins. Caffr., II: 182.

Type Locality: Caffraria; NHRS (Naturhistoriska Riksmuseet, Stockholm, Sweden).

Distribution: Mozambique, South Africa, and Zimbabwe.

27. *Garreta wahlbergi* (Fahraeus, 1857)

1857. *Gymnopleurus wahlbergi* Fåhraeus, *Officina Norstedtiana, Holmiae.* II: 183.

Type Locality: Caffraria; NHRS (Naturhistoriska Riksmuseet, Stockholm, Sweden).

Distribution: Botswana, Mozambique, South Africa, Swaziland, and Zimbabwe.

REFERENCES

Al-Houty, W. & F. Al-Musalam (1997). Dung preference of the dung beetle *Scarabaeus cristatus* Fab (Coleoptera: Scarabaeidae) from Kuwait. *Journal of Arid Environments* 35: 511–516. https://doi.org/10.1006/jare.1996.0179

Chandra, K. & D. Gupta (2014). Studies on tribe Gymnopleurini (Coleoptera: Scarabaeidae: Scarabaeinae) from Madhya Pradesh and Chhattisgarh with a checklist from India. *Proceedings of the National Academy of Sciences of India* (Section B) 84(2): 317–330. https://doi.org/10.1007/s40011-013-0229-z

Davis, A.L.V. & C.M. Deschodt (2018). Two new species of Garreta Janssens, 1940 (Coleoptera: Scarabaeidae: Scarabaeinae) from southern Africa**.** *Zootaxa* 4450(2): 242–248. https://doi.org/10.11646/zootaxa.4450.2.4

Estrada, A. & R. Coates-Estrada (1991). Howler monkeys (*Alouatta palliata*), dung beetles (Scarabaeidae) and seed dispersal: ecological interactions in the tropical rain forest of Los Tuxtlas, Mexico. *Journal of Tropical Ecology* 7(4): 459–474. https://doi.org/10.1017/S026646740000585X

Hadley, D. (2021). 10 Fascinating Facts About Dung Beetles. https://www.thoughtco.com/fascinating-facts-about-dung-beetles-1968119. Assessed on 18 June 2022.

Janssens, A. (1940). Monographie des Gymnopleurides (Coleoptera, Lamellicornia). *Mémoires du Musée Royal d'Histoire Naturelle de Belgique* (2)18: 1–73.

Mittal, I.C. (2011). Synoptic key to Indian species of genus *Garreta* Janssens (Coleoptera: Scarabaeidae: Scarabaeinae) with a new species from Haryana (India). *Journal of Entomological Research* 35: 295–298.

Moretto, P. & F. Génier (2015). La véritable identité de Scarabaeus nitens Olivier, 1789, et *Ateuchus azureus* Fabricius, 1801 (Scarabaeidae, Gymnopleurini). *CATHARSIUS La Revue* 12: 1–32. https://doi.org/10.13140/RG.2.1.4753.7047

Pokorný, S. & J. Zidek (2016). Review of the Gymnopleurini (Coleoptera: Scarabaeidae: Scarabaeinae). III. Asian species of *Garreta* Janssens. *Insecta Mundi* 0483: 1–8.

Pokorný, S. & J. Zidek (2018). Review of the Gymnopleurini. IV. African species of Garreta Janssens, with description of a new species from Guinea. *Folia Heyrovskyana Series* A 26(1): 95–109.

Prasse, J. (1957). Das Brutfursorgeverhalten der Pillenwalzer Sisyphus schaefferi L. und Gymnopleurus geoffroyi Fuessl (Col. Scarab). *Wiss Zeit Uni Halle* 6: 589–614.

Sabu, T.K., K.V. Vinod & P.J. Vineesh (2006). Guild structure, diversity and succession of dung beetles associated with Indian elephant dung in South Western Ghats forests. *Journal of Insect Science* 6(17): 1–12. https://doi.org/10.1673/2006_06_17.1

Scholtz, C.H., A.L.V. Davis & U. Kryger (2009). *Evolutionary biology and conservation of bung beetles.* Pensoft, Moscow, 567 pp.

Schoolmeesters, P. (2017). Scarabs: World Scarabaeidae Database (version Jan 2017). In: Roskov, Y., L. Abucay, T. Orrell, D. Nicolson, T. Kunze, A. Culham, N. Bailly, P. Kirk, T. Bourgoin, R.E. DeWalt, W. Decock & A. de Wever (eds.). Species 2000 & ITIS Catalogue of Life, 2017 Annual Checklist. http://www.catalogueoflife.org/annualchecklist/2017 (accessed 15.01.2023).

Tonelli, M., V.C.G. Gómez, J.R. Verdú, F. Casanoves & M. Zunino (2021). Dung Beetle Assemblages Attracted to Cow and Horse Dung: The Importance of Mouthpart Traits, Body Size, and Nesting Behavior in the Community Assembly Process. *Life* 11(9): 873. https://doi.org/10.3390/life11090873

Vinod, K.V. & T.K. Sabu (2007). Species composition and community structure of dung beetles attracted to dung of gaur and elephant in the moist forests of South Western Ghats. *Journal of Insect Science* 7 (1): 56. https://doi.org/10.1673/031.007.5601

Zidek, J. (2018). Checklist and bibliography of the Gymnopleurini. *Folia Heyrovskyana, series* A 26(1): 161–174.

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OPEN ACCESS

COMMUNICATION

An evaluation of the wetland grass flora of Mizoram, India

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Abstract: Mizoram, a diminutive state in northeastern India forms a major segment of the Indo-Burma biodiversity hotspots. The wetland grasses in the ecosystem are elements adapted in assorted habitat as one of the primary producers. This present assessment is principally focused to augment and evaluate information on the current status of the aquatic and semi-aquatic grasses from the taxonomic and ecological perspectives from this ecoregion. The paper encompasses the present taxonomic account of the wetland grasses with recent citations, protologue, type, basionym, phenology, growth forms, field status, worldwide distribution and specimens examined. The present investigation revealed the occurrence and distribution of 16 genera including 23 species of wetland grasses from this state. This kind of study always sets the ground for launching in-depth ecological projects for working out the present ecological characteristics and status of the wetlands and their restoration and conservation.

Keywords: Biodiversity, evaluation, flora, grass, hotspot, northeastern India, phenology, Poaceae.

Editor: Anonymity requested.

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INTRODUCTION

Wetlands are frequently referred to as the 'Kidneys of landscape' which are the land-water transitional zone between terrestrial and aquatic systems where the water table is usually at or near the surface or the land. The region usually remains covered by marshy, shallow or muddy water. The RAMSAR convention defined wetlands as 'areas of marsh, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters' (Bridgewater & Kim 2021). Wetlands all over the world are threatened directly due to reclamation for development activities, reduction in function due to pollution, water demand, change in hydrologic regime, overexploitation of wetland resources and also due to underlying causes such as market failure, information failure and intervention failure. In this scenario, fundamental knowledge on location, characteristics, functions, values, threats and assessments of status of wetlands are prerequisite for developing sustainable conservation programme for wetlands. They are amongst the most productive ecosystems on earth and any alterations might lead to changes in their bio-physical, socio-economic and climatic conditions.

Grass-dominated communities cover about 24% of the Earth's vegetation (Judd et al. 2002). They not only provide ecosystem services such as water and climate regulation in support of agriculture, biogeochemical cycling, carbon storage, but also form a habitat for a variety of aquatic macro-invertebrates and herbivores (White et al. 2000). Moreover, they have wide ecological amplitude and are able to adapt in diverse habitats as one of the primary producers, as in wetland ecosystems (Mukherjee 1993). The members can acclimatize to far-reaching range of habitations more than sedges and are aptly considered one of the most ecologically successful taxa due to their broad diversification, adaptability and tolerance (Palit et al. 2017).

The graminoids form the fifth largest family of flowering plants (Stevens 2001) but its importance is beyond doubt for it provides to the grasslands which occupy a third of the land's surface (Schantz 1954). They are globally represented by 12,000 species under 780 genera (Christenhusz & Byng 2016) among which India includes 263 genera and 1,291 species (Karthikeyan et al. 1989). There are 18 genera (Sreekumar & Nair 1991) and 350 species (Jain 1986) of grasses which are endemic to India. An exhaustive survey to generate the grass flora of Mizoram amalgamated with literature compilation and herbarium study revealed 64 genera comprising 100 species of grasses. The taxonomic and functional appraisal of the wetland grass flora of this state recorded 16 genera having 23 species which indicates the relevance in ecological management and restoration. This assessment was carried out from 2016 onwards to augment and update information on aquatic and semi-aquatic grass flora from the taxonomic and ecological perspectives. The present commentary includes the current taxonomic status, type, abundance, growth forms, phenology, distribution in India and in the world of the diverse variety of the wetland grass species which are encountered from this geographical area.

MATERIAL AND METHODS

Northeastern India including the state of Mizoram forms a significant segment of the Indo-Burma biodiversity hotspot. The geographical location is between 21º56'–24º31'N & 92º15'–93º26'E having 21,087 km^2 area. The state does not have vast wetland areas or RAMSAR zones however, c. 2.25 ha area forms the wetlands. The major rivers of the state are Chhimtuipui (largest), Tlawng (longest), Tuirial, Teirei, Serlui, Sajek, Tuipui, Kawrpui, & Mengpui and lakes being Palak (largest), Tamdil, Rihdil, & Rengdil (National Wetland Atlas: Mizoram 2010). While studying the grass diversity in Mizoram, special concentration was given to the wetlands because of its intimate aquatic association. Adequate numbers of plant specimens were collected from the wetlands from 2016 onwards, some of which were processed for herbarium preservation at CAL herbarium and the rest were taxonomically worked out. Standard taxonomic methods were applied for description and identification using authentic literature (Bor 1960; Guhabakshi 1984; Baruah & Baruah 2006). The taxonomic account includes current taxonomic citations, protologue, type, basionym, phenology, growth forms, status, field notes, distribution and specimens examined. The genera and species under each genus are arranged alphabetically.

RESULTS AND DISCUSSION

The present survey and investigation revealed the occurrence of 16 genera including 23 species of grasses (Poaceae) from the wetlands of Mizoram.

1 ***Brachiaria ramosa*** (L.) Stapf in Prain, Fl. Trop. Afr. 9(3): 542–544. 1919.

Type: LINN-80.44.

Basionym: *Panicum ramosum* L., Mant. Pl.: 29. 1767.

Phenology: April to October.

Habitat: Grows beside canals, ditches, muddy areas and marshes.

Growth-form: Graminids.

Status: Common.

Distribution: Tropical regions of the world; Sri Lanka. India: Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Nagaland, Odisha, Sikkim, Tamil Nadu.

Specimen examined: Mizoram, Mamit District, fringes of the Dampa canal, 466 m, 02.x.2016, S. Pathak 48541 (CAL).

2. *Brachiaria reptans* (L.) Gard. & C.E. Hubb. in W. Hooker's Ic. Pl. sub tab. 3363. 1938.

Type: *P. Browne* s.n.; LINN-80.52, upper specimen.

Basionym: *Panicum reptans* L., Syst. Nat. (ed. 10) 2: 870. 1759.

Phenology: July to March.

Habitat: Grows along edges of river banks.

Growth-form: Graminids.

Status: Common.

Distribution: Pan-tropical parts of the world. India: Andhra Pradesh, Arunachal Pradesh, Assam, Andaman & Nicobar, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Nagaland, Odisha, Sikkim, Tamil Nadu, West Bengal.

Specimen examined: Mizoram, Chhimtuipui District, banks of Chhimtuipui River, 846 m, 02.viii.2016, S. Pathak 48548 (CAL).

3. *Coix lacryma-jobi* L., Sp. Pl. (ed. 10) 2: 972. 1753.

Type: INDIA (*Indiis*); *Carl Von Linnaeus*, LINN- 1098.1.

Phenology: April to June.

Habitat: Muddy slope of river banks.

Growth-form: Graminids.

Status: Not common.

Distribution: Native to tropical Asia; currently extensively distributed throughout tropics. India: Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Goa, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Chhimtuipui District, along the banks of Chhimtuipui River, 846 m, 02.vi.2017, S. Pathak 48506 (CAL).

4. *Cynodon dactylon* (L.) Pers., Syn. Pl. 1: 85. 1805.

Type: INDIA: Bombay, sand foreshore, June, 1904, *G. Forrest* 358 (K).

Basionym: *Panicum dactylon* L., Sp. Pl. (ed. 1) 58: 1753.

Phenology: Almost throughout the year.

Habitat: Damp waste lands, the edges of small streams and rivers.

Growth-form: Graminids.

Status: Very common.

Distribution: Cosmopolitan. India: Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Aizawl District, beside Turial River, 341 m, 06.x.2016, S. Pathak 48544 (CAL).

5. *Digitaria ciliaris* (Retz.) Koeler., Descr. Gram. 27. 1802.

Type: CHINA: Guangdong, Guangzhou, *Wennerberg* **s.n.**

Basionym: *Panicum ciliare* Retz., Observ. Bot. 4: 16. 1786.

Phenology: April to July.

Habitat: Along shady damp canals, beside ditches and river banks.

Growth-form: Hyperhydate/Helophyte.

Status: Not common.

Distribution: Tropical regions of the world; Africa, Myanmar. India: Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Mamit District, beside Sajek River, 366 m, 02.v.2017, S. Pathak 48346 (CAL).

6. *Digitaria setigera* Roth, Syst. Veg. (ed. 15) 2: 474. 1817.

Type: INDIA: *Heyne* s.n. (*Holo*: B; *Iso*: K).

Phenology: May to February.

Habitat: Grows beside water flowing channels and edges of lakes.

Growth-form: Hyperhydate.

Status: Not very common.

Distribution: Australia, China, Myanmar, South America, Thailand, several parts of tropical Asia. India: Assam, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Aizawl District, marshy banks of Tamdil Lake, 1,170 m, 06.vii.2018, S. Pathak 48567 (CAL).

7. *Echinochloa colona* (L.) Link in Hot. Berol. 2: 209. 1833.

Type: JAMAICA: *Browne* s.n., LINN-80.23.

Basionym: *Panicum colonum* L., Syst. Nat. 2(ed. 10): 870. 1759.

Phenology: May to October.

Habitat: Along banks of lakes and muddy forest trails.

Growth-form: Graminids.

Status: Very common.

Distribution: Africa, Asia, Australia, China, New Zealand, South America, Sri Lanka. India: Andaman & Nicobar, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Aizawl District, Rungdil Lake, 1,143 m, 07.vi.2018, S. Pathak 48480 (CAL).

8. *Eleusine coracana* (L.) Gaertn., Fruct. Sem. Pl. 1: 8, pl. 1, f. 11. 1788.

Type: Plukenet, Phytographia pl. 91, f. 5 .1691.

Basionym: *Cynosurus coracanus* L., Syst. Nat. (ed. 10) 2: 875. 1759.

Phenology: March to May.

Habitat: Beside muddy river slopes.

Growth-form: Graminids.

Status: Not common.

Distribution: Tropical and sub tropical zones of the world. India: Arunachal Pradesh, Bihar, Himachal Pradesh, Jammu & Kashmir, Karnataka, Maharashtra, Meghalaya, Mizoram, Nagaland, Odisha, Tamil Nadu, and West Bengal.

Specimen examined: Mizoram, Aizawl District, way to Turial River, 1,112 m, 06.v.2018, S. Pathak 48562 (CAL).

9. *Eragrostis gangetica* (Roxb.) Steud., Syn. Pl. Glumac. 1: 266. 1854.

Type: INDIA: Native of the banks of the Ganges but scarce (*Holo*: K; *Iso*: BM).

Basionym: *Poa gangetica* Roxb., Fl. Ind., (ed.)1: 341. 1820.

Phenology: March to November.

Habitat: Beside muddy banks of lakes.

Growth-form: Graminids.

Status: Common.

Distribution: Asia, Africa, Myanmar, Sri Lanka. India: Andhra Pradesh, Bihar, Daman & Diu, Goa, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu, Uttar Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Punjab, and West Bengal.

Specimen examined: Mizoram, beside muddy slopes of Tamdil Lake, 887 m, 12.x.2017, S. Pathak 48505 (CAL).

10. *Eragrostis tenella* (L) P. Beauv. ex Roem. & Schult., Syst.Veg. 2:576.1817.

Type: Syst. Veg. (Sprengel) 2: 576. 1817.

Basionym: *Poa tenella* L., Sp. Pl. 1: 69. 1753.

Phenology: June to October.

Habitat: Grows in the moist places along rivers.

Growth-form: Graminids.

Status: Common.

Distribution: Asia, China, Malaysia, Sri Lanka. India: Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Rajasthan, Tamil Nadu, Tripura, and West Bengal.

Specimen examined: Mizoram, Kolasib District, slopes of Tlawng River, 1,508 m, 02.vii.2011, S. Pathak 48321 (CAL).

11. *Leptochloa chinensis* (L.) Nees, Syll. Pl. Nov. 1: 4. 1824.

Type: INDIA: *Osbeck* s.n. LINN- 87.32.

Basionym: *Poa chinensis* L., Sp. Pl. (ed. 1): 69. 1753.

Phenology: May to September.

Habitat: Grows in moist aquatic areas, along canals and muddy river slopes.

Growth-form: Graminids.

Status: Common.

Distribution: Africa, eastern China, southeastern Asia. India: Andhra Pradesh, Assam, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Mizoram, Nagaland, Odisha, Tamil Nadu, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Kolasib District, along Serlui River, 399 m, 05.ix.2018, S. Pathak 48489 (CAL).

12. *Panicum repens* L., Sp. Pl. (ed. 2) 1: 87. 1762.

Type: *Alstroemer* 2a; LINN-80.74.

Phenology: February to December.

Habitat: Along the fringes of rivers.

Growth-form: Graminids.

Status: Semi-common.

Distribution: Tropical and sub-tropical zones. India: Andhra Pradesh, Assam, Bihar, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Manipur, Meghalaya, Mizoram, Odisha, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Aizawl District, along banks of Tlawng River, 808 m, 06.xi.2017, S. Pathak 48542 (CAL).

13. *Paspalidium flavidum* (Retz.) A. Camus, Fl. Indo-Chine 7: 419, 1922.

Type: SRI LANKA: *König* s.n. (in Herb. Retzius) (LD).

Basionym: *Panicum flavidum* Retz., Observ. Bot. 4: 15. 1786.

Phenology: May to March.

Habitat: Grows in patches along marshy edges of lakes.

Growth-form: Ephydate/Pleustophyte/Helophyte.

Status: Scarce.

Distribution: Myanmar, Pakistan, Sri Lanka and parts of Asia, Africa. India: Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Mizoram, Odisha, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Saiha District, marshy edges of Palak lake, 370 m, 06.ix.2017, S. Pathak 48361 (CAL).

14. *Paspalum conjugatum* Bergius in Acta Helv. Phys. Math. 7: 129. t. 8. 1772.

Type: FRENCH GUIANA: Surinam, *F.W. Sieber* 127 (US).

Phenology: May to February.

Habitat: Patches along muddy crevices.

Growth-form: Graminids.

Status: Common.

Distribution: Tropical regions of the world. Africa, Asia, Australia, China, Myanmar, New Zealand, North America. Indi: Andaman & Nicobar, Arunachal Pradesh, Assam, Karnataka, Kerala, Meghalaya, Mizoram, Nagaland, Tamil Nadu, Tripura, and West Bengal.

Specimen examined: Mizoram, Serchhip District, slopes of Tuirihiau falls, 1,179 m, 10.vii.2018, S. Pathak 48360 (CAL).

15. *Paspalum scrobiculatum* L., Mant. Pl. 1: 29. 1767.

Type: INDIA (India oriental), LINN-79.4.

Phenology: Almost throughout the year.

Habitat: Moist fringes of rivers.

Growth-form: Graminids.

Status: Not common.

Distribution: Tropical regions of the world. India: Andaman, Andhra Pradesh, Assam, Arunachal Pradesh, Bihar, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Lawngtlai District, slopes of Chawngte River, 2,186 m, 05.iv.2011, S. Pathak 48556 (CAL).

16. *Phragmites karka* (Retz.) Trin. ex Steud., Nomencl. Bot. (ed. 2) 1: 144. 1840.

Type: INDIA: *Orientali vulgatissima ad tecta Indorum utitur*, *Konig* s.n. (LD).

Basionym: *Arundo karka* Retz., Observ. Bot. 4: 21. 1786.

Phenology: May to September.

Habitat: Along slopes of river fringes and muddy edges.

Growth-form: Hyperhydate.

Status: Common.

Distribution: Tropical Africa, Polynesia, Sri Lanka to southeastern Asia and northern Australia. India: Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Delhi, Gujarat, Himachal Pradesh, Jammu Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Nagaland, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Aizawl District, slopes of marshy banks of Kaladan River, 2,117 m, 10.ix.2018, S. Pathak 48575 (CAL).

17. *Saccharum spontaneum* L., Mant. Pl. 2:183. 1771.

Type: INDIA: Kerala, Malabar (*Malabariae aquosis*), *Koenig* s.n., LINN-77.1.

Phenology: May to September.

Habitat: Along the fringes of rivers.

Growth-form: Graminids.

Status: Not common.

Distribution: Africa, Asia, Australia, China, Europe. India: Arunachal Pradesh, Assam, Bihar, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Aizawl District, slopes of marshy banks of Kaladan River, 2,110 m, 10.ix.2018, S. Pathak 48443 (CAL).

18. *Sacciolepis indica* (L.) Chase in Proc. Biol. Soc. Wash. 21:8, 1908.

Type: SRI LANKA: Sabaraganamuwa Province, Ratnapura District, 22.x.1974, *Davidse & D.B. Sumithraarachehi* 7871 (K).

Basionym: *Aira indica* L., Sp. Pl. 1: 63, 1231, *in errata* after index. 1753.

Phenology: May to November.

Habitat: Along muddy river banks.

Growth-form: Graminids.

Status: Common.

Distribution: Africa, Asia, America, Australia, Brazil, China, Myanmar, New Zealand, Sri Lanka. India: Assam, Arunachal Pradesh, Bihar, Karnataka, Madhya Pradesh, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Tripura, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Kolasib District, slopes of Tlawng River, 1,598 m, 02.vii.2011, S. Pathak 48493 (CAL).

19. *Setaria pumila* (Poir.) Roem. & Schult., Syst. Veg. ed. 15(2): 891. 1817.

Type: Unknown locality (probably FRANCE or NORTH AFRICA), *Desfontaines* s.n. (P).

Basionym: *Panicum pumilum* Poir., Encycl. Suppl. 4(1): 273. 1816.

Phenology: Late February to September.

Habitat: Along the fringes and marshes of the lakes.

Growth-form: Helophyte/ Ephydate.

Status: Common.

Distribution: Tropical regions of the world (Kabeer & Nair, 2009), Bhutan, France. India: Sikkim, Tamil Nadu, West Bengal, and Mizoram (present study).

Specimen examined: Mizoram, Champhai District, on the banks of Rihdil Lake near Zokhawthar, 1,678 m, 16.vi.2016, S. Pathak 48553 (CAL).

20. *Setaria verticillata* (L.) P. Beauv., Ess. Agrostogr. 51, 171. 1812.

Type: EUROPE (*Europa australi & Oriente*).

Basionym: *Panicum verticillatum* L., Sp. Pl. (ed. 2) 1: 82. 1762.

Phenology: Almost throughout the year.

Habitat: Muddy banks of rivers.

Growth-form: Helophyte/ Ephydate.

Status: Common.

Distribution: Tropical regions of the world; Africa, Pakistan, Sri Lanka, introduced in America. India: Assam, Bihar, Madhya Pradesh, Meghalaya, Mizoram, Sikkim, Tamil Nadu, and West Bengal.

Specimen examined: Mizoram, Chhimtuipui District, slopes of Chhimtuipui River, 846 m, 02.viii.2017, S. Pathak 48559 (CAL).

21. *Setaria viridis* (L.) Peauv., Ess. Agrostogr. 51, 171, 178. 1812.

Type: EUROPE (*Europa australi*).

Basionym: *Panicum viride* L., Syst. Nat. (ed. 10) 2: 670. 1759.

Phenology: Almost throughout the year.

Habitat: Along the edges of lakes and streams.

Growth-form: Helophyte/ Ephydate.

Status: Common.

Distribution: China, Eurasia, plateau of Tibet, c. 4,000 m; cooler parts of the world. India: Assam, Arunachal Pradesh, Meghalaya, Mizoram, Nagaland, and West Bengal.

Specimen examined: Mizoram, Saiha District, slopes and edges of Palak Lake, 370 m, 06.ix.2017, S. Pathak 48537 (CAL).

22. *Sporobolus diandrus* (Retz.) P. Beauv., Ess. Agrostogr. 26, 147, 178. 1812.

Type: INDIA: *Koenig* s.n. (*Holo*: LD; *Iso*: BM, C, K, L, NSW).

Basionym: *Agrostis diandra* Retz., Observ. Bot. 5: 19. 1789.

Phenology: April to August.

Habitat: Marshes of the river banks.

Growth-form: Helophyte/Ephydate.

Status: Very Common.

Distribution: Cosmopolitan in the tropical and sub tropical regions; Mynmar, Sri Lanka extending up to Australia. India: Arunachal Pradesh, Assam, Bihar, Madhya Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Odisha, Tamil Nadu, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Lunglei district, marshes of Deh River, 1,009 m, 07.x.2018, S. Pathak 48501 (CAL).

23. *Sporobolus fertilis* (Steud.) Clayton in Kew Bull. 19: 291. 1965.

Type: JAPAN: *Burger* s.n. (*Isolecto*: K, P, L).

Basionym: *Agrostis fertilis* Steud., Syn. Pl. Glumac. 1: 170. 1854.

Phenology: April to December.

Habitat: Along river fringes and muddy slopes.

Image 1. A—Chhimtuipui River | B—Tlawng River | C—Sajek River | D—Rih Lake | E—Tamdil Lake | F—Palak Lake | G—Pala Lake | H—Plant collection. © S. Pathak.

Growth-form: Helophyte/ Ephydate.

Status: Common.

Distribution: Asia, Australia, China. India: Andaman, Andhra Pradesh, Arunachal Pradesh, Bihar, Madhya Pradesh, Meghalaya, Mizoram, Nagaland, Odisha, Tamil Nadu, Uttar Pradesh, and West Bengal.

Specimen examined: Mizoram, Lunglei District, marshes of Deh River, 1,009 m, 07.x.2018, S. Pathak 48396 (CAL).

In the current study, 16 genera having 23 species under family Poaceae (grasses) from the various wetlands of Mizoram were encountered. They were worked out taxonomically, identified and preserved. The study revealed that, the diversity of the wetland grasses observed in the concerned geographical area remained quite dissimilar to other places of India. The assemblage of the grasses in the wetlands significantly altered in accordance with the availability of soil and intensity of light. Moreover, many species exhibited a wide range of tolerance to the variations in the altitude, wind velocity and intensity of submergence. The species also showed longer culms where the height of water was higher than those in the marshy zones. Furthermore, the plant height gradually decreased with the increase in altitude. In addition to the above, the comparative account of the wetland grass species assemblage indicated variations in the richness and the abundance in accordance with the soil and slope pattern. The extent of species range and plant assemblage in close proximity of large water bodies was considerably higher than that of forested wetlands. Thus, the pattern of the assemblage in the wetlands depends on the water regime, soil nutrient content, altitude and use as observed in varied geographical locations.

CONCLUSION

The present study based on 23 wetlands grasses is purely a taxonomic approach with notes on location, type, growth form, phenology, and distribution. Extending the observations to the present context, continuous monitoring of the wetlands should be continued to retrieve the variations in the distribution of the wetland grasses and associated changes in the community structure. These kinds of revisions are always important for the studies of ecological characteristics of the wetlands, their restoration and conservation.

REFERENCES

Baruah, P.P. & C.K. Baruah (2006). An account of grasses of Kaziranga National Park with special reference to their habit characteristics and palatability. *Annals of Forestry* 14: 56–64.

Bor, N.L. (1960). *The Grasses of Burma, Ceylon, India and Pakistan*. Pergamon Press, Oxford, 767 pp.

Bridgewater, P. & R.E. Kim (2021). The Ramsar Convention on Wetlands at 50. *Nature Ecology & Evolution* 5(3): 268–270.

Christenhusz, M.J.M. & J.W. Byng (2016). The number of known plants species in the world and its annual increase. *Phytotaxa* 261: 201–217.

Guhabakshi, D.N. (1984). Flora of Murshidabad District, West Bengal, India. Scientific Publisher, Jodhpur, 176 pp.

Jain, S.K. (1986). The grass flora of India-a synoptic account of uses and phytogeography. *Nelumbo* 28: 229–240.

Judd, W.S., C.S. Campbell, E.A. Kellogg, P.F. Stevens & M.J. Donoghue (2002). *Plant Systematics: A Phylogenetic Approach*. Sinauer Associates, Sunderland, USA, 576 pp.

Karthikeyan, S., S.K. Jain, M.P. Nayar & M. Sanjappa (1989). *Florae indicae enumeratio: Monocotyledonae. Flora of India Series 4.* Botanical Survey of India, Kolkata, 288 pp.

Mukherjee, A. (1993). Reclamation of mined wasteland. *Yojana* 37: 17–18.

National Wetland Atlas: Mizoram (2010). SAC/RESA/AFEG/NWIA/ATLAS/10/2010, Space Applications Centre (ISRO). Ahmadabad, 90 pp.

Palit, D., D. Kar & A. Mukherjee (2017). Studies on Grass Flora in the Wetland of Birbhum District, West Bengal, India. *Journal of Plant Sci*ence 12(2): 59–67.

Shantz , H.L. (1954). The place of grasslands in the earth's cover. *Ecology* 35: 142–145. https://doi.org/10.2307/1931110

Stevens, P.F. (2001). Angiosperm Phylogeny Website. Version 12, July 2012. [http://www.mobot.org/MOBOT/research/APweb/. University of Missouri, St Louis.

Sreekumar, P.V. & V.J. Nair (1991). Flora of Kerala- Grasses. Botanical Survey of India, Kolkata, 470 pp.

White, R.P., S. Murray, M. Rohweder & S.D. Prince (2000). *Pilot Analysis of Global Ecosystems: Grassland Ecosystems*. World Resources Institute, Washington, 69 pp.

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COMMUNICATION

New distribution records of polyporoid fungi (Agaricomycetes: Basidiomycota) from India

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Abstract: A descriptive account of four polypore species collected from Himachal Pradesh, Punjab, and Union Territory of Chandigarh has been provided. Among these, *Fomes dahlii* Henn., *Ganoderma tsunodae* (Yasuda ex Lloyd) Sacc., and *Xanthoperenniporia maackiae* (Bondartsev & Ljub.) B.K.Cui & Xing, Ji are described as new to India and *Ganoderma tropicum* (Jungh.) Bres., as new to Himachal Pradesh and Union Territory of Chandigarh.

Keywords: Basidiocarp, basidiospores, clamp connection, Himachal Pradesh, hyphal system, medicinal mushrooms, pileus, pore, Punjab, white rot.

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Author contributions: AK has collected and worked out macro and micro-morphological details of poyporoid specimens from different parts of Punjab. She has compiled the technical description and line diagrams of the specimens studied. APS has explored the taxonomic literature for identity of the worked out specimens. He has also contributed to the draft of manuscript and photography of the specimens described presently. SA has contributed to the draft and vetting of the manuscript. ER has worked out and described the polypore specimens collected from Kullu district of Himachal Pradesh based on macro and micro-morphological characters. He has prepared the technical description and plates for identification. HK has collected the described poyporoid specimens from different parts of Himachal Pradesh. She has compiled the morphological characters and line diagrams of the specimens worked out. GSD has vetted the manuscript and confirmed the identification of specimens studied during the course of present studies.

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INTRODUCTION

Polypores or polyporoid fungi represent an artificial assemblage of wood decaying fungi classified under various orders of *Agaricomycetes* of *Basidiomycota* (Kirk et al. 2008; Mycobank 2023). These fungi are characteristic in having annual to perennial, resupinate to effused-reflexed to pileate basidiocarps with gymnocarpic hymenium and poroid hymenophore. Polypores show remarkable variation with respect to micromorphological features such as hyphal system, ancillary structures, basidia and basidiospores. These fungi play vital role in the recycling of carbon due to their ability to degrade lingo-cellulosic substances of the wood. There are reports in literature about the use of fructifications of these fungi for curing many diseases (Dai et al. 2007; Song et al. 2008; Chen et al. 2016; Singh et al. 2016).

Keeping in mind the diverse vegetation and climatic conditions exhaustive fungal forays were conducted in the different parts of Himachal Pradesh, Punjab, and Union Territory of Chandigarh. During these forays some interesting polypore fructifications were collected. Based on details pertaining to macro and micro-morphological characters and comparison with published literature (Singh & Bakshi 1961; Singh 1966; Bakshi 1971; Ryvarden & Johansen 1980; Ding 1989; Roy & De 1996; Leelavathy & Ganesh 2000; Foroutan & Vaidya 2007; Bhosle et al. 2010; Ranadive et al. 2011; Sharma 2012; Ryvarden & Melo 2014; Ranadive & Jagtap 2016; Kaur et al. 2017; Brar et al. 2018; Manoharachary et al. 2022, Vinjusha & Kumar 2022, Index Fungorum 2023; Mycobank 2023) these were identified as *Fomes dahlii* Henn., *Ganoderma tropicum* (Jungh.) Bres., *G. tsunodae* (Yasuda ex Lloyd) Sacc. and *Xanthoperenniporia maackiae* (Bondartsev & Ljub.) B.K.Cui & Xing. It is pertinent to mention here that *Fomes dahlii*, *Ganoderma tsunodae* and *Xanthoperenniporia maackiae* are recorded as new to India and *Ganoderma tropicum* as new to Himachal Pradesh and Union Territory of Chandigarh.

MATERIAL AND METHODS

The polypore fructifications were collected during the fungal forays executed in various localities of Himachal Pradesh (28–30 July 2011, 20–23 August 2011, & 02–05 April 2016), Union Territory of Chandigarh (25–28 September 2019 & 07–10 October 2019), and Punjab (15–18 December 2018) (Image 1). The details pertaining to the type and nature of the fruiting body, colour, and appearance of abhymenial and hymenial surface and margins were noted down. The collected specimens were dried in an electric drier at temperature range of 40–45°C and preserved using 1,4-dichlorobenzene in zip lock bags.

For microscopic details, crush mount and free hand section preparations were made using 3%, 5%, & 10% KOH solutions, Congo red (1% in distilled water), Phloxine (1% in distilled water), Cotton blue (1% in lactophenol), Melzer's reagent (0.5 g iodine + 1.5 g KI + 20 g chloral hydrate + 20 ml distilled water), and water. The outline of different microscopic structures was drawn using compound microscope at 100x, 400x, and 1000x with the help of camera lucida. The colour standards are cited as per Kornerup & Wanscher (1978). The identified specimens were submitted to the Herbarium, Department of Botany, Punjabi University, Patiala (PUN).

RESULTS

Fomes dahlii Henn., Aoshima,

Bull. Tokyo Sci. Mus., n.s.: 429 (1971). (Image 2)

Macroscopic characteristics: Fruiting body annual, pileate, pileus up to 16.5 × 13.2 × 1.8 cm, sub-stipitate, solitary, flabelliform; abhymenial surface laccate, concentrically zonate, rugose, greyish-brown to reddish-brown to dark brown when fresh, not changing much on drying; pilear crust very thin, covered with spore dust; hymenial surface poroid, whitish when fresh, greyish-white to yellowish-white on drying; pores suborbicular, 5–7 per mm; dissepiments up to 80 µm wide, entire; context homogenous, zonate, reddish-brown, up to 10 mm wide; tubes light brown, up to 8 mm in depth; stipe lateral, up to 5 cm long, and 4 cm wide, reddish-brown; margins acute, reddish-brown on both abhymenial and hymenial side, sterile up to 2.3 mm on hymenial side.

Microscopic characteristics: Hyphal system trimitic; generative hyphae hyaline, septate, with clamps, up to 4 µm in width, branched, thin-walled; skeleto-binding hyphae yellowish-brown to brown, aseptate, up to 6.2 µm in width, branched, thick-walled, with very narrow lumen; binding hyphae sub hyaline, aseptate, up to 3.4 µm in width, frequently branched, thick–walled, with wide lumen. Pilear crust irregular hymenioderm; cuticular elements sub clavate, thick-walled, yellowish-brown to brown, 42.6–60 × 9.6–10.2 µm, sometimes lobate. Basidia clavate to sub clavate, 14.2–15.3 × 5.1–5.7 µm, with basal clamp, tetrasterigmate; sterigmata up to 3.4 µm long. Basidiospores ellipsoid to broadly ellipsoid, 9.0–13.6 × 6.2–9.6 µm, uniguttulate, truncate at non

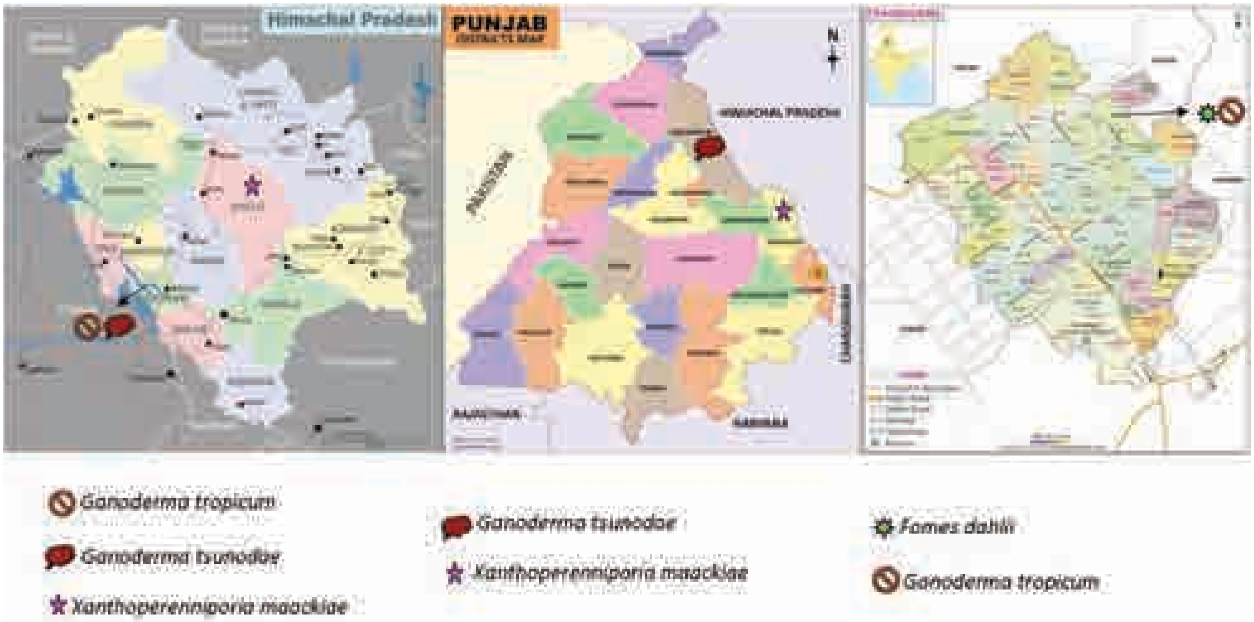

Image 1. Localities of specimen collection.

apiculate end, bitunicate, exospore thin, subhyaline, smooth, endospore thick, brownish, echinulate, tunics connected by inter-wall pillars, inamyloid, acyanophilous.

Collection examined. India, Union Territory of Chandigarh, Lake Reserve Forest, on an angiospermous stump, Avneet 11171 (PUN), 08 October 2019.

Remarks: This species is peculiar in having laccate fruiting body, homogenous context and irregular hymenioderm and causes white rot of angiospermous wood (Ryvarden & Melo 2014). Ding (1989) described it as *Ganoderma dahlii* from China, Philippines and other parts of tropical and subtropical Asia. Presently it is described as *Fomes dahlii* following Mycobank (2023) and is a new record for India.

Ganoderma tropicum (Jungh.) Bres.,

Annales Mycologici 8(6): 586 (1910) – *Polyporus tropicus* Jungh., Praemissa in floram cryptogamicam Javae insulae: 63 (1838). (Image 3)

Macroscopic characteristics: Fruiting body annual, pileate, pileus up to 5.8 × 6 × 1 cm, stipitate, solitary, sub-reniform, sub-flabelliform; abhymenial surface weakly laccate, more or less non laccate towards the margins, faintly zonate, yellowish-brown to reddish-brown when fresh, brownish-orange to violet brown on drying; pilear crust very thin; hymenial surface poroid, whitish when fresh, greyish-white to pale grey on drying; pores round to angular, 4–6 per mm; dissepiments up to 90 µm wide, entire; context homogenous, zonate, brown, up to 6 mm wide; tubes light brown to brown, up to 3 mm in depth; stipe lateral, up to 3.2 cm long, and 2.2 cm wide, violet brown; margins obtuse, brownish orange on abhymenial side and pale grey on hymenial side, sterile up to 3 mm on hymenial side.

Microscopic characteristics: Hyphal system trimitic; generative hyphae hyaline, septate, with clamps, up to 3.4 µm in width, branched, thin-walled; skeleto-binding hyphae yellowish-brown to brown, aseptate, up to 4.5 µm in width, branched, thick-walled, with very narrow lumen; binding hyphae subhyaline, aseptate, up to 3.1 µm in width, frequently branched, thick-walled, with wide lumen. Pilear crust regular hymenioderm; cuticular elements sub clavate, thick–walled, yellowish-brown to brown, 35.5–53 × 7.9–8.6 µm. Basidia not seen. Basidiospores ellipsoid, 7.3–9.6 × 4.5–6.8 µm, truncate at non apiculate end, bitunicate, exospore thin, subhyaline, smooth, endospore thick, brownish, echinulate, tunics connected by inter–wall pillars, inamyloid, acyanophilous.

Collections examined: India, Himachal Pradesh: Bilaspur, Bassi, on angiospermous stump, Harpreet 5283 (PUN), 30 July 2011; Union Territory of Chandigarh, Lake Reserve Forest, on angiospermous stump, Avneet 11172 (PUN), 08 October 2019.

Remarks: This species is characteristic in having weakly laccate fruiting body, regular hymenioderm and smaller basidiospores. It is also reported to cause white rot of hard woods (Ryvarden & Melo 2014). Previously, Vinjusha & Kumar (2022) described it from different localities of Kerala. However, it being described for the

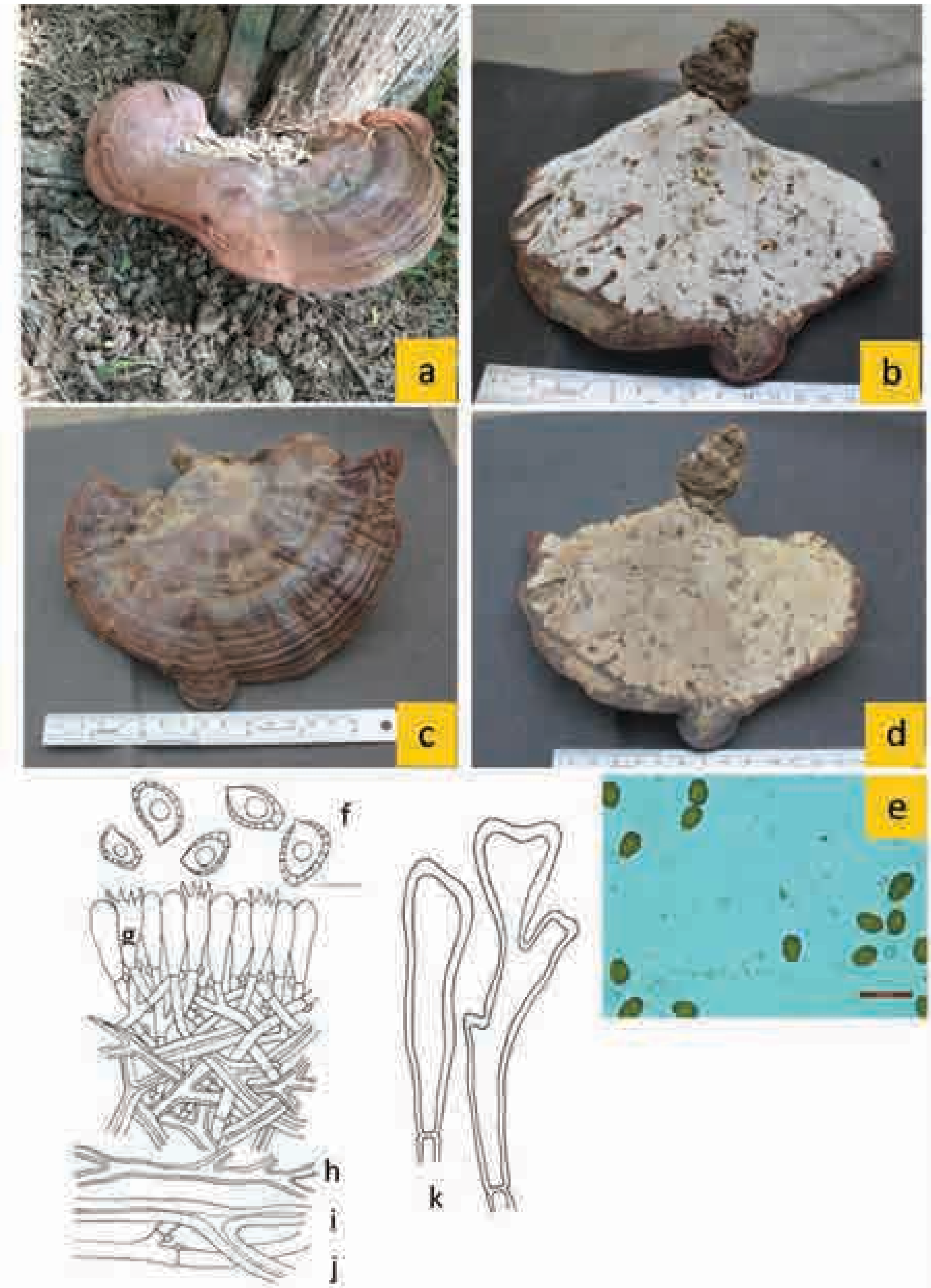

Image 2. *Fomes dahlii* (a–d fruiting body showing): a—abhymenial surface (fresh) | b—hymenial surface (fresh) | c—abhymenial surface (dry) | d—hymenial surface (dry) | e—photomicrograph showing basidiospores | f—basidiospores | g—basidia | h—binding hyphae | i—skeletobinding hyphae | j—generative hyphae | k—cuticular elements.

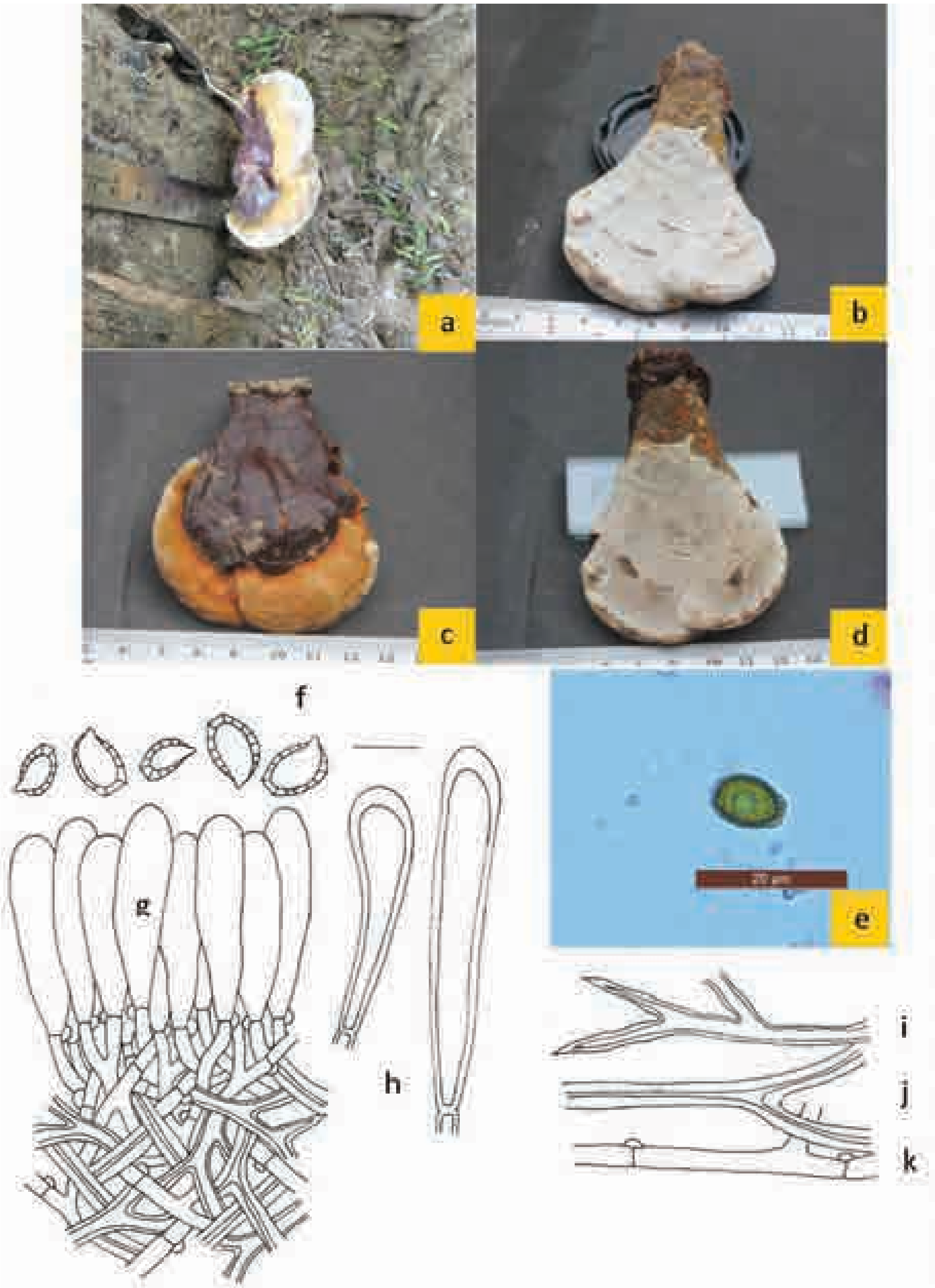

Image 3. *Ganoderma tropicum* (a–d fruiting body showing): a—abhymenial surface (fresh) | b—hymenial surface (fresh) | c—abhymenial surface (dry) | d—hymenial surface (dry) | e—photomicrograph showing a basidiospore | f—basidiospores | g—basidiole | h—cuticular element | i—binding hyphae | j—skeletobinding hyphae | k—generative hyphae.

first time from Himachal Pradesh and Union Territory of Chandigarh.

Ganoderma tsunodae (Yasuda ex Lloyd) Sacc.,

Sylloge Fungorum 23: 139 (1925) – *Polyporus tsunodae* Yasuda ex Lloyd, Mycological Writings 5(55): 792 (1918). (Image 4)

Macroscopic characteristics: Fruiting body annual, pileate, pileus up to 10 × 7.5 × 4.5 cm, sessile, solitary, somewhat fleshy, applanate; abhymenial surface non-laccate, pale yellow to light orange when fresh, not changing much on drying; hymenial surface poroid, greyish-brown to light brown when fresh, not changing much on drying; pores suborbicular, 3–4 per mm; dissepiments up to 100 µm wide, lacerate; context homogenous, yellowish-white, up to 3 mm wide; tubes greyish-brown, up to 1.4 mm in depth; margins obtuse, pale yellow on both abhymenial on hymenial side, sterile up to 1 mm on hymenial side.

Microscopic characteristics: Hyphal system trimitic; generative hyphae hyaline, septate, with clamps, up to 3.4 µm in width, branched, thin-walled; skeleto-binding hyphae yellowish-brown to brown, aseptate, up to 5 µm in width, branched, thick-walled, with very narrow lumen; binding hyphae sub hyaline, aseptate, up to 4 µm in width, frequently branched, thick-walled, with wide lumen. Pilear surface composed of agglutinated generative and skeletal hyphae. Basidia not seen. Basidiospores ovoid to broadly ellipsoid, 12.2–18.2 × 7.9–11.1 µm, uniguttulate, truncate at non apiculate end, bitunicate, exospore thin, subhyaline, smooth, endospore thick, brownish, echinulate, tunics connected by inter-wall pillars, inamyloid, acyanophilous.

Collections examined: India, Himachal Pradesh: Bilaspur, Manjari, on dried tree of *Dalbergia sissoo*, Harpreet 5566 (PUN), 22 August 2011; Punjab: Hoshiarpur, Dasuya Forest Division, on *Mangifera indica*, Avneet 11173 (PUN), 18 December 2018.

Remarks: It is characteristic in having non laccate fruiting body and comparatively larger basidiospores. It is reported to cause white rot of dead and living hardwoods and conifers (Ryvarden & Melo 2014). The former reports of this species are from China, Japan, and Taiwan (Ding 1989; Mycobank 2023).

Xanthoperenniporia maackiae (Bondartsev & Ljub.) B.K.Cui & Xing, Ji,

J. Fungi 9(2): 173 (2023) – *Fomitopsis maackiae* Bondartsev & Ljub., Botanicheskie Materialy Otdela Sporovyh Rastenij Botanicheskogo Instituti Imeni V.L. Komarova 15: 103 (1962). (Image 5)

Macroscopic characteristics: Fruiting body perennial, resupinate to effused-reflexed to pileate, pileus up to 1.7 × 1.2 × 2 cm, sessile, imbricate; abhymenial surface concentrically zonate, radially sulcate, light brown to brown when fresh, not changing much on drying; hymenial surface poroid, yellowish-white to orange white when fresh, not changing much on drying; pores round, 5–6 per mm; dissepiments up to 85 µm wide, entire; context homogenous, yellowish-white, up to 0.8 mm wide; tubes yellowish-white to orange white, indistinctly stratified, composed of two layers, each layer up to 0.6 mm in depth; margins acute, light brown on abhymenial side, yellowish white on hymenial side, sterile up to 1 mm on hymenial side.

Microscopic characteristics: Hyphal system dimitic; generative hyphae hyaline, septate, with clamps, up to 3.7 µm in width, branched, thin-walled; skeletal hyphae yellowish-brown, aseptate, up to 8.1 µm in width, thick-walled, with very narrow lumen. Cystidia absent. Basidia subclavate, 9.3–15.3 × 5.3–7.8 µm, with basal clamp, tetrasterigmate; sterigmata up to 2.5 µm long. Basidiospores ellipsoid, 5.6–7.2 × 4.3–5 µm, truncate at non apiculate end, thick-walled, subhyaline, smooth, dextrinoid, cyanophilous.

Collections examined: India, Himachal Pradesh: Kullu, Banjar, 3 km from Jalori towards Shoja, on coniferous log, Ellu 11175 (PUN), 04 April 2016; Punjab: Rupnagar, Forest Rest House, on *Dalbergia sissoo* Avneet and Avneet 11174 (PUN), 28 September 2019.

Remarks: This species is peculiar in having resupinate to effused-reflexed fructifications with dimitic hyphal system and smaller, truncate basidiospores. It was earlier placed in genus *Perenniporia* and has been reported to cause white rot (Ryvarden & Melo 2014). As per Mycobank (2023) this species is distributed in China and Russia.

DISCUSSION

Among polyporoid genera being described presently the genera *Ganoderma* and *Fomes* have received greater attention of the mycologists due to their medicinal importance (Lee 2005; Joseph et al. 2009). The genus *Ganoderma* has been documented with 58 taxa while *Fomes* sensu stricto has been reported with only two taxa across India (Ranadive et al. 2011; Sharma 2012; Ranadive & Jagtap 2016; Manoharachary et al. 2022; www.fungifromindia.com). As far as the genus *Xanthoperenniporia* is concerned, one of the species, i.e., *X. tenuis* has earlier been described under

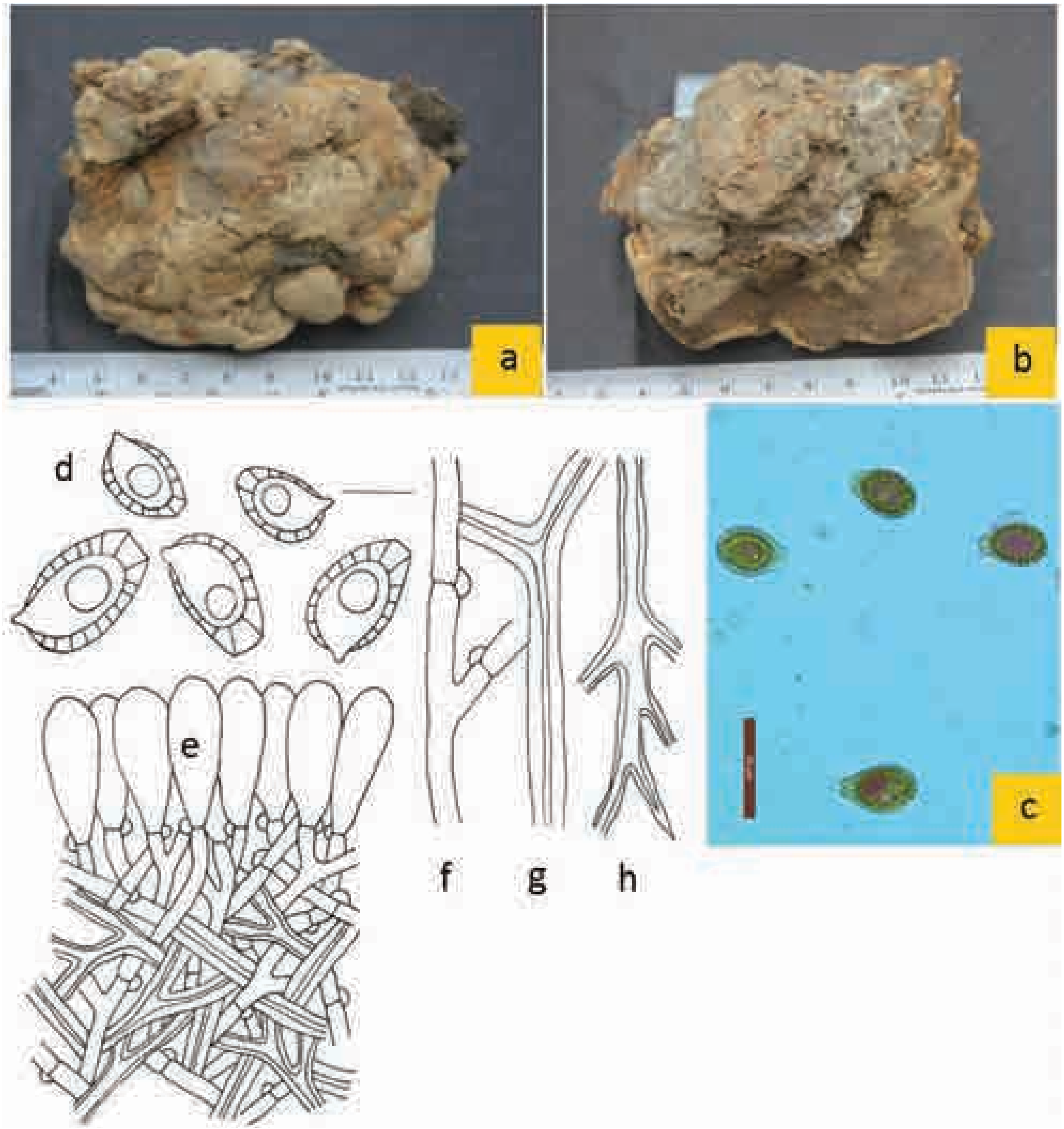

Image 4. *Ganoderma tsunodae* (a-b fruiting body showing): a—abhymenial surface | b—hymenial surface | c—photomicrograph showing basidiospores | d—basidiospores | e—basidiole | f—generative hyphae | g—skeletobinding hyphae | h—binding hyphae .

genus *Perenniporia* from India. The review of literature indicated account of 27 taxa of genus *Ganoderma* and one taxon each of genus *Fomes* and *Xathoperenniporia* from Himachal Pradesh, Punjab and Union Territory of Chandigarh. The present studies have added one species each to the list of Indian records of the genus *Ganoderma, Fomes*, and *Xanthoperenniporia* while *Ganoderma tropicum* has been described as new to Himachal Pradesh and Union Territory of Chandigarh.

REFERENCES

Bakshi, B.K. (1971). Indian *Polyporaceae* (On trees and timber). *ICAR Publication, New Delhi*, 246 pp.

Bhosle, S.R., K. Ranadive, G. Bapat, S. Garad, G. Deshpande & J. Vaidya (2010). Taxonomy and diversity of *Ganoderma* from the Western parts of Maharashtra (India). *Mycosphere* 1(3): 249–262.

Brar, J.K., R. Kaur, G. Kaur, A.P. Singh & G.S. Dhingra (2018). Taxonomic notes on the genus *Ganoderma* from Union Territory of Chandigarh. *Kavaka* 51: 35–48.

Chen, S.Y., C.L. Chang, T.H. Chen, Y.W. Chang & S.B. Lin (2016).

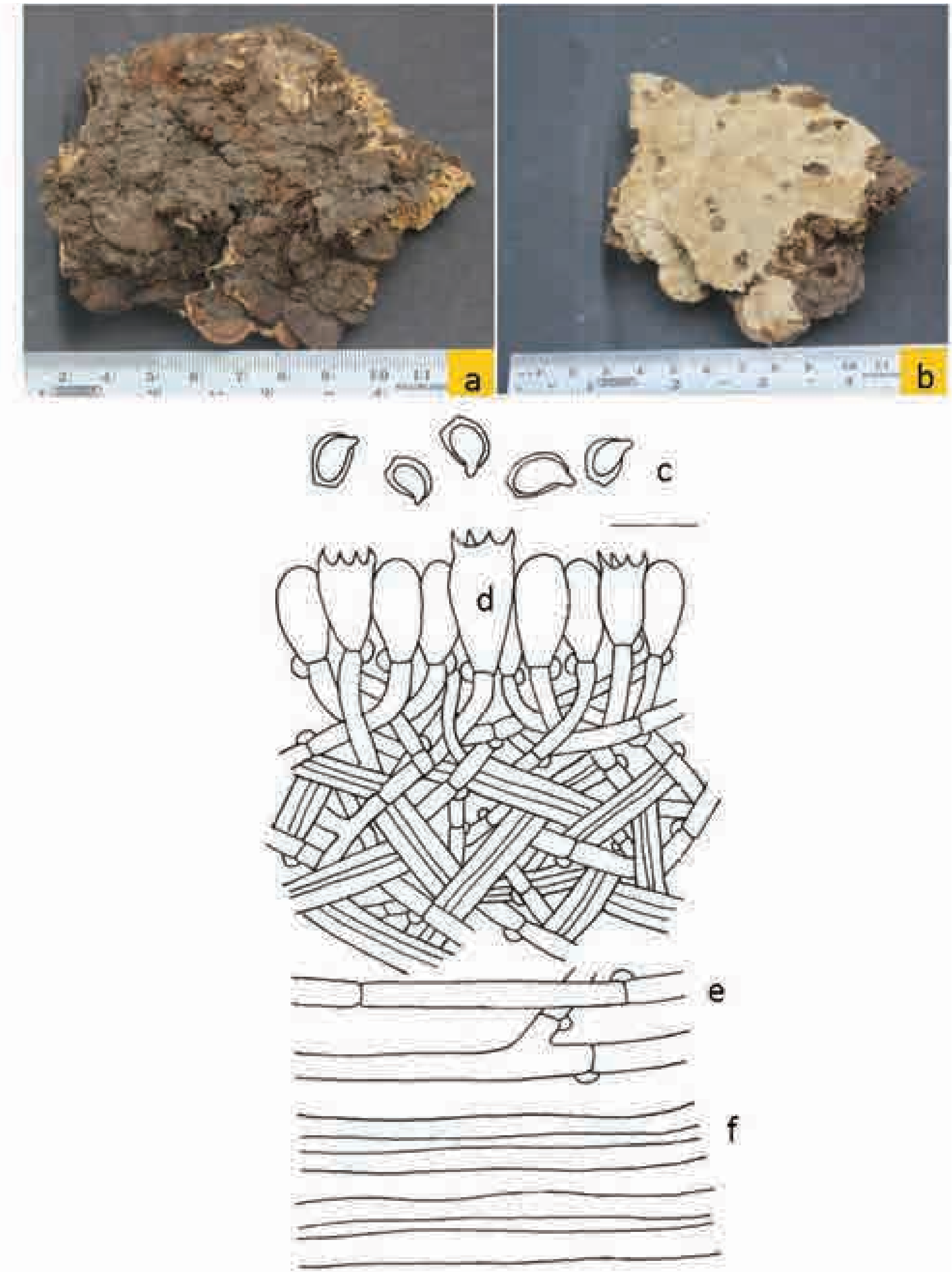

Image 5. *Xanthoperenniporia maackiae* (a–b fruiting body showing): a—abhymenial surface | b—hymenial surface | c—basidiospores | d—basidia | e—generative hyphae | f—skeletal hyphae.

Colossolactone H, a new *Ganoderma* triterpenoid exhibits cytotoxicity and potentiates drug efficacy of gefitinib in lung cancer. *Fitoterapia.* 114: 81–91. https://doi.org/10.1016/j.fitote.2016.08.015

Dai, Y.C., B.K. Cui, H.S. Yuan & B.D. Li (2007). Pathogenic wood-decaying fungi in China. *Forest Pathology* 37: 105–120. https://doi.org/10.1111/j.1439-0329.2007.00485.x

Ding, Z.H. (1989). *The Ganodermataceae in China*. Mycologica, 175 pp.

Foroutan, A. & J.G. Vaidya (2007). Records of New species of Ganoderma in Maharashtra, India. *Asian Journal of Plant Sciences* 6(6): 913–919.

Fungi from India (2023). Indian Aphyllofungal Database. [Accessed: 27 March, 2023] http://www.fungifromindia.com/

Index Fungorum (2023). http://www.indexfungorum.org/names/Names.asp Accessed on 27 March2023.

Joseph, S., B. Sabulal, V. George, T.P. Smina & K.K. Janardhanan (2009). Antioxidative and anti - inflammatory activities of the chloroform extract of *Ganoderma lucidum* found in South India. *Scientia Pharmaceutica* 77(1): 111–122.

Kaur, G., A.P. Singh & G.S. Dhingra (2017). Diversity of the genus *Ganoderma* in Punjab (India). *Mycobiota* 7: 25–49.

Kirk, P.M., P.F. Cannon, D.W. Minter & J.A. Stalpers (2008). *Ainsworth & Bisby's Dictionary of the Fungi*. Centre for Agriculture and Biosciences International, Wallingford, United Kingdom, 771 pp.

Kornerup, A. & J.H. Wanscher (1978). *Metheun's Handbook of colours, 3rd Ed.* Metheun & Co. Ltd., London, 252 pp.

Lee, J.S. (2005). Effects of *Fomes fomentarius* supplementation on antioxidant enzyme activities, blood glucose, and lipid profile in streptozotocin-induced diabetic rats. *Nutrition Research* 25(2): 187–195. https://doi.org/10.1016/j.nutres.2005.01.001

Leelavathy, K.M. & P.N. Ganesh (2000). *Polypores of Kerala*. Daya Publishing House, Delhi, 166 pp.

Manoharachary, C., N.S. Atri, T.P. Devi, D. Kamil, S.K. Singh & A.P. Singh (2022). *Bilgrami's fungi of India list and references (1988–2020)*. Today and Tomorrow, New Dehli, 412 pp.

MycoBank (2023). Fungal database. Nomenclature and species banks. [Accessed: 27 March, 2023] ww.mycobank.org

Ranadive, K.R. & N.V. Jagtap (2016). Checklist of *Ganoderma* P. Karst. (*Ganodermataceae*) from India, pp. 45–48. International Conference on Plant Research and Resource Manangement and 25th APSI meet Silver Jubliee Scientists meet. Anekkant Education Society, Tuljaram Chaturch and College, Baramati.

Ranadive, K.R., J.G. Vaidya, P.K. Jite, V.D. Ranade, S.R. Bhosle, A.S. Rabba, M. Hakimi, G.S. Deshpande, M.M. Rathod, A. Forutan, M. Kaur, , C.D.N. Vaidya, G.S. Bapat & P. Lamrood (2011). Checklist of *Aphyllophorales* from the Western Ghats of Maharashtra State, India. *Mycosphere* 2: 91–114.

Roy, A. & A. De (1996). *Polyporaceae of India*. International Book Distributors, Dehradun, Uttrakhand, India, 309 pp.

Ryvarden, L. & I. Johansen (1980). *A preliminary Polypore flora of East Africa*. Fungiflora, Oslo, 636 pp.

Ryvarden, L. & I. Melo (2014). *Poroid Fungi of Europe*. Fungiflora 31: 455 pp.

Sharma, J.R. (2012). *Aphyllophorales* of Himalaya (*Auriscalpiaceae*, *Tremellodendropsis*). Botanical Survey of India, Ministry of Environment and Forests, Kolkata, India, 590 pp.

Singh, B. (1966). Timber decay due to five species of *Fomes* as new records in India. *Indian Forester* 92: 653 – 655.

Singh, B. & B.K. Bakshi (1961). New records of *Fomes* from India. *Indian Forester* 87(5): 302–304.

Singh, R., G.S. Dhingra & R. Shri (2016). Evaluation of antianxiety potential of four *Ganoderma* (*Agaricomycetes*) species from India in mice. *International Journal of Medicinal Mushrooms* 18(11): 991–998.

Song, Y., J. Hui, W. Kou, R. Xin, F. Jia, N. Wang, F. Hu, H. Zhang & H. Liu (2008). Identification of *Inonotus obliquus* and analysis of antioxidation and antitumor activities of polysaccharides. *Current Microbiology* 57: 454–462. https://doi.org/10.1007/s00284-008-9233-6

Vinjusha, N. & T.K.A. Kumar (2022). *The Polyporales of Kerala*. SporePrint Books, Calicut, Kerala, India, 229 pp.

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SHORT COMMUNICATION

Odonate fauna (Insecta: Odonata) of Kashmir, Jammu & Kashmir, India: a preliminary report

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Abstract: The current study was conducted to investigate the variety of Odonata in Kashmir from November 2020 to November 2022. The study revealed the existence of 24 species, which includes 18 species of Anisoptera (dragonflies) under eight genera & two families and six species of Zygoptera (damselflies) in five genera & three families. New records of four species *Orthetrum sabina* (Drury, 1770), *O. internum* McLachlan, 1894, *Aeshna petalura* Martin, 1906, and *Anax guttatus* (Burmeister, 1839) from the region are provided herewith. Libellulidae (12 spp.) followed by Aeshnidae (six spp.) were recorded as two dominant families. This study provides some important baseline information on the odonates of Kashmir, Jammu & Kashmir, India.

Keywords: Anisoptera, bioindicators, diversity, damselflies, dragonflies, new record, Zygoptera.

Odonates (damselfies and dragonfies) are an primitive winged insect group order with origins in the Carboniferous era about 250 million years ago (Grimaldi & Engel 2005; Tiple et al 2022). They are well-known for their colourful bodies, enormous body size, and association with aquatic surroundings. Except for Antarctica, all continents have odonates, with tropical forests having the highest species richness. (Kalkman et al. 2008). Odonates as being top predators both at larval and adult stages play an important role in both aquatic and terrestrial food chain (Sharma et al. 2007; Tiple et al 2012). They are effective biocontrol agents of mosquitoes, sand flies, stable flies having medical and veterinary importance and harmful insects of crops, orchards and foresthaving agricultural importance (Das et al. 2012; Tiple & Koparde 2015).Odonata are reliable indicators of overall ecosystem health, since they are highly sensitive to environmental changes (Andrew et al. 2008; Tiple & Chandra 2013). Globally 6,392 species of odonates have been described belonging to 693 genera and 18 families (Schoor & Paulson 2023) of which Indian fauna is represented by 498 species in 154 genera and 18 families (Subramanian & Babu 2020).Indian Himalaya has 257 species in 112 genera and 18 families (Subramanian & Babu 2018).

The earliest studies on the odonates of Kashmir was carried out by Calvert (1898) who reported 15 species, which was later updated by Fraser (1933, 1934, 1936) to 21 species. Further studies were added by Singh & Baijal (1954), Chowdhary & Das (1975), and Asahina (1978). In recent years, the odonate fauna has been explored by Riyaz & Sivasankaran (2021) who reported 10 species from Hirpora Wildlife Sanctuary, Shopian, Kashmir and Qureshi et al. (2022) reported 11 species from district Pulwama, Kashmir.

Regional documentation of odonates is important for their long-term conservation and management and to

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study other different aspects of the taxa like taxonomy, biology, ecology, behavior and biogeography. So, the present study was conducted to study Odonata fauna of Kashmir, J&K, India.

Materials and Methods

Study Area

Kashmir, province of Union Territory of Jammu & Kashmir is the northwestern part of Himalaya bounded by Pir Panjal Range from the south-west and Great Himalaya from the north-east. The area of the valley is 15,853 km^2 and geographically it lies between 33.30–34.40° N and 73.45–75.35° E. The average elevation level is 1,666 m although the surrounding mountains are at 3,000–4,250 m. The climate of the valley is temperate and has four distinct seasons (Winter, Spring, Summer, and Autumn). Kashmir is with vast and variety of aquatic and terrestrial resources manifested in the form of rivers, streams, lakes, ponds, wetlands, forests, and meadows. The present study was conducted across the Kashmir valley and 14 sites were selected on the basis of altitude encompassing different ecosystems like rivers, streams, lakes, ponds, wetlands, paddy fields, agricultural fields, forests, meadows, gardens, and parks (Figure 1).

Methods

The odonates of Kashmir were studied monthly from November 2020 to November 2022. All surveys and samplings were carried out during sunny days using a combination of direct search technique (Sutherland 1996) and opportunistic sighting methods. The photographs of the species were taken using Canon EOS 200D II with 250 mm lens. The identification of species was done using taxonomic literature (Fraser 1933, 1934, 1936) and field guides (Subramanian 2009). For species nomenclature and classification, Kalkman et al. (2020) and Subramanian & Babu (2017) were followed. Based on the frequency of sighting, species were locally 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% (Adarsh et al. 2014).

Results and Discussion

A total of 24 species belonging to two suborders under 13 genera and five families were recorded during the present study (Table 1, Image 1). Zygoptera (damselflies) is represented by six species under five genera and three families while Anisoptera (dragonflies)

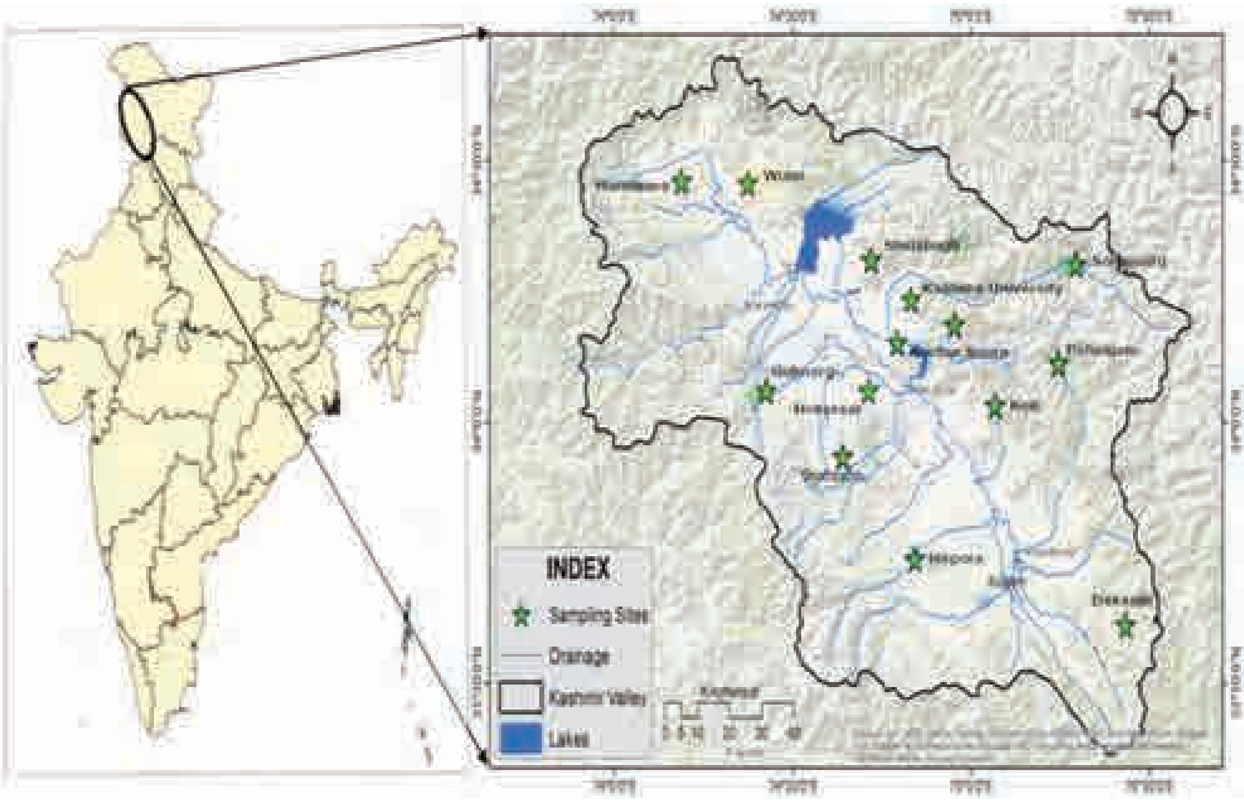


Figure 1. Study area with sampling sites.

Image 1. A—*Megalestes major* | B—*Sympecma paedisca* | C—*Ischnura inarmata* | D—*Lestes barbarus* | E—*Ischnura forcipata* | F—*Enallagma cyathigerum* | G—*Crocothemis servilia* | H—*Orthetrum brunneum* | I—*Orthetrum triangulare* | J—*Orthetrum luzonicum* | K—*Orthetrum glaucum* | L—*Orthetrum internum* | M—*Orthetrum sabina* | N—*Sympetrum commixtum* | O—*Sympetrum fonscolombii* | P—*Sympetrum striolatum* | Q—*Libellula quadrimaculata* | R—*Pantala flavescens* | S—*Aeshna mixta* | T—*Trithemis aurora* | U—*Aeshna petalura* | V—*Anax parthenope* | W—*Anax guttatus* | X—*Aeshna juncea*.

by 18 species under eight genera and two families. The Libellulidae was the most dominant family with 12 species followed by Aeshnidae with six species among the Anisoptera. Coenagrionidae represented the most prevalent family of Zygoptera constituting three species followed by Lestidae and Synlestidae each with two and one species respectively. Among these 24 species, 20 are already reported while four species *Orthetrum sabina* (Drury, 1770), *Orthetrum internum* McLachlan, 1894, *Anax guttatus* (Burmeister, 1839), and *Aeshna petalura* Martin, 1906 are reported first time from Kashmir, India.

On the basis of occurrence of 24 species, six were found to be Very Common; seven species were Common, nine species to be Occasional while two species were

Table 1 . Species recorded during the present study.

	Family /Scientific name	Observed frequency class	IUCN Red List status
	Lestidae		
01	*Lestes barbarus* (Fabricius, 1798)	OC	LC
02	*Sympecma paedisca* (Brauer, 1877)	C	LC
	Synlestidae		
03	*Megalestes major* Selys, 1862	OC	LC
	Coenagrionidae		
04	*Ischnura inarmata* Calvert, 1898	VC	DD
05	*Ischnura forcipata* Morton, 1907	OC	LC
06	*Enallagma cyathigerum* (Charpentier, 1840)	OC	LC
	Libellulidae		
07	*Orthetrum sabina* (Drury, 1770)	OC	LC
08	*Orthetrum triangulare* (Selys, 1878)	C	LC
09	*Orthetrum glaucum* (Brauer, 1865)	C	LC
10	*Orthetrum luzonicum* (Brauer, 1868)	OC	LC
11	*Orthetrum internum* McLachlan, 1894	R	Unknown
12	*Orthetrum brunneum* (Fonscolombe, 1837)	C	LC
13	*Crocothemis servilia* (Drury, 1770)	VC	LC
14	*Libellula quadrimaculata* Linnaeus, 1758	OC	LC
15	*Sympetrum commixtum* Selys, 1884	VC	LC
16	*Sympetrum striolatum* (Charpentier, 1840)	VC	LC
17	*Sympetrum fonscolombii* (Selys, 1840)	VC	LC
18	*Pantala flavescens* (Fabricius, 1798)	VC	LC
	Aeshnidae		
19	*Anax parthenope* (Selys, 1839)	OC	LC
20	*Anax guttatus* (Burmeister, 1839)	C	LC
21	*Trithemis aurora* (Burmeister, 1839)	R	LC
22	*Aeshna petalura* Martin, 1906	OC	LC
23	*Aeshna mixta* Latreille, 1805	C	LC
24	*Aeshna juncea* (Linnaeus, 1758)	C	LC

LS—Least Concern I DD—Data Deficient I VC—Very Common I C—Common I OC—Occasional I R—Rare.

Rare. Among Zygoptera, *Ischnura inarmata* Calvert, 1898 was found to be the most common species. Among the dragonflies *Pantala flavescens* (Fabricius, 1798), *Crocothemis servilia* (Drury, 1770), *Sympetrum commixtum* Selys, 1884, *Sympetrum fonscolombii* (Selys, 1840), and *Sympetrum striolatum* (Charpentier, 1840) were the most common species and *Trithemis aurora* (Burmeister, 1839) and *Orthetrum internum* McLachlan, 1894 were recorded as rare species.

Odonates are an ecologically significant insect group, hence their conservation is critical. Aquatic ecosystems in Kashmir are at high risk of vulnerability due to anthropogenic pressures such as deforestation, encroachment, pollution, and changes in land use patterns. It is critical to raise public awareness and reduce anthropogenic pressures in order to conserve the habitats of these important insects (Sánchez-Bayo & Wyckhuys 2019). As this is a preliminary survey of odonate fauna of Kashmir, we hence recommend more studies to be taken to assess this important group in all aspects like taxonomy, biology, ecology and behavior and biogeography.

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

Asahina, S. (1978). A new and some known species of Odonata from Kashmir. *Senckenbergiana Biologica* 59(1–2): 115–120.

Calvert, P.P. (1898). Odonata (dragonflies) from the Indian Ocean, and from Kashmir, collected by Dr. W.L. Abbott. *Proceedings of the Academy of Natural Sciences of Philadelphia* 50: 141–154.

Chowdhary, S.K. & S.M. Das (1975). Notes on the life history *Coenagrion kashmirus* n. sp. Odonata: Zygoptera: Coenagriidae. 3rd All India Congress of Zoology 60–61.

Das, S.K., R.A. Ahmed, S.K. Sajan, N. Dash, P. Sahoo, P. Mohanta, H.K. Sahu, S.D. Rout & S.K. Dutta (2012). Diversity, distribution and species composition of Odonates in buffer areas of Similipal Tiger Reserve, Eastern Ghats, India. *Academic Journal of Entomology* 5(1): 54–61.

Fraser, F.C. (1933). *Fauna of British India Odonata* 1. Taylor and Francis Ltd. London, 423 pp.

Fraser, F.C. (1934). *Fauna of British India Odonata* 2. Taylor and Francis Ltd. London, 398 pp.

Fraser, F.C. (1936). *Fauna of British India Odonata* 3. Taylor and Francis Ltd. London, 461 pp.

Grimaldi, D.A. & M.S. Engel (2005). *Evolution of the Insects*. Cambridge University Press, 772 pp.

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 Srilanka. *Zootaxa* 4849(1): 001–084. https://doi.org/10.11646/zootaxa.4849.1.1

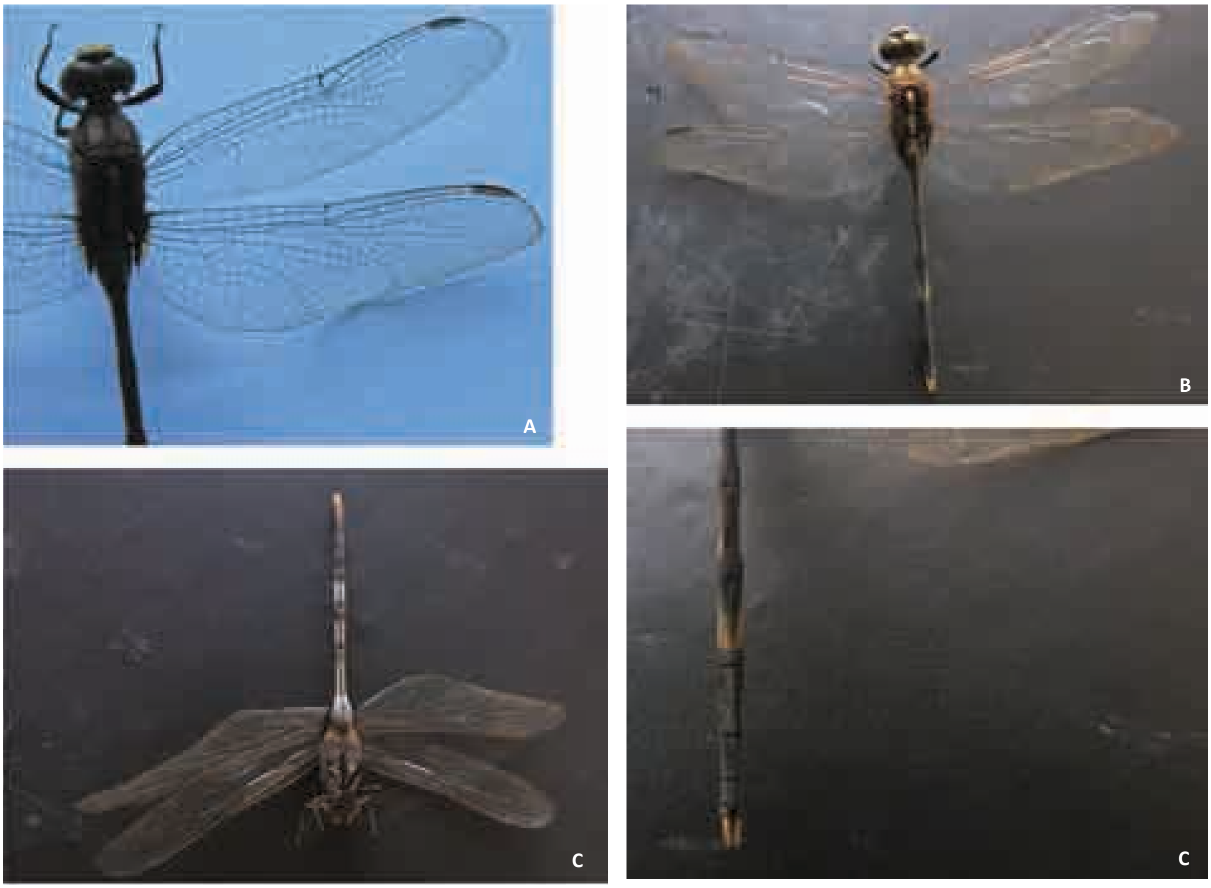
Kalkman, V.J., V. Clausnitzer, K.D.B. Dijkstra, A.G. Orr, D.R. Paulson & J. van Tol (2008). Global diversity of dragonflies (Odonata) in freshwater. *Hydrobiologia* 595(1): 351–363. https://doi.org/10.1007/s10750-007-9029-x

Qureshi, A.A., N.A. Paray, R.M. Khandi, S. Syeed & R.A. Ganai (2022). Diversity of Odonata of District Pulwama of Kashmir. *Indian Journal of Entomology* 1–4. https://doi.org/10.55446/IJE.2021.131

Riyaz, M. & K. Sivasankaran (2021). A preliminary survey of Dragonflies and Damselflies (Insecta: Odonata) in and around Hirpora Wildlife Sanctuary Shopian, Kashmir. *Egyptian Academic Journal of Biological Sciences (A. Entomology)* 14(1): 133–139. https://doi.org/10.21608/EAJBSA.2021.157352

Sánchez-Bayo, F. & K.A.G Wyckhuys (2019). Worldwide decline of the entomofauna: A review of its drivers. *Biological Conservation* 232: 8–27. https://doi.org/10.1016/j.biocon.2019.01.020

Schorr, M. & D. Paulson (2023). World Odonata List. http://www.pugetsound.edu/academics/academic-resources/slater-museum/biodiversity-resouces/dragonflies/world-odonata-list2/. Accessed 20 April 2023.



Supplementary data (*Ortherum Sabina*): A—forewing and hindwing | B—dorsal side | C—ventral side | D—abdomen. © Nisar Paray.

Sharma, G. & P.C. Joshi (2007). Diversity of Odonata (Insecta) from Dholbaha Dam (Distt. Hoshiarpur) in Punjab Shivalik, India. *Journal of Asia-Pacific Entomology* 10(2): 177–180. https://doi.org/10.1016/S1226-8615(08)60350-7

Singh, S. & H.N. Baijal (1954). Entomological Survey of the Himalayas II-on a collection of Odonata. *Agra University Journal Research(Science)* 3(2): 385–400.

Subramanian, K.A. & R. Babu (2017). *Checklist of Odonata (Insecta) of India. Version 3.0. Zoological Survey of India*, Kolkata, 51 pp.

Subramanian, K.A. & R. Babu (2018). Insecta: Odonata, pp. 227–240. In: Chandra, K., D. Gupta, K.C. Gopi, B. Tripathy & V. Kumar (eds.). *Faunal Diversity of Indian Himalaya*. Zoological Survey of India, Kolkata, 872 pp.

Subramanian, K.A. & R. Babu (2020). Dragonflies and Damselflies (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, 450 pp.

Subramanian, K.A. (2009). *Dragonfies and Damselfies of Peninsular India - A Field Guide.* Vigyan Prasar, Noida, India, 168 pp.

Sutherland, W.J. (1996). *Ecological Census Techniques:* A Handbook. Cambridge University Press, UK, 200 pp.

Tiple, A.D. & P. Koparde (2015). Odonata of Maharashtra, India with Notes on Species Distributon. *Journal of Insect Science* 15(1): 1–10. https://doi.org/10.1093/jisesa/iev028

Tiple, A.D. & K. Chandra (2013). Dragonfies and Damselfies (Insecta, Odonata) of Madhya Pradesh and Chhatsgarh States, India. *Care 4Nature* 1(1): 2–11.

Tiple, A.D., R.J. Andrew, K.A. Subramanian & S.S. Talmale (2013). Odonata of Vidarbha region, Maharashtra state, central India. *Odonatologica* 42: 237–245.

Tiple, A.D., S. Paunikar & S.S. Talmale (2012). Dragonfies and Damselfies (Odonata: Insecta) of Tropical Forest Research Insttute, Jabalpur, Madhya Pradesh, central India. *Journal of Threatened Taxa* 4(4): 2529–2533. https://doi.org/10.11609/JoTT.o2657.2529-33

Tiple, A., V. Sharma & S.V. Padwad (2022). Dragonfies and damselfies (Insecta: Odonata) of Jabalpur, Madhya Pradesh, India. *Journal of Threatened Taxa* 14(2): 20740–20746. https://doi.org/10.11609/jot.7306.14.3.20740-20746

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NOTE

Record of Himalayan Marmot *Marmota himalayana* (Hodgson, 1841) (Rodentia: Sciuridae) from Arunachal Pradesh, India

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The mammalian family of Sciuridae includes squirrel species that are adapted to different habitats. Based on their adaptations, they are classified as tree squirrels, gliding squirrels, and ground squirrels. The particular tribe Marmotini, which includes the burrow-dwelling ground species has 13 genera comprising a total of 95 species (Thorington et al. 2012). The species, Himalayan Marmot *Marmota himalayana*, has a large range that extends over a vast area in the mountains of southern Asia, including the Kuenlun, Arkatag, Altyn Tagh, and Nan Shan mountain ranges, the Tibetan Plateau, Sikkim, and Bhutan (Sclater 1891; Bobrinskii 1937; Gromov et al. 1965; Sibo & Ganyun 1983; Bibikov 1989; Nikol'skii et al. 2006). In India, the species occurs in Ladakh, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh.

The present study was carried out in high-altitude grasslands near Mago village of Thingbu Tehsil of Tawang district Arunachal Pradesh (Figure 1). Mago is situated at around 3,600 m elevation and the grasslands are at around 4,000 m elevation where the marmots occur. This particular observation was carried out at Zithang (27.733700°N, 92.285867°E, 4,100 m). Throughout the year, there is no absolute frost-free period. The area is undulating with mountains surrounding the whole area (Image 1). The river that flows in the region is locally known as Yechum. The grasslands are used as grazing lands by the Yak-herders of Brokpa community (Brokpa people are a sect of the Monpa people, who rear livestock such as yak, dzo and sheeps, and live a nomadic lifestyle).

We trekked from the village of Mago to Zithang (Image 2). It took around four hours to reach Zithang. After reaching Zithang, we took shelter in a temporary makeshift tent. Visual observations were made using binoculars (Nikon Prostaff 3S 10x42). The observations were recorded using a camera (Nikon D500).

During our stay at the place, we observed that, when the weather was gloomy, marmots do not come out frequently. But when the weather was clear they spend most of the time, foraging, grooming, and playing (Image 3). We also documented Himalayan Marmots foraging on grass (Image 4). We also documented them coming out from the burrows, taking a mouthful of grass, and again going back to the burrows (Image 5). This can be

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Competing interests: The authors declare no competing interests.

Ethical statement: This study was conducted with permission from the village headmen of the village of Mago. We followed all guidelines for animal care and scientific research ethics.

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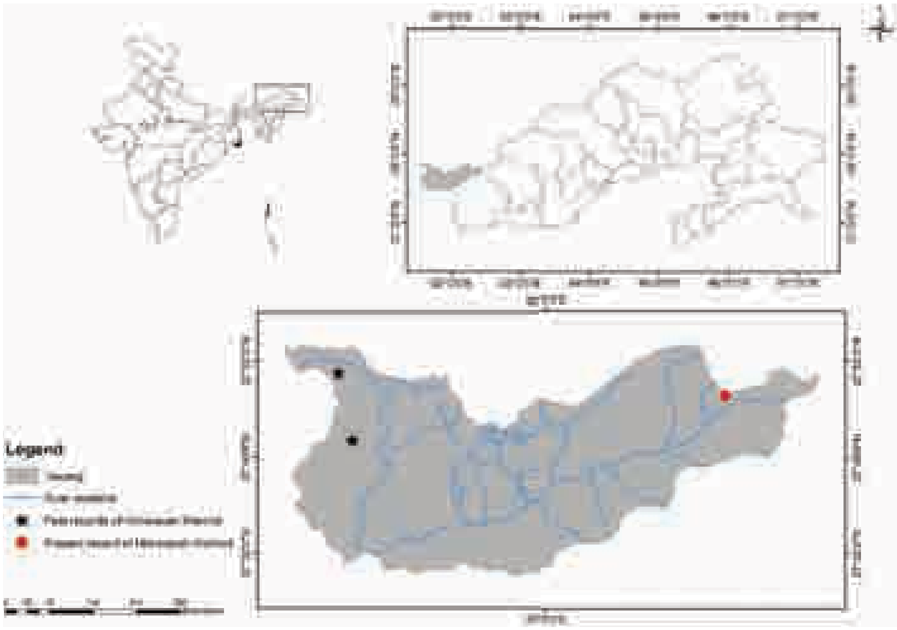

Figure 1. Map of the study area along with past and present records of Himalayan Marmot from Arunachal Pradesh.

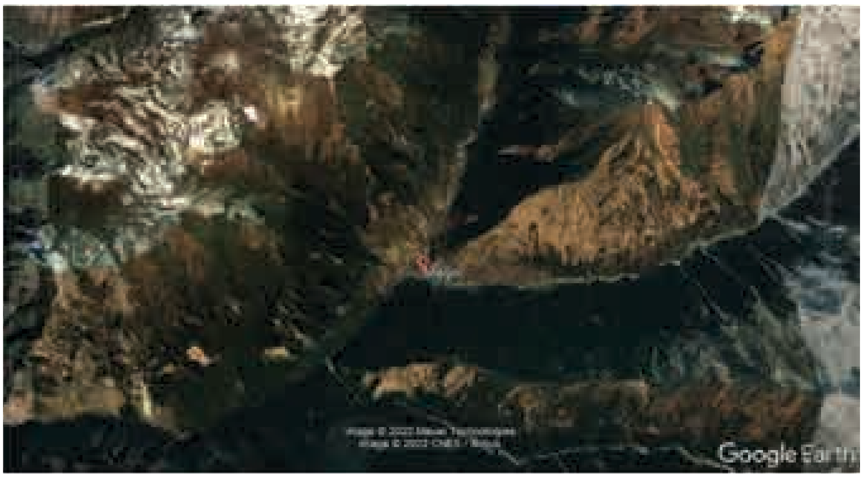

Image 1. Terrain map of Mago.

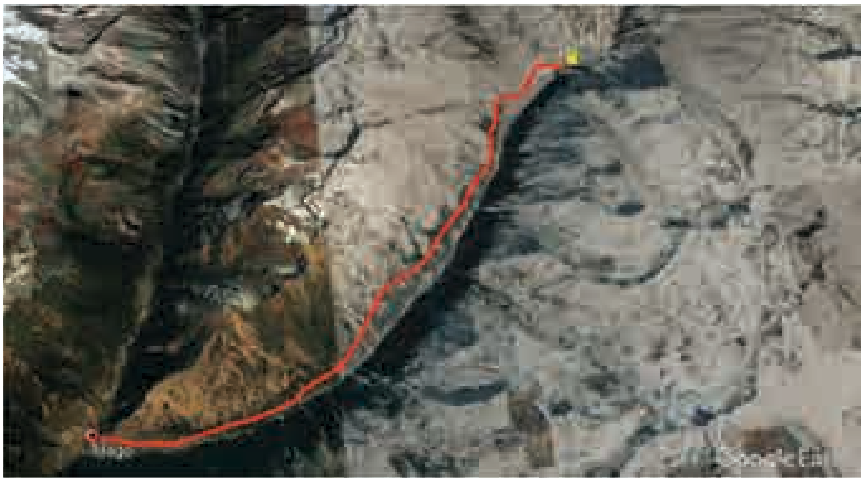

Image 2. Trail from Mago to Zithang.

Image 3. A curious Himalayan Marmot.

Image 4. A foraging Himalayan Marmot.

Image 5. A burrow of Himalayan Marmot.

Image 6. A yak-herding dog.

indicative of preparedness for the harsh winters.

Himalayan Marmot locally in Dirang Monpa (language) is known as 'Gomchen Chikpa' (Gomchen meaning hermit). When asked about why it is called so, they told that since they are not seen during the winters (because they hibernate), they are thought to be meditating in the burrows, like a hermit. As the inhabitants of the region predominantly follow Tibetan Buddhism, they usually do not hunt. But there are reports of using marmots in the preparation of ethnomedicines (Mishra et al. 2006). The fat of the animal is used as a pain reliever. The fat is melted and rubbed in the area of pain. The skin of the animal is also used as a pain-relieving belt and wrapped around the area of pain to get relief from pain. The high-altitude grasslands are used as grazing places for livestock by the Brokpa people. In order to organise and control large numbers of livestock and to protect them from potential predators, herding dogs are used (Image 6). During our visit to the grasslands, we were reported instances of dogs predating on marmots.

There is scanty information available for Himalayan Marmot from Arunachal Pradesh. There are no historical reports of the species in the state, according to previous literature, including works by Ellerman (1961), Alfred et al. (2006), and De et al. (2006). Mishra et al. (2006) recorded the presence of the species in Tawang and West Kameng districts. In the CAMP report, Molur et al. (2005), recorded its occurrence from Manmagyalem and Tawang, the same is followed by Srinivasulu & Srinivasulu (2012) and Menon (2014). However, in the chapter on Sciurids in Mammals of South Asia (Datta & Nandini 2015), there is no mention of any occurrence of the marmot species from Arunachal Pradesh. Therefore, this is the first study that has presented photographic evidence of the species from Arunachal Pradesh.

Conclusion

Though Himalayan Marmot occurs in different areas of India, no systematic work has been done till now to assess their population status and distribution of Himalayan Marmots, let alone in the state of Arunachal Pradesh. So, proper research is needed to fill the knowledge gaps for planning conservation measures for these beautiful creatures.

References

Alfred, J.R.B., Ramakrishna & M.S. Pradhan (2006). Validation of Threatened mammals of India. (Published by the Director, *Zoological Survey of India*, Kolkata), 158 pp.

Bibikov, D.I. (1989). *Surki (The Marmots)*, Agroprom Press, Moscow, 255 pp.

Bobrinskii, N.A. (1937). A Review of Eurasian Marmots (genus Marmota), *in Pamyati akademika M.A. Menzbira (In Memory of Academician M.A. Menzbir)*, Moscow: Akademii Nauk SSSR, 51–68.

Datta, A. & R. Nandini (2015). Sciurids, pp. 513–573. In: Johnsingh, A.J.T. & N. Manjrekar (eds). *Mammals of South Asia Vol. 2*: Universities Press (India), 739 pp.

De, J.K., A.K. Mandal & M.K. Ghosh (2006). Mammals in Fauna of Arunachal Pradesh, State Fauna Series 13 (Part-1) (Published by the Director, *Zoological Survey of India*, Kolkata), 21–68.

Ellerman, J.R. (1961). *The Fauna of India including Pakistan, Burma and Ceylon. Mammalia (Rodentia). 2nd Edition*. Zoological Survey of India, Calcutta, vol. 3 (Part I): 482 pp.

Gromov, I.M., D.I. Bibikov, N.I. Kalabukhov & M.N. Meier (1965). Fauna SSSR. Mlekopitayushchie. Nazemnye belich'i (Marmotinae) [(Fauna of the Soviet Union. Mammals. Ground Squirrels (Marmotinae)], Moscow: Nauka, 464 pp.

Menon, V. (2014). *Indian Mammals- A Field Guide.* Hachette Book Publishing India, 528 pp.

Mishra, C., M.D. Madhusudan & A. Datta (2006). Mammals of the high altitudes of western Arunachal Pradesh, eastern Himalaya: an assessment of threats and conservation needs. *Oryx* 40(1): 29–35.

Molur, S., C. Srinivasulu, B. Srinivasulu, S. Walker, P.O. Nameer & L. Ravikumar (2005). Status of south Asian non-volant small mammals: conservation assessment and management plan (CAMP) workshop report. Zoo Outreach Organization/CBSG-South Asia, Coimbatore, India, 618 pp.

Nikol'skii, A.A. & A. Ulak (2006). Key factors determining the ecological niche of the Himalayan marmot, Marmota himalayana Hodgson (1841). *Russian Journal of Ecology* 37: 46–52.

Sclater, W.L. (1891). *Catalogue of Mammalia in the Indian Museum, Calcutta. Part II (Rodentia, Ungulata, Proboscidea, Hyracoidea, Carnivora, Cetacea, Sirena, Marsupialia, Monotramata)*, Calcutta: Indian Museum, 406 pp.

Sibo, W. & Y. Ganyun (1983). *Rodent fauna of Xinjing*. *Wulumiqi*: Xinjing People's Publishing House, 66–68.

Srinivasulu, C. & B. Srinivasulu (2012). *South Asian Mammals. Their Diversity, Distribution, and Status*. Springer, New York, 468 pp.

Thorington Jr, R.W., J.L. Koprowski, M.A. Steele & J.F. Whatton (2012). *Squirrels of the world*. JHU Press, 472 pp.

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NOTE

First photographic record of the Indian Giant Flying Squirrel *Petaurista philippensis* Elliot, 1839 (Mammalia: Rodentia: Sciuridae) in Badrama Wildlife Sanctuary, Odisha, India

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The Indian Giant Flying Squirrel (IGFS) *Petaurista philippensis* is solitary, nocturnal, and arboreal, and has a wide distribution in China, India, Laos, Myanmar, Sri Lanka, Taiwan, Thailand, and Vietnam. It inhabits dry deciduous and evergreen forests, usually at elevations from 500–2,000 m and has been recorded in plantations (Walston et al. 2016). Currently, 44 species of flying squirrels belonging to 15 genera are recognized world over, with the majority (14 of the 15 genera and 42 of the 44 species) occurring in Eurasia, especially southeastern Asia (Thorington & Hoffmann 2005). So far 14 species of flying squirrels are being reported from India (Koli et al. 2013a; Sharma et al. 2013; Koli 2015; Krishna et al. 2016), and mainly found in the Himalayan and the northeastern regions, while the Western Ghats holds only two species (*Petaurista philippensis* and *Petinomys fuscocapillus*) (Sharma et al. 2013). The distribution of IGFS is restricted and scattered. It has been identified from Gujarat (Nisha & Dharaiya 2016), Andhra Pradesh (Sreekar et al. 2012), Karnataka (Nandini 2000; Kumara & Singh 2004, 2006), Kerala & Tamil Nadu (Rajamani 2000; Umapathy & Kumar 2000; Nandini 2001), Maharashtra (Nandini 2001), Madhya Pradesh & southern Rajasthan (Tehsin 1980; Chundawat et al. 2002; Sharma 2007; Koli 2012; Koli et al. 2013b), and West Bengal, Bihar, & Goa (Ashraf et al.1993; Srinivasulu et al. 2004; Molur et al. 2005). In the global context, this species is of 'Least Concern' (Walston et al. 2016). However, a few studies on *P. philippensis* indicate its decreasing status in India due to hunting (Nandini 2000a,b), anthropogenic disturbances, habitat destruction, and agricultural encroachment (Kumara & Singh 2004, 2006). Here we report first photographic record of Indian Giant Flying Squirrel in Badrama Wildlife Sanctuary, Odisha, eastern India.

The Badrama Wildlife Sanctuary extends over an area of 304.03 km^2 from 21.4971^{0}N to 84.2912^{0}E; (Figure 1), is situated in Sambalpur District of Odisha State. The mean

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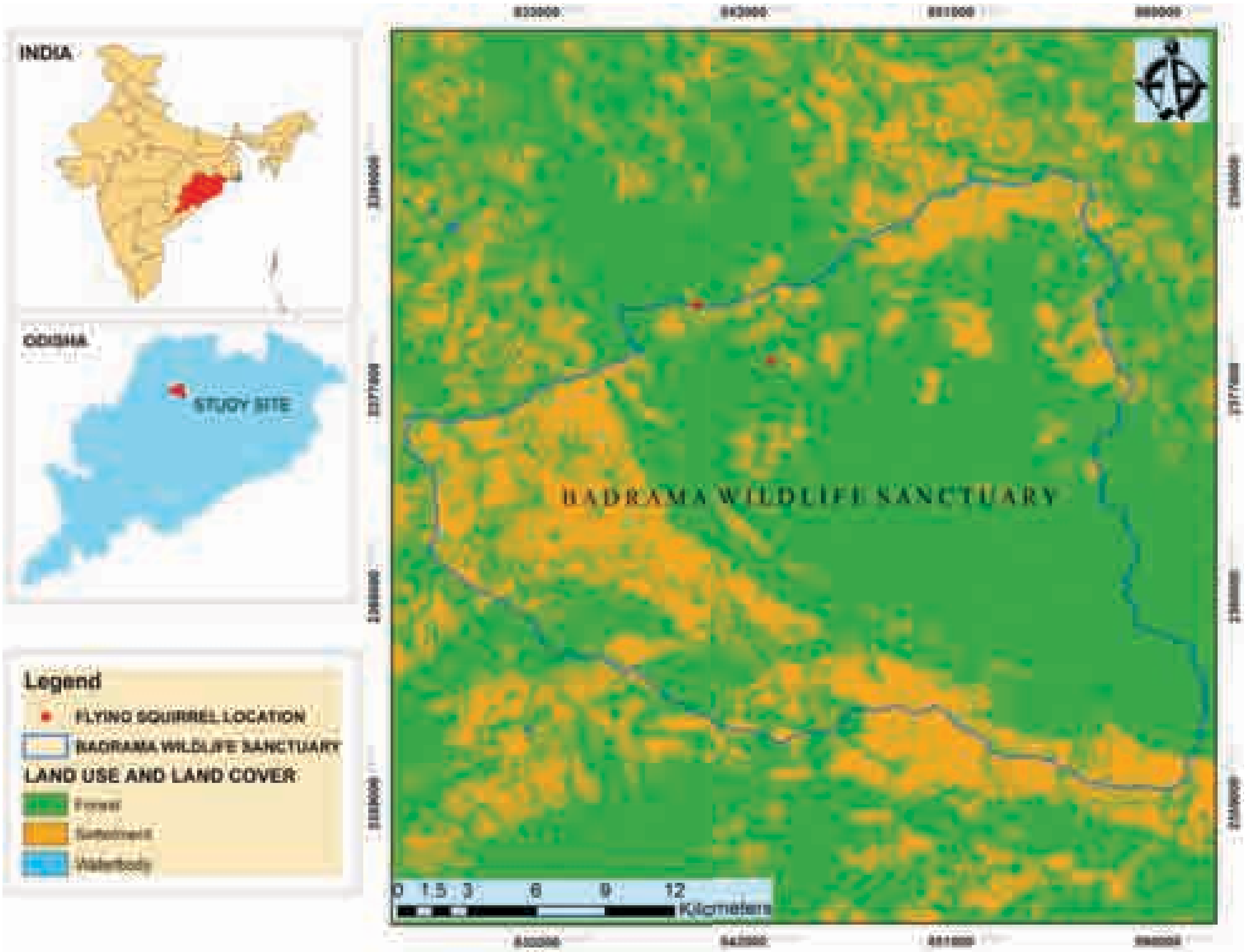

Figure 1. Location map of Badrama Wildlife Sanctuary, Odisha, India, with Indian Giant Flying Squirrel locations at the observation site.

temperatures of winter range 5–20 ˚C and in summers range from 30–45 ˚C. There are three distinct seasons, i.e., summer (March–June), monsoon (July–October), and winter (November–February). The rainfall varies 1,000–1,800 mm. Grazing livestock and collection of forest products are the major activities of the people in the sanctuary. The sanctuary is dominated by northern tropical dry deciduous forests, dry peninsular Sal forests, and northern dry mixed deciduous forests (Champion & Seth 1968). The dominant trees of the sanctuary include *Terminalia tomentosa, Anogeissus latifolia, Pterocarpus marsupium, Diospyros melanoxylon, Adina cordifolia, Terminalia chebula, T. bellirica, Lagerstroemia parviflora, Buchanania lanzan, Lannea coromandelica, and Dalbergia latifolia* (Kumar 2018). The common climbers in these forests are *Bauhinia vahlii* and *Smilax* species, while *Combretum decandrum* occurs in valleys and ravines (Kumar 2018).

In addition to IGFS, important mammals found in the sanctuary are Elephant *Elephas maximus*, Gaur *Bos gaurus*, Sambar *Rusa unicolor*, Barking Deer *Muntiacus muntjak*, Wild Boar *Sus scrofa*, Four-horned Antelope *Tertracerus quadricornis*, Leopard *Panthera pardus*, Rusty-spotted Cat *Prionailurus rubiginosus,* Jungle Cat *Felis chaus*, Indian Grey Wolf *Canis lupus,* Striped Hyena *Hyaena hyaena*, Golden Jackal *Canis aureus,* Indian Fox *Vulpes bengalensis*, Sloth Bear *Melursus ursinus*, Indian Giant Squirrel *Ratufa indica,* Hanuman Langur *Semnopithecus entellus* (Palei et al. 2022).

On 20 October 2021, while traveling in a vehicle at 1800 h from Kutab forest road to Kutab village, we saw an animal with coffee-brown to gray grizzled with white and ears having reddish-brown margins. The tail was brown grey with the tips being darker and the animal was climbing on Sal tree (21.490027ºN 84.474555º E) (Figure 1). When we reached near the tree, the animal had almost climbed the top canopy of the tree, and jumped from the top branch and opened its patagium and glided in the air. The animal sighted was an IGFS. The squirrel glided almost 20 m in the air, and landed on

Image 1. a–d—Indian Giant Flying Squirrel on Sal tree *Shorea robusta* in Badrama Wildlife Sanctuary. © Phalguni Sarathi Mallik.

Image 2. e–h—Indian Giant Flying Squirrel on Tamarind tree *Tamarindus indica* in Badrama Wildlife Sanctuary. © Bhakta Padarbinda Rath.

another Sal tree and started climbing towards the top canopy of the tree. During this, we could successfully photograph the squirrel (Image 1). In frequent intervals the squirrel glided from the Sal tree to the Mahua tree. We also recorded and photographed the squirrel feeding on the seeds of *Tamarindus indica* at 21.467888º N 084.304638º E, which is close to the forest rest house near Badrama Wildlife Range (Image 2).

There has been no record of IGFS from not just the Badrama Wildlife Sanctuary but from the entire Odisha State. This is the first photographic evidence of the species from the sanctuary.

References

Ashraf, N.V.K., A. Kumar & A.J.T. Johnsingh (1993). On the relative abundance of two sympatric flying squirrels of Western Ghats, India. *Journal of the Bombay Natural History Society* 90: 158–160.

Champion H.G. & S.K. Seth (1968). A revised study of the forest types of India. Government of India, New Delhi, India, 404 pp.

Chundawat, P.S., S.K. Sharma & H.S. Solanki (2002). Occurrence of the Large Brown Flying Squirrel (*Petaurista petaurista philippensis*) in Phulwari Wildlife Sanctuary, Rajasthan. *Zoo's Print Journal* 17(11): 941. https://doi.org/10.11609/JoTT.ZPJ.17.11.941

Koli, V.K., C. Bhatnagar & S.K. Sharma (2012). Sun basking behaviour of Elliot's Giant Flying Squirrel *Petaurista philippensis* (Elliot) in Sitamata Wildlife Sanctuary, Rajasthan, India. *Journal of the Bombay Natural History Society* 109: 196–197.

Koli, V.K., C. Bhatnagar & S.K. Sharma (2013a). Distribution and status of Indian giant flying squirrel (*Petaurista philippensis* Elliot) in Rajasthan, India. *National Academy Science Letters* 36: 27–33. https://doi.org/10.1007/s40009-012-0105-z

Koli, V.K., C. Bhatnagar & S.K. Sharma (2013b). Food habits of Indian giant flying squirrel (*Petaurista philippensis* Elliot) in tropical deciduous forest, Rajasthan, India. *Mammal Study* 38: 251–259. https://doi.org/10.3106/041.038.0409

Koli, V.K. (2015). Biology and conservation status of flying squirrels (Pteromyini, Sciuridae, Rodentia) in India: An update and review. *Proceedings of the Zoological Society* 69(1): 9–21. https://doi.org/10.1007/s 12595-015-0141-z

Krishna, M.C., A. Kumar, O.M. Tripathi & J.L. Koprowski (2016). Diversity, distribution and status of Gliding Squirrels in protected and non-protected areas of the Eastern Himalayas in India. *Hystrix* 27(2): 111–119. https://doi.org/10.4404/hystrix-27.2-11688

Kumar, S.N. (2018). *Management Plan of Badrama Wildlife Sanctuary*. Forest and Environment Department, Government of Odisha, 423 pp.

Kumara, H.N. & M. Singh (2004). The influence of differing hunting practices on the relative abundance of mammals in two rainforest areas of the Western Ghats, India. *Oryx* 38: 321–327.

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

Molur, S., C. Srinivasulu, B. Srinivasulu, S. Walker, P.O. Nameer & L. Ravikumar (2005). Status of South Asian Non-volant Small Mammals: Conservation Assessment and Management Plan (C.A.M.P.) Workshop Report. Zoo Outreach Organisation/ CBSG-South Asia, Coimbatore, India, 618 pp.

Nandini, R. (2000). The distribution and status of flying squirrels in Karnataka and Goa. Technical Report. Centre for Ecological Sciences, Indian Institute of Science, Bangalore, 131 pp.

Nandini, R. (2001). The status and distribution of the small Travancore Flying Squirrel (*Petinomys fuscocapillus*s) and the Large Brown Flying Squirrel (*Petaurista philippensis*) in the Western Ghats. Technical Report, SACON, Coimbatore, 42 pp.

Nisha, S. & N. Dharaiya (2016). A virtual survey based debate on conservation strategies of Indian Giant Flying Squirrel (*Petaurista petaurista philippensis*). *Ambient Science* 3(1): 16–21.

Palei N.C., B.P. Rath & P.S. Mallik (2022). Mammalian diversity of Badrama Wildlife Sanctuary, Bamra, Odisha, India. *Cheetal* 59(2): 13–22.

Rajamani, N. (2000). Ecology and behaviour of the Large Brown Flying Squirrel *Petaurista philippensis* in a rain forest fragment, Western Ghats. MS Dissertation, Pondicherry University, Pondicherry.

Sharma, S.K. (2007). Study of biodiversity and ethnobiology of Phulwari Wildlife Sanctuary, Udaipur, Rajasthan. PhD Thesis, Mohanlal Sukhadia University, Udaipur, Rajasthan.

Sharma S.K. & S.K. Sharma (2013). Squirrels of Rajasthan with special reference to Elliot"s giant flying squirrel *Petaurista philippensis*, pp. 563–572. In: Sharma, B.K., S. Kulshreshtha & A.R. Rahmani (eds.). *Faunal Heritage of Rajasthan*. Springer Verlag, New York.

Sreekar, R., C. Srinivasulu, A. Naidu & I. Siddiqi (2012). On the occurrence of the large brown flying squirrel (*Petaurista philippensis*) in Andhra Pradesh, India. *Small Mammal Mail* 4: 14–15.

Srinivasulu, C., S. Chakraborty & M.S. Pradhan (2004). Checklist of sciurids (Mammalia: Rodentia: Sciuridae) of south Asia. *Zoos' Print Journal* 19(2): 1351–1360. https://doi.org/10.11609/JoTT.ZPJ.19.2.1351-60

Tehsin, R.H. (1980). Occurrence of the Large Brown Flying Squirrel and Mouse Deer near Udaipur, Rajasthan. *Journal of the Bombay Natural History Society* 77:498.

Thorington, R.W.J. & R.S. Hoffmann (2005). Family Sciuridae, pp. 754–818. In: Wilson, D.E. & D.M. Reeder (eds.). *Mammal Species of the World: A Taxonomic and Geographic Reference,. 3rd edition*. Johns Hopkins University Press, Baltimore, Maryland, 2142 pp.

Umapathy, G.U. & A. Kumar (2000). The occurrence of arboreal mammals in the rain forest fragments in the Anamalai hills, South India. *Biological Conservation* 92: 311–319.

Walston, J., J.W. Duckworth & S. Molur (2016). *Petaurista philippensis*. The IUCN Red List of Threatened Species 2016: e.T16724A22272037. Downloaded on 30 April 2020. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T16724A22272037.en

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NOTE

Photographic evidence of the Indian Pangolin *Manis crassicaudata* Geoffroy, 1803 (Mammalia: Pholidota: Manidae), in Kaimur Wildlife Sanctuary, Bihar, India

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The Indian Pangolin *Manis crassicaudata* is the most ancient insectivore species belonging to the order Pholidota and the family Manidae (Heath 1995). In India, two species of pangolins are found: the Indian Pangolin *M. crassicaudata*, also called the thick-tailed Pangolin, and the Chinese Pangolin *Manis pentadactyla*. The Indian Pangolin is distributed in southern Asia, from parts of eastern Pakistan through much of India, south of the Himalaya, southern Nepal, Bangladesh, and Sri Lanka (Schlitter 2005; Srinivasulu & Srinivasulu 2012), while the Chinese Pangolin is present in the Himalayan foothills of Nepal, southern Bhutan, and northeastern India (Srinivasulu & Srinivasulu 2012; ZSI 2002). The Indian Pangolin is a medium-sized mammal covered dorsally by 11–13 rows of scales (Mahmood et al. 2020). A terminal scale is also present on the ventral side of the tail, which is absent in the Chinese Pangolin.

The Indian Pangolin is 'Endangered' according to the IUCN Red List (Mahmood et al. 2019). It is also protected as a Schedule I species under the Wild Life (Protection) Act, 1972, and listed in Appendix I of CITES due to being one of the highest-trafficked animals. There is a significant problem of poaching and high demand for its meat, scales, and use in traditional medicine in the international illegal wildlife trading markets (Anonymous 1992; Brown et al. 1996). Furthermore, it is considered a delicacy in many southeastern Asian and European countries (Newton et al. 2008). These factors have led to a declining population trend of the Indian Pangolin across its range (Heinrich et al. 2016; Mahmood et al. 2019).

The current study was conducted in the Kaimur Wildlife Sanctuary (KWS), which covers an area of 1,504.96 km^2 in Bihar (24.594–24.978 ^{0}N to 83.501–84.078 ^{0}E). According to Champion and Seth (1968), the forest type of KWS is Northern mixed deciduous forest. The dominant tree species of KWS is predominantly composed of *Shorea robusta, Terminalia chebula, Cassia*

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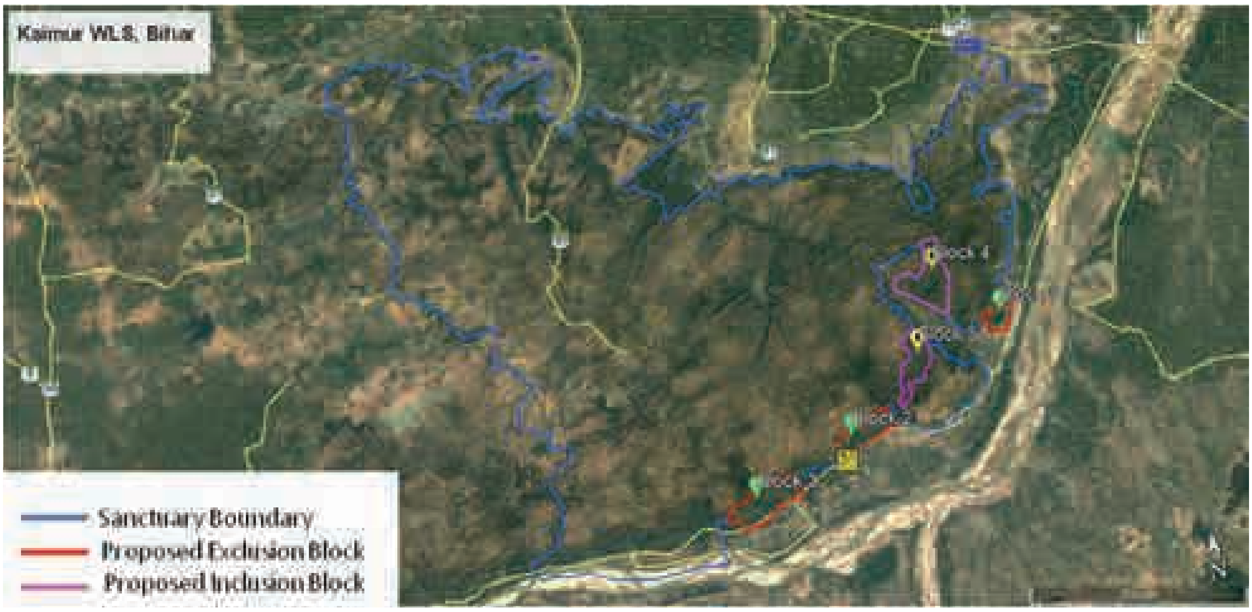

Figure 1. Map of the Kaimur Wildlife Sanctuary, Bihar showing proposed exclusion zone (red colour; Block 1, 2 & 3) and inclusion zone (pink colour Block 4 & 5).

Image 1. Indian Pangolin *Manis crassicaudata* in Kaimur WS, Bihar.

fistula, *Diospyros manoxylon*, *Acacia catechu*, *Terminalia tomentosa*, *Butea monosperma*, *Madhuca indica*, and *Boswellia serrata* (Bhattacharyya & Ghosh 2004). A reconnaissance survey was carried out between 27 June 2019 and 2 July 2019, in the Rohtas and Adhaura range of KWS. The survey aimed to assess the extent and nature of the work involved in the study. A total of 30 km were covered on foot and by vehicle in the exclusion zones (19 km) and inclusion zones (11 km). The specific area i.e., the exclusion block area in question would be excluded from the sanctuary for mining purposes, while another area, i.e., the inclusion block area would be included within the Sanctuary (block area depicted in Figure 1).

The first photographic documentation of an Indian Pangolin within the KWS has been recorded in the Rohtas region, which is contiguous to the Adhaura range of the Sanctuary. The habitat in this area is dry deciduous, dominated by *Acacia catechu* and *Terminalia tomentosa* species. Literature on the Indian Pangolin at the landscape level is scarce. Due to immense poaching and increasing demand for its meat and scales, as well as its use in traditional medicine in the international illegal wildlife trading markets, the population of Indian Pangolins is declining across their habitat (Mahmood

Image 2. Habitat of Indian Pangolin from Kaimur WS, Bihar.

et al. 2012). According to TRAFFIC India, nearly 6,000 Pangolins were poached in India between 2009 and 2017 (Ghosh 2020). The preliminary observation suggests that the Sanctuary holds significant wildlife value, as approximately 15 mammalian species were recorded during our reconnaissance survey. Therefore, a detailed ecological assessment is essential to evaluate the biodiversity value of the Sanctuary.

References

Anonymous (1992). Review of Significant Trade in Animal Species included in CITES Appendix II. Detailed Review of 24 Priority Species. Indian, Malayan and Chinese Pangolin. CITES Animals Committee.

Bhattacharyya, T.P. & M.K. Ghosh (2004). Faunal Composition of Kaimur Wild Life Sanctuary (Bihar Conservation Area Series No. 22: Published by the Director, Zool. Surv. India, 1-49 pp.

Brown, J.R., K. Beckenbach, A.T. Beckenbach & M.J. Smith (1996). Length variation, heteroplasmy and sequence divergence in the mitochondrial DNA of four species of sturgeon (Acipenser). *Genetics* 142(2): 525–535.

Challender, D.W., S.R. Harrop & D.C. Macmillan (2015). Understanding markets to conserve trade-threatened species in CITES. *Biological Conservation* 187: 249–259. https://doi.org/10.1016/j.biocon.2015.04.015

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

Ghosh, S. (2020). One of the world's trafficked animals need focus outside India's protected areas. In: Mongabay series: Beyond Protected Areas. Accessed on 20 October 2022.

Heath, M.E. (1995). *Manis crassicaudata*. *Mammalian Species* 513: 1–4.

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.

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., D. Challender, A. Khatiwada, S. Andleeb, P. Perera, S. Trageser, A. Ghose & R. Mohapatra (2019). *Manis crassicaudata*. The IUCN Red List of Threatened Species 2019: e.T12761A123583998. Accessed on 22 May 2023. https://doi.org/10.2305/IUCN.UK.2019-3.RLTS.T12761A123583998.en

Newton, P., N. van Thai, S. Roberton & D. Bell (2008). Pangolins in peril: using local hunters' knowledge to conserve elusive species in Vietnam. *Endangered Species Research* 6(1): 41–53.

Pantel, E.B.S. & S. Chin (2009). Proceedings of the Workshop on Trade and Conservation of Pangolins Native to South and Southeast Asia. 30 June – 02 July 2008, Singapore Zoo. Traffic Southeast Asia, Petaling Jaya, Selangor, Malaysia, vii+224 pp.

Schlitter, D.A. (2005). *Order pholidota. Mammal Species of the World: A Taxonomic and Geographic Reference.* Johns Hopkins University Press, Baltimore, MD, USA, 530–531.

Srinivasulu, C. & B. Srinivasulu (2012). *South Asian mammals: their diversity, distribution, and status*. Springer Science & Business Media, NY, XII+468 pp. https://doi.org/10.1007/978-1-4614-3449-8_2

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NOTE

Sighting of Lesser White-fronted Goose *Anser erythropus* (Linnaeus, 1758) (Aves: Anseriformes: Anatidae) in Hadinaru Kere, Mysuru, India

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The Lesser White-fronted Goose *Anser erythropus* is classified as 'Vulnerable' by the IUCN Red List due to a decline in the key breeding population in its breeding grounds in Russia, and a further decline in global population (BirdLife International 2023). They are long-distance Palearctic migrants that breed intermittently in the subarctic zone from northern Fennoscandia to eastern Siberia; wintering and staging regions, as well as their migratory routes, are only partially understood (Jones et al. 2008). In India, the bird winters in several areas like Kashmir, Uttar Pradesh, West Bengal, Bihar, Assam, Rajasthan, and Maharashtra (Rahmani 2012). However, most sight records from India are still refuted and best regarded as tentative (Praveen et al. 2014), yet from 2013 onwards the bird has been sighted in the Kutch region of Gujarat (Khan 2013; Shreeram & Deomurari 2014).

On 10 February 2023, the first author on his birding to Hadinaru Lake recorded a smaller bird with a chocolate brown head, a prominent white patch above its pink beak, and a golden yellow eye ring among a huge flock of Bar-Headed Geese *Anser indicus*. Slow approach was made to the bird and was photographed for identification (Image 1,2) and later the bird was identified using field guide (Grimmett et al. 2016) as Lesser White-fronted Goose *Anser erythropus* from its characteristics.

Hadinaru Lake lies between 12.178–12.17 ^{0}N & 76.74 –76.759 ^{0}E, in the Nanjangud Taluk, Mysuru District, Karnataka State. The catchment area of the lake is 8.57 km^2. The lake hosts several migratory birds such as Eurasian Wigeon *Mareca penelope,* Northern Pintail *Anas acuta,* Northern Shoveler *Spatula clypeata,* Common Pochard *Aythya farina,* Striated Heron *Butorides striata,* Eurasian Marsh-Harrier *Circus aeruginosus,* Osprey *Pandion haliaetus,* and Greater Spotted Eagle *Clanga clanga* (Gopal Praphul 2005–2020 pers. obs.). During its peak winter season, the Bar Headed Goose population rises to 400–600. In a total of 15 visits from 10 February 2023 to 4 March 2023, a lone *Anser erthyropus* was documented along with the gaggle of Bar-Headed Geese.

The available literature indicates that all the earlier sightings are confined to northern and northeastern India and a few sporadic sightings in the west (Praveen et al. 2014) (Figure 1). The present record of the bird this far in inland southern peninsula adds to its current distribution range. Thus, the current sighting stands to be the first record for the state of Karnataka and southern India.

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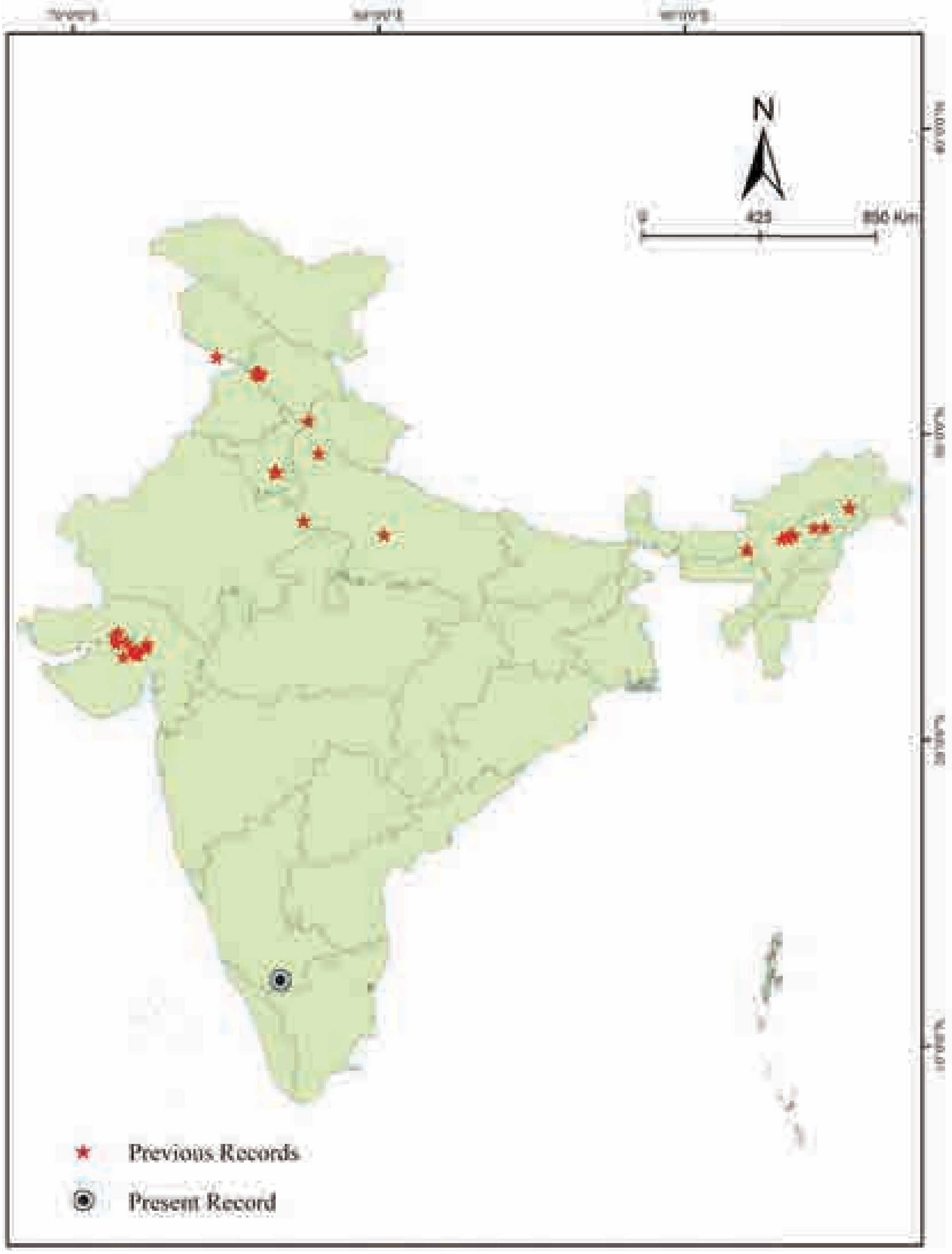

Figure 1. Distribution of the Lesser White-fronted Goose *Anser erythropus* in India.

References

BirdLife International (2023). Lesser White-fronted Goose (*Anser erythropus*)—BirdLife species factsheet: *Anser erythropus*. http://datazone.birdlife.org/species/factsheet/lesser-white-fronted-goose-anser-erythropus. Downloaded on 03 March 2023.

Grimmett, R., C. Inskipp & T. Inskipp (2016). *Birds of the Indian Subcontinent: India, Pakistan, Sri Lanka, Nepal, Bhutan, Bangladesh and the Maldives*. Bloomsbury Publishing, 528 pp

Jones, T., K. Martin, B. Barov & S. Nagy (Compilers) (2008). International single species action plan for the conservation of the Western Palearctic population of the Lesser White-fronted Goose *Anser erythropus*. AEWA Technical Series No.36. Bonn, Germany, 130 pp.

Khan, A. (2013). First Record of Lesser White-Fronted Goose *Anser erythropus* from Gujarat, India. *Journal of the Bombay Natural History Society* 110(3) 224–224.

Praveen, J., R. Jayapal & A. Pittie (2014). Notes on Indian rarities—2: Waterfowl, diving waterbirds, and gulls and terns. *Indian BIRDS* 9(5 & 6): 113–136.

Rahmani, A.R. (2012). *Threatened Birds of India: Their Conservation Requirements*. Bombay Natural History Society, 861 pp.

Image 1. A single Lesser White-fronted Goose *Anser erythropus* among Bar-headed Geese *Anser indicus* in Hadinaru Lake, Mysuru.

Image 2. Lesser White-fronted Goose *Anser erythropus* in Hadinaru Lake, Mysuru.

Shreeram, M.V. & A. Deomurari (2014). A record of Lesser-*Anser erythropus* and Greater-White-fronted Geese *A. albifrons* from Gujarat, India. *Indian BIRDS* 9(5 & 6): 148–149.

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NOTE

New distribution records of two jumping spiders (Araneae: Salticidae) from Gujarat, India

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Indian Plexippini is represented by 18 genera and 56 species (Maddison 2015; Caleb & Sankaran 2023). Of these, seven genera are reported from Gujarat State: *Epeus* Peckham & Peckham, *Bianor* Peckham & Peckham, *Harmochirus* Simon, *Hyllus* C.L.Koch, *Plexippus* C.L.Koch, *Telamonia* Thorell and *Thyene* Simon (Prajapati et al. 2016; Yadav et al. 2017). During recent surveys in Aravalli Hills, we identified two more plexippine jumping spider species which are new to Gujarat State. The present paper thus deals with the discovery and record of two species—*Vailimia ajmerensis* Caleb & Jangid, 2020 and *Modunda staintoni* (O. Pickard-Cambridge, 1872)—for the first time from the Aravalli Hills in Gujarat, India.

The specimens were hand collected and studied under a Leica M205 A stereomicroscope and the microphotographic images were taken by a Leica DFC2900 digital camera attached to the stereomicroscope and enabled with the software package Leica Application Suite (LAS), version 4.5.0. Left pedipalps were removed, studied and were photographed by placing them in a cavity block filled with ethanol. The species were identified by using Logunov (2001) and Basumatary et al. (2020). The examined specimens have been deposited in the reference collection of the Web of Nature (WON) Research Foundation, Gujarat, India.

Family Salticidae Blackwall, 1841
Genus *Modunda* Simon, 1901
Type species: *Modunda phragmitis* Simon, 1901

Modunda staintoni (O. Pickard-Cambridge, 1872)
Image 1, 4–5

Salticus staintoni O. Pickard-Cambridge, 1872: 331, pl. 14, fig. 20

Modunda staintoni Logunov, 2001: 277, figs. 347–366.

Material examined: WON100351, 21.v.2021, 1 male, India, Gujarat, Danta Village (24.191668°N, 77.7706°E), 777 m, from foliage, leg. S. Parmar.

Diagnosis: The species can be easily distinguished by the following characters: male pedipalp with rounded bulb; embolus long and slender, surrounding the bulb; Retrolateral tibial apophysis (RTA) robust, slightly curved (Image 4–5).

Distribution in India: Punjab (Logunov 2001) and Gujarat (new record) (Figure 1).

Genus *Vailimia* Kammerer, 2006
Type species: *Vailima masinei* G.W.Peckham & E.G.Peckham, 1907.

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Image 1–3: 1—*Modunda staintoni* (O. Pickard-Cambridge, 1872), male, dorsal view | 2–3—*Vailimia ajmerensis* Caleb & Jangid, 2020, frontal view. Scale bars: 1 mm (1–3). © Dhruv A. Prajapati.

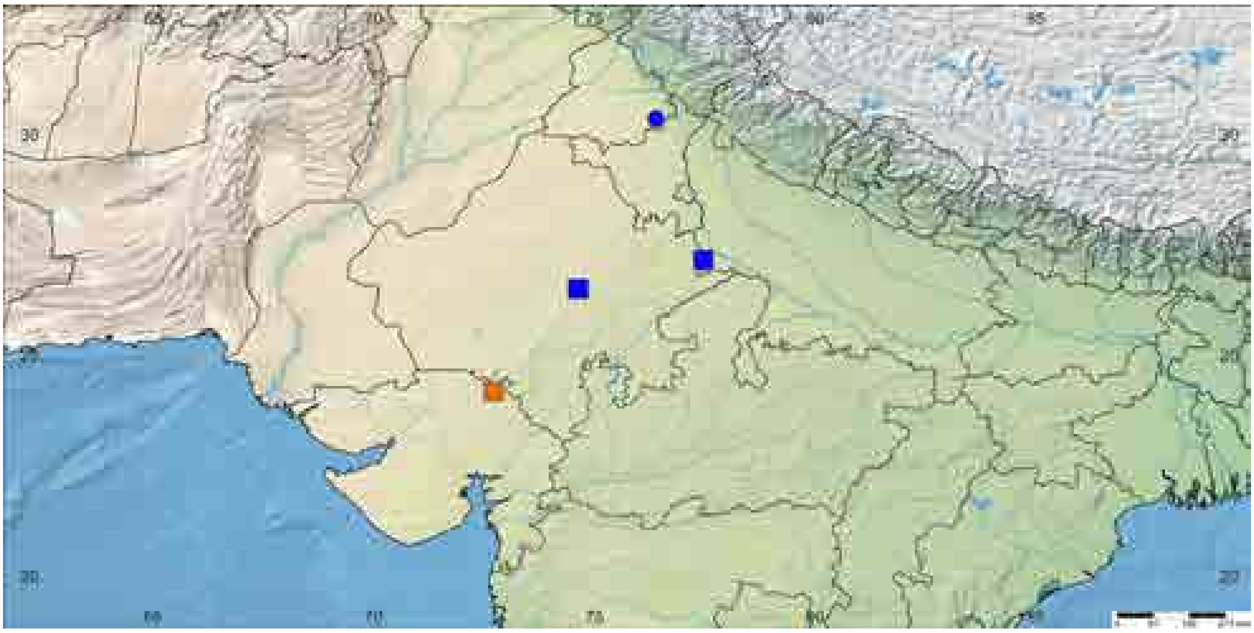

Figure 1. Distribution of *Modunda staintoni* (O. Pickard-Cambridge, 1872) (circles) & *Vailimia ajmerensis* Caleb & Jangid, 2020 (squares) | Blue color—previous record | Saffron color—new record.

Vailimia ajmerensis Caleb & Jangid, 2020

Image 2–3, 6–7

Vailimia ajmerensis Caleb & Jangid, in Basumatary et al. 2020: 180, figs. 1–11.

Material examined: WON100639, 21.v.2021, 1 male, India, Gujarat, Danta Village (24.191667°N, 77.7707°E), 777 m, from foliage, leg. S. Parmar.

Diagnosis: The species can be easily distinguished by the following characters: male pedipalp with long embolus, its base thick and broad and the tip narrowed, directed at 2 o'clock position (Image 6); RTA long and simple, broad at the base and tapered at the tip, with a

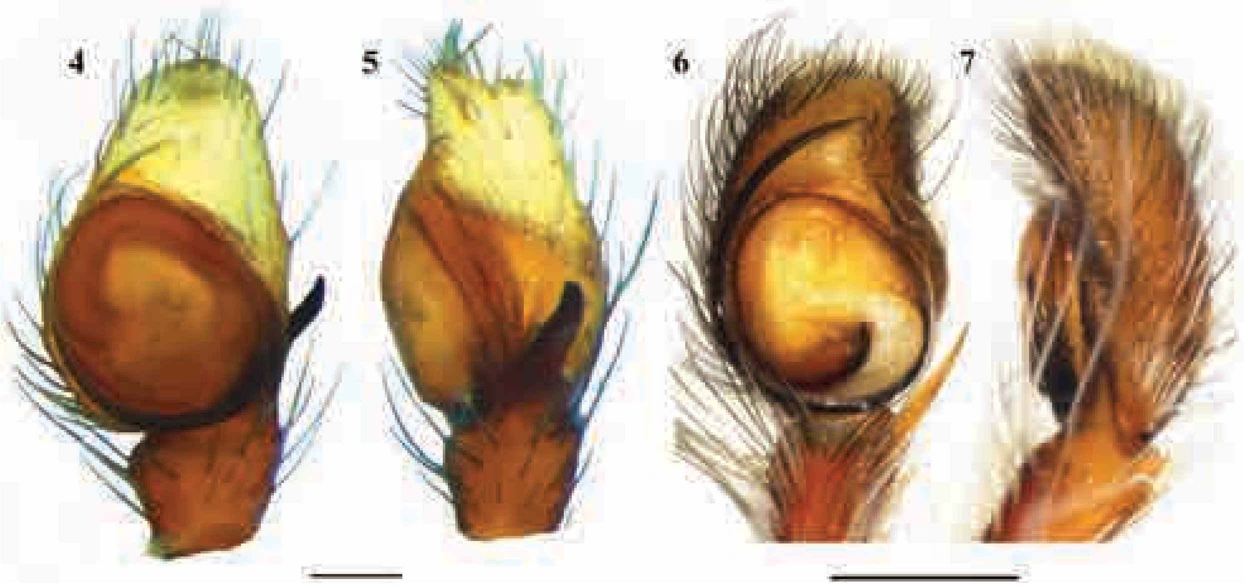

Image 4–7: 4–5—Male left pedipalps of *Modunda staintoni* (O. Pickard-Cambridge, 1872) | 6–7—& *Vailimia ajmerensis* Caleb & Jangid, 2020. (4, 6) ventral view. (5, 7) retrolateral view. Scale bars: 0.1 mm (4–7). © Dhruv A. Prajapati.

slight curve distally (Image7).

Distribution: Rajasthan (Basumatary et al. 2020) and Gujarat (new record) (Figure 1).

References

Basumatary, P., J.T.D. Caleb, S. Das, A.K. Jangid, J. Kalita & D. Brahma (2020). First record of the genus *Vailimia* Kammerer, 2006 from India, with the description of two new species (Araneae: Salticidae: Plexippina). *Zootaxa* 4790(1): 178–186. https://doi.org/10.11646/zootaxa.4790.1.11

Caleb, J.T.D. & P.M. Sankaran (2023). Araneae of India, Version 2023. http://www.indianspiders.in. Accessed 23 March 2023.

Logunov, D.V. (2001). A redefinition of the genera Bianor Peckham & Peckham, 1885 and Harmochirus Simon, 1885, with the establishment of a new genus *Sibianor* gen. n. (Aranei: Salticidae). *Arthropoda Selecta* 9(4, 2000): 221–286.

Maddison, W.P. (2015). A phylogenetic classification of jumping spiders (Araneae: Salticidae). *Journal of Arachnology* 43(3): 231–292. https://doi.org/10.1636/arac-43-03-231-292

Pickard-Cambridge, O. (1872). General list of the spiders of Palestine and Syria, with descriptions of numerous new species, and characters of two new genera. *Proceedings of the Zoological Society of London* 40(1): 212–354. https://doi.org/10.1111/j.1469-7998.1872.tb00489.x

Prajapati, D.A., K.R. Patel, S.B. Munjpara, S.S. Chettiar & D.D. Jhala (2016). Spiders (Arachnida: Araneae) of Gujarat University Campus, Ahmedabad, India with additional description of *Eilica tikaderi* (Platnick, 1976). *Journal of Threatened Taxa* 8(11): 9327–9333. https://doi.org/10.11609/jott.1835.8.11.9327-9333

Yadav, A., R. Solanki, M. Siliwal & D. Kumar (2017). Spiders of Gujarat: a preliminary checklist. *Journal of Threatened Taxa* 9(9): 10697–10716. https://doi.org/10.11609/jott.3042.9.9.10697-10716

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NOTE

Polychorous Puncture Vine *Tribulus terrestris* L. (Zygophyllaceae), a potential forage source for a guild of insect pollinators during the wet season

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In the Zygophyllaceae family, *Tribulus* is a genus of 25 species distributed in the Old World. Several of these species are weedy occupants of dry disturbed habitats. Among weedy species, *T. cistoides* is native to tropical and sub-tropical Africa, and *T. terrestris* to the Mediterranean region. But, these two species are reported to be largely anthropochorous. The spiny mericarp trait is noted to be a perfect mechanism for easy dissemination of these weeds worldwide (Porter 1971). *T. cistoides* is protandrous (Robertson & Gooding 1963) and effectively pollinated by the honey bee, *Apis mellifera,* and solitary bees, *Agapostemon, Halictus* and *Lasioglossum* in Florida, USA (Austin 1972). *T. terrestris* is protogynous with the stigma attaining receptivity on the first day and pollen shedding on the second day (Goldsmith & Hafenrichter 1932). Both the species are out-crossing and pollinated mainly by *Xylocopa darwini* in Galapagos Islands (Porter 1971). Other works have reported that *T. terrestris* is cross-pollinated by insects with a backup self-pollination system in Bulgaria (Semerdjieva et al. 2011). These reports indicate that *T. terrestris* is insect-pollinated while keeping the option open for autonomous autogamy. Further, these studies indicate that few insect species have a role in the pollination of this weed. With this backdrop, the present study is contemplated to report on *T. terrestris* as a potential floral source for a guild of insect pollinators during the wet season in different habitats, especially in open habitats.

T. terrestris a ruderal plant species growing in the open habitat of the Andhra University campus (17°41'25.7064''N and 83°13'51.7764''E) during the wet season from June to October 2022 was used to observe its floral details and the importance of its flowers as a potential food source for visiting insect species. The study indicated that the plant grows well as a common villous herbaceous weed (Image 1a) and produces numerous individuals in open habitats and occurs intermingled with other simultaneously growing low-ground herbaceous taxa. Seed is the only mode of propagation. The plants appear as soon as the first monsoon showers or rainfall occurs. It produces a silky or appressed-hairy stem with even-pinnate compound leaves each with 6–12 elliptic leaflets. The plant produces flowers within three weeks' time and continues the flowering phase until late October but flowering extends and remains so throughout the year in wet habitats. The flowers are pedicellate, solitary, yellow, dish-shaped, bisexual,

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Image 1. ***Tribulus terrestris*****: a—Habit | b—Flower | c—Pollen grain | d—Pistil with capitate stigma | e— Ovules | f—Thrips | g—** ***Apis dorsata*** **collecting nectar | h—*****Apis dorsata*** **collecting pollen | i—*****Apis cerana*** **collecting nectar | j—*****Apis cerana*** **collecting pollen | k—*****Apis florea*** **collecting pollen | l—*****Trigona iridipennis*** **collecting pollen | m—*****Ceratina simillima*** **collecting pollen | n—*****Anthophora bicincta*** **collecting nectar | o—*****Camponotus*** **sp. collecting nectar | p—*****Nomia*** **sp. collecting nectar. © A.J. Solomon Raju.**

actinomorphic, and borne in the axils of leaves (Image 1b). The calyx has five caducous, narrowly lanceolate green sepals. The corolla has five bright yellow petals. The stamens are 10 consisting of five shorter and five longer free yellow stamens arranged in two whorls. The shorter stamens with anthers are placed well below the level of the stigma and arranged opposite the sepals; each of these is subtended by a small gland. The longer stamens with anthers are placed at the level of the stigma and arranged opposite the petals. The pollen grains are oblate-spheroidal, pantoporate, and radially symmetrical; the exine has reticulate ornamentation with straight to slightly expressed wavy barriers with a simple columnar structure (Image 1c) (Semerdjieva et al. 2011). The ovary has five carpels, each one with a single ovule (Image 1e). The style is short, connate into a stout column, 5-ridged, and ends with a 5-lobed papillate capitate stigma (Image 1d). The floral biology and pollination aspects were investigated as per the protocols provided in Dafni et al. (2005). *T. terrestris* flowers open after sunrise from 0600 to 0800 h. The stigma attains receptivity soon after anthesis while the anthers dehisce synchronously by longitudinal slits an hour after the commencement of stigma receptivity indicating the function of protogyny. This finding is not in agreement with the report by Goldsmith & Hafenrichter (1932) that the stigma attains receptivity on the first day and pollen shedding on the second day in *T. terrestris*. The short staminal glands secrete nectar continuously during the open state of the flower and it is accumulated in the hollow calyx. The flowers close back in the late afternoon during which the petals and the longer stamens curl inwards facilitating the contact between these stamens and the stigma which ends up in autonomous autogamy. The flowers do not open again. Such a floral self-pollinating mechanism is a fail-safe strategy for the plant to achieve pollination if the flowers are not pollinated when the flowers are in an open state (Goldsmith & Hafenrichter 1932; Reddi et al. 1981; Semerdjieva et al. 2011).

Tribulus terrestris is reported to be pollinated by a few insect species such as carpenter bees in Galapagos Islands (Porter 1971), honey bees, ants, and butterflies in India (Reddi et al. 1981). In this study, *T. terrestris* is found to be utilized as an important forage source consistently during the wet season in open habitats by hymenopterans and lepidopterans. The hymenopterans represented Apidae, Halictidae and Formicidae families.

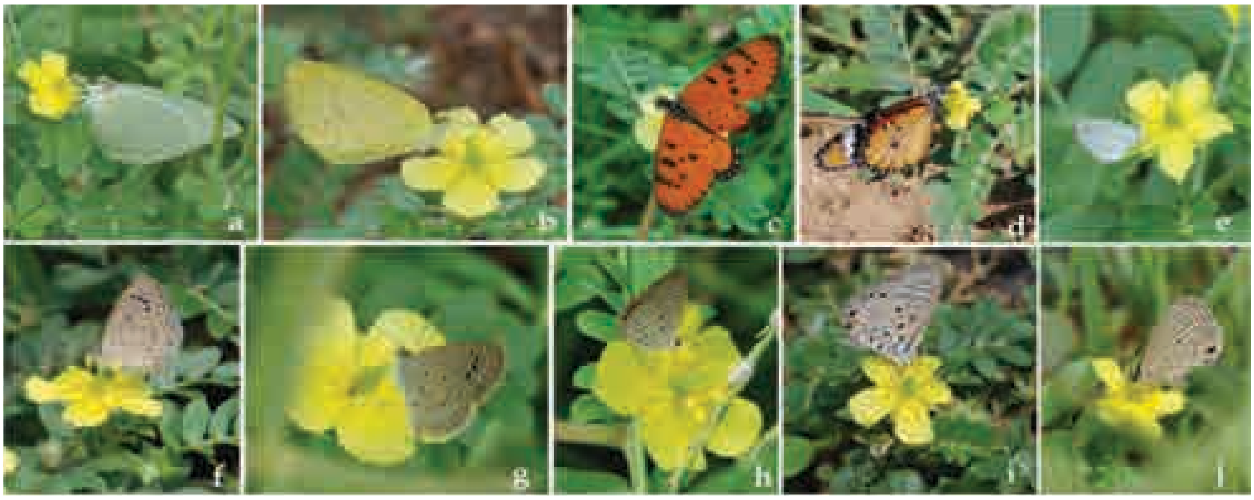

Image 2. ***Tribulus terrestris*****: a&b—Pierid butterflies: a—*****Catopsilia pyranthe*** **| b—*****Eurema hecabe*** **| c&d—Nymphalid butterflies: c—*****Acrae violae*** **| d—*****Danaus chrysippus*** **| e–j—Lycaenid butterflies: e—*****Zizula hylax*** **| f—*****Zizeeria karsandra*** **| g—*****Zizina otis*** **| h—*****Freyeria trochylus*** **| i—*****Azanus jesous*** **| j—*****Chilades pandava*****. © A.J. Solomon Raju.**

The Apidae members were *Apis dorsata* (Fabricius 1793) (Image 1g,h), *A. cerana* (Fabricius 1793) (Image 1i,j), *A. florea* (Fabricius 1787) (Image 1k), *Trigona iridipennis* (Smith 1854) (Image 1l), *Ceratina simillima* (Smith 1854) (Image 1m), *Anthophora bicincta* (Fabricius 1793) (Image 1n). The Halictidae is represented by a single species, *Nomia* sp. (Latreille 1804) (Image 1p). The Formicidae is also represented by a single species, *Camponotus* sp. (Mayr 1861) (Image 1o). All hymenopterans were regular and consistent foragers throughout the day. The lepidopterans observed represented pierid, nymphalid and lycaenid families. Pierids were *Catopsilia pyranthe* (Linnaeus 1758) (Image 2a) and *Eurema hecabe* (Linnaeus 1758) (Image 2b). Nymphalids were *Acraea violae* (Fabricius 1775) (Image 2c) and *Danaus chrysippus* (Linnaeus 1758) (Image 2d). Lycaenids were *Zizula hylax* (Fabricius 1775) (Image 2e), *Zizeeria karsandra* (Moore 1865) (Image 2f), *Zizina otis* (Fabricius 1787) (Image 2g), *Freyeria trochylus* (Freyer 1845) (Image 2h), *Azanus jesous* (Guerin 1847) (Image 2i), and *Chilades pandava* (Horsefield 1829) (Image 2j). Of these, lycaenids foraged on the flowers the most. All hymenopterans except *Camponotus* sp. foraged for both pollen and nectar. *Camponotus* sp. and lepidopterans collected exclusively nectar from the flowers. All these insect species probed the flowers legitimately for forage collection and effected both self- and cross-pollination by contacting the stamens and stigma because the flowers are of the open type with exposed sex organs. Apart from these insects, thrips (unidentified) also used the flowers of *T. terrestris* for breeding during the bud stage and feeding on pollen and nectar during the flower stage with the latter activity resulting in self-pollination (Image 1f). The study indicates that *T. terrestris* does not necessarily require pollinators even for self-pollination but seed production from this pollination mode is detrimental or even fatal in the long run. In this context, the insects using the flowers of *T. terrestris* as their important forage source play an important role in self-pollination between flowers of the same plant and cross-pollination between closely or distantly spaced individuals. The function of autonomous selfing, and selfing and cross-pollination functional through pollinating insects in *T. terrestris* enable it to grow as a successful plant and provide sufficient forage for the foragers visiting its flowers when in flowering. Therefore, *T. terrestris* serves as a potential forage source for a guild of pollinating insects during the wet season.

Fruit maturation takes place within two weeks. The fruit is a schizocarp, woody burr, flattened, hairy, grey to yellow-tan, and separated into five wedge-shaped indehiscent nutlets or cocci or burs each with two stout dorsal spreading spines and several prickles. Seeds vary 2–5 per coccus and remain enclosed inside; they are flattened, triangular-ovate with a sharp lengthened tip and a flat base (Semerdjieva et al. 2011). The bur spines resembling the horns of bulls or goats are sharp enough to puncture bicycle tires and other air-filled tires. For this reason, *T. terrestris* is called Puncture Vine (Adlakha 1961; Julien 1992). The weedy nature of this plant is attributed to its hard spiny fruits which are attached to and disseminated by farm machinery, grazing animals, vehicles, and human clothes and shoes. These modes of seed dispersal indicate that *T. terrestris* is polychorous and this trait is quite advantageous for the plant to disperse its seeds effectively to different habitats and grow as a successful weed. Being a C4 plant, *T. terrestris* can efficiently use water and conserve soil moisture which enables it to grow for longer periods in arid or semi-arid habitats or conditions common to tropical and subtropical latitudes.

References

Adlakha, P. (1961). Incidence and losses caused by particular weeds in different areas and in different crops and preparation of a weed map. *Proceedings of Indian Council of Agricultural Research Seminar on Weed Control, Bombay,* ICAR, New Delhi.

Austin, D.F. (1972). Interactions between *Apis mellifera* (Hymenoptera: Apidae) and *Tribulus cistoides* (Zygophyllaceae). *Rhodora* 74: 117–123.

Dafni, A., P.G. Kevan & B.C. Husband (2005). *Practical pollination biology*. Environquest Ltd., Ontario, 590 pp.

Goldsmith, G.W. & A.L. Hafenrichter (1932). Anthokinetics. The physiology and ecology of floral movements. *Carnegie Institution of Washington Publication* 420: 198 pp.

Julien, M.H. (1992). *Biological Control of Weeds. A World Catalogue of Agents and their Target Weeds*. CAB International, Wallingford, UK, 186 pp.

Porter, D.M. (1971). Notes on the floral glands in *Tribulus* (Zygophyllaceae). *Annals of Missouri Botanical Garden* 58: 1–5. https://doi.org/10.2307/2394924

Robertson, E.T. & E.G.B. Gooding (1963). *Botany for the Caribbean*. Collins, London, 246 pp.

Semerdjieva, I., E. Yankova-Tsvetkova, G. Baldjiev & P. Yurukova-Grancharova (2011). Pollen and seed morphology of *Tribulus terrestris* L. (Zygophyllaceae). *Biotechnology and Biotechnological Equipment* 25: 2379–2382. https://doi.org/10.5504/BBEQ.2011.0031.

Reddi, C.S., E.U.B. Reddi & N.S. Reddi (1981). Breeding structure and pollination ecology of *Tribulus terrestris*. *Proceedings of the Indian National Science Academy* B47: 185–193.

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