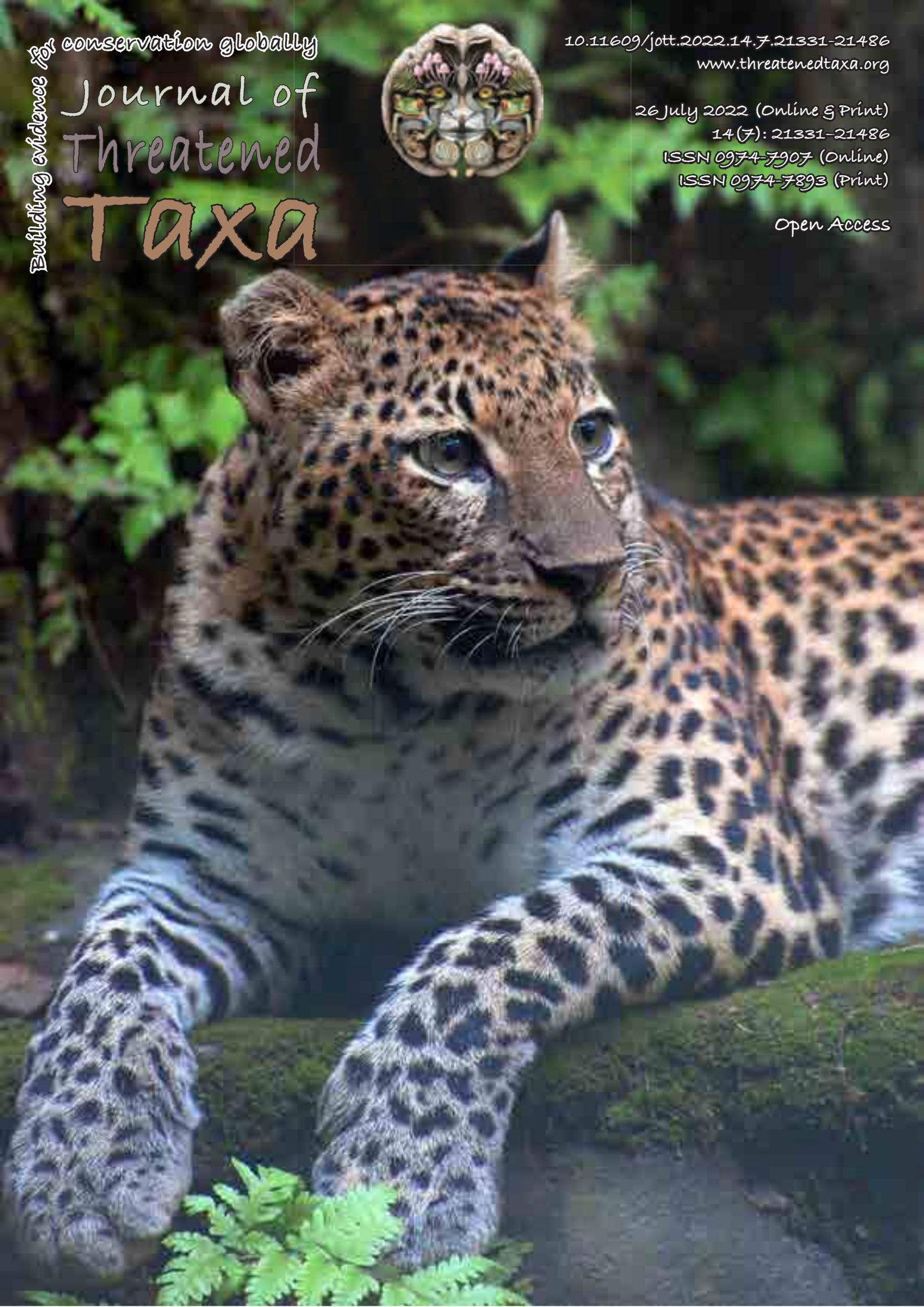

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Cover: A female Javan Leopard *Panthera pardus melas* in rehabilitation phase at Cikananga Wildlife Center. © Yayasan Cikananga Konservasi Terpadu.

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ARTICLE

The Javan Leopard *Panthera pardus melas* (Cuvier, 1809) (Mammalia: Carnivora: Felidae) in West Java, Indonesia: estimating population density and occupancy

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Abstract: The Javan Leopard is endemic to the Indonesian island of Java and has been classified as Endangered. Reliable information about its population status, distribution, and density is lacking but are essential to guide conservation efforts and provide a benchmark for management decisions. Our study represents the first empirical density and occupancy estimates for the Leopard in West Java and provides baseline data for this region. We used camera trap data collected from February 2009 to October 2018 in six study areas comprising a sampling effort of 10,955 camera trap days in a total area of 793.5 km^2. We identified 55 individual Leopards in these areas and estimated Leopard density using spatially explicit capture-recapture. Population density estimates range from 4.9 individuals/100 km^2 in Gunung Guntur-Papandayan Nature Reserve to 16.04 individuals/100 km^2 in Gunung Gede Pangrango National Park. Latter is among the globally highest Leopard densities. Based on detection data, we modelled single-season Leopard occupancy using three sampling covariates and eight site covariates. Modelling revealed that the two covariates forest cover and presence of Wild Boar are the strongest predictors for Leopard occupancy in our study areas. We recommend assessing and monitoring Leopard distribution, density and occupancy in other areas of Java and emphasize that a landscape approach for conservation of the Javan Leopard is imperative.

Keywords: Camera trap, conservation management, habitat use, spatially explicit capture-recapture.

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INTRODUCTION

With a range extending from Africa to eastern and southeastern Asia, the Leopard *Panthera pardus* has the widest distribution of the wild Felidae (Stein & Hayssen 2013). It inhabits arid and rugged montane regions, savanna grasslands, shrubland, temperate forests and rainforests (Nowell & Jackson 1996). Despite its adaptability to a wide range of habitats, it is primarily threatened by habitat fragmentation and depletion of its natural prey base (Stein et al. 2020). Endemic to the Indonesian island of Java, the Javan Leopard *P. p. melas* is classified as Endangered in the IUCN Red List of Threatened Species (Wibisono et al. 2021). It is listed on CITES Appendix I and nationally protected by Indonesian law (Ministry of Environment and Forestry 2018). Yet, reliable information on the Javan Leopard's population status, habitat use and density is lacking (Wibisono et al. 2018).

Java is home to 141 million people, and with 1,115 people/km² (Badan Pusat Statistik 2020) has one of the highest human population densities in the world (Dsikowitzky et al. 2019). West Java is the most densely populated province in Indonesia with 1,394 people/km² (Badan Pusat Statistik 2020). Human pressure on the Leopard's remaining natural habitat continues to increase in Java and has restricted its distribution to an extent that remaining suitable landscapes has been estimated at 11,599 km², which corresponds to 8.9% of the island (Wibisono et al. 2018). Both the Leopard and its prey are threatened by retaliatory killing and poaching, habitat loss and fragmentation, large-scale degradation by plantation companies and human encroachment into protected areas (Ministry of Environment and Forestry 2016; Gunawan et al. 2017). Leopards increasingly approach settlements in search for prey, which results in conflict with people over livestock (Ministry of Environment and Forestry 2016). An annual average of 4.6 Leopards have been removed from the wild between 2007 and 2019 (Adhiasto et al. 2020). In this period, 29 Leopards were captured due to conflict, of which four individuals were released into the wild, five died in captivity, and 20 are still kept in zoos and rescue centres (Adhiasto et al. 2020). These incidents also fuel illegal trade in body parts with 51 Leopards confiscated in 41 seizures between 2011 and 2019 (Gomez & Shepherd 2021).

In 1990, Leopards were known to be present in 12 protected areas with a guesstimated population of 350–700 individuals (Santiapillai & Ramono 1992). By 2013, the Leopard population was estimated at 491–546 individuals occurring in 48 habitat patches across Java's remaining natural forests, based on data collated during a workshop in 2013 (Ministry of Environment and Forestry 2016). Occurrence records obtained from 2013 to 2018 in 22 sites across Java indicate a Leopard population of 188–571 individuals at most (Wibisono et al. 2021). As the potential population loss is uncertain, reliable data and robust analyses are essential for a better understanding of the present Leopard status and viability, and for guiding management decisions (Traylor-Holzer et al. 2020).

Assessing Leopard density is necessary to provide a baseline for future reference and is a useful way to increase the precision of island-wide Leopard status assessments (Ministry of Environment and Forestry 2016). Furthermore, information on population density and distribution are crucial for assessing the effectiveness of conservation interventions and provides considerations to help management authorities for making decisions on conservation planning. In view of suitable habitat patches being small and isolated, it is equally important to understand the distribution and habitat use of the Javan Leopard (Traylor-Holzer et al. 2020; Wibisono et al. 2021). With our study, we aimed at estimating Leopard population density and occupancy in six forest areas in West Java province using camera traps in a closed population spatially explicit capture-recapture (SECR) design and single-season occupancy modelling. These two methods complement each other by providing a more nuanced assessment of the population status than a density estimate alone. We anticipate that our results will form a basis for a comprehensive conservation management plan for the Javan Leopard.

STUDY AREAS

Our study areas were located in six protected areas in the province of West Java (Figure 1), comprising three national parks, one strict nature reserve, one wildlife reserve and one protected forest (Table 1). They are all situated in Java's Southern Mountains, which are part of the Sunda Volcanic Arc that derived from stratovolcano complexes with thermal springs and fumaroles emitting hot fumes, gases, and vapors (Carranza et al. 2008). These six protected areas constitute 14% of Java's Leopard priority landscape (Wibisono et al. 2018). They are located in eight districts with a total population of about 20.54 million people (Badan Pusat Statistik Provinsi Jawa Barat 2021).

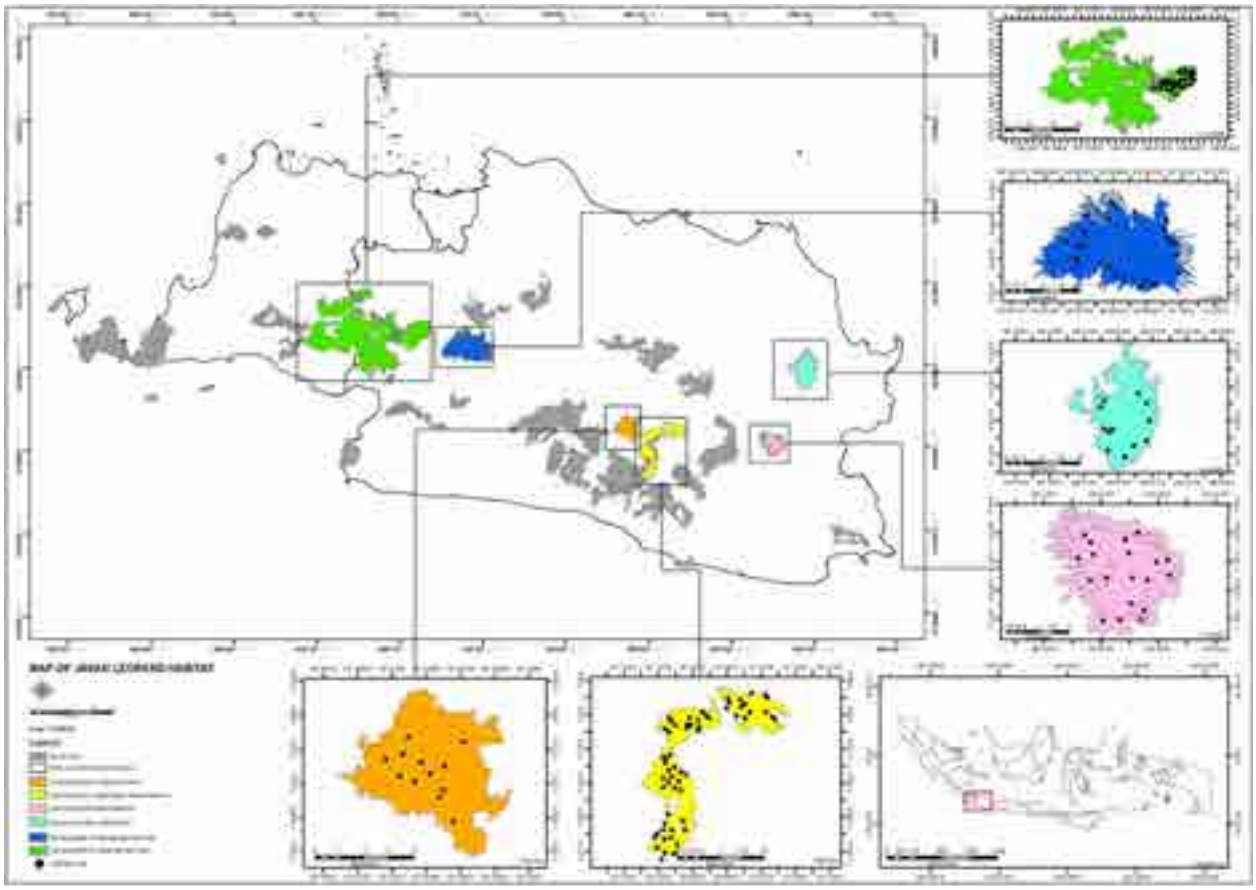

Figure 1. Map of study areas in West Java, Indonesia.

Table 1. List of protected areas in West Java, Indonesia, and their key characteristics.

Name	Size (km²)	Elevation (m)	IUCN Protected Area category	Description
Gunung Gede Pangrango National Park (GGPNP)	242.8	500–3,019	II	GGPNP was designated a biosphere reserve in 1977 and established as national park in 1980. It encompasses two stratovolcanoes with seven craters located at elevations of 2,600–2,927 m. Its topography is hilly and mountainous with forest cover classified as submontane, montane and subalpine forests; annual rainfall is 4,000–6,000 mm, and temperature ranges from 18–23°C (Harris 1996).
Gunung Ciremai National Park (GCNP)	155	500–3,078	II	GCNP was established in 2004. It surrounds a stratovolcano with a more than 20km² summit crater in its centre. The topography is hilly and mountainous with submontane, montane and subalpine forests; annual rainfall is 2,500–4,500 mm with temperatures ranging from 18–22°C (Kebun Raya Bogor 2001).
Gunung Malabar Protected Forest (GMPF)	88.9	1,000–2,300	VI	GMPF is a production forest managed by the Forestry State Enterprise Perhutani (Ario et al. 2018a). It encompasses a stratovolcano with fumaroles, hot springs, mud pools and altered ground on its southern slope (Bogie et al. 2008). The topography is hilly and mountainous with submontane and montane forests; annual rainfall is 2,000–2,500 mm with temperatures of 18–23°C (Ario et al. 2018a). It is disturbed due to encroachment for farming and hunting of wildlife (Ario et al. 2018a)
Gunung Sawal Wildlife Reserve (GSWR)	110	500–1,766	IV	GSWR was established in 1979. It encompasses an extinct volcano. The topography is hilly and mountainous with lowland and submontane forests; annual rainfall is around 2,000–2,500 mm with temperatures of 18–22°C (BBKSDA Jawa Barat 2018).
Gunung Guntur-Papandayan Nature Reserve (GGPNR)	153	773–2,678	IA	GGPNR was established in 2013. It encompasses two stratovolcanoes with active fumarole fields. Its topography is hilly and mountainous with submontane and montane forests; annual rainfall is 2,000–2,500 mm with temperatures from 19–27°C (BBKSDA Jawa Barat 2018).
Gunung Halimun Salak National Park (GHSNP)	877	500–2,211	II	GHSNP was established in 1992. It encompasses two stratovolcanoes with several cone craters at the summit. Its topography is hilly and mountainous with forest cover classified as lowland, submontane and montane forests; annual rainfall amounts to 4,000–6,000 mm, and temperature ranges from 19–23°C (Simbolon et al. 1998)

The tropical climate in the entire region is influenced by the southeastern Asian and Indo-Australian monsoon winds; the former brings rainfall from December to January, and the latter causes a dry season from June to August (Rahayu et al. 2018).

Potential prey species of the Leopard in the study areas include Wild Boar *Sus scrofa*, Red Muntjac *Muntiacus muntjac*, Javan Chevrotain *Tragulus javanicus,* Javan Gibbon *Hylobates moloch*, Javan Lutung *Trachypitecus auratus*, Javan Surili *Presbytis comata*, Long-tailed Macaque *Macaca fascicularis*, and Javan Slow Loris *Nycticebus javanicus* (Ministry of Environment and Forestry 2016; Ario et al. 2018b).

MATERIAL AND METHODS

Data collection

During the survey period from 2009 to 2018, we had three camera trap models at our disposal comprising Cuddeback® Digital Scouting Camera model 1125, Cuddeback® X-change white flash model 1279 (NonTypical Inc., Park Falls, WI, USA) and Bushnell Trophy Cam HD model 119547c. They were set to be active for 24 hours per day with one minute interval between consecutive photographs. We set them to take one to three photographs to select the best photograph for identification.

In each study area, we deployed camera traps in grids of 2 x 2 km^2 cells to maximize the chances that all individuals would be photographed, based on the smallest known Leopard home ranges in Asia (Grassman 1999; Ario et al. 2018b). Similar camera trapping designs were implemented by Borah et al. (2014), Noor et al. (2020) and Kittle et al. (2021). However, we excluded cells in the close perimeters of volcanoes that were difficult or potentially dangerous to access.

Most camera traps were positioned along animal trails where we found signs such as pugmarks, scrapes or faeces, and oriented in a north-south direction to avoid direct sunlight. They were mounted perpendicular to trails at a distance of 3–7 m from the trails' centre and at a height of 40 cm above ground to obtain photographs of the Leopard's flank, body and genitals. This height corresponds roughly with the shoulder height of an adult Leopard (Henschel & Ray 2003).

We surveyed each study area once using one camera trap per location due to the limited number of camera traps at our disposal. We did not use bait and covered all of GHSNP, GGPNP, GCNP, GSWR and GMPF in one survey block each, but two survey blocks in GGPNR. We determined coordinates and elevation of each location using a GPS device Garmin 64s that was set to WGS 84 datum. The distance between locations was 966–1,830 m. We kept camera traps at locations for 92 to 102 days to satisfy the assumption of population closure within each survey (Karanth 1995; Rostro-García et al. 2018). We tested population closure using the statistical program CAPTURE (Otis et al. 1978).

We consider photographs of single individuals and social units of several individuals as one detection of the species. Our definition of the term 'independent detection' refers to a) successive photographs of different individuals or social units of the same species, b) non-consecutive photographs of the same species, and c) one or several consecutive photographs of the same individual taken at the same location within an interval of 30 minutes.

Spatially Explicit Capture–Recapture

We identified individual Leopards by their distinct rosette patterns on both flanks, gauged their age class and sexed them by the size of their heads and bodies, and the presence of testes and dewlaps in males as described by Balme et al. (2012) (Image 1). Six observers independently verified identification of individuals. Blurred photographs were excluded for analysis.

Due to using a single camera trap per location, we separated photographs showing left and right flanks and used the flank with the highest number of identified individuals for analysis following O'Brien et al. (2003). We cross-checked identified individuals across neighbouring study areas, where surveys were conducted over the same period.

We estimated Leopard density in each of the six study areas using the spatially explicit capture-recapture (SECR) package in R version 3.1.5 (Efford 2018; R Core Team 2018). The SECR method combines information about the capture locations of individuals with their capture probability at point locations to estimate density (Efford et al. 2009; Royle et al. 2009). This method is less biased than conventional closed capture-recapture methods by study design, sample sizes and variation in detection probabilities for effective conservation and management (Sollmann et al. 2012; Ramesh & Downs 2013).

To avoid bias in determining the population size estimates for each study area, we used the effective sampled area and calculated SECR as the basis for the size of forest area. We analysed the spatial capture histories of camera traps in a likelihood-based density estimation framework, a method that does not require

the addition of a buffer to the trapping polygon for estimating effective trapping area resulting in less biased estimates (Efford et al. 2009).

As recommended by Tobler et al. (2013), we used sex covariates to improve density estimates and to show biologically important differences in movement patterns and detection probabilities between the two sexes. We used locations and detections of identified individuals on one or more sampling occasions, i.e. their detection histories, as input data for the SECR. We then separated the results of SECR analyses in group according to sex for each location.

The impact of sex on the parameter probability of capture at the activity centre of an individual (g0) and the spatial scale parameter describe the decline in probability of capture with distance from the activity centre (σ) (Efford et al. 2009). We tested g0 and σ through the comparison of four alternative models using the Akaike Information Criterion (AIC) adjusted for small sample size (AICc; Burnham & Anderson 2002): "secr.0" (null model), "secr.sex.g0" (g0 varies between males and females), "secr.sex.σ" (σ varies between males and females), and "secr.sex" (both g0 and σ vary between males and females) (Efford 2015; Boron et al. 2016). This model assumes that the detection of all individuals is governed by the same detection versus distance curve at all detectors on all occasions (Efford 2018).

Occupancy probability

We used single-season occupancy modelling to estimate occupancy probability (ψ) of Leopards at each site, with maximum likelihood estimation based on detection-nondetection data. The single-season model has three assumptions: 1) the method used to detect the species must generate non-equivocal presence data, 2) all the sampled sites must be 'closed' to change in occupancy for the duration of the survey period, and 3) detection of the species at a site should be independent from the detections at any other site. In order to allow for the estimator (ψ) to be interpreted as the proportion of area occupied, the following assumptions of an occupancy model were made: 1) sites are closed to changes in occupancy, i.e. they are either occupied or not by the species for the survey duration; 2) species are correctly identified; 3) detections are independent; and 4) heterogeneity in occupancy or detection probability are modelled using covariates (MacKenzie et al. 2006).

We reconstructed the Leopard camera trap history in each study area and divided the data into sampling occasions. We constructed a detection-nondetection matrix for all camera traps and occasions, with an entry of 1 if a Leopard had been detected at a particular location and occasion, and an entry of 0 otherwise. We categorized photographs into binary detection histories (1 = detected, 0 = not detected) by aggregating 15 survey days as a single survey occasion. The goodness-of-fit of the most complex model that included all contributing covariates (see below) was tested in four different collapsing scenarios (7-, 10-, 12-, and 15-day periods; MacKenzie & Bailey 2004). The 15-day period represented the optimum period length to maximize model fit (Tan et al. 2017). We entered the data into PRESENCE 2 version 12.41 (Hines 2006).

We used a constant model comprising the two components (ψ) and detection probability (p), and included three sampling covariates that potentially affect detection probability: camera traps were placed on animal trails (trail); trigger speed of camera trap model (camera) (Strampelli et al. 2018), and number of days the cameras traps were active in each location (effort) (Tan et al. 2017). We also included five site covariates, namely elevation, forest cover, distance to river, distance to village, and distance to road (Table 2), that potentially affect Leopard habitat use and detection probability (Ngoprasert et al. 2007; Erfanian et al. 2013; Mondal

Table 2. Covariates included in potential candidate detection and occupancy models.

Covariate name	Description
Sampling covariates	
Trail	Camera trap placed on animal trail (1) or not (0)
Camera	Trigger speed of camera trap models (range of 0.2–0.6 seconds)
Effort	The number of days a camera trap was active during each sampling occasion (range of 19–97 days)
Site covariates	
Elevation	Elevation of the camera trap location (range of 818–2,635 m) obtained from GPS device Garmin 64s and cross-checked with database of Badan Informasi Geospasial (2013)
Forest	Percentage of forest cover around camera trap locations (range of 65–98%) using values from Badan Informasi Geospasial (2013) database
River	Distance of the camera trap to the nearest river (range of 15–1,151 m) using values from Badan Informasi Geospasial (2013) database
Road	Distance of the camera trap to the nearest road (range of 215–4,943 m) using values from Badan Informasi Geospasial (2013) database
Village	Distance of the camera trap to the nearest human settlement (range of 481–6,152 m) using values from Badan Informasi Geospasial (2013) database
Boar	RAI of Wild Boar (range of 4.02–12.99 independent detections/100 camera trapping days)
Muntjac	RAI of Red Muntjac (range of 2.32–10.56 independent detections/100 camera trapping days)
Chevrotain	RAI of Javan Chevrotain (range of 1.58–6.07 independent detections/100 camera trapping days)

et al. 2013; Havmøller et al. 2019). We determined elevation using a GPS device Garmin 64s. We extracted values for forest cover and distances from the database of Badan Informasi Geospasial (2013) in ArcGIS version 10.4.1. We used the top ranked model on sampling covariates and site covariates with the lowest AIC score as a constant for building models that influenced habitat use and detection probability (Athreya et al. 2015).

Additionally, we included relative abundance index (RAI) values of three potential ungulate prey species from every camera trap location in each protected area as site covariates. RAI values are calculated as independent detections of these species per 100 days of camera trapping.

We ranked models based on the AICc values and identified those with the lowest AICc values as the best output models (MacKenzie et al. 2006). The best approximating models were selected based on the AICc and Akaike weights (wi). We then designated models with $\Delta AIC \leq 2$ as the top candidate (Burnham & Anderson 2002). From those models, we considered covariates to be important if they had relatively high-summed Akaike weights and outcompeted the null model [ψ(.), p(.)] with constant occupancy and detection to provide the most useful information regarding covariates that relate to Leopard occupancy.

RESULTS

Camera trapping

Between 1 February 2009 and 10 October 2018, we covered a total of 152 locations in an effective sampled area of 793.5km^2 with a total sampling effort of 10,955 camera trap days. We lost 12 camera traps due to theft, and seven were moved by people and covered with large leaves and branches. The surveys yielded 368 independent detections of 55 individual Leopards, comprising 161 of right flanks and 207 of left flanks; they were recorded at 85 locations at an elevation range of 818–2,635 m (Table 3). We discarded 69 blurred photographs for analysis. All identified individuals were adult (Images 2 to 5) and included five melanistic ones (Image 6).

Leopard density

Statistical tests support the population closure assumption for Javan Leopard in GGPNP (z = -0.31; p = 0.37), GCNP (z = 0.45; p = 0.67), GMPF (z = -0.01, p = 0.16), GSWR (z = -0.34, p = 0.37), GGPNR (z = -0.61, p = 0.27) and GHSNP (z = 0.28; p = 0.61).

For estimating Leopard density, the model based on no variation between sexes ranks top in three study areas, whereas variation between sexes ranked top in two study areas (Table 4).

Leopard density ranged from 4.92 ± 2.29 individuals/100 km^2 in GGPNR to 16.04 ± 6.29 individual/100 km^2 in GGPNP. The movement parameter (σ) was lowest in GGPNP with 1,070 m ± 1.81 for males and 676 m ± 1.24 for females, and highest in GGPNR with 4,227 m ± 1.21 and 2,564 m ± 6.69 for males and females, respectively. The probability of detection at home range centre (g0) was lowest in GSWR with 0.01 ± 0.012 for males and 0.031 ± 0.056 for females, and highest in GGPNR with 0.053 ± SE 0.051 for males and 0.064 ± SE 0.051 for females (Table 5).

Based on calculations, the analysis revealed an estimated population of about 20 Leopards in 125.8

Table 3. Sampling effort in six study areas with number of right (R) & left flanks (L), and adult male (M) & female (F) Javan Leopards detected. The bolded independent detections represent the flank used for identification of individuals.

Study area	Sampling period	Elevation	Effective sampled area in km^2	Locations	Camera trap days	Sampling occasion (days)	Independent detections	Adult individuals
GGPNP	01.ii.–03.v.2009	855–2,828	125.8	23	2,082	92	**R = 55**, L = 31	M = 8, F = 10
GCNP	14.i.–15.iv.2013	1,168–2,012	150	12	1,070	92	**R = 10**, L = 8	M = 1, F = 0
GMPF	01.xi.2013–04.ii.2014	1,500–2,226	85	12	1,102	96	**L = 56**, R = 30	M = 3, F = 4
GSWR	27.x.2016–01.ii.2017	818–1,766	86.9	14	1,317	98	**R = 21**, L = 9	M = 2, F = 3
GGPNR	01.vii.–10.x.2018	1,489–2,678	186.8	60	3,614	102	**L = 33**, R = 23	M = 3, F = 6
GHSNP	05.vii.–10.x.2018	964–1,962	159	31	1,770	98	**L = 70**, R = 22	M = 7, F = 8
		Total	793.5	152	10,955	578	R = 161, L = 207	M = 24, F = 31

Image 1. Male and female Javan Leopards in Gunung Gede Pangrango National Park. © Ministry of Environment and Forestry (MoEF) and Conservation International Indonesia (CI).

Image 2. Male Javan Leopard in Gunung Ciremai National Park. © MoEF and CI.

Image 3. Female Javan Leopard in Gunung Malabar Protected Forest. © MoEF and CI.

km² of GGPNP (95% CI: 9.68–42.38), seven Leopards in 85 km² of GMPF (95% CI: 2.62–18.87), five Leopards in 86.9 km² of GSWR (95% CI: 1.62–17.20), nine Leopards in 186.8 km² of GGPNR (95% CI: 3.98– 22.04), and 15 Leopards in 159 km² of GHSNP (95% CI: 7.47–30.04).

Detection probability

The estimated Leopard detection probability (p) ranges from 0.13 in GCNP to 0.22 in GMPF and GGPNP. The top ranked model showed that the detection probability of Leopard was affected by the distance of camera traps from animal trails in GGPNP, GCNP, GMPF, and GHSNP, but by the number of camera trap days in GSWR and GGPNR (Table 6).

Leopard occupancy

The estimated Leopard occupancy (Ψ) ranges from 0.51 (±SE 0.21) in GCNP to 0.94 (±SE 0.13) in GMPF, with a naïve estimate from 0.35 in GGPNR to 0.92 in GMPF (Table 7).

DISCUSSION

With an effective sampled area of 793.5 km² in six study areas, our camera trapping surveys covered about 6.8% of the total landscape identified by Wibisono et al. (2018) as suitable for the Javan Leopard. We identified 55 adult individuals during 578 sampling occasions in the period from February 2009 to October 2018. Although our surveys encompassed all seasons, none of the 31 identified female Leopards was recorded with a

Table 4. Model selection parameters for spatially explicit capture-recapture models.

Study area	Model	Description	AICc	ΔAICc	AICc wi	K
GGPNP	g0~1, σ~h2 (secr.sex.σ)	Variation between sexes affecting σ	179.34	0.00	0.90	5
	g0~1, σ~1 (secr.0)	No variation between sexes	184.40	5.07	0.07	4
	g0~h2, σ~1 (secr.sex.g0)	Variation between sexes affecting g0	186.83	7.50	0.02	5
	g0~h2, σ~h2 (secr.sex)	Variation between sexes affecting g0 and σ	188.71	9.38	0.01	5
GCNP		Not Applicable (NA)	NA	NA	NA	NA
GMPF	g0~1, σ~1 (secr.0)	No variation between sexes	242.47	0.00	1	4
	g0~h2, σ~h2 (secr.sex)	Variation between sexes affecting g0 and σ	280.23	37.76	0	5
	g0~1, σ~h2 (secr.sex.σ)	Variation between sexes affecting σ	284.06	41.59	0	5
	g0~h2, σ~1 (secr.sex.g0)	Variation between sexes affecting g0	284.44	41.97	0	5
GSWR	g0~1, σ~1 (secr.0)	No variation between sexes	270.78	0.00	0.60	4
	g0~1, σ~h2 (secr.sex.σ)	Variation between sexes affecting σ	265.01	5.64	0.24	5
	g0~h2, σ~1 (secr.sex.g0)	Variation between sexes affecting g0	264.37	8.19	0.12	5
	g0~h2, σ~h2 (secr.sex)	Variation between sexes affecting g0 and σ	260.10	10.20	0.04	5
GGPNR	g0~1, σ~1 (secr.0)	No variation between sexes	222.66	0.00	0.79	4
	g0~h2, σ~h2 (secr.sex)	Variation between sexes affecting g0 and σ	225.61	2.95	0.18	5
	g0~1, σ~h2 (secr.sex.σ)	Variation between sexes affecting σ	229.76	7.10	0.02	5
	g0~h2, σ~1 (secr.sex.g0)	Variation between sexes affecting g0	231.40	8.74	0.01	5
GHSNP	g0~h2, σ~h2 (secr.sex)	Variation between sexes affecting g0 and σ	317.14	0.00	0.48	5
	g0~1, σ~1 (secr.0)	No variation between sexes	317.38	0.24	0.43	4
	g0~1, σ~h2 (secr.sex.σ)	Variation between sexes affecting σ	321.93	4.78	0.04	5
	g0~h2, σ~1 (secr.sex.g0)	Variation between sexes affecting g0	322.01	4.87	0.04	5

Notes: the values probability of capture at the home range centre (g0), spatial parameter related to home range size (σ), Akaike information criterion adjusted for small sample size (AICc), difference from best ranking model (ΔAICc), model weighting (AICc wi), and number of model parameters (K).

Table 5. Results from SECR analyses for Leopard density in six study areas.

Study area	Gender	D (± SE) adult individuals/100 km²	LCL (CI 95%)	UCL (CI 95%)	σ (±SE) m	g0 (±SE)
GGPNP	M	4.94 (1.86)	2.46	10.12	1,070 (1.81)	0.026 (0.012)
	F	11.1 (4.43)	5.24	23.58	676 (1.24)	0.036 (0.012)
		16.04 (6.29)				
GCNP	M	Not Applicable (NA)	NA	NA	NA	NA
GMPF	M	3.42 (1.99)	1.19	9.85	2,091 (4.51)	0.023 (0.011)
	F	4.88 (2.47)	1.91	12.45	1,719 (3.59)	0.024 (0.006)
		8.30 (4.46)				
GSWR	M	1.96 (1.39)	0.56	6.8	2,120 (3.94)	0.010 (0.012)
	F	4.16 (2.62)	1.33	12.95	1,447 (5.66)	0.031 (0.056)
		6.12 (4.01)				
GGPNR	M	1.50 (0.85)	0.51	4.22	4,227 (1.21)	0.053 (0.051)
	F	3.42 (1.44)	1.57	7.58	2,564 (6.69)	0.064 (0.051)
		4.92 (2.29)				
GHSNP	M	4.36 (1.65)	1.25	7.51	1,996 (5.61)	0.025 (0.006)
	F	5.08 (1.80)	3.45	11.39	1,827 (3.57)	0.031 (0.008)
		9.44 (3.45)				

Notes: values for density (D), standard error (SE), confidence interval (CI), lower confidence limit (LCL), upper confidence limit (UCL), movement parameter (σ), the probability of detection at home range centre (g0).

cub, which is a matter of concern. In contrast, female Leopards with cubs were recorded between June and November in protected areas in Nepal and Iran (Odden & Wegge 2005; Farhadinia et al. 2009; Ghoddousi et al. 2010), and between February and May in southern Sri Lanka (Kittle et al. 2017).

We recorded only one Leopard in Gunung Ciremai National Park (GCNP) despite an effective sampled area of 150 km^2 in 1,070 camera trap days. Doubts about the small population led the GCNP management to continue the camera trap survey during 2014 to 2018, but not even a single photograph of a Leopard was obtained (R. Gumilang, pers. comm. 20 November 2018). For the recovery of a Leopard population in this area, a male Leopard was translocated to GCNP in July 2019 (Wibisono et al. 2021), and a female Leopard was released in March 2022 (R. Gumilang, pers. comm. 10 March 2022).

Leopard density

Our study provides the first estimate for Leopard density and distribution in montane protected areas of West Java using the spatially explicit capture-recapture method. Our study area in Gunung Halimun Salak National Park yielded the highest number of 70 independent detections (IDs). This is the only study area, in which the sex of 15 identified individuals affects both detection and spatial parameters as best model for estimating density. The slightly lower number of 55 IDs in Gunung Gede Pangrango National Park affects only the spatial parameter as top model, despite 18 identified individuals. The influence of the variation between sexes on density estimates is considerably lower in the remaining study areas, where we identified between five and nine individuals in 21 to 56 IDs. We therefore assume that a minimum of 56 IDs with at least 15–18 identified individuals represent the threshold necessary for modelling sex-specific Leopard density. A higher sample size facilitates modelling sex-specific differences in detectability and spatial patterns (Goldberg et al. 2015; Kittle et al. 2021; Vinks et al. 2021), whereas a smaller sample size is insufficient for this model (Strampelli et al. 2020).

Our study area in Gunung Gede Pangrango National Park covered about 52% of the park's total size and exhibited the highest Leopard density estimate of our study areas, followed by Gunung Halimun Salak National Park. Our study area in latter national park covered about 18.2% of its total size of 876.99 km². Giri & Munawir (2021) estimated that suitable Leopard habitat in Gunung Halimun Salak National Park is limited to about 476 km². Follow-up surveys are necessary to see whether our density estimates hold for all of the extents of these two national parks, and also to assess whether they can indeed support 50 and 100 Leopards, respectively, as assumed by Wibisono et al. (2018).

The Leopard density of 8.30 ± SE 4.46 in a non-conservation area like Gunung Malabar Protected Forest corroborates its suitability as Leopard habitat. The rather low Leopard density of 6.12 ± SE 4.01 and low detection probability at home range centre in Gunung Sawal Wildlife Reserve coincides with the highest frequency of conflict between local people and Leopards documented in Java; 48 cases were reported between 2001 and 2015 (Gunawan et al. 2017). Leopard density was lowest in Gunung Guntur-Papandayan Nature Reserve with 4.92 ± SE 2.29 individuals per 100 km^2 despite a high survey effort of 3,614 camera trap days at 60 locations.

Our density estimates for all study areas are bounded by wide confidence intervals, probably because of the low number of recaptures indicating that Leopards were not always detected when present. Several sampling covariates may have impacted differences in detection probabilities. The surveys were conducted during different seasons, and the sampling effort and duration differed between study areas. Habitat features around locations ranged from open to close vegetation. Avoiding disturbed sites is a common behaviour of the Leopard that has been documented across range countries and study areas (Ngoprasert et al. 2007; Khorozyan et al. 2008; Rosenblatt et al. 2016; Havmøller et al. 2019; Kittle et al. 2021; Islam et al. 2021).

With 16.04 ± SE 6.29 individuals/100 km², our study area in Gunung Gede Pangrango National Park holds a higher density than reported for Ujung Kulon National Park in southwestern Java by Rahman et al. (2018). At present, it ranks high in comparison with other study areas in Leopard range countries (Table 8).

Detection probability

The detection probability was positively correlated with proximity of camera traps to animal trails in Gunung Gede Pangrango National Park, Gunung Ciremai National Park, Gunung Malabar Protected Forest and Gunung Halimun Salak National Park. This reasserts the notion that animal trails facilitate Leopard movement (Borah et al. 2014; Ngoprasert et al. 2017), and that the placement of camera traps close to trails enhances the chances of detecting a Leopard (Strampelli et al. 2018). In contrast, the sampling covariate 'effort', i.e. number of camera trap days, was the principal predictor for detection probability in Gunung Sawal Wildlife Reserve

Table 6. Model selection for detection probability (p) analyses in six sites in West Java.

Study area	Model	AICc	ΔAICc	AICc wi	K	p (±SE)	−2 log likelihood
GGPNP	p(trail)	263.19	0.00	0.95	3	0.22 (0.03)	257.19
	p(effort)	270.92	7.73	0.02	3	0.22 (0.04)	264.92
	p(.)	271.35	8.16	0.02	2	0.22 (0.05)	267.35
	p(camera)	273.27	10.08	0.01	3	0.22 (0.05)	267.27
GCNP	p(trail)	79.97	0.00	0.76	3	0.13 (0.04)	67.97
	p(.)	77.68	3.71	0.12	2	0.12 (0.04)	73.68
	p(effort)	78.61	4.64	0.08	3	0.11 (0.04)	72.61
	p(camera)	79.68	5.71	0.04	3	0.11 (0.05)	73.68
GMPF	p(trail)	180.68	0.00	0.81	3	0.22 (0.04)	174.68
	p(effort)	184.72	4.04	0.11	3	0.22 (0.04)	178.72
	p(.)	186.00	5.32	0.06	2	0.21 (0.04)	182.00
	p(camera)	187.96	7.28	0.02	3	0.21 (0.05)	181.96
GSWR	p(effort)	125.24	0.00	0.41	3	0.16 (0.04)	119.24
	p(camera)	125.99	2.75	0.28	3	0.14 (0.03)	119.99
	p(.)	126.54	4.76	0.21	2	0.14 (0.03)	122.54
	p(trail)	128.00	5.30	0.10	3	0.14 (0.04)	122.00
GGPNR	p(effort)	267.99	0.00	0.63	3	0.16 (0.02)	261.99
	p(.)	270.14	2.15	0.21	2	0.16 (0.04)	266.14
	p(camera)	272.10	4.11	0.08	3	0.14 (0.04)	266.10
	p(trail)	272.13	4.14	0.08	3	0.14 (0.02)	266.13
GHSNP	p(trail)	344.69	0.00	0.70	3	0.17 (0.03)	338.69
	p(effort)	357.14	2.45	0.12	3	0.16 (0.02)	351.14
	p(.)	358.46	3.77	0.10	2	0.16 (0.03)	354.46
	p(camera)	360.20	5.51	0.08	3	0.16 (0.03)	354.20

and Gunung Guntur-Papandayan Nature Reserve. In these two study areas, the ratio of 21–33 independent detections per 5–7 identified individuals was lower than in afore-mentioned study areas. This lower detection rate may be the reason for the site covariate 'trail' being less significant than the sampling covariate 'effort'.

Leopards exhibited marked variation in movement parameters. The high detection probability and high movement parameters of both female and male Leopards in Gunung Guntur-Papandayan Nature Reserve may indicate that they used a high proportion of the surveyed area but avoid the central volcanic part. The lower movement parameters in Gunung Gede Pangrango National Park may indicate a high prey abundance in the surveyed area.

Leopard occupancy

Leopard occupancy in all our study areas was high in forests, a site covariate that has also been shown to be the preferred habitat type of the Leopard across Sri Lanka (Kittle et al. 2017). This stresses the importance of forest cover for Leopard distribution and persistence, especially in rather small isolated areas that do not afford the protection level of national parks like Gunung Sawal Wildlife Reserve and Gunung Malabar Protected Forest. As pointed out by Wibisono et al. (2018), the Javan Leopard has been under high pressure because of habitat isolation as a result of severe forest fragmentation since at least the turn of this century.

In Gunung Gede Pangrango National Park, the Leopard occupancy model based on the relative abundance index (RAI) of Wild Boar ranked even higher than the one based on forest cover. It also ranked high in four study areas, followed by RAI of Red Muntjac in three study areas. This result underscores the significance of integrating RAIs of potential prey species into modelling

Table 7. Single-season occupancy models for Javan Leopard distribution in six study areas in West Java, Indonesia.

Study area	Models	AICc	ΔAICc	AICc wi	K	Naïve estimate	Ψ (±SE)	p (±SE)
GGPNP	Ψ(boar),p(trail)	249.09	0.00	0.55	4	0.65	0.67 (0.13)	0.22 (0.03)
	Ψ(forest),p(trail)	251.91	1.82	0.22	4	0.65	0.67 (0.11)	0.22 (0.03)
	Ψ(muntjac),p(trail)	255.56	1.98	0.20	4	0.65	0.67 (0.12)	0.22 (0.03)
	Ψ(village),p(trail)	256.40	7.31	0.02	4	0.65	0.66 (0.12)	0.22 (0.03)
	Ψ(chevrotain),p(trail)	259.60	10.51	0.01	4	0.65	0.66 (0.11)	0.22 (0.03)
	Ψ(road),p(trail)	260.82	11.73	0.00	4	0.65	0.66 (0.12)	0.22 (0.03)
	Ψ(elevation),p(trail)	263.08	13.99	0.00	4	0.65	0.66 (0.14)	0.22 (0.03)
	Ψ(river),p(trail)	264.98	15.89	0.00	4	0.65	0.66 (0.14)	0.22 (0.03)
	Ψ(.),p(.)	271.35	22.26	0.00	2	0.65	0.67 (0.10)	0.22 (0.03)
GCNP	Ψ(forest),p(trail)	66.90	0.00	0.66	4	0.42	0.51 (0.21)	0.13 (0.04)
	Ψ(village),p(trail)	70.66	3.76	0.10	4	0.42	0.51 (0.21)	0.13 (0.04)
	Ψ(road),p(trail)	70.79	3.89	0.09	4	0.42	0.51 (0.21)	0.13 (0.04)
	Ψ(elevation),p(trail)	70.79	3.89	0.09	4	0.42	0.51 (0.21)	0.13 (0.04)
	Ψ(boar),p(trail)	74.44	7.54	0.02	4	0.42	0.50 (0.24)	0.12 (0.04)
	Ψ(muntjac),p(trail)	75.17	8.27	0.02	4	0.42	0.50 (0.24)	0.12 (0.04)
	Ψ(chevrotain),p(trail)	75.80	8.90	0.01	4	0.42	0.50 (0.24)	0.12 (0.04)
	Ψ(river),p(trail)	75.94	9.04	0.01	4	0.42	0.50 (0.24)	0.11 (0.04)
	Ψ(.),p(.)	77.68	10.78	0.00	2	0.42	0.50 (0.19)	0.11 (0.04)
GMPF	Ψ(forest),p(trail)	178.88	0.00	0.34	4	0.92	0.94 (0.13)	0.22 (0.04)
	Ψ(boar),p(trail)	178.88	1.78	0.13	4	0.92	0.94 (0.13)	0.22 (0.04)
	Ψ(muntjac),p(trail)	178.88	1.90	0.12	4	0.92	0.94 (0.13)	0.22 (0.04)
	Ψ(river),p(trail)	178.88	2.15	0.10	4	0.92	0.94 (0.13)	0.22 (0.04)
	Ψ(chevrotain),p(trail)	184.56	2.36	0.10	4	0.92	0.93 (0.14)	0.22 (0.04)
	Ψ(elevation),p(trail)	184.56	3.80	0.06	4	0.92	0.93 (0.15)	0.21 (0.04)
	Ψ(road),p(trail)	185.68	3.80	0.06	4	0.92	0.93 (0.15)	0.21 (0.04)
	Ψ(village),p(trail)	185.68	3.80	0.06	4	0.92	0.93 (0.15)	0.21 (0.04)
	Ψ(.),p(.)	186.00	7.12	0.03	2	0.92	0.93 (0.08)	0.22 (0.03)
GSWR	Ψ(forest),p(effort)	112.85	0.00	0.39	4	0.57	0.64 (0.15)	0.16 (0.05)
	Ψ(boar),p(effort)	112.85	1.98	0.20	4	0.57	0.64 (0.15)	0.16 (0.05)
	Ψ(river),p(effort)	126.09	3.24	0.09	4	0.57	0.63 (0.15)	0.14 (0.03)
	Ψ(muntjac),p(effort)	126.09	3.60	0.08	4	0.57	0.63 (0.15)	0.14 (0.03)
	Ψ(.),p(.)	126.54	3.69	0.08	2	0.57	0.63 (0.15)	0.14 (0.03)
	Ψ(chevrotain),p(effort)	127.01	5.16	0.06	4	0.57	0.63 (0.15)	0.14 (0.03)
	Ψ(elevation),p(effort)	127.01	5.16	0.01	4	0.57	0.63 (0.15)	0.14 (0.03)
	Ψ(village),p(effort)	127.13	5.28	0.05	4	0.57	0.63 (0.15)	0.14 (0.03)
	Ψ(road),p(effort)	127.24	7.39	0.04	4	0.57	0.63 (0.15)	0.14 (0.03)
GGPNR	Ψ(forest),p(effort)	241.55	0.00	0.34	4	0.35	0.60 (0.08)	0.16 (0.02)
	Ψ(boar),p(effort)	241.55	1.87	0.18	4	0.35	0.60 (0.08)	0.16 (0.02)
	Ψ(elevation),p(effort)	264.79	3.24	0.09	4	0.35	0.60 (0.15)	0.14 (0.02)
	Ψ(muntjac),p(effort)	264.79	3.40	0.08	4	0.35	0.60 (0.15)	0.14 (0.02)
	Ψ(chevrotain),p(effort)	264.79	4.87	0.07	4	0.35	0.60 (0.15)	0.14 (0.02)
	Ψ(village),p(effort)	266.47	4.92	0.07	4	0.35	0.59 (0.16)	0.14 (0.02)
	Ψ(road),p(effort)	268.53	6.98	0.06	4	0.35	0.59 (0.16)	0.14 (0.02)
	Ψ(river),p(effort)	269.91	8.36	0.06	4	0.35	0.58 (0.16)	0.14 (0.02)

Study area	Models	AICc	ΔAICc	AICc wi	K	Naïve estimate	Ψ (±SE)	p (±SE)
	Ψ(.),p(.)	270.14	8.59	0.05	2	0.35	0.58 (0.15)	0.14 (0.02)
GHSNP	Ψ(forest),p(trail)	339.57	0.00	0.51	4	0.74	0.80 (0.11)	0.17 (0.03)
	Ψ(muntjac),p(trail)	339.56	1.56	0.15	4	0.74	0.80 (0.11)	0.17 (0.03)
	Ψ(boar),p(trail)	349.56	1.98	0.12	4	0.74	0.80 (0.12)	0.17 (0.04)
	Ψ(river),p(trail)	349.52	3.95	0.04	4	0.74	0.80 (0.12)	0.17 (0.04)
	Ψ(chevrotain),p(trail)	349.52	3.95	0.04	4	0.74	0.79 (0.11)	0.16 (0.03)
	Ψ(road),p(trail)	346.57	7.00	0.04	4	0.74	0.79 (0.11)	0.16 (0.03)
	Ψ(elevation),p(trail)	346.66	7.09	0.04	4	0.74	0.79 (0.11)	0.16 (0.03)
	Ψ(village),p(trail)	346.69	7.12	0.04	4	0.74	0.78 (0.11)	0.16 (0.03)
	Ψ(.),p(.)	358.46	8.89	0.02	2	0.74	0.78 (0.11)	0.17 (0.03)

Image 4. Male Javan Leopard in Gunung Sawal Wildlife Reserve. © MoEF, TSI, Formata and CI.

Image 5. Female Javan Leopard in Gunung Guntur-Papandayan Nature Reserve. © MoEF and CI.

Leopard occupancy. Lamichhane et al. (2021) showed that the presence of the Wild Boar is a strong predictor of Leopard occupancy in a forested mountain range in Nepal. In several study areas in Asia, the Wild Boar constitutes a major proportion of the Leopard's diet (Sharbafi et al. 2016; Kandel et al. 2020), especially when other prey species are depleted (Ghoddousi et al. 2017). It also exhibits a higher temporal and spatial overlap with the Leopard than other ungulates (Ghoddousi et al. 2020; Kittle et al. 2021; Sehgal et al. 2022).

The remaining site covariates elevation, distance to road, village and river were less important predictors for Leopard occupancy in all our study areas.

Image 6. Male Javan Leopard in Gunung Halimun Salak National Park. © MoEF and CI.

Management implications and recommendations

Density estimates are not equally robust, and under- or over-estimating densities can have substantial implications for conservation management and policy (Foster & Harmsen 2012; Hayward et al. 2015). We recommend to maximise capture and recapture probabilities in future surveys by implementing a closer-knit camera trapping design with a maximum spacing of 1,500 m between locations and placing two opposite camera traps per location. Regular monitoring surveys in all our study areas and beyond are essential for

Table 8. Leopard densities in national parks (NP), wildlife sanctuaries (WS), and protected areas in range countries in Asia.

Study area	Leopard density per 100km²	Source
Rajaji Corbett NP, India	14.99 ± SE 6.9	Harihar et al. (2009)
Mudumalai NP, India	13.17 ± SE 3.15	Kalle et al. (2011)
Ujung Kulon NP, Java	12.8 ± SE 1.99 in dry season 11.24 ± SE 3.16 in wet season	Rahman et al. (2018)
Kuiburi NP, Thailand	12.6 ± SE 3.6	Steinmetz et al. (2009)
Ruhuna (Yala) National Park, Sri Lanka	12.1	Kittle et al. (2017)
Horton Plains NP, Sri Lanka	11.7 ± SE 5.5	Kittle & Watson (2017)
Kuno WS, India	11 ± SE 4.6	Pawar et al. (2019)
Wilpattu NP, Sri Lanka	10.4 ± SE 1.9	Kittle et al. (2021)
Sarigol NP, Iran	8.86 ± SE 3.60	Farhadinia et al. (2019)
Royal Manas National Park, Bhutan	6.25–15.93	Goldberg et al. (2015)
Mondulkiri Protected Forest, Cambodia	3.6 ± SE 1.0	Gray & Prum (2012)
Manas NP, India	3.4 ± SE 0.82	Borah et al. (2014)
Tembat Forest Reserve, Malaysia	3 ± SE 1.02	Hedges et al. (2015)
Bamu NP, Iran	1.87 ± SE 0.07	Ghoddousi et al. (2010)
Shaanxi Province, China	2.0 ± SE 0.53; 2.4 ± SE 0.67	Yang et al. (2021)
Kamdi Biological Corridor, Nepal	1.5 ± SE 0.49	Kandel et al. (2020)
Jigme Singye Wangchuck NP, Bhutan	1.04 ± SE 0.01	Wang & Macdonald (2009)
Srepok WS, Cambodia	1	Rostro-García et al. (2018)

assessing changes in Leopard densities as a baseline for readjusting management interventions.

Efforts to recover the Javan Leopard need focus on maintaining landscape integrity and reducing poaching (Wibisono et al. 2018). Integrated management of suitable Leopard habitat in West Java is utmost important, because Leopards inhabit forest types under three different management regimes, namely conservation forests, protected forests and production forests, which are currently managed by three different authorities. Priority management interventions inside and outside protected areas must be aimed at preventing further habitat fragmentation and decline of prey species. Degraded habitats need to be restored to improve habitat quality, ideally with the support of multiple stakeholders. Since a large part of landscapes suitable for Leopard survival includes production and secondary forests (Wibisono et al. 2018), we strongly recommend identifying and mapping potential wildlife corridors with low conflict risk that are suitable to increase connectivity between forest patches and protected areas. We emphasize that both a landscape approach and conflict mitigation is imperative to ensure the long-term viability of both Leopard and prey populations.

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Bahasa: Macan Tutul Jawa adalah satwa endemik pulau Jawa di Indonesia dan diklasifikasikan sebagai *Endangered species*. Informasi terpercaya tentang status populasi, distribusi, dan kepadatannya masih kurang, namun sangat penting sebagai pedoman dalam upaya konservasi dan memberikan tolok ukur untuk intervensi pengelolaan. Studi kami mewakili perkiraan kepadatan dan hunian empiris pertama untuk Macan Tutul di Jawa Barat dan menyediakan data dasar untuk wilayah ini. Kami menggunakan data *camera trap* yang dikumpulkan dari Februari 2009 hingga Oktober 2018 di enam wilayah studi yang meliputi upaya pengambilan sampel selama 10.955 hari rekam di total area seluas 793,5 km². Kami mengidentifikasi 55 individu Macan Tutul di seluruh wilayah studi dan memperkirakan kepadatan Macan Tutul menggunakan *spatially explicit capture-recapture*. Perkiraan kepadatan berkisar dari 4,9 individu/100 km² di Cagar Alam Gunung Guntur-Papandayan hingga 16,04 individu/100 km² di Taman Nasional Gunung Gede Pangrango, yang merupakan salah satu kepadatan macan tutul tertinggi secara global. Berdasarkan data deteksi, kami memodelkan hunian Macan Tutul satu musim menggunakan tiga kovariat pengambilan sampel dan delapan kovariat lokasi. Pemodelan mengungkapkan bahwa dua kovariat yaitu tutupan hutan dan keberadaan Babi Hutan adalah prediktor terkuat untuk hunian Macan Tutul di wilayah studi kami. Kami merekomendasikan untuk menilai dan memantau distribusi, kepadatan dan hunian Macan Tutul di wilayah lain di Jawa dan menekankan bahwa pendekatan lansekap sangat penting untuk konservasi Macan Tutul.

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Author contributions: All authors contributed equally to conceiving and designing the study and assisted in data collection. AA performed the analyses and wrote the manuscript.

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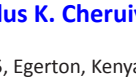

ARTICLE

Breeding phenology and population dynamics of the endangered Forest Spiny Reed Frog *Afrixalus sylvaticus* Schiøtz, 1974 in Shimba Hills, Kenya

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Abstract: *Afrixalus sylvaticus* Schiøtz, 1974 is a species of hyperoliid frog inhabiting coastal forest Kenya. It is classified as endangered under IUCN B2ab(iii) ver 3.1 and occurs in the Shimba Hills National Park and hinterlands. Habitat loss and other human activities are threatening the species. Therefore, understanding the breeding ecology and population dynamics is important for its conservation. This study assessed the breeding ecology and population dynamics of the species in the protected and community landscapes in Shimba Hills National Reserve in Kenya. Data was collected through ecological surveys conducted from June 2016 to July 2017 using a visual encounter surveys (VES) method. The results show that the species was more abundant during the wet season than dry (58% and 42%, respectively). The population estimate was 192 individuals and a density of 0.98 individuals/km^2. Regarding the morphology, the mean snout-vent length (SVL) for males was 15.12 mm and females 15.96 mm, but there was no significant difference (t-test = 0.87, p = 0.390, df = 39). The mean weight of both gravid and non-gravid females was 6.05 g and males was 4.82 g. The weights were statistically different between both sexes (t-test = 3.50, p-value = 0.001, df = 39). The sex ratio was 1:2 (male: female). There was more activity in the wet season (April and May), and the breeding habitats were reeds and water lilies. The threats identified to their habitat include; human activities such as bush burning, livestock grazing, drainage, and plantation of exotic tree species (*Eucalyptus* sp.) that have led to habitat loss and degradation. The study recommends that the reforestation processes such as plantation of exotic species such as *Eucalyptus* sp. and *Casuarina* sp. and bush burning in the wetlands and species habitats must be discouraged among the stakeholders (community and park management). Moreover, more synchronized studies are necessary to highlight the driver(s) of imbalanced sex ratios and species habitat shifts.

Keywords: Amphibians, anura, ecology, habitat, hyperoliid frog, morphometrics.

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Author contributions: AK—(principal investigator) being the lead researcher contributed to the data collection, processing and drafting of the manuscript. GE and BK were project patrons and contributed to data processing and editing of the manuscript. PKC assisted in field work coordination, collection of data and proofreading of the manuscript.

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INTRODUCTION

Amphibians throughout the world are in decline, with 41% of the world's 6,638 known amphibian species threatened with extinction (Walls et al. 2017; Grant et al. 2020). A global decline in amphibians was first recognized in 1989 (Vitt et al. 1998; Wake 1991), and the situation has not improved since then. According to IUCN (2010a), towards the end of 1998, 124 species of amphibians were categorized as threatened; but by 2010 the number had increased more than 15 times to 1898 threatened species (Hamer & Parris 2011). This decline represents 29% of the total number of amphibian species described in the IUCN Red List (IUCN 2010a), more than any other category of animals. The decline is likely to have implications on the ecosystem services provided by amphibians such as biological pest controlling and bioturbation (Valencia-Aguilar et al. 2013).

Afrixalus sylvaticus Schiøtz, 1974 is a species of frog in the family Hyperoliidae (Frost, 2022). The species is categorised as Vulnerable in the IUCN Red List (IUCN SCC Amphibian Specialist Group 2016), and the distribution range is limited to Shimba Hills (Kenya), through the East Usambara foothills in northeastern Tanzania. The species occurs only very patchily within the mapped range due to limited suitable habitat. Its natural habitats are dry forests, moist lowland forests, intermittent freshwater marshes, plantations, and degraded forest.

The primary threat to this species is habitat loss through drainage of wetlands and afforestation (Bwong et al. 2017). In several areas of prime habitat, the planting of exotic trees such as *Eucalyptus* sp. and *Casuarina* sp. forests has lowered the water table to such a degree that many ponds within the coastal dune forest have entirely disappeared (Martin et al. 2004). Along the gradient of Shimba Hills National Reserve, there are wide-ranging human activities that extend to the protected area since the reserve policy in Kenya allows human activities within the national reserves (The Wildlife Act Chapter 376 of 2010). These activities include resins collection, fuel wood collection, and herbs collection. Shimba Hills is under category "B" together with Arabuko Sokoke Forest Reserve, Ndere Island and Tana Primate Reserve. Along the gradient of the reserve boundaries, there were human settlement, agro-ecosystems, infrastructure such as roads, making it an "ecological island."

Beebee & Griffiths (2005) noted that the global amphibian decline phenomenon is associated with population decrease and extinctions in many regions of the world. The need for ecological studies of amphibians, especially those addressing population dynamics, is a priority (Houlahan et al. 2000). The main objective of this research was to assess the breeding ecology and population dynamics of the species in the protected area and community lands.

MATERIALS AND METHODS

Study area

We carried out the study in Shimba Hills National Reserve and its hinterlands (4.2572°S, 39.3877°E) in Kwale County, Kenya (Figure 1). The area was selected as it is the only remaining habitat that *Afrixalus sylvaticus* is found after the cultivation of rice schemes in former habitats (Kaloleni areas). The Shimba Hills National Reserve is part of the larger Shimba Hills ecosystem, which also comprises the Mwaluganje Elephant Sanctuary, the Mwaluganje Forest Reserve, the Mkongani North Forest Reserve and the Mkongani West Forest Reserve and covers a total area of 250 km² (Bwong et al. 2017).

Methods

Ecological surveys were conducted for 60 days in September–December 2016 (dry season) and another 60 days in April–June 2017 (wet season). The sampling was done along six transects distributed equally both in protected and unprotected areas. The unprotected parts were characterized by human activities ranging from agro-ecosystems to settlements and infrastructure. During the fieldwork , visual encounter surveys (VES) (Crump & Scott 1994: Peek et al. 2017) were used in all potential microhabitats of the species. The survey was along the river transect (1,000 m) but the sampling protocol was adjusted in some areas due to difficult terrain or at pools of water where line transect was limiting. The number of individuals encountered within 10m of each side of the transect line was captured, marked, morphometric/biometric and population attributes recorded. Marking was by using toe clipping as adopted by (Donnelly et al. 1994).

Morphometric parameters measured were; snout-vent length (SVL) in mm ±0.01mm, weight (g), head width (HW), number of resting lines (RL) and population attributes were sex, age, and other visible traits such as skin colour or visible eggs. The maturity levels were classifiesd using the presence of resting lines (that are found usually only in adults). Additionally, we determined the sex of the individuals using coarseness of the dorsum. Males have a coarse dorsum, while females have smooth dorsum (Tillack et al. 2021). Additionally, males develop nuptial pads on the underside of limbs

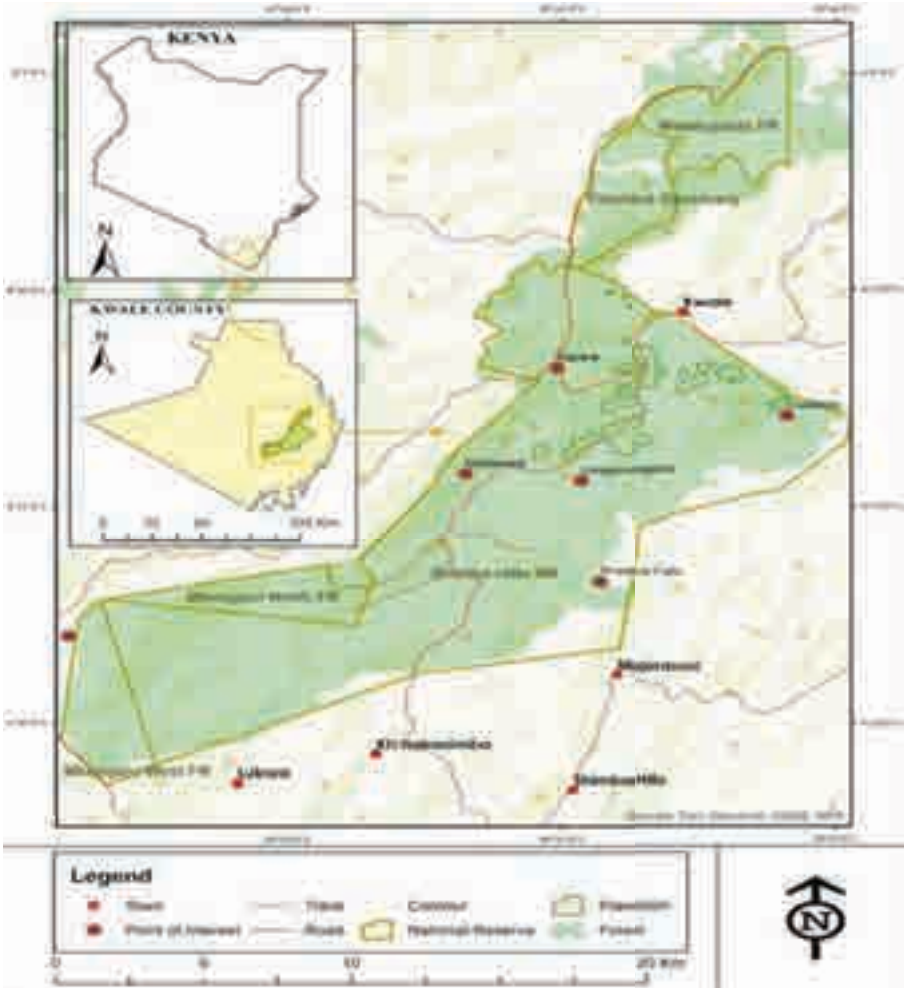

Figure 1. Study area—Shimba Hills National Reserve (Source: Modified data from ESRI, 2016).

and toes which facilitate amplexus. These are patches of darkened skin which are rough to touch. The parameters recorded during sampling include: seasons, land tenure system, time of the surveys and weather. The population density within the study areas was determined using Peterson method (Krebs, 1989) comparing the observed individuals between sample periods once every month. Chi-square test, ANOVA, and t-tests were used for comparisons of variables.

Population estimate was determine using repeat mark-recapture technique

$$N = \frac{M_2 C_2}{R_2} + \frac{M_3 C_3}{R_3} + \frac{M_3 C_3}{R_4} \quad \text{..... (1)}$$

Where:
N-Estimated population size
M-Number Marked in first catch
C-Number caught in second catch in total
R-Number Recaptured in second catch

The two sampling periods were treated as separate marking exercises, as there were no recaptures in wet period that were marked in dry period. M_3 was total of captures in second month and first month minus the recaptures in second round of sampling and C_3 was total of captures in 3rd month in each sampling period while R3 was total recaptures in 3rd month. Population density was estimated using Canonical density estimator since in some situations, the transect layout was non-uniform (not linear for instance in water pool).

$$D = \frac{n}{a} \quad \text{..... (2)}$$

Where:
D-Density of the species
N-Total number of animals counted
A-Total area located at random (transect)

RESULTS

Species occurrences in sampling sites

Within the protected area, Shimba lodge marshes were densely populated (Wet season: 13 and Dry season: 6). It represents 19% of the entire sampling sites. Other sites in the protected area were; Manolo and Mwele catchment (Table 1). In the community lands, Mwandabara represents the highest population density zone (seven individuals in each season).

Population size and related parameters

The total population estimate of the species was 192 individuals (95% confidence interval) with a density of 0.98 individuals/km^2. Generally, the species was more abundant during the wet season than dry (58% and 42%, respectively). This represents a significant difference (t-value = -3.38, p-value = 0.002, df = 30) in the individuals recorded in two different seasons. Land tenure types in this area are private and public land ownership. The distribution was almost equal in both land tenure types (51% in protected and 49% in community land). Regarding the time of the survey, more individuals were encountered during morning sampling than other sampling periods though there was no significant difference (F-value = 0.25, df = 2, p-value = 0.781). Weather played a role in the species capture success as, during the cool and rainy period we captured the highest number of individuals (47%) as compared to the cool and dry period (8%) where only five individuals were captured. The results are shown in Table 2.

Morphology

The mean snout-vent length (SVL) for males was 15.12 mm, while mean SVL for females was 15.96 mm. The maximum and minimum SVL of females was 24mm and 4mm respectively, while that of males was 22 mm and 5 mm, respectively. The SVL for females was higher than that of males, but there was no significant difference (t-test = 0.87, p = 0.390, df = 39). ANOVA, however, shows that there was a statistical difference between the mean of males, females, and juveniles SVL (F-test = 11.00, df = 2, p-value = 0.000). Consequently, the mean weight of females was higher than males (6.05 g and 4.82 g, respectively). This shows females are significantly heavier than males (t-test = 3.50, p-value = 0.001, df = 39), a demonstration that sexual dimorphism is evident in the species. The other morphometric characteristics taken include head width (HW) and resting lines (RL). On average, females had higher HW than males (4.3 mm and 3.5 mm). The resting lines were more related to both males and females but were missing in juveniles. On average both male and female had 1.59 and 1.2 resting lines respectively whereas juveniles had none (Table 3).

Table 1. Number of *Afrixalus sylvaticus* captured in each transect during wet and dry seasons.

	Dry season	(%)	Wet season	(%)	Total
Kivumoni	4	44	5	56	9
Marere	2	50	2	50	4
Mwandabara	7	50	7	50	14
Manolo	3	38	5	63	8
Mwele catchment	3	60	2	40	5
Shimba lodge	6	32	13	68	19
Total	25	**42**	34	**58**	**59**

Population structure and sex ratio

There were more individuals captured during the wet period (57.4%) as compared to the dry period (42.3%). In terms of population structure, the largest proportion are females (29) and juveniles the smallest (10). There was no significant difference across all categories (Pearson chi-square = 2.068, df = 2, p-value = 0.356). Sexual dimorphism in young individuals was difficult to point out, and we classified them as juveniles (Table 4).

The sex ratio was relatively stable throughout the sampling period, but females were more than male, an indicator of the population's reproductive potential (Yildiz & Göcmen 2012). The sex ratio was 1:1 in the year 2016, but the following year it was 1:2 in favor of females.

Activity period and breeding ecology

Activity periods

The activity of the amphibians is associated with calls. We recorded a number of calls of the species and other species in each habitat for five hours every sampling period, a reflection of the activity period (Table 6). The mean calls show there was more activity in the wet than the dry season. On maximum, four calls/min were recorded in dry at 2000 h. This was the time with maximum activity (x = 0.875calls/min) as the number of calls peaked (Figure 2). In wet season, however, the maximum activity period was at 1900 h. In both periods, the number of calls declined from 2000 h and was lowest at 2200 h.

In comparison with other species in each habitat, the *A. sylvaticus* calls represents a small proportion. There average calls of other species combined were above 4.5 calls, and the maximum was 7.7 calls/min (Figure 3).

Table 2. Population size and related parameters.

Parameter	Category	N	Mean	SE (±)	SD (±)	Min	Max	Percent
Season	Dry	25	1.042	0.0417	0.204	1	2	42
	Wet	34	1.417	0.103	0.504	1	2	**58**
Land tenure type	Protected area	30	1.364	0.064	0.326	1	2	**51**
	Community area	29	1.115	0.105	0.492	1	2	49
Time of survey	Evening	18	1.286	0.125	0.469	1	2	31
	Morning	21	1.235	0.106	0.437	1	2	36
	Night	20	1.177	0.095	0.393	1	2	34
Weather	Cool and dry	5	1.667	0.333	0.577	1	2	8
	Cool and rainy	28	1.167	0.078	0.381	1	2	**47**
	Hot and dry	8	1.000	0.000	0.000	1	1	14
	Warm and dry	18	1.385	0.140	0.506	1	2	31

Table 3. Morphometric characteristics of *Afrixalus sylvaticus*.

Parameter	Sex	Mean	SE	SD	Var	Min	Max
SVL(mm)	Female	**15.96**	1.22	5.73	32.86	4	**24**
	Juvenile	5	1.98	5.23	27.33	0	13
	Male	**15.12**	1.11	4.83	23.37	5	**22**
Wg(g)	Female	**6.05**	0.228	1.069	1.143	3.4	7.2
	Juvenile	0.9429	0.0481	0.1272	0.0162	0.8	1.1
	Male	**4.821**	0.229	0.996	0.993	2.9	6
Hw(mm)	Female	**4.318**	0.363	1.701	2.894	3	5
	Juvenile	1.143	0.634	1.676	2.81	0.2	2
	Male	**3.579**	0.377	1.644	2.702	1.2	4
RL(Count)	Female	1.591	0.17	0.796	0.634	0	3
	Juvenile	0	0	0	0	0	0
	Male	1.211	0.164	0.713	0.509	0	3

Like the *A. sylvaticus*, the mean number of calls of other species also declined after 2000 h and was at lowest as 2200 h.

Breeding ecology

During the activity periods, some solitary and mating pairs of *A. sylvaticus* were seen in the reeds and water lilies in waterlogged habitats (Image 1a,b). We captured one pregnant female notable from a swollen abdomen. After two days, we found the spawn deposited at the place (Image 2a). In some situations, spawn were also deposited in leaf foldings. The breeding of the species was predominantly on reeds and water lilies (Image 1a,b and 2b). The breeding period was confined to the months of April and May, during which the highest number of calls were recorded (Figure 4).

Influence of human activities on species population attributes

Although wetlands such as marshes and water pools were abundant in human occupied lands including Mwandabara and Kivumoni, human activities such as bush burning, livestock grazing, drainage, and plantation of exotic tree species (*Eucalyptus* sp.) has converted most wetlands to terrestrial habitats and limit the species occupancy. However, there was no significant difference in species population between protected area and community area (At 95% CI, P-Value = 0.795, DF = 36).

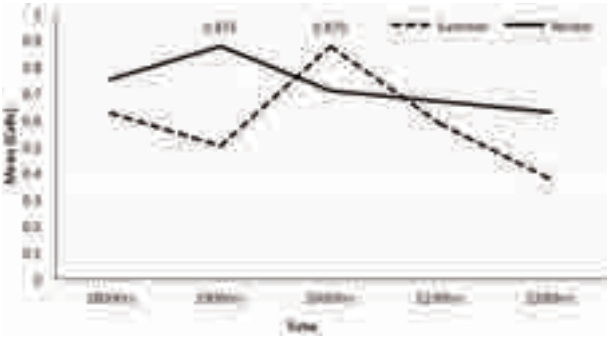

Figure 2. Activity trends in dry and wet seasons

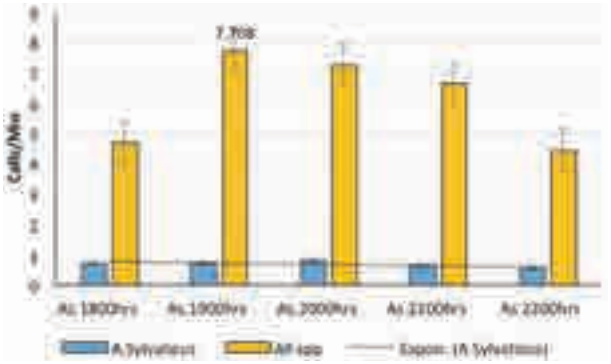

Figure 3. Number of calls/min of *Afrixalus sylvaticus* and other species.

Table 4. Population structure.

	Dry season	(%)	Wet season	(%)	Total
Female	10	34.48	19	65.52	29
Juvenile	4	40	6	60	10
Male	9	45	11	55	20
Total	**25**	**42.37**	**34**	**57.63**	**59**

Table 5. Sex Ratio

Year	Sampling 1	Sampling 2	Sampling 3	Annual
2016	1:2	1.3:1	2:1	1:1
2017	1:1	4:1	1.3:1	2:1

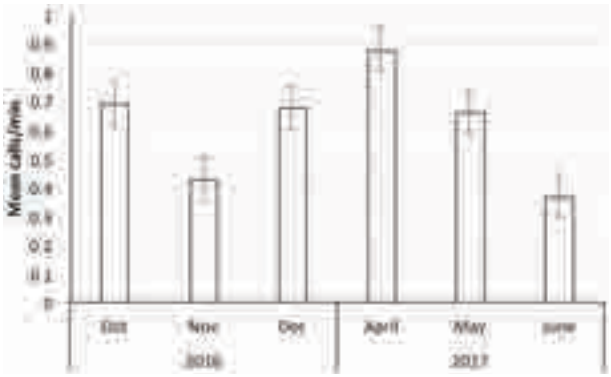

Figure 4. Activity periods per month.

DISCUSSION

Population Size, Structure and Dynamics

The abundance of the species during the wet season demonstrated the synchrony of breeding with season and availability of breeding habitats such as water pools and moist reeds. The species deposit the spawn masses in the aquatic plants. While there was no previous study outlining the population status of the species, the IUCN Red List indicates the species is declining. In the study sites, numerous human activities such as wetland drainage, livestock grazing in wetlands and bush burning are attributed to the decline of the species population. Habitat loss has received much attention as a driving factor in amphibian declines and is widely considered one of the leading causes (Gallant et al. 2007; Gardner et al. 2007).

During dry weather, most sightings were largely of adults, as compared to the wet season, when there were more sightings of juveniles. This difference can be attributed to the influence of temperatures and favorable breeding weather. Temperature and moisture influence amphibian ecology, physiology, and behavior because amphibians must maintain moist skin for oxygen and ionic exchange and temperature influences metabolic rates (Burrowes et al. 2004; Blaustein et al. 2010). Additionally, apart from particulate dynamics, tadpoles may be influenced by dissolved nutrients in streams (Hamer & Parris 2011), especially in the dry season when densities are high and flow is relatively low.

The species is not very mobile as it is endemic to Shimba Hills (Spawls et al. 2019) and we hold the assumption that the marking did not affect their movement or catchability. The population size and density of this species are insignificant compared to other amphibians in the area (192 individuals and density of 0.98/km^2). Many factors are significant in influencing the small species population. In the previous field surveys, the species was sighted in Kivumoni Gate Swamp, Marere headworks, Sheldrick Falls, and Shimba Lodge Swamp (Bwong et al. 2017). However, we made a transect sampling in some of these sites, but there was no capture for the entire survey (both in the dry and wet season). This suggest a potential shift in species

Table 6. Activity periods

Variable	Season	Mean	SE	SD	Var	Min	Max
1800 h	Dry	0.625	0.189	0.924	0.853	0.000	3.000
	Wet	0.750	0.150	0.737	0.543	0.000	2.000
1900 h	Dry	0.500	0.147	0.722	0.522	0.000	2.000
	Wet	**0.875**	0.193	0.947	0.897	0.000	3.000
2000	Dry	**0.875**	0.220	1.076	1.158	0.000	**4.000**
	Wet	0.708	0.175	0.859	0.737	0.000	3.000
2100 h	Dry	0.583	0.190	0.929	0.862	0.000	3.000
	Wet	0.667	0.155	0.761	0.580	0.000	2.000
2200 h	Dry	**0.375**	0.132	0.647	0.418	0.000	2.000
	Wet	0.625	0.145	0.711	0.505	0.000	2.000

The figures in bold represent the highest and lowest mean number of calls.

habitat or decline in the species population. Stuart et al. (2004) projected that the loss of habitat is relevant to all regions and is also linked to habitat fragmentation and degradation.

In other studies, conducted elsewhere, Hamer & Parris (2011) noted that in tropical regions, the roles of amphibians in both aquatic and terrestrial habitats are more consistent through time because of their more stable seasonal abundance patterns, high species richness, and diversity of reproductive modes. In this species, however, there was an unstable age structure, more females, few juveniles, and few males.

Schmidt et al. (2002) noted that the estimation of basic demographic parameters and the identification of their determinants are essential to improve the understanding of population dynamics and life histories of amphibians. The general observation from the survey shows declining habitats, as some wetlands are converted to farmlands, livestock grazing fields, and tree plantations (Image 1a and b).

Morphology

Afrixalus is a sub-Saharan genus containing about 35 taxa (Pickersgill 2005). Most of the members in this genius are referred to as 'dwarf' because of their small body length and weight. The term 'dwarf' was loosely applied to species which did not exceed 25 mm in length (Pickersgill 2005). This species averaged less than 24 mm in SVL and weighs about 6.05 g.

In *A. sylvaticus* recorded in Tanzania, the males' length was between 15.2–21.1 mm (mean 18.1 mm, N = 28), females 17.2–25.0 mm (mean 20.3 mm, N = 41) (Pickersgill 2005). This morphometrics features confirms the relationships of the species in different habitats and the sexual dimorphism where female is slightly larger in size than males. It was also evident that males are fewer than females, but the reason for the variation is still not clear. Schiøtz (1999) records a snout-vent length of up to 24 mm in females with dorsal asperities fine and weak, confined to head or at least not extending to tibiae and feet; gular disc with or without fine asperities; no ventral asperities. Additionally, Schiøtz recorded the length of males from 18.0–20.8 mm (mean 19.4 mm, N = 17), females 20.6–22.8 mm (mean 21.8 mm, N = 3).

In most anurans, females are bigger than males, but males are bigger in some species in which males have physical competition for mating (Shine 1979). The principal diagnostic characters in *Afrixalus* are mostly secondary sexual characters present only in male frogs (Pickersgill 1984). For this reason, outside the species descriptions, all morphological analyses of frogs are based on sexually mature males. *Afrixalus* are often known as Spiny Reed Frogs due to the presence of minute spinules, or asperities, in the skin of most species. We followed the detection technique previously used (Pickersgill 1984). The primary means of detection was through a 10X or 20X hand lens, with the wet specimen held at an angle to a light source so that as the fluid evaporated from the skin, the asperities pierced the surface film. In most mature individuals we captured, the color of the dorsum was silverish to greenish-yellow, usually with scattered dark spots and with up to three darker transversely oriented bands which we labeled resting lines.

Breeding ecology and activity periods

According to Pickersgill (2005), this species is commonly referred to as 'Leaf folding Frogs' because of the typical mode of oviposition, they occupy a range of habitats from seasonally moist open grassland and savanna to rain forest, and from sea level to altitudes

Image 1. a—*Afrixalus sylvaticus* in reeds at 2000 h | b—*Afrixalus sylvaticus* and *Hyperoleous rebrovermicalatus* at 0700 h. © Authors, 2019.

Image 2. a—Spawn of *Afrixalus sylvaticus* | b—*Afrixalus sylvaticus* in water lilies. © Authors, 2019.

above 2,000 m. Though it was not found in savanna, there was evidence that it occupies the moist grassland during the dry period, as was the case in Mwandabara and Marere. However, the species is commonly found in reeds and wetland vegetation in water lilies and reeds.

Forest species produce some of the shortest and simplest *Afrixalus* calls, and voice evolution in the closely related species *A. stuhlmanni* complex, may reflect a transition between forest and savanna habitation (Pickersgill 2005). An analysis of voices in the genus *Afrixalus* shows a gradual increase in the number of pulses per call, from *A. sylvaticus* with 2–5 pulses to the dry savanna (Martin et al. 2004; Pickersgill 2005). While we also noted the variation in habitats, we did not compare the wetlands to savanna. It was only evident that the calls vary significantly between the dry and wet season. This is attributed to the activity of breeding influenced by a rainy period. Pickersgill (2005) also found the variation in the number of calls in different temperature conditions and concluded that there is a negative correlation between

number of calls and temperature.

We found more activity during the wet period than dry, and consequently, more captures were done during the cold and rainy weather. The activity was high in the month of April, with heavy rains, but it declined in the subsequent months of May and June (2017). This confirms the breeding period peaks in wet season and not common in the dry season.

CONCLUSION

The distribution of the species is patchy and limited to some regions within the study area. There was evidence that the species is shifting sites or declining in their numbers as some of the previous sites no longer support the species. Some sites are shrinking in size and habitat quality, such as Kivumoni and Mwandabara. There is an imbalance in sex ratio, and more synchronized population dynamic studies are needed to highlight the driver(s) behind the male decline. Moreover, efforts to safeguard the species habitats, especially in community lands, are essential to enhance the species niches.

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ARTICLE

Ichthyofaunal diversity of Senkhi stream, Itanagar, Arunachal Pradesh: a comparative status between 2004–05 and 2018–19

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Abstract: An investigation was conducted during 2018–19 after a time span of 13 years in the Senkhi stream, an important hill stream that flows through western corner of the capital city, Itanagar. The present study aims to compare decadal changes in ichthyofaunal diversity, status, and abundance with reference to the impact of increasing urbanization in the capital city. The ichthyofaunal diversity assessed presently is restricted to 37 species spreading over 30 genera under 13 families which include four species more, not reported in the past. Thus, of the 37 species recorded, 33 species only could be compared, and noticeably resulted ultimate reduction of 14 species belonging to 11 genera under 10 families from the study area. It indicated that nearly 64% decline in fish abundance within stream zone under urban area and about 46% reduction in undisturbed area. The present study hitherto revealed the alarming rate of decline in fish diversity and also unfolded key factors responsible for crucial decline of fish diversity along with the possible mitigation measures.

Keywords: Catch frequency, diversity loss, electrofishing, habitat degradation, restoration, urbanization.

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Author contributions: Authors have equally contributed in the study.

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INTRODUCTION

Biodiversity is essential for stabilization of ecosystems and protection of overall environmental quality (Ehrlich & Wilson 1991). Freshwater fish are one of the most threatened taxonomic groups (Darwall & Vie 2005) because of their high sensitivity to the quantitative and qualitative alteration of aquatic habits (Laffaille et al. 2005; Sarkar et al. 2008; Kang et al. 2009). Conservation of fish diversity and associated habitats is a great challenge (Dudgeon et al. 2006). Conservation measures to mitigate the impact of the pressures have largely been slow and inadequate and as a result populations of many of the species are declining rapidly. The Himalayan region in India has been identified as one of the 36 biodiversity 'hotspot' areas of the world (https://www.conservation.org) where the state of Arunachal Pradesh (26.28–29.30 °N & 91.30– 97.30 °E) constitutes 60.93% of the region and is characterized in having varied topographical features that forms a huge watershed network provided with numerous aquatic habitats. There are 2,500 species of freshwater fishes that have been recognized in the Indian subcontinent out of which 930 are categorized as freshwater species (Jayaram 2010) and 1,570 are marine (Kar 2003; Vijaykumar et al. 2008). Fishing is a common recreational activity and fish is a good source of protein required for a good health. The tribal populace of the state of Arunachal Pradesh are fond of fish and practice fishing and harvesting seasonally from streams and rivers by employing traditional fishing gears and traps as common property resource. However, depletion of the aquatic biodiversity is gradually increasing due to use of modern contraptions in most of the streams and rivers of Arunachal Pradesh (Chaudhry & Tamang 2007; Tamang & Shivaji 2012). A glimpse of such non-conventional methods of fishing using inverter and battery had once been highlighted in the local news (Arunachal24. dated 24 September 2020) operating within D'Ering Wildlife Sanctuary (DEWS).

Senkhi is an important and lonely hill stream, one of the tributary of upper Brahmaputra River and is the prime source of water for people inhabiting Itanagar that caters about 70% of drinking water to urban populace. The stream originates from about 7 km inside dense forest fed by merging various small drainages, before entering a beautiful valley popularly known as 'Senkhi Valley' in the north. The freshwater stream moves downwards traversing urban areas like Chandranagar, Police colony, IRBN colony and subsequently meets with Chimpu stream near IRBN firing ground. Thereafter, it forms a contiguous water body with Pachin and eventually confluences with Dikrong river at RCC bridge, Doimukh, covering about 30 km towards east. It consists of varied microhabitats ranging from deep water to fast-flowing riffles. The substratum comprised of medium to large boulders, pebbles, cobbles, and sand. Density of medium to large boulders are higher upstream than downstream. Sand and mixture of various colored gravels are dense towards lower reaches after Jullang village and density of sand increases thereafter up to Doimukh, through twin capital Naharlagun. On account of having varied physiographic features, the stream harbours a good number of fish diversity.

As far as ichthyofauna of the state is concerned, McClelland (1839) seemed to be the earliest pioneer worker followed by Chaudhuri (1913), Hora (1921), Jayaram (1963), Jayaram & Mazumdar (1964), Srivastava (1966), Dutta & Sen (1977), Dutta & Barman (1984, 1985), and Sen (1999). The first compilation of fish fauna of the state was made by Nath & Dey (2000) who listed a total of 131 species, followed by Bagra et al. (2009) who added 82 more totalling to 213 species. Finally, Darshan et al. (2019) listed 218 species, based on field surveys and available literatures.

Tamang et al. (2007b) earlier reported 47 species belonging to 35 genera and 17 families from Senkhi stream. Tamang et al. (2006; 2007a; 2008) had also reported first distributional record of three fish species: *Pseudolaguvia shawi, Balitora brucei*, *Glyptothorax telchitta* for the state and one new species *Erethistoides senkhiensis* from this stream. Therefore, the stream also acts as an important habitat for ichthyological research. Chaudhry & Tamang (2006) had also reported practicing of non-conventional method of fishing like using of chemicals, electrocution and it has been being continued by many people since long time. Thus to validate the current status of ichthyofaunal diversity of the stream, the present study has been conducted, so that the information may be used for restoration of the ongoing situation. Besides, the paper aims to highlight the major key factors responsible for rapid depletion of fish population in the Senkhi stream along with necessary policy decision to be taken for conservation and mitigation of the stream.

MATERIAL AND METHODS

The reinvestigations were conducted after a time span of 13 years from 02 September 2018 to 22 September 2019. Two sampling sites were selected in Senkhi stream with a gap of about 3 km in between

Image 1. Drainage and satellite map view of Itanagar city, showing study sites (Site-I and Site-II) indicated by red lines, gap in between two sites (white line) and Chimpu stream (blue line).

Site-I and Site-II. The site-I extends from Chandranagar - hanging bridge downwards to D.N.G. College, (27.088^{0}N & 93.601^{0}E) covering a total distance of about 3 km and is entirely situated within urban disturbed area. Site-II was selected as control condition (outside urban area) in order to have a comparison with Site-I. Site-II extends from confluence point of Senkhi and Chimpu stream (27.08 °N & 93.60 °E) near IRBN firing ground to Jullang village (27.06 °N & 93.63 °E) about 3 km downstream (Image 1). Habitat pattern: Site-I consists of large to medium sized boulders, pebbles and cobles with low quantity of sand deposit, width of stream narrow causing high pressure water during monsoon. Site-II: Stream gradually becoming wider towards downstream, and stream bed consists of large number of pebbles, cobbles, gravels, and sand, but few numbers of large boulders, placed collectively at beginning, middle and end of the site. Overall, it somewhat resembles with plain stream of Assam. However, both the sites mostly share gravelly bed which characterized true hill stream habitat. Random sampling was carried out weekly after dusk from 1800 to 2200 h using a cast net with radius of 2.30 m and 7 x 7 mm mesh size. Sampling in site-II was done in other alternate day. Weekly samplings were restricted to four weeks in a month. The frequency of occurrence of each species was calculated based on the numbers of occasions the species were collected during the samplings. Finally the data of total catch frequencies (%) of species encountered from two respective sites were compared and each result was compared with data of 47 species of the past record (Tamang et al. 2007b), prior to total number of species encountered in each site. Samplings were carried out covering various microhabitats such as shallow to deep and moderate to torrential flowing water. The collected samples were brought to laboratory of Rajiv Gandhi University for identification. The identification of fishes was confirmed following Talwar & Jhingran (1991), Nath & Dey (2000), and Darshan et al. (2019) and subsequently deposited in Rajiv Gandhi University Museum of Fishes (RGUMF). Trophic niche model may be useful for assessing altered as well as less altered fish habitat of the tropical rivers. Trophic niche of the species were recognized examining morphology of mouth, body shape and paired fins. Species having inferior mouth, cylindrical or dorso ventrally flattened body or horizontally situated paired fins are considered as bottom feeder, whereas terminal to sub-terminal mouth with compressed body are categorized as column feeder and upturned mouth with compressed body as surface feeder. The five previously misidentified species were rectified and fourteen name of species were revised and upgraded (indicated by symbol # and ** respectively in Table 1) following "Eschmeyer's Catalogue of Fishes, 2019. The catch frequency of common (91–100%) and abundant (81–90%) as per Tamang et al. (2007b) were used as standard norms of frequency scale (Table 2). Thus, % catch frequency with respect to species richness is computed as Abundant: 91–100%, Common: 81–90%, Frequent: 61–80%, Occasional: 31–60%, Sporadic: 15–30%, Rare: 05–14%, Extremely rare <05%. The conservation status of the encountered species were categorized following IUCN Red List of Threatened Species (2019-3).

RESULTS AND DISCUSSION

The ichthyofaunal diversity in the present study is restricted to 37 species belonging to 30 genera under 13 families, including additional four species

(not recorded in the past study). While comparing present data (excluding 4 additional species) with that of the past (Tamang et al. 2007b) presented in Table 2, revealed disappearance of 14 species, viz., *Glyptothorax pectinopterus, Glyptothorax brevipinnis, Glyptothorax telchitta, Glyptothorax cavia, Botia dario, Heteropneustes fossilis,Channa orientalis, Oreichthys cosuatis, Clarias magur, Labeo gonius, Mystus montanus, Oreochromis mossambica, Mastacembalus armatus, Badis badis* belonging to 11 genera under 10 families and identified as mostly bottom feeder (10 species), rarely column (4 species). Among all, the family cyprinidae was found to be highly dominant represented by 13 species (35%), followed by danionidae represented by nine species (24%). Other rarely diversified families are: Nemacheilidae, three species (8%), Ambassidae & Amblycipitidae, two species (5%) each, and Anguillidae, Balitoridae, Botiidae, Cobitidae, Erethistidae, Bagridae, Psilorhynchidae, and Sisoridae with one species (3%) each (Figure 3). With regard to 14 disappeared species, presently it is unwise to consider them as extinct as they may be existing in undisturbed upstream habitat far beyond study sites inside Senkhi valley or other drainage system within the vicinity of Itanagar Wildlife Sanctuary. Therefore, at present, species diversity is raised to 50 species excluding one exotic species *Oreochromis mosssambica,* which had been reported earlier.

Comparative analysis between two sites (Site-I: urban area) and (Site-II: undisturbed area): Of the total 37 species collectively encountered, distribution of 31 species were common in both sites except for six species. The comparative analysis of total catch frequency obtained from 37 species, showed 467.1 and 682.2 in site I and site II respectively, resulting deduction of 215.1, i.e., 31.5% catch frequency in Site-I than Site-II. This is the point in fact which shows that % catch frequency in Site-I is lower, since it is being situated in urban disturbed area compared to Site-II (Table 2). Of the remaining six species, four species—*Danio rerio, Bangana dero, Chanda nama,* and *Parambassis ranga*—were only caught in Site-II and two species—*Opsarius tileo* and *Anguilla bengalensis*—in Site-I. This may be due to habitat preferences, as *Danio rerio*, *Chanda nama* and *Parambassis ranga* are typically occurs in slow moving water of the plain, characteristics somewhat familiar with Site-II. However, *Bangana dero* occurs in plain as well as upstream. So, may be due to water contamination, it migrated to lower reaches. The occurrence of *Opsarius tileo* and *Anguilla bengalensis* in Site-I is genuine as *Opsarius tileo* occurs in both the habitat in hill streams. This may be due to low population density, occasionally caught in the past study too. So, *Opsarius tileo* might not have caught during sampling in Site-II. *Anguilla bengalensis* was accidentally caught during flood.

The comparative analysis of 33 species (excluding 4 additional species) with those of 47 species of Tamang et al. (2007b) showed respectively 1295.9 and 457.5 total catch frequencies resulting in deduction of 838.4, i.e., 64.7% in Site-I and similarly total catch frequencies 1295.9 and 697.6 respectively which depicts decline of total catch frequency 598.3, i.e., 46.2% in Site-II. This clearly indicates drastic decline of abundance of fish fauna in the study sites. Further, the data of comparative analysis between two sites also revealed 64.7–46.2% = 18.5% relatively more decline in urban area than undisturbed area, except *Neolissochilus hexagonolepis, Botia rostrata* and *Tariqilabeo latius* which showed 5.8%, 11.6%, 1.9% higher, respectively (Table 2 and Figure 1). Only one species *Opsarius bendelisis* showed cent percent catch frequencies in both sites as well as in the past. This indicates that *Opsarius bendelisis* is the most dominant and adoptive species in the stream.

The percent declining trend of each species in descending order are as follows (Table 2): Site-I (29 out of 47 species earlier study): *Tor tor* and *Garra birostris* declined to 65.4% each*, Aborichthys kempi* and *Garra annandalei* 61.5%, *Neolissochilus hexagonolepis* 48.1%, *Psilorhynchus balitora* 44.2%, *Schistura devdevi* and *Botia rostrata* 42.3% each, *Opsarius tileo* 40.4%, *Cyprinion semiplotum* 30.8%, *Balitora brucei* 28.9%, *Devario aequipinnatus* 26.9%, *Tariqilabeo latius* 25%, *Chagunius chagunio* 23.1%, *Opsarius barna* 19.2%, *Danio dangila* 17.4%, *Pseudolaguvia shawi* 13.4%, *Pethia conchonius* 11.5%, *Paracanthocobitis botia* 9.6%, *Devario devario, Puntius sophore*, & *Lepidocephalichthys guntea* 5.8% each, *Pethia ticto*, *Raiamas bola*, & *Puntius chola* 3.9% each, and *Cabdio jaya, Olyra longicaudata*, & *Amblyceps arunachalensis* 1.9% each. Out of 29, only one species, *Opsarius bendelisis* showed 100% abundance and hence considered as highly dominant species. Overall, it is clearly indicated that out of 47 earlier reported species, i.e., 18 species were not retraced in Site-I in present study. With regard to Site-II (32 out of 47 species earlier reported), 19 species had declined: *Tor putitora* declined to 59.7%, *Garra birostris* 57.7%, *Neolissochilus hexagonolepis* and *Botia rostrata* 53.9% each, *Aborichthys uniobarensis* (53.8%), *Garra annandalei* (48%), *Schistura devdevi* (40.4%), *Balitora brucei* (26.9%), *Tariqilabeo latius* (26.9%), *Psilorhynchus balitora* (25%), *Devario aequipinnatus* (25%), *Danio dangila* (11.6%), *Pseudolaguvia shawi* (9.6%), *Opsarius barna* (7.7%), *Paracanthocobitis botia* (5.8%),

Table 1. The revised and updated list of fish species encountered during past study (Tamang et al. 2007b) including four additional species in present study (2018–19), trophic niche and IUCN conservation status.

	Family	Species name listed in Tamang et al. 2007b	Species name (valid)	Trophic niche	IUCN Red List status
1	Nemacheilidae	*Aborichthys elongatus*	*Aborichthys uniobarensis#*	Bottom	NE
2	Nemacheilidae	*Acanthocobitis botia*	*Paracanthocobitis botia***	Bottom	LC
3	Cyprinidae	*Acrossocheilus hexagonolepis*	*Neolissochilus hexagonolepis ***	Column	NT
4	Amblycipitidae	*Amblyceps arunachalensis*	*Amblyceps arunachalensis*	Bottom	EN
5	Cyprinidae	*Aspidoparia jaya*	*Cabdio jaya***	Column	LC
6	Badidae	*Badis badis*	*Badis badis*	Bottom	LC
7	Balitoridae	*Balitora brucei*	*Balitora brucei*	Bottom	NT
8	Danionidae	*Barilius barna*	*Opsarius barna***	Column	LC
9	Danionidae	*Barilius bendelisis*	*Opsarius bendelisis***	Column	LC
10	Danionidae	*Barilius bola*	*Raiamas bola*	Column	LC
11	Danionidae	*Barilius tileo*	*Opsarius tileo ***	Column	LC
12	Botiidae	*Botia dario*	*Botia dario*	Bottom	LC
13	Botiidae	*Botia rostrata*	*Botia rostrata*	Bottom	VU
14	Danionidae	*Brachydanio rerio**	*Danio rerio***	Column	LC
15	Cyprinidae	*Chagunius chagunio*	*Chagunius chagunio*	Bottom	LC
16	Ambassidae	*Chanda nama**	*Chanda nama*	Column	LC
17	Channidae	*Channa orientalis*	*Channa orientalis*	Column	NE
18	Claridae	*Clarias batrachus**	*Clarias magur#*	Bottom	LC
19	Cyprinidae	*Crossocheilus latius latius*	*Tariqilabeo latius***	Bottom	LC
20	Danionidae	*Danio aequipinnatus*	*Devario aequipinnatus***	Surface	LC
21	Danionidae	*Danio dangila**	*Danio dangila*	Surface	LC
22	Danionidae	*Danio devario**	*Devario devario***	Surface	LC
23	Cyprinidae	*Garra annandalei*	*Garra annandalei*	Bottom	LC
24	Cyprinidae	*Garra gotyla*	*Garra birostris #*	Bottom	NE
25	Sisoridae	*Glyptothorax brevipinnis*	*Glyptothorax brevipinnis*	Bottom	DD
26	Sisoridae	*Glyptothorax cavia*	*Glyptothorax cavia*	Bottom	LC
27	Sisoridae	*Glyptothorax pectinopterus*	*Glyptothorax pectinopterus*	Bottom	LC
28	Sisoridae	*Glyptothorax telchitta*	*Glyptothorax telchitta*	Bottom	LC
29	Sisoridae	*Hara hara*	*Pseudolaguvia shawi#*	Bottom	LC
30	Heteropneustidae	*Heteropneustes fossilis*	*Heteropneustes fossilis*	Bottom	LC
31	Cyprinidae	*Labeo dero**	*Bangana dero***	Bottom	LC
32	Cyprinidiae	*Labeo gonius*	*Labeo gonius*	Bottom	LC
33	Cobitidae	*Lepidocephalichthys guntea**	*Lepidocephalichthys guntea*	Bottom	LC
34	Mastacembelidae	*Mastacembalus armatus**	*Mastacembalus armatus*	Bottom	LC
35	Bagridae	*Mystus montanus*	*Mystus montanus*	Column	LC
36	Bagridae	*Olyra longicaudata**	*Olyra longicaudata*	Bottom	LC
37	Cyprinidae	*Oreichthys cosuatis*	*Oreichthys cosuatis*	Column	LC
38	Cichlidae	*Oreochromis mossambica*	*Oreochromis mossambica*	Column	NT
39	Ambassidae	*Parambassis ranga**	*Parambassis ranga*	Column	LC
40	Psilorhynchidae	*Psilorhynchus balitora*	*Psilorhynchus balitora*	Bottom	LC
41	Cyprinidae	*Puntius chola*	*Puntius chola*	Column	LC
42	Cyprinidae	*Puntius conchonius*	*Pethia conchonius***	Column	LC
43	Cyprinidae	*Puntius sophore**	*Puntius sophore*	Column	LC

	Family	Species name listed in Tamang et al. 2007b	Species name (valid)	Trophic niche	IUCN Red List status
44	Cyprinidae	*Puntius ticto*	*Pethia ticto***	Column	LC
45	Nemacheilidae	*Schistura devdevi*	*Schistura devdevi*	Bottom	NT
46	Cyprinidae	*Semiplotus semiplotus*	*Cyprinion semiplotum* **	Bottom	VU
47	Cyprinidae	*Tor tor*	*Tor putitora#*	Column	EN
	Additional species				
48	Erethistidae	-	*Erethistoide senkhiensis*	Bottom	DD
49	Danionidae	-	*Barilius vagra*	Column	LC
50	Anguillidae	-	*Anguilla bengalensis*	Bottom	NT
51	Amblycipitidae	-	*Amblyceps apangi*	Bottom	LC

*—fish caught outside regular sampling site in the past study by Tamang et al. (2007b) | **— revised name of the species | #—corrected name of the species previously misidentified.

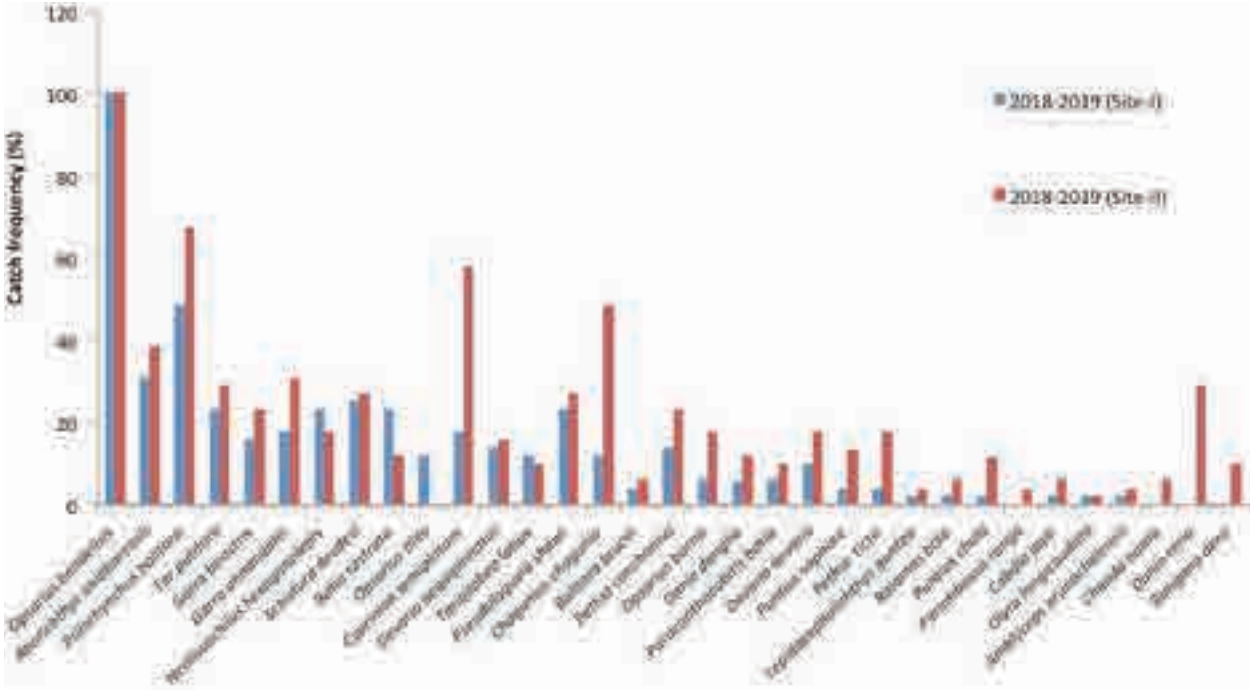

Figure 1. Comparative analysis of catch frequency (%) 33 species (including uncommon 5 species) of both (SITE-I and SITE-II). The graph showed that frequencies of catch is higher in Site-II compared to Site-I except *Neolissochilus hexagonolepis, Botia rostrata*, and *Tariqilabeo latius. Opsarius bendelisis* showed cent percent catch frequency and considered highly dominant species among all.

Lepidocephalichthys guntea (3.9%), *Parambassis ranga* (2%), *Olyra longicaudata* (1.9%), *Pethia conchonius* (1.9%), whereas, 10 species showed increase in catch frequency, viz., *Devario devario* (1.9%), *Cabdio jaya* and *Chanda nama* (2%), *Puntius sophore* (3.7), *Puntius chola* (5.6%), *Bangana dero* (7.7), *Cyprinion semiplotum* & *Pethia ticto* (9.6%), *Chagunius chagunio* (13.5%), *Danio rerio* (26.9%), and two species, namely, *Raiamas bola* & *Amblyceps arunachalensis* showed neither decline nor increase (Table 2). In this case too *Opsarius bendelisis* showed 100% abundance, and rest of the remaining 15 species were not retracted. Overall result indicates that Site-I (urban area) is more disturbed area than that of Site-II (outside urban area) for which there is severe decline in catch frequency in Site-I (64.7%) whereas moderate in Site-II (46.2%).

The conservation status of 37 fishes as per IUCN Red list (2019-3) revealed that majority (70%) of fish fauna are listed as Least Concern (LC), followed by 11% of them as Near Threatened (NT), 5% Vulnerable (VU), and

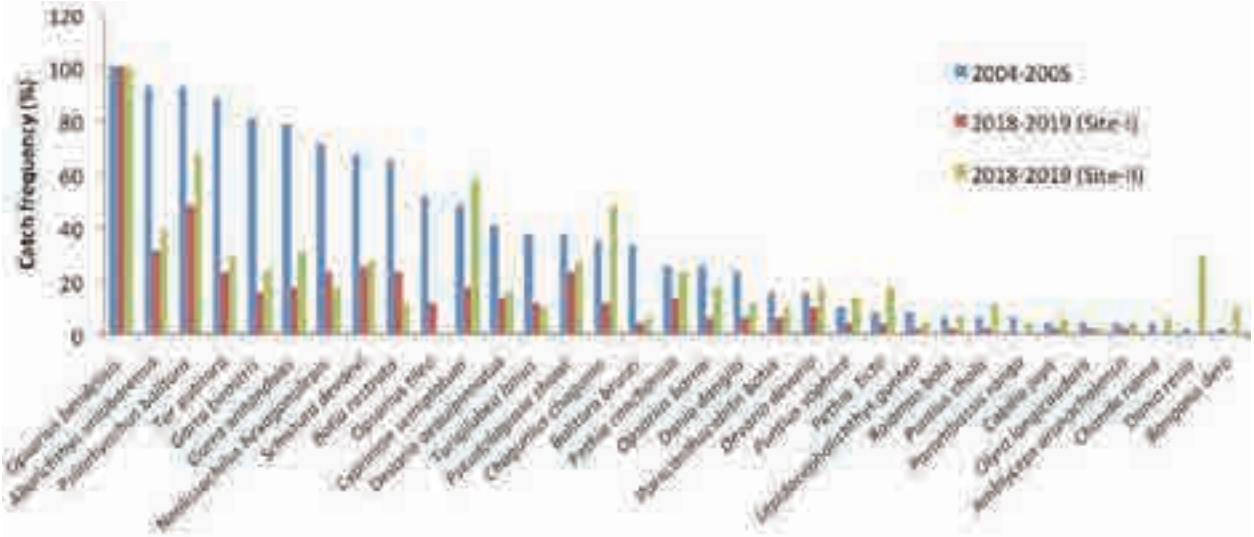

Figure 2. Graph showing comparative analysis of catch frequency (%) of 33 species, during present (2018–2019; SITE-I and SITE-II) and past (2004–2005; Tamang et al. 2007b) studies. The graph depicts overall drastic declining of catch frequency except first one species *Opsarius bendelisis* that showed cent percent abundance.

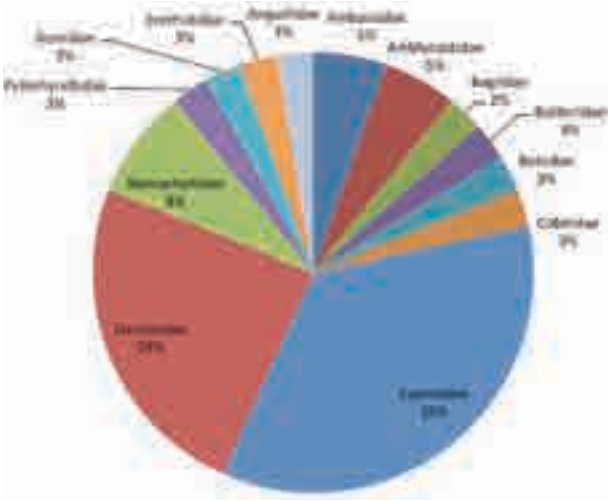

Figure 3. Percentage of species composition under 13 families in the present study (Site-I and Site-II).

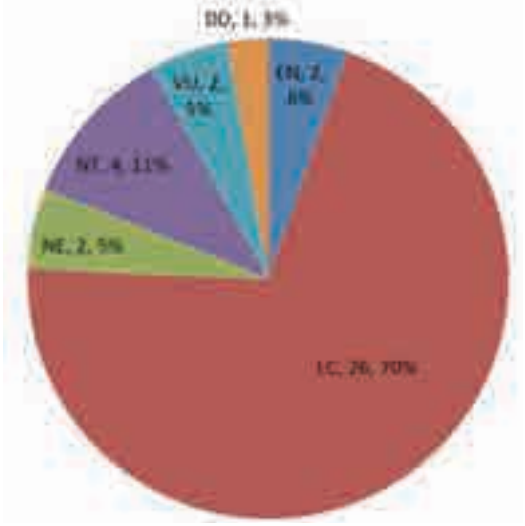

Figure 4. Combined IUCN conservation status of both Sites (I &II).

3% are Data Deficient (DD), 5% Not Evaluated (NE), and Endangered (EN) each (Figure 4). The 14 disappeared species mostly belong to LC category, i.e., 11 species and 1 species to NT, DD, and NE (Table 1). However, in case of local abundance, these species fall under extremely rare (8), rare (4) and occasional (2) categories (Table 2).

In the case of ecological trophic niche is concern, it is found that majority of the species are belong to bottom feeder represented by 19 species (51%), followed by 14 (38%) column feeders and four (11%) surface feeders (Figure 5). The percent catch frequencies of each species and availability status are presented in Table 2. The species under extreme threats are: *Amblyceps arunachalensis* recognized as 'Endangered' among all, followed by *Neolissochilus hexagonolepis, Schistura devdevi, Balitora brucei*, & *Anguilla bengalensis* as 'Near Threatened', and *Botia rostrata* & *Cyprinion semiplotum* as 'Vulnerable'. In the present study four species—*Erethistoides senkhiensis*, *Barilius vagra, Anguilla bengalensis,* and *Amblyceps apangi*—were additionally caught. *Erethistoides senkhiensis* was doubted to be a new species in the past study and not included in Tamang et al. (2007), and later published as a new species (Tamang et al. 2008). Though, as per

Table 2. Comparative percentage of catch frequencies and species abundance status of past study (Tamang et al. 2007b) and present study (Site-I and Site-II) conducted during 2018–19.

	Scientific name	Catch frequency (%) (2004–2005)		Catch frequency (%) (2018–2019)			
			Status	SITE-I	Status	SITE-II	Status
1	2	3	4	5	6	7	8
1	*Opsarius bendelisis* (Hamilton, 1822)	100	Abundant	100	Abundant	100	Abundant
2	*Aborichthys uniobarensis* Nanda et al., 2021	92.3	Abundant	30.8	Sporadic	38.5	Occasional
3	*Psilorhynchus balitora* (Hamilton, 1822)	92.3	Abundant	48.1	Occasional	67.3	Occasional
4	*Tor tor* (Hamilton, 1822)	88.5	Common	23.1	Sporadic	28.8	Sporadic
5	*Garra birostris* Nebeshwar & Vishwanath, 2014	80.8	Common	15.4	Sporadic	23.1	Sporadic
6	*Garra annandalei* (Hora, 1921)	78.8	Frequent	17.3	Sporadic	30.8	Occasional
7	*Neolissochilus hexagonolepis* (McClelland, 1839)	71.2	Frequent	23.1	Sporadic	17.3	Sporadic
8	*Schistura devdevi* (Hora, 1935)	67.3	Frequent	25.0	Sporadic	26.9	Sporadic
9	*Botia rostrata* Gunther, 1868	65.4	Occasional	23.1	Sporadic	11.5	Rare
10	*Opsarius tileo* (Hamilton, 1822)	51.9	Occasional	11.5	Rare	-	-
11	*Cyprinion semiplotum* (McClelland, 1839)	48.1	Occasional	17.3	Sporadic	57.7	Occasional
12	*Devario aequipinnatus* (McClelland, 1839)	40.4	Occasional	13.5	Rare	15.4	Sporadic
13	*Tariqilabeo latius* (Hamilton, 1822)	36.5	Occasional	11.5	Rare	9.6	Rare
14	*Pseudolaguvia shawi* (Hora, 1921)	36.5	Occasional	23.1	Sporadic	26.9	Sporadic
15	*Glyptothorax pectinopterus* (McClelland, 1842)	34.6	Occasional	-	-	-	-
16	*Chagunius chagunio* (Hamilton, 1822)	34.6	Occasional	11.5	Rare	48.1	Occasional
17	*Balitora brucei* (Gray, 1830)	32.7	Occasional	3.8	Extremely rare	5.8	Rare
18	*Botia dario* (Hamilton, 1822)	30.8	Occasional	-	-	-	-
19	*Pethia conchonius* (Hamilton, 1822)	25	Occasional	13.5	Rare	23.1	Sporadic
20	*Opsarius barna* (Hamilton, 1822)	25	Sporadic	5.8	Rare	17.3	Sporadic
21	*Danio dangila* (Hamilton, 1822)	23.1	Sporadic	5.7	Rare	11.5	Rare
22	*Acanthocobitis botia* (Hamilton, 1822)	15.4	Sporadic	5.8	Rare	9.6	Rare
23	*Devario devario* (Hamilton, 1822)	15.4	Sporadic	9.6	Rare	17.3	Sporadic
24	*Glyptothorax brevipinnis* Hora, 1923	11.5	Rare	-	-	-	-
25	*Heteropneustes fossilis* (Bloch, 1794)	9.6	Rare	-	-	-	-
26	*Puntius sophore* (Hamilton, 1822)	9.6	Rare	3.8	Extremely rare	13.3	Rare
27	*Pethia ticto* (Hamilton, 1822)	7.7	Rare	3.8	Extremely rare	17.3	Sporadic
28	*Lepidocephalichthys guntea* (Hamilton, 1822)	7.7	Rare	1.9	Extremely rare	3.8	Extremely rare
29	*Channa orientalis* Bloch & Schneider, 1801	5.8	Rare	-	-	-	-
30	*Oreichthys cosuatis* (Hamilton, 1822)	5.8	Rare	-	-	-	-
31	*Raiamas bola* (Hamilton, 1822)	5.8	Rare	1.9	Extremely rare	5.8	Rare
32	*Puntius chola* (Hamilton, 1822)	5.8	Rare	1.9	Extremely rare	11.4	Rare
33	*Parambassis ranga* (Hamilton, 1822)	5.8	Rare	-	-	3.8	Extremely rare
34	*Cabdio jaya* (Hamilton, 1822)	3.8	Extremely rare	1.9	Extremely rare	5.8	Rare
35	*Olyra longicaudata* McClelland, 1842	3.8	Extremely rare	1.9	Extremely rare	1.9	Extremely rare
36	*Amblyceps arunachalensis* Nath & Dey, 1989	3.8	Extremely rare	1.9	Extremely rare	3.8	Extremely rare
37	*Chanda nama* (Hamilton, 1822)	3.8	Extremely rare	-	-	5.8	Rare
38	*Clarias magur* (Linnaeus, 1758)	1.9	Extremely rare	-	-	-	-

	Scientific name	Catch frequency (%) (2004–2005)		Catch frequency (%) (2018–2019)			
			Status	SITE-I	Status	SITE-II	Status
1	2	3	4	5	6	7	8
39	*Labeo gonius* (Hamilton, 1822)	1.9	Extremely rare	-	-	-	-
40	*Mystus montanus* (Jerdon, 1849)	1.9	Extremely rare	-	-	-	-
41	*Oreochromis mossambica* (Peters, 1852)	1.9	Extremely rare	-	-	-	-
42	*Glyptothorax telchitta* (Hamilton, 1822)	1.9	Extremely rare	-	-	-	-
43	*Mastacembalus armatus* (Lecepede, 1800)	1.9	Extremely rare	-	-	-	-
44	*Badis badis* (Hamilton, 1822)	1.9	Extremely rare	-	-	-	-
45	*Glyptothorax cavia* (Hamilton, 1822)	1.9	Extremely rare	-	-	-	-
46	*Danio rerio* (Hamilton, 1822)	1.9	Extremely rare	-	-	28.8	Sporadic
47	*Bangana dero* (Heckel, 1822)	1.9	Extremely rare	-	-	9.6	Rare
	Additional species encountered						
48	*Erethistoides senkhiensis* Tamang, Chaudhry & Choudhury, 2008)	-	-	9.6	Rare	11.5	Rare
49	*Barilius vagra* (Hamilton, 1822)	-	-	9.6	Rare	17.3	Sporadic
50	*Anguilla bengalensis* (Gray, 1831)	-	-	1.9	Extremely rare	-	-
51	*Amblyceps apangi* Nath & Dey, 1989	-	-	1.9	Extremely rare	3.8	Extremely rare
Total of catch frequency (%)		**1295.9**		**467.1**		**682.2**	

Abundant—91–100% | Common—81–90% | Frequent—61–80% | Occasional—31–60% | Sporadic—15–30% | Rare—05–14% | Extremely rare—<05% | (-)—indicated in catch frequency (%) (2018–19) denotes species disappeared.

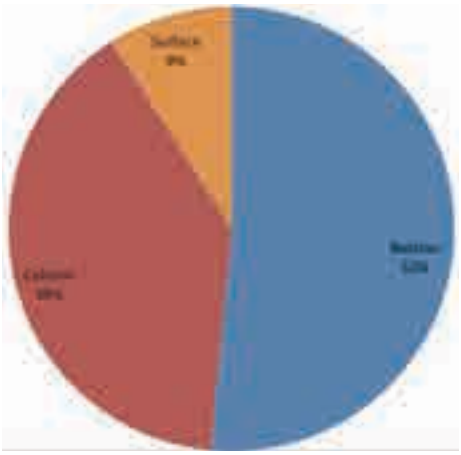

Figure 5. Ecological niche of different fish species encountered in the present study (2018–2019), showing maximum species as bottom feeders.

present study it seems to be locally a rare species and consequently considered Data Deficient in IUCN Red List of Threatened Species. The population density of *Barilius vagra* seems to be very low and might not have caught in the past study. Even in the present sampling its catch frequency is rare in upstream (Site-I) and sporadic in downstream (Site-II). *Anguilla bengalensis* was accidentally caught during flood. Moreover, its population seems to be very low as they mostly lives under hollow gaps of large boulders or rocks which is rarely seen in the study sites and is usually inappropriate and difficult to catch by castnet because of its robust and slippery body. *Amblyceps apangi* mostly hide beneath pebbles and cobbles and usually not comes in castnet, but sometime occasionally entangle, which may be the reason it could not be sampled in the past study.

Altogether the result of the present reinvestigation prior to disappearance of 14 species and drastic decline in catch frequencies within a time span of thirteen years broadly revealed rapid dwindling of existing fish fauna in the study sites primarily due to human intervention on various aspects.

On the backdrop of human interaction in the stream we gathered the information from dwelling people using unstructured questionnaire along with physical observation throughout the study sites. In fact the major key factors that has seriously jeopardized the stream ecosystems leading to sharp declination of fish fauna

Image 2. Organic and inorganic wastes accumulated in the study site-I, near Police colony, Itanagar, Arunachal Pradesh. © Lakpa Tamang.

Image 4. Electro-fishing in the study site-I, at Police Colony, Itanagar, Arunachal Pradesh. © Lakpa Tamang.

Image 3. a—Habitat degradation by mining activities near Jullang village | b—Earth work by JCB machine for construction of wall at Police colony, Itanagar, Arunachal Pradesh. © Lakpa Tamang.

may be as follows:

1. Electro-fishing: Electric fishing was frequently observed in the study site-I and rarely in Site-II. Chaudhry & Tamang (2006) had already reported the practicing of nonconventional method of fishing like using of chemicals (lime and bleaching power) and electrofishing in the Senkhi stream. This is basically operated during winter season (November–February) when water level comes down and intensity of current becomes more effective. Electro fishing is mostly dreadful to bottom dwelling fishes like species belonging to genera *Glyptothorax*, *Garra*, *Schistura*, *Aborichthys*, *Channa*, *Anguilla*, *Mastacembelus*, *Pseudolaguvia*, *Olyra* and *Amblyceps* as members of these genera live inside boulders and cannot escape or run away immediately when electric rod is run over the boulders. Besides, eggs, fish larva, juveniles, crustacean (crab and shrimp), various aquatic insects, and zooplankton which are prime food for growing larval fishes are also destroyed. Such fishing technique enables easy and more collection in short time with less effort (Image 4). However, using of chemicals was not observed as reported earlier, mainly due to siltation of organic wastes.

2. Water contamination: Being a solvent the water gets polluted very easily and causes various water borne internal and external diseases. Water contamination has been observed mostly in urban area within study site-I which covers Police colony, Chandranagar, and IRBN colony. Discharge of untreated domestic savage into the stream is one of the key factors responsible for water contamination and habitat degradation in Senkhi stream.

3. Sewage disposal: The study site is primarily fed by a major perennial drainage that brings all sorts of organic and inorganic wastes far off Ganga market places (ca 3 km) and other surrounding areas during heavy floods (June-August). Our field observation throughout

the study sites and at the time of sampling, has led to identification of the following sewage wastes mostly in Site-I (urban area): (i) Organic wastes (vegetable): cabbage, cauliflower, tomato, peels of potato, onion, long guard, and pumpkin; radish, green lettuce, french bean, soya bean, bitter guard, brinjal, ladies finger etc.; fruits: spoiled apple, banana, orange, lemon, pineapple and its peels; dead animal: pig, dog, cat, poultry bird were occasionally seen entrapped between boulders and sometime on marginal area of the stream, and intestine, skull, bony jaws of commercial cattle were frequently seen in the stream bed; (ii) Inorganic wastes: all sorts of cold drink plastic bottles and packets were seen densely accumulating among the boulders towards banks and middle section of the stream; footwear: plastic, foam, rubber, nylon and leather shoes and slippers; other items include large number of wrapped polythene bag, commercial fish thermocol box, plates, plastic sheets, vinyl carpet, cement bags, rubber pipe, pieces of tin sheet, umbrella, helmet, vehicle tyre, blanket, plastic sheets, plastic ball etc. Siltation of organic and inorganic debris over stream bed seen till premonsoon season; (iii) Human waste: typically human faecal matter is known to spread many water borne diseases to human like diarrhoea, typhoid, cholera, polio, hepatitis, and skin borne diseases. Some direct disposal of wastes have been seen within study Site-I as well as along the main drainage mentioned above.

4. Habitat degradation and disruption of riparian vegetation: Habitat alteration was more commonly seen in the lower reaches of the stream near Jullang village and beyond it. This was extraction of bed materials like boulders, cobbles, pebbles, gravels, and sand for developmental activities (Image 3a). This mining operation seems increasing due to increase in demand for developmental activities within capital city and its vicinity. Ecologically viable riparian vegetation have been replaced by residential houses and walls creating fish habitat congested, unsuitable and threatening mostly in Site-I (Image 3b). Habitat loss is also seen by displacing heavy boulders towards stream banks by JCB machine to protect from flash flood devastation. Moreover, due to disruption of aquatic ecosystem, one sustainable recreational angling, practiced especially for *Cyprinion semiplotum* using bamboo rod, nylon line and loops were entirely disappeared which was popular in the year 1995–1998 (personal observation).

CONCLUSION

In modern days management of fish diversity and its relevant habitats is a great issue and challenges (Dudgeon et al. 2006). Fresh water fish are one of the most threatened taxonomic groups (Darwall & Vie 2005) because of their high sensitivity to the quantitative and qualitative alteration of aquatic habits (Laffaille et al. 2005). One of the regular visible sign of development efforts in Itanagar, the capital, is the rapid urbanization and spreading of settlements which have adverse effect on stream ecosystem and its fauna. Much of the upstream areas near by Senkhi valley have already low vegetation cover consequences to low water discharge in the stream. Therefore, adoption of all above mentioned activities would only aggravate the already existing problems, first by destruction of the minimal viable population and secondly, by the destruction of the habitat itself. It has been observed that Senkhi stream harbors a good number of fish diversity. However, most of the fish fauna are freshwater bottom feeders which are very sensitive to ecosystem alteration. It was observed that anthropogenic activities may be the sole reasons responsible for the worsening condition of the Senkhi stream ecosystem. Hence, this might have resulted serious fish stock depletion and disappearance of 14 species in the present catch.

The fish are staple diet of the tribal folklore and an important source of protein required for the hardworking tribal communities of the state. Hence, sustainability of fish harvesting must continue for future generations. One can emulate examples from the state itself, where the tribal customary laws protect the flora and fauna in their own village area.

Keeping in view all above mentioned issues and overall result of the present study suggests urgent adoption and implementation of the following conservation strategies and mitigation measures by the concerned state government departments/ non-government agencies/ local volunteer organizations:

i. Disposal of organic and inorganic wastes into the stream should be banned.

ii. Disposal of human wastes directly into the stream should be replaced by safety tank.

iii. Illegal and unscientific methods of fishing should be strictly band.

iv. Construction of residential houses and walls closely attached to stream banks should be avoided by laws. Moreover, the hilly regions are prone to flash flood and land slide which is risky to life.

v. Creation of awareness campaign among

the local communities relating to importance of fish biodiversity, ecosystem and water source.

If urgent steps are not taken in appropriate time, the serious irreparable damage may cause to stream in near future. Therefore, the documentation of available present fish species and its rapid declining trend status is utmost important for conservationist, researcher, planner, relevant government department/ institution/ non-government agencies and local volunteer organization so that immediate necessary conservation strategies and mitigation measures could be implemented for restoration of aquatic fauna, its habitat and water resource.

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ARTICLE

First record of *Proceratium* Roger, 1863, *Zasphinctus* Wheeler, 1918, and *Vollenhovia* Mayr, 1865 (Hymenoptera: Formicidae) from the Western Ghats of peninsular India, description of three new species, and implications for Indian biogeography

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Abstract: Three new ant species from the genera *Proceratium* Roger, 1863, *Zasphinctus* Wheeler, 1918, and *Vollenhovia* Mayr, 1865 are described from the Western Ghats of southern India. This is the first report of *Proceratium* and *Zasphinctus* from peninsular India and the first record of *Vollenhovia* from the Western Ghats mountain range proper. *Proceratium gibbosum* sp. nov. is described from Periyar Tiger Reserve in Kerala, being the first record of the *stictum* species group from the Indian subcontinent; it differs from other members of the *stictum* group by the mesonotum bearing a prominent rounded dorsal hump (tumulus) and petiole devoid of ventral tooth. The first record of the genus *Zasphinctus* Wheeler, 1918 from the Indian region is also presented here, with a description of a new species. *Zasphinctus sahyadriensis* sp. nov. differs from all known Afrotropical and Asian *Zasphinctus* by a combination of characters including clypeal area with single median tooth, occipital margin being regular in outline, and head sculpture sparsely punctate. The occurrence of the genus *Vollenhovia* Mayr, 1865 is confirmed from peninsular India, with the description of the female castes of *Vollenhovia keralensis* sp. nov. We provide ecological notes on these new taxa. In addition, separate identification keys based on the worker caste are also presented to Indo-Malayan species of *Proceratium*, Afrotropical-Indomalayan species of *Zasphinctus*, and *Vollenhovia* of the Indian subcontinent. The biogeographical implications of the presence of these three genera are also discussed in relation to plate tectonics of the Indian subcontinent.

Keywords: Agasthyamalais, ant taxonomy, Cretaceous, Dorylinae, Gondwana, Kerala, Myrmicinae, Paleogene, Proceratiinae, Tectonics.

Abbreviations: DSLR—Digital SLR | NCBS—National Centre for Biological Sciences | SEM—Scanning electron microscope | TARG—TNHS Ant Research Group | TNHS—Travancore Nature History Society | ZSI—Zoological Survey of India.

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Author contributions: KS and MK together did the field-work and photography. KS wrote the manuscript and MK gave his suggestions.

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INTRODUCTION

The Western Ghats complex is one of the world's major biodiversity hotspots (Myers et al. 2000). Lying on the western edge of the Indian peninsula, this mountain chain runs for over 1,600 km (8–21^0 N), with a single major break– the Palghat gap (Subramanyam & Nayar 1974). Although the region houses exceptional biodiversity and endemism especially for invertebrates, the speciation and biogeographic processes are not well known (Joshi & Karanth 2013). As per Sheela et al. (2020), there are currently 455 species of ants including 123 endemics in 75 genera in the Western Ghats. Since Bingham (1903), many new species were reported in the region from few isolated studies, including range extensions for some genera. But, there has not been any comprehensive work on ants of the Western Ghats, making it a relatively less explored region (Sheela et al. 2020). We came across three new generic records from the region—*Proceratium* Roger, 1863, *Zasphinctus* Wheeler, 1918, and *Vollenhovia* Mayr, 1865—in studies on ants in southern Western Ghats of the Kerala state, during the last decade.

Ants of the genus *Proceratium* are cryptic, hypogaeic (subterranean) in habits and nest in rotting wood, leaf litter, topsoil, and below stones as far as known (Brown 1974; Urbani & De Andrade 2003; Staab et al. 2018). The genus has a global distribution, and most species are rarely collected due to their cryptobiotic lifestyle (Urbani & De Andrade 2003). Currently, 86 extant and six fossil species are known (Urbani & De Andrade 2003; Bolton 2021). The natural history of this genus remains mostly unknown, with a few fragmentary reports based on observations of a small number of species (Garcia et al. 2015). The genus was recorded for the first time in India with the description of *P. williamsi* Tiwari, 2000, from East Khasi Hills in Meghalaya (Mathew & Tiwari 2000). Up to this study, it was the only known species from the country (AntWeb 2021; Bharti et al. 2016).

Zasphinctus is a genus of subterranean doryline ants with Afrotropical, Indomalayan, and Australasian distribution. Currently, 23 valid species of this genus have been described, with most species found in the Australasian region. The only species recorded from mainland Asia was *Z. siamensis* (Jaitrong, 2016) from Thailand, initially described in the genus *Sphinctomyrmex*. Until now, no species of *Zasphinctus* were reported from the Indian subcontinent (Bharti et al. 2016; Sheela et al. 2020; AntWeb 2021).

Vollenhovia are myrmicine ants belonging to the tribe Crematogastrini Forel 1893 (Ward et al. 2015). These are small to moderate-sized monomorphic ants (Bolton 2003) and some of them are social parasites (Terayama & Kinomura 1997). Globally, currently 59 extant species, 18 subspecies, and three fossil species are recognized (Bolton 2021). The genus is distributed in Australasia, Indomalaya, Malagasy, Oceania, and Palearctic biogeographic regions. It is found in Seychelles in the Malagasy region, but is curiously absent from Madagascar, Reunion, Mauritius, and Africa (Fisher 1996; AntWeb 2021). In 2013, *V. gastropuncta* Bharti & Kumar, 2013 was described from Himachal Pradesh in India thereby extending the range of this genus to the western Himalaya. Even though the presence of the genus *Vollenhovia* is reported from the adjacent Biligiri Rangaswamy Temple Wildlife Sanctuary, to the east of Nilgiris, the taxon was undescribed (Rajan et al. 2006). Presently, there are no confirmed records of *Vollenhovia* from the Western Ghats mountain range proper (Sheela et al. 2020; AntWeb 2021).

We describe here one new species from each of these genera. *Proceratium* is reported here from the tropical evergreen forests of Periyar Tiger Reserve of Kerala, *Zasphinctus* from a mixed evergreen forest of Ponmudi hills from Agasthyamalai, and *Vollenhovia* from the primary evergreen and mixed forests of Periyar and Agasthyamalai. We also provide taxonomic keys based on the worker caste of Indo-Malayan species of *Proceratium* (modified from Urbani & De Andrade (2003)); Afrotropical-Indomalayan species of *Zasphinctus* (modified from Garcia et al. (2017)); and *Vollenhovia* of the Indian subcontinent.

METHODS AND TERMINOLOGY

The two study locations were Ponmudi hills in Agasthyamalai, Thiruvananthapuram District and Periyar Tiger Reserve, Idukki District, both in the Western Ghats of Kerala State of southern India (Image 1). Ants were collected from tray-sifted leaf litter samples and preserved in 1.5 ml plastic vials containing absolute ethanol. Morphological characters were studied and measurements taken with the help of a HEADZ Model HD81 stereomicroscope. Photographs were taken with a Canon 7D Digital SLR and MPE 65 f 2.8 1–5x Lens. Photographs of whole ants and surface sculpturing of parts were obtained using a FEI Quanta 200 scanning electron microscope (SEM). The holotypes were photographed with a DSLR camera and paratypes were subjected to electron microscopy. The morphological terminology follows Garcia et al. (2015)

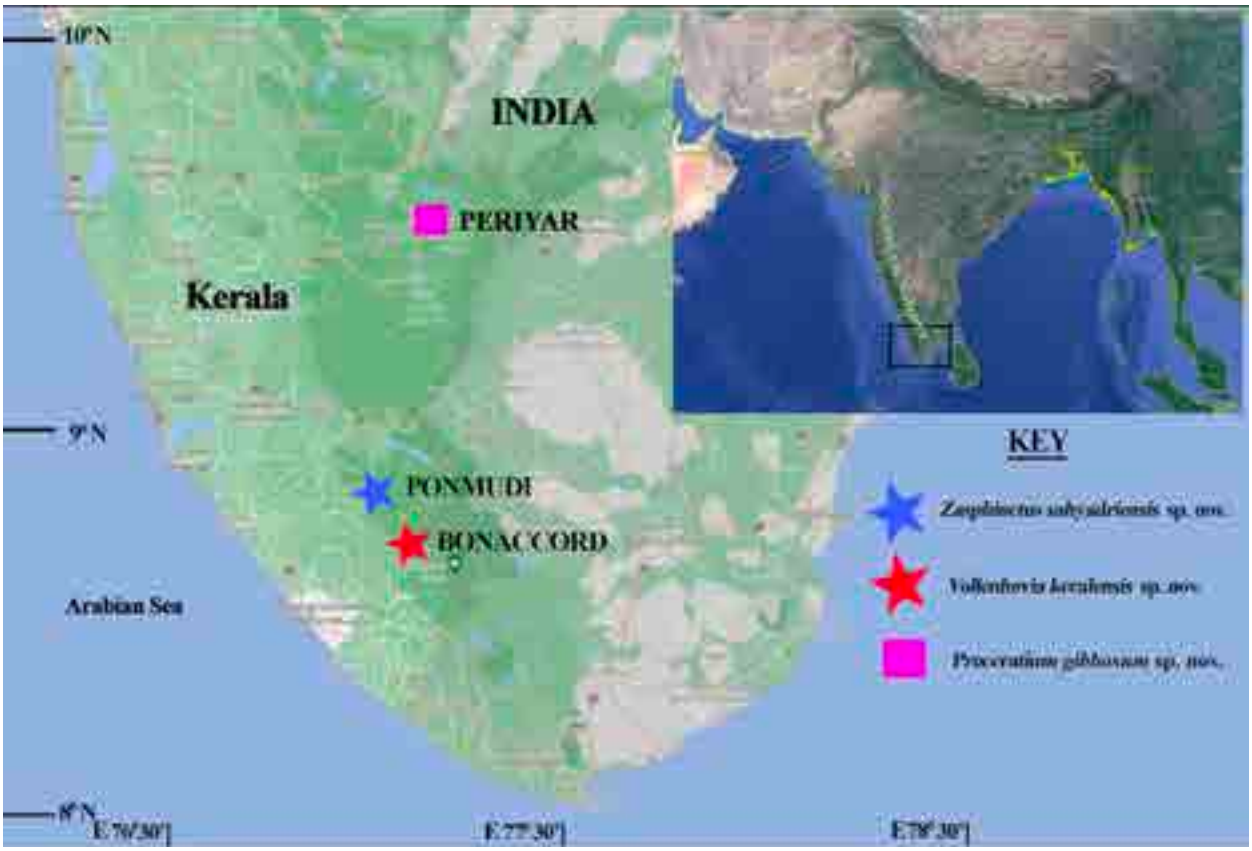

Image 1. Type localities of *Proceratium gibbosum* sp. nov., *Zasphinctus sahyadriensis* sp. nov., and *Vollenhovia keralensis* sp. nov. in southern Western Ghats, India, based on GoogleEarth. © Google 2021.

for *Proceratium* and Borowiec (2016) for *Zasphinctus*. They use certain terms that are specific to these taxa in their descriptions and identification keys. The terms in Garcia et al. (2015) and Borowiec (2016) are adhered to facilitate comparison to these works. Gyne morphology follows Boudinot (2015). Wilson (1955) was followed for pubescence and pilosity. The terminology for the description of surface sculpturing is based on Harris (1979). The term abdominal segment III is alternately used for the postpetiole and abdominal segment IV for the gastral segment I following Fisher (2005). Abdominal segments 1 to 4 are denoted as AI, AII, AIII and AIV, respectively. We use the term 'calcar of strigil' following Keller (2011). Measurements follow Ward (1988) and Garcia et al. (2015, 2017). All measurements are in millimetres unless otherwise specified. Research permissions granted to us precludes publication of GPS points for places inside protected areas as a publication policy, hence we are unable to provide them.

The following measurements and indices are used:

EL—Eye length: maximum length of eye measured in lateral view | HL—Head length: maximum measurable distance from the mid-point of the anterior clypeal margin to the mid-point of the posterior margin of head, measured in full-face view | HW—Head width: maximum head width directly behind the eyes, measured in full face view | SL—Scape length: maximum length of scape shaft excluding basal condyle | PH—Pronotal Height: the maximum height of the pronotum in profile | PW—Pronotal Width: the maximum width of the pronotum in dorsal view | DML—Dorsal Mesosoma Length: maximum length of mesosomal dorsum from antero-dorsal margin of pronotum to dorsal margin of propodeal declivity | WL—Weber's Length of Mesosoma: the maximum diagonal length of the mesosoma in profile, from the angle at which the pronotum meets the cervix to the posterior basal angle of the metapleuron | HFeL—Metafemur Length: the maximum straight-line length of the metafemur, measured in dorsal view | HTiL—Hind tibia length: maximum length of hind tibia measured on its external face | HBaL—Hind basitarsus length: maximum length of hind basitarsus measured along its external face | PeL—Abdominal Segment II (petiole) Length: the maximum length of abdominal segment II (petiole), measured in dorsal view | PeH—Abdominal Segment II (petiole) Height: the maximum height of the

petiolar tergum in profile view, including laterotergite, excluding petiolar sternum | PeW—Abdominal Segment II (petiole) Width: the maximum width of abdominal segment II (petiole), measured in dorsal view | A3L—Abdominal Segment III Length: the maximum length of abdominal segment III, measured in dorsal view | A3W—Abdominal Segment III Width: the maximum width of abdominal segment III, measured in dorsal view | A3H—Postpetiole Height: Maximum height of postpetiole in profile |

A4L—Abdominal Segment IV Length: the maximum length of abdominal segment IV, measured in dorsal view | A4W—Abdominal Segment IV Width: the maximum width of abdominal segment IV, measured in dorsal view | LS4—Abdominal sternum IV length: maximum length of abdominal sternum IV in lateral view | A5L—Abdominal Segment V Length: the maximum length of abdominal segment V, measured in dorsal view | A5W—Abdominal Segment V Width: the maximum width of abdominal segment V, measured in dorsal view | A6L—Abdominal Segment VI Length: the maximum length of abdominal segment VI, measured in dorsal view | A6W—Abdominal Segment VI Width: the maximum width of abdominal segment VI, measured in dorsal view | WL—Weber's length: diagonal length of mesosoma in lateral view from the anterior-most point of pronotal slope (excluding neck) to posteroventral margin of propodeal lamella or lobe | TL—Total body length: combined length of HL + WL + PeL + A3L + A4L for Proceratiinae and HL + ML + PeL + A3L + GL for Myrmicinae.

Indices

CI—Cephalic index: HW / HL × 100 | OI—Ocular index: EL / HW × 100 | SI—Scape index: SL / HL × 100 | DMI —Dorsal Mesosoma Index: PW / WL × 100 | DMI2 —Dorsal Mesosoma Index 2: DML / WL × 100 | LMI —Lateral Mesosoma Index: PH / WL × 100 | DPe (DPI)—Dorsal petiole index: PeW / PeL × 100 | LPI —Lateral Petiole Index: PeL / PeH × 100 | MFI —Metafemur Index: HFeL / HW × 100 | ASI—Abdominal segment index: A4L /A3L × 100 | IGR—Gastral reflexion index: LS4 / A4L.

RESULTS

Genus *Proceratium* Roger, 1863

Description of worker caste *stictum* species group

Monomorphic hypogaeic ants of tribe Proceratiini with petiole narrowly attached to the first gastral segment; tergite of second gastral segment strongly arched and vaulted with remaining segments directed anteriorly; eyes present even if small; mandible linear to triangular with three or more teeth, not overhung by the clypeus; apical funicular segment moderately enlarged but not strongly bulbous well-developed (Bolton 2003). Medially excavated clypeus protruding anteriorly, vertex in full-face view weakly concave, calcar of strigil with a basal spine, belonging to the *stictum* species group as defined by Urbani & De Andrade (2003).

Proceratium gibbosum

Sadasivan & Kripakaran sp. nov.

(Image 2A–C)

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Material Examined

Holotype: NRC-AA-3758, 23 May 2016, Worker, Vallakadavu, Periyar Tiger Reserve, Idukki District, Kerala State, India, at 900 m, coll. by Kalesh Sadasivan, tray-sifting loose soil under a decaying log, in forest floor of a primary evergreen forest, deposited in the insect collection facility of the NCBS (National Centre for Biological Sciences), Tata Institute of Fundamental Research, GKVK, Bellary Road, Bengaluru, Karnataka 560065, India. Earlier, the holotype was with number TARG-1007, mounted for morphological study and later removed & preserved as wet specimen in absolute alcohol, deposited in the research collections facility at the Travancore Nature History Society (TNHS), Thiruvananthapuram, Kerala.

Measurements: EL 0.05, HW 0.80, HL 0.90, HFeL 0.75, HTiL 0.55, HBaL 0.40, A3L 0.90 A4L 0.45, LS4 0.25 PeL 0.47, PeW 0.34, SL 0.50, WL 1.09, TL 3.91, CI 89, OI 6.25, SI 55.55, DPeI 72.34, ASI 50, IGR 55.56.

Head: In full-face view marginally longer than wide (CI 89). Vertexal margin almost straight with only very shallow concavity. Head wider at midway distance between the level of eyes and the lateral angle of the vertex. Clypeus narrow, not surrounding the antennal insertions and projecting inferiorly only in the area between the anterior margin of the frontal carinae. Anterior clypeal margin notched medially. The frontal carinae are well-separated, running in parallel anteriorly and then diverging posteriorly. The frontal carinae reaches up to midway between the anterior clypeal margin and the level of the eyes (Image 2C). Eyes simple (single ommatidium), located slightly below the mid-length of the head in full-face view. Ocelli absent. Antennal scape distally incrassate and not reaching the vertexal margin. Antennal scape as long as broad, all other segments broader than long. Length of last funicular segment equal to the sum of lengths of 7–11 funicles. Mandibles with three denticles before the apical tooth. Palp formula 4,3.

Image 2. *Proceratium gibbosum* sp. nov. holotype (NRC-AA-3758): A—lateral view | B—dorsal view showing the mesonotal tumulus | C—fronto-oblique view of the head and antennae. © Manoj K.

Mesosoma: In lateral view, slightly convex; mesonotum presenting a visible tumulus. Mesosoma slightly longer than the sum of HL and mandible length. Both the promesonotal suture and metanotal groove shallow and barely discernible. Propodeal margins with a well-defined tooth, lobes expanded into a broad lamella. In dorsal view, pronotal margin angulate, but lacking projections, tooth or spines. The mesonotum bears on its mid-dorsal surface aspect a large tumulus (0.25 mm), occupying almost half of the area on dorsal side of the mesonotum (Images 2B). The propodeum has the tooth directed postero-laterally and the broad propodeal lobes. Propodeal declivity slightly concave, almost flat. The posterolateral aspect of metapleuron with a concavity bearing the opening of the metapleural gland.

Petiole: In dorsal view, slightly longer than broad (PeL 0.47, PeW 0.34). The narrowest part of the petiole is its anterior end (peduncle). The sides of the node are diverging to about the beginning of distal third where it is the widest and the converges slightly towards the posterior end. The anterior margin of the peduncle is thickly marginated. In profile view, a mid-ventral keel extends till the end of the junction of the anterior and middle third of the length of the petiole. No tooth or spine present ventrally (Images 2A,B).

Postpetiole: In lateral view, postpetiole is 2.5 times the length of the petiole. Dorsal profile broadly convex, ventrally the anterior half is slightly concave and distal half is convex in outline (Image 2A). The sides of the tergite are convex and the anterior end is produced as a small blunt triangular extension. In ventral view, the sternite has a mid-carina which is rudimentary. The anterior margin of the sternite extends as a broad triangular extension (Images 2A,B).

Gaster: Constriction between the post petiole (abdominal segment AIII) and first gastral segment (AIV) well defined and deep (Image 2A). Tergite of the AIII twice the length of the post petiole (AII). The tergite of AIII double the length of tergite of AIV. The first gastral segment recurved ventrally to almost a right angle and its curvature is smooth and convex. The distal edge of the AIII was marginated. Remaining gastral segments curved ventrally and telescoped inside the gaster. Sting present, robust (0.2 mm long).

Legs: All tibiae with pectinate spur. Calcar of strigil with a basal spine. Hind basitarsi slightly longer than half the length of the hind tibia.

Sculpture and Pilosity: Head, mesosoma, petiole and AIII irregularly foveolate with sparse tiny nodules. The irregular edges of the foveolae gives a scabrous appearance to the surface. Area of the mesonotal tumulus finely granular. AIV almost scabrous in appearance. Legs covered in dense but shallow foveolae, giving them a reticular appearance. Body is covered in four types of hairs:

1) Very short decumbent hairs on the antennal funicles;

2) Short sub-decumbent hairs, which are denser on the legs and the mesonotal tumulus;

3) Long sub-erect hairs throughout the whole body;

4) Short appressed hairs on the apical antennal funicle.

Short hairs on the mesonotal tumulus irregular, disposed with the tips pointing to the centre of the tumulus.

Color: Live specimens dark brown. Petiole, the mesonotal tumulus and the propodeum darker. The pronotum, postpetiole and head slightly paler. Legs and antennae dark orange brown. Hairs pale amber brown.

Additional Material Examined

Paratype workers (n = 3) (Images 3–5): NRC-AA-3759, 28 March 2021, Worker, Vallakadavu, Periyar Tiger Reserve, Idukky District, Kerala State, India, at 930 m, coll. Kalesh Sadasivan, tray-sifting leaflitter, in forest floor of a primary evergreen forest, deposited in the insect collection facility of the NCBS (National Centre for Biological Sciences), Tata Institute of Fundamental Research, GKVK, Bellary Road, Bengaluru, Karnataka 560065, India. Earlier, paratype number TARG-1008, preserved in absolute alcohol and currently deposited in the research collections facility at the TNHS, Trivandrum, Kerala.

Two other paratype workers, same data as paratype above. One paratype (TARG-1009) and (TARG-1010) both in absolute alcohol, to be deposited in the insect collection of Zoological Survey of India (ZSI), Kozhikode, Kerala.

Measurements: EL 0.05–0.06, HW 0.70–0.80, HL 0.80–0.90, HFeL 0.80–0.90, HTiL 0.50–0.60, HBaL 0.35–0.45, A3L 0.90–1.00, A4L 0.45–0.50, LS4 0.20–0.30, PeL 0.47–0.50, PeW 0.34–0.40, SL 0.50–0.70, WL 1.09–1.30, TL 3.71–4.20, CI 87.5–89, OI 6.20–7.50, SI 55.55–77.78, DPeI 72–80, ASI 50.00, IGR 44.40-60.

Variation in workers. No variation except subtle differences in body measurements as given above.

Gyne: Unknown

Male: Unknown

Etymology: The specific epithet *gibbosum* (from Latin 'gibbosus', meaning protruding or humpbacked) is a singular neuter adjective in the nominative case and refers to the hump-like protuberance on the mesonotum, characteristic of the species.

Ecological Notes: This species nests in the forest floor

Image 3. *Proceratium gibbosum* sp. nov. Scanning electron images of a paratype from TARG collection of the same colony as the holotype: A—dorsolateral view of a paratype with tumulus (white arrow) | B—close-up of dorsolateral view of petiolar node showing surface sculpture | C—closeup of the propodeal spines and lobe (white arrows).

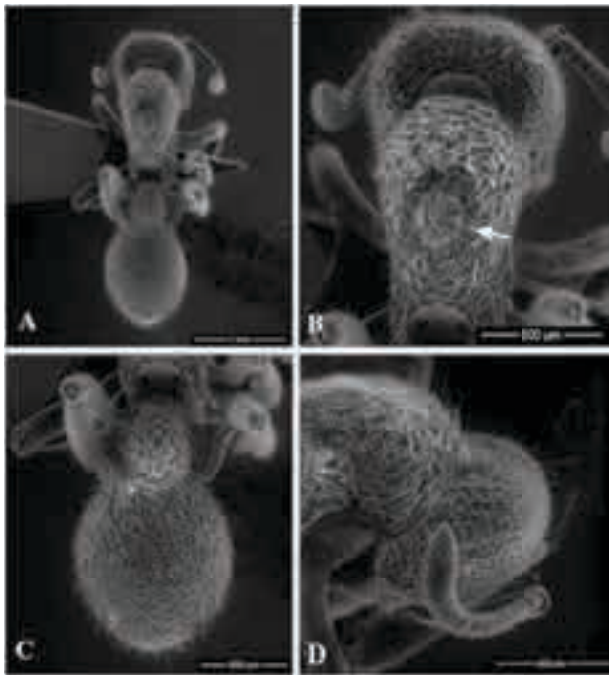

Image 4. *Proceratium gibbosum* sp. nov. Scanning electron images of a paratype from TARG collection of the same colony as the holotype: A—dorsal view of a paratype | B—closeup of the mesonotal tumulus (white arrow) | C—close-up of gaster and petiole | D—close-up of latero-oblique view of head and pronotum showing the sculpture.

and the colonies are probably small. This new species can be found in wet evergreen and secondary tropical rainforests, nesting in the interphase of soil and leaf litter or in the debris along sheltered edges of decaying logs on floor (Image 6). Workers are solitary foragers and move at a slow pace. They feign dead when disturbed, camouflaging against the soil (Image 5D). In captivity, the workers readily accepted spider eggs as food (Image 5E) and built a nest chamber with spider silk and soil. Workers were slow in movement, looked generally uncoordinated and were averse to light. Other species that were found in the same microhabitat of *P. gibbosum* were *Tyrannomyrmex alii* Sadasivan & Kripakaran, 2017, *Protanilla* sp., *Discothyrea* sp., and *Recurvidris* sp. So far, this new species is restricted to the mid-elevation tropical evergreen jungles of the Periyar Tiger Reserve, in Kerala.

Diagnosis and Remarks

The new taxon is characterised by a clypeus, protruding anteriorly, surrounding the antennal sockets and medially excavated (distinctly and broadly notched), vertex in full-face view weakly concave; calcar of strigil

Image 5. *Proceratium gibbosum* sp. nov. Images of a live paratype from TARG collection of the same colony as the holotype: A—lateral view | B—dorsal view | C—close-up of head with antennae and mandibles | D—foraging workers in soil | E—foraging worker with spider egg. © A–C Kiran. M.R. | D–E © Manoj. K.

Image 6. *Proceratium gibbosum* sp. nov. Image showing the habitat of type locality at Periyar Tiger Reserve, Western Ghats, Kerala. © Raghuram, E.

with a basal spine; hence of the *stictum* species group (Urbani & De Andrade 2003). According to Staab et al. (2018), the *stictum* species group is exclusively tropical with taxa in Africa, Madagascar, the Mascarene Islands of southeastern Asia, Indochina, Australia, and Mesoamerica. There are four known species of the *stictum* species group from the oriental region. The species *P. deelemani* Perrault, 1981 is distributed in Borneo, Brunei Darussalam, Malaysia (Sabah & Sarawak), Thailand, and Singapore; *P. foveolatum* Baroni Urbani and de Andrade, 2003 is reported from Borneo, Brunei Darussalam, Indonesia and Malaysia; *P. stictum* Brown, 1958 is found in Queensland, Australia; and, *P. shohei* Staab, Xu & Hita Garcia, 2018 was described from a tropical forest of Yunnan Province in China. Thus, this is the first record of a taxon of the *stictum* species group for India.

Proceratium gibbosum differs from the other members of the *stictum* species group by the following character combination: mesonotum with a small rounded dorsal hump, and petiole lacking ventral projections. *Proceratium gibbosum* also presents a pedunculate petiole with its dorsal margin convex in profile; all tibiae with pectinate spur, calcar of strigil with a basal spine; eyes composed of a single large convex ommatidium; propodeum unarmed but angulate, convex in profile, propodeum with a robust spine on each side, propodeal lobes broad lamellaceous expansions; head, mesosoma, petiole and postpetiole irregularly foveolate; first gastral tergite convex in profile; antennal funicles wider than long; total length <4.8 mm; propodeum with a robust spine on each side, the propodeal lobes with broad lamellaceous expansions.

The other *Proceratium* species from India are *Proceratium bhutanense* de Andrade, 2003, described from Phuntsholing in Bhutan, Darjeeling in West Bengal, Kumaon in Uttar Pradesh (Uttarakhand), and Khasi Hills in Meghalaya (Urbani & De Andrade 2003). Bharti and Wachkoo (2014) found *P. bhutanense* to be conspecific with *P. williamsi* Tiwari, 2000 and hence is now treated as the junior synonym of the latter. The species *P. williamsi* belongs to the *itoi* species group with the fourth abdominal segment sternite protruding over the third abdominal sternite (Urbani & De Andrade 2003).

According to the identification key from Urbani & De Andrade (2003), the closest known species in the *stictum* species group seems to be *P. deelemani*. However, *P. deelemani* lacks the distinct small rounded dorsal hump present on the new species. In addition, the petiole of the new species lacks any ventral projections, while in *P. deelemani* it has a distinct ventral tooth. To *P. stictum*, the new species differs in the cephalic sculpture, deeply impressed on *P. gibbosum* and shallow on the former. Additionally, the frontal carinae of the new species diverge posteriorly, where in *P. stictum* they are not as divergent. Anteriorly, the frontal carinae are closer to each other in *P. gibbosum,* while they are farther away in *P. deelemani*. The frontal carinae run to a level almost midway between the anterior clypeal margin and the level of the eyes, but they extend only one third the same distance in *P. deelemani* (the frontal carinae are shorter in *P. deelemani*). The species is differentiated from *P. foveolatum* by the first gastral tergite being angulate on dorsum, while it is round on the curvature in *P. gibbosum.* The new species is diagnosed from *P. shohei* by the head being widest midway between the eyes and vertex, while the head is widest at the level of eyes in *P. shohei.* The petiolar node is relatively compressed dorsoventrally in *P. shohei,* while *P. gibbosum* has a pedunculate petiole, convex in profile.

Modified part of the key to Indo-Malayan species of *Proceratium* Roger, 1863 based on the worker caste, from Urbani & De Andrade (2003) with placement of the known species from India.

1) Petiole with peduncle, convex or subconvex in profile; anterior clypeal border strongly protruding anteriorly or at least medially triangular 2
- Petiole without peduncle, rectangular in profile; anterior clypeal border straight or weakly concave, never protruding anteriorly ..... (Continued to couplet number '6' in Baroni Urbani & De Andrade 2003)

2) Propodeal angle with a developed spine; propodeal lobes with a broad lamellaceous tooth...3
- Propodeal angle at most with a small tip, without a true spine; propodeal lobes without broad lamellaceous tooth, at most with a lamella over the whole declivitous face 5

3) First gastral tergite angulate on the dorsum (Malaysia).....*P. foveolatum* De Andrade, 2003
- First gastral tergite round on the dorsal curvature 4

4) Mesonotum without any dorsal tumulus; petiole with a mid-ventral tooth (Borneo, Brunei, Malaysia, Thailand and Singapore) ..... *P. deelemani* Perrault, 1981
- Mesonotum with a rounded dorsal tumulus; petiole lacking ventral projections (Western Ghats, India) ..... ***P. gibbosum* sp. nov.**

5) Frontal carinae fused; clypeus strongly protruding anteriorly; mesosoma, petiole, postpetiole and gaster foveolate (Malaysia) ..... *P. microsculptum* De Andrade, 2003
- Frontal carinae not touching each other; clypeus reduced, a triangular tooth like projection between the antennal sockets; mesosoma, petiole and postpetiole granulate, gaster punctat 6

6) Body without long erect hairs; lateral propodeal margin at most with a narrow lamella; hairs on mesobasitarsi shorter than 1/2 the mesobasitarsal length (Himalayas from Uttarakhand to Meghalaya in Northeast India, Bhutan) ..... *P. williamsi* Tiwari, 2000
- Body with long erect hairs; lateral propodeal margin with a broad lamella; mesobasitarsi with hairs 1/2 the mesobasitarsal length (Malaysia) ..... *P. malesianum* de Andrade, 2003

Genus *Zasphinctus* Wheeler, 1918

Description of Worker Caste

Antennae with 12 segments, pygidium armed with numerous peg-like or spiniform setae, much thicker than surrounding fine hairs; waist with abdominal segment III at least weakly differentiated from segment IV; the latter with a constriction between its pre- and post-sclerites; mid- and meta-tibiae with a single spur; tarsal claws of hind legs simple; mesosoma and gaster not conspicuously dorso-laterally marginate pore plate of metatibial gland not in a depression; in lateral view pronoto-mesopleural suture fused, never as a curved slit in the cuticular surface, and approaching dorsolateral margins of promesonotum; circumference of helcium smaller relative to abdominal segment II (petiole) and placed at about mid-height, resulting in pronounced posterior face to abdominal segment II and conspicuous anterior face of abdominal segment III; opening of metapleural gland conspicuous elongate and trench-like and its diameter larger than that of the propodeal spiracle; and constrictions present at anterior end of abdominal segments V and VI (Borowiec 2016).

Zasphinctus sahyadriensis
Kripakaran & Sadasivan sp. nov.
(Image 7A–C)
urn:lsid:zoobank.org:act:423E5FC4-315A-44E1-9C14-C66B2D02268F

Material Examined

Holotype: NRC-AA-3760, 15 October 2015, Worker, Ponmudi, Agasthyamalai, Thiruvananthapuram District, Kerala State, India, at 600 m, coll. Manoj Kripakaran, collected under a small rock, in the forest floor of a mixed evergreen forest, deposited in the insect collection facility of the NCBS (National Centre for Biological Sciences), Tata Institute of Fundamental Research, GKVK, Bellary Road, Bengaluru, Karnataka 560065, India. Earlier, the holotype was with number TARG-1011, mounted for study and preserved as wet specimen in absolute alcohol, deposited in the research collections facility at the TNHS, Thiruvananthapuram, Kerala.

Measurements: HL 0.70, HW 0.40, SL 0.32, PH 0.40, PW 0.50, DML 0.90, WL 1.00, HFeL 0.42, PeL 0.32, PeH 0.23, PeW 0.50, A3L 0.35, A3W 0.43, A4L 0.30, A4W 0.58, A5L 0.30, A5W 0.59, A6L 0.30, A6W 0.60, CI 57.14, SI 45.71, DMI 50, DMI2 90, LMI 40, MFI 105, LPI 139, DPI 156, DA3I 123, DA4I 193, DA5I 197, DA6I 200.

Head: Antennae with 12 segments and relatively short (SI 44–56), scapes reaching half of the height of the head in full-face view. Apical antennal segment is conspicuous, longer than two preceding segments

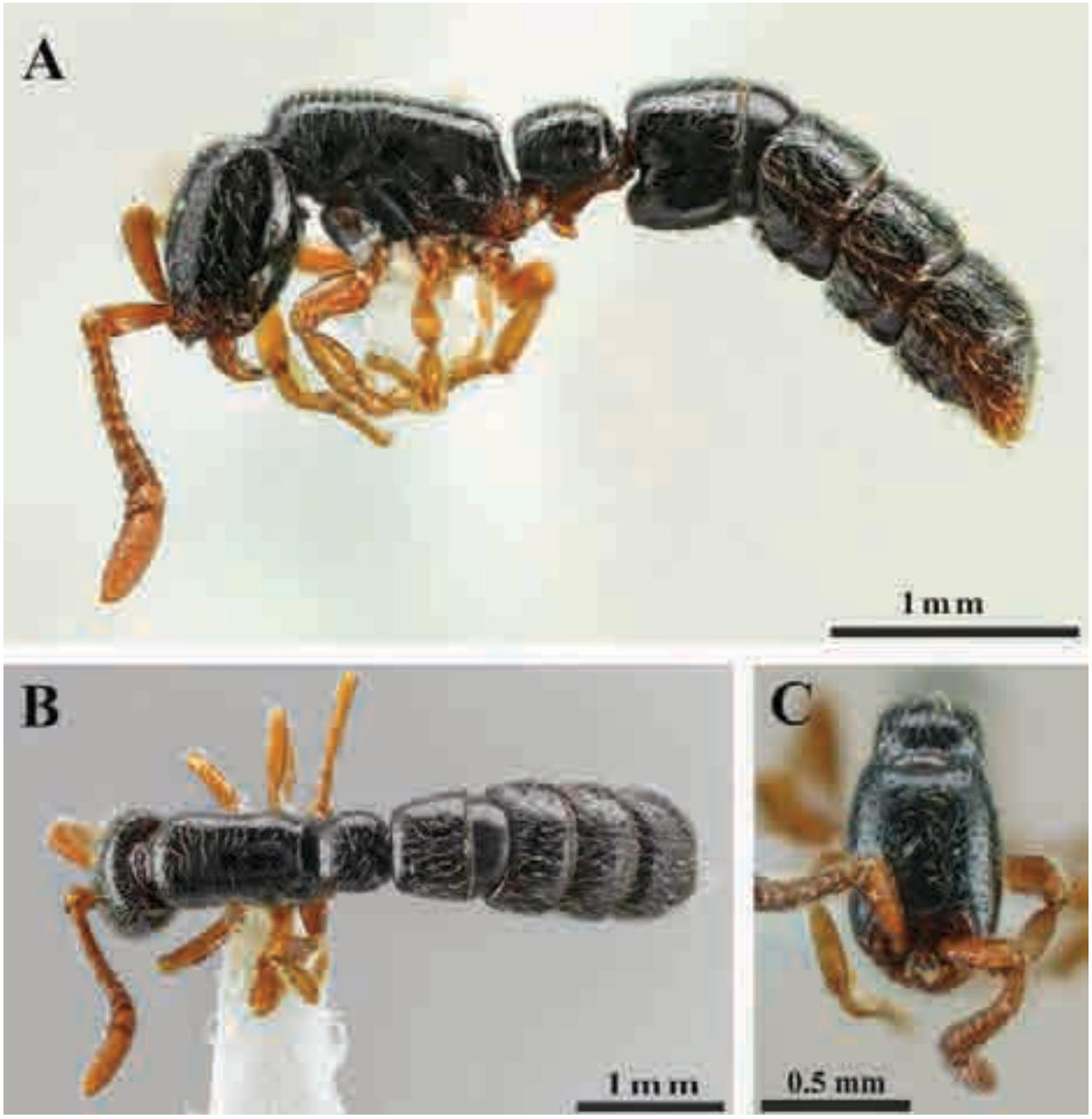

Image 7. *Zasphinctus sahyadriensis* sp. nov. holotype (NRC-AA-3760): A—lateral view | B—dorsal view | C—full-face front view. © Kalesh Sadasivan.

combined. Head distinctly longer than broad (CI 56–59). Parafrontal ridges present and well-developed but somewhat irregular. Torulo-posttorular complex vertical reaching only below half of the height of the parafrontal ridges. Antennal scrobes absent. Median clypeal area with a single short but conspicuous tooth (Image 7C). Palp formula 3,3 (visible palpomeres). Mandibles elongate triangular and curved; masticatory margin almost plain, basal region with inconspicuous denticles. Eyes and ocelli absent. Vertex concave. Head capsule with a well-differentiated vertexal margin with prominent lateral angles.

Mesosoma: Mesosoma in lateral view the profile is almost straight (LMI 40–44). Sides are rounded and not marginate (Images 7A).

In dorsal view, slightly more than twice as long as broad (DMI2 88–93). Promesonotal suture completely fused. Pronotomesopleural suture absent. Mesometapleural groove not impressed. Transverse groove dividing mesopleuron absent. Pleural endophragmal pit concavity

present. Mesosoma dorsolaterally immarginate. Metanotal depression or groove on mesosoma absent. Propodeal spiracle situated low below mid-height on the sclerite. Propodeal declivity almost vertical with an angle of 110 degrees to the dorsum. Propodeal declivity with distinct dorsolateral and lateral edge or margin, and declivity is nearly semi-circular in posterior view. Metapleural gland without bulla visible through the cuticle. Propodeal lobes developed.

Metasoma: Abdominal segment II (petiole) sessile, without peduncle. Petiolar node well-developed. In profile, petiolar tergum 1.4 times longer than high (LPI 136–139). Petiole anterodorsally marginate but blunt, dorsolaterally well rounded, and laterally above spiracle weakly marginate. Subpetiolar process well-developed with strongly anteroventrally projecting "eagle beak" shaped with tip hooked posteriorly (Image 7A) The subpetiolar process without fenestra. Prora on the anterior aspect of the ventral part of abdominal segment III is simple and heart shaped. Spiracle openings of abdominal segments IV–VI circular. Abdominal segment III anterodorsally emarginate and dorsolaterally emarginate. Abdominal segment III distinctly longer than succeeding segment IV, in both dorsal and ventral views. Girdling constrictions of segments IV, V, VI present and distinct. Abdominal tergite IV not folding over sternite, and anterior portions of sternite and tergite equally well visible in lateral view. Pygidium large, with weakly impressed and hypopygium moderately concave proximally, with the posterior end bossed on its midline bearing the ventral part of the tiny sting.

Legs: Pro-, tibia, meso-, and metatibiae with single pectinate spur. Tarsal claws simple. Metafemur moderately long (MFI 105-112).

Sculpture and Pilosity: The head, mandibles, mesosoma, legs and metasoma are generally smooth and shiny, with sparse piligerous punctae and a much lesser number of glabrous punctae. Sculpture on ventral margin of antennal scape, propodeal declivity and helcium imbricate to reticular. Most of body with numerous short to moderately long, decumbent to suberect setae. Few erect hairs present around the pygidium and hypopygium. Pygidium near the sting and the lateral margins armed with short and stout, tubiform to conical setae. Long semierect filiform setae present around the pygidium and hypopygium. The area between vertexal margin and occipital margin unsculptured.

Color: Mainly black, appendages and subpetiolar process amber brown. Mandibles dark amber brown. Hairs pale yellowish and translucent (Image 7).

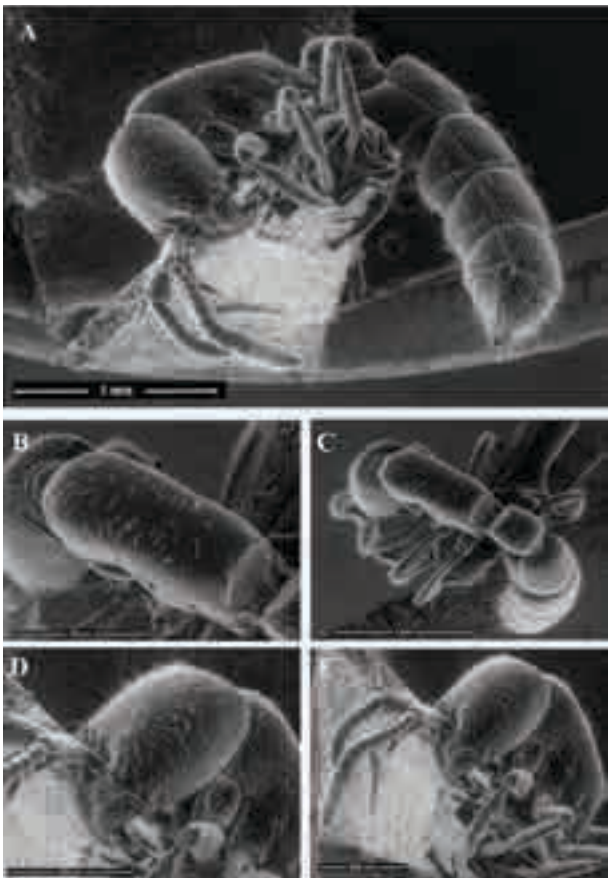

Image 8. *Zasphinctus sahyadriensis* sp. nov. Scanning electron images of a paratype from TARG collection of the same colony as the holotype: A—lateral-ventral view | B—dorsolateral view | C—closeup of mesosoma showing the rounded lateral borders and absence of any prominent sutures | D—close-up of sculpture and pilosity of head | E—lateral-oblique view of head.

Additional Material Examined

Paratype workers (n = 3) (Images 8,9): NRC-AA-3761, Worker with the same collection data as holotype above. Earlier, the paratype was with number TARG-1012, wet specimen in absolute alcohol, currently deposited in the research collections facility at the TNHS, Trivandrum, Kerala.

Two other paratype workers both with the same collection data as paratype above. Of them one worker (TARG-1013), wet specimen in absolute alcohol, will be deposited in the insect collection of ZSI, Kozhikode, Kerala and the other worker (TARG-1014), wet specimen in absolute alcohol, will be retained as voucher specimen in collection facility of TNHS, Thiruvananthapuram, Kerala.

Measurements: HL 0.68–0.72, HW 0.38–0.42, SL 0.31–0.32, PH 0.40–44, PW 0.49–0.54, DML 0.88–0.93, WL 0.98–1.10, HFeL 0.40–0.45, PeL 0.30–0.34, PeH 0.22–0.25, PeW 0.48–0.54, A3L 0.32–0.38, A3W 0.42–0.45,

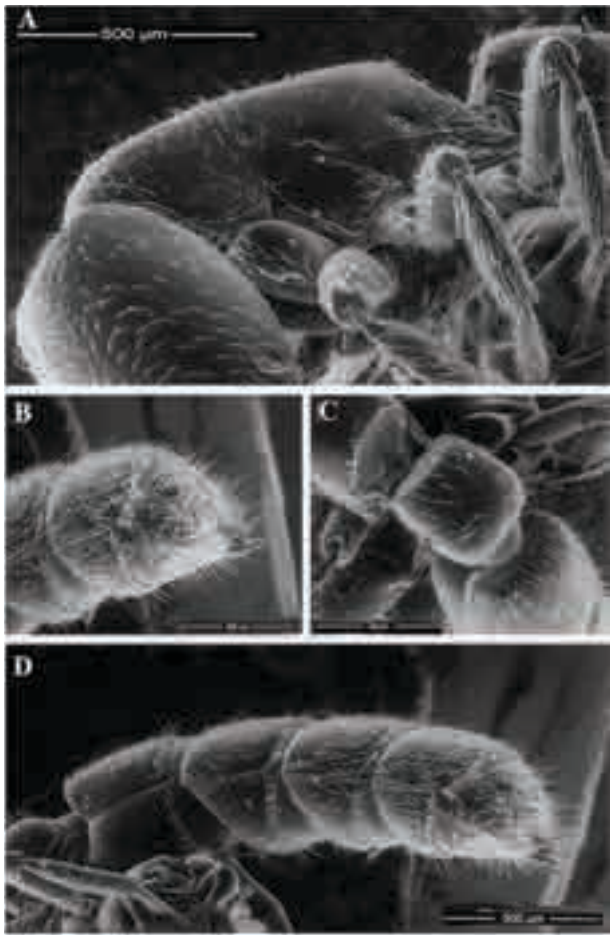

Image 9. *Zasphinctus sahyadriensis* sp. nov. Scanning electron images of a paratype from TARG collection of the same colony as the holotype: A—close-up of latero-oblique view of mesosoma | B—close-up of pygidium | C—dorso-oblique view of petiolar node | D—lateroventral view of metasoma.

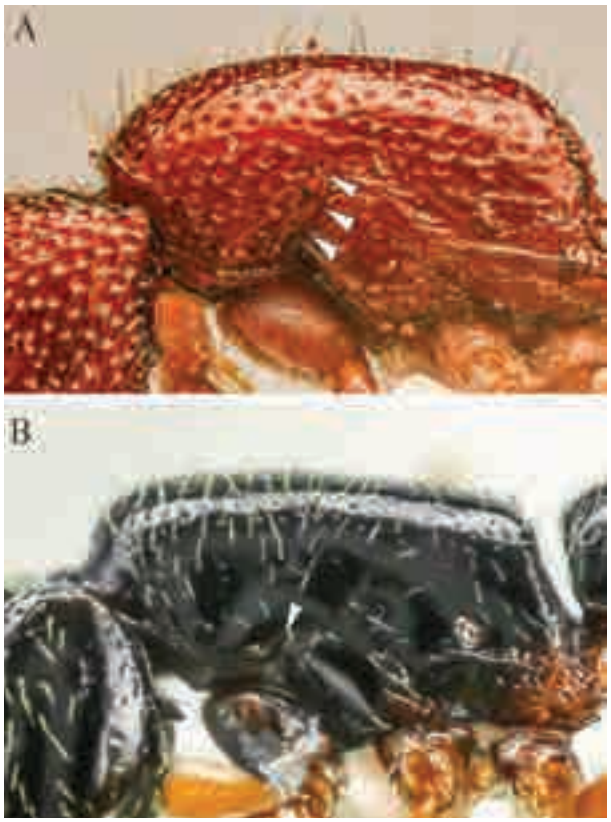

Image 10. Pronotomesopleural sutures *Eusphinctus* and *Zasphinctus* from Agasthyamalai. Kerala, Western Ghats (white arrows): A—*Eusphinctus* with pronotomesopleural suture as a long deep cut in the cuticle | B—*Zasphinctus* with short and rudimentary pronotomesopleural sutures. © Kalesh Sadasivan & Manoj K.

A4L 0.30–0.32, A4W 0.56–0.59, A5L 0.28–0.32, A5W 0.56–0.60, A6L 0.28–0.32, A6W 0.58–0.61, CI 55.88–58.33, SI 44.44–55.56, DMI 49–54, DMI2 88–93, LMI 40–44, MFI 105–107, LPI 136–139, DPI 156–160, DA3I 118–131, DA4I 184–193, DA5I 188–200, DA6I 191–207.

Variation in workers: No variation except in the subtle differences in body measurements indicated above.

Gyne. Unknown

Male. Unknown

Etymology. The epithet '*sahyadriensis*' is masculine and derived from the Sanskrit and regional Malayalam language word '*Sahyadri*', denoting the Western Ghats.

Ecological Notes. The species was found in a tropical evergreen forest floor. Five workers were collected from a subterranean tunnel under a small rock, near the buttress of a tree (Image 11). The workers were moving in the narrow tunnel which happened to get opened when the rock was removed. The movement was army ant-like, fast, irregular, and the ants were averse to light. In captivity, workers accepted brood of a *Pheidole* species as food. The species is restricted to Ponmudi hills in Agasthyamalai region of southern Western Ghats in Kerala state of southern India as far as is known.

Diagnosis and Remarks

Following Borowiec (2016), the genus *Sphinctomyrmex* now refers to species from the Neotropics, with the Old World taxa now placed in *Zasphinctus* Wheeler, 1918 and *Eusphinctus* Emery, 1893. *Zasphinctus* is easily differentiated from *Eusphinctus* by pronotomesopleural suture being present as a deep cut in the cuticle in the latter (Image 10) (Borowiec 2016). *Zasphinctus* can be distinguished from other doryline lineages with pronounced abdominal constrictions by highly-positioned propodeal spiracles, propodeal lobes present, pygidium large and armed with modified setae, and pronotomesopleural suture fused (Borowiec 2016). *Zasphinctus* is a moderately speciose lineage of

Image 11. *Zasphinctus sahyadriensis* sp. nov. Image of habitat at the type locality in Agasthyamalais. © Raghuram, E.

specialized ant predators, most prominently distributed in Australia (AntWeb 2021). Workers are of variable size, color, and sculpturation, but always possessing conspicuous girdling constrictions between abdominal segments IV, V, and VI. The eyes are absent in most species.

This is the first confirmed report of the occurrence of *Zasphinctus* for the Indian Subcontinent. The new species seems to be a subterranean predatory in the mid-elevation of mixed evergreen forests (600 m) of Western Ghats (Image 11). *Zasphinctus sahyadriensis* is easily differentiated from the sympatric *Eusphinctus furcatus* Emery, 1893, occurring in the same habitat. Although superficially similar, *Z. sahyadriensis* has 12-segmented antennae, a shallow pronotomesopleural suture, smaller size (TL 3.04–3.33), and shiny black color, while *E. furcatus* has 11-segmented antennae, a deep pronotomesopleural suture, larger size (TL 6.85–6.90 mm), and dark brown integument coloration. Additionally, *E. furcatus* was recorded above 900 m, while the highest elevation for *Z. sahyadriensis* was 700 m.

Analysis of AntWeb (2021) images revealed morphological similarities between *Zasphinctus sahyadriensis* and other shiny black Afrotropical species (*Z. sarowiwai* Hita Garcia, 2017, *Z. obamai* Hita Garcia, 2017, and *Z. wilsoni* Hita Garcia, 2017). The presence of the conspicuous tooth in the median clypeal area distinguishes the new species from *Z. obamai* and *Z. wilsoni* Hita Garcia. From *Z. sarowiwai,* the new species is diagnosed by the irregular occipital margin of the former. With the sole Asian species *Z. siamensis*, the new taxon Z. *sahyadriensis* shares the median clypeal tooth and the regular occipital margins; but the new species is easily distinguished by the black integumental coloration (brown on *Z. siamensis*) and the sparsely punctate head sculpture (densely foveolate on *Z. siamensis*).

Key to Afrotropical-Indomalayan species of *Zasphinctus* Wheeler, 1918 based on worker caste (modified from Hita Garcia et al. **2017).**

Note: *Z. rufiventris* (Santschi, 1915) and *Z. chariensis* (Santschi, 1915) are known from males only.

1) With head in full-face view, median clypeal area with conspicuous tooth 2
- With head in full-face view, median clypeal area without a conspicuous tooth 4

2) Occipital margin regular (Image 8B) 3
- Occipital margin irregular .... *Z. sarowiwai* Hita Garcia, 2017

3) Sculpture of head sparsely punctate (Image 8D) ..... ***Z. sahyadriensis* sp. nov.**
- Sculpture of head densely foveolate .... *Z. siamensis* (Jaitrong, 2016)

4) With head in full-face view, parafrontal ridges with irregularly shaped dorsal outline petiolar tergum in profile relatively lower, 1.2 times longer than high (LPI 117–123) .... *Z. obamai* Hita Garcia, 2017
- With head in full-face view, parafrontal ridges with regularly shaped dorsal outline; petiolar tergum in profile relatively higher, 1.1 times longer than high (LPI 112) .... *Z. wilsoni* Hita Garcia, 2017

Genus *Vollenhovia* Mayr, 1865

Description of worker caste

Based on Bolton (2003), Eguchi et al. (2011) and Ward et al. (2015), monomorphic myrmicine ants of tribe Crematogastrini Forel, 1893; head in full-face view subrectangular; frontal carina and antennal scrobe absent; median portion of clypeus raised, laterally margined with a slight to conspicuous longitudinal carina; anteromedian portion often forming a transverse strip; an isolated median seta absent; posteromedian portion relatively narrowly inserted between frontal lobes; lateral portion of clypeus never modified into a distinct ridge or wall in front of antennal insertion; mandible triangular; masticatory margin with six or more teeth; antennae 12-segmented, with 3-segmented club; eye present; mesosoma in lateral view long and low; promesonotum in lateral view usually not domed; promesonotal suture absent dorsally; metanotal groove weakly to slightly impressed dorsally; posterodorsal portion of propodeum with rounded corners; propodeal lobe present as low lamella; petiole nodiform; anterior peduncle short and obscure; posterodorsal margin of petiole produced posterodorsad as a rim which is distinctly higher than the dorsal outline of helcium of petiole; subpetiolar process developed as a large lamella; gastral shoulder absent.

***Vollenhovia keralensis* Kripakaran & Sadasivan sp. nov.**

(Images 12A–C)

urn:lsid:zoobank.org:act:3D7B8E5C-DD40-4396-83E3-30E6944DC46C

Material Examined

Holotype: NRC-AA-3762, 23 March 2011, Worker, Bonaccord, Peppara Wildlife Sanctuary, Trivandrum District, Kerala State, India, at 900 m, coll. Manoj Kripakaran, from under the bark of a dead and fallen tree in a primary evergreen forest, deposited in the insect collection facility of the NCBS (National Centre for Biological Sciences), Tata Institute of Fundamental Research, GKVK, Bellary Road, Bengaluru, Karnataka 560065, India. Earlier, the holotype was with number TARG-1015, mounted for study and preserved in absolute ethanol, currently deposited in the research collections facility at the TNHS, Thiruvananthapuram, Kerala.

Measurements: HL 0.86, HW 0.81, SL 0.51, EL 0.14, Clypeal groove 0.36, DML 1.01, PW 0.52, PeL 0.31, PeW 0.23, PeH 0.30, A3L 0.30, A3W 0.27, A3H including the ventral tubercle 0.24, GL 1.14, Subpetiolar process H 0.10, TL 3.62, CI 94.19, SI 62.96.

Head: Head length and width almost equal, subquadrate (CI 94.19), vertexal margin with mild depression medially (Image 12C); mandibles with eight teeth: a well-developed basal tooth, and masticatory margin of mandibles with large apical and pre-apical teeth followed by six teeth, gradually decreasing in size towards the base of the mandible; anteroclypeal margin convex, with a single median tooth; antennae 12-segmented with inconspicuous three-segmented club; eyes large, placed just below the middle of side margin of head (Images 12A). Lateral head margin weakly convex.

Mesosoma: Pronotum slightly convex in lateral view, mesonotum flat and sloping toward propodeal declivity, promesonotal suture indistinct; metanotal groove distinct and impressed (Images 12A–B); propodeal dorsum convex, posterodorsal corners rounded and unarmed, propodeal lobes developed.

Petiole: In lateral view, the dorsal margin convex, node longer than wide, posterodorsal margin angulate; subpetiolar process well-developed, its free lower edge rounded; on ventral view it diverges in the middle-third and then gently slopes to merge with the petiole at the junction of middle and distal third of the ventral margin of petiole. Subpetiolar process lamellar wall distinctly longer than high.

Postpetiole: in lateral view, slightly longer than high, dorsal margin convex; in dorsal view, almost spherical; in profile; a well-developed rounded process present on its ventrum almost occupying the anterior half.

Gaster: In profile, elliptical, dorsoventrally flat. Sting present, small (Images 12A).

Color, Sculpture and Pilosity: Blackish-brown head and body, gaster shiny blackish-brown. Mandible, antennae and legs brownish (Images 12A–C). Whole body foveolate except the median polished area on the anterior part of mesosoma, dorsolateral aspect of vertex, inferior half of propodeal declivity, the anterior aspect and anterior half of the mid-dorsum of the petiole. Gaster finely punctate, mostly by piligerous punctae, more abundantly on the anterior half of the tergite and across the sternite of the first gastral segment. The distal margin of the tergum and sternum of the first gastral segment reticulate. Surface of the other gastral segments finely reticular on both sides. Body is covered in sparse semierect hairs, brownish white and seen on entire head, body and gaster including petiole and postpetiole. Hairs are absent on the lateral aspect of the mesonotum and propodeum. Few long hairs on the lateral margin of the clypeus, a pair of such hairs on each side much longer and prominent. Distal aspect of gaster near the sting bears some long erect hairs. About 15 vertical rows of piligerous foveolae between the anterior

Image 12. *Vollenhovia keralensis* sp. nov. holotype NRC-AA-3762: A—lateral view | B—dorsal view | C—full-face view. © Manoj K.

margin of the eyes and the midline of the head in full-face view. Opening of metapleural gland guarded by two stout filiform hairs, directed anterodorsally.

Additional Material Examined

Paratype workers (n = 3) (Images 13–15): NRC-AA-3763, 28 March 2021, Worker, Vallakadavu, Periyar Tiger Reserve, Idukky District, Kerala State, India, at 935 m, coll. Kalesh Sadasivan under the bark of a dead and fallen tree in a primary evergreen forest, deposited in the insect collection facility of the NCBS (National Centre for Biological Sciences), Tata Institute of Fundamental Research, GKVK, Bellary Road, Bengaluru, Karnataka 560065, India. Earlier the paratype was with number TARG-1016, in absolute ethanol, currently deposited in the research collections facility at the TNHS, Thiruvananthapuram, Kerala.

Two other paratype workers both with same data as paratype above. TARG-1017 and TARG-1018 to be deposited in the insect collection of the ZSI, Kozhikode, Kerala.

Measurements: HL 0.84–0.86 , HW 0.79–0.81, SL 0.49–0.51, EL 0.14, Clypeal groove 0.35– 0.36, DML 1.00–1.02, PW 0.51–0.53, PeL 0.29–0.31, PeW 0.22–0.24, PeH 0.30 –0.31, A3L 0.28–0.30, A3W 0.27, A3H including the ventral tubercle 0.23–0.25, GL 1.12– 1.016, Subpetiolar

Image 13. *Vollenhovia keralensis* sp. nov. gyne and male: A—lateral view of gyne | B—lateral view of male | C—full-face view of gyne | D—full-face view of male. © Kalesh Sadasivan.

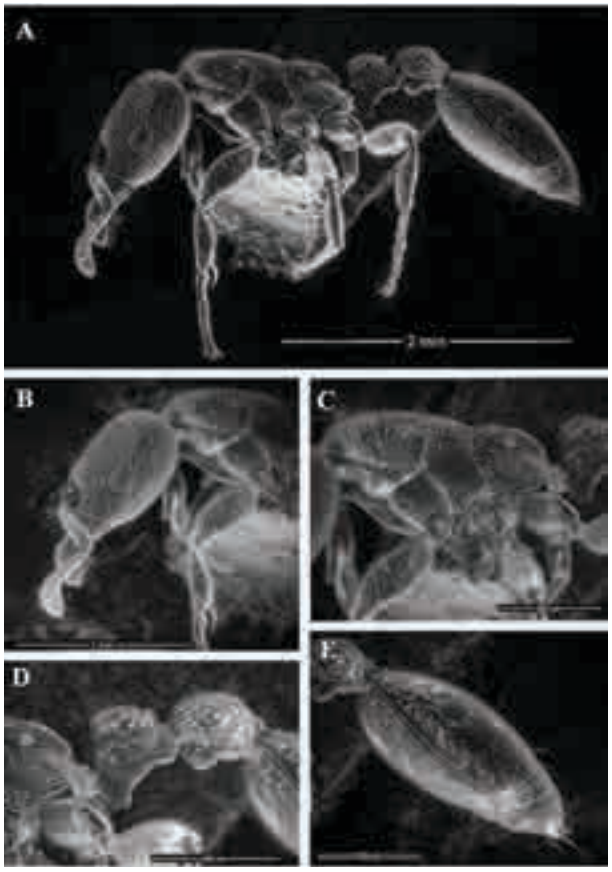

Image 14. *Vollenhovia keralensis* sp. nov. Scanning electron images of a paratype from TARG collection of the same colony as the holotype: A—lateral view | B—head lateral view | C—lateral view of mesosoma | D—lateral close-up view of petiole and postpetiole | E—lateral view of gaster.

process: H 0.08–0.12. TL 3.53–3.65, CI 94.04–94.18, SI 62.03–62.96.

Variation in workers: Some variation was noted in the body measurements (see above) and surface sculpture. The shiny mid-dorsal area on mesosoma was variable amongst the workers of the same colony. The variation ranged from the polished surface extending across the whole dorsum of mesosoma to the propodeum (Image 15A), to highly reduced to the anterior portion of the pronotum (Image 12B).

Gyne (Images 13A,C, 15D,F)

Measurements (n = 1). HL 0.94, HW 0.90, SL 0.54, Clypeus groove: 0.53, EL 0.21, DML 1.52, PW 0.78, PeL 0.38, PeW 0.32, PeH 0.45 (including the subpetiolar process), A3L 0.46, A3W 0.38, A3H 0.32, GL 1.52, Subpetiolar process H 0.20, TL 4.81, CI 95.74, SI 60.00.

Head blackish-brown, shaped similar to the worker, mandible with eight teeth, antennae 12-segmented. Antennal club not distinct from rest of the antennae. Ocelli present. Mesosoma blackish brown, shaped as in the worker except for the wing sockets. On lateral view, mesoscutum almost flat at the same level as the rest of the thorax. Parapsidal lines running longitudinally extending to almost half of the mesoscutum (Image 15f). Promesonotal and mesometanotal sutures distinct. Inferior half of the anepisternum and the superior higher portion of the katepisternum smooth (Image 15D). Mesoscutellum gently sloping towards the metanotum. Petiole and postpetiole same as worker, with well-developed subpetiolar process. Gaster shiny black, otherwise same as worker. Sculpture of head, mesosoma and first gastral tergite punctate, other gastral tergites finely reticulate. Body covered in sparse semierect hairs, brownish white in color throughout the entire body, including petiole and postpetiole (Images 15D,F).

Male (Images 13B,D)

Measurements (n = 1). HL 0.61, HW 0.65, SL 0.12, EL 0.22, Clypeal groove: 0.16, DML 1.20, PW 0.65, PeL 0.30, PeW 0.21, PeH 0.18, A3L 0.26, A3W 0.23, A3H 0.22 including tubercle, GL 1.10, TL 3.47, CI 1.06, SI 17.98.

Smaller than conspecific female castes. Head blackish-brown, wider than long, eyes large and occupying the lower half of the lateral head margin. Three large ocelli present. Mandibles highly reduced, masticatory margin toothless. Antennae 12-segmented, scape short, almost

equal to other segments of the antennae (Images 13B,D). Frontal margins subparallel, extending from the lower median ocelli downwards. Vertexal margin straight. In lateral view, mesosomal dorsum convex. Propodeal declivity less pronounced than in the workers. Subpetiolar process absent. Postpetiole lacking ventral tubercles. Body shiny (especially gaster) and generally finely punctate. Pilosity sparse, whole body covered by semierect whitish hairs and longer brownish hairs (Image 13B).

Etymology: The specific epithet *keralensis* is feminine, and refers to the state of Kerala, in southern India, where the species was discovered.

Ecological Notes: The species is currently only known from Agasthyamalais and Periyar Tiger Reserve in the southern Western Ghats of Peninsular India. This species was collected in tropical evergreen forests and mixed forests, ranging from 500–1,200 m. In the west coast tropical evergreen forest, habitat was characterized by *Myristica* (Myristicaceae) swamp forests and southern sub-tropical hill forests in the southern Western Ghats. Ants were observed moving on fallen tree trunks in shaded regions (Image 16A). On further investigation, the colonies were located inside crevices and under the bark of dead tree trunks. Upon disturbance, workers would disappear into tiny holes and crevices in the dead wood. One full colony was found at 800 m in Agasthyamalai had 52 workers, 20 males, 10 alate gynes, larvae and pupae in various stages of development. Occasionally, solitary gynes were observed under tree bark. No evidence of parasitic behaviour was noticed during our observation, although this needs detailed investigation. Workers were observed preying on beetle larvae and small arthropods nesting on tree bark, dead wood, and bracket fungi (Image 16B).

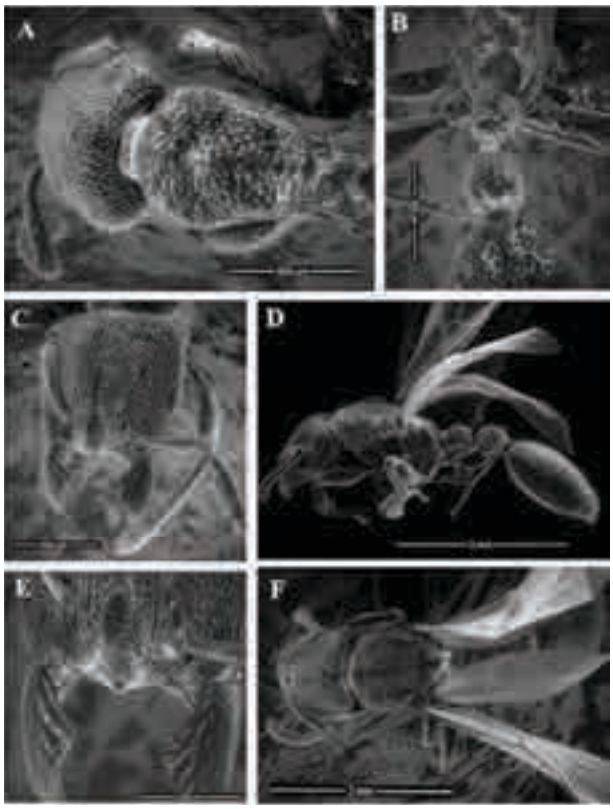

Image 15. *Vollenhovia keralensis* sp. nov. Scanning electron images of paratype worker (A–C &E) and gyne (D&F) in TARG collection: A—dorsal close-up of head and cervix and mesosoma | B— dorsum of petiole and postpetiole | C—head in latero-frontal | D—dorsolateral view of gyne | E—view close-up of clypeus, highlighting anteromedial tooth | F—dorso-oblique view of mesosoma of gyne.

Diagnosis and Remarks

Based on descriptive and morphometric data on workers of *Vollenhovia* from Forel (1911, 1912), Bharti & Kumar (2013), and images of other related species from the AntWeb (2021) (see key below), we found that the workers of *Vollenhovia keralensis* can be distinguished from other *Vollenhovia* species reported for the Indian subcontinent and adjoining Indian Ocean Islands by the following combination of characters: body size (TL 3.53–3.65 mm); convex anterior clypeal margin with a single median tooth; masticatory margin of mandibles with eight teeth, increasing in size from base to apex, and a well-developed subpetiolar process. From *V. oblonga* subspecies (*V. oblonga alluaudi* Emery, 1894 from Seychelles and Andaman and Nicobar Islands, as well as *V. oblonga levithorax* Emery 1889 from Tenasserim hills of Indo-Malaysia), the new species is easily differentiated by having a single median tooth on the clypeal margin, feature absent on *V. oblonga* and its subspecies. *Vollenhovia keralensis* can be differentiated from *V. penetrans* (Smith, 1857) – only known from alate gynes (AntWeb 2021) – based on the petiole length (subequal in the former), and petiole height (higher than long). *Vollenhovia escherichi* Forel, 1911 from Sri Lanka can be easily differentiated from the new species based on its size (TL ≤2.1 mm) as per Forel (1911), and pale yellowish-brown integumental coloration. With *V. piroskae* Forel, 1912 (from Seychelles), *V. keralensis* shares the clypeus with a single median tooth, but the former can be distinguished by its smaller size (TL 2.2–2.4 mm) and mandible with 6–7 teeth while *V. keralensis* is larger (TL 3.53–3.65 mm) and worker having eight teeth on the mandible. *V. keralensis* is distinguished from the Himalayan *V. gastropunctata* by the workers of the former having masticatory margin with a large apical and preapical teeth and followed by five teeth of equal

Image 16. *Vollenhovia keralensis* sp. nov.: A—habitat at the type locality | B—foraging worker, searching bracket-fungus for beetle larva in a dead wood on forest floor. © Kalesh Sadasivan.

size, and body length (≤2.55 mm in *V. gastropunctata*). Additionally, the anterior margin of clypeus is convex with a single median tooth in *V. keralensis* which is concave in *V. gastropunctata*.

Key to *Vollenhovia* species of Indian subcontinent based on the worker caste

1) Comparatively small species (TL ≤2.1 mm); Head small HW less than 0.4 mm; color pale yellowish-brown ..... *V. escherichi* Forel, 1911
- Comparatively larger species (TL >2.1 mm); HW more than 0.5 mm; color dark brown to black 2

2) Anterior clypeal margin convex with a single median tooth 3
- Anterior clypeal margin concave with no such median tooth 4

3) Size smaller (TL <2.50 mm); mandible with 7 teeth or less..... *V. piroskae* Forel, 1912
- Size larger (TL >3.50 mm); mandible with 8 teeth ..... ***V. keralensis* sp. nov.**

4) Mandible with 6 teeth or less ..... *V. oblonga* (Smith, 1860) and its subspecies
- Mandible with 7 teeth .... *V. gastropunctata* Bharti & Kumar, 2013

DISCUSSION

The report of the three new generic records from the Western Ghats region of peninsular India presents interesting observations on ant biogeography of the Indian region.

The new *Proceratium* species is a hypogaeic denizen of wet tropical rainforests at mid-elevation (900–1,200 m). The nearest record of the genus *Proceratium* in the Indo-Malayan region is Meghalaya in India and Bhutan, and in the Afrotropical region from Mauritius, Madagascar and mainland Africa. The discovery of the new species of *Proceratium* in peninsular India provides support to vicariant speciation of its ancestors from Gondwana into mainland Africa, Malagasy region and Indian subcontinent. There are similar examples of such evolutionarily intriguing distributions of Gondwanan hypogaeic lifeforms between Africa, Malagasy, and Kerala state in Western Ghats. The fossorial amphibian *Nasikabatrachus sahyadriensis* Biju & Bossuyt, 2003 from the family Nasikabatrachidae in Kerala is related to Sooglossidae, an amphibian family found only in the Seychelles archipelago (Zachariah et al. 2012). Other examples are found in subterranean freshwater cave fishes of the genus *Horaglanis* Menon, 1950 (Clariidae) which are related to *Uegitglanis* Gianferrari, 1923 (Uegitglanididae) from Somalia (Menon 1951; Silas 2010), and decapod crustaceans of the genus *Eurindicus* De Grave, Arjun & Raghavan, 2018 (Euryrhynchidae) which are related to three west African species (De Grave et al. 2018).

The nearest distribution range of *Zasphinctus* is mainland Africa on the west and Thailand on the east. The absence of the genus from middle east Asia (AntWeb, 2021), Madagascar (Fisher 1996), Mauritius, Reunion, and Seychelles is interesting, although may also be due to collection bias or regional extinction. Most species of *Zasphinctus* are recorded from the Australasian region (AntWeb 2021), with one species recorded from Thailand (Jaitrong 2016). The known distribution of *Zasphinctus* aligns with the tectonics of the region, as Africa and India were in close contact after the Indian plate separated from Madagascar-

Seychelles about 65 mya (Briggs 2003), while the Indian plate had already come into contact with the Eurasian plate (55–65 mya). During the northward migration of India, its land mass maintained close contact with mainland Africa. Since the epicentre of speciation of *Zasphinctus* seems to be the Australasian region, the ancestor of this genus might have reached Africa via the Indian plate. This highlights the fact that the depiction of India as a completely isolated island in the Cretaceous is erroneous (Briggs 2003) and the question raised by Fisher (1996) with respect to the absence of a significant number of endemic taxa in India. Thus, *Zasphinctus*, is a good myrmecological example of east to west faunal dispersal to Africa through India in the late Cretaceous.

The known representatives of genus *Vollenhovia* from the Indian region were from the Himalayas, Burma, rest of the Indo-Malayan region in southeastern Asia, and the associated islands in the Bay of Bengal. The subspecies *V. oblonga levithorax* Emery 1889 is known from the Tenasserim hills of Indo-Malaysia (Bingham, 1903), and *V. oblonga alluaudi* Emery, 1894 is reported from the nearby Andaman & Nicobar Islands. For the Andaman & Nicobar Islands, there are also records of *V. penetrans* (Smith, 1857) as per Bharti (2016) and AntWeb (2021). Sri Lanka has one endemic species – *Vollenhovia escherichi* Forel, 1911, with the remaining members of this genus distributed in the Southeast Asian region and Australasia and further into the Americas (AntWeb 2021). The genus is currently thought to be absent in mainland Africa, Mauritius, and Reunion. Interestingly, the Seychelles Islands in the Malagasy bioregion has two taxa, *V. oblonga* Emery, 1894 (subspecies *alluaudi*) and *V. piroskae* Forel, 1912. Both these species are represented in the Australasian, Oceania, and Andamans in Malayan bioregions, but curiously absent from peninsular India as far as known, even though the latter is closer to the Malagasy region. This presents an interesting mode of distribution as explained below. The ancestors of *Vollenhovia* must have reached the Indian peninsula after its separation from mainland Africa in the Paleogene. By this time, Africa and Seychelles were probably completely separated from the northward-moving Indian plate (Briggs 2003). It may seem plausible that the colonisation of Seychelles might be a recent event for *V. piroskae*, but the other taxon probably colonized much earlier and had sufficient time to evolve as subspecies (*V. o. alluaudi),* and hence are not recent introductions. This biogeographical scenario can probably be a result of a dispersal event from Australasian and Oceania bioregions across the Indian Ocean, rather than by vicariance from Gondwana, as evidenced by their absence in mainland Africa. The mode of arboreal life and lignicolous nesting in dead logs might offer a clue for the survival of colonies and queens along dispersal across the open seas (Brown 1973; Fisher 1996). The dispersal events could be initiated by cyclones of Bay of Bengal and fuelled by the oceanic currents, an example of the latter is the south equatorial current of the Indian Ocean, that run between the Indo-Malayan region and Seychelles (Tomczak & Stuart 2003).

In conclusion, the new distribution records of the three genus add interesting observations on biogeographic origins of ants for the Indian region. The genus *Proceratium* is a good candidate for a vicariance model of speciation from Gondwana into the Indian plate. *Zasphinctus* adds to the body of evidence of linking Africa to mainland Asia by the Indian plate during late Cretaceous. Finally, *Vollenhovia* is a good example of east-to-west faunal dispersal from Malayan bioregion to Western Ghats of India in the Paleogene, in similarity to other ant genera with an Indomalayan distribution like *Tyrannomyrmex* Fernández, 2003 and *Indomyrma* Brown, 1986 (Zryanin 2012). The addition of these new taxa to the building body of molecular phylogenies could provide interesting avenues for future biogeographic analyses.

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COMMUNICATION

New queen? Evidence of a long-living Jaguar *Panthera onca* (Mammalia: Carnivora: Felidae) in Tikal National Park, Guatemala

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Abstract: Despite the abundant literature on the Jaguar *Panthera onca*, several aspects of its natural history and ecology such as longevity and residency of wild individuals are still little studied and poorly known. We conducted a camera trapping study in Tikal National Park, Guatemala, during the dry season and early rainy season from April to July 2018. We compared our results with results of previous studies and thereby came across a presumably female adult individual that was recorded in 2009 and again during our survey. We therefore assume that this virtual female is a potential long-term resident Jaguar in this core zone of the Selva Maya, one of the largest and well-conserved forests in the Neotropics and a priority area for the conservation of this species. We recommend implementing systematic and long-termed studies in Guatemala as a tool for the evaluation and management of the species, and to monitor the effectiveness of protected and priority areas in order to ensure the conservation of the Jaguar.

Keywords: Longevity, Maya Biosphere Reserve, protected areas management, residency, Selva Maya, wildlife management.

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INTRODUCTION

The majestic Selva Maya is the largest tropical forest remnant in Central America and is shared between joint areas in northern Guatemala, southern Mexico, and north-western Belize (Hansen et al. 2013). Selva Maya includes different types of area management and administration in each country. In Guatemala and Mexico, a great section includes multiple-use areas that are used by local communities to implement sustainable forestry (Radachowsky et al. 2012). Another section is restricted to protected areas purely for conservation (Radachowsky et al. 2012), such as national parks and protected biotopos as core zones within the Guatemalan side, national parks and biosphere reserves within Mexico, and wildlife sanctuaries within Belize. Maya Biosphere Reserve in Guatemala is a priority area for the conservation of the viable Selva Maya population of the threatened Jaguar *Panthera onca* and for habitat connectivity for wildlife between these countries (Sanderson et al. 2002).

Selva Maya is considered a Type I Jaguar Conservation Unit by the Wildlife Conservation Society, which indicates that it is of critical importance to Jaguar conservation (Marieb 2006). It is fundamental to implement long-term monitoring programs for Jaguar populations in such priority areas throughout their distribution, since this species has been categorized as "Near Threatened" on the IUCN Red List (Quigley et al. 2017). From the 34 recognized subpopulations of the Jaguar, only the Amazon Forest subpopulation is considered as "Least Concern", while the remaining are considered Endangered or Critically Endangered (de la Torre et al. 2017). Because of this, long-term studies are necessary to detect and respond to changes in Jaguar populations to monitor the effectiveness of protected and priority areas for its conservation, and develop strategies under alternative scenarios for their conservation, enhancing management efforts. They are also important to mitigate threats such as human-Jaguar interactions and to assess and update population status of the Jaguar in currently recognized subpopulations (Clutton-Brock et al. 2010; de la Torre et al. 2017; Harmsen et al. 2017).

Monitoring protocols have been applied for several sites for studying Jaguar populations (Silver 2004; Ceballos et al. 2011; Harmsen et al. 2017). However, most surveys are short-termed (Foster & Harmsen 2012), and long-termed studies quite scarce (Gutiérrez-González et al. 2015; Harmsen et al. 2017). Long-term monitoring studies help to ensure the effectiveness of protected areas and allows conservationists to assess the viability for Jaguar populations through life-history parameters such as survival and mortality of individuals, longevity, sex ratio, home ranges, and residency (McCain & Childs 2008; Watkins et al. 2014; Gutiérrez-González et al. 2015; Zanin et al. 2015; de la Torre et al. 2017; Olson et al. 2019a,b).

Furthermore, in wide-ranging, low-density, and long-lived species like the Jaguar, high variations in population density and abundance estimates are expected in repeated surveys over several years (Harmsen et al. 2017). This is because transient individuals are likely to be detected less often than resident individuals in single survey sites, as they may range foremost outside respective survey sites or may avoid trails used by resident individuals (Harmsen et al. 2017).

In Maya Biosphere Reserve, no continuous long-term monitoring studies targeting the Jaguar have been carried out within specific management areas, but sporadic and short-term studies implemented independently by different administrators and actors in the reserve (Kawanishi 1995; Moreira et al. 2008, 2009, 2010; García-Anleu et al. 2015; González-Castillo et al. 2018; García et al. 2019). In addition, most of these studies' results remain unpublished or grey literature. Because Maya Biosphere Reserve is an important international conservation area for the Jaguar, we report evidence of a long-living Jaguar individual in Tikal National Park, based on independent surveys. This communication represents an input for the management and assessment of the reserve and help to better understand the ecology of long-living Jaguars within the management type of areas where occur.

STUDY AREA

Maya Biosphere Reserve, in northern Guatemala, represents the largest continuous forest patch and protected area complex in Central America, stretching over more than 2,110km^2 in area (Radachowsky et al. 2012). Its administrative division comprises the buffer zone, the multiple use zone, and many core zones such as national parks and protected biotopos (CONAP 2015). Tikal National Park comprises 575.83km^2 and is one of the first core zones declared even before the declaration of the Maya Biosphere Reserve by the Guatemalan government in 1990 (CONAP 2015). Tikal National Park borders the Buffer Zone to the south, El Zotz Protected Biotopo to the west, Yaxhá National Park to the east and the Multiple Use Zone in the north (Figure 1). According to Guatemalan legislation, category 1 protected areas

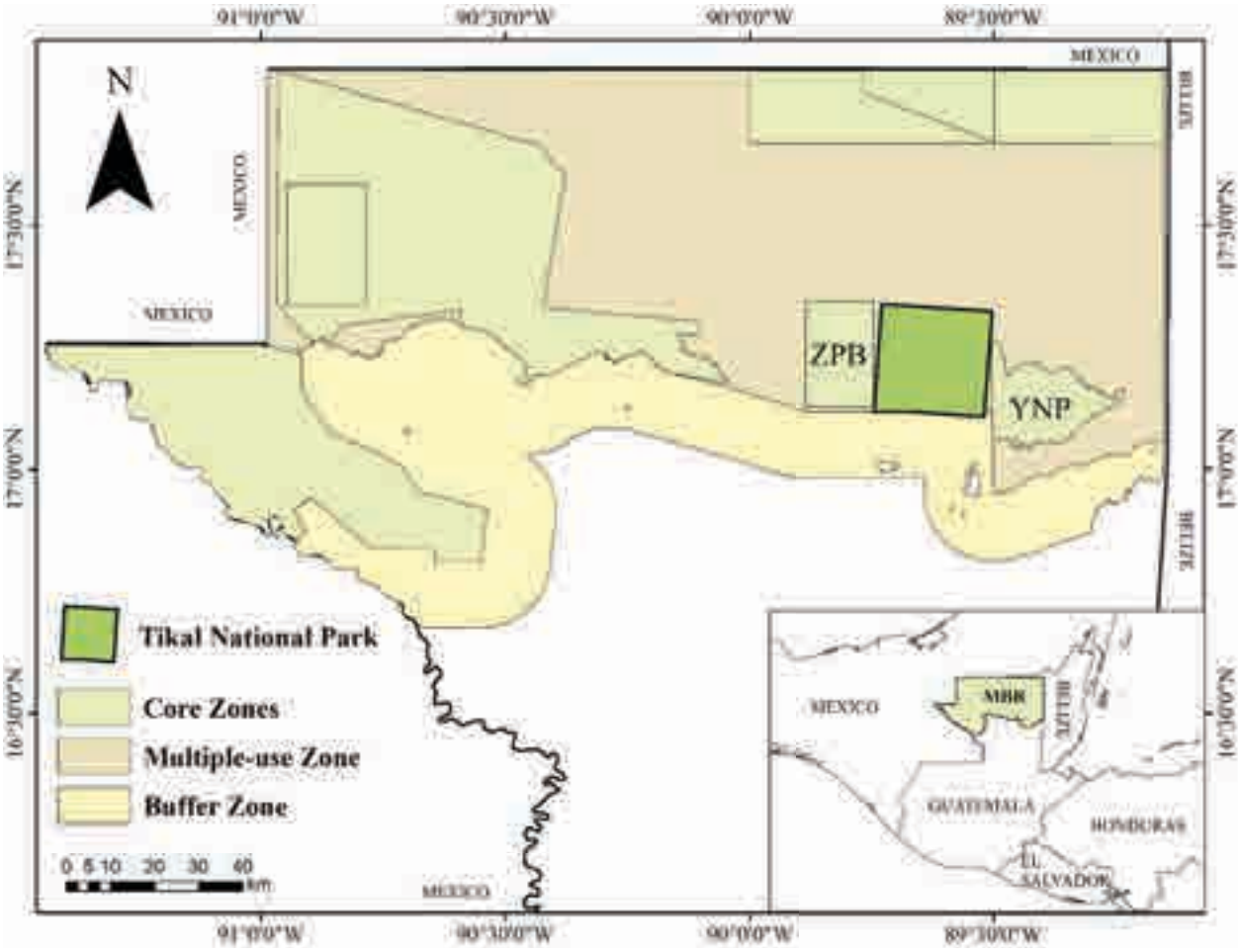

Figure 1. Location of Tikal National Park and management area types within Maya Biosphere Reserve in Guatemala, Central America. ZPB: El Zotz Protected Biotopo; YNP: Yaxhá National Park.

such as core zones are intended exclusively for scientific research and for low-impact tourism, and most resulting in areas with minimal human impact (CONAP 2015).

However, because of the international fame of Tikal National Park as an iconic archaeological site and as a cultural World Heritage Monument with a high incidence of tourism activities (Cleere 1995), important ecological changes have been detected as low detectability of highly mobile species such as Baird's Tapir *Tapirella bairdii*, White-lipped Peccary *Tayassu pecari*, Collared Peccary *Pecari tajacu* and Jaguar (García et al. 2019; McNab et al. 2019).

Tikal National Park and Maya Biosphere Reserve comprise low-land at elevations of 307–630 m with karstic and permeable soils, whereas the lower areas of the forest have the highest percentage of clayey soil and less permeability. These conditions favour the formation of water ponds that store rainwater during rainy season and become main bodies of water during dry season, playing an ecological importance for interaction of individual Jaguars (García et al. 2018; Gaitán et al. 2021).

The climate is tropical with temperatures ranging from 20°C to 30°C with an annual average of 25°C and an annual precipitation of 1,160 to 1,700 mm with seasonal variations (CECON 1996). During rainy seasons in winter from June to December, the water bodies and the lower parts are flooded due to a monthly precipitation of 150mm. During the dry season from February to May, the area receives little to no rain, especially during the climatic event "El Niño", and the water resource is limited for wildlife, as well as for administrators and visitors to the area.

MATERIAL AND METHODS

During the dry season and early rainy season from April to July 2018, the Centro de Estudios Conservacionistas

of the University of San Carlos of Guatemala (CECON/USAC) research team and the Biology Unit of Tikal National Park implemented a targeted sampling study for Baird's Tapir in different core zones of Maya Biosphere Reserve following the Guatemala Baird's Tapir Conservation Program of the CECON and Fundación Defensores de la Naturaleza (CECON & Defensores de la Naturaleza 2016). We installed sampling stations using Bushnell Trophycam 8M camera traps providing a photo resolution of 8 Megapixels, which were set to taking three photos per capture event with a 15 second interval between photographs (García et al. 2019). One sampling station consisted of one single camera trap per 9km^2 large cell, deployed at approximately 40cm above ground and affixed to trees (García et al. 2019).

We compared rosette patterns of recorded Jaguar individuals with photographs of individuals from previous studies in Tikal National Park and other areas within Maya Biosphere Reserve (Table 1; Karanth & Nichols 1998; Wallace et al. 2003; Silver et al. 2004; Moreira et al. 2008, 2009, 2010; Ruano et al. 2010; García-Anleu et al. 2015).

RESULTS

Our survey lasted from 4 April to 26 July 2018 with a total survey effort of 540 camera trap days in six locations. We obtained 10 photographs of right flanks of two Jaguar individuals entering a pond from one single camera trap station (16.7%) placed near one of the few river flows in Tikal National Park (Figure 2 and Image 1).

DISCUSSION

One of the two Jaguar individuals photographed during our survey was previously recorded during a 2-week survey from September and October 2009 by Ruano et al. (2010) as a sub-adult individual around 1–2 years old (Image 1). We therefore consider this individual as a potential long-term resident Jaguar in Tikal National Park since it would be 10–11 years old in 2018 and we called it "Unen B'alam". Rosette patterns on the right upper and lower flanks can be confirmed to belong to the same individual by comparing the most conspicuous horizontal small linear rosette surrounded by four major rosettes in a cross-like arrangement (Image 1). The sampling station in which Unen B'alam was recorded in 2018 is located 11.25km from the sampling station in which it was first recorded in 2009 (Ruano et al. 2010; Figure 2, Image 1).

This photographic record of the long-lived Jaguar Unen B'alam represents the longest-lived Jaguar record in the wild to date within Maya Biosphere Reserve and Guatemala. Jaguars are considered to be sub-adult at the minimum age of 15 months to two years (Seymour 1989; Sunquist & Sunquist 2002; Nowak 2005). We estimate that Unen B'alam was in this age group of 1–2 years old when first recorded, so in 2018, it was at least 10–11 years old.

García-Anleu et al. (2015) recorded an adult female named "Rosario, the Queen of Tikal" in Tikal National Park that was recorded again five years later from its first record. Olson et al. (2019a) collated records of long-lived wild Jaguars and reported 15 individuals that lived for more than 11 years. Due to interaction of Jaguars among conspecifics occurring only during reproductive and cub

Table 1. Details of individual Jaguars recorded during camera trapping surveys in Tikal National Park and other areas within Maya Biosphere Reserve, Guatemala. NP: National Park; LC: Logging concession; F: Female, M: Male, U: Unknown sex, * Unen B'alam.

Area surveyed	Sampling stations	Survey effort (camera trap days)	Individuals recorded				Reference
			Total	F	M	U	
Tikal NP	18	574	1			1	Kawanishi (1995)
Tikal NP	19	510	7	1	3	3	García et al. (2006)
Tikal NP	25	384	7	1	5	1*	Ruano et al. (2010); García-Anleu et al. (2015)
Tikal NP	9	630	1		1		García et al. (2019)
Tikal NP	6	540	2			1, 1*	This study
Carmelita LC	20	900	10	3	7		Moreira et al. (2008)
Laguna del Tigre NP	24	1,127	9	4	5		Moreira et al. (2009)
Melchor de Mencos LC	23	1,035	9	4	4	1	Moreira et al. (2010)

Figure 2. Camera trap locations of records of long-living Jaguar Unen B'alam in Tikal National Park, Maya Biosphere Reserve, Guatemala. Red circle corresponds to the camera station installed in 2009 by WCS Guatemala (Ruano et al. 2010). Yellow star corresponds to the camera station installed by CECON/USAC in 2018. Distance between both camera trap sampling stations: 11.25 km. Brown line: road; blue line: rivers.

raising periods (Jorge-Neto et al. 2018), we suggest that both individuals recorded in Tikal National Park in 2018 are either a reproductive couple or a mother female with a cub. As our photographs indicate that Unen B'alam is accompanied (followed) by a supposedly male Jaguar, it is presumably a mature female, and due to its behaviour was similar to Rosario's reported by García-Anleu et al. (Rosario being followed by an adult male; 2015).

In view of other records of long-lived wild Jaguars, the estimated life span for this species is of 11.3 ± 1.0 years for females, with the oldest known female reaching 13 years (Olson et al. 2019a). Unen B'alam would represent a relatively old female Jaguar and represents a record between the longest-lived wild Jaguars throughout all the species range (Olson et al. 2019a; b). When compared this record with similar-aged and older long-lived wild Jaguars reported in the literature for Argentina, Belize, Brazil, Costa Rica, United States and Venezuela (Scognamillo et al. 2003; McCain & Childs 2008; Rabinowitz 2014; Harmsen et al. 2017; Glennie et al. 2019; Olson et al. 2019a,b), Unen B'alam's age would suit to this kind of analysis.

Long-term studies on Jaguars have demonstrated that populations consist of resident and transient Jaguar individuals in Belize within the Selva Maya (Harmsen et al. 2017). This could be the case too for the Jaguar population of Tikal National Park, since Rosario, the Queen of Tikal (García-Anleu et al. 2015) and Unen B'alam are the only two individuals (11.8 % of at least 17 individuals recorded; Table 1) that have been spoted as potential residents in the medium and in the long-term within Maya Biosphere Reserve in Guatemala. In addition, since resident Jaguars must be recorded for at least three consecutive years in a row (Harmsen et al. 2017), we are highlighting Unen B'alam as potential resident by lacking complementary data. None of the other individuals recorded in 1994, 2005, 2009 and 2018 in Tikal National Park have been recorded repeatedly

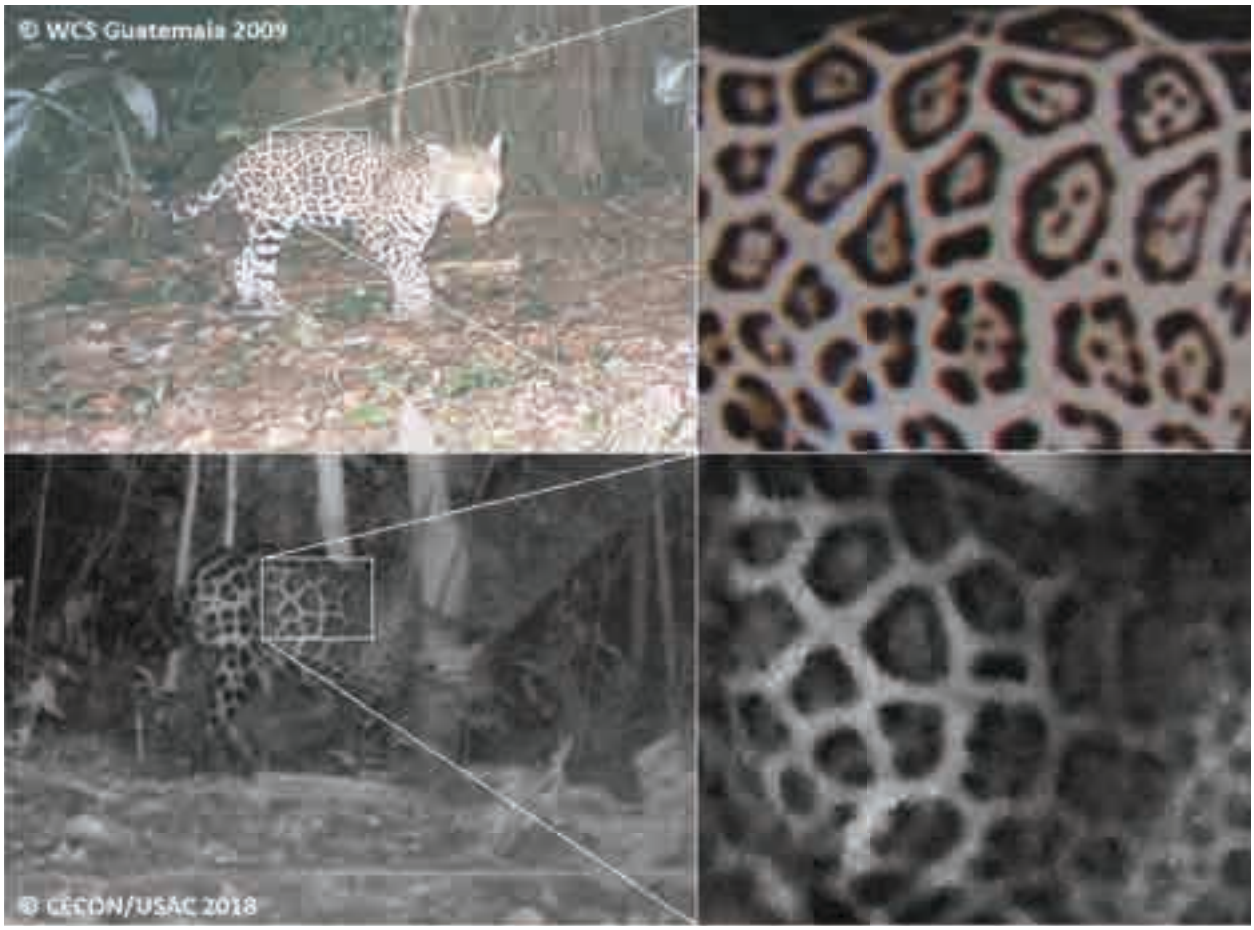

Image 1. Rosettes pattern on long-living Jaguar Unen B'alam photographed in 2009 (upper left; Ruano et al. 2010) and in 2018 (lower left; this study) in Tikal National Park, Maya Biosphere Reserve, Guatemala.

(Table 1; Kawanishi 1995; García et al. 2006; Moreira et al. 2008, 2009, 2010; Ruano et al. 2010; García-Anleu et al. 2015; García et al. 2019).

Female Jaguars tend to exhibit higher fidelity to their home range than males (Rabinowitz & Nottingham 1986; Cavalcanti 2008). In Tikal National Park, long-term survey efforts are required to detect and identify resident Jaguars. The failure to detect resident male Jaguars during such surveys may indicate a high mobility or in the worst scenario high mortality of male Jaguars in Tikal National Park and in Maya Biosphere Reserve (Harmsen et al. 2017).

This record of a long-living adult Jaguar may indicate that both the habitat quality and prey availability for the Jaguar population in Tikal National Park has remained stable according to García-Anleu et al. (2015). However, this national park of Maya Biosphere Reserve is prone to anthropogenic disturbances due to its location near the Buffer Zone (García et al. 2020; Figure 1). We therefore agree with previous authors that the conservation status of the habitat needs to be evaluated (Morato et al. 2016; González-Gallina et al. 2017; García et al. 2019) as despite Tikal National Park remains with high forest cover but with possible low ecological integrity (García et al. 2019; 2020).

Due to the apparent increase in the number of male individuals over surveys (Table 1), it would be suggested that Tikal National Park is an area with a high male Jaguar home range overlap degree as García-Anleu et al. (2015) have suggested. We strongly recommend implementing a long-term survey in Tikal National Park targeting both Jaguar and prey populations. This information will provide the baseline data required for estimating and monitoring population changes in the different types of area management of Maya Biosphere Reserve such as core zones.

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COMMUNICATION

First camera trap record of Striped Hyena *Hyaena hyaena* (Linnaeus, 1758) (Mammalia: Carnivora: Hyaenidae) in Parsa National Park, Nepal

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Abstract: The Striped Hyena occurs in the Tarai and midhill regions of Nepal, where limited information is available on species distribution. A camera trap survey was conducted in Parsa National Park in 2016 (Feb–May) and 2016–2017 (Nov–Feb) to monitor tigers at 158 locations for 21 days (6,615 trap efforts in total). This study successfully captured the 15 hyena images in 5 grids of eastern part (named as extension area) of national park. A total of 17 mammal species were captured simultaneously in hyena captured grid during the survey period. The presence of hyenas in Parsa National Park indicates the collective efforts of the government, conservation organizations and local communities in hyena conservation. A detailed ecological study of this species has been recommended for designing hyena conservation plan in the region.

Keywords: Camera trap survey, conservation, distribution, extension area, grid, hyenas, mammal.

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Author contributions: PRR, MC, HA, NS & BL: conceptualize the study; PRR, PS, DA: conducted field survey, PRR, PS, DA: compiled and cleaning the data; PRR, MC: finalized the manuscript;MC, HA, NS & BL: supervised the study.

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INTRODUCTION

Striped Hyena *Hyaena hyaena* occupy a large geographic range that encompasses eastern Africa, central Asia, the Indian subcontinent, Turkey, and central Tanzania (Mills & Hofer 1998). Hyenas are solitary nocturnal scavengers, feeding on carcasses, dead remains, and waste produced by human communities (Yirga et al. 2014). They survive 10–12 years in the wild. Hyenas are recorded at up to 1,750 m in Nepal (Bhandari & Bhusal 2017) and 3,300 m in Pakistan (Alam et al. 2014). In Nepal, hyenas are distributed in the lowland areas (protected & outside of the protected areas) of the Tarai and midhill regions, and there are estimated to be fewer than 100 individuals in the wild (Jnawali et al. 2011).

Hyenas are a nationally protected priority species under the National Parks and Wildlife Conservation Act, 1973 and listed as Endangered in the National Red List Series (Jnawali et al. 2011). They are listed as the Near Threatened category in the IUCN Red List of Threatened Species, and believed to be fewer than 10,000 mature individuals worldwide (AbiSaid & Dloniak 2015). Their population is declining across its geographic range due to habitat alteration (Ripple et al. 2014) and facing various anthropogenic pressure, habitat loss & fragmentation, prey population depletion, poaching & illegal trade, retaliatory killing, and competition with other large carnivores species like tigers, and leopards (Inskip & Zimmermann 2009). Their historic and present range including their distribution, population, habitat, ecology, and diet preferences are little known due to limited study (Singh et al. 2010). Although, several national surveys for tigers and their prey base monitoring were conducted before 2015, there was no photographic evidence and scientific documentation of the presence of hyenas in the Parsa National Park (PNP). This article presents camera trap records of hyenas in PNP for the first time. Mammals associated with hyenas that were captured during the survey period are also discussed. It is hoped that this study will bring attention of the government and concerned conservation agencies to conduct further ecological studies of this important scavenger.

MATERIALS AND METHODS

Study Area

The study area in PNP (Figure 1) is located in the south-central lowland areas of the Tarai region (27.25–27.55 °N, 84.68–84.97 °E). It covers an area of 627.39 km^2 and is 188 km (south-west) from Kathmandu. The park covers three districts: Parsa (70%), Bara (18%), and Makwanpur (12%). Historically, Parsa served as a vacation and hunting site for the Rana Rulers of Nepal. It was established as a wildlife reserve in 1983 encompassing an area of 499 km^2 to protect the habitat of Asian Wild Elephants. In 2005, the Government of Nepal (GoN) declared the Buffer Zone area (285 km^2) around the reserve and implemented community-based conservation programs. The GoN extended the reserve area by 128 km^2 in 2015 in the eastern part (named as the extension area), highlighting that this forest area serves as an important habitat for globally threatened animals including tigers and rhinos. There have been past records of tigers, their cubs and other animals in camera trap monitoring conducted in the extension area (PNP 2020). In 2017, the reserve was gazetted as a national park to preserve and improve the habitat of wildlife and support landscape-level conservation. The PNP provides an extended habitat for the spill-over population of megafauna as it adjoins to Balmiki Tiger Reserve of Bihar state of India in the south and Chitwan National Park in the west.

The PNP harbors diverse animals including Bengal Tiger *Panthera tigris tigris*, Common Leopard *Panthera pardus*, Striped Hyena *Hyaena hyaena*, Dhole *Cuon alpinus,* Golden Jackal *Canis aureus,* Indian Fox *Vulpes bengalensis,* and Honey Badger *Mellivora capensis.* Wild herbivore prey species include Gaur *Bos gaurus gaurus,* Sambar *Rusa unicolor,* and Nilgai *Boselaphus tragocamelus,* Spotted Deer *Axis axis,* Barking Deer *Muntiacus vaginalis,* and Wild Pig *Sus scrofa.* Non-human primates include langur *Semnopithecus* sp. and Rhesus Monkey *Macaca mulatta.* 37 mammal species, 31 butterflies, 13 reptiles, and 490 birds were recorded in the park (PNP 2018). The forests of PNP and its buffer zones consist of 70% vegetation which is dominated by Sal *Shorea robusta* forest, and the vegetation can best be described as a subtropical, dry, deciduous forest with colonizing wild sugarcane *Saccharum spontaneum*, and Cogon Grass *Imperata cylindrica* on the dry riverbeds and the floodplains, to a climax Sal forest on Bhabhar and hillsides. In the Churia hills, Chir Pine *Pinus roxburghii* grows, and along the streams and river sides, Khair *Acacia catechu,* Sissoo *Dalbergia sissoo,* and Silk Cotton Tree *Bombax ceiba* occur. Sabai grass *Enlaliopsis binata,* a commercially important grass, grows well on the southern face of the churia hills. The elevation of the park ranges between 100–950 m and lies in a humid subtropical climatic zone with a record of the mean minimum temperature of 7°C to mean maximum

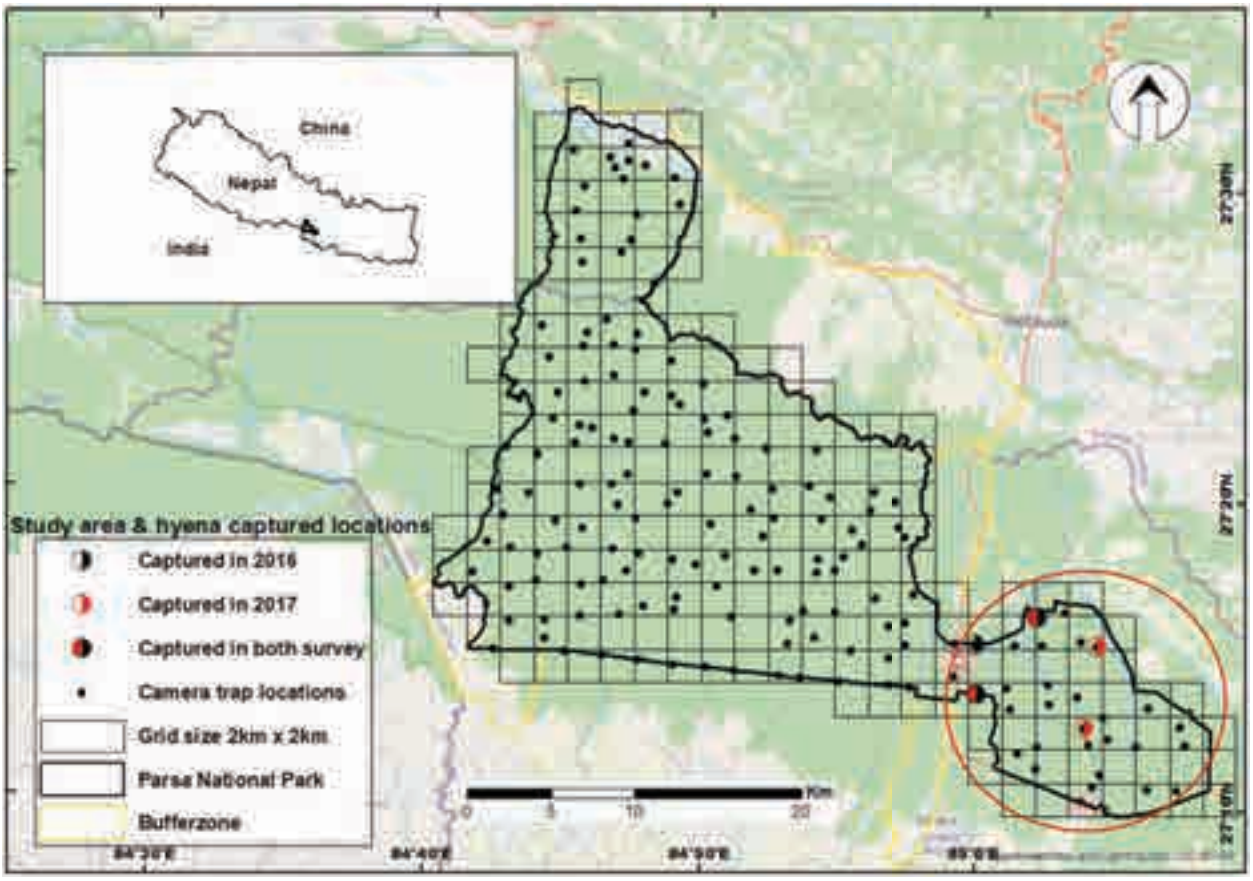

Figure 1. Survey grids with hyenas captured locations in multiple years in Parsa National Park, Nepal. The circle shown on the map is an extension area of the park.

temperature of 39°C; 83% of the total precipitation occurs mainly from June to September (PNP 2018).

Camera trap survey

Two camera trap surveys were carried out in PNP. The first was in 2016 (Survey I) and the second survey in 2016–2017 (Survey II). Both surveys covered the whole area of the national park, which was divided into three blocks. The camera trapping survey was conducted in three deployment phases to manage the availability of skilled manpower, camera number, financial constraints, and surveyed all blocks. We overlaid a total of 167 systematic grids 2 x 2 km in area. A pair of camera traps was placed on each systematic grid cell, set 4–6 m apart, 45–60 cm above the ground surface for 21 days. Wegge et al. (2004) recommended that a trapping duration at each set of camera traps (i.e., sampling occasion) should be at least 15 days (nights), with a distance between neighboring traps not exceeding 2 km. The cameras were operational and functional 24 hours of a day, and were monitored every 1–3 days of deployment to check their performance, battery status and photo capture, and to collect data of animal tracks and movements in the areas. Panthera V5 cameras were used in this study. The same method was used for both years. Images captured at an interval of 30 minutes were considered independent events (Silver et al. 2004; Thapa et al. 2014). The trapping rate was calculated by the number of independent images/total number of captured images per 100 trap nights (Karanth & Nichols 2002). We also examined associated species and discuss their presence.

RESULTS

A total of 158 and 157 cameras were functional in Survey I & Survey II, respectively. The total trap efforts were 3,318 in the first survey and 3,297 in the second survey. We obtained 15 images of hyenas from five grids (Survey I–III grids: 8 images, Survey II- 4 grids: 7 images) and captured four independent hyena images in two consecutive surveys (Image 1A,B). We obtained images of a hyena from the camera traps installed at the eastern part of the national park at Mahendra

Table 1. Hyena captured details in Parsa National Park, Nepal.

	Parameters	Survey period	
		2016 (Feb–May)	2016–2017 (Nov–Feb)
1	Total survey area	627.39 km^2	627.39 km^2
2	Camera trap location	158	157
3	Sampling occasion	21	21
4	Trap efforts	3318	3297
5	Hyena captured grids	3	4
6	Independent capture events	4	4
7	Capture rate/100 traps	0.120	0.121

Image 1. Striped Hyena captured on camera in Parsa National Park, Nepal: A—Right flank | B—Left flank.

Highway (Amlekhgunj Pathlaiya Section) and the newly extended area (Figure 1). The capture rate of hyenas was calculated at 0.120 and 0.121 per 100 trap nights in Surveys I and II, respectively (Table 1). We captured hyenas in camera traps located 1 to 1.5 km away from the nearest human settlement and water sources of the extension area (Table 2). Altogether, 17 mammal species were recorded in hyena capture grids during the two consecutive survey periods (Table 3).

DISCUSSION

We recorded the first photographic evidence of a Striped Hyena in Parsa National Park, Nepal. A recent paper which was based on a literature review also mentioned the presence of hyena in PNP (Neupane et al. 2021) but lacks photographic evidence. Camera trap monitoring of tigers and their prey in PNP during surveys conducted in 2009, 2013, and 2014, did not detect the presence of hyenas. In 2016 and 2017, we captured hyena images in grid at the eastern part (extension area) of PNP near human settlements and water sources (Table 2), consistent with other reports (Hofer 1998) that hyenas frequently forage on garbage and carrion near human habitations (Tourani et al. 2012; Alam et al. 2014; AbiSaid & Dloniak 2015). Similarly, hyenas choose disturbed/fringe habitats due to the availability of easy food sources (Singh et al. 2014). Halkhoriya Daha (lake) is the major water source of the extension area of PNP and supports various species of wildlife. The availability of water sources might have attracted hyenas in the area.

In PNP, the park authorities are conducting habitat management activities (e.g., grassland management, patrolling, fireline maintenance, pond construction) and enabling law enforcement (DNPWC & DFSC 2018) which may provide adequate food for the hyena. Such activities in the park might help hyenas and their associated species in recolonizing the area. Also, the northern part of PNP is contagious to the churia hills that encompass hilly terrain habitats and thus may provide optimal refuges and denning sites for hyenas. We recorded 17 mammal species in hyena image capture locations during two survey years (Table 3), with tiger and leopard being the major sympatric carnivores. Hyenas are directly or indirectly affected by decreasing natural food resources (Khorozyan et al. 2011), high competition, and increased anthropogenic pressure. The latest tiger monitoring reveals that the Tiger numbers in PNP are increasing (Lamichhane et al. 2018), which might push hyenas more into fringe areas in the future, although hyenas occur sympatrically with tigers in various parts of India (Harihar et al. 2010). Hyenas were not recorded in the camera traps deployed in the core areas of the western part of the national park. This might be due to inadequate water resources, preferred habitat and prey availability, and competition with carnivore species such as tigers and leopards. Hyenas are very susceptible to

Table 2. Hyena captured location details of Parsa National Park, Nepal.

Captured Grid ID	Captured year	Habitat type	Settlements distance (km)	Distance to water sources (km)
P16	2016	Sal forest	6.3 (Pathlaiya) 2.1(Amlekhgunj)	1
P17	2016 & 2016/2017	Sal forest	4.9 (Amlekhgunj) 3.6 (Pathlaiya)	0.5
R15	2016 & 2016/2017	Sal forest	3.6 (Dammarpur) 1.5 (Chakari)	0.5
S18	2016/17	Riverbed	4.93 (Piluwa) 4.76 (Ratanpuri)	0.1
T16	2016/17	Sal forest	2.6 (Dammarpur) 2.2 (Ratanpuri)	0.7

Table 3. Associated mammalian species recorded in hyena captured grid cells during the survey period.

			Survey period	
	Species name	Scientific name	2016 (Feb–May)	2016–2017 (Nov–Feb)
1	Four-horned Antelope	*Tetracerus quadricornis*	√	√
2	Barking Deer	*Muntiacus vaginalis*	√	√
3	Spotted Deer	*Axis axis*	√	√
4	Indian Hare	*Lepus nigricollis*	√	√
5	Wild Boar	*Sus scrofa*	√	√
6	Bengal Fox	*Vulpes bengalensis*	√	√
7	Golden Jackal	*Canis aureus*	X	√
8	Jungle Cat	*Felis chaus*	√	√
9	Leopard	*Panthera pardus*	√	√
10	Leopard Cat	*Prionailurus bengalensis*	√	√
11	Tiger	*Panthera tigris*	√	X
12	Indian Grey Mongoose	*Urva edwardsii*	X	√
13	Terai Langur	*Semnopithecus hector*		X
14	Rhesus Monkey	*Macaca mulatta*	√	√
15	Indian Crested Porcupine	*Hystrix indica*	X	√
16	Honey Badger	*Mellivora capensis*	X	√
17	Large Indian Civet	*Viverra zibetha*	√	√

√—presence | X—absence.

accidental or targeted poisoning (AbiSaid & Dloniak 2015). Recently, Adhikari et al. (2018) recorded a road kill of hyena outside the eastern part of PNP nearby Nijgadh City which is contiguous to the PNP boundary. Similarly, other top carnivore species predation to livestock accelerates the retaliatory killing which may directly or indirectly affect the hyena population.

The overall trapping rate of hyenas in our study was 0.120 and 0.121 in 2016 and 2017, respectively. The low trapping rate implies that the population is very low in the region. This may be due to the presence of a low prey population in the area. Also, the prey density estimates in PNP and its adjoining forests was 22 (SE 3.8)/ km^2, which is rather lower than the neighbouring Chitwan National Park (DNPWC & DFSC 2018). Similarly, the Government of Nepal conservation organization, and communities are carrying out conservation activities especially focusing on tigers and rhinos in lowland protected areas. This has limited the conservation and research priority to other important species (Katuwal et al. 2018) including hyenas. The extension area of PNP can be an ideal site for hyenas if the concerned authorities continue their efforts on habitat management activities and law enforcement. The awareness activities and conservation programs in the buffer zone area of the national park are solely needed for the long-term conservation of hyenas.

Furthermore, a detailed ecological study particularly focusing on hyenas is required for estimating their abundance, distribution, diet preferences, and assessing current conservation threats. This information will be crucial in future for designing hyena conservation plans in the region.

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COMMUNICATION

Range extension and new ecoregion records of the Crocodile Monitor *Varanus salvadorii* (Peters & Doria, 1878) (Reptilia: Varanidae) in Papua New Guinea

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Abstract: The Crocodile Monitor *Varanus salvadorii* is one of the longest lizards and an apex predator in New Guinea. Limited information is available on its ecology and distribution, mainly due to its arboreal lifestyle and preference for inaccessible primary forest habitats. Here we provide the first published record, using camera trapping technology in the Torricelli Mountain Range, of *V. salvadorii* living at a higher elevation than previously recorded in montane rainforest habitat. This range extension implies the occupation of a distinctive ecoregion for the species: the Northern New Guinea Montane Forest, a substantially cooler region from the formerly known distribution area. We present trail camera images of an active animal at an elevation of 1,500 m & at 18°C temperature and we discuss the implications of this finding for understanding the behaviour & conservation of the Crocodile Monitor.

Keywords: Distribution, monitor lizard, Northern New Guinea Montane Forest, Tenkile Conservation Alliance, threats, Torricelli Mountain Range.

Tok Pisin Abstract: Bikpela stori bilong dispela wok: Dispela pukpuk nem bilong em Monitor *Varanus salvardorii* em wanpla bigpla na longpela palai tru na i stap namba wan long Niu Gini olsem animol we i save killim na kaikai olgeta arapela animol. Bikos dispela pukpuk i save laik long stap antap tu long ol diwai na laikim tumas bigpela bush we nogat man i save go, yumi nau no save tumas long ples we dispela pukpuk i save stap long em na tu yumi no klia gud yet long wonem hap kona blo kantri tru dispela pukpuk igo kamap pinis.Mipla painim aut sampla moa nupla samtin long dispela pukpuk na nau mipla wokim namba wan toksave long kantri na olgeta man meri long ples graun olsem dispela pukpuk *V. salvadorii* i stap tu long maunten ples antap moa we ol lain bipo ino bin lukim long em bikos ol i bin painim em tasol long bus blo liklik maunten lo nambis sait tasol. Mipela usim kamera olsem trap bilong kisim foto long dispela pukpuk antap long maunten blo Torrecelli Range. Dispela luksave nau i soim olsem pukpuk *V.salvadorii* i go stap antap long ol maunten na nupla hap tu: Em long hailens bus na maunten bilong Sepik we ples i kol na bipo dispela pukpuk ino bin stap long em.Ol dispela piksa mipla i soim em bilong dispela pukpuk i raun painim kaikai we kemera i kisim long em antap long maunten i sanap olsem 1,500 m na ples i kol olsem long 18oC. Mipla i stori tu long wonem samtin i mas kamap nau antap long dispela save na wonem wei tru yumi ken wok wantaim long lukautim dispela pukpuk Monitor *V. salvadorii*.

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Author contributions: Both authors have participated in organizing and analyzing the data. BR wrote the manuscript and JT wrote the methods and revised the manuscript.

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INTRODUCTION

New Guinea is considered a high-biodiversity wilderness area, an important region for conservation that combines a large percentage of intact habitats with rich endemism, exceptionally diverse biota, and low human population density (Richards 2007; Mittermeier et al. 2011). With the remaining natural forest cover extending over 90% of its land, Papua New Guinea (hereafter PNG) is one of the least explored regions in the world (Mittermeier et al. 2003; Vizzuality 2010; PNG Data Portal 2021). The Torricelli Mountain Range is among the remotest areas of this island (Diamond 1985; Flannery 1995; Kraus & Allison 2006; Beehler & Prawiradilaga 2010; Thomas 2014). Located primarily in Sandaun Province (northwestern PNG), the Torricelli Mountains form the northern coastal range of PNG together with Prince Alexandre and Bewani Mountains stretching from the East Sepik Province to the Keerom regency in Papua province (Indonesia) in the west (Image 1). These mountains are part of the New Guinea north coastal ranges which also includes the Cyclops, Foja, and Van Rees mountains located in Papua province. The Torricelli Mountains consist of limestone and montane forest and harbours several endemic vertebrate and invertebrate species, and the description of new species is considered very likely (Flannery 1995; Allison 1996; Wikramanayake et al. 2002; Kraus 2010; Thomas 2014). Furthermore, this area is considered the third most diverse region for lizards in New Guinea (Heads 2002). The Torricelli Mountain Range is enveloped by two key biodiversity areas (KBAs), the East and West Torricelli's, and is a proposed conservation area (Dalsgaard & Pedersen 2015; Schwartz et al. 2021).

The Crocodile Monitor *Varanus salvadorii* is the largest lizard of New Guinea and an apex predator on this island (Heinsohn & Hope 2006). A handful of studies exist on this elusive species in captivity (Adams 1995; Waterloo & Bayless 2006; Mays 2007; Trout 2007; Camina et al. 2013; Reh et al. 2021) but *V. salvadorii* has been poorly studied in the wild, mainly because it is restricted to commonly inaccessible forests, strictly avoids contact with humans, and predominantly displays arboreal behaviour (Horn et al. 2007; Pattiselanno 2007; Shea et al. 2016).

The distribution of the species includes lowland and hill forests around most of the coastal lowlands of New Guinea. However, it has not been reported to occur in habitats above 600 m. The species has previously been reported from open woodland habitats within the Trans-Fly region, and lowland and mangrove forests on the islands of Salawati, Warir, and Selat Sagawin (north-west tip of Papua) (Allison 2006; Horn et al. 2007; Borja Reh pers. comm. 1.xii.2009). Crocodile Monitors are excellent swimmers, and individuals have been observed in forests along rivers (Marshall & Beehler 2011).

Here we report the first discovery of Crocodile Monitors in the Torricelli Mountain Range captured with trail camera traps at elevations above 1,000 m.

MATERIALS AND METHODS

The Tenkile Conservation Alliance (TCA) has been conducting research in the Torricelli Mountain Range since 2002. From 2002 a total of 16 sites have been established for sampling, specifically point transect sampling and initially for scat surveys for tree kangaroos. Each research site consists of 20 transects with a total of 150 transect points for scat surveys and setting camera traps. Camera trapping began in 2010 with six camera traps. From 2013 to 2018, the number of cameras increased to 30, and in 2019 the number reached to 50 camera traps.

TCA uses Reconyx cameras (models 650 and 850) that are rotated for each survey, and no more than 25 are deployed at any one time. The cameras are attached to a tree 30 cm above the ground, the area is cleared of debris and tested before being set for each survey. Camera traps are left in the field for three months before being collected, and then results are analysed. Further information regarding camera trap setup by the TCA can be found at the link https://tenkile.com/wp-content/uploads/2022/02/Camera-Trap-Field-Manual.pdf

Each camera trap survey consists of a team of 12 people from the villages close to the research site. Each team consists of four research officers and eight rangers.

The trail cameras provide temperature data, time of capture, and moon phase. When triggered by motion sensors, predefined settings of the trail cameras are to take three photos at three-second intervals and leave a 10-minute delay to prevent repeated photography of the same individual.

The elevation is recorded at each trail camera location with a Garmin GPS and confirmed using the map of global terrain elevations by Yamazaki et al. (2017).

The images collected are reviewed by experts looking at key indicators of species such as colour pattern, size, posture, and the shape of the body. The animals are also compared with sympatric species of the same family.

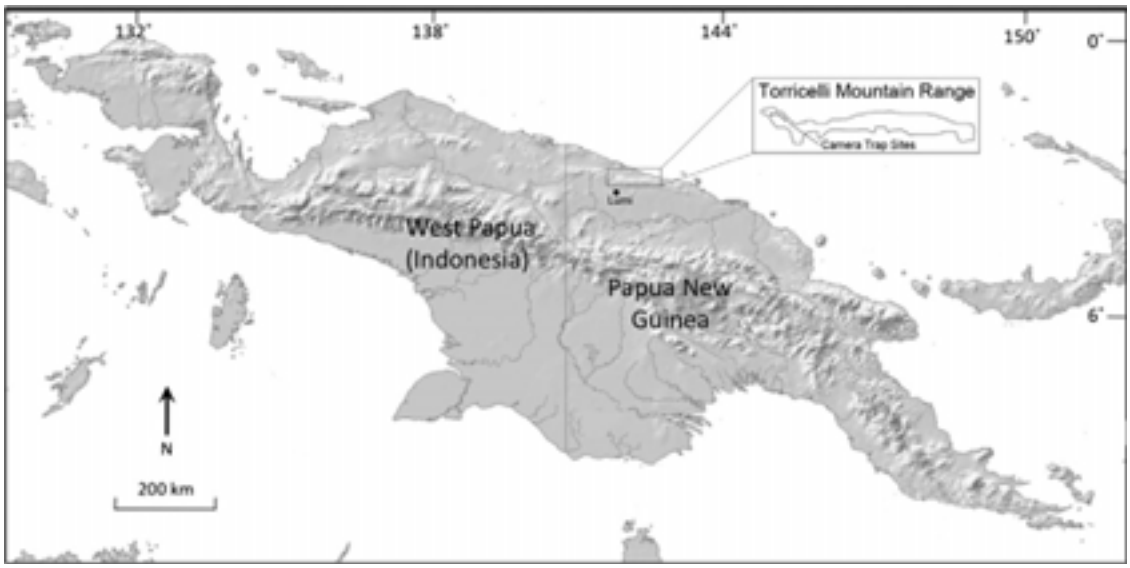

Image 1. Location of the Torricelli Mountain Range in Papua New Guinea. Tenkile Conservation Alliance.

RESULTS

Over the study period, TCA could collect data from 140 GPS camera monitoring sites ranging at elevations 700–1,600 m, corresponding to the Northern New Guinea Montane Forest ecoregion (Wikramanayake et al. 2002) (Image 2). More than 10,000 images have been collected from the camera traps. Birds and mammals account for the majority of animal photos. Only two reptile species (*V. salvadorii* and *V. doreanus*) were recorded by camera traps.

Two Crocodile Monitors were photographed, with camera traps in the Torricelli Mountain Range. The first was at the 'Waliapilk' research site in 2012, and at the second at the 'Birr' research site in 2015. Both sites are outside the previously known elevation distribution range for the species (Image 3).

Individual 1, a suspected adult of unknown gender was captured at 1032 h on 12 August 2012, at ground level and 1,522 m elevation with an air temperature of 18 °C. GPS location 3.4075 °S & 142.1819 °E. Although a series of three images were taken, only the first image shows enough of the animal to identify the species (Image 4).

Individual 2, a suspected adult of unknown gender was captured at 1114 h on 8 August 2015, at ground level and 1,200 m elevation when the air temperature was 20°C. GPS location 3.4038 °S & 142.2205 °E. The animal was walking at a normal pace (Image 5).

DISCUSSION

Elevation distribution data of *V. salvadorii* were compiled by Horn et al. (2007) based on available data. The authors reported 25 locations from museum specimens and 20 specimens from the literature and direct observations. Most individuals were recorded below 200 m, with two exceptions at 550 and 600 m. Pattiselanno et al. (2007) reported one Crocodile Monitor in the Arfak Mountains at 650 m. The locations we describe herein confirm an elevational range extension of Crocodile Monitors based on reliable photo records of the species in the Torricelli Mountain Range. Moreover, it indicates the tolerance of Crocodile Monitors to a new ecoregion, the Northern New Guinea Montane Forest.

Although principally deployed to capture images of tree kangaroos, camera traps set by TCA in the Torricelli Mountain Range have successfully recorded species of all terrestrial vertebrates (Thomas 2014). The Tenkile and Weimang tree kangaroos are the flagship species for TCA; however, unexpected results, such as those for *V. salvadorii*, are welcomed and emphasise the importance of protected areas and biodiversity monitoring.

The present findings also shed some light on the possibility of *V. salvadorii* occurring in the North Coastal Ranges of PNG (Bewani-Torricelli-Prince Alexander Mountain Ranges) after several reports of 'kundu drums' made with Crocodile Monitor skin in villages in that region (Horn et al. 2007). The species has been ever-present in the area, being revered, feared and respected. Traditional stories by the Tambuna tribe people suggest the animal can attain great lengths and consume village hunting dogs.

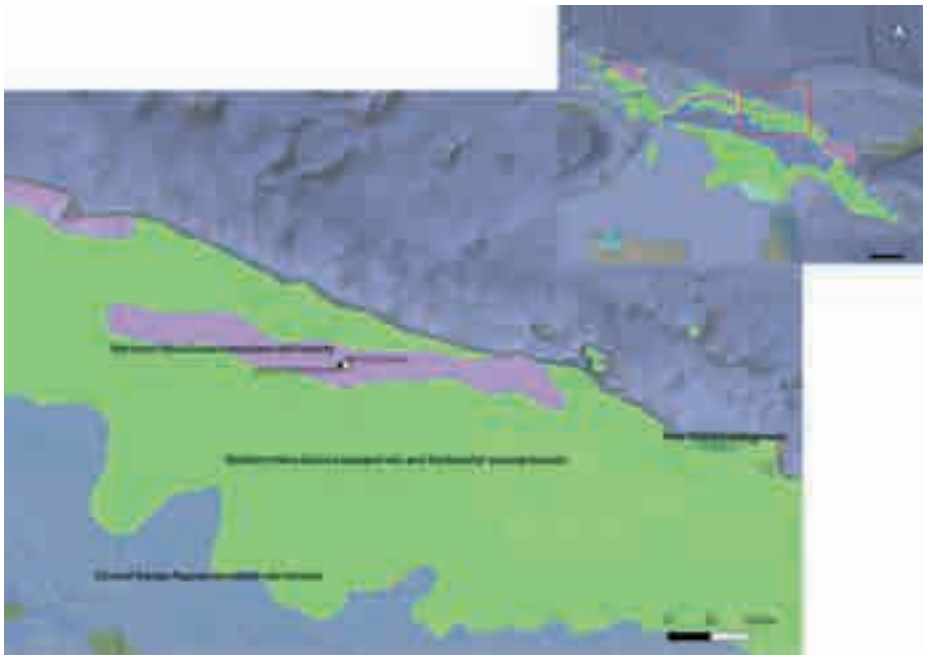

Image 2. Ecoregions of Papua New Guinea, and location of the trail cameras (Dinerstein et al. 2017).

Image 3. New location of *Varanus salvadorii* in the Torricelli Mountain Range. inset shows the species global range according to its IUCN Red List Assessment (Shea et al. 2016).

Small animals have been caught, and their skins are used for making drums (Jim Thomas pers. comm. 10.xii.2021). However, due to their life history traits they are difficult to observe without camera traps.

TCA has used camera traps in the Torricelli Mountain Range since 2010, but only two Crocodile Monitors have so far been recorded. This could be due to an extremely low population density in the region or due to the setting of the cameras at low height not targeting this species specifically, or because no bait lures were used. Crocodile Monitors are mainly arboreal, spending most of their time in trees (Reh et al. 2021).

Image 4. Red arrow denotes a Crocodile Monitor captured by camera trap at the Waliapilk site in 2012. © Tenkile Conservation Alliance.

This species is known to inhabit a range of habitats, including rainforest vegetation such as mixed alluvial and mixed hill forest types, as well as lowland and riparian forests (Horn 2004; Horn et al. 2007). Additionally, the present data indicate that the Crocodile Monitors also inhabit the Northern New Guinea Montane Forest.

Our new reported localities also call into question the minimum preferred temperature range of *V. salvadorii*. Under captive conditions the species is known to significantly reduce activity levels at temperatures below 24 ºC (Reh et al. 2021). However, images from the trail cameras show active individuals at 18 °C and 20 ºC. Furthermore, the mean annual maximum and minimum temperatures at an elevation of 1,500 m range is between 24.9 ºC and 14 ºC, according to the PNG Resource Information System (Bryan & Shearman 2008).

There are several possible explanations for activity at higher and cooler environment; (1) individuals can elevate their body temperatures by basking on a tree or in patches of sunlight on the forest floor to permit activity, and (2) individuals may move along the ground to escape inter or intraspecific confrontations even at cooler temperatures (Borja Reh pers. comm. 21.xii.2021). Crocodile Monitors have keen senses that allow them to perceive and avoid threats. Using the ground is an excellent way to remain undetected, especially by conspecifics.

Crocodile Monitors are assessed as Least Concern (LC) by the IUCN Red List (Shea et al. 2016). However, their ecological role within habitats is not clear, and they should be considered a focal species for monitoring ecosystem health given their status as apex predators (Simberloff 1998; Sergio et al. 2008; Ray 2015).

New Guinea is experiencing one of the fastest deforestation rates in the world (Curtis et al. 2018; Amindoni & Henschke 2020). The increasing trend of habitat loss due to logging concessions is affecting the primary forest habitat of Crocodile Monitors and other under-researched species, including those that remain undescribed (Allison 1996; Kraus 2010; Miettinen et al. 2011; Letsoin et al. 2020; PNG Data Portal, 2021). Habitat loss is an increasing concern for the conservation of Crocodile Monitors. However, the impact of this threat has not been studied.

Despite its remoteness and inaccessibility, the Torricelli Mountain Range is suffering one of the highest deforestation rates on the island due to clearing and logging (Bryan et al. 2015). Industrial logging persists and is increasing in the area, with new roads being proposed across the range.

Therefore, habitat loss must be considered an increasing concern for the conservation of Crocodile Monitors. The effect of this threat on the viability of *V. salvadorii* populations remains unexplored. It is thus critical that significant records and information of unknown species, such as the Crocodile Monitor, are published to trigger conservation measures and help protect their area.

Camera traps have proven to be effective in capturing large monitor lizards (Ariefiandy et al. 2013; Jessop et al. 2013) and may offer a suitable solution to more effectively describing the distribution range and behaviour of Crocodile Monitors and many other species that remain understudied in New Guinea (Thomas 2014). However, modifications to existing protocols – such as including meat-based baits or lures or deployment of arboreal camera traps might increase the number of monitors recorded as well as other wildlife unlikely to be detected at ground level (Gregory et al. 2014; Moore et al. 2021).

Image 5. Photo sequence. Crocodile Monitor captured by camera trap at the Birr site in 2015. © Tenkile Conservation Alliance.

With an expansion of methods with camera traps and increasing biodiversity surveys, the TCA aims to increase its' data collection for biodiversity via camera traps, phone applications and staff patrols into the Torricelli Mountain Range.

The present data highlight the limited information available about one of the top predators and larger animals in New Guinea. The Crocodile Monitor has been far more studied in captivity than in wild, where virtually nothing is known about their biological traits. Therefore, more in-depth field studies are needed to understand the distribution patterns and the impact of anthropogenic threats in order to take timely measures to conserve and protect the species in the long term.

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COMMUNICATION

A checklist of fish and shellfishes of the Poonthura estuary, southwestern coast of India

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Abstract: A systematic checklist of fish and shellfishes of the Poonthura estuary, Kerala, India is provided including notes on their conservation status. This checklist includes 66 finfish and five shellfish, belonging to 17 orders, 35 families, and 60 genera. Carangiformes is the richest order (11 species, eight genera, and three families), representing 15.4% of the total fish diversity. Carangidae, is the most diverse family with nine representatives, contributing to 12.6% of the total fish diversity. Following the IUCN Red List Categories, of the total 69 species (excluding both exotic and transplanted fish species), 59 belong to the 'Least Concern', while one species *Pampus argenteus* is listed as 'Vulnerable', four are 'Data Deficient' (*Megalops cyprinoides, Arius maculatus, Cynoglossus semifasciatus*, and *Epinephelus tauvina)* and five are 'Not Evaluated' (*Nuchequula blochii, Channa pseudomarulius, Penaeus indicus, P. monodon*, and *Scylla serrata*). Around 94% of the recorded fish fauna have commercial value and contribute to subsistence fisheries throughout the year. Taxonomy and diversity of fish fauna of least studied or isolated estuarine ecosystems should be updated with proper documentation of their conservation status, in order to design and implement pragmatic management and conservation programs.

Keywords: Brackish water, fish diversity, Ichthyofauna, Kerala estuaries.

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INTRODUCTION

Estuaries are transitional zones between sea and freshwater that are inhabited by both inland and marine species, including their juvenile stages (McLusky & Elliott 2006; Elliott et al. 2007; Franco et al. 2008; Potter et al. 2010; Sreekanth et al. 2018). Compared to marine or freshwater systems, estuaries are variable, complicated, and stressful habitats (Selleslagh & Amara 2008; Human et al. 2016; Kiranya et al. 2022). Many commercially important fish species benefit from the highly productive nature of estuaries as their nursery area (Harrison & Kelly 2013). Therefore, much emphasis is required to protect estuarine environments so as to ensure the growth and survival of commercially important fish and shellfish species (Elliott et al. 2007).

The estuaries, backwaters, coastal creeks and large brackishwater systems contribute to a significant part of fish production in India (Nair et al. 1983; Tudu et al. 2018). The peculiarity of Indian estuaries is that they are characterized by high species diversity with low numerical abundance (Sreekanth et al. 2019). Poonthura Estuary situated in the Thiruvananthapuram district of Kerala is comparatively small and shallow, and is formed due to the formation of a sand bar near the estuarine mouth (Kiranya et al. 2018). Previous authors who worked on this estuary have reported its ecological degradation mainly due to indiscriminate fishing and pollution from point and non-point sources (Kiranya et al. 2018).

In Kerala, considerable number of studies have dealt with taxonomic entities within estuarine systems, i.e., species composition, species distribution, and abundance, and spatial and temporal variations in fish diversity (Bijukumar & Sushama 2000; Harikrishnan et al. 2011; Regi & Bijukumar 2012; Kiranya et al. 2018; Roshni et al. 2021; Kiranya et al. 2022), with many such studies concentrated on a single estuary, the Vembanad Lake (Kurup & Samuel 1987; Menon et al. 2000; Harikrishnan et al. 2011; Roshni et al. 2021). There is considerable knowledge gap on the fish diversity and distribution patterns in many estuaries of Kerala, notably in the case of smaller systems such as Poonthura estuary, because of their isolated nature (Kiranya et al. 2018, 2022). Considering this lacuna, the present study focuses on presenting a comprehensive checklist of fish and shellfish species of Poonthura estuary, along with their systematic position, and conservation status (according to the IUCN Red List). The increasing availability of data on estuarine fish and shellfish fauna will facilitate their use in greater detail to design and implement pragmatic strategies and programs for estuarine fisheries management and conservation.

MATERIALS AND METHODS

Study area

The Poonthura Estuary (0.9 km^2 long and 0.1 km wide) is one of the most ecologically significant, and at the same time a polluted estuary in Thiruvananthapuram, Kerala (Kiranya et al. 2022). The estuary is micro-tidal and partially mixed, with an average tidal range of 1.5 m, and separated from the Lakshadweep Sea by a sand bar at Poonthura. The sand bar opens during the monsoon due to heavy discharge of water from the River Karamana. During heavy river discharge and land drainage during the monsoon, the sand bar between sea and estuary is either naturally, or manually opened. Artificial breaching of the estuary is also a frequent practice in this area to avoid flooding into nearby human settlements (Kiranya et al. 2018). The Poonthura estuary has also been undergoing severe ecological degradation with its bottom being muddy with a pungent smell, due to the unmanaged disposal of municipal sewage, land drainage, and industrial effluents (Kiranya et al. 2018). Full-time, part time and migrant fishers of 200 families of the adjoing areas belonging to the traditional sector depend on this estuary both directly and indirectly for subsistence, almost throughout the year (Kiranya et al. 2018).

Sampling and analysis

The present study was carried out in multiple phases from June 2016 to October 2020. Three sampling stations were fixed based on the fishing activity, tidal influx, and drainage from rivers/ land. Monthly samples of fish and shellfish were collected from the selected stations (Image 1). Sampling was performed during early morning using 110 m surface and bottom set gillnets (mesh size 30 mm) and 4.5 m cast net (mesh size 8 mm) (one sampling each using both bottom set gillnet, surface gill net and cast net at a sampling station) operated from a small plank-built canoe (3 m LOA). Identification of fish and shellfishes were done at the species level by using published keys (Jayaram 1981; Fischer & Bianchi 1984). Identification of *Channa pseudomarulius* followed Britz et al. (2017). Taxonomic status and systematic position of fishes follow the Catalog of Fishes (Fricke et al. 2021) and World Register of Marine Species database (WoRMS 2021). Vernacular and local names of fish and shellfish species were collected from the traditional fishers

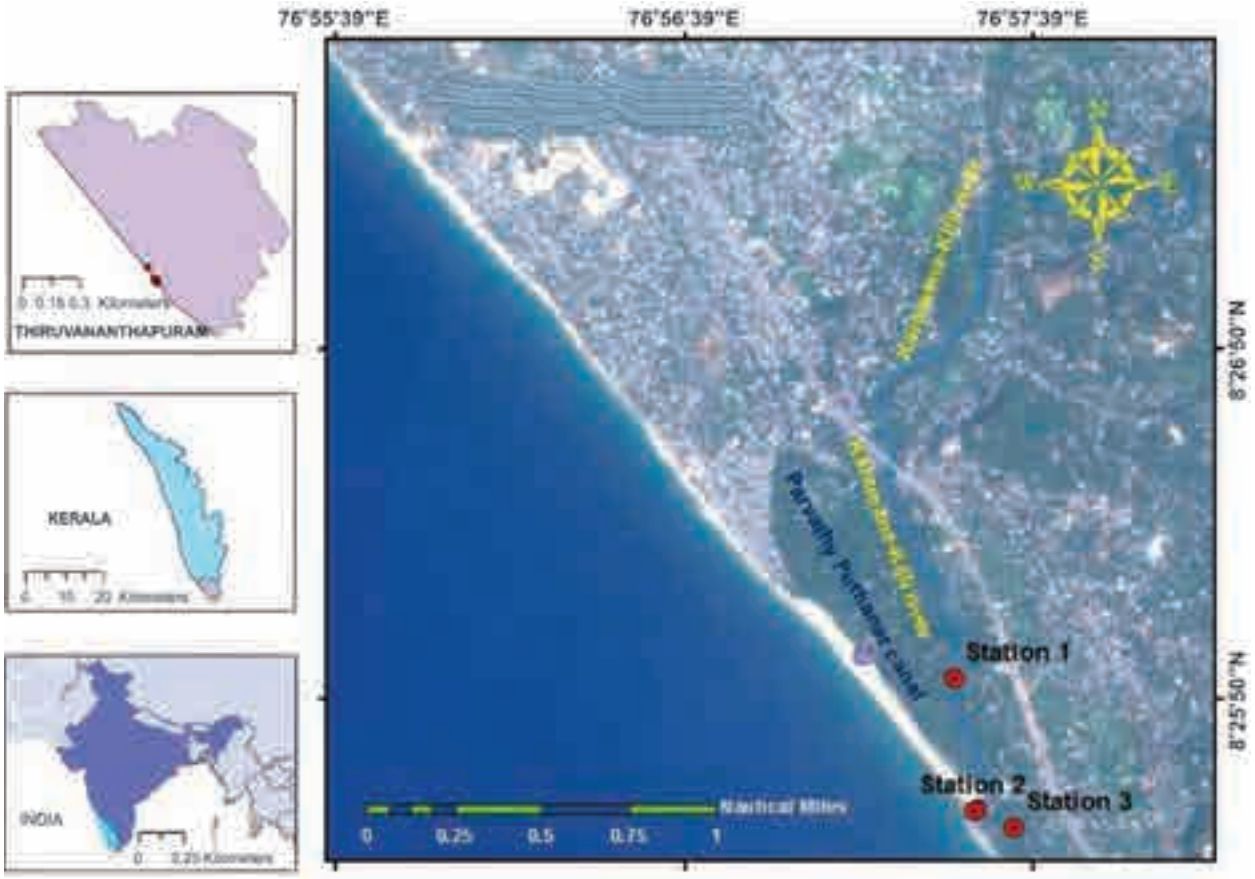

Image 1. Map of Poonthura estuary, with three sampling stations marked.

through questionnaires. The conservation status of fish species is based on the IUCN Red List of Threatened Species (IUCN 2021). Voucher specimens and photo vouchers (of those species whose specimens were not collected) are deposited in the Department of Fisheries Resource Management, Kerala University of Fisheries and Ocean Studies, Kochi, Kerala, India.

RESULTS AND DISCUSSION

Total of 71 species (66 finfish and five shellfishes) within 17 orders and 35 families and 60 genera were recorded from Poonthura estuary (Table 1) (Image 2a–g). The dominant fish orders recorded were Carangiformes (15.4%) with 11 species followed by orders Clupeiformes (14%), Perciformes (11.2%), Mugiliformes (7.04%), Cypriniformes (7.04%), and members of the crustacean order Decapoda (7.04%) (Figure 2). Comparable results were recorded by Regi & Bijukumar (2012), who observed that Perciformes, Siluriformes, Clupeiformes, and Mugiliformes, were the most common taxonomic orders in the Veli-Akkulam backwaters which is the adjacent backwater system (13 km away from Poonthura estuary) and shares similar characteristics with Poonthura estuary such as small size, isolated, and temporarily closed nature.

The dominant finfish families recorded in Poonthura estuary (Figure 3) were Carangidae with nine species (12.6%), Clupeidae with six species, Mugilidae and Cyprinidae with five species each (7.04%), and Leiognathidae and Ambassidae with four species (5.6%). The major species within family Carangidae were *Atule mate*, *Caranx ignobilis*, *Alepes djedaba*, and *Trachinotus blochii*.

Species such as *Etroplus suratensis*, *Oreochromis mossambicus, Gerres filamentosus*, *Chelon parsia, Mugil cephalus, Arius arius,* and *Caranx ignobilis* represented the most common species of the estuarine system, with *Etroplus suratensis* and *Oreochromis mossambicus* being recorded throughout the year during the study period. The present study also revealed the occurrence of two fish species having ornamental value, the filament barb, *Dawkinsia filamentosa and* the silver moony,

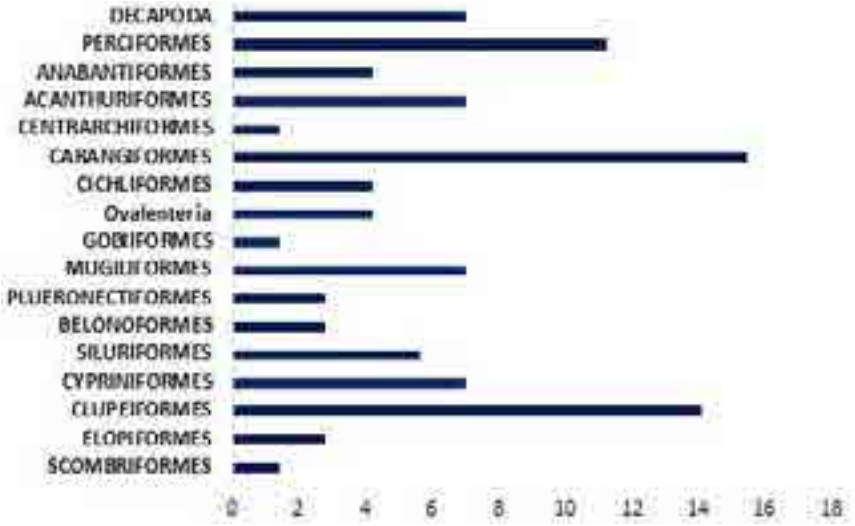

Figure 1. Order-wise composition of fish and shellfish species recorded from the Poonthura estuary.

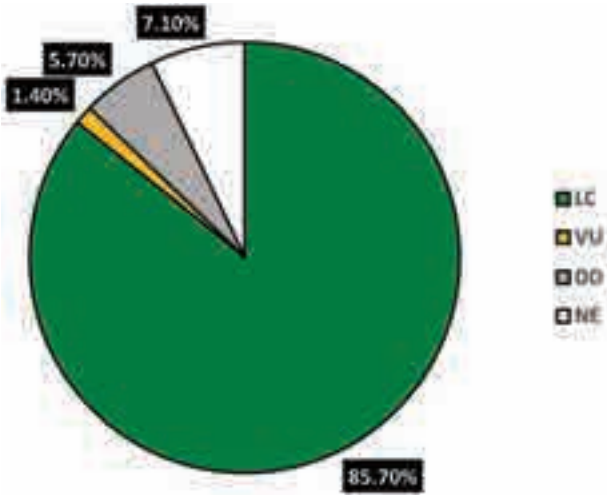

Figure 2. IUCN conservation status of fish and shellfish species recorded from Poonthura estuary.

Monodactylus argenteus.

Of the four species of shrimps/prawns recorded from the estuary, *Penaeus indicus* was the dominant species followed by *P. monodon* and *Macrobrachium rosenbergii*. The mud crab *Scylla serrata was* the only representative of crabs that was observed in the local catches.

Based on the IUCN Red List of Threatened Species, of the 69 species recorded (excluding exotic and translocated species) from Poonthura Estuary, 85.7% (59 species) were under the 'Least Concern' category, one species was under the 'Vulnerable' category (*Pampus argenteus*), four species under the 'Data Deficient' (*Megalops cyprinoides, Arius maculatus, Cynoglossus semifasciatus*, and *Epinephelus tauvina*) and five under the 'Not Evaluated' (*Nuchequula blochii, Channa pseudomarulius, Penaeus indicus, P. monodon*, and *Scylla serrata*) categories (Figure 3).

Several authors have studied estuarine fish diversity of west flowing river systems in Kerala, most of them pointing at the predominance of finfish species. Bijukumar & Sushama (2000) presented an overview of the ichthyofauna of the Ponnani estuary representing 112 finfish species belonging to 14 orders, 53 families, and 80 genera. Kurup & Samuel (1987) recorded 150 species of fishes from Vembanad lake, while a recent study by Roshni et al. (2021) reported 90 species of fish belonging to 17 orders and 40 families suggesting a 40% reduction in fish fauna since 1980s. Raj et al. (2014) reported 68 species of finfishes, five species of crabs, nine species of prawns from the Ashtamudi estuary, and stated that pearlspot and mullets supported good local fisheries. From Chettuva estuary, Johny et al. (2016) recorded 68 species of fish belonging to 45 genera while the diversity of nearby Azhikode estuary was known to comprise of 30 finfishes (Harikrishnan et al. 2011). Fifty species under 40 genera of finfish were recorded from the Akathumuri backwaters (Satheesan et al. 2014). Regi & Bijukumar (2012) also reported the occurrence of two non-native/ exotic species (*Oreochromis mossambicus* and *Clarias gariepinus*) from the Veli-Akkulam lake. According to the above authors, *O. mossambicus* has dominated the native fish species in many Indian water bodies due to its prolific breeding, voracious feeding habits, and hardy nature.

Table. 1 Checklist of fish and shellfish recorded from Poonthura estuary, their taxonomic position, common and vernacular names, IUCN Red List status and voucher numbers.

	Order/Family/Species	Common name	Vernacular name	IUCN status	Voucher number
I	**ORDER ELOPIFORMES**				
1	**ELOPIDAE (Ten pounders/Lady fishes)**				
	Elops machnata (Forsskål, 1775)	Ladyfish/ten pounder	Oluvia meen	LC	Photo voucher
2	**MEGALOPIDAE (Tarpons)**				
	Megalops cyprinoides Broussonet, 1782	Indo-pacific tarpon	Kannamalavu	DD	KUFOS.FV.2019.1041
II	**ORDER CLUPEIFOMRES**				
3	**CLUPEIDAE (Herrings, Sardines, Sprats)**				
	Anodontostoma chacunda (Hamilton, 1822)	Shortnose gizzard shad	Noona	LC	KUFOS.FV.2019.1042
	Amblygaster sirm (Walbaum, 1792)	Spotted sardine	Keeri chaala	LC	KUFOS.FV.2019.1045
	Dayella malabarica (Day, 1873)	Day's round herring	Kayal netholi	LC	KUFOS.FV.2016.1007
	Nematalosa nasus (Bloch, 1795)	Bloch's gizzard shad	Kuthavu	LC	Photo voucher
	Sardinella albella (Valenciennes, 1847)	White sardine	Chappa chaala	LC	KUFOS.FV.2019.1044
	Sardinella gibbosa (Bleeker, 1849)	Goldstripe sardinella	Mullan chaala	LC	KUFOS.FV.2019.1043
4	**ENGRAULIDAE (Anchovies)**				
	Encrasicholina devisi (Whitley, 1940)	Devi's anchovy	Netholi	LC	KUFOS.FV.2019.1046
	Stolephorus indicus (Van Hasselt, 1823)	Indian anchovy	Vella Netholi	LC	KUFOS.FV.2019.1047
	Thryssa mystax (Bloch & Schneider, 1801)	Moustached anchovy	Mullan manangu	LC	Photo voucher
5	**CHIROCENTRIDAE (Wolf herring)**				
	Chirocentrus dorab (Forsskål, 1775)	Dorab wolf-herring	Mulluvaala	LC	KUFOS. FV.2017.1009
III	ORDER CYPRINIFORMES				
6	**CYPRINIDAE (Minnows and Carps)**				
	Amblypharyngodon microlepis (Bleeker, 1853)	Indian carplet	Vayambu	LC	KUFOS.FV.2020.1002
	Dawkinsia filamentosa (Valenciennes, 1844)	Filament barb	Kayal Paral	LC	KUFOS.FV.2020.1001
	Labeo catla (Hamilton, 1822)	Catla	Katla	TR	KUFOS.FV.2019.1049
	Puntius parrah Day, 1865	Parrah barb		LC	KUFOS.FV.2019.1050
	Systomus sarana (Hamilton, 1822)	Olive barb	Kuruva	LC	KUFOS.FV.2019.1048
IV	**ORDER SILURIFORMES**				
7	**BAGRIDAE (Bagrid catfishes)**				
	Mystus armatus (Day, 1865)	Kerala mystus	Chillan thedu	LC	KUFOS.FV.2019.1051
8	**ARIIDAE (Sea catfishes)**				
	Arius arius (Hamilton, 1822)	Threadfin sea catfish	Thedu	LC	KUFOS.FV.2020.1003
	Arius maculatus (Thunberg, 1792)	Spotted catfish	Kadal thedu	DD	Photo voucher
9	**HETEROPNEUSTIDAE (Stinging catfish)**				
	Heteropneustes fossilis (Bloch, 1794)	Stinging catfish	Karuppan thedu	LC	KUFOS.FV.2020.1004
V	**ORDER BELONIFORMES**				
10	**BELONIDAE (Needle fish)**				
	Xenentodon cancila (Hamilton, 1822)	Freshwater garfish	Chundu mural	LC	KUFOS.FV.2019.1052
11	HEMIRAMPHIDAE (Half beaks)				
	Hyporhamphus xanthopterus (Valenciennes, 1847)	Valenciennes halfbeak	Kolaachi	LC	KUFOS.FV.2016.1001
VI	**ORDER GOBIIFORMES**				
12	**GOBIIDAE (Gobies)**				
	Glossogobius giuris (Hamilton, 1822)	Tank goby	Poonthi	LC	KUFOS.FV.2017.1001

	Order/Family/Species	Common name	Vernacular name	IUCN status	Voucher number
VII	**ORDER Incertae sedis under Ovalenteria**				
13	**AMBASSIDAE (Asiatic glassfishes)**				
	Ambassis gymnocephalus (Lacepède, 1802)	Naked- head glassy perchlet	Mullu nandhan	LC	KUFOS.FV.2020.1007
	Parambassis dayi (Bleeker, 1874)	Day's glassy perchlet	Nandhan	LC	KUFOS.FV.2020.1020
	Parambassis thomassi (Day, 1870)	Westernghat glassy perchlet	Nandhan	LC	KUFOS.FV.2020.1006
VIII	**MUGILIFORMES**				
14	**MUGILIDAE (Mullets)**				
	Chelon parsia (Hamilton, 1822)	Gold spot mullet	Kadam maalvu	LC	KUFOS.FV.2020.1008
	Crenimugil seheli (Fabricius, 1775)	Blue spot mullet	Parichal	LC	KUFOS.FV.2020.1002
	Mugil cephalus Linnaeus, 1758	Grey mullet	Maalavu	LC	KUFOS.FV.2019.1055
	Osteomugil perusii (Valenciennes, 1836)	Long finned mullet	Kadapola	LC	KUFOS.FV.2019.1053
	Planiliza subviridis (Valenciennes, 1836)	Green black mullet	Kelayan	LC	KUFOS.FV.2019.1054
IX	**CICHLIFORMES**				
15	**CICHLIDAE (Cichlids)**				
	Etroplus suratensis (Bloch, 1790)	Banded pearl spot	Karimeen	LC	KUFOS.FV.2016.1003
	Oreochromis mossambicus (Peters, 1852)	Mozambique tilapia	Piloppi	EX	KUFOS.FV.2016.1002
	Pseudetroplus maculatus Bloch, 1795	Orange chromide	Pallathi	LC	KUFOS.FV.2020.1009
X	**ORDER CARANGIFORMES**				
16	**CARANGIDAE (Jacks and Pompanos)**				
	Alepes djedaba (Forsskål, 1775)	Shrimp scad	Thovi paara	LC	KUFOS.FV.2017.1011
	Alepes vari (Cuvier, 1833)	Herring scad	Thali paara	LC	KUFOS.FV.2020.1022
	Atule mate (Cuvier, 1833)	Yellowtail scad	Manjaval paara	LC	KUFOS.FV.2016.1008
	Caranx heberi (Bennett, 1830)	Blacktip trevally	Karuppuvalan paara	LC	KUFOS.FV.2020.1023
	Caranx hippos (Linnaeus, 1766)	Common jack	Neelan paara	LC	KUFOS.FV.2016.1007
	Caranx ignobilis (Forsskål, 1775)	Yellowfin trevally	Velaa paara	LC	KUFOS.FV.2016.1009
	Decapterus russelli (Rüppell,1830)	Indian scad	Kannan kozhiyala	LC	KUFOS.FV.2017.1012
	Megalaspis cordyla (Linnaeus, 1758)	Torpedo scad	Vankada	LC	KUFOS.FV.2020.1024
	Selar crumenophthalmus (Bloch,1793)	Big eye scad	Kaata paara	LC	KUFOS.FV.2017.1010
17	**SPHYRAENIDAE (Barracudas)**				
	Sphyraena barracuda (Edwards, 1771)	Great barracuda	Cheelavu	LC	KUFOS.FV.2019.1058
18	**LATIDAE (Lates perches)**				
	Lates calcarifer (Bloch, 1790)	Asian seabass	Kalaanji	LC	KUFOS.FV.2020.1012
XI	**ORDER ANABANTIFORMES**				
19	**ANABANTIDAE (Climbing gouramies)**				
	Anabas testudineus (Bloch, 1792)	Climbing perch	Karippidi	LC	KUFOS.FV.2017.1002
20	**CHANNIDAE (Snakeheads)**				
	Channa pseudomarulius (Günther, 1861)	Great snake head	Chaerumeen	NE	KUFOS.FV.2020.1010
	Channa striata (Bloch, 1793)	Striped snakehead	Varal	LC	KUFOS.FV.2017.1003
XII	**PLUERONECTIFORMES**				
21	**CYNOGLOSSIDAE (Tongue fishes)**				
	Cynoglossus semifasciatus Day, 1877	Bengal tonguesole	Nangu	DD	KUFOS.FV.2017.1004
22	**SOLEIDAE (Soles)**				
	Brachirus orientalis (Bloch & Schneider, 1801)	Oriental sole	Kuruvan nangu	LC	KUFOS.FV.2020.1011
XIII	**ORDER SCOMBRIFORMES**				
23	**STROMATEIDAE (Butter fishes)**				

	Order/Family/Species	Common name	Vernacular name	IUCN status	Voucher number
	Pampus argenteus (Euphrasen, 1788)	Silver pomfret	Vella avoli	VU	KUFOS.FV.2019.1059
XIV	**ORDER PERCIFORMES**				
24	**GERREIDAE (Mojarras)**				
	Gerres filamentosus (Cuvier, 1829)	Whipfin silverbiddy	Pulli prachi	LC	KUFOS.FV.2020.1013
	Gerres setifer (Hamilton, 1822)	Black tipped silverbiddy	Prachi	LC	KUFOS.FV.2020.1014
25	**SILLAGINIDAE (Sillagos or Whitings)**				
	Sillago sihama (Forsskål, 1790)	Silver whiting	Kalimeen	LC	KUFOS.FV.2020.1017
26	**SERRANIDAE (Groupers)**				
	Epinephelus tauvina (Forsskål, 1775)	Greasy grouper	Kalava	DD	Photo voucher
27	**MONODACTYLIDAE (Moon fishes)**				
	Monodactylus argenteus (Linnaeus, 1758)	Silver moony fish	Kannadimeen	LC	KUFOS.FV.2016.1004
28	**LUTJANIDAE (Snappers)**				
	Lutjanus argentimaculatus (Forsskål, 1775)	Mangrove red snapper	Velameen	LC	KUFOS.FV.2020.1016
	Lutjanus fulviflamma (Forsskål,1775)	Dory snapper	Pulli chemballi	LC	Photo voucher
29	**HAEMULIDAE (Sweet lips)**				
	Plectorhinchus gibbosus (Lacepède, 1802)	Brown sweetlips	Kaili	LC	KUFOS.FV.2020.1019
XV	**ORDER CENTRARCHIFORMES (Sun fishes)**				
30	**TERAPONTIDAE (Grunters or Tigerfishes)**				
	Terapon jarbua (Forsskål, 1775)	Crescent perch	Konankora	LC	KUFOS.FV.2020.1015
XVI	**ORDER ACANTHURIFORMES (Surgeon fishes**				
31	**LEIOGNATHIDAE (Pony fishes or Slip mouths)**				
	Eubleekeria splendens (Cuvier, 1829)	Splendid ponyfish	Mullukaara	LC	KUFOS.FV.2019.1061
	Gazza minuta (Bloch, 1795)	Toothed ponyfish	Chadhakaara	LC	KUFOS.FV.2019.1060
	Leiognathus equulus (Forsskål,1775)	Commmon ponyfish	Kaara poochi	LC	KUFOS.FV.2016.1005
	Nuchequula blochii (Valenciennes, 1835)	Twoblotch ponyfish	Paalkaara	NE	KUFOS.FV.2019.1062
32	**SCATOPHAGIDAE (Scats)**				
	Scatophagus argus (Linnaeus, 1766)	Spotted butterfish	Poola	LC	KUFOS.FV.2016.1006
XVII	**ORDER DECAPODA**				
33	**PALAEMONIDAE (Palaemonid shrimps)**				
	Macrobrachium idella (Hilgendorf, 1898)	Slender river prawn	Koona konju	LC	KUFOS.CV.2020.1018
	Macrobrachium rosenbergii (De Man, 1879)	Giant river prawn	Kaalan konju	LC	KUFOS.CV.2017.1005
34	**PENAEIDAE (Penaeid shrimps)**				
	Penaeus indicus (H. Milne-Edwards, 1837)	Indian white prawn	Naaran konju	NE	KUFOS.CV.2019.1063
	Penaeus monodon (Fabricus, 1798)	Giant tiger prawn	Kara konju	NE	KUFOS.CV.2017.1006
35	**PORTUNIDAE**				
	Scylla serrata (Forsskål, 1775)	Green mud crab	Kayal Njandu	NE	KUFOS.CV.2017.1007

LC—Least Concern | DD—Data Deficient | NE—Not Evaluated | VU—Vulnerable | TR—Transplanted | EX—Exotic | B—Brackishwater | F—Freshwater | M—Marine.

The conservation and management of Poonthura estuary necessitates a holistic approach that takes in to account the ecosystem balance and function as well as the restoration of the natural fish diversity of the estuary, thus ensuring fishing activities that are economically viable in the long-term.

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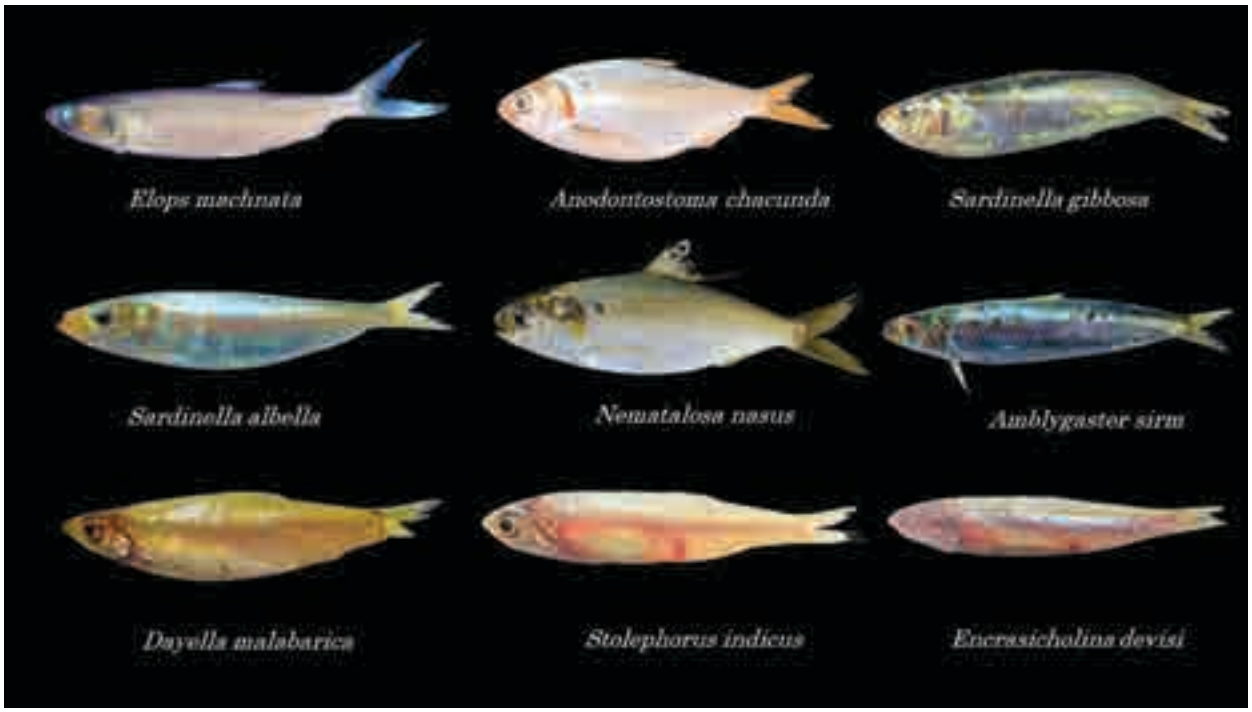

Image 2a . Fish species recorded from the Poonthura estuary. © Kiranya B.

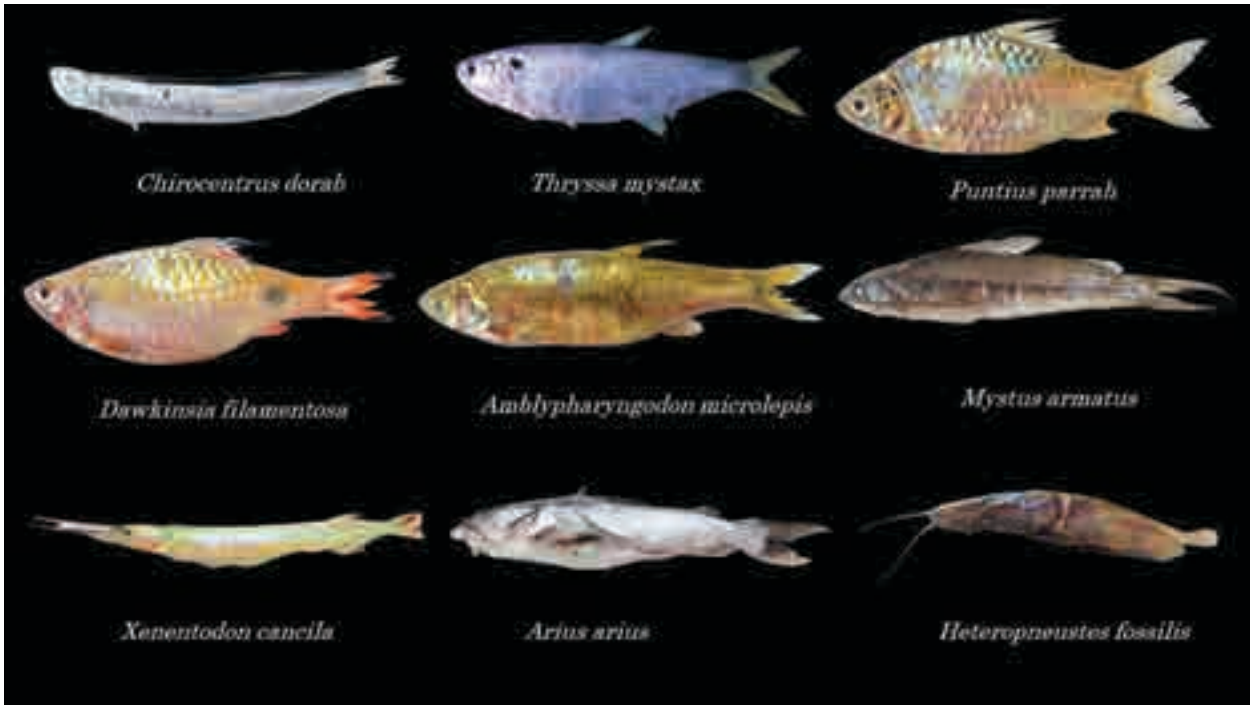

Image 2b. Fish species recorded from the Poonthura estuary. © Kiranya B.

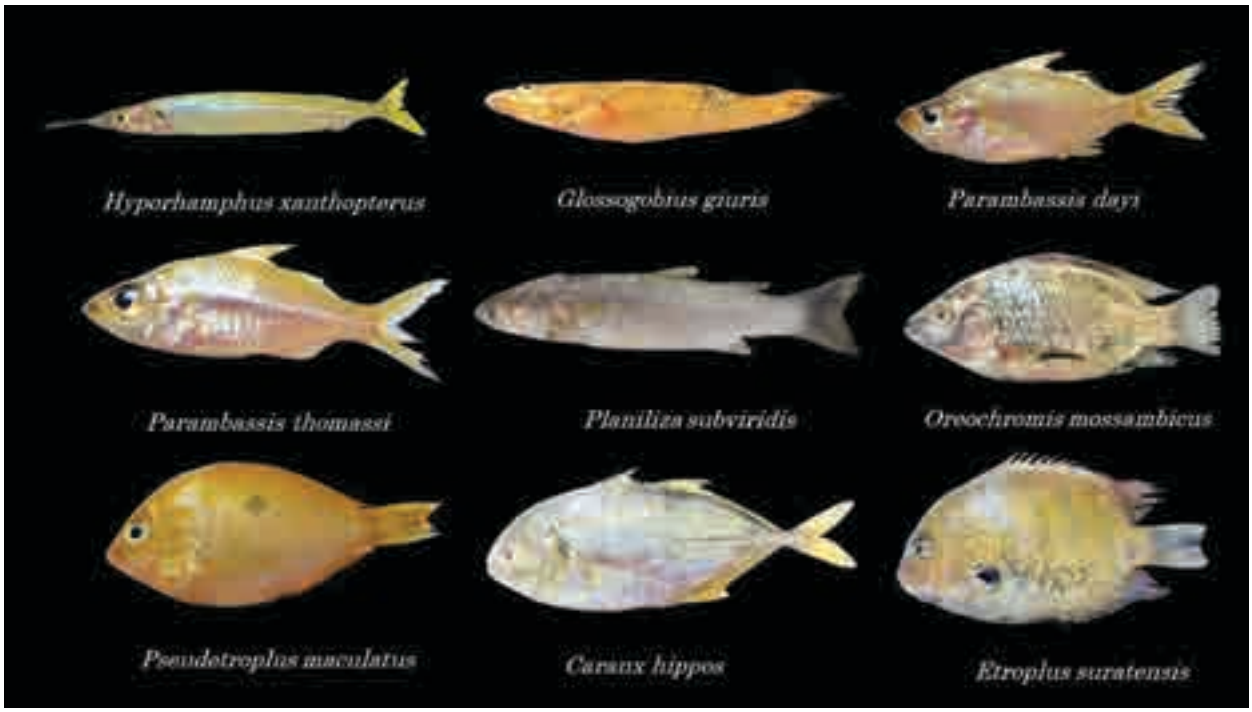

Image 2c. Fish species recorded from the Poonthura estuary. © Kiranya B.

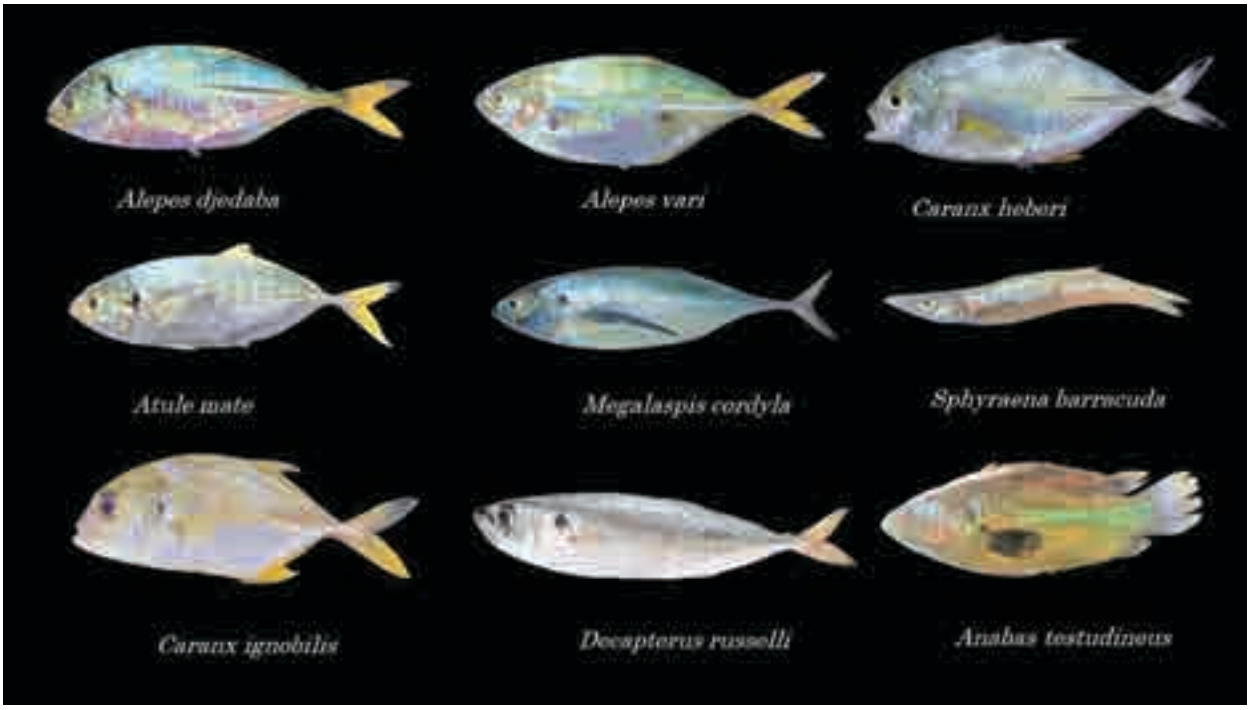

Image 2d. Fish species recorded from the Poonthura estuary. © Kiranya B.

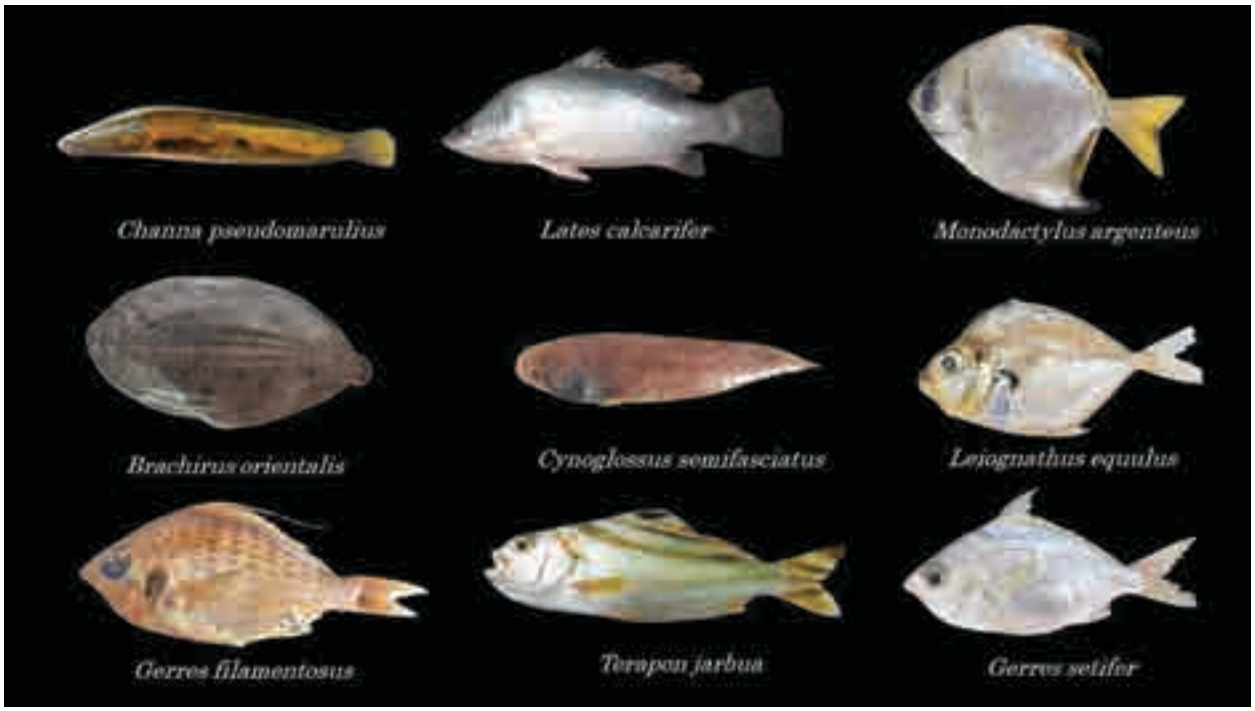

Image 2e. Fish species recorded from the Poonthura estuary. © Kiranya B.

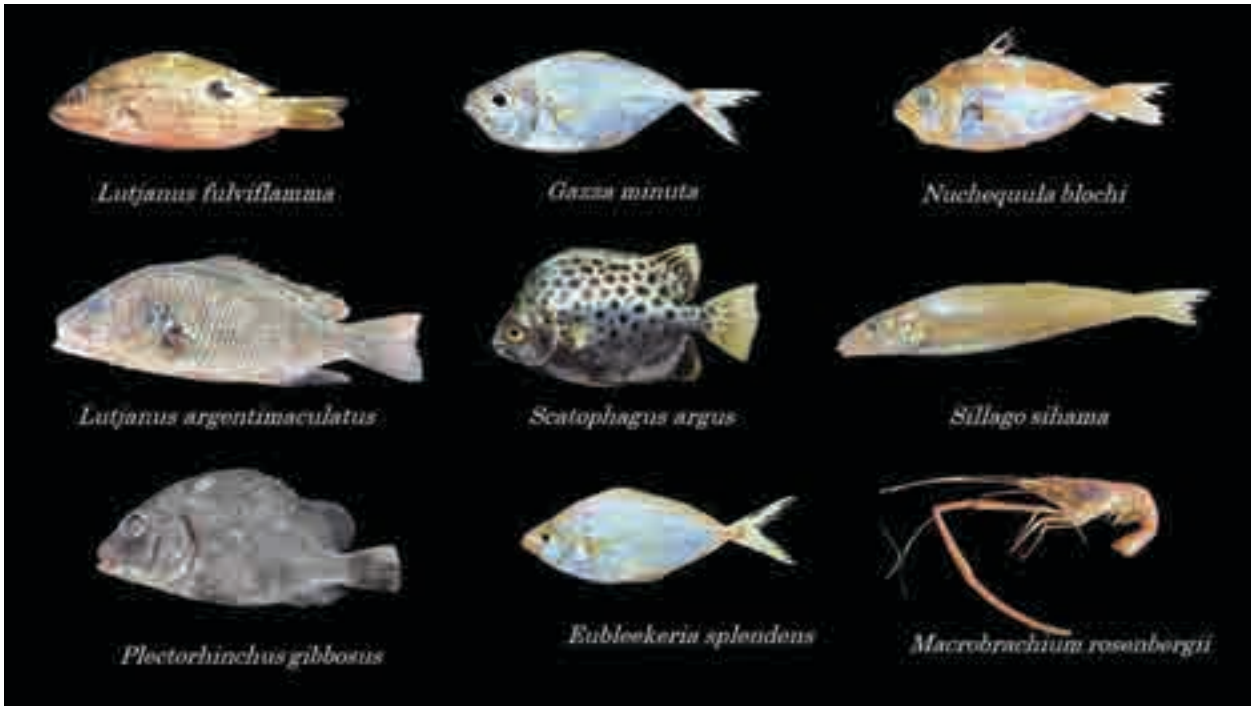

Image 2f. Fish species recorded from the Poonthura estuary. © Kiranya B.

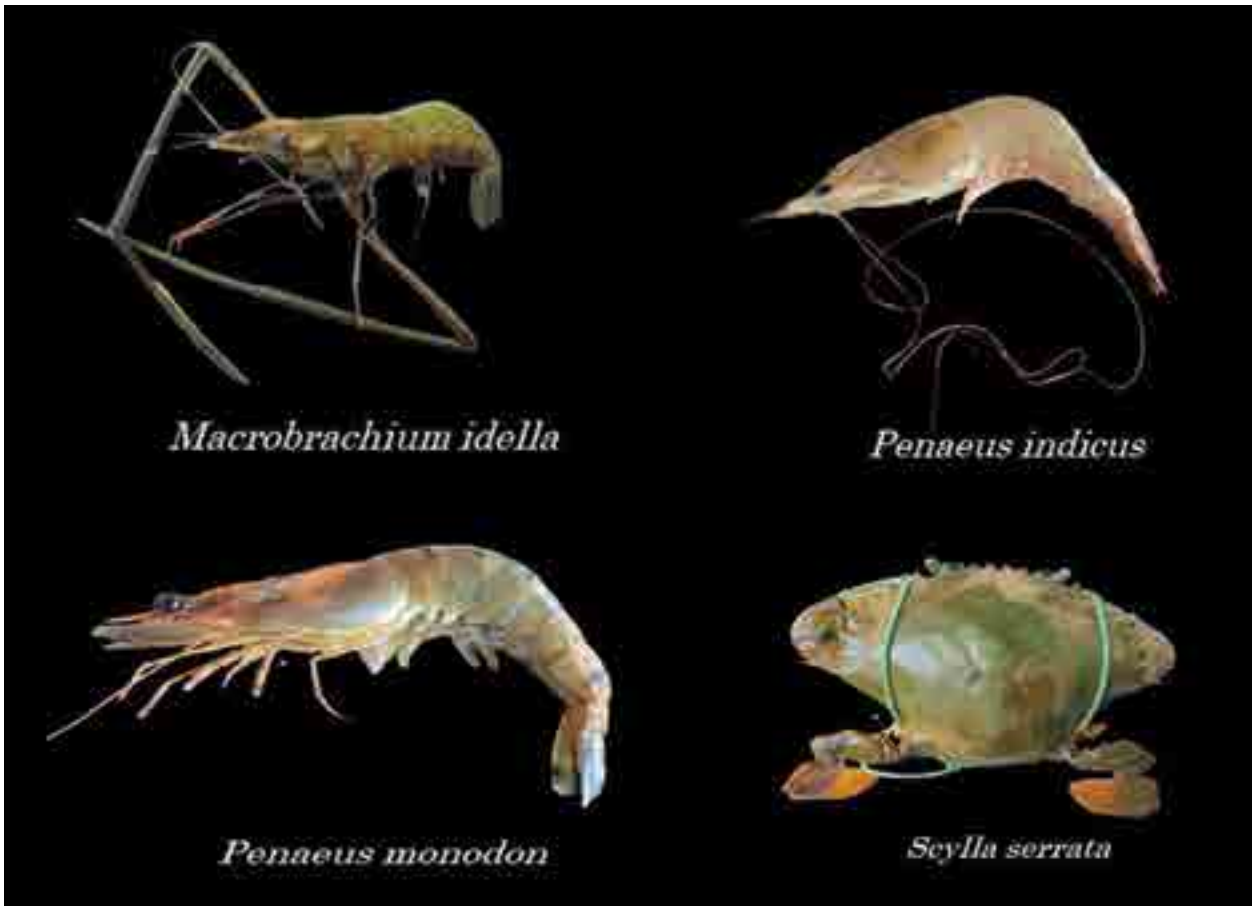

Image 2g. Shellfish species recorded from the Poonthura estuary. © Kiranya B.

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COMMUNICATION

A new species of *Protosticta* Selys, 1885 (Odonata: Zygoptera: Platystictidae) from Western Ghats, India

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Abstract: A new species of *Protosticta* Selys, 1885 is described from Anamalai Hills of southern Western Ghats in peninsular India. The new species is distinguished from its regional congeners by the posterior lobe of the prothorax being devoid of spines; anterior 1/3rd of S8 pale yellow, the marking not connected dorsally; S9 completely black; caudal appendages short, sinuous, and only twice the length of S10, cerci with a small blunt basal tooth; the tip of the superior lobe of cerci not bilobed but straight, paraprocts beveled at the tip, not clubbed; pterostigma of both wings trapezoidal with maximum length less than twice the breadth, forewing with nine & hindwing with eight postnodals, and the structure of male genital ligula. The new species is described from Peechi Wildlife Sanctuary on the northwestern flanks of the Anamalai hills. A key to the identification of *Protosticta* of the Western Ghats is provided based on mature males.

Keywords: Anamalai Hills, damselfly, endemic species, Kerala, new description, Peechi Wildlife Sanctuary.

Abbreviations: Ax—antenodal crossveins | Fw—forewing | Hw—hindwing | Px—postnodal crossveins | Pt—pterostigma | S1–10—abdominal segments | TL—total length of the specimen including appendages | AL—abdominal length | FL—forewing length | HL—hindwing length | TNHS—Travancore Nature History Society | TORG—Travancore Odonate Research Group | KS—Kalesh Sadasivan.

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Author contributions: KS discovered the species in field and wrote the manuscript. VPN did fieldwork and edited the drafts. AS helped with the drafting and edits of the final manuscript.

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INTRODUCTION

The genus *Protosticta* Selys, 1885 consists of slender built damselflies commonly known as reed-tails or shadow-damsels. They inhabit hill streams in tropical, subtropical, and temperate jungles of the Indian subcontinent and southeastern Asia. In India, they are distributed in the Western Ghats and northeastern region towards Myanmar (Fraser 1933). The genus was described from Sulawesi (formerly the Celbes) in Indonesia, with *Protosticta simplicinervis* Selys, 1885, as the type species. The genus has 53 extant species distributed from Pakistan, through the Indian subcontinent to Indo-China and southeastern Asian islands (Paulson et al. 2022). There are 15 species of *Protosticta* in the Indian region and 12 of them inhabit the Western Ghats: *P. gravelyi* Laidlaw, 1915, *P. hearseyi* Fraser, 1922, *P. sanguinostigma* Fraser, 1922, *P. antelopoides* Fraser, 1924, *P. mortoni* Fraser, 1924, *P. davenporti* Fraser, 1931, *P. rufostigma* Kimmins, 1958, *P. ponmudiensis* Kiran, Kalesh & Kunte, 2015, and *P. monticola* Emiliyamma & Palot, 2016 (Kiran et al. 2015; Emiliyamma & Palot 2016; Joshi et al. 2020). *Protosticta myristicaensis* Joshi & Kunte, 2020; *P. sholai* Subramanian & Babu, 2020; and *P. cyanofemora* Joshi, Subramanian, Babu & Kunte, 2020 were recently described from the Western Ghats (Joshi et al. 2020).

Odonates of this genus have relatively small interspecific differences which are as follows: the coloration of the head, thoracic and abdominal markings, the structure of the prothorax, and anal appendages in the male. Diagnostic characters of females include the structure of prothorax and anal appendages (van Tol 2009; Bedjanič et al. 2016; Joshi et al. 2020). During the faunal exploration of Anamalais near the Palghat gap in the southern Western Ghats, the authors came across an undescribed species inhabiting the mid-elevation streams. This taxon is here described as new to science. In addition, a key to the males of all known species of *Protosticta* from the Western Ghats is provided. Image 1 shows the type locality of the new species.

MATERIALS AND METHODS

Damselflies were collected in the field with an insect net and preserved in absolute ethanol as wet specimens. Nomenclature follows Subramanian & Babu (2017) and Paulson et al. (2022). Taxonomic keys to the species have been modified based on Fraser (1933) and Joshi et al. (2020). The morphological description follows Garrison et al. (2010). The known distribution of the species follows Subramanian et al. (2018) and Joshi et al. (2020). The wing venation terminology follows Riek & Kukalová-

Image 1. Map showing the type locality of *Protosticta anamalaica* sp. nov. in Anamalai hills.

Peck (1984). Measurements and morphological details of all species mentioned and compared in the text are based on specimens in voucher collections of TORG. Photographs of the specimens were taken with Canon EOS 70D DSLR fitted with 180 mm macro lens and MPE 65 f 2.8 1–5x lens. The anal appendages have been studied by dissecting them and illustrated by KS using a stereo-zoom microscope (HEADZ Model HD81). Comparison of caudal appendages were done from fresh material with the exception of *P. antelopoides* and *P. hearseyi*, which were referred from Fraser (1933), Emiliyamma & Palot (2016), and Joshi et al. (2020). The superior division/fork of the male cerci is termed as the superior lobe and the inferior is termed the inferior lobe. The genital ligula of the holotype is preserved and the illustration is based on another male paratype in TORG collection.

RESULTS

***Protosticta anamalaica* sp. nov.**

(Image 2D, 3, 5A–C,H,I)

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Material Examined

Holotype: TORG 1001, 26.xi.2021, male, Ponmudi Hill, Peechi Wildlife Sanctuary, Thrissur District, Kerala, India. 950 m, coll. Kalesh Sadasivan. Currently with TORG collections, Trivandrum, Kerala.

Paratype: (TORG 1002, 26.xi.2021, female, same data as of the holotype.

Holotype and paratype, both wet specimens, will be deposited in the insect collection facility of Zoological Survey of India (ZSI), Kozhikode.

Additional material studied: TORG 1003, male; TORG 1004 & 1005, females—all wet specimens in ethanol, bearing the same collection details as the holotype no. TORG 1001. These will be retained as voucher specimens in TORG collections. Two males and females were observed and photographed in the field but not collected, at the type locality.

Etymology: The species is named '*anamalaica*' after the Anamalai hills, on which lies Peechi Wildlife Sanctuary, the type locality.

Suggested common name: The Anamalai Reedtail is the common name suggested for this species based on its distribution in the Anamalai Hills.

Description of male holotype

(TORG 1001) (Image 1, 2, 3, 5A–E, 5 H & I)

Head (Image 3A,C,E). Eyes anteriorly greyish-blue, antero-dorsally black, greenish-brown postero-dorsally, and infero-laterally greenish-white. Mandible bluish-white, its inferior border, black, up to a third of its height. Labium pale translucent brown and anteriorly brown. Labrum is pale bluish-white, slightly darker compared to the antefrons, its entire free edge bordered in black which extends to one-fourth of the height of the labrum. Genae blackish-brown. Vertex dark bronze. Anteclypeus pale bluish-white. Postclypeus bronze metallic lustre. Antefrons and postfrons with dark metallic bronze lustre, extending into the ocular margin. Occiput matte brownish-black with an occipital bar having bronze tinge. Post-ocular lobe black. Ocelli waxy white. Antennae basal segment and half of the first segment translucent white, rest of the segments dark brownish-black. Sparse brownish hairs on the lateral aspect of the anteclypeus and free edge of the labrum. Long pale brown hairs along the inferior border of anteclypeus and on the labium.

Prothorax (Image 3E). The anterior lobe is almost half the length of middle lobe, posterior lobe is almost 2/3rd the length of the middle lobe. The general colour is brown but the notopleural suture and adjoining aspect of the anterior lobe are suffused in black. The junction of the anterior and middle lobe is demarcated in a suffused blackish band that extends vertically along the middorsal aspect. Superior two-thirds of propleuron are brown while its inferior third is pale brownish-white. There are no expansions or spines on the lobes of the prothorax. On ventral view, there is a central band of black on its posterior edge, between the coxae. The foreleg coxae, trochanter, femur, and tibia are pale brownish-white. The lateral aspect of the femur and tibia are stippled in brown. The spines, ends of the femur near the tibiofemoral joint, and the claws black.

Synthorax (Image 3C–E). General colour is brown marked with pale yellowish-white and black. On dorsal view, mesostigmal plate black. Mid-dorsal carina brown anteriorly and the posterior fourth is blackish. On the lateral view, the mesepisternum is shiny bronze and the mesepimeron brown. Mesinfraepisternum centrally dark brownish-black, superior fourth brown and inferior fourth brownish-white; markings suffused. Metepisternum with superior half pale yellowish-white, inferior half brown which turns black anteriorly. Metepimeron with the superior half of the anterior 3/4th brown, the rest pale yellowish-white. Metinfraepisternum brown and inferiorly margined in pale brownish-white. Metathoracic spiracle brown. On ventral view, venter of the metathorax is pale brownish-white, the rest matte black. The mid and hindleg coxae, trochanter, femur, and tibia are pale brownish-white.

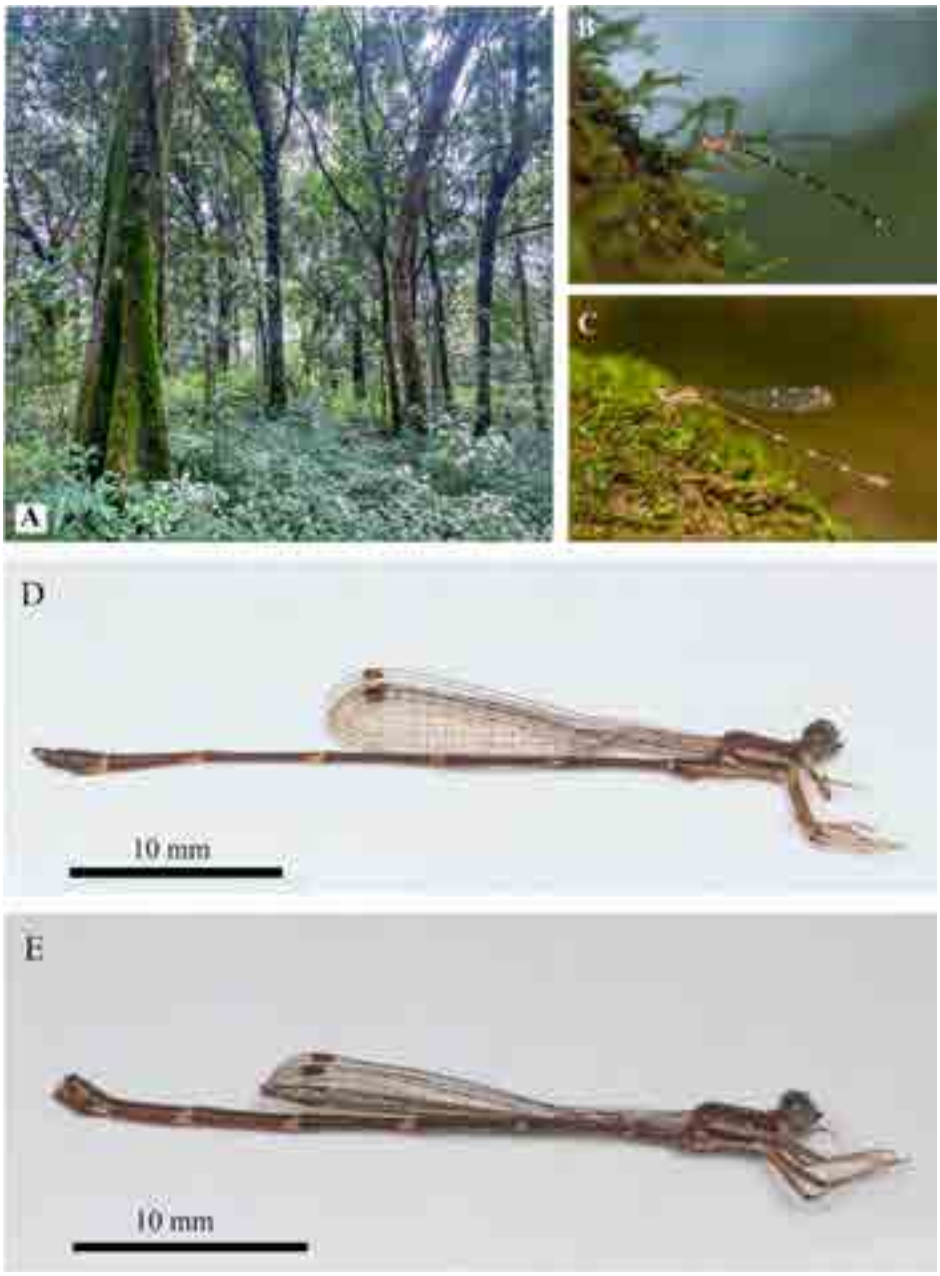

Image 2. *Protosticta anamalaica* sp. nov.: A—habitat, semi-evergreen forest | B—immature male in field | C—immature female in field | D—holotype male (TORG 1001) | E—paratype female (TORG 1002). © Kalesh Sadasivan.

The lateral (extensor) aspect of the femur and tibia are stippled in brown. Spines, ends of the femur near the tibiofemoral joint, and the claws dark brownish-black. Flexor aspect pale amber brown.

Wings (Image 5B,C). Hyaline; Pt of both wings brown occupying less than one and one-third cells, trapezoidal; anterior border slanting posteriorly; posterior border vertical thus making the superior border shorter than the inferior; inferior border almost straight. Pt length at its middle twice its breadth. Anal bridge absent. Ax–2 in all wings. Px– Fw 9 and Hw 8. The number of cells between the bifurcation of R2 and origin of IR2 in Fw is 1 and in Hw is 2.

Abdomen (Image 2D, 3A). General colour dark blackish-brown and marked in pale yellowish-white as follows: S1 laterally pale yellowish-white smudged in brown; S2 below a diagonal connecting the anterosuperior to the posteroinferior edges; S3–7 marked with very thin basal annuli, ventral part of them extending posteriorly than laterally; the mark on

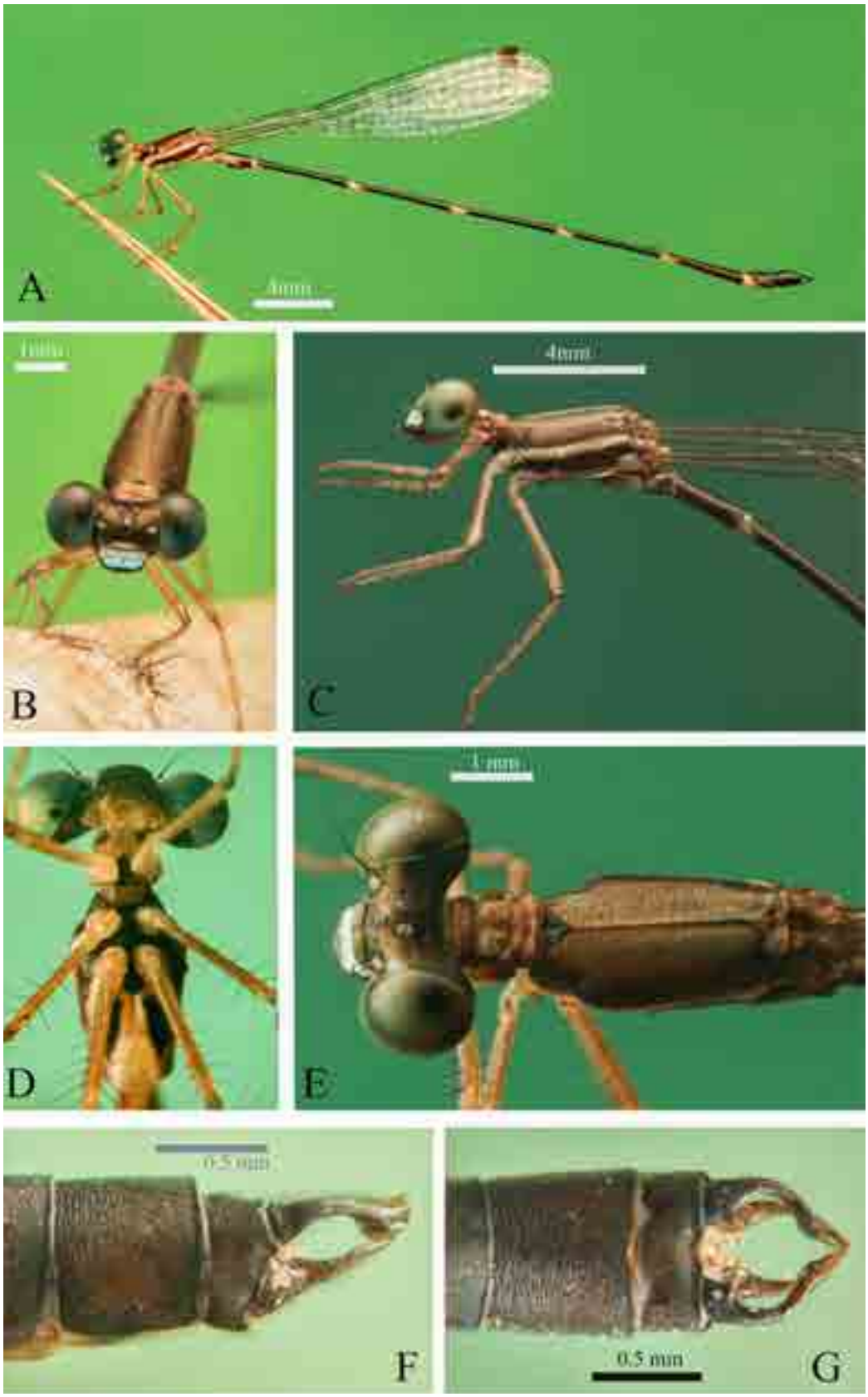

Image 3. *Protosticta anamalaica* sp. nov., holotype male (TORG 1001): A—lateral view of the whole insect | B—close-up of face | C—close-up view of lateral aspect of head, prothorax and synthorax | D—ventral side of synthorax | E—dorsal images of prothorax and synthorax | F—left lateral view of the caudal appendages of male | G—dorsal view of the caudal appendages of male. © Kalesh Sadasivan.

S7 extending thinly ventrally on its anterior thirds; the annuli of S3 conspicuously thinner (reduced to almost half) than on the rest of the segments. Annuli on S7 & S8 incomplete dorsally. S8 annulus is the largest of the annuli and on the ventrolateral aspect stops just short of its distal margin. S9 & S10 are fully black. Genital ligula as illustrated bearing very minute setae on either side of the shaft of the distal end of the first segment (Image 5 D, E), based on male paratype (TORG 1003).

Caudal appendages (Image 3F,G, 5H,I) Coloured black, the thinner tips of cerci and paraprocts brown. Length twice that of S10 on dorsal view. Cerci widest at the base; furnished with a small triangular tooth at the basal fourth of the cerci; middle third uniformly tapering and curved inwards. The distal third expands into the forcipate tip, with a superior and inferior lobe. The superior lobe is thick, with the tip straight and blunt, not incurved. The inferior lobe is thin and slightly shorter than the superior lobe. Outer margin of cerci sinuous with a depression/concavity at the origin of the superior lobe of cerci. Paraprocts uniformly curved inwards; long, ending just short of the distal end of the inferior lobe of the cerci. Paraprocts with tip bevelled dorso-ventrally and truncated not bulbous.

Measurements (mm). Total length (TL) 38.5 mm, abdominal length (AL) 33 mm, Fw length (FL) 19 mm, Hw Length (HL) 18 mm.

Description of female paratype

(TORG 1002) (Image 2E, 5F,G).

Head (Image 4B–E) Exactly as in the male. Labrum pale blue, its distal free margin jet black, this black extends to about half of its height in the midline. Mandible pale blue and its free end (distal third) jet black, the borders between the colours smudged. Anteclypeus pale bluish-white; postclypeus shiny bronze. Rest of the head the genae, vertex bronze. Occiput as in males. Eyes bluish as in males but slightly greener. Ocelli and antennae as in males.

Prothorax (Image 4E) as in males, no spines or ornamentations.

Synthorax (Image 4A–E) as in males.

Wings (Image 4A). Hyaline; Pt of both wings brown occupying less than one and one-third cells, trapezoidal; anterior border slanting posteriorly; posterior border vertical thus making the superior border shorter than the inferior; inferior border much more convex than in male. Pt length at its middle twice its breadth. Anal bridge absent. Ax–2 in all wings. Px– Fw 10 and Hw 10. The number of cells between bifurcation of R2 and origin of IR2 in Fw 1 and Hw 1.

Abdomen (Image 4A). Segments S1–S7 coloured as in the male, but shinier bronze with the caudal end of each segment almost black. Segment 8 bears the lateral triangular pale yellowish-white patch. Lateral aspect of S9 including its middle third reddish-brown, rest of it dark brown. Segment 10 dark brownish-black. S8 is twice the length of S10, while S9 is thrice the length of S10.

Caudal appendages (Image 5F,G). Cerci brownish-black, broader at the base, 0.6 times the length of S10, triangular in lateral view with a superior border slightly concave, tip blunt; paraprocts reduced, rounded brown, less than a third of the length of cerci; dorsal half of valve of ovipositor brown, ventral half dark brown, terebra brown, triangular, twice as long as cerci; ovipositor brown, ending in a brownish-black style reaching just beyond cerci and valve.

Measurements (mm). Total length (TL) 34.5 mm, abdominal length (AL) 27 mm, Fw length (FL) 19 mm, Hw Length (HL) 18 mm.

Variation in paratypes. In males, the variation was observed in the size total length (TL) 36.55 ±2.90 (n = 2). The Px is always 10 less than in both sexes but an occasional aberrant may have 11, unilaterally in Fw of females (n = 6).

Diagnosis The new species is distinguished from its congeners in the Western Ghats by the combination of posterior lobe of prothorax devoid of spines and its posterior border not expanded; anterior 1/3rd of S8 pale yellow and the marking not connected dorsally; S9 completely black; pterostigma dark brown, trapezoidal with a length twice the breadth, and Fw and Hw with 10 or less Px; cerci with a small blunt basal protuberance; paraprocts not clubbed at apices, the outer fork of cerci not bilobed, its tip being straight and not incurved.

Habitat and Ecology

The species was first collected from a mid-elevation semi-evergreen forest at 950 m bordering a secondary grassland in Peechi Wildlife Division on the western flanks of Anamalais in November 2021 (Image 2A). The females were first discovered perched on dark trunks of trees at heights less than 2 m above the forest floor (Image 2C). They flew to higher levels of the trunk when disturbed. The males were also found in the same habitat on tree trunks (Image 2B). The females generally outnumbered the males (males: female, 1:2). A small shallow perennial seepage (50 cm wide, 10 cm depth) was found within 150 m of the forest where the males and females were first sighted. Males were seen perched on the low fringing vegetation and twigs (<10 cm high)

Image 4. *Protosticta anamalaica* sp. nov., paratype female (TORG 1002): A—lateral view of the whole insect | B—close-up of face | C—dorsal images of prothorax and synthorax | D—close-up view of lateral aspect of head, prothorax, and synthorax. © Kalesh Sadasivan.

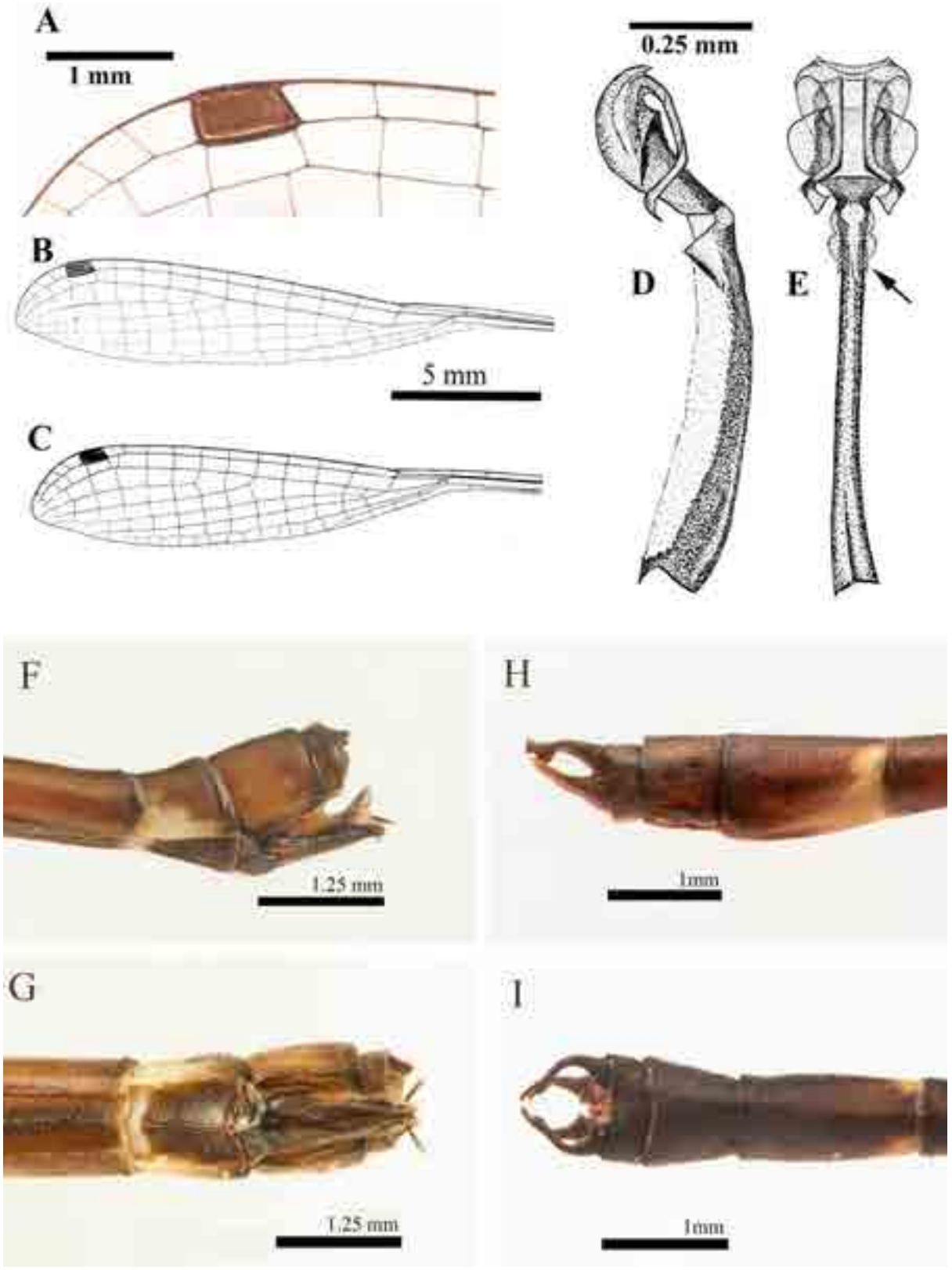

Image 5. ***Protosticta anamalaica*** **sp. nov.: A—pterostigma of left forewing of male (TORG 1001) | B—venation left forewing of male (TORG 1001) | C—venation left hindwing of male (TORG 1001) | D—lateral view of the genital ligula (TORG 1003) | E—ventral view of the genital ligula, black arrow pointing to the setae (TORG 1003) | F—left lateral view of female caudal appendages (TORG 1002) | G—ventral view of female caudal appendages (TORG 1002) | H—right lateral view of male caudal appendages and terminal segments S8–10 (TORG 1001) | I—dorsal view of male caudal appendages and terminal segments S8–10 (TORG 1001). © Kalesh Sadasivan.**

very close to the edge of the water defending their very small territories (roughly 25 cm^2). Males from adjacent territories were seen fighting head-on to protect their waterfront. The females were seen perched on dark shady pockets of the vegetation along the edges of the hill stream. Tenerals were also seen during the last week of November 2021. The damselflies sought shelter in the adjacent forest in windy weather.

DISCUSSION

Based on the structure of the male cerci, structure & coloration of prothorax, shape & colour of Pt, colour & pattern of eyes, labrum, mandibles, femur, and spot in S8 the new species can be easily separated from its congeners.

The new species of *Protosticta* is easily differentiated from *P. antelopoides* and *P. ponmudiensis* by the absence of any spines on its prothorax.

The recently described *P. myristicaensis* is small (TL <25 mm), has postclypeus bright blue and mandibles brown, while the new species is larger (TL >38 mm) postclypeus bronze colour and mandibles blue with black margins in *P. anamalaica* sp. nov.; anterior 1/3rd or more of S8 marked with bright turquoise-blue, the markings connected dorsally (S8 marking pale yellowish-white and incomplete dorsally in *P. anamalaica*); apical fork of cerci deeply incised more than 1/3rd of the total length and cerci with a small tubercle at the middle of the apical fork (shallow incision with no such tubercles in *P. anamalaica*).

From *P. gravelyi* and *P. mortoni,* the new species is diagnosed by the shallowly incised apical lobe of cerci, while the other two have them deeply incised more than 1/3rd of the total length. In addition, *P. gravelyi* has a hexagonal black marking covering the central portion of posterior lobe and a small portion of the middle lobe on the prothorax and *P. mortoni* has anterior and middle lobes of prothorax blue while no such marks or blue colour is seen in *P. anamalaica*, which has a brown prothorax with the notopleural suture and adjoining part of the anterior lobe suffused in black.

Protosticta hearseyi another small species (TL <30 mm), has blue prothorax and the caudal appendages are characterized by the very short inferior lobe of cerci, and superior lobe not expanded, while *P. anamalaica* has brownish prothorax and the inferior lobe of cerci only a little short of the superior.

P. davenporti and *P. rufostigma* has a different structure of male caudal appendages with the distal end of the superior lobe of cerci being consciously expanded on dorsal view, while it appears straight and rounded in the new species. The color of the prothorax is also different with the anterior and middle lobes of prothorax pale yellow, posterior lobe partially or completely black, while it is brown with black suffusion in the new species. The Pt in *P. rufostigma* is almost squarish with the length always less than twice the breadth, while the length of Pt is twice the breadth in *P. anamalaica.* The markings in S8 connected dorsally in *P. davenporti* and *P. rufostigma* (S8 marking pale yellowish-white and incomplete dorsally in *P. anamalaica*).

The S8 with the basal markings unconnected dorsally is a feature common to *P. sholai*, *P. sanguinostigma*, *P. cyanofemora*, *P. monticola,* and the new species. The recently described *P. sholai* has S9 laterally marked with a large yellow at the anterior border, reaching more than 2/3rd of the segment and paraprocts thin, long, and clubbed at apices, while it is unmarked and the paraprocts are not clubbed in *P. anamalaica.* Further, the mandibles are black and postclypeus bright blue in *P. sholai,* while mandibles are blue with black margins and postclypeus bronze in *P. anamalaica.* The downcurved cerci with a long robust basal spine, the bilobed tip of the superior lobe of cerci, and the brown equatorial band of eyes are characters of *P. sanguinostigma*, which the new species lack. Besides, the blood-red colour of the Pt and an elongated spot in S8 are also characteristics that *P. anamalaica* lacks. *Protosticta cyanofemora*, has eyes and flexor surface of femur bright blue (greyish-blue eyes and pale brownish legs in *P. anamalaica*). The mandibles and postclypeus are black in *P. cyanofemora* while the mandible is pale blue with a black margin, and postclypeus is bronze coloured in *P. anamalaica.* The prothorax purple, marked extensively with black in *P. cyanofemora*, while it is brown with a black smudge in *P. anamalaica.* The caudal appendage of the new species is similar to *P. cyanofemora,* but is shorter. The caudal appendages are more uniformly curved and only twice the length of S10 in *P. anamalaica*, while it is comparatively straighter and thrice the length of S10 in *P. cyanofemora.* The outer margin of the superior lobe of cerci in *P. cyanofemora* is relatively straight compared to the conspicuously convex margin of *P. anamalaica.* In field *P. anamalaica* superficially resembles *P. monticola,* from which it is diagnosed by the long Pt (length > twice the breadth) and the higher Px (always >10) in both wings of the latter. The caudal appendages are more uniformly curved and only twice the length of S10 in *P. anamalaica*, while it is comparatively straighter and thrice the length of S10 in *P. monticola*. Moreover, the tip of the superior

Key to species of *Protosticta* Selys, 1885 from Western Ghats based mature males modified from Joshi et al. (2020)

1 The posterior lobe of prothorax with spines 2
- Posterior lobe of prothorax without spines (Image 3E) 3

2 The posterior lobe of prothorax with a pair of long, divaricate horn-like spines; S7 faintly marked at base or unmarked; paraprocts bifid at apex ..... *P. antelopoides*
- Posterior lobe of prothorax with a pair of short lateral spines and internally two medial spines; S7 with extensive blue markings; paraprocts twisted and curved inwards, not bifid at apex ..... *P. ponmudiensis*

3 Anterior 1/3rd or more of S8 bright turquoise blue, connected dorsally 4
- Anterior 1/3rd of S8 yellow or blue, not connected dorsally (Image 5I) 9

4 Apical fork of cerci deeply incised more than 1/3rd of the total length 5
- Apical fork of cerci shallow incised, much less than 1/3rd of total length (Image 3F) 7

5 Cerci with a small tubercle at middle of the apical fork; length of abdomen + caudal appendages <25 mm ..... *P. myristicaensis*
- Cerci without such a tubercle at its center; length of abdomen + caudal appendages >25 mm 6

6 Prothorax with a hexagonal black marking covering central portion of posterior lobe and small portion of middle lobe; cerci with a prominent laterally pointed basal spine; paraprocts with an inner stout spine at base ..... *P. gravelyi*
- Anterior and middle lobes of prothorax colored blue, no hexagonal black mark; cerci with a small laterally pointed basal spine; paraprocts without an inner stout spine at base ..... *P. mortoni*

7 Prothorax completely blue; length of abdomen + caudal appendages <30 mm; inferior lobe of cerci very short, superior lobe not expanded ..... *P. hearseyi*
- Anterior and middle lobes of prothorax pale yellow, posterior lobe partially or completely black; length of abdomen + caudal appendages >30 mm; inferior lobe of cerci more than 1/3rd length of superior lobe, the latter expanded 8

8 Dorsum of middle portion of posterior lobe of prothorax completely black extending as two points to the dorsum of middle lobe; inner fork of cerci thin and small, superior lobe rounded at apices and more than twice the length of inferiror ..... *P. davenporti*
- Dorsum of posterior lobe of prothorax black, laterally brown; middle lobe of prothorax with a small dorsal faint black spot; inner fork of cerci thick, superior lobe ending in a quadrangle, less than twice the length of inferior ..... *P. rufostigma*

9 S9 completely black or marked only at ventral border; posterior border of prothorax not expanded; paraprocts not clubbed at apices 10
- S9 laterally marked with a large yellow at anterior border, reaching more than 2/3rd of the segment, not connected apically in both sexes; posterior border of prothorax expanded; paraprocts thin, long and clubbed at apices ..... *P. sholai*

10 Pt red; Cerci with a prominent and robust basal spine; tip of superior lobe of cerci bilobed ..... *P. sanguinostigma*
- Pt black or brown; cerci with a small blunt basal protuberance, inwardly pointed; tip of outer fork of cerci not bilobed 11

11 Pt rectangular with length more than twice the breadth; Px in all wings always 11 or more; caudal appendages thrice the length of S10; outer margin of cerci including the superior lobe comparatively straighter on dorsal view 12
- Pt trapezoid with length twice the breadth (Image 5A); Px in all wings 10 or less (Image 5B,C); caudal appendages only twice the length of S10 (Image 5H, I); outer margin of cerci sinuous; tip of superior lobe of cerci straight on dorsal view ..... ***P. anamalaica* sp. nov.**

12 Eyes blue; femur bright blue internally; S8 with a bright blue annule extended laterally 2/3rd of its length; tip of superior lobe of cerci straight ..... *P. cyanofemora*
- Eyes grey and brown; femur pale yellow internally; S8 black dorsally, ventro-laterally yellow extends to the distal end; tip of superior lobe of cerci bent inward at apices ..... *P. monticola*

Table1. Comparison of morphometric characters of *Protosticta monticola*, *P. cyanofemora* and *P. anamalaica* sp. nov., based on data from Emiliyamma & Palot, 2016, Joshi et al. (2020) and TORG specimens.

	Character of males, measurements in mm	*P. monticola*	*P. cyanofemora*	*P. anamalaica* sp. nov.
1	Total Length (TL)	41.0–44.0	37.3	38.5
2	Abdominal length (AL)	33.0–35.0	37.0	33.0
3	Fw length (FL)	23.0–24.0	22.6–23.0	19.0
4	Hw Length (HL)	21.0–22.0	21.9–22.2	18.0
5	Post nodal count Fw, Hw (Px)	12, 11	13, 11–12	9, 8

lobe of the tip of cerci is incurved in *P. monticola,* while it is straight in *P. anamalaica.* The two species are also niche separated, *P. monticola* is a montane species seen >1,600 m of the subtropical temperate forests while the new species is from the mid-elevations below 1,000 m as far as known in the tropical semievergreen forest belt. See Table 1 for a comparison of morphometric characters of the closely similar *P. monticola*, *P. cyanofemora,* and *P. anamalaica*.

CONCLUSION

The species *P. anamalaica* sp. nov. is an inhabitant of the first-order streams of mid-elevation forests of Anamalais in the Western Ghats. These species from seepages, streamlets, and hill streams are the most vulnerable in the wake of climate change (Rogers et al. 2020). As per Nair et al. (2021), the checklist of odonates of Western Ghats currently stands at 207 species with 80 endemics. The state of Kerala has 181 odonate species with 68 endemics (Nair et al. 2021). Thus, the addition of *P. anamalaica* raises the Odonata species diversity of Western Ghats to 208 species with 81 endemics, and that of Kerala to 182 species with 69 endemics. The discovery of a new species reiterates the fact that more systematic exploration of this biodiversity hotspot should be carried out in the southern Western Ghats, especially in the light of increasing anthropogenic influences and habitat transformations.

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COMMUNICATION

A case study on utilization and conservation of threatened plants in Sechu Tuan Nalla Wildlife Sanctuary, western Himalaya, India

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Abstract: During the course of surveys between 2016 and 2019 in the Sechu Tuan Nalla Wildlife Sanctuary, 37 species were reported of which, two critically endangered, 18 endangered, 13 vulnerable, four data deficient and one endemic to western Himalayas were recorded. All the species recorded are highly priced medicinal herbs. It also discussed the sustainable use and conservational approach adopted by the local people dwelling in the vicinity of the protected area for an endangered medicinal plant, *Fritillaria cirrhosa* D.Don.

Keywords: Endangered, endemic, *Fritillaria cirrhosa*, high altitude, Jangli lahsun, Pangi Valley, medicinal plants.

Abbreviations: STNWS—Sechu Tuan Nalla Wildlife Sanctuary | WS—Wildlife Sanctuary | GOI—Government of India | BSD—Herbarium of Botanical Survey of India, Northern Regional Centre, Dehradun | IUCN—International Union for Conservation of Nature | CAMP—Conservation Assessment and Management Prioritization | CITES—Convention on International Trade in Endangered species of Fauna and Flora | RDBIP—Red Data Book of Indian Plants | UT—Union territory.

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Author contributions: PK and HS did the field surveys and collection as well as drafting of the article. SKS help in making the article.

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INTRODUCTION

The biodiversity is deteriorating at faster rate and ecosystem services are greatly affected and are among one of the major issues encountered by humanity today (Piccolo 2017). Protected areas form the basis of biodiversity conservation worldwide and play a vital role in the rehabilitation of deteriorated natural habitat (Margules & Pressey 2000; Mashizi & Sharafatmandrad 2020). Assessment of threatened plant diversity of protected areas is essential for the protection and appropriate management of biodiversity. The study of protected areas offers plenty of scope for framing suitable management policies. These areas are important for the collection and documentation of scientific data on bio-resources which provide gateways for sustainable use and conservation. Several protected areas including national parks and wildlife sanctuaries have been evaluated for endemic and threatened plants throughout the country.

In this paper, we aim to highlight the sustainable approach towards the conservation and use of *Fritillaria cirrhosa* D.Don. (syn. *Fritillaria roylei* Hook.) by the people in and around the WS. *F. cirrhosa* D.Don is a threatened medicinal herb, flourishing well in high-altitude areas on grassy slopes (Image 2a–e) of western Himalaya of India (Jammu & Kashmir UT, Ladakh UT, Himachal Pradesh, and Uttarakhand), Afghanistan, and Pakistan. Local people of Pangi valley call it 'Jangli lahsun' otherwise known as 'Kakoli' in other parts of the Himalayan region. Bulbs of this Himalayan medicinal herb has an international market and are highly priced (INR 8,000–20,000 /kg). Bulbs are chiefly used in traditional Ayurvedic and Chinese medicine system. The plant flourishes in the upper reaches of the two forest beats (Tuan and Sechu) of the WS. The bulbs are beneficial in the cure of rheumatism, cough, fever and many other ailments (Kirtikar & Basu 1984). The species is prized for its immense medicinal properties and constitutes an important part of many herbal formulations (e.g., Astavarga, Chyavanprash). The tribal populace harvests the plant from the wild and sell it to the buyers sometimes directly or at times through middlemen. These middlemen are either agents of pharmaceutical or ayurvedic companies or of wholesale raw material suppliers that connect the distant farmer to the buyer. As a result of its relentless exploitation from the wild, this medicinal herb has become endangered in the Indian Himalayan region. The population status of the medicinally important species has deteriorated to the extent that it has now been considered endangered in Western Himalaya (IUCN 2001; Kuniyal et al. 2015). There is an urgent need to address the declining population of this species and to take initiative for suitable conservation strategies along with sustainable utilization.

The distribution of published information on the conservation status of plants can be effective to increase the level of awareness among stakeholders. Therefore, in the present communication, we also aimed to bring a list of the number of threatened plants which are growing in wild in the wildlife sanctuary. This study also highlights some of the threatened plants grown by local people and forest department officials. Some gap areas and recommendations are also provided in the paper.

MATERIALS AND METHODS

Study area

Sechu Tuan Nalla Wildlife Sanctuary is a remote WS in the interior Himalaya in the Pangi tehsil of Chamba district of Himachal Pradesh, India (Image. 1). It is home to many rare, endemic and threatened species of flora and fauna (GOI 2016). The WS was established in 1974 with a purpose of conservation of Brown Bear and Snow Leopard. However, it has also conserved over the years the rich floral wealth of the region. The flora is distinct with floral elements from temperate to alpine to cold desert biome. Several endemic and threatened plant species thrive and flourish in the region. This is due to the sustainable approach followed by the people inhabiting the eco-sensitive zone of WS, i.e., the *Pangwals* and the *Bhots* tribal communities. The sanctuary is in a very remote region with adverse climatic conditions and no proper road or telecom connectivity. People dwelling in these regions have no other option for their economic upsurge other than to market the local natural resources available. With the trending use of Ayurveda and traditional system of medicines in the modern-day world, there has been a gradual increase in demand of plant based Ayurvedic and medicinal products. The region being rich in medicinal plants especially highly priced Himalayan herbs is emerging as a supplier of raw materials.

Plant explorations and identification

Plant specimens were collected in the study site using a random sampling approach. Information on the uses of plants was collected from the local people inhabiting in the vicinity of the wildlife sanctuary. Informants comprised of 15 people from each village including elderly and younger ones. Local people were interviewed for the uses, cultivation practices and any potential threat to these species according to their perception.

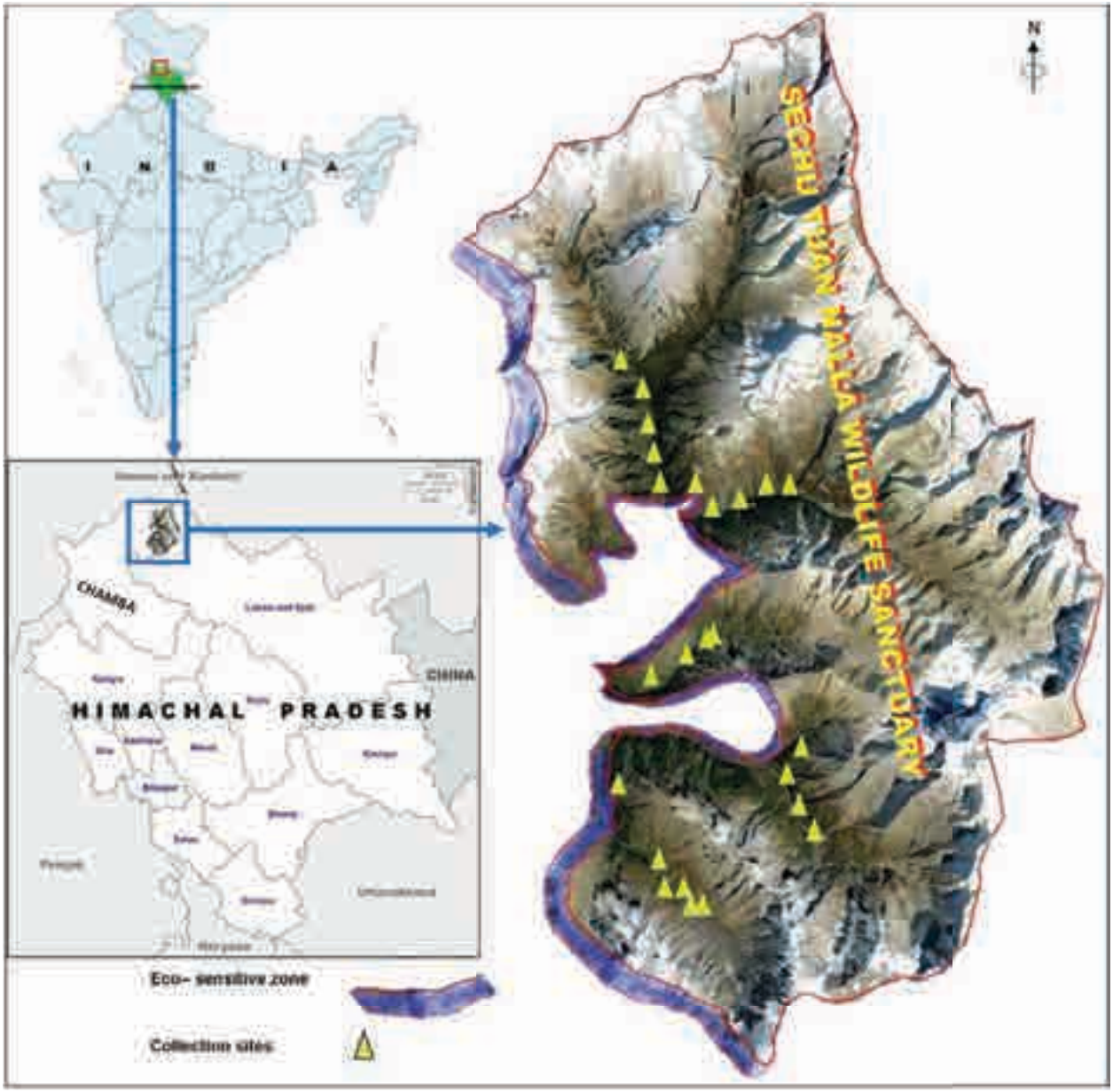

Image 1. Map of study area with collection sites in Sechu Tuan Nalla Wildlife Sanctuary in Chamba district, Himachal Pradesh, India.

The collected plant specimens were identified with the help of the herbarium (BSD) of Botanical Survey of India, Northern Regional Centre, Dehradun, Uttarakhand, India and other regional floras. Conservation status given in table 1 is as per Red List of plants in International Union for Conservation of Nature and Natural Resources (IUCN 2001), Conservation Assessment and Management Prioritisation (Ved et al. 2003), Convention on International Trade in Endangered (CITES, http://www.bsienvis.nic.in/Database/bsi_3949.aspx), Red Data Book of Indian Plants (Jain & Sastry 1980, 1984; Nayar & Sastry 1987, 1988, 1990; Rao et al. 2003) and recent literature (Rawat 2005; Rana & Samant 2010) on assessment of these plants in western Himalaya by various active and prominent researchers.

RESULTS

Overall, 37 threatened and endemic plant species (Table 1, image 3a–f) were found in the sanctuary and its environs. A total of two species, *Lilium polyphyllum* D.Don and *Saussurea costus* (Falc.) Lipsch. or 5.40% of taxa assessed were listed as Critically Endangered (CR) (Figure

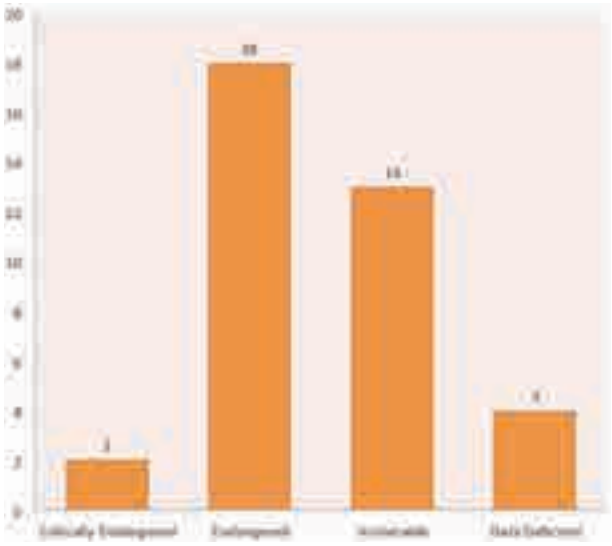

Figure 1. Number of species in various threat catagories.

1). In the meantime, 18 (48.65%) of taxa were classified as Endangered (EN) and 13 (35.14%) were classified as Vulnerable (VU). Another four (10.81%) were listed as Data Deficient (DD) which means that there is inadequate data for appropriate assessment of conservation status to be prepared. As far as the frequency of occurrence in the study is concerned, out of 37 species, 28 (75.68 %) are infrequent while nine (24.32 %) are scarce in the study area.

DISCUSSION

Local people of Pangi valley call it Jangli lahsun otherwise known as kakoli in other parts of Himalayan region.

'Praja', the local indigenous governing body plays a major role in managing the local resources of the area. The Praja is a local institution comprising of at least a single member of every household in the village and acts as an administrative and social reforming body. The Praja appoints people of the village to keep an eye on any kind of illegal activity by outsiders that may destroy the plants in the wild. People or other tourists need to get themselves registered or to provide prior information at the village before entering the adjoining forest during the harvest season.

The systematic and phase-wise collection of bulbs of Jangli lahsun from the wild is allowed to only the inhabitants of hilly regions of the state (Badola & Butola 2004). However, no one can harvest the plant before the seed is set and dispersed; ensuring sufficient seed is available for germination for the next year. While collecting the bulb of the plant care is taken not to disturb the adjoining vegetation. Such simple yet powerful efforts by the locals have led to a very healthy population of the species in Tuan Forest beat of the WS. Therefore, these traditional practices keep a check on illegal means of exploitation of this plant species and have positive effects on its conservation. On the contrary, Sindhani Dhar, an inaccessible region of the WS from the Sechu beat was once home to a very healthy population of Jangli lahsun, which over the span of 4–5 years was ruined by outsiders from the adjoining regions. The plant was so badly exploited in the Sindhani region that the population once in thousands came to a scattered few plants. Habitat degradation has also led to substantial pressure on the wild population of *F. cirrhosa* in many parts of western Himalaya. The population of the species in the western Himalaya has declined to an alarming situation (Chauhan et al. 2011). This decline is attributed to the uprooting of the whole individual at early growth stages before the seed sets. Bisht et al. (2016) cited some other factors such as early snowfall and frequent grazing by migratory animals in alpine meadows which affected the regeneration of the species. The species population has declined to the level that it has been put into the endangered category in western Himalaya (IUCN 2001; Kumar et al. 2011; Kuniyal et al. 2015; Bisht et al. 2016). All the species of an ecosystem are important and equally contribute to stabilizing a particular ecosystem, and loss of a single species can have grave consequences. Therefore, regardless of medicinal or any other importance, all the species should be treated important for the preservation of biodiversity.

Positive approach through sustainable utilization coupled with conservation efforts

The traditional practices to keep check on illegal means of exploitation of this plant species have positive effects on its conservation. Probably the lacuna is that there is no such effective and efficient management plan existing in the area for cultivation of most other medicinal endangered plant species except for few. *Dioscorea deltoidea* Wall. ex Kunth, *Picrorhiza kurroa* Royle ex Benth., *Sinopodophyllum hexandrum* (Royle) T.S.Ying, *Saussurea costus* (Falc.) Lipsch. are being cultivated in the forest nurseries (Image 4). Both the extraction of the medicinal plants for household purpose by the local people and illegal destructive harvesting by outsiders is mainly from wild populations. As the socio-economic condition of the local inhabitants depends upon the natural resources available, cultivation of medicinal

Table 1. Endemic and threatened species from Sechu Tuan Nalla Wildlife Sanctuary.

Name of species	Local name (if any)	Family	Habit	Locality with altitude	Collection no.	Conservation Status as per IUCN, CAMP, RDBIP& Regional Publications	Occurrence in study area	Cause
1. *Acer caesium* Wall. ex Brandis		Aceraceae	Tree	Saichu Dhar, 2,888 m	Puneet Kumar 127737 (BSD)	VU	Scarce	Exploitation in the past for timber.
2. *Aconitum violaceum* Jacquem. ex Stapf		Ranunculaceae	Herb	Chasak Bhattori to Sechu, 3,696 m	Puneet Kumar 127624 (BSD)	VU	Infrequent	Over exploitation of medicinal roots.
3. *Aconitum heterophyllum* Wall. ex Royle	Atish	Ranunculaceae	Herb	Along Sindhmarh Nalla, 3,592 m	Puneet Kumar 127609 (BSD)	EN	Infrequent	Over exploitation of medicinal roots.
4. *Allium stracheyi* Baker	Jambu	Alliaceae	Herb	Eco-sensitive zone around Hillu-Tuan, 3,272 m	Puneet Kumar 128034 (BSD)	VU	Scarce	Exploitation of corms.
5. *Angelica glauca* Edgew.	Chura	Apiaceae	Herb	Eco-senstive zone (on way to Chasak Bhatori), 3,453 m	Puneet Kumar 132603 (BSD)	EN	Infrequent	Over exploitation of medicinal rhizomes.
6. *Aralia cachemirica* Decne.		Araliaceae	Herb	Harbi Dhar, 3,457 m	Puneet Kumar 127305 (BSD)	VU	Scarce	Very few individuals. Endemic to NW Himalaya.
7. *Arenaria neelgherrensis* Wight & Arn.		Caryophyllaeae	Herb	Pepe Nalla, Chasakh Bhatori, 3,988 m	Puneet Kumar 127451 (BSD)	DD	Scarce	Very few individuals.
8. *Berberis pseudoumbellata* R. Parker	Kiamal	Berberidaceae	Shrub	Harbi Dhar, 3,128 m	Puneet Kumar 127817 (BSD)	DD	Infrequent	Exploited for medicinal uses.
9. *Bergenia ciliata* (Haw.) Sternb.	Shapdochi	Saxifragaceae	Herb	On way to Sidhani Dhar 2,712 m	Puneet Kumar 127961 (BSD)	VU	Infrequent	Exploitation of medicinal rhizomes.
10. *Bergenia stracheyi* (Hook.f. & Thomson) Engl.	Shapdochi	Saxifragaceae	Herb	Along Triund Nalha towards Chogalu Dhar, 3,551 m	Puneet Kumar 132519 (BSD)	VU	Infrequent	Exploitation of medicinal rhizomes.
11. *Bunium persicum* (Boiss.) B. Fedtsch.	Kala Zeera	Apiaceae	Herb	Eco-sensitive zone, Mujh village, 3,121 m	Puneet Kumar 128032 (BSD)	EN	Infrequent	Exploitation directly from wild, whole plant uprooted for seeds.
12. *Corallorhiza trifida* Châtel.		Orchidaceae	Herb	Sidhani Dhar, 3,469 m	Puneet Kumar 132562 (BSD)	EN, CITES Appendix II	Infrequent	Limited distribution with few individuals (single locality in study area) in Western Himalaya.
13. *Dactylorhiza hatagirea* (D. Don) Soó	Hathpanja or Salam Panja	Orchidaceae	Herb	Eco-sensitive zone near Sindhari, 3,544 m	Puneet Kumar 127643 (BSD)	EN CITES Appendix II	Scarce	Over exploitation of medicinal root-tubers.
14. *Dioscorea deltoidea* Wall. ex Kunth		Dioscoreaceae	Climber	Harbi Dhar, 3,350 m	Puneet Kumar 127309 (BSD)	EN, CITES Appendix II and Negative List of Exports	Infrequent	Decline in population owing to over exploitation of medicinal/edible rhizome. Tough to cultivate commercially due to its very slow growth.
15. *Epipactis helleborine* (L.) Crantz		Orchidaceae	Herb	Sidhani Dhar, 2,879 m	Puneet Kumar 132591 (BSD)	VU, CITES Appendix II	Infrequent	With very few individual and habitat specific.

Name of species	Local name (if any)	Family	Habit	Locality with altitude	Collection no.	Conservation Status as per IUCN, CAMP, RDBIP& Regional Publications	Occurrence in study area	Cause
16. *Eremurus himalaicus* Baker	Piyau	Asphodelaceae	Herb	Sidhani Dhar, 2,931 m	Puneet Kumar 128011 (BSD)	EN, Endemic to Western Himalaya.	Infrequent	Exploited for edible foliage roots.
17. *Ferula jaeschkeana* Vatke	Kurash	Apiaceae	Herb	Along Triund Nalha, 3,207 m	Puneet Kumar 127872 (BSD)	EN	Infrequent	Exploited for medicinal uses.
18. *Fritillaria cirrhosa* D. Don	Jangli Lahsun	Liliaceae	Herb	Along Triund Nalha towards Chogalu Dhar, 3,503 m	Puneet Kumar 128149 (BSD)	EN	Infrequent	Ashtavarga herb, Bulbs (medicinal) are sold at very high prices Rs. 4000-5000/kg. Extracted from wild and no cultivation.
19. *Gymnadenia orchidis* Lindl.		Orchidaceae	Herb	Sidhani Dhar, 3,625 m	Puneet Kumar 132561 (BSD)	EN, CITES Appendix II	Infrequent	With very few individuals in study area.
20. *Hedysarum astragaloides* Benth. ex Baker		Fabaceae	Herb	Pepe Nalla, Chasakh Bhatori, 3,826 m	Puneet Kumar 127422 (BSD)	DD	Infrequent	With very few individuals in study area.
21. *Hedysarum microcalyx* Baker		Fabaceae	Herb	Towards North of Bhatori Seri along Sindhmarh Nala, 3,693 m	Puneet Kumar 127557 (BSD)	Vulnerable	Scarce	With very few individuals in study area.
22. *Hyoscyamus niger* L.	Khurasani Ajwain	Solanaceae	Herb	Saichu Dhar, 2,868 m	Puneet Kumar 127755 (BSD)	VU	Infrequent	Over exploitation of medicinal.
23. *Dolomiaea macrocephala* DC.	Dhoop	Asteraceae	Herb	Along Sindhmarh Nalla, 3,294 m	Puneet Kumar 127602 (BSD)	EN	Infrequent	With very few individuals in study area. Exploitation of aromatic and medicinal rhizome.
24. *Lilium polyphyllum* D. Don	Ksheerkakoli	Liliaceae	Herb	Along Sindhmarh Nalla, 3,405 m	Puneet Kumar 127594 (BSD)	CR	Infrequent	Ayurvedic herb. Harvested for its bulbs. A whole plant is uprooted and disturbed. Of its total Geographical distribution in Himalayan region, 80% is in India.
25. *Malaxis muscifera* (Lindl.) Kuntze	Rshbhak	Orchidaceae	Herb	Towards north of Bhatori Seri along Sindhmarh Nalla, 3,595 m	Puneet Kumar 127549 (BSD)	EN, CITES Appendix II	Infrequent	Ashtavarg herb. Corms medicinal.
26. *Meconopsis aculeata* Royle	Veerbhuti	Papaveraceae	Herb	Pepe Nalla, Chasakh Bhatori, 3,740 m	Puneet Kumar 127468 (BSD)	EN	Scarce	Exploited for medicinal uses. Habitat destruction.
27. *Picrorhiza kurroa* Royle ex Benth.	Kour	Plantaginaceae	Herb	Sidhani Dhar, 3,670 m	Puneet Kumar 132569 (BSD)	EN, CITES Appendix II and Negative List of Exports	Infrequent	Over exploitation of medicinal rhizomes.

Name of species	Local name (if any)	Family	Habit	Locality with altitude	Collection no.	Conservation Status as per IUCN, CAMP, RDBIP& Regional Publications	Occurrence in study area	Cause
28. *Sinopodophyllum hexandrum* (Royle) T.S. Ying	Bankakri	Berberidaceae	Herb	Along Jambu Nalla towards Ghatitar, 3,302 m	Puneet Kumar 127258 (BSD)	EN, CITES Appendix II and Negative List of Exports	Infrequent	Over exploitation from wild for its medicinal value.
29. *Polygonatum cirrhifolium* (Wall.) Royle	Salam mishri	Convallariaceae	Herb	Sidhani Dhar, 2,716 m	Puneet Kumar 132577 (BSD)	VU	Infrequent	Ashtavarga herb Rhizomatous rootstock medicinal.
30. *Polygonatum verticillatum* (L.) All.	Salam mishri	Convallariaceae	Herb	Along Triund Nalha towards Chogalu Dhar, 3,504 m	Puneet Kumar 132510 (BSD)	VU	Infrequent	Ashtavarga herb Rhizomatous rootstock medicinal.
31. *Rheum spiciforme* Royle	Chukri or Revand chini	Polygonaceae	Herb	Sidhani Dhar, 3,177 m	Puneet Kumar 132599 (BSD)	VU	Scarce	Exploitation of medicinal rootstock.
32. *Rheum webbianum* Royle	Chukri or Revand chini	Polygonaceae	Herb	Pepe Nalla, Chasakh Bhatori, 3779 m	Puneet Kumar 127455 (BSD)	VU	Infrequent	Exploitation of medicinal rootstock.
33. *Saussurea costus* (Falc.) Lipsch.	Kuth	Asteraceae	Herb	Towards North of Bhatori Seri along Sindhmarh Nalla, 3,677 m	Puneet Kumar 127501 (BSD)	CR, CITES Appendix I and Negative List of Exports	Infrequent	Indiscriminate collection (for its roots) and destruction of habitat. Few individuals in cultivation in the vicinity of villages.
34. *Saussurea roylei* (DC.) Sch. Bip.		Asteraceae	Herb	Sidhani Dhar, 3,959 m	Puneet Kumar 132553 (BSD)	DD	Infrequent	Whole plant is exploited for medicinal uses.
35. *Taxus wallichiana* Zucc.	Rakhal	Taxaceae	Tree	On way to Sidhani Dhar, 2,879 m	Puneet Kumar 132587 (BSD)	EN, CITES Appendix II and Negative List of Exports	Infrequent	Over exploitation of medicinal bark.
36. *Trillium govanianum* Wall. ex D. Don	Nag Chhatri	Trilliaceae	Herb	Sidhani Dhar, 3,240 m	Puneet Kumar 132532 (BSD)	EN	Scarce	Exploited for medicinal uses.
37. *Trollius acaulis* Lindl.		Ranunculaceae	Herb	Seen on way to Sidhani Dhar, 3,176 m		EN	Infrequent	Only three individuals seen in single locality near glacier.

CR—Critically Endangered | EN—Endangered | VU—Vulnerable | DD—Data Deficient | BSD—Herbarium of Botanical Survey of India, Northern Regional Centre Dehradun.
Note: Due to sensitivity of critically endangered species we are not giving geo-coordinates here in this communication however, in case anybody required data for genuine research purpose can get information by contacting the corresponding author.

Image 2 (a–e). a—*Fritillaria cirrhosa* D. Don., growing in its natural habitat on alpine grassy slopes, single flower in inset | b—Three terminal solitary drooping flower's top view | c—Inverted flower view to show stigma and anthers | d—Upright maturing capsules coming out of the withering floral parts | e—Bulb (arrowed), along with two uprooted young plants. © Puneet Kumar.

Image 3. (a–f) Threatened plants. a—*Dactylorhiza hatagirea* (D. Don) Soó | b—*Trillium govanianum* Wall. ex D. Don | c—*Lilium polyphyllum* D. Don | d—*Saussurea costus* (Falc.) Lipsch. | e—*Sinopodophyllum hexandrum* (Royle) T.S. Ying | f—*Picrorhiza kurroa* Royle ex Benth. © Puneet Kumar.

and aromatic plants should be encouraged among the farmers for their betterment. Though the local people have shown interest in the cultivation of these medicinal plants, the efforts turn out to be futile probably due to unscientific cultivation practices. The scientific community should come forward to help in improving the methods of cultivation presently employed by these farmers. Although many of the important medicinally

Image 4. A forest nursery in the vicinity of study area. © Harminder Singh.

threatened plants still need more research to bring them successfully to the farmer's field for cultivation, priority should be given to the restoration and rehabilitation of these medicinal plants in their natural habitat. Otherwise, direct extraction from wild resources may result in the vanishing of these important medicinal plants from this remote area of western Himalaya.

These plants are used by the locals in a sustainable way and not harvested before seed is set. The plants are left untouched when local tribes collect fodder for winter stock. As a result, majority of the populations of these medicinal plants are flourishing well near the villages in the vicinity of eco-sensitive zone of the sanctuary. Furthermore, it is suggested local nurseries should be strengthened with recent cultivation techniques of plants of high altitudes and also local people should be made aware of the natural resources around them by conducting awareness programs and workshops. Increasing awareness on the part of people can improve the possibility of endurance of rare, endemic, threatened, and medicinal plant species.

CONCLUSION

The study highlighted the sustainable approach of local people towards the use of resources around the WS. Local people and their efforts are the very essence that has conserved the floral heritage of the Great Himalaya over the centuries. Linking local communities to conservation programs for natural resources and management of forests can be the way forward to biodiversity protection and sustainable development. The study highlighted the sustainable approach of local people towards the use of resources around the WS.

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COMMUNICATION

A survey of ethno-medicinally important tree species in Nauradehi Wildlife Sanctuary, central India

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Abstract: The study was carried out in Nauradehi Wildlife Sanctuary, central India. The forest is classified as a tropical dry deciduous type, with teak *Tectona grandis* as the predominant species. Extensive field trips were carried out during 2018–2020 to document the medicinally important tree species. The medicinal importance of these plants was recorded through interviews, group discussions with local tribal communities and on the basis of the literature available. Enumeration of tree species in this area showed occurrence of 50 tree species belonging to 37 genera and 21 families. The study further observed that several species were being used as traditional medicine by the local tribal folks, traditional healers in the study area, and also by pharmaceutical industries. The study observed that some species in the sanctuary were rare due to several developmental projects, forest destruction, and over-exploitation. The study provides details about the botanical identity, family, local name, plant parts utilised and uses for treatment of diseases. The present paper identified the tree species for their conservation status and accordingly recommends the priority for their conservation in the study area. We recommend that tree species documentation might be helpful for drug formulation and the preservation of traditional knowledge.

Keywords: Ethnobotany, forest trees, Madhya Pradesh, traditional medicines, tropical dry deciduous forest.

Hindi: यह अध्ययन मध्य भारत के नौरादेही वन्यजीव अभयारण्य में किया गया था। जंगल को एक उष्णकटिबंधीय शुष्क पर्णपाती प्रकार के रूप में वर्गीकृत किया गया है, जिसमें सागौन (टेक्टोना ग्रैंडिस) प्रमुख प्रजाति के रूप में हैं। औषधीय रूप से महत्वपूर्ण वृक्ष प्रजातियों का दस्तावेजीकरण करने के लिए 2018-2020 के दौरान व्यापक क्षेत्र यात्राएं की गईं। इन पौधों के औषधीय महत्व को साक्षात्कार, स्थानीय आदिवासी समुदायों के साथ समूह चर्चा और उपलब्ध साहित्य के आधार पर दर्ज किया गया था। इस क्षेत्र में वृक्ष प्रजातियों की गणना में 37 जेनरा और 21 परिवारों से संबंधित 50 वृक्ष प्रजातियों देखी गई। अध्ययन में आगे पाया गया कि स्थानीय आदिवासी लोगों, अध्ययन क्षेत्र के पारंपरिक चिकित्सकों और दवा उद्योग द्वारा कई प्रजातियों का उपयोग पारंपरिक चिकित्सा के रूप में किया जा रहा था। अध्ययन में पाया गया कि कई विकास परियोजनाओं, वन विनाश और अति-शोषण के कारण अभयारण्य में कुछ प्रजातियां दुर्लभ थीं। यह अध्ययन वानस्पतिक पहचान, परिवार, स्थानीय नाम, पौधों के उपयोग और रोगों के उपचार के लिए उपयोग के बारे में विवरण प्रदान करता है। वर्तमान शोध पत्र में वृक्ष प्रजातियों की उनके संरक्षण की स्थिति के लिए पहचान की गई और तदनुसार अध्ययन क्षेत्र में उनके संरक्षण के लिए प्राथमिकता की सिफारिश की गई है। हम अनुशंसा करते हैं कि वृक्ष प्रजातियों के दस्तावेज औषधि निर्माण और पारंपरिक ज्ञान के संरक्षण के लिए सहायक हो सकते हैं।

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Author contributions: TK collected the data, conduct the field work, analysis and designed the manuscript, AK helped to conduct the field work, AJB helped in the manuscript writing and field work, PKK helped in plant identification and manuscript writing.

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INTRODUCTION

Biodiversity is an essential component of our health and existence (Ogunkunle et al. 2019). India is the largest producer of medicinal herbs and hence termed as the 'botanical garden' of the world (Seth & Sharma 2004). It is estimated that more than 50,000 plant species are utilised for medicinal purpose around the world (Schippmann et al. 2002). Ethno-botany is a growing field of research that studies the utilization of various plant species and their qualities as food, medicine, and other purposes (Prescott-Allen & Prescott-Allen 1990). Nature has been a source of medicines for thousands of years, and plant-based system continues to play an essential role in primary health care for 80% of the world's population (Gupta 2001). In the beginning, these were the main sources of folk or ethno-medicine (Bargali & Shrivastava 2002). During the last few decades, there has been an increasing interest in the study of medicinal plants and their traditional use in different parts of the world (Hanazaki et al. 2000; Al-Qura'n 2005). In India, since early times, human beings have been exploring plants for various uses such as fodder, food, medicines, fuel-wood, resins, timber, gums, papers, tannins, spices, and beverages (Samant et al. 1998; Bargali et al. 2009; Swamy et al. 2010). Madhya Pradesh has the biggest proportion of India's tribal population. According to the 2011 census, the state's tribal population is 15.31 million which constitutes about 21.1 percent of the total population. Madhya Pradesh harbors 46 tribal communities with over 100 ethnic groups. The state has a high level of biodiversity and ethno-diversity. The indigenous people are dependent on the forest for food, shelter, medicine, and clothing. To meet their daily needs, they harvest non-timber forest products (NTFPs) such as roots, tubers, flowers, fruits, fibres, gum, resin, dye, tannins, honey, and wax. A major part of the Sanctuary is covered by dense forest in which Gond tribes are predominant. Medicinal plants are the only easily accessible health care alternative for most of the population in rural and tribal area. About 85% of the rural population of India depends on wild varieties of medicinal plants for the treatment of various diseases. It is still considered the first line of primary health-care even in the present age to major segments of the population worldwide (Jain et al. 2011; Gwalwanshi & Bishwas 2016). Even today, plant materials continue to play a major role in primary health care as therapeutic cures in many developing countries (Lawal et al. 2010). It has been reported that natural products (their derivatives and analogues) represent over 50% of all drugs in clinical use, in which natural products derived from higher plants represent about 25% of the total (Cragg & Newman 2013). The World Health Organization assessed that over 80% of the people in developing countries depend on traditional remedies, for their day to day needs and about 855 traditional medicines including crude plant extracts (Tilburt & Kaptchuk 2008). With the growing threat of losing traditional knowledge in the recent time, several efforts have been made to record and publish this knowledge. In the past few years, there has been a renewed interest in traditional medicine worldwide. The traditional knowledge of herbal medicine and practises transferred from generation to generation has been challenged by modern medicine and technology. Many of these traditional remedies have been largely forgotten or are really no longer practiced (Gruyal et al. 2014). Knowledge or information about traditional herbal medicine is no longer recognised as beneficial particularly among the younger and more educated population (Ducusin 2017). This present study was conducted to document the knowledge of indigenous plant utilization and healthcare practices utilizing tree species by tribals and villagers in the Nauradehi Wildlife Sanctuary and to enumerate the tree species richness and their ethnomedicinal values.

MATERIALS AND METHODS

Study area

The Nauradehi Wildlife Sanctuary in central India covers an area of about 1,197.042 km^2. It lies between 23.083–23.716 N and 79.083–79.416 E, at an average altitude of 600 m above mean sea level (Figure 1). It comprises the reserved and protected forests of South Sagar, Damoh, and Narsingpur forest divisions. Based on average annual rainfall, temperature and humidity conditions, the climate of the Sanctuary can be broadly termed as seasonal. The year is divisible into three well-marked seasons, i.e., rainy (mid June–September), winter October–February), and summer (March–mid June). The average annual rainfall of the area is 1,200 mm. About 90% of the annual rainfall is received during the south-west monsoon period, only 5.5% and about 4.5% during winter and summer seasons, respectively. January is the coldest month with temperature as low as 5 ^{0}C. Highest temperature reaches up to 48 ^{0}C during the month of May.

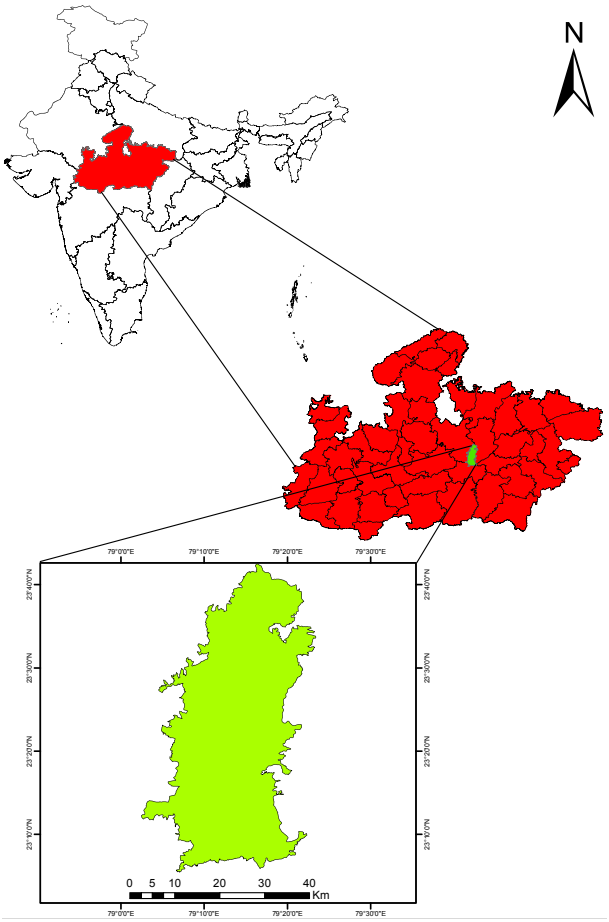

Figure 1. Map of Nauradehi Wildlife Sanctuary.

Sampling

Field survey of the sanctuary was done during 2018–2020 in different seasons of each year to collect all the forest tree species from each sub habitat, i.e., plateau, slopes, and plains. Further, areas with varying microclimate conditions such as moist, dry, and mesic places were given emphasis for plant collection. Specimens were shown to local indigenous people for local names and their medicinal uses. Their traditional knowledge for use and preparation of decoction/ powdering was also documented. These specimens were dried and pressed in the field and transported to the laboratory and were prepared and deposited in the Herbarium, Department of Botany, Dr. Harisingh Gour Central University, Sagar, Madhya Pradesh. For identification, micro-morphological characters of the plant were detailed. All the specimens were critically examined and identified with the help of different flora and published literature (Mudgal et al. 1997; Singh et al. 2001; Verma et al. 1993). The threat status of the identified plant species were assessed after consultation with relevant literature (IUCN 2021; Khanna et al. 2021; Vattakaven et al. 2016). Medicinal plant species are alphabetically addressed in tabular form, accompanied by the author's abbreviations, family name, local name, parts used and disease treatment (Table 1).

RESULTS AND DISCUSSION

Across the study area, a total of 50 species belonging to 37 genera and 21 families were recorded. Fabaceae was found to be the most abundant family with 14 species followed by Combretaceae (06), Moraceae (05), and Myrtaceae with 04 species. All other families were found to have two or one species (Figure 2). The trees species recorded in field surveys are listed in Table 1 along with their botanical name, vernacular/local name, family, parts used, and their ethnobotanical uses in alphabetical order. The study shows that, various parts of plants such as rhizome, roots, fruits, and leaves are used to cure various ailments. Constructive dialogue with the local people revealed that, they have unique knowledge to cure human diseases and disorders by using these tree species. These are administered in the form of medicinal recipes such as extract, powder, juice, paste, oil, etc. Sometimes, various domestic substances like ghee, milk, oil, and turmeric powder are also employed for preparing medicinal recipes. A number of species of trees were found to have multiple uses. Among the five tribal zones in India, this sanctuary belongs to the central zone, dominated by the Gond tribe descended from Rajgonds, a principal tribe of the Dravidian family and perhaps the most important of the non-Aryan or forest tribes in India (Dubey 2004). Information on traditional knowledge related to India is also shared by CSIR's TKDL (Traditional Knowledge Digital Library). Further to protect the knowledge from patenting, the National Biodiversity Authority (NBA) and state biodiversity boards (SBBS) have taken steps to conserve and digitize this information. Overexploitation of some tree species particularly for the collection of roots and underground parts from trees is shrinking their extent. Therefore, there is a need to create awareness among the local people for the importance as well as conservation of these tree species in their original habitat. The importance of various forms of knowledge, particularly Indigenous and local knowledge, in understanding and managing climate change is becoming more widely recognised (IPCC 2022).

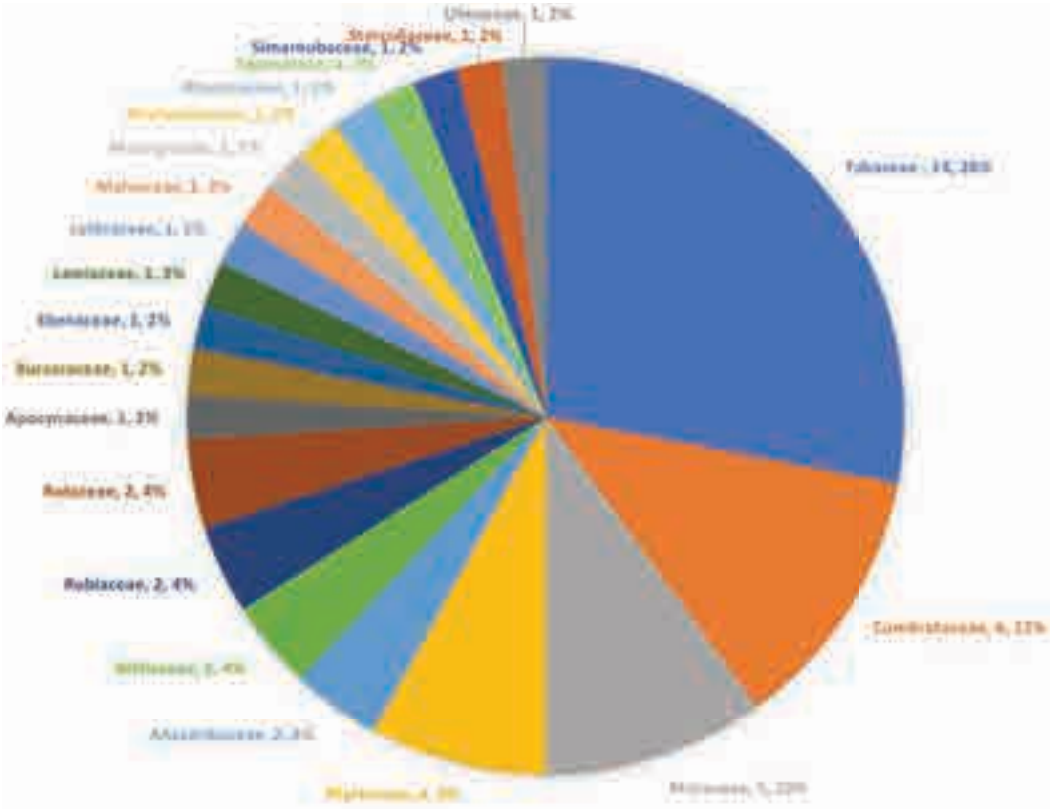

Figure 2. Families with tree species of Nauradehi Wildlife Sanctuary.

CONCLUSION

Wild medicinal plants of Nauradehi Wildlife Sanctuary were documented to initiate a framework for traditional medicinal investigation in Central India. This study provides suitable data for ethnomedicinal plant researchers to further identify new biomolecules for the treatment of various illnesses. There is an urgent need to acquire and preserve this traditional system of medicine by proper documentation and identification of species. The information is also useful for sustainable development of a small-scale pharmaceutical industries for the welfare of the community. It is recommended to formulate conservation strategies for tree species as per their threatened status before they are pushed to extinction.

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Table 1. Details of forest tree species recorded during the survey from Nauradehi Wildlife.

	Botanical name	Family	Local name	Parts used	Ethnomedicinal uses	Status
1	*Acacia catechu* (L.*f.*) Willd.	Fabaceae	Khair	Root, Bark	The root bark of *Anogeissus latifolia*, *Acacia catechu*, *Ziziphus xylopyrus* and whole plant of *Viscum articulatum* given orally with water in bleeding piles, as well as when there is bleeding from nose and mouth.	Near Threatened
2	*Acacia leucophloea* (Roxb.) Willd.	Fabaceae	Reonja	Seed	Seed paste obtained by rubbing, taken orally to cure dysentery.	Least concern
3	*Acacia nilotica* (L.) Willd. ex Delile	Fabaceae	Babool	Flower	Flower powder of this plant mixed with water is given orally to an animal twice a day to cure jaundice.	Least concern
4	*Aegle marmelos* (L.) Correa	Rutaceae	Bael	Fruit	Pulp of ripened fruit is used in diarrhoea. Local people use ripe fruit to cure the digestive disorder.	Near Threatened
5	*Ailanthus excelsa* Roxb.	Simaroubaceae	Mahaneem	Leaves	Decoction of leaves is used in ague (malarial fever) in cattle.	Not Evaluated
6	*Albizia lebbek* (L.) Benth.in Hook.	Fabaceae	Kala siris	Latex	Milk of goat mixed with latex of plant, is used as eye drops to cure conjunctivitis.	Least concern
7	*Albizia procera* (Roxb.) Benth.	Fabaceae	Gurar	Bark	Bark powder is applied on insect bite.	Least concern
8	*Anogeissus latifolia* (Roxb.ex DC.) Wall. ex Guill.	Combretaceae	Dhavda	Bark	Bark paste is used for healing wounds.	Near Threatened
9	*Anogeissus pendula* Edgew.	Combretaceae	Kardhai	Bark	Stem bark used in wound healing.	
10	*Artocarpus heterophyllus* Lam.	Moraceae	Kathal	Leaves	Leaves are effective in healing cuts, wounds and abscesses.	Not Evaluated
11	*Azadirachta indica* A. Juss.	Meliaceae	Neem	Bark, Leaves	Leaf juice is given for treat of fever. Bark decoction is used to cure diarrhoea.	Least concern
12	*Bauhinia racemose* Lamk.	Fabaceae	Kachnar	Root	Pieces of root cuttings are hung around the neck for maggot wounds.	Not Evaluated
13	*Bauhinia variegata* L.	Fabaceae	Maahuli	Flower	The flowers are used in piles, oedema.	Least concern
14	*Bombax ceiba* L.	Malvaceae	Semal	Bark, Leaves	Bark paste is applied on fractured bones, plastered with *Bombusa arundinaceae* strips and tied with the help of fallen human hairs dipped in mustard oil. Paste of leaves is used over wound.	Least concern
15	*Boswellia serrata* Triana & Planch.	Burseraceae	Salai	Bark	Bark paste applied on aches.	Vulnerable
16	*Buchanania lanzan* Spreng.	Anacardiaceae	Chironji	Gum, Leaves	Leaves are used for promoting wound healing. The gum from the bark is used for treating diarrhoea.	Near Threatened
17	*Butea monosperma* (Lamk.) Taub.	Fabaceae	Palas	Bark	Crushed bark paste used in fractures.	Least concern
18	*Cassia fistula* L.	Fabaceae	Amaltas	Bark	Stem bark is ground with pepper and garlic and the mixture is given to cure fever.	Least concern
19	*Dalbergia latifolia* Roxb.	Fabaceae	Dhobin	Leaves	Leaf juice is used for eye ailments.	Vulnerable
20	*Dalbergia sissoo* Roxb.	Fabaceae	Shisham	Leaves	The infusion of leaves is used for gargling against throats infection. Decoction of leaves is used to cure gonorrhoea.	Least concern
21	*Diospyros melanoxylon* Roxb.	Ebenaceae	Tendu	Bark	A paste of bark applied to boil and tumours.	Not Evaluated
22	*Eucalyptus umbellata* Dum.	Myrtaceae	Liptis	Leaves	Heated leaves used to cure headache and cold.	-
23	*Feronia limonia* (L.) Swingle	Rutaceae	Kaitha	Fruit	Fruits are used as a liver and cardiac tonic.	Not Evaluated
24	*Ficus benghalensis* L.	Moraceae	Bargad	Latex	Latex is applied on the affected parts.	Not Evaluated

	Botanical name	Family	Local name	Parts used	Ethnomedicinal uses	Status
25	*Ficus hispida* L. *f.*	Moraceae	Kathumar	Fruit	Fruit juices along with honey act as a good anti haemorrhagic.	Least concern
26	*Ficus racemosa* L.	Moraceae	Umar	Root, Bark, Leaves and Fruit	Juice of 250 g of unripe fruit is boiled with water and given to pregnant women thrice a day for 10-12 days for preventing conception. The juice of its leaves extracted by holding them near a fire can be used as an ear drop. Its bark is used to heal wounds. The roots are chewed to prevent gum diseases. (if the woman is already pregnant how can you prevent conception?)	Least concern
27	*Ficus religiosa* L.	Moraceae	Peepal	Bark	Decoction of bark is given to cure foot & mouth diseases.	Not Evaluated
28	*Holarrhena pubescens* (Buch. - Ham.) Wall. ex G. Don	Apocynaceae	Doodhi	Bark	Bark is used in dysentery, leaf and seeds as febrifuge.	Least concern
29	*Holoptelea integrifolia* (Roxb.) Planch.	Ulmaceae	Chirol	Seed	Seeds are externally applied in the form of poultice on injured parts.	Not Evaluated
30	*Lagerstroemia parviflora* Roxb.	Lythraceae	Karia seja	Leaves	Decoction of leaves is used for asthma.	-
31	*Leucaena leucocephala* (Lamk.) de Wit.	Fabaceae	Subabul	Seed	The roasted seeds are an emollient.	-
32	*Madhuca longifolia* (J. Koenig. ex L.) Macbr.	Sapotaceae	Mahua	Flower	Flowers decoction is used to expel stomach worms in a calf.	-
33	*Mangifera indica* L.	Anacardiaceae	Aam	Leaves, Seed	2-4 drop of fresh leaf juice put in earache. The leaf should be used in luck worm. Powder of seed used in diarrhoea.	Data Deficient
34	*Melia azedarach* L.	Meliaceae	Bakain	Leaves, Bark	Paste of roots is applied for headache. The bark is boiled in water. After filtration, it is used as mouthwash, very useful in loose teeth.	Least concern
35	*Mitragyna parviflora* (Roxb.) Korth.	Rubiaceae	Kaim	Root, Bark	Bark and roots are given during fever and colic.	Not Evaluated
36	*Morinda pubescens* Sm.	Rubiaceae	Ael	Bark, Root	Bark and roots are given during fever and colic.	Not Evaluated
37	*Moringa oleilfera* Lamk.	Moringaceae	Munaga	Leaves	Leaf paste is applied on area of swelling.	-
38	*Phyllanthus emblica* L.	Euphorbiaceae	Aonla	Fruits	Dry fruits pieces mixed with fodder for treating Abdominal disorder.	Least concern
39	*Pongamia pinnata* (L.) Pierre	Fabaceae	Karanj	Bark, Root	Decoction of bark and root are useful in expelling worms from the body.	Least concern
40	*Psidium guajava* L.	Myrtaceae	Amrood	Fruit	Fruits roasted in hot ash and then administered orally in cough.	Least concern
41	*Sterculia urens* Roxb.	Sterculiaceae	Kullu	Seed	Extract of the seeds cures dysentery and stomach pain.	Vulnerable
42	*Syzygium cumini* (L.) Skeels	Myrtaceae	Jamun	Bark	Bark powder is effective in preventing vomiting and diarrhoea.	Least concern
43	*Syzygium heyneanum* Wall. ex Wight & Arn.	Myrtaceae	Katjamun	Bark	Bark paste is given in diarrhoea	-
44	*Tamarindus indica* L.	Fabaceae	Imli	Leaves	Powder of dry leaves is useful as gargle for sore throat.	Least concern
45	*Tectona grandis* L. *f.*	Verbenaceae	Sagon	Root	Decoction of root is given in anuria.	Not Evaluated
46	*Terminalia arjuna* (Roxb. ex DC) Wight & Arn.	Combretaceae	Arjun	Roots, bark	Root decoction is used for headache. Bark decoction is used for diabetes and heart problems.	-
47	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	Bahera	Root, fruits	Pieces of root cuttings hung around the neck for maggot wounds. Fruit is given 2–3 times a day in hyper acidity.	Least concern

	Botanical name	Family	Local name	Parts used	Ethnomedicinal uses	Status
48	*Terminalia chebula* Reiz.	Combretaceae	Harra	Seed	Seeds powder mixed with *Tamarindus indica* in water and the juice is given orally for bloating.	Near Threatened
49	*Terminalia elliptica* Willd.	Combretaceae	Saaj	Bark	Stem bark made into a paste, 3–6 g is given in diarrhoea and dysentery.	-
50	*Zizyphus jujuba* Mill.	Rhamnaceae	Ber	Fruit	Fruits of *Zizyphus jajuba* with *Allium cepa* are grounded and mixed with hot water and given orally for cough & fever.	Least Concern

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SHORT COMMUNICATION

Effects of a Bengal Slow Loris *Nycticebus bengalensis* (Primates: Lorisidae) bite: a case study from Murlen National Park, Mizoram, India

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Abstract: Lorisids are the only known venomous primates. Threatened by habitat loss and pet trade, lorises and the effects of their bite, have received little attention to date. Given the growing number of accounts of bites by lorises on humans and paucity of information on their venom, here we present a case study on the context and results of a Bengal Slow Loris bite that occurred in the vicinity of Murlen National Park, Mizoram, India.

Keywords: Awareness, conservation, Lorisids, Murlen village, northeastern India, threatened species, victim.

The Bengal or Northern Slow Loris *Nycticebus bengalensis* is an arboreal strepsirrhine primate (Lorisidae) and one of the eight species in the same genus. Found in the tropical evergreen, semi-evergreen, tropical mixed-deciduous, and sub-tropical broadleaf forests of southeastern Asia (Choudhury 2001; Radhakrishna et al. 2006), it is part of a family that includes the only known venomous primate species (Choudhury 2001; Nijman et al. 2014). Slow lorises are distributed across northeastern India, eastern Bangladesh, southern China, Myanmar, northern and central Vietnam, Laos, Cambodia, Thailand, and possibly in northern Peninsular Malaysia (Nekaris et al. 2013; Nijman et al. 2014; Roos et al. 2014). In India, *N. bengalensis* can be found in the northeastern states of Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, and Tripura (Choudhury 1992, 2001; Kumar 2009; Das et al. 2016). It is categorized as a Schedule I species under India's Wildlife Protection Act, 1972, Appendix I species by CITES (Nekaris & Nijman 2007) and is also listed as 'Endangered' as per the IUCN Red List of Threatened Species (Nekaris et al. 2020). Anthropogenic activities such as clearing of forests, forest fires, shifting cultivation, hunting, poaching, pet trade, and importance given to ethno-medicinal uses, all present direct and indirect threats to lorises, and increase the risk of human encounters by several fold (Rowe 1996; Radhakrishna et al. 2006; Nekaris et al. 2013; Kumar et al. 2014; Perkin 2019; Lyngdoh et al. 2021). Cases of slow loris getting electrocuted and frequent encounters in human dominant areas have also increased in Mizoram due to recent incidences of forest fire in the state (Sushanto Gouda pers. obs. since 2016). When threatened or disturbed, slow lorises tend to bite using teeth resembling a 'needle-like toothcomb' and, in the process, they release a venomous secretion obtained from licking a specialised brachial sebaceous

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gland (Rode-Margono & Nekaris 2015). Upon mixing with its saliva, this secretion can cause anaphylactic shock in humans and other mammals when bitten (Wilde 1972; Nekaris et al. 2013; Gardiner et al. 2018). Over the past several decades, many cases of bites by slow lorises have been reported, particularly in the past 10 years (Wilde 1972; Kumar et al. 2014; Madani & Nekaris 2014; Inoue et al. 2021). Here we describe an actual incident, which involved a Bengal Loris biting a person from Murlen village, a largely rural community located on the periphery of Murlen National Park (MNP) in Mizoram, India.

Study Area

This report originates from Murlen village (23.671^{0}N, 93.273^{0}E), a fringe village located just outside MNP about 30 km from the Myanmar border. MNP is a protected area of 100 km² which falls within the Indo-Burma Biodiversity hotspot. Situated in the Champhai district of Mizoram, the area is very close to the Chin Hills. MNP has six fringe villages, including Murlen village, which has a human population of 240 individuals. Locals here are dependent mainly on agriculture, and practice the slash and burn cultivation method. The individual loris discussed herein was eventually released back into the wild unharmed after being rescued from the site where the incident occurred.

Case report

On 22 of January 2022, our team visited a shifting cultivation area, approximately 4 km from Murlen village. This is an area where local people were clearing the secondary forest for subsistence agriculture. During our visit, we came upon a Bengal Slow Loris on a branch at the top of a *Castanopsis tribuloides* tree (local name- *Thing-sia*). The slow loris was in the process of descending the tree as it was about to be cut down (Image 1). Unfortunately, members of the local community decided they were going to kill it, due in part to the fact that no vegetation remained in the surrounding areas to which it could escape. However, we intervened, offering to rescue and release it into MNP. After dropping down to the ground, the loris tried to hide among branches that had been felled from the tree. Before we could reach the spot where it was 'hiding', a local farmer (age 54) tried to capture it with his bare hands and in the process he was bitten on the middle finger of his left hand. The animal held fast for at least two minutes (Image 2) and after some struggle, we forcibly extricated the finger also freeing the loris. The bite victim insisted on pulling off some body hair from the loris and applied it to his wound, a decision influenced by the local belief that slow loris hairs have great medicinal value and can reduce further bleeding or ill effects. Eventually, AKB placed a jacket over the loris after which it was temporarily placed into a carry bag, made locally from old cotton clothing, for its own protection and safety of everyone else. The bite victim also applied extract to the wound ground from leaves of the plant *Thunbergia grandiflora* (local name-*Va-ko*) (Image 3). We were told this was also to stop the bleeding, and prevent further infection.

Approximately 15 minutes after being bitten, the farmer began to experience severe stomach pain. This was followed by chest pain, difficulty in breathing, nausea, headache, and temporary loss of vision. His face started to swell especially his lips and he began to feel cold. He also mentioned feeling a 'flow of current'

Image 1. Bengal Slow Loris *Nycticebus bengalensis*: a—Before the attempted capture and biting incident | b—upon release back into the wild.

Image 2. Bite marks from the Bengal Slow Loris.

Image 3. Leaves of *Thunbergia grandiflora*, which was applied on the bite victim's wound to stop the bleeding.

around the wound and even across his whole hand and then pain around his mouth. Because the location was very remote (i.e., ~ 50 km from the nearest hospital in the town of Champhai), we could provide no additional medication to him. Upon consulting other farmers who were working in a nearby forest, the bite victim was provided with 500 mg of Paracetamol (Acetaminophen: a pain reliever), 250 mg of Avil (Pheniramine maleate: an antihistamine), and some warm water. He then attempted to rest by laying down, during which he was frequently spitting up, experiencing pain in his neck, and was not able to talk.

After three hours of rest, the farmer felt better and was able to walk back to the village. However, on his way back, he complained of a headache and stomach pain. Upon reaching the village, we went to the nearest forest adjacent to MNP, and safely released the slow loris (Image 1). When we inquired about the health condition of the farmer the next day, he had completely recovered with no symptoms of the slow loris's venom, nor did he need or ask for any additional medications.

Discussion

Although the slow loris is generally regarded as a shy and cryptic species, it is also frequently exploited for the pet trade through-out southeastern Asia (Nijman & Nekaris 2014; Lyngdoh et al. 2021). In the northeastern states of India, locals are known to hunt and also consume the meat of slow loris, whereas their fur is believed to have ethno-medical uses in treating excessive bleeding and other injuries (Jugli et al. 2020). Most cases involving a venomous loris bite on humans across southeastern Asia are reported for Pygmy Slow Loris (*N. pygmaeus*), although others have included the Bengal Slow Loris (*N. bengalensis*), Philippine Slow Loris (*N. menagensis*) and Javan Slow Loris (*N. javanicus*) (Gardiner et al. 2018). In prior cases, the impact of Slow Loris bites has ranged from passing or fleeting to more long lasting effects or complications, with healing time ranging from one day to >8 months (Rode-Margono & Nekaris 2015; Inoue et al. 2021). The farmer in this case had previously also been bitten by a highly venomous red-tailed Bamboo Pit Viper (*Trimeresurus erythrurus*) which could have led to greater immunological resistance, and thus aided his speedy recovery. Avil (Pheniramine maleate) and paracetamol (Acetaminophen) are not necessarily known to be prescribed drugs for loris bites, yet this combination of antihistamine and pain reliever may have proven effective in this case.

Finally, after interviewing some local people from the village around MNP, we learned that in past years, there were at least three cases of slow loris bites. We found that two of the victims reported similar experiences to the one of the farmer we describe here, whereas the other suffered no symptoms at all. Though the effect seemed in our case to last only a few hours, considering the remoteness of the area and the lack of medical facilities, enhanced awareness about the outcomes of potential human interactions with lorises is important to the future safety of both primates and humans. This includes the role that habitat loss, particularly due to extensive shifting cultivation practices and logging, may play in the future and inevitability of such interactions.

The participation of both local communities and forest departments is urgently needed to foster coexistence with, and possibly even stewardship of, slow lorises.

Consent: Written informed consent was obtained for the publication of this report and all accompanying images.

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SHORT COMMUNICATION

First record of *Garra birostris* Nebeshwar & Vishwanath, 2013 (Cypriniformes: Cyprinidae) from Doyang and Dikhu rivers of Brahmaputra drainage, Nagaland, India

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Abstract: *Garra birostris* is recorded for the first time from the Doyang and Dikhu tributaries of the Brahmaputra drainage, Nagaland, northeastern India. The detailed morphometric and meristic data of the specimens that forms the basis of this new record are presented.

Keywords: Freshwater fish, meristic data, northeastern India, stone suckers, taxonomy.

Members of the labeonine genus *Garra* Hamilton, 1822 are widely distributed from Sub-Saharan Africa to Borneo through the Arabian Peninsula, southern, and southeastern Asia, and southern China (Zhang & Chen 2002). The genus *Garra* is diagnosed in possessing a specialized adhesive pad or modified lower lip forming a gular disc, that displays extraordinary variations in the snout (Kottelat 2020a). They can also be distinguished by their pharyngeal teeth arranged in three rows, the origin of dorsal fin which starts slightly anterior to pelvic fins, and an anal fin originating well behind the pelvic fins (Stiassny & Getahun 2007).

Northeastern India, part of the Himalaya Biodiversity Hotspot is represented by 56 nominal species of the genus *Garra* which are distributed in the Brahmaputra, Barak, Kaladan, Karnaphuli, and Chindwin drainages, respectively (Vishwanath 2017; Roni & Vishwanath 2018; Fricke et al. 2022). Rivers in the state of Nagaland harbour 13 species of the genus *Garra—G. annandalei* Hora, 1921, *G. gravelyi* Annandale, 1919, *G. gotyla* Gray, 1830, *G. kempi* Hora, 1921, *G. lamta* Hamilton, 1822, *G. lissorhynchus* McClelland, 1842, *G. mcclellandi* Jerdon, 1849, *G. notata* Blyth, 1861, *G. naganensis* Hora, 1921, *G. nasuta* McClelland, 1838, *G. rupicola* McClelland, 1839, *G. chathensis* Ezung, Shangningam & Pankaj, 2020 and *G. langlungensis* Ezung, Shangningam & Pankaj, 2021 (Ezung et al. 2020a,b,c). So far, *Garra birostris*is known to occur in Arunachal Pradesh (Nebeshwar & Vishwanath 2013) and Assam (Basumatary et al. 2017)

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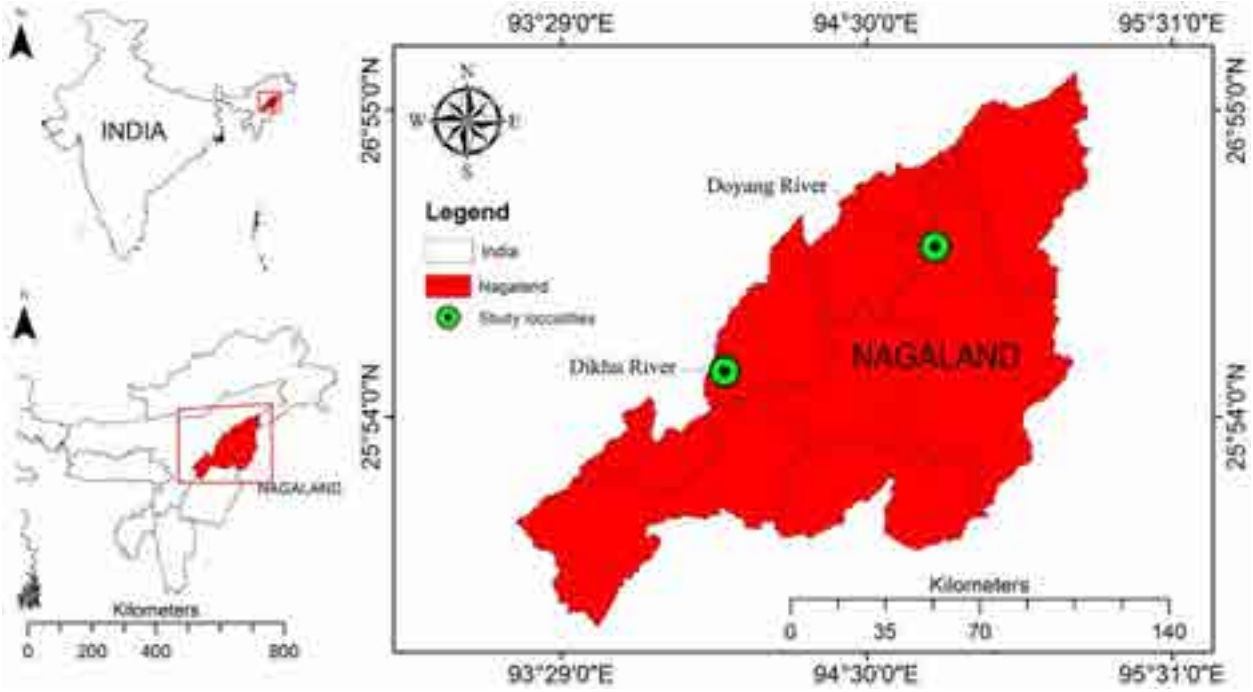

Figure 1. Collection locations of *Garra birostris* in the Doyang River and Dikhu River, Nagaland, India.

as well as in neighbouring Bhutan (Thoni et al. 2016). The present study records for the first time the occurrence of *Garra birostris* from two major river systems of Nagaland state—Dikhu and Doyang—are tributaries of the Brahmaputra.

Materials and Methods

Specimens were collected from the Doyang (26.0605^{0}N, 94.0005^{0}E) and Dikhu rivers (26.4506^{0}N, 94.7033^{0}E) of the Brahmaputra drainage, in Nagaland, India (Figure 1). Specimens were fixed in 10% formalin on site, and subsequently transferred to 70% ethanol for permanent storage. All measurements were recorded to the nearest 0.1 mm using digital calipers including the first non-zero digit from the left, through the last digit. Meristic and morphometric data followed Kottelat (2000b) and Nebeshwar & Vishwanath (2013). Gular disc terminology followed Kottelat (2020a). Meristic data were taken under a Leica M205A stereo-zoom microscope. ArcGIS tool was used to map the spatial distribution of specimens (ESRI 2017). Specimens are deposited at the Zoological Survey of India (ZSI), Kolkata and Nagaland University Fish Museum (NUFM), Nagaland.

Results

Specimens were identified as *Garra birostris* primarily based on the presence of a prominent, bilobed proboscis, bearing large, tri- to tetra-cuspid acanthoid tubercles on each lobe, a transverse lobe with small to large acanthoid tubercles, deep transverse groove, a black spot at the upper angle of gill opening and six lateral black stripes on the caudal peduncle (Image 1,2). Meristic and morphometric data are presented in Table 1. Dorsal fins with two simple and, 8½ branched rays. Pectoral fin with one simple and, 12–15 branched rays. Pelvic fin with one simple and 8 branched rays. Anal fin with two simple and 5½ branched rays. Predorsal scales 10–11. Lateral line complete with 33–34 scales. Circumpeduncular scales rows 16. Transverse scale rows above lateral line scale 4½, and, between lateral line and pelvic-fin origin 3½.

Distribution and Habitat

Previously known only from the rivers in Arunachal Pradesh (Nebeshwar & Vishwanath 2013), Assam (Basumatary et al. 2017), and Bhutan (Thoni et al. 2016), this study extends the distribution of the species into the Doyang and Dikhu rivers of Nagaland. *Garra birostris* tends to inhabit swiftly-flowing sections of headwaters and tributaries of large river systems, but also occurs in some wider, lowland river channels, as well as reservoirs. Ideal habitats comprise clear and slightly basic (pH: 7.5–8.08), oxygen-saturated water (10.02–11.38 mg/l) with a total hardness (82.39–72.52) and total dissolved solids under the desirable limits of 500 mg/l.

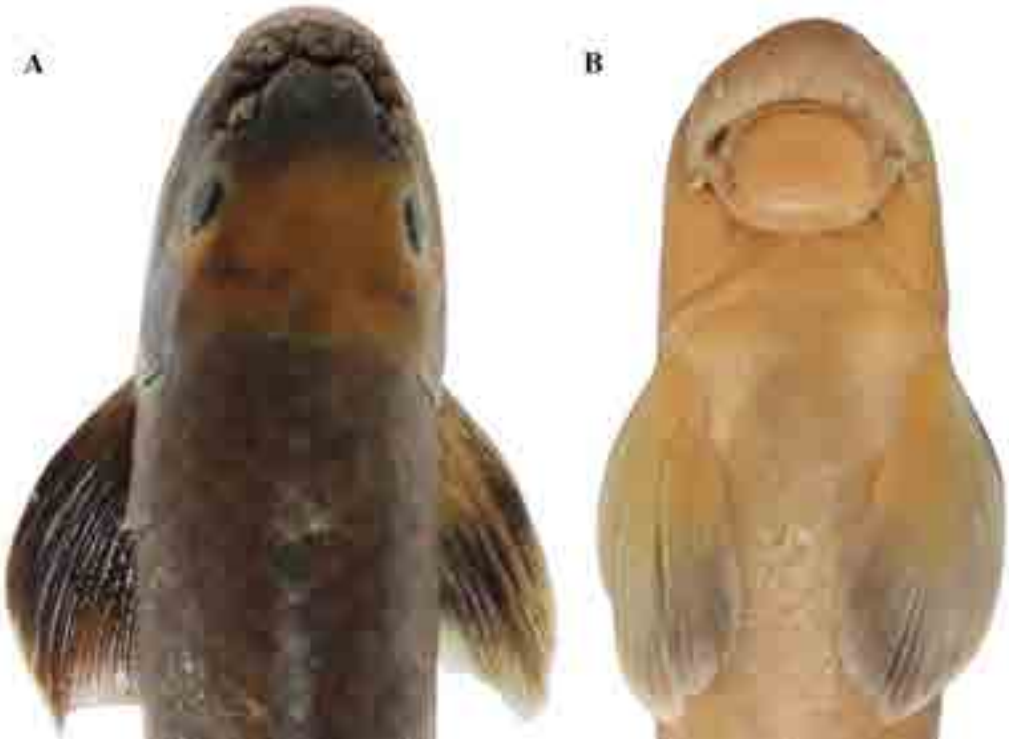

Image 1. *Garra birostris*, NUFM 1302, 113.1 mm SL, Dikhu River in Nagaland: A—dorsal view | B—ventral view. © Metevinu Kechu.

Image 2. *Garra birostris*, ZSI FF 7151, 67.12 mm SL, Doyang River in Nagaland: A—lateral view | B—dorsal view. © Metevinu Kechu.

Discussion

Members of the genus *Garra* shows varied snout morphology (Nebeshwar & Vishwanath 2017). *Garra birostris* specimens collected as part of the present study belonged to group possessing a snout with proboscis (bi-lobed) and a prominent transverse lobe as described by Nebeshwar & Vishwanath (2017). *Garra birostris* is rheophilic cyprinid with a flat belly and the lower lip expanded at its posterior rim to form an oval sucking pad and a greatly diminished vomero-palatine organ.

Table 1. Biometric data of *Garra birostris*. N—number of specimens | SD—standard deviation.

River	Doyang river (n = 04)			Dikhu river (n = 05)		
Locality	**Liphiyan**			**Longleng, Yong**		
Altitudes	**371 m**			**371 m**		
	Range	Mean	SD	Range	Mean	SD
Standard length (mm)	52.7–80.5			113.1–138.7		
In percent of standard length						
Head length	24.1–27.7	25.7	1.5	23.3–25.3	24.4	0.7
Body depth at dorsal fin origin	21.1–23.4	22.2	1.0	20.1–24.9	22.7	1.7
Predorsal length	45.6–47.7	46.4	0.9	44.5–47.4	46.1	1.1
Preanus length	66.3–70.9	68.7	1.9	67.4–72.8	69.4	2.0
Preanal length	59.8–78.3	72.1	8.3	75.1–78.2	76.1	1.2
Prepectoral length	21.9–46.1	28.8	11.6	19.9–23.1	21.7	1.5
Prepelvic length	48.3–53.6	50.7	2.2	49.1–52.3	50.5	1.2
Dorsal-fin base length	15.5–18.7	17.8	1.5	17.1–20.1	18.8	1.1
Dorsal-fin length	23.2–26.4	24.9	1.3	24.1–27.7	25.3	1.4
Pectoral-fin length	22.2–26.4	23.4	2.0	19.3–23.7	21.9	1.6
Pelvic-fin length	18.8–21.1	20.1	1.0	20.1–23.1	21.7	1.2
Anal-fin base length	6.4–9.4	7.5	1.4	7.1–10.0	8.3	1.1
Anal-fin length	18.6–20.7	19.6	1.0	20.3–22.0	21.1	0.8
Vent to anal distance	6.2–7.1	6.5	0.4	5.4–7.1	6.4	0.6
Caudal peduncle length	14.3–20.8	18.7	3.0	15.2–17.2	15.9	0.7
Caudal peduncle depth	12.5–13.8	13.1	0.6	12.3–14.1	13.1	0.6
Caudal fin length (upper lobe)	20.4–26.4	24.3	2.7	24.4–28.1	26.6	1.5
Disc length	9.5–10.8	10.1	0.6	6.3–10.5	8.4	1.6
Disc width	11.4–13.5	12.2	0.9	9.8–13.8	12.2	1.4
Pulvinus length	6.4–6.6	6.5	0.1	3. 1–6.3	5.5	1.3
Pulvinuswidth	8.3–8.6	8.4	0.1	5. 7–9.1	8.1	1.3
In percent of head length						
Head depth at occiput	59.7–75.1	68.8	6.8	67.4–72.1	69.9	1.8
Snout length	47.0–58.6	53.7	5.4	51.2–58.3	53.8	3.2
Interorbital width	33.7–44.8	41.7	5.3	37.9–43.5	41.1	2.1
Eye diameter	22.1–29.2	26.3	3.2	16.1–19.5	17.8	1.5
Disc length	37.4–41.2	39.2	1.6	26.4–43.3	34.5	6.6
Disc width	44.9–50.6	47.6	2.5	41.1–56.9	50.1	6.1
Pulvinus length	23.5–27.0	25.3	1.4	13.2–26.2	22.7	5.3
Pulvinus width	30.0–34.3	32.7	1.8	23.6–36.3	33.2	5.3
Meristic counts	N = 04			N = 05		
Dorsal-fin rays	ii8½			ii8½		
Pectoral-fin rays	i12–14			i14–15		
Pelvic-fin rays	i8			i8		
Anal-fin rays	ii5½			ii5½		
Pre-dorsal scales	10–11			10–11		
Lateral line scales	33–34			33–34		
Transverse scales	4½|1|3½			4½|1|3½		
Circumpeduncular scale rows	16			16		

Garra biloborostris (Roni & Vishwanath, 2017) and *Garra chathensis* (Ezung et al., 2020b) are the closest congeners of *Garra birostris* as they belong to the 'proboscis species-group' with a prominent bilobed proboscis (Nebeshwar & Vishwanath 2017). The presence of large tri- or tetra-cuspid acanthoid tubercles on each lobe in *G. birostris*, three acanthoid tubercles on each lobe in *G. biloborostris*, and large bicuspid acanthoid tubercles on each lobe in *G. chathensis* are the most important characters distinguishing the three species.

In the present study, *G. birostris* was identified based on the large, tri- to tetra-cuspid acanthoid tubercles on each lobe, having 4½|1|3½ transverse scale rows and a black spot at the upper angle of the gill opening. Our specimens of *G. birostris* differed to a certain extent in the characters mentioned in the original description in having fewer dorsal fin ii8½ (vs iii8½) and anal fin rays ii5½ (vs iii5½) which may be to the result of differences in habitat physio-chemistry and climatic conditions.

The first record of *G. birostris* from Nagaland, adds yet another species to Nagaland's ichthyofauna. This species is locally known as Aaghungu in Sumi Naga dialect, Angad in Ao Naga dialect and Engoro in Lotha Naga dialect. The prevailing threats to the fish species and their habitat occur mostly due to over exploitation including using destructive fishing methods, various anthropogenic activities hazards, such as irrigation water for human needs and plastic waste discharge, and sand & boulder mining. Public awareness campaigns among the general public could be the most effective step toward preserving and conserving native fisheries resources. Anthropogenic activities must be regulated, especially those negatively impacting aquatic ecosystems and their resources. It is also necessary to conduct continued research to investigate and document the ichthyofauna in this region, especially from poorly-explored tributaries, as to develop sustainable exploitation and for conservation plans for the fish fauna.

Materials examined

Garra biloborostris: ZSI FF 7928, 2 paratypes, 69.1–75.6 mm; India, Assam, Chirang District, Kanamakra River, Brahmaputra basin, Sewali and Paraty.

Garra chathensis: ZSI FF 8037, holotype, 65.6 mm SL; India: Nagaland: Chathe River, Brahmaputra basin, Ezung et al. (2020)

Garra birostris: Data from Nebeshwar & Vishwanath (2013)

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SHORT COMMUNICATION

Two new records of Lilac Silverline *Apharitis lilacinus* (Lepidoptera: Lycaenidae) from northeastern India

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Abstract: Lilac Silverline *Apharitis lilacinus* is a butterfly native to southern, northeastern, & northern India and northern Myanmar. In northeastern India it was known from a single record: H. Stevens from N. Lakhimpur, Assam in 1925. Four individuals were photographed on 15 May 2018 in D'Ering Wildlife Sanctuary, Arunachal Pradesh, which is the first record of the species after more than 90 years in northeastern India and the first record from Arunachal Pradesh. The species was again recorded on 22 June 2020 from Dibru-Saikhowa National Park, Assam. The aerial distance between both records was 36.5 km. This species is legally protected under Schedule II, Wildlife (Protection) Act, 1972.

Keywords: Arunachal Pradesh, Assam, butterfly, distribution, new record.

Apharitis ranges from southwestern Sahara (Afrotropical) to the northeastern Himalaya (Indo-Malayan). There are 11 species in total with three reported in India. *Apharitis* was previously placed under *Cigaritis* and *Spindasis*. It is different from *Aphnaeus* in having 11 veins instead of 12 (unlike *Cigaritis* and *Spindasis*). Lobe to hindwing not very marked in *Apharitis*, whereas in *Cigaritis* there is no lobe to hindwing, and lobe well developed in *Spindasis*. The species of this genus can be separated readily from *Cigaritis* by the shape of the wing, and from *Spindasis* by the coloration (Riley 1925).

Lilac Silverline *Apharitis lilacinus* belongs to the blues butterfly family, measuring 32–36 mm. This group is called Silverline because brilliant and faded silver lines run through the red bands of the butterfly. The species is endemic to India and Myanmar. In northeastern India, the species was previously known from North Lakhimpur, Assam based on a single record by H. Stevens (Riley 1925) which is the only record of the species in northeastern India. On 15 May 2018, one male and three females were photographed from D'ering Wildlife Sanctuary, Arunachal Pradesh (27.925N, 95.435E) (Image 1, 2). Two years later, another female was recorded from Dibru Saikhowa National Park, located at Tinsukia & Dibrugarh district of Assam (27.606N, 95.361E) on 22 June 2020 (Image 3, 4). The aerial distance between the two records is 36.5 km. The specimens from northeastern India appear to have darker pigmentation than those from southern India.

The habitat of *A. lilacinus* is medium height mostly *Impereta cylindrica* in D'ering Wildlife Sanctuary, Arunachal Pradesh and *Vivtiveria* sp., *Saccrum spontaenium* in Dibru-Saikhowa National Park, Assam

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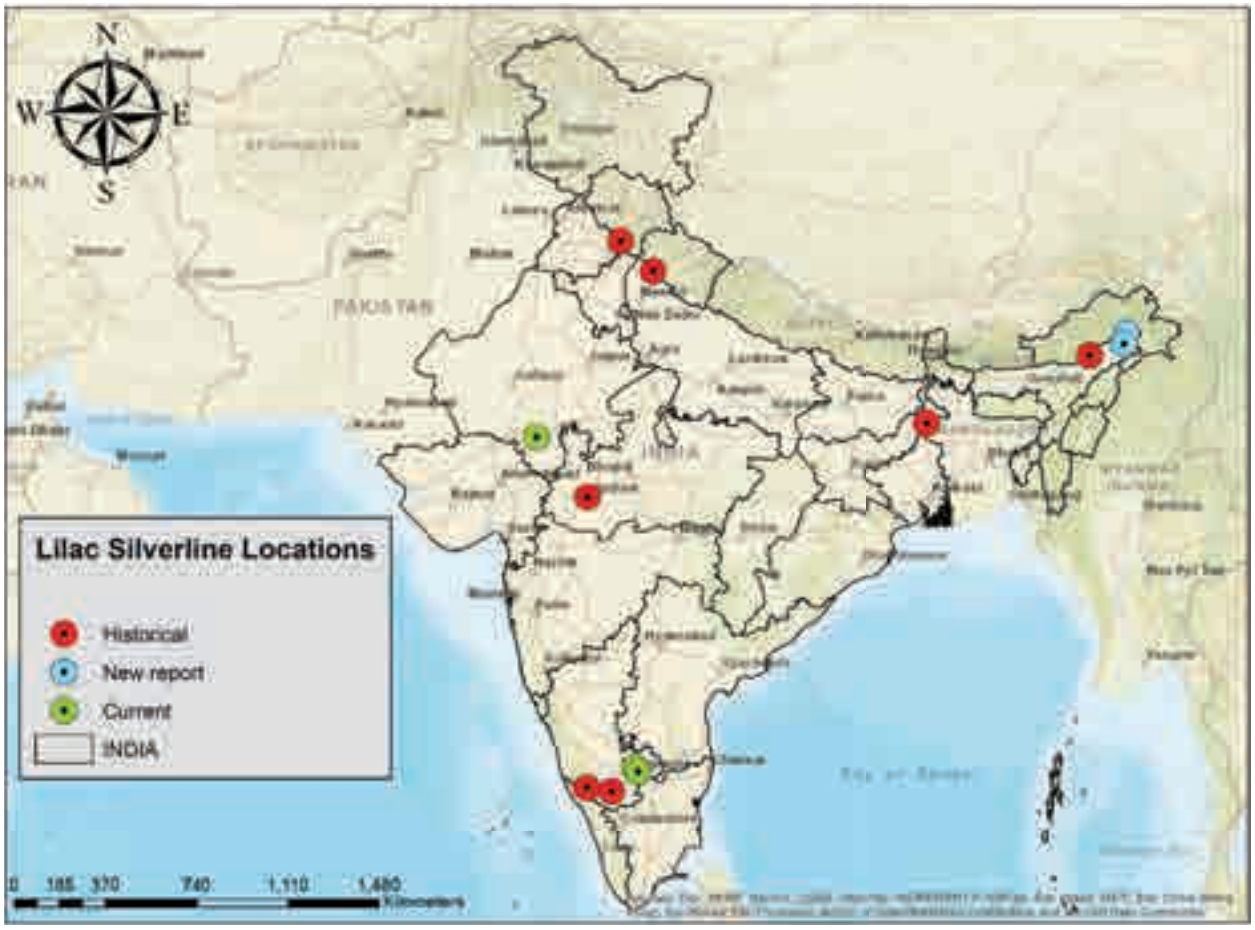

Figure 1. Map showing distribution of Lilac Silverline *Apharitis lilacinus* in India

whereas the other *Spindasis* sp. in northeastern India, prefer woodland/forest habitats. The species is possibly not rare in a few localities of D'Ering Wildlife Sanctuary and Dibru-Saikhowa National Park. British North Lakhimpur covers the present Lakhimpur, Dibrugarh, Dhemaji and Tinsukia district, so the exact record of the species by H. Stevens could not be ascertained and it could be within Dibru Saikhowa National Park. This species is legally protected under Schedule II, Wildlife (Protection) Act, 1972.

The species is presently known to occur from Hessarghata Lake, Benguluru, where it was photographed for first time in 2012 (https://www.ifoundbutterflies.org/sp/2125/Apharitis-lilacinus). It was also reported from Agastya Campus, Andhra Pradesh (unpublished data) & Kumbhalgarh Wildlife Sanctuary, Rajasthan (Sundar et al. 2020) (Figure 1), however the paper wrongly mentions the record from North Lakhimpur as Uttar Pradesh instead of Assam. Other than these, there are no present known record of the species in India.

Historically, the species was known to occur in Mhow, Madhya Pradesh after it was described in 1884 (Swinhoe 1887); Malda, West Bengal (de Nicéville 1890). Also known from Mysore, Karnataka; Kasaul, Himachal Pradesh; Hardwar, Uttarkhand, (N Lakhimpur) Assam (Riley 1925) and from Coorg, Karnataka (Yates 1931). The species is known from Assam based on lone record of the butterfly in North Lakhimpur by H Stevens (Riley 1925; Evans 1932), the only record of the species in northeastern India (Figure 1).

The species is also known to occur in Myanmar and possibly in northern Thailand (De Abera 1986), however no recent record is available from either of these countries. Also, there is no specific locality of the species mentioned by De Abera 1986 in northern Thailand (Ek-Amnuay 2012). Hence, the species occurring in northern Thailand is doubtful.

Although the species is historically known from many locations in India, the record from North Lakhimpur, Assam (Riley 1925) is the lone record of the species in northeastern India. Our records from

Image 1. Lilac Silverline *Apharitis lilacinus* male in D'ering Wildlife Sanctuary, Arunachal Pradesh, 15 May 2018.

Image 2. Lilac Silverline *Apharitis lilacinus* female in D'ering Wildlife Sanctuary, Arunachal Pradesh, 15 May 2018.

Image 3. Lilac Silverline *Apharitis lilacinus* female in Dibru Saikhowa National Park, Assam, 22 June 2020.

Image 4. Lilac Silverline *Apharitis lilacinus* female in Dibru Saikhowa National Park, Assam, 22 June 2020.

D'ering Wildlife Sanctuary, Arunachal Pradesh in May, 2018 and Dibru-Saikhowa National Park, Assam in June, 2020 confirms the existence of the species in northeastern India and first record of the species after more than 90 years in the region. The record of the species from D'Ering Wildlife Sanctuary, Arunachal Pradesh is also the first record of the species from Arunachal Pradesh and the record of the species from Dibru-Saikhowa National Park of Assam is the second record of the species from Assam since the record of H. Stevens from North Lakhimpur (Riley 1925). On both the occasions, the species was recorded in grassland habitats of D'Ering Wildlife Sanctuary and Dibru-Saikhowa National Park respectively, which emphasis the importance of grassland habitat in Brahmaputra floodplains for butterflies and other invertebrates. The species was not recorded in the unprotected grassland habitat in Brahmaputra floodplain lying adjacent to D'Ering Wildlife Sanctuary or Dibru-Saikhowa National Park, suggesting that the species might not occur in non-protected grasslands and the butterfly probably prefer medium height grasses with no cattle grazing in protected areas of Brahmaputra floodplains.

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SHORT COMMUNICATION

Illustrated description of the mantis *Mesopteryx platycephala* (Mantodea: Mantidae) collected from West Bengal, India

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Abstract: The mantis, *Mesopteryx platycephala*, is redescribed with digital images. Although known from Assam, West Bengal and other areas, the mantis is not recently collected or illustrated from India so far and is perhaps a rare species. This short note aims to fill up the lacuna.

Keywords: Dictyoptera, Mantini, Paramantinae, praying mantis.

A mantis collected in Alipurduar, West Bengal, was identified as *Mesopteryx platycephala* (Stål, 1877) based on keys in Mukherjee et al. (1995). According to Giglio-Tos (1927) and Ehrmann (2002), there are only three species under this genus, namely *Mesopteryx alata* Saussure,1870, *Mesopteryx platycephala* (Stål, 1877), and *Mesopteryx robusta* Wood- Mason, 1882. All these three mantids are large, elongate (more than 90 mm total length), and all are very similar to the members of the genus *Tenodera* but possess longer body and broader head. Stål (1877), in fact, had described this species as *Tenodera platycephala*.

The keys in Mukherjee et al. (1995) include only two species which were differentiated on the presence of transverse black lines on lamellar portion of prosternum under metazona (*platycephala*) or absence of such lines (*robusta*). Giglio-Tos (1927) briefly redescribed all the three species and separated different species by a key; in the same key *Mesopteryx alata* and *Mesopteryx platycephala* are separated on the basis of length of forewing in female: forewing longer than pronotum (*alata*) and forewing very short than pronotum (*platycephala*). But the characters of wings for males were not given. In recent years, Ehrmann (2002) also gave detailed diagnosis of the genus *Mesopteryx* and our specimen fits well in this genus.

Our specimen was diagnosed as *Mesopteryx platycephala* using the keys in Mukherjee et al. (1995) which considered only *platycephala* and *robusta* to be found in India at that time. Of these two, *robusta* is much elongate form, in excess of 115 mm in total length. The specimen being briefly redescribed here is shorter in body length and has distinct, complete and incomplete transverse lines on the lamellar portion of prosternum under metazona.

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Redescription

Classification according to Ehrmann (2002):

Dictyoptera, Mantodea, Mantidae, Paramantinae, Mantini.

Genus *Mesopteryx* Saussure, 1870

Coloration: Overall uniformly pale brown dorsally. Ventrally also pale brown but there is a tinge of greenish coloration on prosternum and anterior side of femora and tibia. In forewings costal margin is distinctly light green and is bordered below by dark reddish-brown line (Image A 1,2 & Image B 3).

Spines: Fore femur with antero-ventral series blackish-brown with black tips (Image B1) with postero-ventral series pale brown with black tips (Image B2); of these longer spines are darker; discoidal spines internally (anteriorly) black; externally (posteriorly) pale brown. Prosternal expansion with many transverse blackish lines, some of which are complete end to end, some are incomplete while some are like dots (Image C1,2).

General: Large, elongate, brown colored, and relatively robust mantis (Image A).

Head: Triangular. Vertex slightly convex, smooth with distinct juxtraoccular lobes. Eyes oblong, slightly globular, projecting and widely separated. Ocelli small. Antennae thin, filliform. Frontal sclerite (lower frons) transverse, more than three times wider than high, its superior border arched (Image B4).

Pronotum: long, depressed (dorsoventrally flattened), lateral borders of metazona lamellar; prozona with serrated margin, only anterior half of the metazonal margin feebly serrated; lateral edges of metazona almost parallel, supracoxal dilation indistinct; prozona with a longitudinal median sulcus in posterior half whereas metazona with smooth and round median carina, which is prominent in posterior half; prosternum with four distinct denticulate carinae (Image C2) whereas disc of metasternum smooth and flat. Metazona longer than fore coxae.

Legs: Fore legs: coxae: anterior edge with many tubercles and spinules, hence appearing rough; preapical lobes (fore coxal lobes) convergent. Fore femur: Elongate, slightly narrowed apically. Dorsal margin straight and smooth external (postero-ventral) spines – four, internal spines (antero-ventral) – 15, all black at tip only, discoidal spines – four, all discoidal spines black on anterior side; claw groove (tibial spur groove) near middle. Fore tibia: Internal (antero ventral) spines – 15; external (postero-ventral) spines – 11, all black at tips only, their lengths increasing from base to apex (Image B1,2).

Spine formula: F=4DS/15AvS/4PvS; T=15AvS/11PvS

Mid and Hind legs: Long and slender; mid legs moderately long while hind legs longer; legs covered with short, fine setae. Femora without apical spine. Tibial spur prominent. Tarsus long; basitarsus longer than rest of the segments taken together.

Wings: Both wings shorter than body, costal area of fore wing green, opaque, rest of the wing highly reticulated and translucent (Image B3).

Abdomen: Abdominal segments longer than broad, genital segments and genitalia damaged. The slender body and long wings suggest it to be a male.

Material examined: Regn. No. MCZM 55, 10.v.2006, 1 male, genital region mutilated, Alipurduar, West Bengal, coll. Sachin Ranade. This mantis was collected as a dead specimen killed under a vehicle, later presumably partly eaten by ants.

Discussion

As mentioned earlier, based on keys / descriptions in Giglio-Tos (1927) and Mukherjee et al. (1995) our specimen is *Mesopteryx platycephala*. The third species *Mesopteryx alata* of Saussure was differentiated from *platycephala* on the basis of comparative length of elytra (forewings) and pronotum of female (see Giglio-Tos 1927) but our specimen is a male, on the basis of the shape of abdomen. In the specimen with us, the forewings are much longer than pronotum. The other character to distinguish these two species can be total length based on Giglio-Tos's (1927) data: male of *platycephala* is about 90 mm and female 110 mm long and in *alata,* length of the body in female is 106 mm. Giglio-Tos (1927) also gave other measurements such as length pronotum, metazona and length of fore wings, in males as well as females, of *M. platycephala* and these are comparable with similar measurement in our specimen, leaving no doubt that our specimen is *M. platycephala*. Male genitalia of none of these species have been studied and in our specimen also the genitalia are damaged.

Subsequent to Mukherjee et al. (1995), Ehrmann (2002) gives distribution of *alata* as southern China, northern India, and the Philippines. Latest checklist by Mukherjee et al. (2014) gives distribution as "India: (Assam, Sikkim, West Bengal); Elsewhere: Cambodia, Myanmar and Nepal". Thus all the three species are present in India. As there are a very few records or new collections of this insect, this appears to be a rare mantis. The only other recent record of the same species is of Ehrmann & Borer (2015) from Nepal wherein the male is said to be 89–103 mm long while the female is 110–113 mm; the same paper gives the distribution

Image A. *Mesopteryx platycephala* habitus: 1—dorsal view | 2—ventral view. © Hemant V. Ghate.

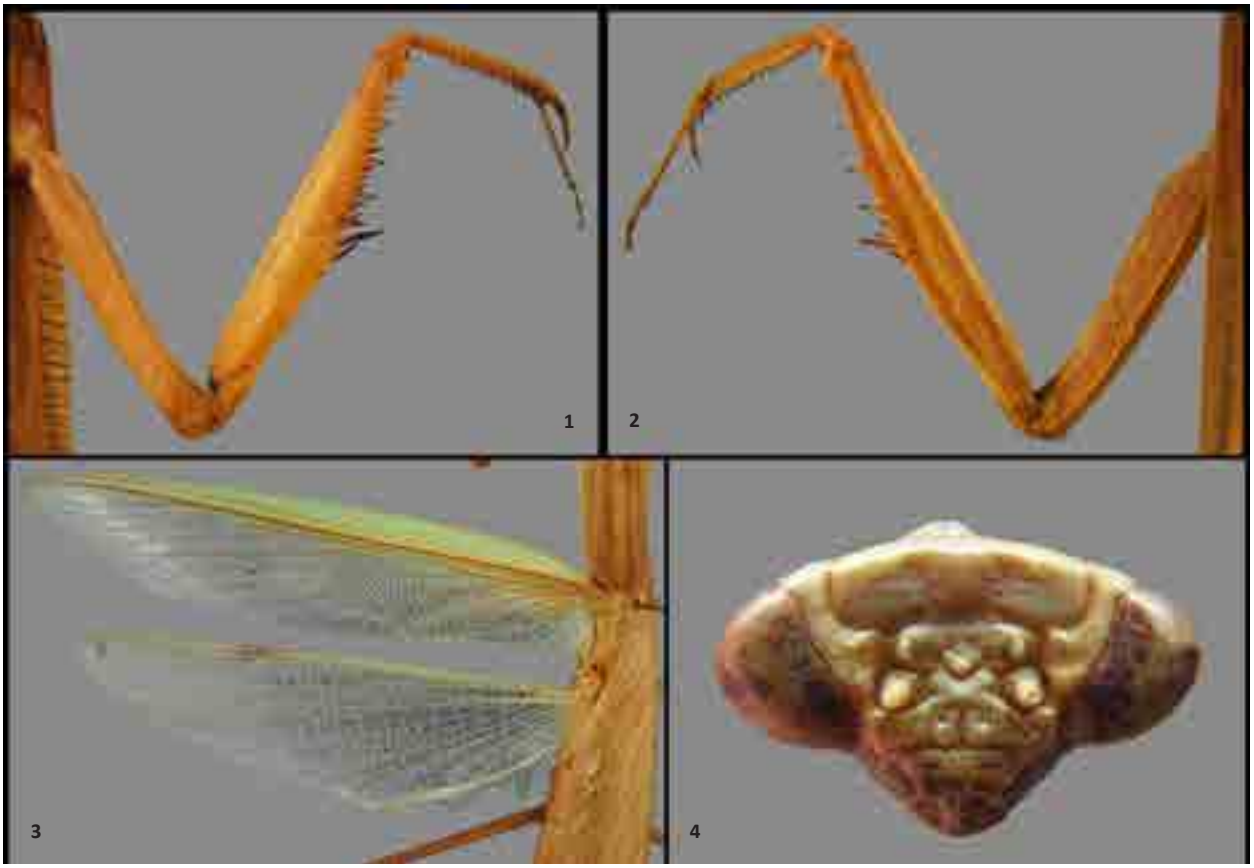

Image B. *Mesopteryx platycephala* structure details: 1—femoral spines antero-ventral | 2—femoral spines postero-ventral | 3—wings in dorsal view | 4—head, frontal view. © Hemant V. Ghate.

Image C. *Mesopteryx platycephala* close up: 1—pronotum dorsal view | 2—pronotum ventral view. © Hemant V. Ghate.

of *M. platycephala* as present in northeastern India, Cambodia, Myanmar, and Nepal. So our specimen is male even when size is compared. Future studies on genitalia will throw more light on this genus.

Measurements in (mm):

Total length 95; tip of the abdomen damaged. Pronotum 35 (Prozona 7 and Metazona 28); fore wings 50; hind wings 42.

Fore leg—Coxa 17; Femur 20; Tibia 8; Tarsus 8; (Basitarsus 5).

Mid leg—Coxa 5; Femur 18; Tibia 16; Tarsus 7; (Basitarsus 4).

Hind leg—Coxa 6; Femur 26; Tibia 27; Tarsus 10; (Basitarsus 5).

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SHORT COMMUNICATION

Cetrelia isidiata (Asahina) W.L. Culb. & C.F. Culb. (Parmeliaceae) – an addition to the Indian lichen biota

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Abstract: *Cetrelia isidiata* (Asahina) W.L. Culb. & C.F. Culb., is characterized by the presence of isidia, pseudocyphellae on thallus, and containing anziaic acid. The species is reported here as an addition to the Indian lichen biota from Arunachal Pradesh. A detailed description along with key to isidiate species of the genus known is provided.

Keywords: Ascomycetes, biodiversity, lichenized, taxonomy.

The genus *Cetrelia* W.L. Culb. & C.F. Culb. (Parmeliaceae) is represented by 18 species from the world Randlane et al. (2013), of which 10 species are reported from India (Mishra & Upreti 2015). According to Randlane & Saag (2004) the isidiate species of *Cetrelia* show their restricted distribution in Asia whereas sorediate species are found in European and Asian countries. Culberson & Culberson (1968) provided a monograph on the genera *Cetrelia* and clearly mentioned that *Cetrelia isidiata* might be mistaken from *C. pseudolivetorum* in colour spot test as both species produce a pink colour in C reaction, therefore, thin layer chromatography (TLC) test will be desirable for the recognition of olivetoric and anziaic acids. *Cetrelia braunsiana* (Müll. Arg.) W.L. Culb. & C.F. Culb., and *C. pseudolivetorum* are isidiate species of *Cetrelia* earlier reported from India (Singh & Sinha 2010).

Materials and Methods

The present study is based on the *Cetrelia* specimen preserved in the herbarium of CSIR-National Botanical Research Institute, Lucknow (LWG). The specimen was examined morphologically, anatomically, and chemically. Thin hand-cut sections of thalli were mounted in water or cotton blue and 5% KOH and observed under a compound microscope. For chemical spot tests the usual reagents of K, C, KC, and P were used. TLC was performed in solvent system A (Toluene: 1, 4-dioxane: acetic acid: 180: 60: 8 ml), following the technique of Orange et al. (2001). The specimen was identified up to the species level with the help of publications of Mishra

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& Upreti (2015) and Culberson & Culberson (1968).

Result

Cetrelia isidiata was reported earlier from China, Japan, and Taiwan (Randlane & Saag 2004). It is a new record for Indian lichen biota recorded for the first time in Arunachal Pradesh. A detailed taxonomic description of the species is provided together with illustration, key to the isidiate species and comparative characteristic features of Indian isidate species of the genus *Cetrelia* (Table 1).

***Cetrelia isidiata* (Asahina) W.L. Culb. & C.F. Culb.**
(Image 1, Figure 1)

Contr. U. S. Natl. Herb. 34: 510 (1968).

= *Cetrelia sanguinea* Schaer. f. *isidiata* Asahina, Nov. Fl. Jap. 5: 73 (1939).

Thallus foliose, corticolous, loosely attached to the substratum, 5–19 cm across; lobes 0.5–1.5 cm broad; upper surface grayish or light brownish, pseudocyphellate; pseudocyphellae tiny and infrequent; isidia present on mostly margin of lobes, simple, globose or sometime coralloid or poorly developed; lower surface black, margins brown or concolorous to upper surface; rhizines black; medulla white. Apothecia and pycnidia not seen.

Chemistry: Medulla K–, C+ pink or red, KC–, P–; anziaic acid as major compound, ±atranorin.

Remarks: *Cetrelia isidiata* morphologically exhibits its similarity with *C. braunsiana* and *C. pseudolivetorum* but differs in presence of anziaic acid in the thallus. The species is also close to *C. sanguinea* (Schaer.) W.L. Culb. & C.F. Culb., in having anziaic acid in the thallus but differs by lacking isidia. In India, the species is found growing on bark of trees at an elevation of 2,966 m in Eastern Himalayan state of Arunachal Pradesh.

Specimen examined: 15-037820 (LWG), 16.vii.2015, India: Arunachal Pradesh, Tawang district, around monastery, on bark, 27.585N, 91.857E, 2,966 m, coll. R. Bajpai.

A key to the isidiate species of *Cetrelia*

1. Medulla C+ red or pink and thallus containing olivetoric or anziaic acids 2
1a. Medulla C- and thallus containing alectoronic and α-collatolic acids ..... *C. braunsiana*
2. Isidia poorly developed and anziaic acid present in the thallus ..... *C. isidiata*
2a. Isidia well developed and olivetoric acid present in the thallus ..... *C. pseudolivetorum*

Figure 1. Distribution of *C. isidiata* in India.

Image 1. *Cetrelia isidiata* (Asahina) W.L. Culb. & C.F. Culb. (scale = 1 mm). © G.K. Mishra.

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Table 1. Comparative characteristic features of Indian isidate species of the genus *Cetrelia*.

Characteristics	Name of the species		
	Cetrelia braunsiana	***Cetrelia isidiata***	***Cetrelia pseudolivetorum***
Thallus size	8–12 cm across	5–19 cm across	5–15 cm across
Lobes	5–15 mm wide	0.5–1.5 cm wide	0.5–1.5 cm wide
Upper surface	Gray or ashy-white	Grayish or light brownish	Grayish or grayish-white or uniformly light brownish or tan in old herbarium specimens
Isidia	Simple, marginal to sometimes laminal; often coralloid	Mostly on margin of lobes; simple, globose or sometime coralloid or poorly developed	Along margin and on surface; simple or coralloid, turning into dorsiventral dissected lobules
Pseudocyphellae	Punctiform to irregular, rarely more than 1 mm broad	Tiny and infrequent	Punctiform or slightly elongate
Lower surface	Brown to grayish, the margins brown or grayish like the colour of the upper surface	Black, margins brown or concolorous to upper surface	Black, margins brown or concolorous to upper surface
Apothecia	Rare, submarginal, perforate, about 0.5 mm broad, asci 8 spored, ascospores ovoid, 12–15 × 8–9 µm.	Absent	Absent
Pycnidia	Rare, marginal, black, pruinose; conidia 1 × 4–6 µm, rod-shaped	Absent	Absent
Spot test	Medulla K–, C–, KC+ pink, PD–	Medulla K–, C+ pink or red, KC–, P–	Medulla K–, C+ pink or red, KC– or KC+ pink to red, P–
Chemistry	Alectoronic and α-collatolic acids (as major substance), ±atranorin.	Anziaic acid (as major compound), ±atranorin	Olivetoric (acid as major compound), ±atranorin.
Distribution in India	Himachal Pradesh, Sikkim, Uttarakhand and West Bengal	Arunachal Pradesh	Himachal Pradesh, Sikkim, Uttarakhand and West Bengal

(Parmeliaceae, Ascomycota) in India. *Phytotaxa* 236(3): 201–214.

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NOTE

A new southern distribution record for Pacific Marten *Martes caurina*

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Martens in North America are forest-specialist mesocarnivores that are listed by the IUCN with an overall status of Least Concern (Helgen & Reid 2015), but they are often locally a species of conservation concern. Although all martens in North America were previously considered one species, recent advances in genetics show there are two distinct species of martens (Carr & Hicks 1997; Lucid et al. 2020; Schwartz et al. 2020): American Martens *Martes americana* and Pacific Martens *Martes caurina*. Pacific Martens inhabit North America from the Rocky Mountains to the West coast of the Pacific Ocean and from the boreal forests of southern British Columbia to the southern terminus of the Rocky Mountains in north-central New Mexico. Martens were historically limited by overharvest from the fur trade, but they are currently more threatened by habitat degradation and fragmentation (Helgen & Reid 2015).

Pacific Martens were likely never common in New Mexico, which is at the southern edge of their range (Image 1), but are now rare and classified as threatened in the state (Threatened and Endangered Species of New Mexico 2020). The New Mexico Department of Fish and Game has completed multiple surveys for martens in New Mexico since 1997. Pacific martens have been consistently found in the North Central mountains near Taos and Chama (Long et al. 2015), with martens seeming to be most abundant in Taos County (Long et al. 2015). It is unclear, however, if the surveys have clearly defined the southern boundary of the population, and individuals at the southern end of their range could be going undetected.

Here we report a recent Pacific Marten detection and explore its implications for the marten population in the Rocky Mountains. On 4 September 2020, during a hike in the Rocky Mountains north-east of Santa Fe, New Mexico, we observed a Pacific Marten at 35.835, -105.750 (Image 2).

This detection is farther south than any confirmed Pacific Marten sighting in the published literature since 1884 (Image 3). In 1884, two specimens were collected by L. Dyche in the Las Vegas Mountains; however, the exact locality information for these specimens is not known, and our observation could be anywhere from 0 to 15 km farther south (Durrant 1952) (Image 3).

It is unknown if this sighting represents the documentation of a population or just a lone individual. There have been unverified scat and tracks, which are notoriously difficult to identify accurately, in the same

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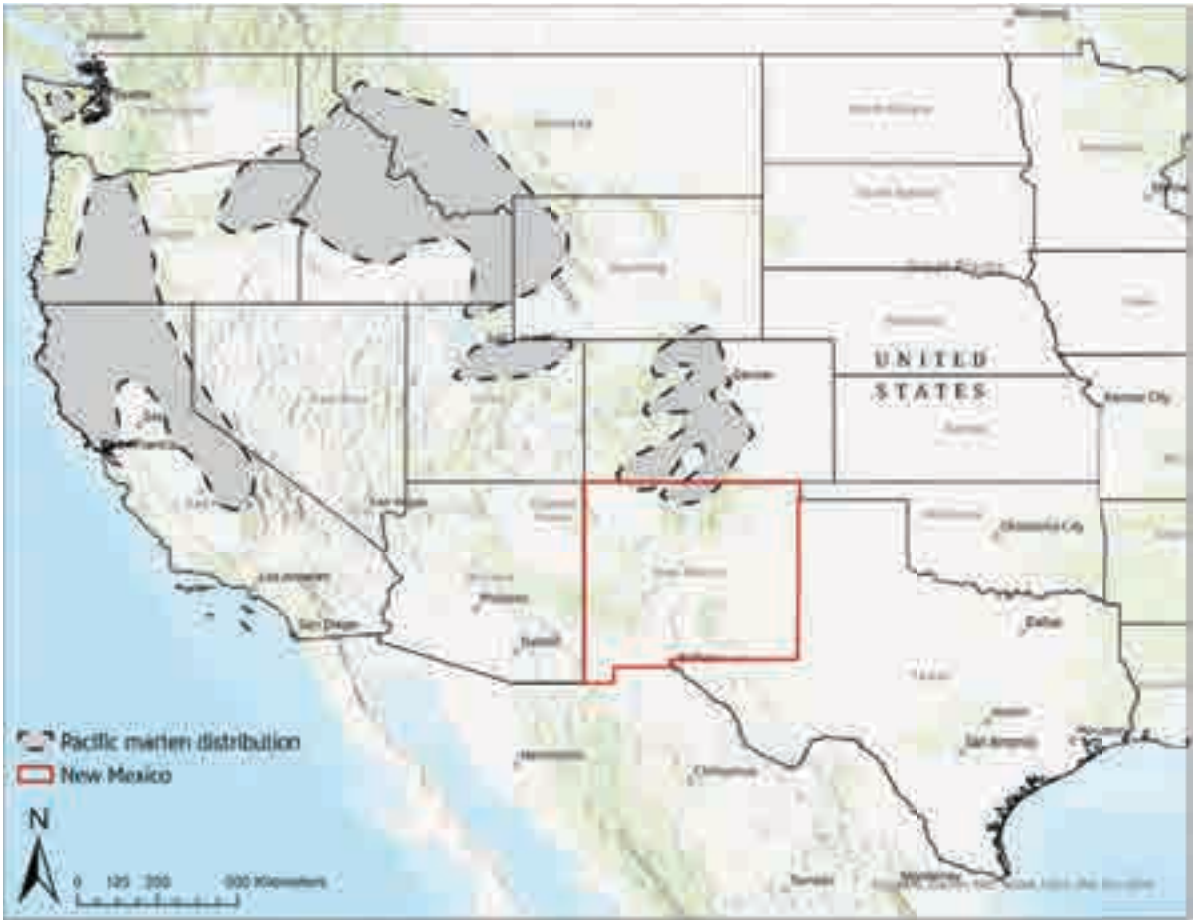

Image 1. The range map for Pacific Martens *Martes caurina* in the United States of America, with their range in New Mexico highlighted.

Image 2. Pacific Marten observed during a hike near Santa Fe, New Mexico. © B. Kenny.

general area (Long 2001; Long et al. 2015). Thus, it is possible Pacific Martens have been present in the area but have gone undetected, or that martens are expanding back into the southern extent of their historic range. It is unlikely that Pacific Martens will be found farther south as potential suitable habitat is limited to high elevation forests that are only found in the Rocky Mountains (Long 2001), which end nearby. In addition, as climate and land use change progresses, species ranges may also shift further north or higher in elevation to track climate,

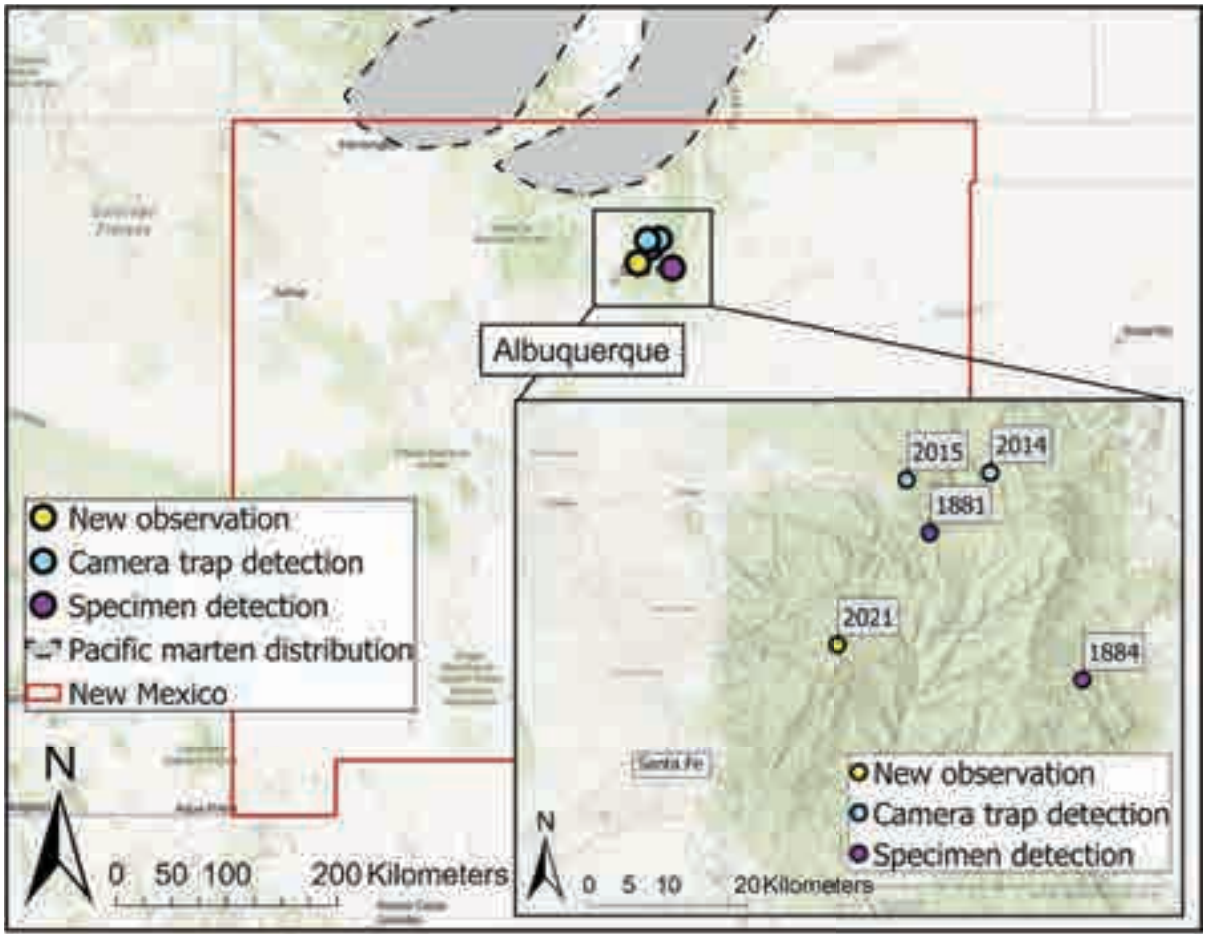

Image 3. A map showing the recent observation of a Pacific Marten in the Rocky Mountains of New Mexico. This observation is farther south than any documented observation since 1884, and other recent sightings are shown to put the observation in context.

weather, or structural features (e.g., complex forest) that they are adapted to (Martin et al. 2021). A systematic survey to determine the occupancy and abundance of martens in the southern limit of the population could be a valuable follow up study. Calls for public observations, including posting observations to sites readily available to scientists such as iNaturalist (www.inaturalist.org), could also be beneficial in determining locations in the rugged Rocky Mountains where Pacific Martens are either expanding or may have persisted.

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NOTE

First Asian record of Light-mantled Albatross *Phoebetria palpebrata* (Foster, 1785) from Rameswaram Island, Tamil Nadu, India

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This is the first documented record of the Light-mantled Albatross *Phoebetria palpebrata* from Rameswaram Island in southern India: an unusual sighting from the region as it has not previously been recorded from either southern Asia or the Oriental region.

Albatrosses (Procellariiformes: Diomedeidae) are big birds primarily found in the southern hemisphere (Sick 1997). The Light Mantled Albatross is the most common species in the Antarctic seas (Ainley et al. 1984). It is listed as 'Near Threatened' by the IUCN Red List because of diminishing population mainly due to being trapped as bycatch in longline fisheries and also, perhaps, due to the effects of imported predators (BirdLife International 2022).

With broad pelagic habits, the species maintains a circumpolar distribution in the Southern Ocean, mainly south of the subantarctic convergence between 40° and 60° S (Carboneras 1992; Brooke 2004). In summer, it spreads across frigid Antarctic waters as far south as the pack ice (Weimerskirch & Robertson 1994; Phillips et al. 2005; Terauds & Gales 2006; Lawton et al. 2008; Mackley et al. 2010), but in winter, it ranges north into temperate and subtropical seas.

The birds breed on several sub-Antarctic islands, including Heard, MacDonald, and Macquarie Islands (Australia), South Georgia (United Kingdom), Prince Edward and Marion Islands (South Africa), Iles Kerguelen and Crozet (France), and Auckland, Campbell, and Antipodes Islands (New Zealand), and forage over cold Antarctic waters as far south as the pack ice in summer (ACAP 2012). This species is a biannual breeder that usually nests alone or in tiny colonies. Most eggs are placed between October and November; hatch between December and January; the chicks fledge between May and June (Croxall & Gales 1998). Breeding birds on Macquarie Island generally feed in shelf seas around the island, but they also use sub-Antarctic and Antarctic waters southwest of the island (BirdLife International 2004). The diet consists primarily of cephalopods and euphausiids but they also consume fish and carrion (Thomas 1982; Cooper & Klages 1995).

The worldwide population was estimated in 1998 to be 21,600 breeding pairs (Gales 1998); 5,000 breeding pairs, 25% of the global population, nest in the Auckland Islands (ACAP 2012), 1,850–2,450 pairs on Macquarie

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Image 1. Light-mantled Albatross *Phoebetria palpebrata* while rescuing from the beach.

Island, 1,949 pairs in the Crozet group, 5,000 pairs on South Georgia, 3,000–5,000 pairs on Kerguelen, at least 1,600 pairs on Campbell Island, and 170 pairs on the Antipodes Islands (Croxall & Gales 1998; Taylor 2000), 350 pairs on Marion Island, and 129 pairs on Prince Edward Island (ACAP 2012).

This note reports the sighting of an adult Light-mantled Albatross bird on 8 September 2020 at 1300 h at Anthoniyapuram beach (9.291806 N, 79.251155 E) at Rameswaram Island in Ramanathapuram district of Tamil Nadu state, India. This location is part of Palk Bay and near the Gulf of Mannar, an Important Bird Area (IBA) on India's southeastern coast (Balachandran 2006).

The second author spotted the bird on the seashore. The bird was quite frail, may be dehydrated, and unable to fly, and this was informed to the forest department (FD) by the fishermen. The FD people and the fishermen looked after the bird, rested it, and attempted feeding it before releasing it into the sea.

The Light-mantled Albatross has sooty plumage with a light grey back, a vinaceous dark brown head, darker wings and tail with the contrasting light grey back clearly distinguishing the white crescent framing the top of the eye and the black bill with narrow pale bluish sulcus and white shafts (Harrison 1983, 1987; Enticott & Tipling 1997; Onley & Scofield 2007). The above description was found to be so fit for our bird that its identification was confirmed (Image 1&2).

Image 2. Checking the feathers for any damage.

The bird has not been previously recorded from southern Asia (Rasmussen & Anderton 2012) or the Oriental Region (Inskipp et al. 1996). This is the first

record from the region. It is assumed that the bird was driven to the location by a wind current or a storm; however, there was no storm in the vicinity. Behavioural studies (Spruzen & Woehler 2002) on Light-mantled Albatross found no association with a high or low-pressure system in the atmosphere for movement for foraging. As a result, in addition to pelagic birding, we must maintain close contact with our fellow fishermen to gain more such incredible bird sightings. This find also sheds light on bird migration away from well-known and established routes and sites.

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Salvia misella Kunth (Lamiaceae) - a new record for Eastern Ghats of India

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Salvia Tourn. ex L. is the largest genus in the family Labiatae (Lamiaceae nom. alt.) comprising about 950 species and distributed in tropical, subtropical and temperate regions of the world with greater species diversity in America including Mexico, and good numbers in Africa, Europe, Sino-Himalayan region and southwestern Asia (Mabberley 2017). Based on field survey and consultation of the specimens in different herbaria of Botanical Survey of India, universities and institutions in India, Sunojkumar & Rinshy (2017) reported the occurrence of 31 species of *Salvia* in India including some introduced species, while Kumar et al. (2020) listed 23 species and four varieties, which include only wild and naturalized taxa. Of these, species such as *Salvia coccinea* Buc'hoz ex Etl., *S. leucantha* Cav., and *S. plebeia* R.Br. are invasive weeds in several states.

During plant inventory of Eastern Ghat region of Odisha, the authors located three populations of an interesting species of *Salvia* with glandular-pubescent calyx and small blue flowers along Jeypore-Koraput road (National Highway no. 326) of Koraput District of Odisha and collected specimens for identification. On detailed examination of plant specimens, consultation of relevant literature and matching with authentic herbarium specimens including images of specimens in Kew Herbarium Catalogue (https://apps.kew.org/herbcat/ navigator.do), it was identified as *Salvia misella* Kunth (Lamiaceae). This species is considered as an invasive weed in tropical America (Williams 1972; Richardson & Keng 2010), Australia, Papua New Guinea, and Africa. Sunojkumar & Pradeep (2015) have reported its occurrence from Kerala, whereas Kottaimuthu et al. (2016) recorded it from Western Ghats of Tamil Nadu state, India. The present wild occurrence of *Salvia misella* from Koraput district of Odisha is very interesting from phytogeographical point of view and extends the distributional range of the species to Eastern Ghats of the country. The nomenclature, botanical description, phenology, habitat, specimens studied and colour photographs are provided below for easy identification of the species.

Salvia misella Kunth, [H.B.K.] 2: 290. 1818; Epling in Fedd. Rep. Beih. 16: 110. 1938; Back. & Bakh.f., Fl. Java 2: 627. 1965; Sunojk. & Pradeep, Phytotaxa 230 (3): 281. 2015; Kottaimuthu et al., Journ. Biol. Records 1(3): 124. 2016 (Image 1).

Annual or biennial herbs, up to 1m tall. Stem erect, profusely branched, quadrangular, sulcate, minutely gland-dotted, covered with hispidulous or pilose hairs. Leaves sessile, membranous, broadly ovate or lanceolate-ovate, 4–6.5 × 1–4 cm, apex acute, margin serrate, base decurrent upon length of petiole,

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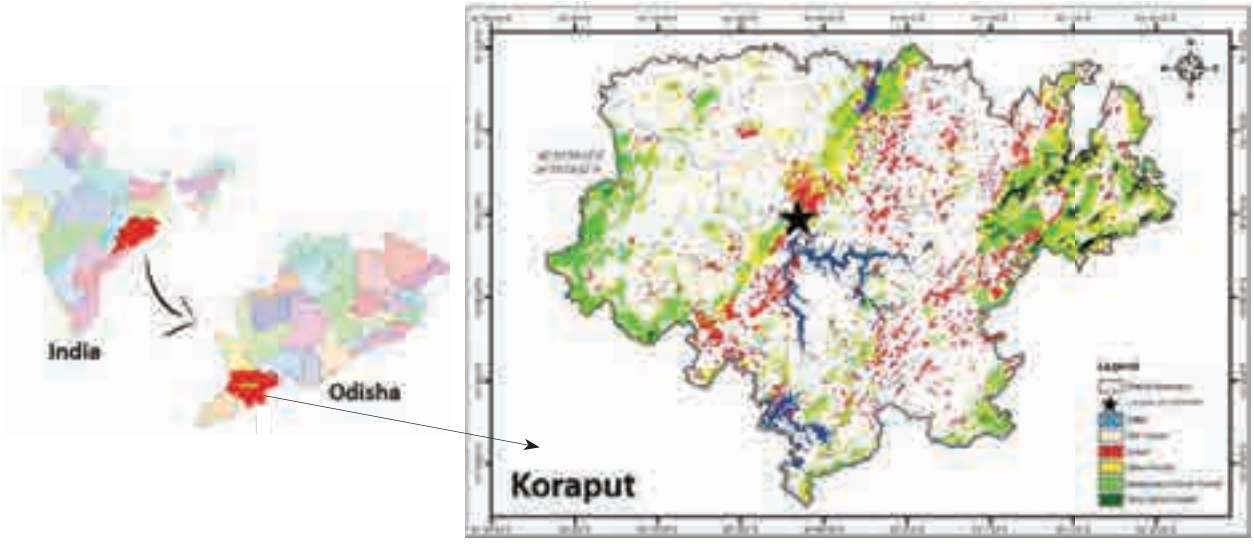

Figure 1. Map showing the distribution of *Salvia misella* in Koraput district of Odisha, India.

dull green, densely hispid on bothsides, more so on lower veins. Inflorescence simple, terminal racemes, 16–20 cm long, with 12–20 interrupted verticils of 1–2 flowers each; peduncles 2–5 cm long, glandular-pubescent. Bracts broadly ovate, 1.5–3.0 mm long, persistent, glabrous inside, glandular-pilose outside. Calyx campanulate, 4–5 mm long, clothed with dense glandular-pubescent hairs all over, 10–12-veined, lips shortly cleft; upper lip rounded, shortly caudate; lower lip 2-toothed, each lobe with single teeth, rostrate. Corolla blue, white towards base and white strips from throat downwards, 6–8 mm long; tube 3–4 mm long; posterior lip concave, glandular-pubescent along ventral margins; anterior lip 4–5 mm long, 3-lobed, middle lobe emarginate. Stamens 2, included in corolla tube or exserted, articulated on filament; filaments 1.2–1.3 mm long, connectives produced, adnate towards lower half and pubescent. Style glabrous, included, 5–6 mm long; stigma bifid. Mericarp oblong, grey with dark streaks, mucilaginous when wet; seeds greyish to brown in color, obovate, with highly reticulate venation.

Flowering and fruiting: November to February.

Distribution: The species has been reported to occur in Central America, Australia, Papua New Guinea, and central Africa. In India, the species has been recorded from Western Ghats (Kerala and Tamil Nadu) and with the present report from Odisha, its distribution range is extended to Eastern Ghats (Figure 1).

Habitat: Moist habitats, around 250 m.

Salvia misella is considered as a weed in tropical America (Williams 1972; Richardson & Keng 2010). In Western Ghats, this species is reported to grow along with several other weedy species. The newly located populations of the species in Koraput district of Odisha were found in three separate small patches growing as an understory plant in semi-shaded locations in moist habitats close to the National Highway no. 326 at an elevation of about 255 m. The common associates are *Ageratum conyzoides* L., *Chromolaena odorata* (L.) R.M.King & H.Rob., *Vernonia* cinerea (L.) Less, *Mimosa pudica* L., *Chloris barbata* Sw., and *Sporobolus indicus* (L.) R.Br. It is most likely that the seeds of *Salvia misella* might have been dispersed through vehicles carrying food grains or construction materials from above mentioned southern Indian states.

Specimens Examined: 11076 (RPRC), 11.xii.2019, India, Odisha, Koraput, Kalabhairabi, along National Highway no. 326, 18.838^{0}N and 82.616^{0}E, 255 m, coll. P.K. Das & P.K. Kamila (Image 2).

Specimens image viewed: 245 (K), S. Coll., Jamaica (K000479224); 322 (K), 24.xi.1975, Mexico, Guerrero, 1250 m, coll. K.M. Peterson, C.R. Broome & R.M. Harley (K000266705)

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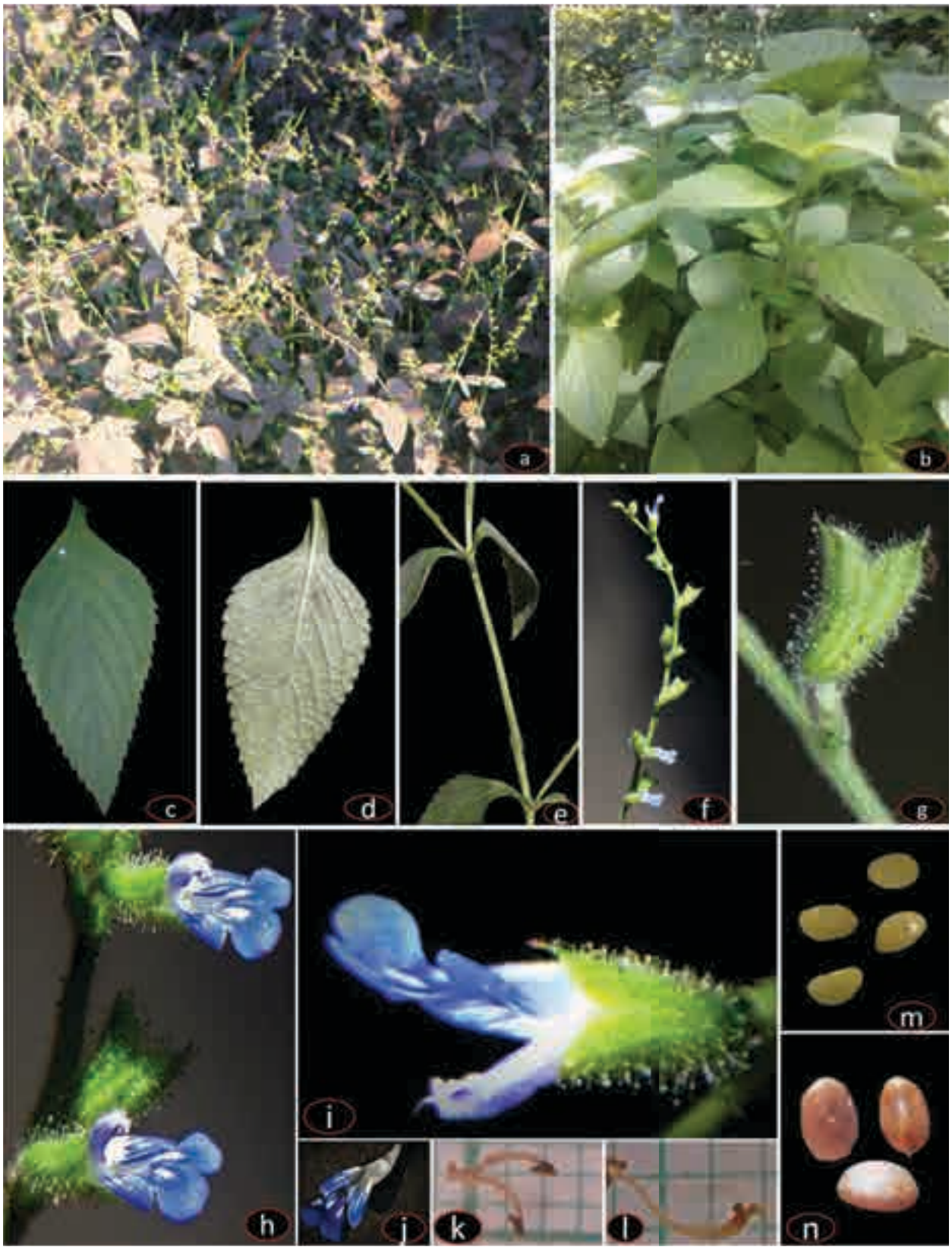

Image 1. *Salvia misella*: a—habitat | b—whole plant | c–d—leaves with venation | e—stem | f—inflorescence | g—calyx with glandur hairs | h–i—flowers | j—corolla tube | k—anthers | l—style and stigma | m–n—immature and mature seeds. © Prabhat Kumar Das.

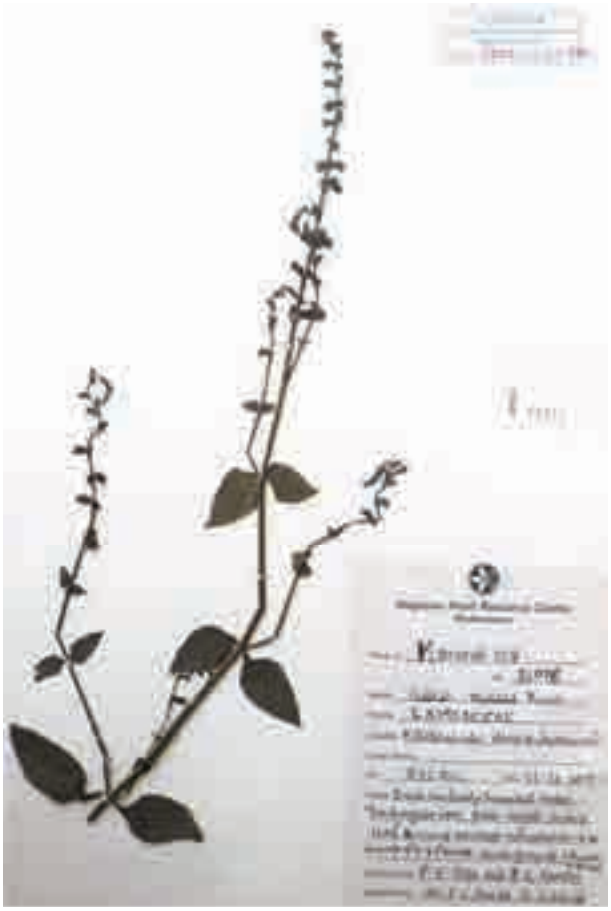

Image 2. Herbarium specimen of *Salvia misella* deposited in the herbarium of Regional Plant Resource Centre, Bhubaneswar.

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NOTE

Salsola oppositifolia Desf. in Great Rann of Kachchh, Gujarat – a new record for India

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The genus *Salsola*, usually having small shrubby habit, commonly occurs in arid, semi-arid, and temperate regions of the world (Rasheed et al. 2013; Hanif et al. 2018). There are 100–150 species of this genus in the world (Altay & Ozturk 2020). The genus is characterized by the presence of axillary flowers with conspicuous bracteoles, winged fruit, and superior ovary (Borger et al. 2008). The name *Salsola* is derived from the Latin word 'Salsus' meaning 'salty' (Mosyakin 1996). *Salsola* taxon belongs to *Salsola* sect and it is distributed across Mediterranean region mostly prevalent from Morocco to Palestine (Botschantzev 1976; Greuter et al. 1984; Peruzzi & Passlacqua 2004). In India, five species of *Salsola* are recoded: *Salsola kali*, *S. hartmanii*, *S. monoptera*, *Caroxylon imbricatum*, *Halogeton glomeratus*. Among them, the latter two are more well-known through the synonyms *Salsola baryosma* and *Salsola glomerata*, respectively (BSI 2022; FOI 2022). They are recorded from different states of India like Rajasthan, Kashmir, Ladakh, Gujarat, Delhi, Haryana, and Punjab. They are used as fodder in many parts of the country (Altay & Ozturk 2020).

A hitherto unrecorded species of halophyte, *Salsola oppositifolia* Desf., belonging to the family Amaranthaceae was recorded in the Great Rann of Kachchh (Kachchh district, Gujarat) in October 2021 during a study on flora and fauna of Great Rann of Kachchh by Gujarat Ecological Education and Research (GEER) Foundation. *Salsola oppositifolia* was recorded in three different localities of Great Rann of Kachchh between August 2021 and December 2021. This species constitutes a new record for India. The specimen was confirmed by a scientist at Botanical Survey of India (BSI), Jodhpur. The sample is deposited at BSI, Jodhpur (Accession No.: BSJO51890). Great Rann of Kachchh is the largest saline desert-cum-seasonal wetland in Gujarat, which is spread over an area of around 18,000 km^2. It is important not only due to vast area, but also owing to some of its unique aspects like its dual ecosystem characteristic (i.e., saline desert-cum-seasonal wetland), unique genesis, evolution, and presence on hilly islands ('bets'). The Great Rann has been identified as one of the eight nationally important wetlands in Gujarat by MoEFCC. A large portion of it is under legal protection as a wildlife sanctuary named as Kachchh Desert Wildlife Sanctuary. 'Flamingo city' within the Great Rann is an

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Competing interests: The authors declare no competing interests.

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important bird and biodiversity area (IBA).

***Salsola oppositifolia* Desf.,** Fl. Atl. 1: 219 (1798); *Salsola longifolia* Forsskal var. *oppositifolia* (Desf.) Viciosa in Anal. Jard. Bot. Madrid 6(2): 25 (1946); *Seidlitzia oppositifolia* (Desf.) Iljin in Bot. Mater. Bot. Inst. Komarova Akad. Nauk. SSSR 16: 88 (1954). (Image 1)

Description: Perrenial, succulent, shrub, 1–2 m tall, branches are not jointed. Stem erect, 5–10 mm diameter, branched with opposite branches, glabrous, cylindrical, woody base, rarely prostate, stipules absent. Leaves upto 20–30 mm, cylindrical to terrete, decurrent, sheathing at base and adanate to stem, ramal, opposite (two leaves at each node), ramal, opposite (two leaves at each node), 6–10 x 2–3 mm in size, sessile or amplexicaul, tip acute or pointed, subulate lips, apiculate depressed above. Flowers are axillary and solitary, hermaphrodite. Bracts linear to oblong, keeled, sessile, lower bract larger, clavate to dumb-bell shaped. Bracteoles are acute, linear to oblong about 3–4 mm long and 0.5-0.8 mm broad. Perianth ovoid, 15–20 mm in diameter, yellowish, fructiferous t. Tepals 4–5 mm long, 2–3 mm wide elliptical, rounded apex and undulate margin. Stamens 4–5, 1–2 mm long, exerted. Anther tetragonal and two styles. Staminodes are absent. Fruits are winged, homogeneous, about 10–15 mm broad. Wings 2–3 mm, orbicular, unequal (two smaller and three bigger). The smaller wings are about 4–6 mm wide while bigger wings are 9–10 mm wide. Seed is horizontal and covered with smooth membrane.

(Dichotomous Key)

1a) Annual herb, leaves and bracts spinose or aspinose at the apex 2

2a) Plant erect or prostrate, Leaves and bracts spinose at the apex 3

3a) Plant erect, Spines long upto 1–2 cm or more ..... *Salsola kali*

3b) Plant prostrate, Spines short less than 1 mm ... . *Salsola monoptera*

2b) Plant erect or prostrate, Leaves and bracts aspinose at the apex 4

4a) Plant erect, Stem curved .... *Salsola glomerata*

4b) Plant prostrate ..... *Salsola hartmanii*

1b) Shrubs, leaves and bracts without spines 5

5a) Leaves alternate, stem hairy .... *Salsola baryozoma*

5b) Leaves opposite, stem glabrous .... *Salsola oppositifolia*

Flowering and Fruiting: October–January

Habitat: It was often found in association with *Sueada nudiflora*. It was recorded on muddy bunds and on the hilly outcrops.

Distribution: Italy, northern Africa, Palestine, Spain, western Sahara (Brullo 1982; Peruzzi & Passalacqua 2004).

Conservation status as per IUCN Red Data List of Threatened Species: Not Evaluated (NE).

Taxonomic notes: *Salsola oppositifolia* species was first described by Desfontaines in 1798 (Brullo 1982). In early 1800, this species was considered to be identical to *Salsola longifolia* and S. *verticillata* (Fiori 1923; Maire 1962; Zohary 1966). But later on, it was proved that three species are completely distinct from one another. *Salsola longifolia* and S. *verticillata* was kept in *Darniella* (Maire & Weller) Brullo. Sect while *S. oppositifolia* was kept in *Coccosalsola* Fenzl. sect. of *Salsola* (Brullo 1982, 1984). Out of the six species of *Salsola* recorded in India, four species are distinct in one or another morphological characters like herbaceous habit, presence of spines, and prostrate stem. The only species having a close resemblance with *Salsola oppositifolia* is *Salsola baryozoma*. On close observation of characters of the two taxa, it was found that both the taxa are morphologically different. This species (= *Salsola oppositifolia*) was not recorded in India. In India, *Salsola baryozoma* is most commonly occuring species of this genus. *Salsola baryozoma* recorded in India has alternate leaves and hairy stem, while S. *oppositifolia* has opposite whorl of leaves and glabrous stem. Both are branched though.

Specimen examined: Tunisia, 06.x.1981, Brullo, S., Fl005525(FI); Spain, Canary Island, Tenerife, La Orotava, 28.291N, 16.629W, 2,481m, 01.xii.1985, Bourgeu, K000243929 (RBGK); India, Gujarat, Kutch, Khadir bet, 23.818N, 70.328E, 15.5 m, 24.viii.2021, Vinesh Gamit & Rakesh Gujar GRK002 (GEERF) (Image 2).

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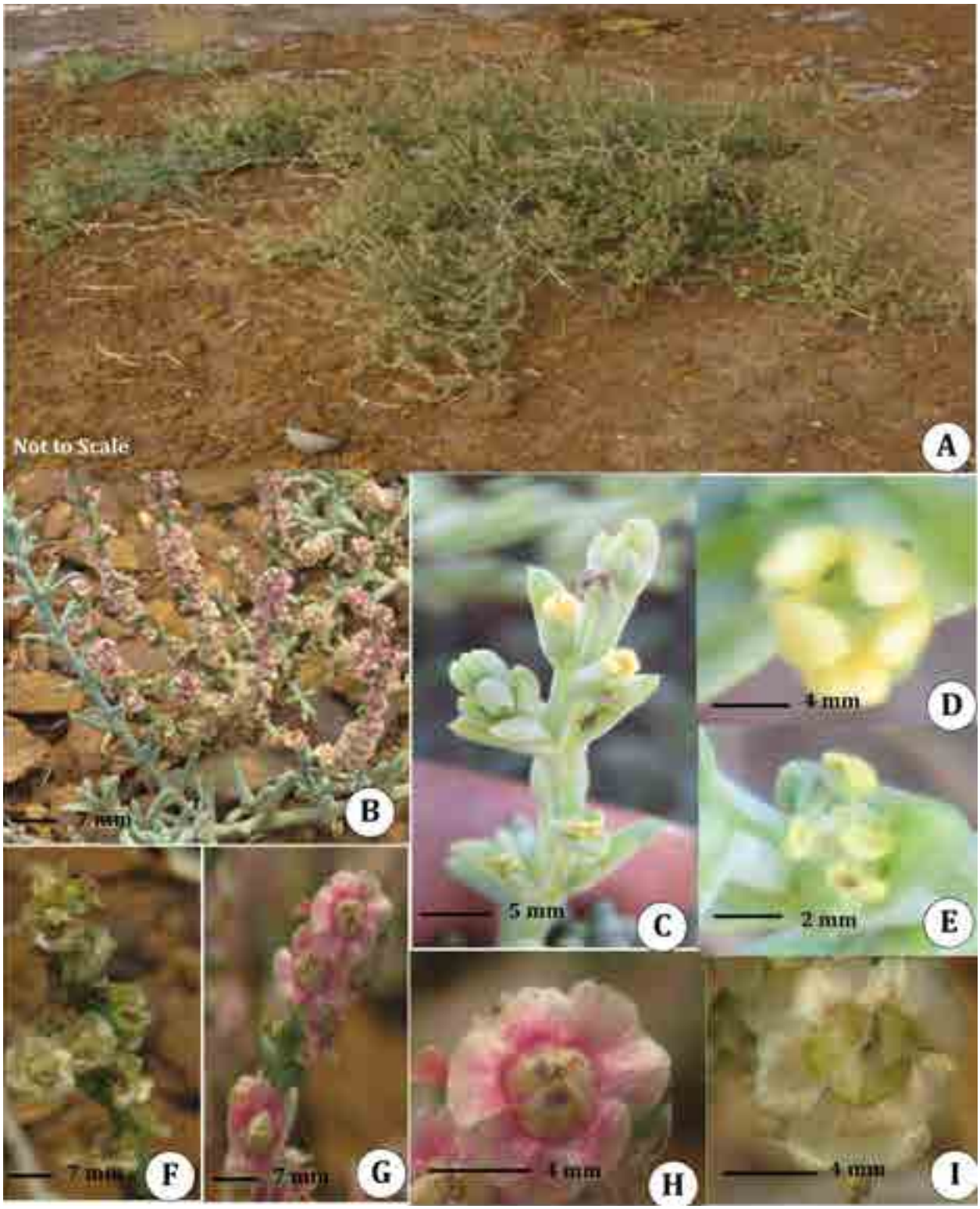

Image 1. ***Salsola oppositifolia*** **Desf.: A,B—Habit | C—Flowering branch | D—Flower | E—Anthers | F,G—Fruiting branch | H,I—Fruit.**
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Image 2. Herbarium sheet of *Salsola oppositifolia* Desf. [GRK002].

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NOTE

Extended distribution of *Impatiens scapiflora* (Balsaminaceae) to the flora of Eastern Ghats, India

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During the floristic exploration in the Shevaroy Hills, Yercaud, Salem district of Tamil Nadu, the authors have collected an interesting specimens belonging to the genus *Impatiens* in flowering condition. After critical examination of the specimens with pertinent literature (Ramamoorthy 1978; Yoganarasimhan et al. 1982; Vajravelu 1983; Almeida 1996; Vivekananthan et al. 1997; Mudaliar & Prasad 2000; Rathakrishnan et al. 2005; Dessai & Janarthanam 2011; Bhaskar 2012), it was identified as *Impatiens scapiflora* B. Heyne ex Roxb. Earlier records indicate that *Impatiens scapiflora* occurs only in the Western Ghats (Matthew 1983; Dessai & Janarthanam 2011; Nayar et al. 2014) and hitherto not reported in the Eastern Ghats. Therefore, the present collection from Shevaroy hills, Yercaud constitute new distributional record of *Impatiens scapiflora* for Eastern Ghats of Tamil Nadu.

Impatiens scapiflora B. Heyne ex Roxb. in Fl. Ind. 2: 464. 1824; Vajravelu in Nair & Henry, Fl. Tamil Nadu 1: 56. 1983; Sharma et al. in Fl. Karnataka 39. 1984; Almeida in Fl. Maharashtra 1: 196. 1996; Saldanha in Fl. Karnataka 2: 257. 1996; Vivekananthan et al. in Hajra et al., Fl. India 4: 208. 1997; Mudaliar & Prasad in Singh & Karthikeyan, Fl. Maharashtra State Dicotyl. 1: 461. 2000; Rathakrishnan et al. in Daniel, Fl. Kerala 1:557. 2005. Dessai & Janarthanam in Rheedea 21(1): 35. 2011. (Image 1).

Terrestrial scapigerous herbs, up to 21.5 cm high. Rootstocks tuberous, 1.3 cm across, oblongoid. Stems acaulescent, usually rooting at lower nodes. Leaves radical, 7.5 x 5.8 cm, reniform-orbicular, cordate-rounded at base, margins obscurely crenate-serrate, acute-obtuse at apex, sparsely pubescent above, glabrous below; petioles 15.4 cm long, glabrous, pinkish-red. Inflorescence 5-many flowered raceme. Flowers 3.7 cm across, pinkish; bracts 0.3 x 0.2 cm, ovate, acute at apex, glabrous, persistent; pedicels 4.2 cm long, slender, deflexed in fruits, glabrous; lateral sepals 0.4 x 0.2 cm, ovate, obtuse at apex, glabrous; standard petal 0.8 x 1.2 cm, reniform, obcordate at apex, glabrous; wing petals tri-lobed; basal lobe 1.4 x 0.4 cm, oblong, obtuse at apex; mid-lobe 0.8 x 1.2 cm, ovate, obtuse at apex; distal lobe 1.5 x 0.5 cm, oblong, obtuse at apex; lip 7.8 x 0.5 cm, 0.4 cm deep, saccate, acute at apex, glabrous; spur 7.5 cm long, tubular, obtuse at apex, straight, glabrous; column 0.4 x 0.2 cm; stamens 5, anthers bi-locular;

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Competing interests: The authors declare no competing interests.

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Image 1. *Impatiens scapiflora* B. Heyne ex Roxb.: A—Habit | B—Inflorescence (close up).

Image 2. Herbarium sheet of *Impatiens scapiflora* B. Heyne ex Roxb.

ovary 5 locular, ovate-lanceoloid, glabrous; capsules 1.2 cm long, lanceoloid, glabrous; seeds many, oblongoid, brown, hairy throughout.

Specimen examined: 136013 (MH), 11.ix.2014, India: Tamil Nadu, Salem district, Yercaud, Shevaroy temple, 11.817N, 78.216E, ± 1,577 m , coll. S. Kaliamoorthy, T.S. Saravanan, & M.Y. Kamble (Image 2).

Flowering and Fruiting: September–January.

Ecology: Growing along with grasses, *Impatiens balsamina* L., *Drosera burmanni* Vahl., and *D. peltata* Thunb., on wet and dripping open rocky slopes at elevations between 1,500 and 1,600 m.

Distribution: India: Karnataka, Kerala, Maharashtra, Tamil Nadu. Endemic to Peninsular India.

Conservation status: Less than 25 individuals were noticed during the field survey at Shevaroy temple, Yercaud. Extensive field study in similar habitats in the adjacent localities is required to determine its exact IUCN threat status. Live specimens brought from the study area are being multiplied and maintained as germplasm collection at NOEG, BSI, SRC, Yercaud.

Notes: Mathew (1983) collected the species *Impatiens scapiflora* in Yercaud hills and included in his floristic work entitled "The flora of Tamil Nadu Carnatic (VOL.3, p.194)". Though the illustration of the species shown to be similar to *I. scapiflora* but was misidentified as *Impatiens acaulis*. This was kept unnoticed for nearly 38 years until the authors of this article collected and identified it as *Impatiens scapiflora.*

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