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ARTICLE

Distribution, diet, and trophic level of *Arvicanthis abyssinicus* and *Tachyoryctes splendens* around the area of recently extinct Ethiopian Wolf *Canis simiensis* on Mount Guna, northwestern Ethiopia

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Abstract: Abyssinian Grass Rats *Arvicanthis abyssinicus* and Common Mole Rats *Tachyoryctes splendens* are preyed upon by the Ethiopian Wolf *Canis simiensis*. The aim of this study was to assess distribution, diet and trophic level of *Arvicanthis abyssinicus* and *Tachyoryctes splendens* on Mount Guna, where wolves have recently become extinct. Rodents were captured with Sherman trap and identified, and samples were taken to Debre Tabor University for dissection and diet analysis via microscopy examination of stomach contents. 110 *A. abyssinicus* and 52 *T. splendens* were captured from the study area, and the estimated population sizes of *A. abyssinicus* and *T. splendens* in Mt. Guna computed by Peterson-Lincoln Index were 1,364 and 416, respectively. In addition, 379 burrows (203 of *A. abyssinicus* and 176 of *T. splendens*) were counted. Both species were observed to consume plants and arthropods, with plants predominant. We recommend that intensive studies should be carried out to determine the effects of rodent communities upon Mt. Guna afroalpine and subafroalpine ecosystems.

Keywords: Afroalpine, diets, Mt. Guna, stomach analysis, subafroalpine.

Afan Oromo abstract: Guduunfaa: Gosoota hantuutaa keessaa tuqaa (*Tachyoryctes splendens*) fi hantuutni huuraa (*Arvicanthis abyssinicus*) soorata jeedala diimtuu (*Canis simiensis*) keessaa isaan tokko. Kaayyoon qo'annoo kanaa bakka duraan jeedalli diimtuu irra jiraachaa turte keessatti iddoowwan hantuutotni armaan olii kun qubatan, nyaata isaanii fi sadarkaa saaphaphuu nyaataa isaan irratti argaman adda baasuu ture. Hantuutotni kunneen erga kiyyeeffamanii booda nyaata garaacha isaanii keessatti argamu adda baasuuf gara Yuunivarsiitii Dabra Taaboritti geeffaman. Bu'aan qo'annichaa akka mul'isutti hantuuta huuraa lakkoofsaan 110 ta'anii fi tuqaa lakkoofsaan 52 ta'antu bakka qo'annoon kun itti gaggeeffame sanaa qabame. Lakkoofsi hantuutota sanaa yaroo 'Peterson-Lincoln Index'n shallagamu kan hantuuta huuraa 1,364 fi kan tuqaa 416'tti tilmaamama. Dabalataanis, boolla hantuutaa gara 379 (kan hantuuta huuraa 203 fi kan tuqaa 176) ta'antu bakkichaa adda ba'e. Caalatti biqiltoota kan sooratan ta'anis, gosootni hantuutotaa kun mukootaa fi ilbiisotaa garaagaraa akka nyaatantu qo'annoo kanaan mirkanaa'e. Bu'aa qo'annoo kanaarratti hundaa'uun dhiibbaan gosootni hantuutaa kun Gaara Gunaa irraan ga'aa jiran gadi fageenyaan akka qoratamu yaada dhiyeessina.

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Author contributions: All authors equally contributed to proposal development, data collection, and write up of this study. However, the corresponding author has prepared the manuscript for publication and carried out activities during publication process.

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INTRODUCTION

Rodents exploit a wide range of habitats throughout the world (Lange et al. 2004). Their distribution and abundance is influenced by vegetation structure and composition (Gebresilassie et al. 2004; Kannan & James 2009), which influence micro-climate and provide food and cover against predators (Hansson 1999).

Ethiopia is a physically and biologically diverse country in Africa, where differences in climate and topography have resulted in a wide diversity of habitats and species (Tedla 1995; Abunie 2000). Of 284 mammals identified from Ethiopia, rodents comprise 25% and contribute about 84% of the total endemic species (Yalden & Largen 1992; Bekele et al. 1993; Bekele & Leris 1997; Laverenchenko et al. 1997). Ecological knowledge about these rodent, including their distribution and abundance, is limited (Habtamu & Bekele 2008).

Distribution and abundance of rodents can be estimated by trapping and recording of animals signs, holes, or related elements that infer the presence of animals (Krebs 1978; Rabinovich 1980). The best techniques are those based on the use of capture traps and recording of signs, due to the crepuscular habits of rodents (Aplin et al. 2003).

Rodents are omnivorous, mainly consuming plant parts such as fruits and seeds, as well as small arthropods (Best et al. 1993). Techniques commonly used to assess the diets of rodents include field observations of partially consumed organisms (Meyer & Shiels 2009), captive-feeding trials (Shiels 2011), and stomach content analysis (Ruffino et al. 2011). While effective, stomach content analysis has in a relatively small number of studies (Hope & Parmenter 2007).

The Ethiopian Wolf *Canis simensis* is a Critically Endangered medium-sized canid highly adapted to live in Ethiopian afroalpine and subafroalpine ecosystems above altitudes of 3,000 m, and it is the almost exclusive predator of high altitude rodents (Marino et al. 2010; Yihune & Bekele 2012). The Ethiopian Wolf Conservation Program (EWCP) team confirmed the extinction of this species from Mt. Guna in 2011, after several years of serious decline (IUCN/SSC 2011). A preliminary survey by Debre Tabor University staff in 2014 confirmed that the Ethiopian Wolf had not been seen for the last four years in Mt. Guna (Sillero-Zubiri & Macdonald 1997). As a result, rodent numbers were observed to have increased on Mt. Guna, possibly resulting in ecosystem disturbance.

Fluctuations in rodent population density can have major impacts on the dynamics of their food (arthropods and plants) and predators (Ims & Fuglei 2005). If the population density of rodents in an ecosystem exceeds the carrying capacity, prey can be affected by overconsumption and the ecosystem can collapse unless control measures are taken. Conversely, if the population density of rodents is too low to sustain predators, they can become locally extinct. The aim of the present study was to assess distribution, diet and trophic level of two rodent species on Mt. Guna known to be prey of the now-extinct Ethiopian Wolf population.

MATERIALS & METHODS

Study area

Mt. Guna is located in South Gondar Zone at 11.750^{0}N, 38.250^{0}E, with a peak rises to 4,231 m (Figure 1). Mt. Guna has afroalpine (3,500–4,231 m) and subafroalpine (3,200–3,500 m) ecosystems suitable to Ethiopian Wolf *Canis simensis* and mountain rodents. The area coverage is 210 km^2 of land above 3,200 m, and 110 km^2 above 3,400 m, but no more than 40 km^2 above 3,800 m which is good habitat for Ethiopian Wolf (Sillero-Zubiri & Macdonald 1997; Belste et al. 2012)

Mt. Guna is surrounded by six districts of South Gondar Zone namely Lay and Tach Gayint, Farta, East Este, Simada, and Dera. The economy of the people living in those districts is mainly dependent on subsistence Agriculture. They cultivate crops like barley, wheat, bean, potato, and own livestock including cattle, sheep, donkey, and horse. The vegetation of Mt. Guna includes different grass species like 'guassa' and tree species with many animal lives including rodents, jackals, gelada baboons, hyenas, and rock hyraxes. The area is also inhabited by giant lobelia tree which is known to be the unique characteristic to afroalpine and subafroalpine ecosystems (ALZR 2006; Belste et al. 2012).

Data collection

Before starting the field work, permission for rodent collection and habitat observation was acquired from South Gondar Zone Wildlife Conservation Authority Office, Ethiopia. A quantitative cross-sectional study was conducted in the dry season of 2015 on Mt. Guna, northwestern Ethiopia. Samples were collected at three localities: bottom, middle and top of Mt. Guna. Three 60 X 60 m trapping grids (1.08 ha) were set at each site, and 36 Sherman traps were placed: 12 at top of afroalpine, 12 at middle, and 12 at bottom of subafroalpine ecosystem in the sampling period. Traps were baited with a mixture of rolled oats and peanut butter. The traps were set

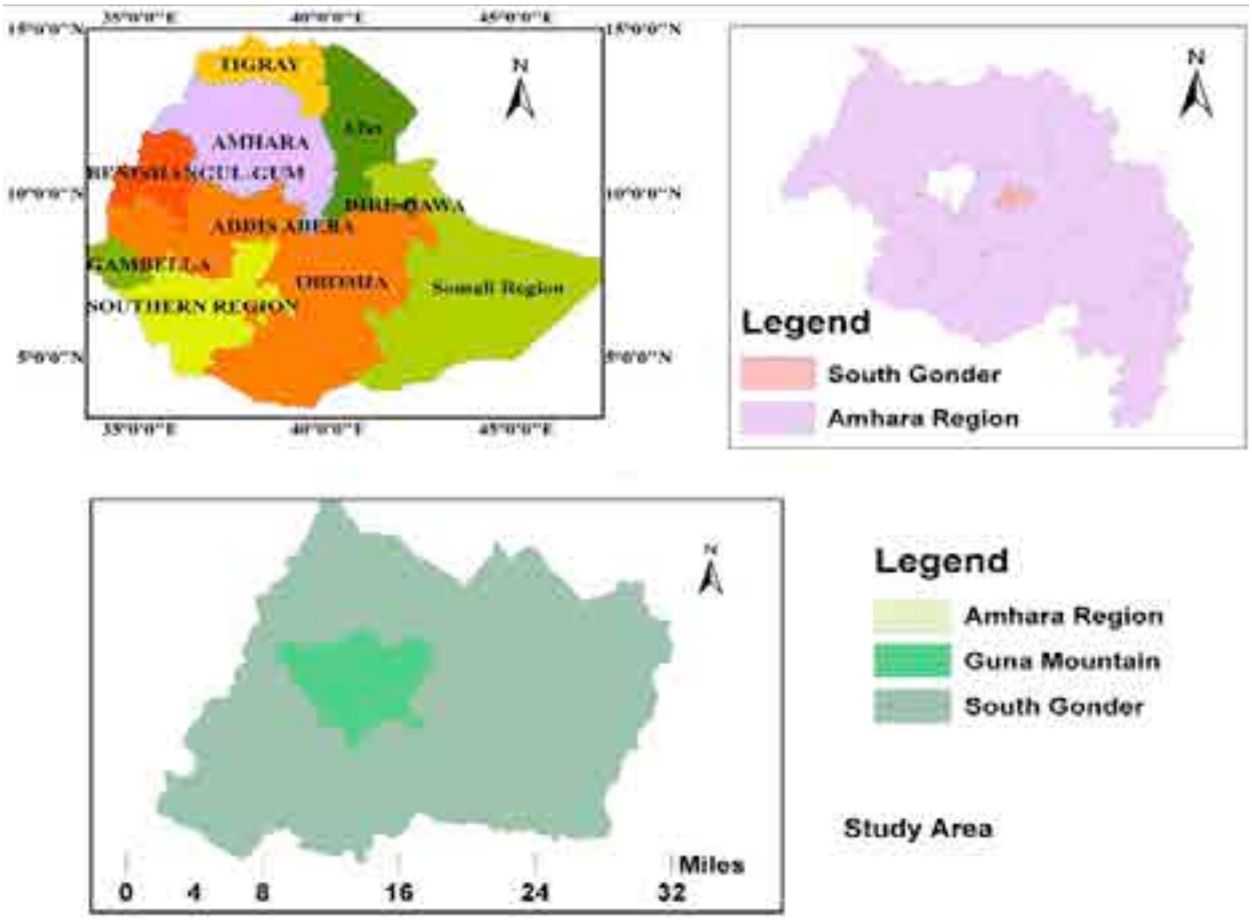

Figure 1. Map of Mt. Guna

in the late afternoon (1500–1600 h) and left in the sampling sites for three consecutive days and nights. They were checked during the morning (0600–1200 h) and afternoon (1600–1800 h). Capture terms consisted of two sampling periods (February and March) separated by a month interval without trapping. All captured rodents were used for species identification, distribution, as well as stomach contents analysis according to the standard (Hope & Parmenter 2007). After identification done through morphological characteristics including differences in body size, shape, fur texture and colour (Aplin et al. 2003; Jonathan 2004), only two species of rodent namely Abyssinian Grass Rat *A. abyssinicus,* and Common Mole Rat *T. splendens* were counted, marked and released to their respective habitats with other trapped rodents when encountered. In addition, active burrows (fresh burrows that have marks of rodents and freshly excavated soil and cut parts of various plants) of the above rodents were identified and counted from the same grids for further determination of distribution and abundances. Percentage of active burrows in the area was estimated as:

Population of active burrows %= (Number of active burrows/Total burrows examined all over) * 100 (Feliciano et al. 2002; Desoky 2007).

Eight rodents (four for each species) were taken to Debre Tabor University, laboratory of Department of Biology, for dissection to remove the gastro-intestinal contents. Diet analysis was carried out using the method of DeBlasé & Martin (1981). Accordingly, contents of the stomach were placed in a petri dish and thoroughly mixed to loosen material to give all constituents a uniform distribution. Then the contents were examined under a light microscope at 20x magnification to identify food items. Four fields of observation were examined. The diagram of food web was also drawn and trophic level of rodents was shown for Mt. Guna based on current result and the literature.

Since Belste et al. (2012) reported the presence of Ethiopian Wolf in Mt. Guna after the report of species extinction (IUCN/SSC 2011), interview questions were administered to check the presence-absence of the species. Fifty local people were purposively selected and interviewed to know when the wolf was observed for the last time in the study area and the reason for extinction. The local people were purposively selected based on the knowledge of the wolf, distance from the study area (nearby) and residence in the adjacent villages.

Data analysis

Distribution of *A. abyssinicus* and *T. splendens* was calculated with descriptive statistics. Number of rodents and their burrows collected from the three sites was shown on table and graph. Absolute number of the rodents in a population was calculated by Peterson-Lincoln index (Seber 1982) as follows. $N = \frac{M.S}{R}$, where N= population size estimate, M= marked individuals released, S= size of second sample captured, and R= marked animals recaptured.

Food web for the overall study area was shown by table and diagram. Independent two-sample t-test on Minitab software was used to compare food items eaten by both species. In addition, Independent two-sample t-test on R-software was used to compare distribution of both species among the three sites. Statistical value of 0.05 was taken as significance level.

RESULTS

Rodent species identification and distribution

In the present study, two species of rodent namely Abyssinian Grass Rat and Common Mole Rat were collected from afroalpine and subafroalpine ecosystems of Mt. Guna (Image 1). From all sites, a total of 162 rodents were captured during the first session of study period. From these, 110 (52.73% from the top, and 47.27% from the middle) were *A. abyssinicus* and 52 (23.08% from the top, 26.92% from the middle, and 50% from the bottom) were *T. splendens*. Regarding to the distribution, high number of *A. abyssinicus* (52.73%) was collected from the peak of the mountain following the middle (47.27%); however, low number of *T. splendens* (23.08%) was collected from the top, even though there was no significant differences among the three sites (p= 0.41, df= 2.22). On the other hand, high number of *T. splendens* (50%) was sampled from the bottom of Mt. Guna from where no single *A. abyssinicus* was collected as indicated on Table 1. In addition, 124 *A. abyssinicus* and 48 *T. splendens* were captured in the second session of the study period with almost similar distribution as of first session (Table 2). The overall estimated population number of *A. abyssinicus* and *T. splendens* in the study area computed by Peterson-Lincoln Index was 1,364 and 416, respectively.

A total of 379 burrows, of which 179 were active, were counted from the same grids laid in total of 3.24 ha to sample rodents. As shown on Table 1, there was no *A. abyssinicus* burrow counted from the bottom of the study area whereas 104 (59.09 %) *T. splendens* burrows were counted from the same site. However, there was high population of *A. abyssinicus* at the top (n= 107, 52.63 %) followed by the middle (n= 96, 47.37 %) of the mountain. These distribution differences of burrows among the three sites were also not significant (p= 0.84, df= 2). Out of the total burrows of each rodent, 51.14 % of them were active for *T. splendens*, whereas 43.84 % were active for *A. abyssinicus*. Such high percentage of active burrows supports the existence of significant numbers of both rodents in the study area.

Stomach content analysis

Eight rodents: four *T. splendens* and four *A. abyssinicus* were dissected and stomach contents were taken. Diets of each rodent were identified into plant and arthropod types under the light microscope. Accordingly, *T. splendens* and *A. abyssinicus* have been identified to consume both plants and arthropods (Table 3). In contrast, there was no significant difference on the consumption of arthropods between both species (p= 0.466, df= 4). In addition to the stomach content analysis, the remains of leftover of plant parts and arthropod parts after their feeding were observed on the way to their burrows during field work.

Habitat observation

During data collection, the authors have repeatedly observed Mt. Guna afroalpine and subafroalpine ecosystems. Destruction of grasses and other vegetation due to high population of rodents, rock hyraxes and livestock at the bottom and middle of the ecosystems was observed (Figure 2). Furthermore, the same condition was seen at the top of afroalpine due to high populations of rodents and some groups of Gelada *Theropithecus gelada,* endemic to Mt. Guna, foraging in the same habitat. Moreover, rodents living adjacent to agricultural lands were observed to migrate to agricultural fields and damage farmers' crops.

Assessment on the extinction of Ethiopian wolf

Side by side with data collection of rodents in Mt. Guna, 50 respondents were interviewed to check whether Ethiopian Wolf is present or locally extinct. All interviewees assured the local extinction of the wolf

Table 1. Number of rodents collected in first session and total burrows counted from the three sites of Mt. Guna.

	No. of rodent		No. of burrows	
Grids	*A. abyssinicus*	*T. splendens*	*A. abyssinicus*	*T. splendens*
Top	58 (52.73%)	12 (23.08%)	107 (52.63%)	12 (6.82%)
Middle	52 (47.27%)	14 (26.92%)	96 (47.37%)	60 (34.09%)
Bottom	---	26 (50%)	---	104 (59.09%)
Total	110 (100%)	52 (100%)	203 (100%)	176 (100%)
	df= 2.22 p= 0.41		df= 2 p= 0.84	

Table 2. Number of first captures and recaptures of *A. abyssinicus* and *T. splendens* by Sherman traps from three sites (three grids from each site= S1, S2 and S3) of Mt. Guna

Species	Site	First capture (marked individuals and released)	Second capture	Marked animals recaptured
A. abyssinicus	Top			
	S1	23	27	2
	S2	20	19	1
	S3	15	21	1
	Total	58	67	4
	Middle			
	S1	15	20	2
	S2	20	19	2
	S3	17	18	2
	Total	52	57	6
	Overall total	110	124	10
T. splendens	Top			
	S1	4	5	--
	S2	5	2	--
	S3	3	4	1
	Total	12	11	1
	Middle			
	S1	6	8	1
	S2	3	5	1
	S3	5	4	--
	Total	14	17	2
	Bottom			
	S1	7	5	--
	S2	9	7	1
	S3	10	8	--
	Total	26	20	1
	Overall total	52	48	4

by habitat destruction in spite of other factors such as human killing, rabies virus and climate change they were asked. Most of the respondents had observed the wolf between 6–8 years followed by before 10 years. All of them responded that they have never seen the wolf since four years (Figure 2). They said that a single wolf has been observed for years until total disappearance from the study area in 2011.

Image 1. Grid sites: A—bottom | B—middle | C—top of Mt. Guna. © Hirpasa Teressa

Table 3. Frequency of plants and arthropods diet identified from the stomach of four *T. splendens* and four *A. abyssinicus* collected from Mt. Guna.

Rodent species		Frequency of plant parts	Frequency of arthropod parts
T. splendens (T)	T1	38 (73.08%)	14 (26.92%)
	T2	53 (79.10%)	14 (20.90%)
	T3	41 (82%)	9 (18%)
	T4	48 (90.56%)	5 (9.44%)
Average		45 (81.08%)**	10.5 (18.92%)*
A. abyssinicus (A)	A1	31 (75.61%)	10 (24.39%)
	A2	28 (71.79%)	11 (28.21%)
	A3	25 (64.10%)	14 (35.90%)
	A4	34 (69.38%)	15 (30.62%)
Average		29.50 (70.24%)**	12.5 (29.76%)*

** Significant at 0.05 significance level (P= 0.017, df= 3)
* Not significant at 0.05 significance level (P= 0.466, df= 3)

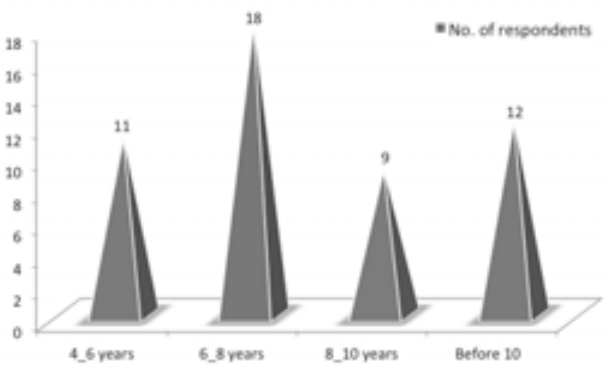

Figure 2. Number of respondents according to their year of observation of wolf in Mt. Guna.

DISCUSSIONS

In the present study, distribution, diets and trophic level of two species of rodents, the Abyssinian Grass Rat and Common Mole Rat, were assessed. Both species were identified in afroalpine and subafroalpine ecosystems of Mt. Guna. Mark-recapture method indicated that there was high population of *T. splendens* at the bottom, while *A. abyssinicus* was abundant at the peak of Mt. Guna. In agreement to the current study, Belste et al. (2012) identified Abyssinian Grass Rat and Common Mole Rat along with common home rat *Arvicanthis* spp., Harrington's Rat *Desmomys harringtoni*, Harsh-furred Rat *Lophuromys flavopunctatus*, and White-footed Rat *Stenocephalemys albipes* from the study area.

Since active burrows give an idea of the number of rodents living in the study area (Desoky 2007), burrow count was also carried out to support the mark-recapture method. The result of burrow counts confirmed the existence of high population of *A. abyssinicus* and *T. splendens* in the study area. Like trap method, burrow count method also indicated that there was high population of *T. splendens* at the bottom, but *A. abyssinicus* was totally absent from the bottom grids though field observation depicted the existence of it in smaller number. However, there was high distribution of *A. abyssinicus* at the top and middle of the ecosystems. Study conducted by Yihune & Bekele (2012) in afroalpine habitat of Simien Mountains National Park (SMNP) also identified significant number of *A. abyssinicus* and *T. splendens*.

Environmental degradation due to high population of rodents as a result of the extinction of wolf predator from Mt. Guna was clearly seen through field observation. In support to this, study shows that cyclic fluctuations in population density of rodents have major impacts on the dynamics of their food and vertebrate predators (Ims & Fuglei 2005). In addition, high population of livestock was observed in the ecosystems. Such pressures can lead to massive destruction, depletion and degradation of wildlife habitats as well as severe reduction in wildlife population (Hillman 1993). Furthermore, field observation and interviews of local farmers showed that those rodents living in the study area migrated to nearby agricultural fields for searching of additional foods. Such migration observed to cause crop damage in agricultural fields even though it was not quantified by the present study.

Out of the total diets consumed by both species, there was high frequency of plant parts (not identified into species level) in their stomach contents which assures the fact that the majority of their diet is plant. However, more plant parts were consumed by Common Mole Rats than by Abyssinian Grass Rats. Even though both species consume arthropods (not identified into species level), it was significantly less when compared to plant parts. In agreement to the current study, Best et al. (1993) identified that rodents are omnivorous animals mainly consuming large quantities of plant parts. This might be due to the availability, selectivity, and palatability of plant diets in afroalpine and subafroalpine habitat as already stated by Beyene (1986) for other species of the *Tachyoryctes* genera.

Based on the current result of stomach content analysis and other published literatures, trophic levels and food web have been diagrammatically shown for the study area. Besides to the stomach content analysis,

Table 4. Major animals identified from Mt. Guna and their food items.

Animal species (Belste et al. 2012)	Food items	Identification of food items
Rodents		
Common Mole Rat *Tachyoryctes splendens*	Plant parts, arthropods	Current Lab work
Abyssinian Grass Rat *Arvicanthis abyssinicus*	Plant parts, arthropods	Current Lab work
Harrington's Rat *Desmomys harringtoni*	---	xx
Harsh-furred Rat *Lophuromys flavopunctatus*	Arthropods, small vertebrates, plant matter	Dieterlen 1976
White-footed Rat *Stenocephalemys albipes*	---	xx
Carnivores		
Common Jackal *Canis aureus*	Rodents, ungulates, livestock	Bošković et al. 2013
Black-backed Jackal *Canis mesomelas*	Rodents, ungulates, birds, Reptiles, insects, grass	Humphries et al. 2015
Ethiopian Wolf *Canis simensis**	Rodents, sheep (rare)	Ashanafi et al. 2005
Caracal *Caracal caracal*	Rodents, birds, ungulates	Braczkowski et al. 2012
Wildcat *Felis silvestris lybica*	Shrews, rabbits, birds, reptiles, rodents, insects	Moleón & Gil-Sánchez 2003
Serval *Leptailurus serval*	Rodents, antelopes, insects, reptiles	Ramesh & Downs 2014
Leopard *Panther pardus*	Livestock, monkey, rodents, birds, hares	Kshettry et al. 2018
Spotted Hyena *Crocuta crocuta*	Livestock, human, porcupine, hare, bushbuck, kudu, waterbuck, common duiker	Yirga et al. 2015
Striped Hyena *Hyaena hyaena*	mammals, rodents, insects, livestock	Alam & Khan 2015
Common Dwarf Mongoose *Helogale parvula*	Insects, spiders, scorpion, lizards, snakes, small birds and rodents	Ramulondi & Zengeya 2014
African civet *Civettictis civetta*	mammals, birds, reptiles, insects, plant parts	Tadesse et al. 2017
Primates		
Gelada baboon *Theropithecus gelada*	Grasses, herbs, other plant parts	Kelil et al. 2018
Vervet Monkey *Cercopithecus aethiops*	Invertebrates, plant parts	Tournier et al. 2014
Olive baboon *Papio anubis*	Plant parts, insects, birds, mushrooms	Okecha & Newton-Fisher 2006
Herbivores		
Common Duiker *Sylvicapra grimmia*	Herbivores feed on vegetation such as grasses, fruits, leaves, roots, bulbs, etc.	Karmiris et al. 2011
Klipspringer *Oreotragus oreotragus*		
Rock Hyrax *Heterohyrax brucei*		
Birds		
Hooded Vulture *Necrosyrtes monachus*	A review by Lopes et al. (2016) identified all diet types and food categories for tropical birds. The study revealed 23 food types frequently eaten by birds and proposed standard names for birds (e.g., granivore, frugivore, and insectivore). Accordingly, plant diet consumed by birds mainly are fruits, seeds, grains, plant fluids, leaves, buds, grasses, nectar, pollen, etc. In addition, birds also consume insects including ants, cockroaches, termites, locusts, bugs, beetles, flies, butterflies, dragonflies, bees, wasps, stoneflies, and mayflies. Birds of prey eat animal flesh including fish, reptiles,mammals, birds, insects, and molluscs.	
Greater Spotted Eagle *Aquila clanga*		
Red-throated Bee-eater *Merops bullocki*		
Blue-winged Goose Cyanochen cyanopterus		
Wattled Ibis *Bostrychia carunculata*		
Black-winged Lovebird *Agapornis taranta*		
White-collared Pigeon *Columba albitorques*		
Ring-necked Dove *Streptopelia capicola*		
Red-eyed Dove *Streptopelia semitoquata*		
Thick-billed Raven *Corvus crassirostris*		
Fan-tailed Raven *Corvus rhipidurus*		
Abyssinian Long Claw *Macronyx flavicollis*		
Abyssinian Catbird *Parophasma galinieri*		
Ankober Serin *Serinus ankoberensis*		
White-cheeked Turaco *Tauraco leucotis*		
Moorland Francolin *Francolinus psilolaemus*		
Red-fronted Parrot *Poicephalus gulielmi*		
African Firefinch *Lagonosticta rubricate*		
Ethiopian Swallow *Hirundo aethiopica*		
Widowbird *Euplectes orix*		

*—Locally extinct | **—No published work on the diets of the animals.

Figure 3. Diagram of food web in Mt. Guna (sketched by Hirpasa Teressa).

diets of animals existing in Mt. Guna were reviewed and summarized in Table 4. Based on the summary, a diagram of food web was drawn (Figure 3).

As shown on Figure 4, *T. splendens* and *A. abyssinicus* consume both plants and arthropods, hence grouped under omnivorous animals (2^{nd}, 3^{rd} and even more trophic levels). However, it is difficult to determine specific position of omnivores' trophic level since they consume materials from different trophic levels of the food web (Williams & Martinez 2004).

Ethiopian Wolf *Canis simensis*, which is endemic to Ethiopia, is the rarest canid in the world with a total global population of 500 individuals and classified as 'Endangered' on the IUCN Red List of Threatened Species (Marino & Sillero-Zubiri 2013; Marino et al. 2017). The wolf highly adapted to live in afroalpine and subafroalpine ecosystems above altitudes of 3,000 m, and is almost exclusively the predator of high altitude rodents (Marino et al. 2010; Yihune & Bekele 2012). Study shows that Ethiopian Wolf is an important flagship species for conservation of the afroalpine biodiversity (IUCN/SSC 2011), but faces serious threats to its survival in its ecosystem. In the present study, all the interviewees agreed the local extinction of Ethiopian Wolf *Canis simensis* due to habitat degradation. According to the respondents the single wolf was seen in 2011 for the last time. This agrees with the report by IUCN/SSC (2011) on its extinction from Mt. Guna although Belste et al. (2012) claimed to identify the wolf from the same study area referring to the local community. For long, the ecosystems of Ethiopian highlands had been threatened by overpopulation, overgrazing, and crop cultivation (Leipzig 1996). Similarly, Mt. Guna is currently under human induced threats from agricultural expansion, livestock overstocking, overharvesting of natural resources and settlements (Belste et al. 2012) that might mainly resulted in the local extinction of Ethiopian Wolf.

CONCLUSION

In the current study, the distribution, diets and trophic level of two rodent species namely Abyssinian Grass Rat and Common Mole Rat was assessed from Mt. Guna afroalpine and subafroalpine ecosystems. The results from Sherman traps and burrows count showed that both species were identified to be highly populated in the study area. Stomach content analysis revealed that both species consume both plants and arthropods, hence grouped under omnivorous animals (2^{nd}, 3^{rd} and even more trophic levels). Furthermore, Ethiopian Wolf was also confirmed to be locally extinct from Mt. Guna due to habitat degradation.

Based on the current study, we recommend that intensive studies should be carried out to analyse the effect of rodent community on Mt. Guna ecosystems due to the extinction of Ethiopian Wolf. To reduce effects of rodent pests and environmental degradation in the present study area, the long run rodent prey control by their predator, and habitats conservation should also be taken into consideration. Further study that include different seasons and impact of pest rodents on agricultural lands should also be carried out in Mt. Guna.

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COMMUNICATION

Seasonal composition of avian communities in different habitats of Harike Wetland, a Ramsar site in Punjab, India

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Abstract: The documentation of avifauna of Harike wetland was carried out during November, 2019 to November, 2021 in different habitats and seasons. A total of 225 bird species belonging to 18 orders and 61 families were recorded; 18 fall under the Red List of IUCN, with 11 categorized as Near Threatened, six vulnerable, and one Endangered. Order Passeriformes had the greatest number of species, and mosaic habitats with diverse vegetation showed the highest bird diversity. This study will aid future conservation measures and wetland management programs.

Keywords: Bird diversity, conservation, largest freshwater riverine wetland, threatened species.

ਹਰੀਕੇ ਵੈੱਟਲੈਂਡ (ਝੀਲ) ਦੇ ਦਸਤਾਵੇਜ਼ੀ ਅਤੇ ਸਥਿਤੀ ਸਰਵੈ ਅਨੁਸਾਰ ਸਾਲ 2019-21 ਦੌਰਾਨ ਇੱਥੇ ਆਉਣ ਵਾਲੇ ਪੰਛੀਆਂ ਦਾ ਅਲੱਗ ਅਲੱਗ ਸਥਾਨ ਅਤੇ ਵੱਖਰੀਆਂ ਰੁੱਤਾਂ ਵਿੱਚ ਅਧਿਐਨ ਕੀਤਾ ਗਿਆ, ਜਿਸ ਅਨੁਸਾਰ ਇਸ ਥਾਂ ਦਾ ਪੰਜਾਬ ਵਿੱਚ ਪੰਛੀਆਂ ਦੀ ਵਿਭਿੰਨਤਾ ਦੇ ਨਜ਼ਰੀਏ ਤੋਂ ਕਾਫੀ ਮਹੱਤਵ ਹੈ। ਹਰੀਕੇ ਝੀਲ ਵਿੱਚ ਪੰਛੀਆਂ ਦੀਆਂ 225 ਪ੍ਰਜਾਤੀਆਂ ਪਾਈਆਂ ਜਾਂਦੀਆਂ ਹਨ ਜੋ ਕਿ 18 ਆਰਡਰ ਅਤੇ 61 ਫੈਮਲੀਆਂ ਨੂੰ ਸਬੰਧ ਰੱਖਦੀਆਂ ਹਨ। ਇਹਨਾਂ 225 ਪ੍ਰਜਾਤੀਆਂ ਵਿੱਚੋਂ 18 ਪ੍ਰਜਾਤੀਆਂ IUCN ਦੀ ਲਾਲ ਸੂਚੀ ਵਿੱਚ ਆਉਂਦੀਆਂ ਹਨ, 11 ਪ੍ਰਜਾਤੀਆਂ ਲੁਪਤ ਹੋਣ ਦੇ ਖਤਰੇ ਦੀ ਕਗਾਰ ਦੇ ਨੇੜੇ ਹਨ ਜਿਨ੍ਹਾਂ ਵਿੱਚੋਂ 6 ਕਮਜ਼ੋਰ/Vulnerable ਹਨ। ਇਹਨਾਂ ਵਿੱਚੋਂ ਇੱਕ ਪ੍ਰਜਾਤੀ ਬਿਲਕੁੱਲ ਲੁਪਤ ਹੋਣ ਦੀ ਕਗਾਰ ਤੇ ਹੈ ਅਤੇ ਬਾਕੀ ਪ੍ਰਜਾਤੀ ਸੁਰੱਖਿਅਤ ਹਨ। ਆਰਡਰ ਪੇਜ਼ਰੀਫਾਰਮਿਸ ਦੀਆਂ ਪ੍ਰਜਾਤੀਆਂ ਇਲਾਕੇ ਵਿੱਚ ਸਭ ਤੋਂ ਵੱਧ ਦਬਦਬਾ ਰੱਖਦੀਆਂ ਹਨ। ਅਧਿਐਨ ਅਨੁਸਾਰ ਇਹ ਵਧੇਰੇ ਸਪਸ਼ਟ ਰੂਪ ਵਿੱਚ ਸਾਹਮਣੇ ਆਇਆ ਕਿ ਪ੍ਰਜਾਤੀਆਂ ਦੀ ਬਹੁਤਾਤ ਉਸ ਥਾਂ ਵੱਧ ਮਿਲਦੀ ਹੈ ਜਿੱਥੇ ਪਾਣੀ ਦੇ ਨਾਲ ਨਾਲ ਬਨਸਪਤੀਆਂ ਵੀ ਹੋਣ। ਸੋ ਪੰਜਾਬ ਦੇ ਵਾਤਾਵਰਣ ਨੂੰ ਧਿਆਨ ਚ ਰੱਖਦੇ ਹੋਏ ਇਹ ਬਹੁਤ ਮਹੱਤਵਪੂਰਨ ਸਥਾਨ ਹੈ ਜੋ ਕਿ ਸੰਭਾਲਣਾ ਬਹੁਤ ਜਰੂਰੀ ਹੈ।

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INTRODUCTION

Wetlands are among the most fragile and productive habitats on earth (Mitsch & Gosselink 2000; Ladhar 2002; Kumar et al. 2005; Brraich & Singh 2021; Kaur & Brraich 2021). Harike Bird Sanctuary has wide flood plains along the confluence of the rivers Satluj and Beas in the Punjab districts of Ferozepur, Tarn Taran, and Kapurthala (Najar et al. 2017; Singh et al. 2020). India harbours over 1,400 bird species, of which over 300 rely on wetlands (Kumar et al. 2005; Praveen et al. 2016, 2020). Harike wetlands provide breeding, feeding, roosting and staging sites for many birds (Rahmani et al. 2016), and local bird diversity has been studied by various workers (Ali et al. 1981; Robson 1996; Kazmierczak et al. 1998; Robson 1999; Sawant & Sudhagar 2013; Prasad 2008a,b; Sangha 2013, 2017; Singh & Brraich 2021). The area is also home to the Smooth Indian Otter *Lutra perspicillata*, Golden Jackal *Canis aureus*, and Dolphin *Platanista gangetica minor* (Sinha 1997).

Birds are key components of wetland ecosystems. They are indicators of wetland health, as they respond to habitat changes such as human disturbance, poisoning, pollution, eutrophication, and siltation. They also reflect the productivity and tropic structures of wetlands (Morrison 1986; Subramanya 1996). Habitats play a significant role in bird diversity, and understanding habitat choices is important for bird conservation (Tavernia et al. 2016). In this study, a major aim was to prepare an inventory of avifaunal diversity in the various habitats of Harike wetland in different seasons.

Study Area

Harike Wetland is a large manmade freshwater riverine wetland and Wildlife and Bird Sanctuary in Punjab, India. Geographically, this sanctuary is located at latitudes of 31°060N & 31°120N and longitudes 74°550E & 75°050E semi-arid biogeographical zone formed by construction of Harike barrage in 1950 on river Beas and Satluj covering 8,435 ha area on the borders of districts Ferozepur, Tarn Taran, and Kapurthala and designated as Ramsar sites in 1990 (Image A) (Najar et al. 2017; Singh et al. 2020). Harike wetland was designated as wildlife sanctuary by the Ministry of Environment, Forest (MoEF), Government of India in 1982 later on it was declared as a bird sanctuary by the Punjab state government in 1992 (Mabwoga & Thukral 2014).

MATERIALS AND METHODS

Study site was visited in different seasons of Punjab for the span of two years (November 2019–November 2021) and birds are classified into three categories annual, winter, and summer birds (Mavi & Tiwana 1993). Survey was conducted during the maximum bird activity, predominantly between 0600–1100 h and 1500–1700 h adopting various methods like point count method, strip transect sampling, travelling with a manually propelled wooden fishing boat, visual counter method (Bibby et al. 2000; Buckland et al. 2001). Totally eight transect were designed to carry out the survey Image 2 and designated as I (6.23 km), II (6.95 km), III (2.25 km), IV (3.32 km), V (4.64 km), VI (5.47 km), VII (2.47 km), VIII (1.2 km) (Image 1 & 2). Observations of birds were made in all habitats which were classified as agriculture, built up (urban, rural, hamlet), forest (plantation, tree clad), water bodies (ponds, canal, brushwood along canal), wasteland (scrubland sandy area, shrubs/ grasses, dry bed of seasonal river), wetland (waterlogged aquatic vegetation, swampy land with scrub, reed, marshes) (Image 2) (Kalsi 1998; Kalsi et al. 2015; Singh et al. 2020). Photography of birds was done during the survey with DSLR camera Canon 1200D (75–300 mm zoom lens) and binocular (Olympus 8-16*40 zoom DPS-I) were used for spotting, and field notes were prepared, followed by identification of birds using field guides (Ali & Ripley 1983; Grewal et al. 1995; Grimmett et al. 2012) and nomenclature and classification is followed according to Praveen et al. (2016). The conservation status of species was assessed according to International Union for Conservation of Nature (2017), and residential and migratory status is based earlier literature and their presence or absence at study site (Grimmett & Inskipp 2010; Rai & Vanita 2021). Relative abundance is based upon the frequency of sightings birds were classified into different categories Very Common (recorded in more than 9–10/10 visits), Common (between 6–8/10 visits), Uncommon (between 3–5/10 visits) and Rare (recorded 1–2/10 visits) relative abundance on the basis of (McKinnon & Philips 1993). The relative diversity (RDi) of different families was calculated following La Torre-Cuadros et al. (2007) equation:

RDi= (Number of Bird species in Family/Total Number of Bird Species) X 100

Image 1. Harike Wetland, the study site.

Image 2. Different transects and habitat surveyed during the studied period.

RESULTS AND DISCUSSION

During the present investigations, total of 225 bird species under 18 orders and 61 families were reported from the Harike wetland and its surrounding areas (Table 1). This wetland supports 113 migrant and 112 resident bird species. Overall, Passeriformes are the dominant order with 38% (85 species), consistent with their being the dominant avian taxa of India (Praveen et al. 2016). They were followed by Charadriiformes 16% (37 species), Anseriformes 8.4% (19 species), Pelecaniformes 7.6% (17 species), Accipitriformes 5.8% (13 species), Coraciiformes 3.6% (8 species), Gruiformes 3.1% (7 species), Columbiformes 2.7% (6 species), and Strigiformes 2.2% (5 species). Orders like Cuculiformes, Piciformes, Podicipediformes, and Suliformes were represented by 1.8% (4 species) followed by Galliformes and Ciconiiformes with 1.3% (3 species) each. Birds were also found from orders Apodiformes, Falconiformes, and Psittaciformes (Table 3).

Species represented by orders Anseriformes, Pelecaniformes, Charadriiformes, Ciconiiformes, Galliformes, Gruiformes, Podicipediformes, and Suliformes were the major water birds, the rest are wetland-dependent birds (Kumar et al. 2005). Relative diversity data shows that family Anatidae was most diverse (19 species, RDi 8.444) with similar observations made at Basai wetland and Nangal wetland (Rai et al. 2019; Kaur & Brraich 2021), followed by Scolopacidae (14 species, RDi 6.22), Ardeidae (13 species, RDi 5.777), Accipitridae (12 species, RDi 5.333), Muscicapidae (11 speices, RDi 4.888), Laridae and Motacillidae (10 species, 4.444), Cisticolidae (8 species, RDi 3.555), Rallidae (7 speices, RDi 3.11), Charadriidae, Columbidae, Hirundinidae, and Sturnidae (6 speices, RDi 2.666), Cuculidae, Estrildidae, Phylloscopidae, Podicipedidae, Strigidae, and Threskiornithidae (4 species, RDi 1.777), Acrocephalidae, Alaudidae, Alcedinidae, Ciconiidae, Laniidae, Leiothrichidae, Phalacrocoracidae, Phasianidae, Picidae, and Ploceidae (3 species, RDi 1.333) lastly Anhingidae, Bucerotidae, Burhinidae, Coraciidae, Dicruridae, Jacanidae, Locustellidae, Monarchidae, Nectariniidae, Oriolidae, Pandionidae, Pellorneidae, Pycnonotidae, Rostratulidae, Stenostiridae, Tytonidae, Upupidae, Vangidae, and Zosteropidae were poorly diverse representing 1 species each and RDi 0.444 (Table 2).

Data on relative abundance show that 111 species were Very common, 69 species were common, 37 species were Uncommon and eight species were rare in the area. A comparative analysis of residential status of observed species with relative abundance shows that out of 112 resident species, 65 species were very common, 34 common, 11 Uncommon, and two rare; among 17 summer migrants; seven species were very common, three common, six uncommon, and one rare and trend in winter migrants which were 96 in number: 40 species were very common, 32 common, 19 common, and five rare (Figure 1). The population trends of present species and relative abundance shows that 68 species which are decreasing globally were present, of which 33 were very common, which shows the importance of unique habitat in the wetland in increasing trends. Eighty-seven species were globally stable, and the status of 35 was unknown as per IUCN (2021) (Figure 2).

Wetlands support globally threatened species such as Ferruginous Duck, Black-tailed Godwit, River Tern, Eurasian Curlew, River Lapwing, Painted Stork, Red-necked Falcon, Rufous-vented Grass Babbler, Black-headed White Ibis, Alexandrine Parakeet, Oriental Darter categorized under Near Threatened, Greater Spotted Eagle, Common Pochard, Woolly-necked Stork, Bristled Grass-Warbler, Jerdon's Babbler, Horned Grebe were listed under vulnerable category by IUCN. Bristled Grass-Warbler and Jerdon's Babbler were earlier recorded from this wetland (Kazmierczak et al. 1998; Prasad 2008b; Sawant & Sudhagar 2013; Singh & Brraich 2021). Interestingly, Jerdon's Babbler was found with nesting material, which shows their probable breeding record at Harike Wetland.

Seasonal data show that 112 species (50%) are present throughout year, 96 species (43%) were found

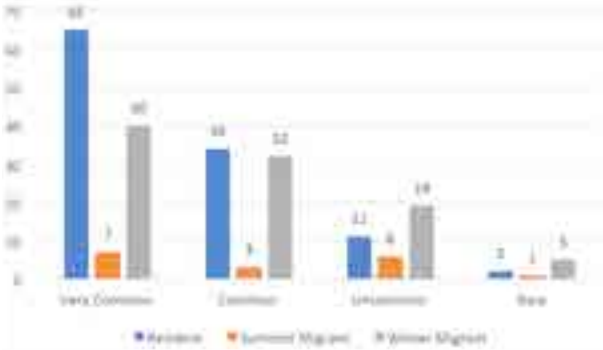

Figure 1. Comparison of residential status and abundance status of species in Harike Wetland.

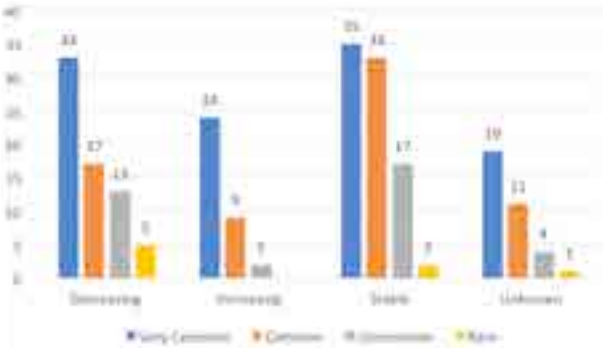

Figure 2. Relationship between population trends and abundance status of species at Harike Wetland.

in winter during migration, and the least number of species were found in summer (17 species; 7.6%). Habitat preference data revealed that combination of habitats like wetland, forest, waterbodies show the maximum number of birds, on the other hand build up, agriculture and wasteland show comparatively less bird diversity, resultantly it is concluded that to attract of more bird species wetland vegetation should be more diverse. Heterogenetic habitats and to the initiations of conservation measures always show more diversity (Burger 1985; Brown et al. 2001; Kushlan et al. 2002; Tu et al. 2020). Beside birds, wetlands are important habitats for reptiles like Gharial *Gavialis gangeticus* (Critically Endangered), mammals like Golden Jackal *Canis aureus*, Wild Boar *Sus scrofa*, Smooth-coated Otter *Lutrogale perspicillata* (Vulnerable), and Indus River Dolphin *Platanista gangetica* (Endangered). From diversity point of view, wetlands are most important in Punjab. Further, it is observed that wetland is highly human-dominated, and under severe pressure of resource extraction for various purposes. Wetlands and adjoining areas are facing land encroachment for agriculture, livelihood and

Table 1 . List of birds in different seasons and habitats with their conservation status.

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
Order: Accipitriformes							
1	Black Kite *Milvus lineatus* (Boddaert, 1783)	Accipitridae	Summer, Rainy, Autumn, Winters, Spring	Forest /Water bodies / Built up	Least Concern/ Stable	Resident	VC
2	Black-winged Kite *Elanus caeruleus* (Desfontaines, 1789)	Accipitridae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Water bodies/ Agriculture land/ Built Up	Least Concern/ Stable	Resident	VC
3	Booted Eagle *Hieraaetus pennatus* (Gmelin, 1788)	Accipitridae	Autumn, Winters, Spring	Forest/ Water bodies	Least Concern/ Stable	Winter Migrant	UC
4	Crested Serpent-Eagle *Spilornis cheela* (Latham, 1790)	Accipitridae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Water bodies	Least Concern/ Stable	Resident	UC
5	Eurasian Sparrowhawk *Accipiter nisus* (Linnaeus, 1758)	Accipitridae	Autumn, Winters, Spring	Forest/ Water bodies	Least Concern/ Stable	Winter Migrant	C
6	Shikra *Accipiter badius* (Gmelin, 1788)	Accipitridae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Water bodies/ Built Up/ Agriculture	Least Concern/ Stable	Resident	VC
7	Steppe Eagle *Aquila nipalensis* Hodgson, 1833	Accipitridae	Autumn, Winters, Spring	Forest/ Water bodies	Endangered/ Decreasing	Resident	UC
8	Short-toed Snake-Eagle *Circaetus gallicus* (Gmelin, 1788)	Accipitridae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Water bodies	Least Concern/ Stable	Resident	UC
9	Greater Spotted Eagle *Clanga hastate* (Pallas, 1811**)**	Accipitridae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Water bodies	Vulnerable/ Decreasing	Resident	UC
10	Common Buzzard *Buteo buteo* Linnaeus, 1758	Accipitridae	Autumn, Winters, Spring	Forest/ Water bodies	Least Concern/ Stable	Winter Migrant	UC
11	Oriental Honey-Buzzard *Pernis ptilorhynchus* (Temminck, 1821)	Accipitridae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Water bodies	Least Concern/ Stable	Resident	C
12	Osprey *Pandion haliaetus* (Linnaeus, 1758)	Pandionidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Water bodies	Least Concern/ Increasing	Winter Migrant	C
13	Hen harrier *Circus cyaneus* (Linnaeus, 1766)	Accipitridae	Autumn, Winters, Spring	Forest/ Water bodies/Wasteland	Least Concern/ Decreasing	Winter Migrant	R
Order: Anseriformes							
14	Bar-headed Goose *Anser indicus* (Latham, 1790)	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
15	Comb Duck *Sarkidiornis melanotos* (Pennant, 1769)	Anatidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Resident	VC
16	Common Pochard *Aythya ferina* (Linnaeus, 1758)	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Vulnerable/ Decreasing	Winter Migrant	VC
17	Common Teal *Anas crecca* Linnaeus, 1758	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	VC
18	Cotton Teal *Nettapus coromandelianus* (Gmelin, 1789)	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Stable	Winter Migrant	UC
19	Eurasian Wigeon *Anas penelope* Linnaeus, 1758	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
20	Gadwall *Anas strepera* Linnaeus, 1758	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
21	Garganey *Anas querquedula* Linnaeus, 1758	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
22	Grey-leg Goose *Anser anser* (Linnaeus, 1758)	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
23	Indian Spotbill Duck *Anas poecilorhyncha* J.R. Forester, 1781	Anatidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies/ Agriculture	Least Concern/ Decreasing	Resident	VC
24	Lesser Whistling Duck *Dendrocygna javanica* (Horsfield, 1821)	Anatidae	Summer, Rainy	Wetland/ Waterbodies/ Agriculture	Least Concern/ Decreasing	Summer Migrant	VC
25	Northern Shoveller *Anas clypeata* Linnaeus, 1758	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
26	Northern Pintail *Anas acuta* Linnaeus, 1758	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
27	Red Crested Poachard *Netta rufina* (Pallas, 1773)	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	VC
28	Ruddy Shelduck *Tadorna ferruginea* (Pallas, 1764)	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	VC
29	Common Shelduck *Tadorna tadorna* (Linnaeus, 1758)	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
30	Mallard *Anas platyrhynchos* Linnaeus, 1758	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
31	Ferruginous Duck *Aythya nyroca* (Guldenstadt, 1770)	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Near Threatened/ Decreasing	Winter Migrant	VC
32	Tufted Duck *Aythya fuligula* (Linnaeus, 1758)	Anatidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Stable	Winter Migrant	VC
Order: Apodiformes							
33	House Swift *Apus affinis* (J.E. Gray, 1830)	Apodidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland	Least Concern/ Increasing	Resident	VC
34	Alpine Swift *Tachymarptis melba* (Linnaeus, 1758)	Apodidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland	Least Concern/ Stable	Resident	VC
Order: Charadriiformes							
35	Black-tailed Godwit *Limosa limosa* (Linnaeus, 1758)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Wasteland	Near Threatened/ Decreasing	Winter Migrant	VC
36	Black-winged Stilt *Himantopus himantopus* (Linnaeus, 1758)	Recurvirostridae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies/ Wasteland/ Agriculture	Least Concern/ Increasing	Resident	VC
37	Common Redshank *Tringa totanus* (Linnaeus, 1758)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	VC
38	Common Sandpiper *Actitis hypoleucos* Linnaeus, 1758	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
39	Common Snipe *Gallinago gallinago* (Linnaeus, 1758)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	C
40	Dunlin *Calidris alpina* (Linnaeus, 1758)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
41	Eurasian Thick-Knee *Burhinus oedicnemus* (Linnaeus, 1758)	Burhinidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland	Least Concern/ Decreasing	Resident	C
42	Green Sandpiper *Tringa ochropus* Linnaeus, 1758	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
43	Greenshank *Tringa nebularia* (Gunner, 1767)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Stable	Winter Migrant	VC
44	Small Pratincole *Glareola lactea* Temminck, 1820	Glareolidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland/ Waterbodies	Least Concern/ Unknown	Resident	C

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
45	Little Ringed Plover *Charadrius dubius* Scopoli, 1786	Charadriidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Stable	Winter Migrant	VC
46	Common Ringed Plover *Charadrius hiaticula* Linnaeus, 1758	Charadriidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	C
47	Little Stint *Calidris minuta* (Leisler, 1812)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
48	Marsh Sandpiper *Tringa stagnatilis* (Bechstein, 1803)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	C
49	Pheasant Tailed Jacana *Hydrophasianus chirurgus* (Scopoli, 1786)	Jacanidae	Summer, Rainy	Wetland/ Waterbodies	Least Concern/ Decreasing	Summer Migrant	VC
50	Pied Avocet *Recurvirostra avosetta* Linnaeus, 1758	Recurvirostridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	VC
51	Red-wattled Lapwing *Vanellus indicus* (Boddaert, 1783)	Charadriidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland	Least Concern/ Unknown	Resident	VC
52	River Lapwing *Vanellus duvaucelii* (Lesson, 1826)	Charadriidae	Autumn, Winters, Spring	Waterbodies/ Wetland	Near Threatened/ Decreasing	Winter Migrant	C
53	Ruff *Philomachus pugnax* (Linnaeus, 1758)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
54	Spotted Redshank *Tringa erythropus* (Pallas, 1764)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Stable	Winter Migrant	C
55	Temminck Stint *Calidris temminckii* (Leisler, 1812)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	C
56	White-tailed Lapwing *Vanellus leucurus* (Lichtenstein, 1823)	Charadriidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	VC
57	Wood Sandpiper *Tringa glareola* Linnaeus, 1758	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Stable	Winter Migrant	VC
58	Eurasian Curlew *Numenius arquata* (Linnaeus, 1758)	Scolopacidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Near threatened/ Decreasing	Winter Migrant	C
59	Yellow Wattled Lapwing *Vanellus malabaricus* (Boddaert, 1783)	Charadriidae	Summer, Rainy	Wasteland	Least Concern/ Stable	Summer Migrant	UC
60	Oriental Pratincole *Glareola maldivarum* J.R. Forster, 1795	Glareolidae	Autumn, Winters, Spring	Waterbodies	Least Concern/ Decreasing	Summer Migrant	UC
61	Greater Painted Snipe *Rostratula benghalensis* (Linnaeus, 1758)	Rostratulidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	UC
62	Black-headed Gull *Larus ridibundus* Linnaeus, 1766	Laridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	C
63	Brown-headed Gull *Larus brunnicephalus* Jerdon, 1840	Laridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Stable	Winter Migrant	C
64	Gull-billed Tern *Gelochelidon nilotica* (Gmelin, 1789)	Laridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	C
65	Pallas's Gull *Larus ichthyaetus* Pallas, 1773	Laridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
66	Yellow-legged Gull *Larus cachinnans* Pallas, 1811	Laridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
67	Heuglin's Gull *Larus heuglini* Bree, 1876	Laridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	C
68	Little Gull *Larus minutus* Pallas, 1776	Laridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	C

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
69	River Tern *Sterna aurantia* J.E. Gray, 1831	Laridae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Near Threatened/ Decreasing	Resident	VC
70	Little Tern *Sterna albifrons* Pallas, 1764	Laridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	UC
71	Whiskered Tern *Chlidonias hybridus* (Pallas, 1811)	Laridae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern / Stable	Winter Migrant	VC
Order: Ciconiiformes							
72	Asian Openbill Stork *Anastomus oscitans* (Boddaert, 1783)	Ciconiidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Resident	C
73	Painted Stork *Mycteria leucocephala* (Pennant, 1769)	Ciconiidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Near Threatened/ Decreasing	Resident	VC
74	Woolly-necked Stork *Ciconia episcopus* (Boddaert, 1783)	Ciconiidae	Autumn, Winters, Spring	Wasteland/ Waterbodies/ Wetland	Vulnerable/ Decreasing	Winter Migrant	C
Order: Columbiformes							
75	Rock Pigeon *Columba livia* Gmelin, 1789	Columbidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Built up/ Agriculture	Least Concern/ Decreasing	Resident	VC
76	Eurasian Collared Dove *Streptopelia decaocto* (Frivaldszky, 1838)	Columbidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Increasing	Resident	C
77	Laughing Dove *Streptopelia senegalensis* (Linnaeus, 1766)	Columbidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	C
78	Red Turtle Dove *Streptopelia tranquebarica* (Hermann, 1804)	Columbidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Decreasing	Resident	C
79	Spotted Dove *Streptopelia chinensis* (Scopoli, 1786)	Columbidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies/ Built up	Least Concern/ Increasing	Resident	C
80	Yellow Footed Green Pigeon *Treron phoenicoptera* (Latham, 1790)	Columbidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies/ Built up	Least Concern/ Unknown	Resident	VC
Order: Coraciiformes							
81	Common Kingfisher *Alcedo atthis* (Linnaeus, 1758)	Alcedinidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wetland/ Waterbodies	Least Concern/ Unknown	Resident	VC
82	Eurasian Hoopoe *Upupa epops* Linnaeus, 1758	Upupidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wetland/ Waterbodies/ Built up	Least Concern/ Decreasing	Resident	VC
83	Green Bee-Eater *Merops orientalis* Latham, 1801	Meropidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Increasing	Resident	VC
84	Indian Grey Hornbill *Ocyceros birostris* (Scopoli, 1786)	Bucerotidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Stable	Resident	VC
85	Indian Roller *Coracias benghalensis* (Linnaeus, 1758)	Coraciidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Increasing	Resident	C
86	White-Throated Kingfisher *Halcyon smyrnensis* (Linnaeus, 1758)	Alcedinidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wetland/ Waterbodies/ Built up	Least Concern/ Unknown	Resident	VC
87	Lesser Pied Kingfisher *Ceryle rudis* (Linnaeus, 1758)	Alcedinidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wetland/ Waterbodies	Least Concern/ Unknown	Resident	VC
88	Blue Tailed Bee Eater *Merops philippinus* Linnaeus, 1766	Meropidae	Summer, Rainy	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Summer Migrant	VC
Order: Cuculiformes							
89	Asian Koel *Eudynamys scolopacea* (Linnaeus, 1758)	Cuculidae	Summer, Rainy	Forest/ Waterbodies/ Built up	Least Concern/ Stable	Summer Migrant	VC

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
90	Greater Coucal *Centropus sinensis* (Stephens, 1815)	Cuculidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Built up	Least Concern/ Stable	Resident	VC
91	Pied Crested Cuckoo *Clamator jacobinus* (Boddaert, 1783)	Cuculidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Stable	Resident	C
92	Common Hawk-cuckoo *Hierococcyx varius* (Vahl, 1797)	Cuculidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Stable	Resident	C
Order: Falconiformes							
93	Peregrine Falcon *Falco peregrinus* Tunstall, 1771	Falconidae	Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Stable	Resident	R
94	Red necked Falcon *Falco chicquera* Daudin, 1800	Falconidae	Autumn, Winters, Spring	Forest/Waterbodies	Near Threatened/ Decreasing	Winter Migrant	R
Order: Galliformes							
95	Grey Francolin *Francolinus pondicerianus* (Gmelin, 1789)	Phasinidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland/Forest/ Built Up	Least Concern/ Stable	Resident	VC
96	Indian Peafowl *Pavo cristatus* Linnaeus, 1758	Phasinidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Wasteland/ Built up	Least Concern/ Stable	Resident	VC
97	Black Francolin *Francolinus francolinus* (Linnaeus, 1766)	Phasianidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland	Least Concern/ Stable	Resident	C
Order: Gruiformes							
98	Common Coot *Fulica atra* Linnaeus, 1758	Rallidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
99	Common Moorhen *Gallinula chloropus* (Linnaeus, 1758)	Rallidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Stable	Resident	VC
100	Purple Moorhen *Porphyrio porphyrio* (Linnaeus, 1758)	Rallidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Resident	VC
101	White-Breasted Waterhen *Amaurornis phoenicurus* (Pennant, 1769)	Rallidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies/ Agriculture	Least Concern/ Unknown	Resident	VC
102	Watercock *Gallicrex cinerea* (Gmelin, 1789)	Rallidae	Summer, Rainy	Wetland/ Waterbodies/ Agriculture	Least Concern/ Decreasing	Summer Migrant	C
103	Baillon's crake *Zapornia pusilla (Pallas, 1776)*	Rallidae	Summer, Rainy	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	R
104	Ruddy-breasted Crake *Porzana fusca* (Linnaeus, 1766)	Rallidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	UC
Order: Passeriformes							
105	Long Tail Shrike *Lanius schach* Linnaeus, 1758	Laniidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland/ Waterbodies	Least Concern/ Unknown	Resident	C
106	Ashy Prinia *Prinia socialis* Sykes, 1832	Cisticolidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC
107	Asian Pied Starling *Sturnus contra* Linnaeus, 1758	Sturnidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ waterbodies/ Built Up	Least Concern/ Increasing	Resident	VC
108	Bank Myna *Acridotheres ginginianus* (Latham, 1790)	Sturnidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland/ Waterbodies	Least Concern/ Increasing	Resident	VC
109	Barn Swallow *Hirundo rustica* Linnaeus, 1758	Hirundinidae	Summer, Rainy	Wasteland/ Waterbodies	Least Concern/ Decreasing	Summer Migrant	VC
110	Baya Weaver Bird *Ploceus philippinus* (Linnaeus, 1766)	Ploceidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Resident	VC
111	Baybacked Shrike *Lanius vittatus* Valenciennes, 1826	Laniidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
112	Bengal Bushlark *Mirafra assamica* Horsfield, 1840	Alaudidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland/ Waterbodies	Least Concern/ Stable	Resident	C
113	Black Drongo *Dicrurus macrocercus* Vieillot, 1817	Dicruridae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies/ Built Up	Least Concern/ Unknown	Resident	VC
114	Black Redstart *Phoenicurus ochruros* (Gmelin, SG, 1774)	Muscicapidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies/ Buil Up	Least Concern/ Increasing	Winter Migrant	VC
115	Black-headed Bunting *Emberiza melanocephala* Scopoli, 1769	Emberizidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	C
116	Bluethroat *Luscinia svecica* (Linnaeus, 1758)	Muscicapidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Winter Migrant	VC
117	Blyth's Reed Warbler *Acrocephalus dumetorum* Blyth, 1849	Acrocephalidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	C
118	Booted Warbler *Hippolais caligata* (Lichtenstein, 1823)	Acrocephalidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	UC
119	Brahminy Myna *Sturnus pagodarum* (Gmelin, 1789)	Sturnidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies/ Built Up	Least Concern/ Unknown	Resident	VC
120	Brown Rock-Chat *Cercomela fusca* (Blyth, 1851)	Muscicapidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies/ Built Up	Least Concern/ Unknown	Resident	VC
121	Brown Shrike *Lanius cristatus* Linnaeus, 1758	Laniidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
122	Citrine Wagtail *Motacilla citreola* Pallas, 1776	Motacillidae	Autumn, Winters, Spring	Wetland/ Wasteland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
123	Common Babbler *Turdoides caudatus* (Dumont, 1823)	Leiothrichidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC
124	Common Chiffchaff *Phylloscopus collybita* (Vieillot, 1817)	Phylloscopidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
125	Common Myna *Acridotheres tristis* (Linnaeus, 1766)	Sturnidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies/ Built Up	Least Concern/ Increasing	Resident	VC
126	Greater Whitethroat *Sylvia communis* (Latham, 1787)	Sylviidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	UC
127	Crested Lark *Galerida cristata* (Linnaeus, 1758)	Alaudidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Decreasing	Resident	C
128	Golden Oriole *Oriolus oriolus* (Linnaeus, 1758)	Oriolidae	Summer, Rainy	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Summer Migrant	C
129	Gray-Throated Martin *Riparia chinensis* (Gray, JE, 1830)	Hirundinidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland/ Waterbodies	Least Concern/ Decreasing	Resident	VC
130	Plain Martin *Riparia paludicola (Vieillot, 1817)*	Hirundinidae	Summer, Rainy	Wasteland/ Waterbodies	Least Concern/ Decreasing	Summer Migrant	VC
131	Grey Wagtail *Motacilla cinerea* Tunstall, 1771	Motacillidae	Autumn, Winters, Spring	Wetland/ Wasteland/ Waterbodies	Least Concern/ Stable	Winter Migrant	VC
132	House Crow *Corvus splendens* Vieillot, 1817	Corvidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies/ Built Up	Least Concern/ Stable	Resident	VC
133	Indian Robin *Saxicoloides fulicata* (Linnaeus, 1776)	Muscicapidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
134	Indian Silverbill *Lonchura malabarica* (Linnaeus, 1758)	Estrildidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC
135	Jungle Babbler *Turdoides striatus* (Dumont, 1823)	Leiothrichidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies/ Built Up	Least Concern/ Stable	Resident	VC
136	Large Grey Babbler *Turdoides malcolmi* (Sykes, 1832)	Leiothrichidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC
137	Lesser Whitethroat *Sylvia curruca* (Linnaeus, 1758)	Sylviidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Winter Migrant	UC
138	Oriental Magpie Robin *Copsychus saularis* (Linnaeus, 1758)	Muscicapidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC
139	Indian White Eye *Zosterops palpebrosa* (Temminck, 1824)	Zosteropidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	C
140	Paddyfield Pipit *Anthus rufulus* Vieillot, 1818	Motacillidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	C
141	Pied Bushchat *Saxicola caprata* (Linnaeus, 1766)	Muscicapidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	C
142	Plain Prinia *Prinia inornata* Sykes, 1832	Cisticolidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC
143	Rufous-vented grass babbler *Prinia burnesii* (Blyth, 1844)	Pellorneidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Near Threatened/ Decreasing	Winter Migrant	UC
144	Yellow-bellied Prinia *Prinia flaviventris* (Delessert, 1840)	Cisticolidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	C
145	Purple Sunbird *Nectarinia asiatica* (Latham, 1790)	Nectariniidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC
146	Red-Rumped Swallow *Hirundo daurica* Linnaeus, 1771	Hirundinidae	Summer, Rainy	Waterbodies/ Wasteland/	Least Concern/ Stable	Summer Migrant	VC
147	Red-vented Bulbul *Pycnonotus cafer* (Linnaeus, 1766)	Pycnonotidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Increasing	Resident	VC
148	Richard's Pipit *Anthus richardi* Vieillot, 1818	Motacillidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Winter Migrant	C
149	Rosy Pipit *Anthus roseatus* Blyth, 1847	Motacillidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Winter Migrant	C
150	Indian Tree Pie *Dendrocitta vagabunda* (Latham, 1790)	Corvidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Decreasing	Resident	VC
151	Siberian Chiffchaff *Phylloscopus tristis* (Blyth, 1843)	Phylloscopidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Unknown	Resident	C
152	Siberian Stonechat *Saxicola maurus* (Pallas, 1773)	Muscicapidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	C
153	Sind Sparrow *Passer pyrrhonotus* Blyth, 1844	Passeridae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	C
154	Scaly- breasted Munia *Lonchura punctulata* (Linnaeus, 1758)	Estrildidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC
155	Zitting Cisticola *Cisticola juncidis* (Rafinesque, 1810)	Cisticolidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Increasing	Resident	VC
156	Sykes's Warbler *Iduna rama* (Sykes, 1832)	Acrocephalidae	Summer, Rainy, Autumn, Winters, Spring	Wasteland/ Waterbodies	Least Concern/ Stable	Resident	C

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
157	Tailor Bird *Orthotomus sutorius* (Pennant, 1769)	Cisticolidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	VC
158	Tree Pipit *Anthus trivialis* (Linnaeus, 1758)	Motacillidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	VC
159	Black-headed Munia *Lonchura malacca* (Linnaeus, 1766)	Estrildidae	Autumn, Winters, Spring	Wasteland/ Waterbodies/Forest	Least Concerned/ Stable	Winter Migrant	C
160	Verditer Flycatcher *Eumyias thalassina* (Swainson, 1838)	Muscicapidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Winter Migrant	C
161	Western Yellow Headed Wagtail *Motacilla flava* Linnaeus, 1758	Motacillidae	Autumn, Winters, Spring	Wetland/ Waterbodies// Wasteland	Least Concern/ Decreasing	Winter Migrant	C
162	White Tailed Stonechat *Saxicola leucurus* (Blyth, 1847)	Muscicapidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Resident	C
163	White Wagtail *Motacilla alba* Linnaeus, 1758	Motacillidae	Autumn, Winters, Spring	Wetland/ Waterbodies/ Wasteland	Least Concern/ Stable	Winter Migrant	C
164	Wire Tailed Swallow *Hirundo smithii* Leach, 1818	Hirundinidae	Summer, Rainy	Wasteland/ Waterbodies	Least Concern/ Increasing	Winter Migrant	VC
165	Yellow Eyed Babbler *Chrysomma sinense* (Gmelin, 1789)	Paradoxornithidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ waterbodies/ Wasteland	Least Concern/ Stable	Resident	C
166	Streaked Weaver *Ploceus manyar* (Horsfield, 1821)	Ploceidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Resident	VC
167	Indian Paradise-Flycatcher *Terpsiphone paradisi* (Linnaeus, 1758)	Monarchidae	Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Summer Migrant	UC
168	European Starling *Sturnus vulgaris* Linnaeus, 1758	Sturnidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Decreasing	Resident	VC
169	Eurasian Wryneck *Jynx torquilla* Linnaeus, 1758	Picidae	Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Decreasing	Winter Migrant	UC
170	Grey Headed Canary Flycatcher *Culicicapa ceylonensis* (Swainson, 1820)	Stenostiridae	Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Winter Migrant	UC
171	Common Woodshrike *Tephrodornis pondicerianus* (Gmelin, 1789)	Vangidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Resident	UC
172	House Sparrow *Passer domesticus* (Linnaeus, 1758)	Passeridae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Decreasing	Resident	C
173	Jungle Myna *Acridotheres fuscus* (Wagler, 1827)	Sturnidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Decreasing	Resident	C
174	Water Pipit *Anthus spinoletta* (Linnaeus, 1758)	Motacillidae	Autumn, Winters, Spring	Waterbodies/ Wasteland	Least concern/ Stable	Winter Migrant	C
175	Red-Headed Bunting *Emberiza bruniceps* Brandt, 1841	Emberizidae	Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Winter Migrant	C
176	Red Avadavat *Amandava amandava* (Linnaeus, 1758)	Estrildidae	Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Winter Migrant	UC
177	Streak Throated Swallow *Hirundo fluvicola* Blyth, 1855	Hirundinidae	Summer, Rainy, Autumn, Winters, Spring	Waterbodies/ Wasteland	Least Concern/ Increasing	Resident	C
178	Indian Bushlark *Mirafra erythroptera* Blyth, 1845	Alaudidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Resident	C

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
179	Rufous-fronted Prinia *Prinia buchanani* Blyth, 1844	Cisticolidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Resident	UC
180	Gray-breasted Prinia *Prinia hodgsonii* Blyth, 1844	Cisticolidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Resident	C
181	Long-billed Pipit *Anthus similis* Jerdon, 1840	Motacillidae	Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Winter Migrant	C
182	Hume's Warbler *Phylloscopus humei* (Brooks, 1878)	Phylloscopidae	Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Winter Migrant	UC
183	Black Breasted weaver *Ploceus benghalensis* (Linnaeus, 1758)	Ploceidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Resident	C
184	Graceful Prinia *Prinia gracilis* (Lichtenstein, 1823)	Cisticolidae	Summer, Rainy, Autumn, Winters, Spring	Waterbodies/ Wasteland	Least Concern/ Stable	Resident	C
185	Asian brown flycatcher *Muscicapa dauurica* Pallas, 1811	Muscicapidae	Summer, Rainy	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Summer Migrant	C
186	Variable wheatear *Oenanthe picata* (Blyth, 1847)	Muscicapidae	Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland	Least Concern/ Stable	Winter Migrant	C
187	Bristled Grass-Warbler *Chaetornis striatus* (Jerdon, 1841)	Locustellidae	Summer, Rainy	Waterbodies/ Wasteland/Forest	Vulnerable/ Decreasing	Summer Migrant	R
188	Jerdon's Babbler *Chrysomma altirostre* Jerdon, 1862	Paradoxornithidae	Summer, Rainy, Autumn, Winters, Spring	Waterbodies/ Wasteland/Forest	Vulnerable/ Decreasing	Resident	UC
189	Sulphur-bellied warbler *Phylloscopus griseolus* Blyth, 1847	Phylloscopidae	Autumn, Winters, Spring	Forest/Wasteland/ Waterbodies	Least Concern/ Stable	Winter Migrant	UC
Order: Pelecaniformes							
190	Black Headed White Ibis *Threskiornis melanocephalus* (Latham, 1790)	Threskiornithidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Forest/ Waterbodies	Near Threatened/ Decreasing	Resident	C
191	Glossy Ibis *Plegadis falcinellus* (Linnaeus, 176	Threskiornithidae	Autumn, Winters, Spring	Waterbodies/ Wetland/ Forest	Least Concern / Decreasing	Winter Migrant	VC
192	Cattle Egret *Bubulcus ibis* (Linnaeus, 1758)	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies/ Wasteland/ Agriculture/ Built Up	Least Concern/ Increasing	Resident	VC
193	Eurasian Spoonbill *Platalea leucorodia* Linnaeus, 1758	Threskiornithidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	UC
194	Grey Heron *Ardea cinerea* Linnaeus, 1758	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Wetland / Waterbodies	Least Concern/ Unknown	Resident	VC
195	Indian Pond Heron *Ardeola grayii* (Sykes, 1832)	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies/ Agriculture	Least Concern/ Unknown	Resident	VC
196	Intermediate Egret *Egretta intermedia* Wagler, 1829	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Wetland and Waterbodies/ Agriculture	Least Concern/ Decreasing	Resident	VC
197	Great Egret *Egretta alba* Linnaeus, 1758	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Wetland and Waterbodies	Least Concern/ Unknown	Resident	C
198	Little Egret *Egretta garzetta* (Linnaeus, 1766)	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Resident	VC
199	Night Heron *Nycticorax nycticorax* (Linnaeus, 1758)	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Wetland / Waterbodies	Least Concern/ Decreasing	Resident	VC

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
200	Purple Heron *Ardea purpurea* Linnaeus, 1766	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Wetland / Waterbodies	Least Concern/ Decreasing	Resident	VC
201	Red Naped Ibis *Pseudibis papillosa* (Temminck, 1824)	Threskiornithidae	Summer, Rainy, Autumn, Winters, Spring	Wetland / Waterbodies/ Agriculture	Least Concern/ Decreasing	Resident	VC
202	Yellow Bittern *Ixobrychus sinensis* (Gmelin, 1789)	Ardeidae	Summer, Rainy	Wetland / Waterbodies	Least Concern/ Unknown	Summer Migrant	UC
203	Cinnamon Bittern *Ixobrychus cinnamomeus* (Gmelin, 1789)	Ardeidae	Summer, Rainy	Wetland / Waterbodies	Least Concern/ Stable	Summer Migrant	UC
204	Striated Heron *Butorides striata* (Linnaeus, 1758)	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Wetland / Waterbodies	Least Concern/ Decreasing	Resident	UC
205	Great Bittern *Botaurus stellaris* (Linnaeus, 1758)	Ardeidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Winter Migrant	R
206	Black Bittern *Dupetor flavicollis* (Latham, 1790)	Ardeidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Summer Migrant	UC
Order: Piciformes							
207	Brown Headed Barbet *Megalaima zeylanica* (Gmelin, 1788)	Megalaimidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies	Least Concern/ Stable	Resident	VC
208	Coppersmith Barbet *Megalaima haemacephala* (P.L.S. Müller, 1776)	Megalaimidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies	Least Concern/ Increasing	Resident	C
209	Lesser Goldenbacked Woodpecker *Dinopium benghalense* (Linnaeus, 1758)	Picidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies	Least Concern/ Stable	Resident	C
210	Yellow Crowned Woodpecker *Leiopicus mahrattensis*(Latham, 1801)	Picidae	Summer, Rainy, Autumn, Winters, Spring	Forest/ Waterbodies	Least Concern/ Stable	Resident	UC
Order: Podicipediformes							
211	Little Grebe *Tachybaptus ruficollis* (Pallas, 1764)	Podicipedidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Decreasing	Resident	VC
212	Great Crested Grebe *Podiceps cristatus* (Linnaeus, 1758)	Podicipedidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	UC
213	Black-necked Grebe *Podiceps nigricollis* Brehm, 1831	Podicipedidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	UC
214	Horned Grebe *Podiceps auritus* (Linnaeus, 1758)	Podicipedidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Vulnerable/ Decreasing	Winter Migrant	R
Order: Psittaciformes							
215	Alexandrine Parakeet *Psittacula eupatria* (Linnaeus, 1766)	Psittaculidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Near Threatened/ Decreasing	Resident	UC
216	Rose Ringed Parakeet *Psittacula krameri* (Scopoli, 1769)	Psittaculidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Increasing	Resident	VC
Order: Strigiformes							
217	Barn Owl *Tyto alba* (Scopoli, 1769)	Tytonidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Stable	Resident	UC
218	Indian Scops Owl *Otus bakkamoena* Pennant, 1769	Strigidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Stable	Resident	R
219	Spotted Owlet *Athene brama* (Temminck, 1821)	Strigidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Stable	Resident	VC
220	Short-eared Owl *Asio flammeus* (Pontoppidan, 1763)	Strigidae	Autumn, Winters, Spring	Forest/Waterbodies	Least concern/ Decreasing	Winter Migrant	UC

	Name/ Scientific name	Family	Seasons	Preferred habitat	IUCN Status/ Population trends	Migratory/ Residential status	Abundance
221	Rock Eagle-Owl *Bubo bubo* (Linnaeus, 1758)	Strigidae	Summer, Rainy, Autumn, Winters, Spring	Forest/Waterbodies	Least Concern/ Stable	Winter Migrant	C
Order: Suliformes							
222	Great Cormorant *Phalacrocorax carbo* (Linnaeus, 1758)	Phalacrocoracidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Increasing	Resident	C
223	Little Cormorant *Phalacrocorax niger* (Vieillot, 1817)	Phalacrocoracidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Resident	VC
224	Indian Cormorant *Phalacrocorax fuscicollis* Stephens, 1826	Phalacrocoracidae	Autumn, Winters, Spring	Wetland/ Waterbodies	Least Concern/ Unknown	Winter Migrant	C
225	Oriental Darter *Anhinga melanogaster* Pennant, 1769	Anhingidae	Summer, Rainy, Autumn, Winters, Spring	Wetland/ Waterbodies	Near Threatened/ Decreasing	Resident	VC

Table 2. Showing the Relative diversity (RDi) of various avian families at Harike Wildlife Sanctuary.

Avian families	Number of species	RDi value
Accipitridae	12	5.333
Acrocephalidae, Alaudidae, Alcedinidae, Ciconiidae, Laniidae, Leiothrichidae, Phalacrocoracidae, Phasianidae, Picidae, Ploceidae	3	1.333
Apodidae, Corvidae, Emberizidae, Falconidae, Glareolidae, Megalaimidae, Meropidae, Paradoxornithidae, Passeridae, Psittaculidae, Recurvirostridae, Sylviidae	2	0.888
Anatidae	19	8.444
Anhingidae, Bucerotidae, Burhinidae, Coraciidae, Dicruridae, Jacanidae, Locustellidae, Monarchidae, Nectariniidae, Oriolidae, Pandionidae, Pellorneidae, Pycnonotidae, Rostratulidae, Stenostiridae, Tytonidae, Upupidae, Vangidae, Zosteropidae	1	0.444
Ardeidae	13	5.777
Charadriidae, Columbidae, Hirundinidae, Sturnidae	6	2.666
Cisticolidae	8	3.555
Cuculidae, Estrildidae, Phylloscopidae, Podicipedidae, Strigidae, Threskiornithidae	4	1.777
Laridae, Motacillidae	10	4.444
Muscicapidae	11	4.888
Rallidae	7	3.11
Scolopacidae	14	6.22

Table 3. Showing the percentage of birds in different orders.

Avian Orders	Number of species	Percentage
Passeriformes	85	37.77%
Charadriiformes	37	16.44%
Anseriformes	19	8.44%
Pelecaniformes	17	7.55%
Accipitriformes	13	5.77%
Coraciiformes	8	3.55%
Gruiformes	7	3.11%
Columbiformes	6	2.66%
Strigiformes	5	2.22%
Cuculiformes, Piciformes, Podicipediformes, Suliformes	4	1.77%
Galliformes, Ciconiiformes	3	1.33%
Apodiformes, Falconiformes, Psittaciformes	2	0.88%

other commercial activities. Similar observations have been made by Singh et al. (2020). In a highly populated country like India with less resources, resolving this issue is a tough task. Awareness among local populations with combined efforts of researchers, conservators, stake holders and government agencies can support sustainability of avifaunal diversity.

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COMMUNICATION

Temporal changes in species richness of waterfowl (Anseriformes) community in D'Ering Memorial Wildlife Sanctuary, Arunachal Pradesh, India

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Abstract: We conducted five yearly field surveys to assess long-term changes in the species richness, abundance, and composition of waterfowl populations (Anseriformes) in the D'Ering Memorial Wildlife Sanctuary, a significant staging area on migratory flyways with one of the largest concentrations of waterfowl in Arunachal Pradesh, especially during winter. A total of 8,040 birds belonging to 17 species of Anatidae were recorded, including two threatened species. The most abundant species were *Tadorna ferruginea*, *Anas poecilirhnycha*, and *Bucephala clangula*, with relative abundances of 29%, 10%, and 9.4%, respectively. Species richness was highest in winter (H'= 2.40; January H'= 2.43) and lowest in the monsoon (H'= 1.48; August, H'= 1.12). Seasonal difference in species richness was noticed for winter visitors, but not for year-round residents. We observed a major declining trend for seven species. Findings from this study can be used for further ecological assessment of the waterfowl community of the sanctuary.

Keywords: Anatidae, Critically Endangered, diversity indices, Near Threatened, Ramsar Site, Vulnerable.

Adi abstract: Ngolu diitak-diitak pe takngo aping lok Asi pejab (Anseriformes) kanam, alumnam delokke jabdum-jabrum e kae-kakur namem kenkipe emla, Bomong kiibung Giite kone solok gai yalumna jablimoduk giiko delokke digin toodi em Asi pejab boje yalum pe yedum suko D'Ering Memorial Wildlife Sanctuary (DEMWS) lo sabgong la poribomto. Tani among sokke Nyokdak kena Jablum annyi ko sabtak sula, 17 Jablum Anatidae emnam erang lokke ke bodum e 8040 pejab kope sabto. Takam lokke bojeyalum ne Jabling *Tadorna ferruginea* (29%), Ibung-atak-gena Pejab *Anas poecilirhnycha* (10%) delokke Amik-yegena Pejab *Bucephala clangula* (9.4%) kope ido. Sabgong ko solo Jablum e digin toodi lo bojeyape kado (H' = 2.40; Bising polo H' = 2.43) delokke dojeng toodi lo anyong yape kado (H' = 1.48; Tanlo polo, H' = 1.12). Digin toodi em Jabli modukla ana pejab kidar si Jablum kanam e todi-todi lo angu-angu do idakla ditak rubung em dusina Jablum kidar solo todi-todi em Jablum angunam kapamado. Ngolu Jablum kinit ko bojerupe diitak-diitak lo anyong yayang idope sabgap toh. Sim sabgap la rilen tunam sim sanctuary solok Asi pejab turgang-yegang em aimonam lo ager gerna laye.

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Author details: Tapak Tamir is a PhD scholar with an interest in bird communities, ecology, and species distribution patterns, and Dr. Daniel Mize is an Associate Professor with a specialisation in birdlife, wildlife status, and conservation issues with an interest in education and awareness needed to conserve wildlife.

Author contributions: TT did the field survey, data collection, and manuscript preparation, while DM supervised the field data collection and gave important inputs for the study. Both authors contributed towards writing the manuscript.

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INTRODUCTION

Habitat is a fundamental unifying entity and concept in wildlife ecology and conservation (Block & Brennan 1993), its use and selection vary seasonally, especially for migratory species (Kaminski & Elmberg 2014). Habitat configuration and composition of the landscape affect the occurrence of species and richness (Guadagnin & Maltchik 2007; Mora et al. 2011; Xu et al. 2014; Zhang et al. 2018), and the seasonal distributions of waterbirds are influenced by various conditions like habitat types, climatic conditions, resource stability, and immediate human impact. Availability of water bodies, wetland size, and wetland connectivity positively affect waterfowl species occurrence and richness (Guadagnin & Maltchik 2007; Zhang et al. 2018). There is about 75,819 km^2 of wetlands in India, which make up 5% of the world's wetland area (AWB & WWF-India 1993), covering 4.1 million hectares and corresponding to 18.4% of the country's land area (MoEF 2003). A total of 2,175 wetlands, covering a total area of 1.5 million hectares, are natural, and 65,254 are manmade, with a total area of 2.6 million hectares (Chatrath 1998). At present, 46 sites in India have been designated as wetlands of international importance, especially as waterfowl habitats (Ramsar Sites) covering an area of 1,083,322 hectares (Ramsar Sites Information Service, 2021).

D'Ering Memorial Wildlife Sanctuary (DEMWS) is the only wildlife sanctuary with subtropical forest, grassland, riverine, and inland water body habitats in Arunachal Pradesh, harbouring a variety of waterfowl species and other birds. Birdlife International has declared DEMWS an Important Bird Area (IBA). Covering an area of 190 km^2, the entire area is a riverine plain criss-crossed by the rivers Siang and Sibia, forming several riverine islands. The sanctuary's dominant grasses are *Arundo donax*, *Erianthus ravannae*, *Imperata cylinderica*, *Phragmites karka*, *Saccharum spontaneum*, *S. arundinaceum*, & *Neyraudia rennaudiana* and dominant tree species are *Albizzia procera*, *Amoora wallichi*, *Bombax ceiba*, *Dalbergia sisoo*, *Daubanga grandiflora*, *Dillenia indica*, *Lagerstroemia speciosa*, & *Terminalia myriocarpa*. The altitudinal gradient of the sanctuary ranges 135–140 m, which gradually decreases from north to south. Within a 10-km radius of the sanctuary are 22 villages with a population of 40,065 (2011 census). The whole sanctuary is surrounded by river water on all sides, making it suitable for various migratory waterfowl.

The term 'waterfowl' has been applied to the members of the family Anatidae, popularly known as ducks, geese, swans, and smaller teals (Delacour 1974). The Ramsar Convention, on the other hand, defines waterfowl as birds 'ecologically dependent on wetlands', and in the second edition of Wetlands International and Waterfowl Population Estimates, waterfowl was defined more precisely as all species of the 33 families (WI 2002). Among these 33 families, eight families are found in DEMWS (Mize et al. 2014), viz., Phalacrocoracidae, Anhingidae, Ardeidae, Ciconiidae, Anatidae, Charadriidae, Scolopacidae, and Laridae.

Various works done by Osmaston (1922), Singh (1929), Ali (1932), Ghazi (1962), Kannan (1980), Mujumdar (1984), Davidar (1985), Newton et al. (1986), Jhingran (1988), Ghosal (1995), Wadatkar & Kasambe (2002), Kulkarni et al. (2005), and Harney (2014) have studied waterbird communities for seasonal variations in abundance and species composition from different freshwater bodies of India but such study is yet to be unveiled in DEMWS. Only a few studies like population status and distribution of Bengal Florican (Rahmani et al. 1991), the population status of Swamp Francolin (Singh 1995), 113 species of bird including 14 species of waterfowl (Barman 1996), the occurrence of White-winged Wood Duck *Asarcornis scutulata* (Choudhury 1996, 2002), records of 55 species of birds and Near Threatened Cinereous Vulture *Aegypius monachus* (Mize et al. 2016), and recent records of Swamp Grass Babbler *Laticilla cinerascens* (Hussain et al. 2019) had been done here.

As per our preliminary field investigations and interactions with hunters of the villagers residing near the sanctuary area, we have found that waterfowl belonging to the family Anatidae (ducks, geese, and swans, hereinafter 'waterfowl') are frequently hunted for meat and traded by them. Considering this vital information and the significance of DEMWS, an effort has been made to investigate the long-term temporal changes, species richness, and species abundance of the waterfowl (Anseriformes) community in DEMWS. This information will be useful for better understanding the underlying mechanisms of how seasonal variation affects different migratory species of waterfowl in the sanctuary, so that targeted conservation strategies can be developed. The study will also add to the existing information on the previous checklist of birds of DEMWS and stimulate interest in waterfowl watching, which will help the wildlife division and researchers.

STUDY AREA AND METHODS

Study Area

The study was carried out in the D'Ering Memorial Wildlife Sanctuary (DEMWS) in the East Siang District of the state of Arunachal Pradesh, northeastern India. The sanctuary area is divided into three managerial ranges, namely, the Anchalghat Range, the Sibiamukh Range, and the Borguli Range (Figure 1). It is located at latitudes ranging from 27.850–28.083 N and longitudes from 95.366–95.483 E. In terms of topography, 80% of the sanctuary is grassland, with the remaining being riverine forest patches with mixed bamboo and secondary forests. The region has climatic conditions that are sub-tropical with average temperature variations of 5 °C during winter to 45 °C during summer and comprises four seasons, taking mean climatic conditions into account, viz., pre-monsoon (March–May), monsoon (June–August), post-monsoon (September–November), and winter (December–February). The lowest rainfall occurs in January with an average of 41.80 mm, and the highest rainfall occurs in July with an average of 1,433.20 mm.

Field Surveys

Five-year field surveys were carried out from March 2015 to February 2020, dividing the year into four seasons. For the waterfowl survey, a modified point count method—vantage points counts—was used (Bhupathy et al. 1998). A total of 15 vantage points were designated, covering the whole of the Anchalghat Range and Sibiamukh Range of DEMWS, based on the best visibility of the site from where the fixed- area was scanned for waterfowl flocks (Figure 1). Due to logistical constraints, the Borguli Range of the Sanctuary was excluded for the study. Each vantage point was visited at least once every month on foot on days with suitable weather, avoiding rainy days because rain interferes with visibility (Ralph et al. 1993). Twenty minutes were spent at each vantage point recording waterfowl in the water or on the shoreline and its vicinity using binoculars (8 × 56 and Olympus 10 × 50); almost 65% of our observations were photo-documented with a DSLR camera (NIKON, D5200 with 70–300 mm lens). Waterfowl species were identified following Grimmett et al. (2011) and Ali & Ripley (1995); and we followed the classification used in the checklist of the birds in the Oriental Region, Oriental Bird Club (Inskipp et al. 2001) for species' systematic position (order, family), common name, and scientific name. A Garmin GPS device with a mobile app was used to record the locations for conducting the waterfowl survey at that particular sampling vantage

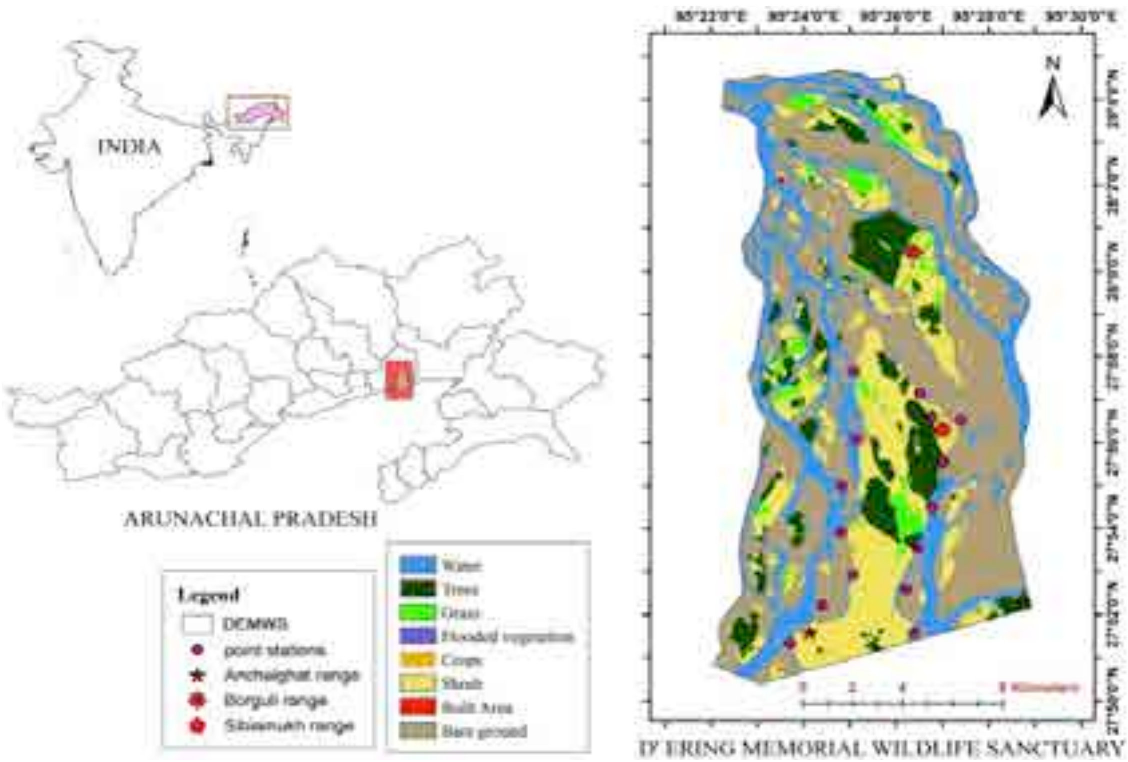

Figure 1. Map of study area (Developed by using Arc GIS Version 10.4).

point. Waterfowl were found active the most after sunrise to midmorning and before sunset; therefore, the timing was adjusted depending on the day length of the seasons, viz., late sunrise in winter and post-monsoon observation was done (0600–1100 h) and (1400–1630 h) and early sunrise in pre-monsoon and monsoon observation was done (0500–1000 h) and (1430–1730 h). The count period covered all the seasons, but the most extensive data was collected in the years 2018–2020, and less frequent counts occurred in 2015–2017, when counts were not able to cover all three months of the monsoon seasons due to heavy rainfall and heavy floods along the Siang River, as already mentioned in the study area.

Data Analysis

The relative abundance of a species is its percentage among all species utilising the same habitat (Simon & Okoth 2016; Walag & Canencia 2016; James et al. 2017). By assessing the relative abundance of species, one can identify the most common or rare species in a given area. The relative abundance (%) of waterfowl species was determined using the following formula:

$$\text{Relative Abundance} = \frac{ni}{N} X\ 100$$

Where, n*i*= total number of waterfowl of each species and N= total numbers of waterfowl of all species detected in DEMWS following (Bibby et al. 2000; Hubbell 2001; McGill et al. 2007).

Strictly regarding study area, based on presence or absence of species throughout the study periods, we have distinguished four categories of relative seasonal occurrence and residential status of waterfowl as: (a) year-round residents—waterfowl recorded throughout the year; (b) winter visitors—waterfowl recorded in abundance during winter seasons; (c) monsoon migrants—species that occur only during the monsoon; and (d) passage migrants—waterfowl that stay for a short time in the sanctuary during the study period. The abundance status of the recorded waterfowl species was established, viz., common (C), fairly common (FC), uncommon (UC), and rare (RA), based on frequency of sighting following (Kumar & Gupta 2009). The conservation status and global trend were assessed according to IUCN (2021). The diversity indices were determined as follows: Simpson's diversity index (1-D) (Simpson 1949), Shannon-Wienner index for alpha diversity (Shannon & Weinner 1949), Margalef index for species richness (Margalef 1958), and Pielou's evenness index for species evenness (Pielou 1966):

Simpson's diversity index (1-D): was calculated using the formula

$$D = \frac{1}{\sum(Pi^2)}$$

Where D= Simpson's index

P= total proportion of each species in sample

Shannon-Wienner index: Measures the average diversity of a sample and is given by equation:

$$H' = -\sum Pi \ln(Pi)$$

Where H'= Shannon-Wiener index

P= total proportion of each species in sample

Margalef's diversity index: M is calculated by using the formula

$$M = \frac{(S-1)}{\ln N}$$

Where, M = Margalef's diversity index

S= number of species

N= number of individuals

Pielou's evenness index: Measures evenness with which individuals were distributed among the species.

$$J = \frac{H'}{\ln S}$$

Where S= number of observed species

H'= Shannon-Wiener index

All survey data were compiled using Microsoft Excel Version 2010. The yearly observations and diversity index data were pooled together within four seasons to test the seasonal pattern of the waterfowl assemblage in DEMWS. The data was further subjected to non-parametric Kruskal-Wallis tests with subsequent post-hoc Tukey's HSD (Honestly Significant Difference) tests, performed separately to determine the seasonal difference between species richness across all the seasons in DEMWS as well as between year-round residents, winter visitors, monsoon migrants, and passage migrants. Statistical tests were computed using PAleontological STatistics Version 4.03. All statistical tests were set at a significance level of $p < 0.05$.

RESULTS

During the five-year study in DEMWS, we have recorded 8,040 birds of waterfowl belonging to 17 species of the family Anatidae of the Order Anseriformes at a rate of 1,608 birds per year (Table 1, Image 1–12). The most abundant species are Ruddy Shelduck *Tadorna ferruginea*, followed by Indian Spot-billed Duck *Anas poecilorhyncha* and Common Goldeneye *Bucephala clangula*, with relative abundances of 28.96%, 10.24%, and 9.38%, respectively (Table 1). The relative seasonal and residential status of different waterfowl species

Table 1. Checklist and status of waterfowl found in DEMWS from March 2015–February 2020.

	Common name	Species (Scientific name & authors)	IUCN status	Relative abundance %	Residential status	Abundance status	Global trend
1	Baer's Pochard	*Aythya baeri* (Radde, 1863)	CR	2.28%	WV	RA	Dec
2	Common Goldeneye	*Bucephala clangula* (Linnaeus, 1758)	LC	9.38%	WV	FC	Stable
3	Goosander	*Mergus merganser orientalis* (Gould, 1845)	LC	2.95%	YRR	FC	Unknown
4	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	VU	5.00%	WV	UC	Dec
5	Common Teal	*Anas crecca* (Linnaeus, 1758)	LC	4.40%	WV	UC	Unknown
6	Cotton Pygmy-goose	*Nettapus coromandelianus* (J.F. Gmelin, 1789)	LC	2.40%	WV	RA	Stable
7	Ferruginous Duck	*Aythya nyroca* (Güldenstädt, 1770)	NT	4.76%	WV	UC	Dec
8	Fulvous Whistling-duck	*Dendrocygna bicolor* (Vieillot, 1816)	LC	0.37%	PM	RA	Dec
9	Gadwall	*Mareca strepera* (Linnaeus, 1758)	LC	6.60%	WV	FC	Inc
10	Indian Spot-billed Duck	*Anas poecilorhyncha* (J.R. Forster, 1781)	LC	10.24%	YRR	C	Dec
11	Lesser Whistling-duck	*Dendrocygna javanica* (Horsfield, 1821)	LC	0.87%	MM	RA	Dec
12	Mallard	*Anas platyrhynchos* (Linnaeus, 1758)	LC	6.28%	YRR	C	Inc
13	Northern Pintail	*Anas acuta* (Linnaeus, 1758)	LC	4.29%	YRR	C	Dec
14	Red-breasted Merganser	*Mergus serrator* (Linnaeus, 1758)	LC	0.39%	WV	RA	Stable
15	Red-crested Pochard	*Netta rufina* (Pallas, 1773)	LC	6.69%	WV	FC	Unknown
16	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	LC	28.96%	YRR	C	Unknown
17	Tufted Duck	*Aythya fuligula* (Linnaeus, 1758)	LC	4.14%	WV	UC	Stable
Total 17 Species		**Total**		**100.00%**			

Legends: IUCN—International Union for Conservation of Nature | LC—Least Concerned | NT—Near Threatened | VU—Vulnerable | CR—Critically Endangered | YRR—Year Round Resident | WV—Winter Visitor | MM—Monsoon migrant | PM—Passage Migrants | C—Common | FC—fairly common | UC—Uncommon | RA—Rare | Inc—Increasing | Dec—Decreasing | Unk—Unknown.

revealed that 10 species (59%) were winter visitors, five species (29%) were year-round residents, one species (6%) was a monsoon migrant, and one species (6%) was a passage migrant (Figure 2). The waterfowl species richness was highest in January (H'= 2.43) and lowest in August (H'= 1.12) (Figure 3). Similarly, the overall seasonal species richness is highest in winter (H'= 2.40) and lowest in the monsoon (H'= 1.48) (Figure 4). The Shannon-Weiner species richness index was highest in winter (H'= 2.398) and lowest in the monsoon (H'= 1.483), but the Simpson dominance index and Margalef species richness index were highest in the pre-monsoon (1-D= 0.8817) and (M= 2.024), respectively, and lowest in the monsoon (1-D= 0.7371) and (M= 0.8138), respectively, whereas Pielou's evenness index was highest in the monsoon (J= 0.7343) and lowest in the post-monsoon (J= 0.5744), showing the high temporal variations of various diversity indices. The present study shows an increasing trend in the yearly total population of waterfowl (Figure 6), and a major declining trend of population of seven species (Figures 7 & 8). The non-parametric Kruskal-Wallis test results in no significant seasonal variation in species richness of year-round resident waterfowl (Kruskal-Wallis test: K= 7.769, df= 3, p= 0.051), which remains almost similar throughout the study period. On the other hand, a significant seasonal difference was noticed in the case of winter visitors (Kruskal-Wallis test: K= 16.65, df= 3, $p < 0.05$). The Fulvous Whistling Duck *Dendrocygna bicolor* was the only passage migrant species that was observed only in May in a very small population. Similarly, the sanctuary's only single monsoon migrant, the Lesser Whistling Duck *Dendrocygna javanica* has been observed mostly during June, with the largest flock of 20 in 2015. The number of winter visitors significantly increased in October–November (post-monsoon season), reached its peak in January (winter) and then sharply declined in the pre-monsoon (Figure 5). The results of the Tukey's HSD post-hoc tests using the Lund-Lund (1983) procedure also revealed that the species richness of year-round residents varies insignificantly (Table 2), whereas the species richness of winter visitors varies significantly ($p < 0.05$) (Table 3). The Tukey's HSD Multiple Comparison test among all seasons also shows significant at $p < 0.05$; winter vs pre-monsoon (p= 0.000591), winter vs monsoon (p= 0.000225), and winter vs post-monsoon (p= 0.000465) (Table 4).

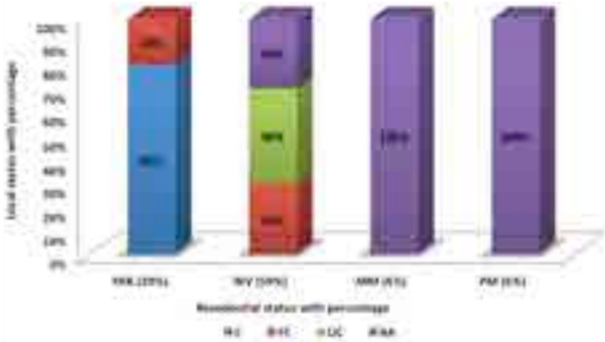

Figure 2. Comparision of percentage of residential and local abundance status of waterfowl in DEMWS from March 2015–February 2020.

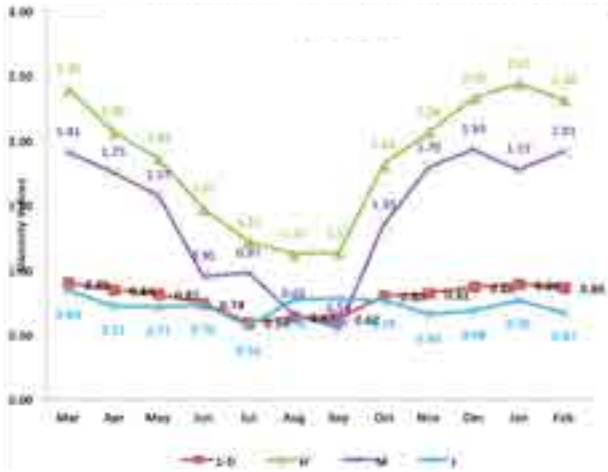

Figure 3. Monthly trend of diversity indices of waterfowl in DEMWS from March 2015–February 2020.

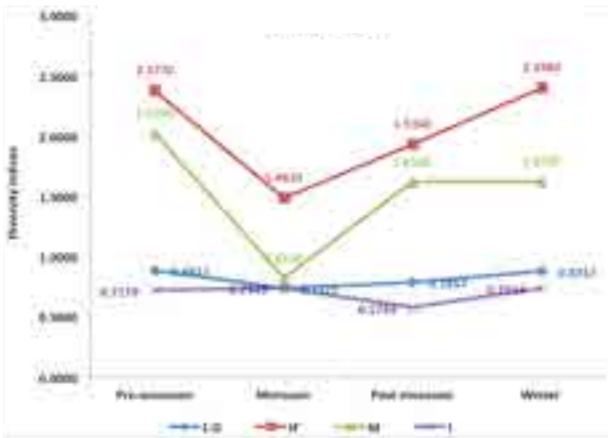

Figure 4. Diversity indices of waterfowl in different season in DEMWS from March 2015–February 2020.

Table 2. Tukey's HSD multiple comparison test among all season of YRR (p <0.05).

	Pre-monsoon	Monsoon	Post-monsoon	Winter
Pre-monsoon		0.998	1.000	0.225
Monsoon	0.269		0.990	0.165
Post-monsoon	0.160	0.429		0.268
Winter	2.845	3.114	2.685	

Table 3. Tukey's HSD multiple comparison test among three season of WV (p <0.05, significant in bold).

	Pre-monsoon	Post-monsoon	Winter
Pre-monsoon		0.9149	**0.000131**
Post-monsoon	0.5692		**0.000128**
Winter	8.492	9.061	

Table 4. Tukey's HSD multiple comparison test among all season (p <0.05, significant in bold).

	Pre-monsoon	Monsoon	Post-monsoon	Winter
Pre-monsoon		0.9608	0.9997	**0.000591**
Monsoon	0.6948		0.9788	**0.000225**
Post-monsoon	0.1343	0.5604		**0.000465**
Winter	5.952	6.647	6.087	

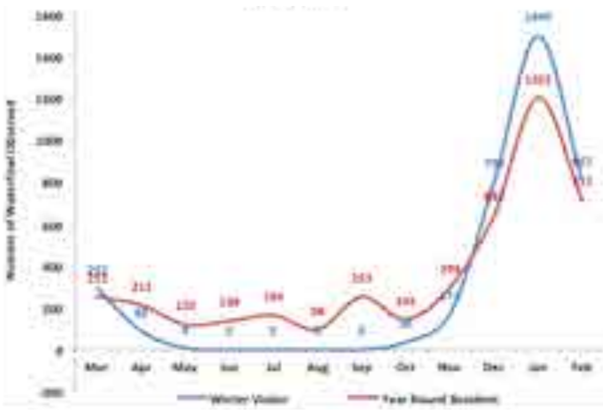

Figure 5. Monthly Population variation of YRR & WV in DEMWS from March 2015–February 2020.

DISCUSSION AND CONCLUSION

The results showed the presence of 17 species of waterfowl (Anseriformes) in DEMWS. This includes the first-time reports of three species from DEMWS: Baer's Pochard *Aythya baeri*, Fulvous Whistling Duck *Dendrocygna bicolor*, and Red-breasted Merganser *Mergus serrator*. These species were not reported from the sanctuary by early observations (e.g., Rahmani et al. 1991; Singh 1995; Barman 1996; Choudhury 1996, 2002; Mize et al. 2014; Hussain et al. 2019). The other 13 species were already recorded and cited earlier (Barman 1996; Borang 2013; Mize et al. 2014). The present study shows high temporal changes in the waterfowl community, as shown in the results. In contrast to the increasing trend of the total population of waterfowl in the study area (Figure 6), there is a major declining trend among the seven species of waterfowl (Figure 6). This includes one Critically Endangered species Baer's Pochard *Aythya baeri*, Common Merganser *Mergus merganser*, Common Pochard *Aythya ferina*, Fulvous Whistling Duck *Dendrocygna bicolor*, Lesser Whistling Duck *Dendrocygna javanica*, Red-breasted Merganser *Mergus serrator*, and Red-crested Pochard *Netta rufina*. Year-wise records of declining waterfowl populations are provided in Figure 7.

Globally, 28% of all assessed species are threatened with extinction (IUCN 2021), confirming the importance of monitoring species' abundance. Baer's Pochard *Aythya baeri*, Common Pochard *Aythya ferina* and Ferruginous Pochard *Aythya nyroca* are the Critically Endangered, Vulnerable and Near Threatened waterfowl species, respectively, recorded in DEMWS (IUCN 2021). Baer's Pochard was classified as vulnerable in 1994 but, following an assessment that probably fewer than 1,000 individuals remained, it was listed as Endangered in 2008 (Wang et al. 2012). It was upgraded to Critically Endangered (BirdLife International 2021). The largest flock of 30 birds was observed in January 2016. The last observation was flocks of six birds diving almost 2 km away from the observer near the Sibiamukh range in February 2020. Baer's Pochard is extremely difficult to find anywhere in its range (Richard et al. 2013) hence, this observation needs attention from the scientific world as this globally threatened bird has a serious contraction in wintering distribution and is heading for extinction in the wild (Chowdhury et al. 2012; Wang et al. 2012; Richard et al. 2013). The Common Pochard *Aythya ferina* a globally threatened waterfowl breeds largely in freshwater to the south of the tundra region across the Palearctic, from Iceland to the steppe lakes of Mongolia and the Daurian region (Kear 2005). However, due to rapid population decline across the majority of the range, it has therefore been uplisted to Vulnerable (BirdLife International 2021). During the study periods, a total of 400 adult individuals

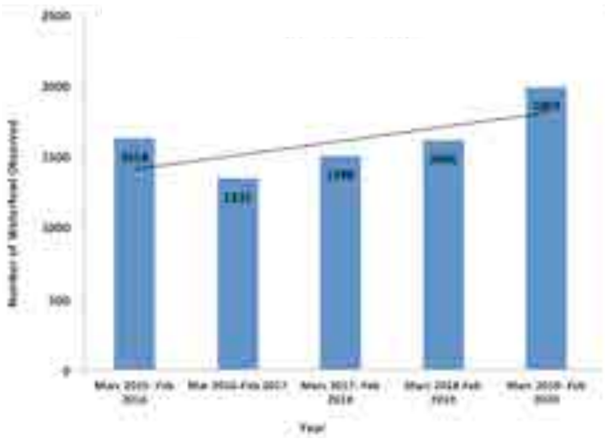

Figure 6. Yearly trend of total number of waterfowl observed in DEMWS from March 2015–February 2020.

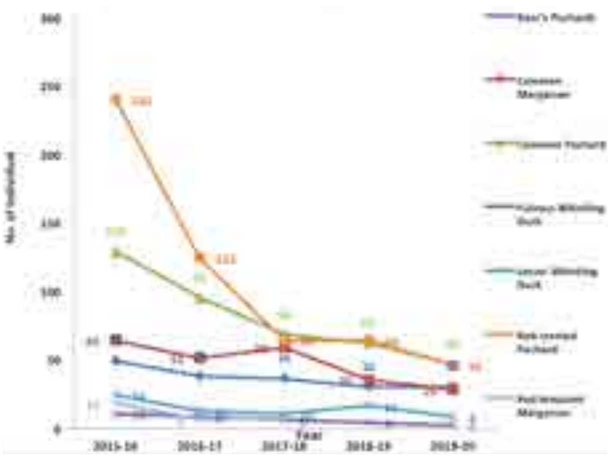

Figure 7. Year-wise decreasing trend of seven species of waterfowl in DEMWS.

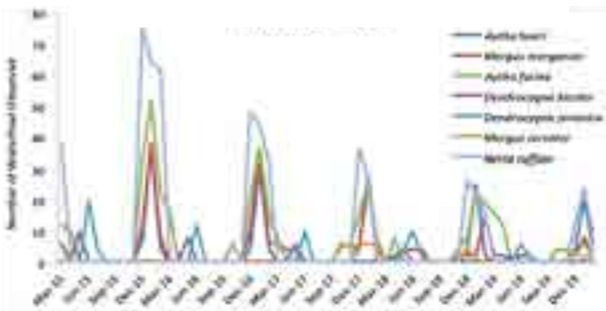

Figure 8. Monthly decreasing trend of seven species of waterfowl population in DEMWS from March 2015–February 2020.

Image 1. Common Goldeneye *Bucephala clangula*.

Image 2. Common merganser *Mergus merganser orientalis*.

Image 3. Common Pochard *Aythya ferina*

Image 4. Common Teal *Anas crecca*.

Image 5. Ferruginous Duck *Aythya nyroca*.

Image 6. Gadwal *Anas strepera*.

Image 7. Indian Spot-billed Duck *Anas poecilirhnycha*.

Image 8. Lesser Whistling Duck *Dendrocygna javanica*.

Image 9. Mallard *Anas platyrhynchos*.

Image 10. Red-crested Pochard *Netta rufina*.

Image 11. Ruddy Shelduck *Tadorna ferruginea*.

Image 12. Tufted Duck *Aythya fuligula*.

were observed, i. e., 2015–16 (129 individuals), 2016–17 (95 individuals), 2017–18 (68 individuals), 2018–19 (62 individuals), and 2019–20 (46 individuals). The largest flock of 52 was seen in January 2016 and the last record was a pair of adults in February 2020. Ferruginous Pochard is a winter visitor to the Indian subcontinent and has been subjected to a variety of human-induced disturbances for a long time (Islam 2003). During the second half of the 20th century, its population underwent a global, large, long-term decline due to habitat destruction and hunting (BirdLife International 2021). The species is not only listed as Near Threatened, but it is a priority species across four prominent international conservation treaties: the European Union Bird Directive, the Bern Convention, the

Bonn Convention, and the African Eurasian Migratory Waterbird Agreement (Robinson & Hughes 2003). During the study periods, a total of 383 adult individuals were observed, i.e., 2015–16 (61 individuals), 2016–17 (66 individuals), 2017–18 (77 individuals), 2018–19 (82 individuals), and 2019–20 (97 individuals). The largest flock of 38 was seen in January 2020.

Throughout the five years of waterfowl surveys in the sanctuary, we did not encounter the White-winged Duck *Asarcornis scutulata*, an endangered species recorded earlier from the sanctuary (Barman 1996; Choudhury 1996, 2002). There have been no sighting records of this waterfowl in the sanctuary for the last eight years, the last being November 2012 (Mize et al. 2014). However, this bird has been reported from various locales including Nameri National Park, Assam (Saikia & Saikia 2011; Das & Deori 2012); Pakke Tiger Reserve, Arunachal Pradesh (Selvan et al. 2013); in Hollongapar Gibbon Sanctuary, Assam (Sharma et al. 2015); at Hkakabo Razi Landscape, Kachin State, Myanmar (Lin et al. 2018). Although we made an extra effort to locate this waterfowl in suitable areas by following (Saikia & Saikia 2011), it was in vain. Field staff reports and the extent of suitable habitat in the study area suggest that this species is perhaps not seen in DEMWS, as all the suitable habitat for this waterfowl has been destroyed by the frequent flooding of Siang Rivers and changing watercourses.

Long-term monitoring of population numbers, population structure, and demographic rates improves our understanding of the biological reasons for population trends (Nichols 1991; Thomas & Martin 1996). DEMWS seems an important staging place on migratory flyways and has one of the highest populations of waterfowl in Arunachal Pradesh, especially during the winter. Furthermore, some globally threatened waterfowl like Baer's Pochard *Aythya baeri*, Common Pochard *Aythya ferina*, and Ferruginous Pochard *Aythya nyroca* are also supported in this sanctuary. Due to logistic issues as well as monsoon floods on the Siang River, it was difficult to cover whole areas of DEMWS and all months of the year. Nonetheless, in this study, we have attempted to cover all the months of various seasons in the most suitable ranges of the sanctuary. Our findings on the temporal changes of waterfowl in this sanctuary can be used for further ecological assessment of the waterfowl community. Nevertheless, detailed studies should be undertaken, focusing especially on the habitat use, nesting, breeding, and foraging ecology of these waterfowl, to understand their critical role in performing various ecosystem services and the underlying causes of the variation in trends.

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COMMUNICATION

Reptilian assemblages in the wetlands of Amboli hill complex, northern Western Ghats, Maharashtra, India during the monsoon season

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Abstract: We studied the reptilian diversity in and around five man-made wetlands in Amboli hill complex of the northern Western Ghats, in the monsoon seasons from 2011 to 2015. During the study we recorded 37 reptile species: 26 snakes, 10 lizards, and one turtle. Several endemic, range-restricted and newly-described species were recorded. We recorded the Indian Black Turtle *Melanochelys trijuga*, which is under 'Near Threatened' category of IUCN Red List 2020. We observed the greatest species richness at Gavase and Dhangarmola wetlands, followed by Khanapur, Yarandol, and Ningudage.

Keywords: Anthropogenic activities, biodiversity hotspot, exotic vegetation, man-made wetlands.

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INTRODUCTION

India is home to approximately 610 species of reptiles, about 50% of which are endemic (Khandekar et al. 2021). Reptile diversity of the northern Western Ghats (WG) in Kaas (Maharashtra part) comprises 57 species (Chickane & Bhosale 2012), while the Gujarat part comprises 65 species (Patel et al. 2018), the central WG contain 71 species (Ganesh et al. 2013) and certain parts of southern WG 46 species (Chandramouli & Ganesh 2010).

Wetlands provide important habitats for fish, amphibians, reptiles, and birds. Although not all reptiles are completely dependent on water bodies, some prefer to live on the edges due to the abundance of prey. One study of European reptiles noted 17 species at Romanian shore (Florina et al. 2015). Some reptiles are permanently dependent on wetlands and some are ephemerals (Griffin & Channing 1991). In India, Vyas et al. (2012) reported 25 species of reptiles in and around the five man-made wetlands in Gujarat. As of 2012, 117 species of reptiles were recorded from Maharashtra (Dasgupta et al. 2012). Several reptile studies have been done in India, but there remains a deficiency of information regarding reptiles in wetlands. The present project focused on the study of reptiles in and around wetlands in the northern WG.

MATERIALS AND METHODS

Study area

The present study was carried in the Ajara Tehsil, located in the southern part of Kolhapur district, Maharashtra (Figure 1). It is located on the eastern edge of the Western Ghats, where the hill ranges run north-south. The forests mainly belong to 3B/C2 – southern moist mixed deciduous forests and 2A/C2 – west coast semi-evergreen - mixed forests, as classified by Champion & Seth (1968). Recently, the state government of Maharashtra declared Ajara forest as a 'conservation reserve'. This declaration will help in conservation of both the habitat and its wildlife. The current study was carried in five man-made wetlands built under a 'watershed development program' by the government of Maharashtra with the aim of supplying water for agriculture and consumption (Table 1).

Methods

Reptiles were recorded using visual the encounter

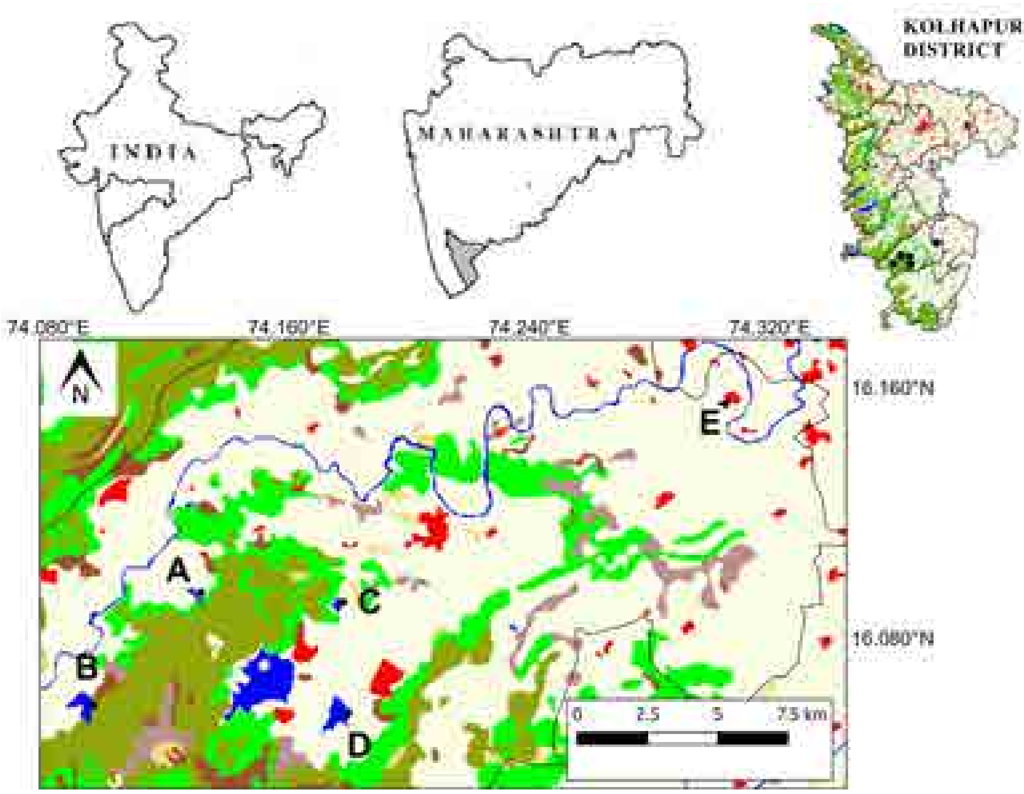

Figure 1. Study area: A—Gavase | B—Dhangarmola | C—Khanapur | D—Yarandol | E—Ningudage.

survey (Campbell & Christman 1982) and time-constrained method (Eekhout 2010). The survey was carried in the monsoon season, from 2011–2015. In this survey, we walked along the edge of the wetlands and searched for reptiles in and around the sampling locations. The survey was carried out in the morning from 0830 to 1000 h; each wetland was surveyed five times per monsoon season. Every survey was carried out for 90 minutes; all the observations were carried out by a single observer. Rarefaction curve was generated based on the number of sightings in the survey; along with it opportunistic sightings were used for preparation of checklist. Reptiles were photographed using a DSLR camera (Canon 600D); identification characters were based on consultation of standard literature (Daniel 2002; Das 2008; Whitaker & Captain 2008). For nomenclature, we followed Khandekar et al. (2021), effecting other nomenclatural updates from recent publications (Ganesh et al. 2020, 2021; Mallik et al. 2020, 2021; Deepak et al. 2021; Gowande et al. 2021). Jaccard's similarity index of species richness between wetlands was calculated using PAST software (Hammer et al. 2001).

Table 1. Description of man-made wetlands.

	Name of the Wetland (Coordinates)	Submergence area (ha)	
		Monsoon	Summer
1	Gavase (16.094°, 74.130°)	37.04	3.79
2	Dhangarmola (16.058°, 74.094°)	55.17	7.32
3	Khanapur (16.091°, 74.177°)	20.71	3.13
4	Yarandol (16.055°, 74.179°)	71.48	36.52
5	Ningudage (16.154°, 74.305°)	4.28	2.35

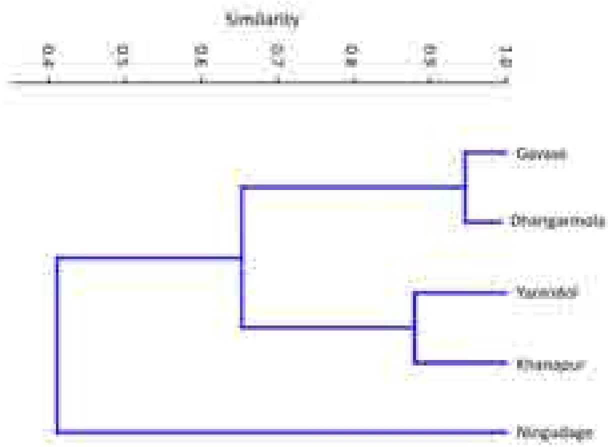

Figure 2. Jaccard's similarity index on presence-absence data of species found at five wetlands.

RESULTS AND DISCUSSION

Overall 37 reptile species, belonging to 13 families (Table 2) were recorded. Colubridae was the most diverse family, comprising 16 species. Out of 37 species, 26 were snakes, 10 were lizards, and one was a turtle. The highest number of species were recorded from Gavase and Dhangarmola (36 species), followed by Khanapur (25 species), and Yarandol (22 species), while the lowest was from Ningudage (13 species). Jaccard's similarity index on presence-absence data of species shows that Gavase and Dhangarmola are more similar in their reptilian species richness (Figure 2). The alpha and beta diversity values of the sampling sites are given in Tables 3 and 4, respectively.

The results of Whittaker's B-diversity for reptiles (Table 3) showed that the species composition and abundance of reptiles are comparable at Gavase and Dhangarmola, whereas Khanapur was slightly different from the rest. However, a high degree of dissimilarity was observed between Gavase and Ningudage, which may be due to the variation in the anthropogenic disturbance levels among these reservoirs. Whittaker's B- diversity for reptiles indicates that the selected sites for the present study can be significantly categorized on the basis of ecological status.

Diversity indices for reptiles (Table 4) at Gavase freshwater reservoir computed from 139 individuals which belong to 24 taxa resulted in values having a lower dominance index (0.084). On the other hand, Ningudage water body value, computed based on 29 individuals, which belong to 9 taxa resulted in readings with the maximum dominance value (0.291). The sampling sites here arranged in the ascending order of dominance (D) index are Gavase (0.084) <Dhangarmola (0.1) <Khanapur (0.104) <Yarandol (0.182) <Ningudage (0.291).

On the results obtained above, the species richness was observed highest at Gavase water body while lowest was noted at Ningudage water body. Furthermore, based on trends, diversity indices observed from present study indicate three different categories of reservoirs: those in Gavase & Dhangarmola in category I, Khanapur water body in category II, and Yarandol & Ningudage in category III. The results obtained for Shannon (D), Simpson (1-D), and Shannon's evenness value indicates that previous three were similar values. Additionally, the latter two showed quite similar index ratios.

The Shannon (H), Simpson (1-D), and Shannon's evenness indices for reptilian diversity at all the reservoirs in descending order are Gavase, Dhangarmola, Khanapur,

Table 2. List of reptile species recorded at the five wetlands.

	Common, scientific name	A	B	C	D	E
	Typhlopidae					
1	Beaked Worm Snake *Grypotyphlops acutus* (Duméril & Bibron, 1844)	+	+	-	-	+
	Uropeltidae					
2	Large-scaled Shieldtail *Uropeltis macrolepis* (Peters, 1862)	+	+	+	+	-
	Pythonidae					
3	Indian Rock Python *Python molurus* (Linnaeus, 1758)	+	+	-	-	-
	Erycidae					
4	Red Sand Boa *Eryx johnii* (Russell,1801)	+	+	-	+	-
5	Common Sand Boa *Eryx conicus* (Schneider,1801)	+	+	+	+	-
	Colubridae					
6	Oriental Rat Snake *Ptyas mucosa* (Linnaeus, 1758)	+	+	+	+	+
7	Banded Kukri Snake *Oligodon arnensis* (Shaw, 1802)	+	+	+	+	-
8	Bronzeback Tree Snake *Dendrelaphis tristis* (Daudin, 1803)	+	+	-	-	-
9	Checkered Keelback *Fowlea piscator* (Schneider, 1799)	+	+	+	+	+
10	Striped Keelback *Amphiesma stolatum* (Linnaeus, 1758)	+	+	+	+	-
11	Green Keelback *Rhabdophis plumbicolor* (Cantor, 1839)	+	+	+	+	+
12	Common Cat Snake *Boiga trigonata* (Schneider, 1802)	+	+	-	-	-
13	Forsten's Cat Snake *Boiga forsteni* (Duméril, Bibron & Duméril, 1854)	+	+	-	-	-
14	Beddome's Cat Snake *Boiga beddomei* (Wall, 1909)	+	+	-	-	-
15	Green Vine Snake *Ahaetulla oxyrhyncha* (Bell, 1825)	+	+	+	+	-
16	Brown Vine Snake *Ahaetulla sahyadrensis* (Mallik, Srikanthan, Pal, D'Souza, Shanker & Ganesh, 2020)	+	-	-	-	-
17	Common Trinket Snake *Coelognathus helena* (Daudin, 1803)	+	+	+	+	+
18	Montane Trinket Snake *Coelognthus helena monticolaris* (Schulz, 1992)	+	+	+	+	-
19	Barred Wolf Snake *Lycodon striatus* (Shaw, 1802)	+	+	-	-	-
20	Travancore Wolf Snake *Lycodon travancoricus* (Beddome, 1870)	+	+	-	+	-
21	Banded Racer *Platyceps plini* (Merrem, 1820)	+	+	+	+	+
	Elapidae					
22	Common Indian Krait *Bungarus caeruleus* (Schneider, 1801)	+	+	+	+	+
23	Spectacled Cobra *Naja naja* (Linnaeus, 1758)	+	+	+	+	+
	Viperidae					
24	Russell's Viper *Daboia russelii* (Shaw & Nodder, 1797)	+	+	+	+	+
25	Bamboo Pit Viper *Craspedocephalus gramineus* (Shaw, 1802)	+	+	-	-	-
26	Malabar Pit Viper *Craspedocephalus malabaricus* (Jerdon, 1854)	+	+	+	+	-
	Agamidae					
27	Sahyadri Forest Lizard *Monilesaurus rouxii* (Duméril & Bibron, 1837)	+	+	+	+	-
28	Indian Garden Lizard *Calotes vultuosus* (Harlan, 1825)	+	+	+	+	+
	Scincidae					
29	Bronze Grass Skink *Eutropis* cf. *macularia* (Blyth, 1853)	+	+	+	+	-
30	Common Keeled Skink *Eutropis carinata* (Schneider, 1801)	+	+	+	+	+
31	Günther's Supple Skink *Riopa guentheri* (Peters, 1879)	+	+	+	+	-
	Lacertidae					
32	Lacertid lizard *Ophisops cf. beddomei* (Jerdon, 1870)	+	+	-	-	-
	Gekkonidae					
33	Yellow Green House Gecko *Hemidactylus flaviviridis* (Rüppell, 1835)	+	+	-	+	+

34	Spotted Rock Gecko *Hemidactylus maculatus* (Duméril & Bibron, 1836)	+	+	+	+	+
35	Deccan Ground Gecko *Cyrtodactylus deccanensis* (Günther, 1864)	+	+	-	-	-
	Varanidae					
36	Bengal Monitor Lizard *Varanus bengalensis* (Daudin, 1802)	+	+	+	+	-
	Geoemydidae					
37	Indian Black Turtle *Melanochelys trijuga* (Schweigger,1812)	-	+	-	-	-
		36	36	22	25	13

+—Present |-—Absent | A—Gavase | B—Dhangarmola | C—Yarandol | D—Khanapur | E—Ningudage.

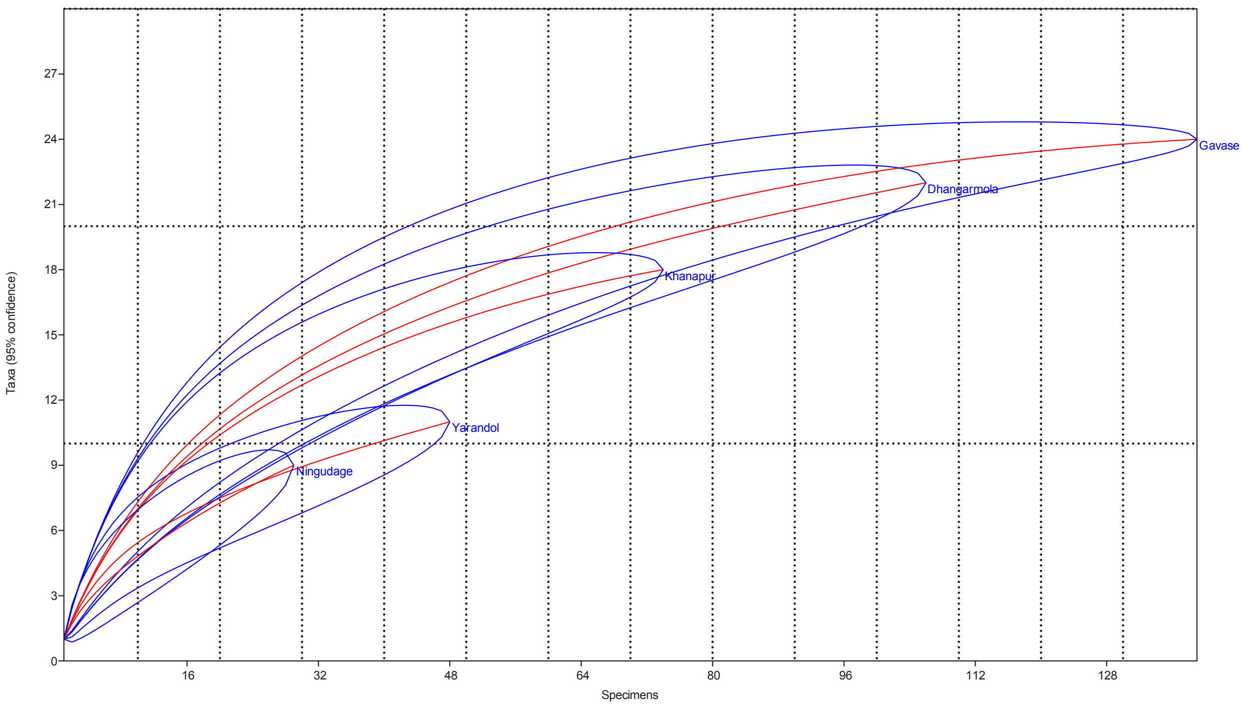

Figure 3. Rarefaction curve of species richness at wetlands. Note: Blue lines indicate 95% confidence interval estimated by bootstrapping.

Yarandol, and Ningudage. Individual rarefaction curves for all reservoirs are in Figure 3.

The study of reptilian fauna revealed that minimum individuals were observed at Ningudage water body. On that basis, a rarefaction curve was drawn that indicates that Gavase reservoir has maximum richness while Yarandol and Ningudage water bodies are at minimum richness levels. The results obtained from this method are similar to that of Shannon and Simpson indices.

Reyni's diversity profile for all reservoirs is depicted in Figure 4. The investigation of Renyi's diversity profile for reptiles indicates that the Gavase is at the top with respect to distribution of species; followed by Dhangarmola and Khanapur. Computed lines of Dhangarmola and Khanapur water bodies intersect each other and hence one cannot compare these sites. Since the computed line of Ningudage is steeper, it indicates the uneven distribution of species in that site.

Gavase and Dhangarmola wetlands showed the highest species richness among all wetlands and have the highest species similarity. Both these wetlands are in the same hill range; located on hillslopes covered with forest from three sides and anthropogenic disturbances are low. Khanapur wetland is also located in the same hilly range, but vegetation surrounding the wetland is a monoculture plantation of *Acacia auriculiformes,* and anthropogenic activities were observed. Despite its similarity and proximity with the above two wetlands, Khanapur wetland showed reduced species compared to above-mentioned wetlands. Exotic plants reduce reptilian diversity (Martin & Murray 2011), and *Acacia auriculiformes* might have reduced richness of reptile

Table 3. Alpha-diversity indices of reptiles among the study sites.

Reservoir/ Indices	Taxa_S	Individuals	Dominance_ D	Simpson_1-D	Shannon_H	Evenness_e^H/S
Gavase	24	139	0.084	0.916	2.758	0.657
Lower	17	139	0.0899	0.8683	2.344	0.5336
Upper	23	139	0.1316	0.9096	2.652	0.6956
Dhangarmola	22	106	0.1	0.9	2.613	0.62
Lower	15	106	0.0899	0.8637	2.29	0.5541
Upper	22	106	0.1362	0.9101	2.652	0.7221
Yarandol	11	48	0.182	0.818	1.945	0.636
Lower	11	48	0.0885	0.8307	2.054	0.6263
Upper	18	48	0.1684	0.9106	2.607	0.8233
Khanapur	18	74	0.104	0.896	2.513	0.686
Lower	14	74	0.0869	0.855	2.21	0.5877
Upper	20	74	0.1446	0.9131	2.661	0.7741
Ningudage	9	29	0.291	0.709	1.627	0.565
Lower	9	29	0.0916	0.8038	1.895	0.6718
Upper	15	29	0.1962	0.9084	2.53	0.8804

Table 4. Whittaker's B- Diversity of reptiles among the study sites.

Reservoirs	Gavase	Dhangarmola	Yarandol	Khanapur	Ningudage
Gavase	0				
Dhangarmola	0.0435	0			
Yarandol	0.3714	0.3333	0		
Khanapur	0.1429	0.1	0.2414	0	
Ningudage	0.4546	0.4194	0.3	0.3333	0

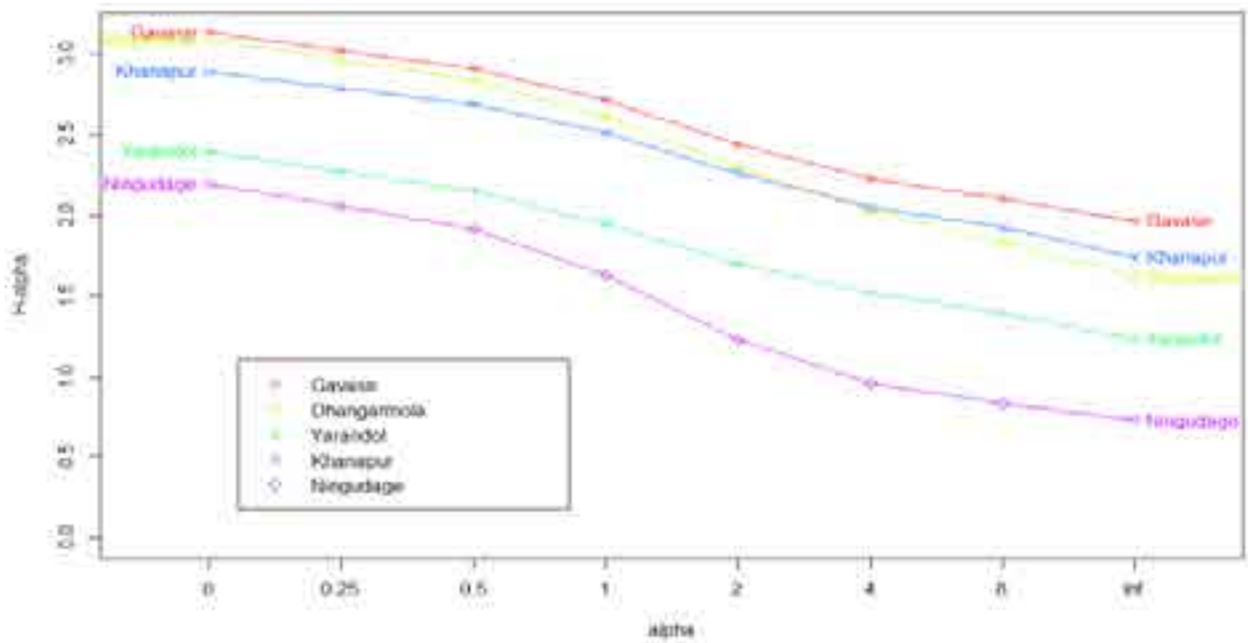

Figure 4. Renyi's diversity profile for reptiles for individual study sites.

species at the Khanapur wetlands. Yarandol and Ningudage wetlands are located away from forest area; anthropogenic activities were considerably high due to their location near the human settlement.

The study reconfirmed that different reptile taxa occupy various microhabitats. Among all the taxa, three species are burrowing snakes—*Grypotyphlops acutus*, *Eryx johnii*, and *Eryx conicus*—all these were recorded under leaf litter. Keelback snakes such as *Fowlea piscator, Amphiesma stolatum*, and *Rhabdophis plumbicolor* were recorded from water bodies and fringes. Six species of arboreal snakes were observed at the study site, viz: *Boiga forsteni*, *Boiga beddomei, Ahaetulla oxyrhyncha*, *Ahaetulla sahyadrensis, Craspedocephalus gramineus*, and *C. malabaricus. Boiga trigonata, Lycodon striatus*, and *Lycodon travancoricus* are terrestrial and arboreal in habit. Lizards, except *Monilesaurus rouxii* are predominantly ground-dwelling. However, *Calotes vultuosus* was frequently found on the trunks of trees. But for these arboreal agamids, all other species of lizards were found under leaf litter and beneath crevices of fallen logs on ground and crevices of rocks. This aspect was studied to prove that non-aquatic reptiles will also benefit by conserving certain ear-marked wetlands. During the survey only one turtle species *Melanochelys trijuga* was found, which is under the 'Near Threatened' category of IUCN Red List (Ahmed et al. 2020); aquatic in habit. We opine that other aquatic turtles known from this region, such as *Lissemys punctata* and *Nilssonia leithi* could not be recorded due to lack of intensive aquatic sampling in the water bodies.

The present study area in the Ajara range is just 30 airline km away from Amboli, site of several previous herpetological expeditions that reported many new lizards and snakes, including *Melanophidium khairei, Rhabdops aquaticus, Dendrelaphis girii, Calliophis castoe, Hemidactylus varadgirii* and several new species of *Cnemaspis* (Vogel & van Rooijen 2011; Smith et al. 2012; Gower et al. 2016; Giri et al. 2017; Sayyed et al. 2018; Chaitanya et al. 2019; Deepak et al. 2021). However, these species could not be recorded during the present study, likely due to the easterly position of the Ajara range compared to Amboli, which is situated well within the Western Ghats.

It is to be acknowledged that man-made constructions of wetlands, especially as a result of damming, have proven to be counter-productive for biodiversity conservation in the Western Ghats (Mohite & Samant 2012). However, scientifically-informed management interventions consisting of artificial creating or propagation of wetlands will help in biodiversity conservation. It is thus concluded that man-made wetlands do support a sizeable amount of reptilian diversity. Awareness about the biodiversity value of wetlands among the citizens is therefore necessary for its conservation. Based on these results, we recommend intensive biodiversity studies in the far larger Hidkal Reservoir, situated 40 airline km west of Ajara Tehsil, abutting the state boundary in Karnataka.

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COMMUNICATION

Butterfly diversity and composition at Chemerong Amenity Forest, Terengganu, Malaysia

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Abstract: A study of butterfly species diversity was conducted in Chemerong Amenity Forest, Terengganu, Malaysia. A total of 939 individuals from 198 butterfly species were obtained using fruit-baited sweep nets and modified VanSomeren-Rydon cylinder traps. The biodiversity of butterflies in the study area was considered high, with a Shannon index (H') of 4.1, Simpson's index ($D_{Simpson}$) of 0.042, and Margalef index ($I_{Margalef}$) of 28.78. Individuals within the community were not evenly distributed among the species (EShannon= 0776). Nymphalidae was found to be the most dominant family (48.5%), and *Lexias dirtea merguia* was the most abundant species recorded with 114 individuals (12%). From the total of eight species protected under Malaysia legislation, one species *Trogonoptera brookiana* was also listed under CITES Appendix II, while only one protected species *Agatasa calydonia calydonia* of the family Nymphalidae (the brush-footed or four-footed) was considered rare. Other rare species found in this study included *Arhopala lucida*, *Curetis saronis sumatrana*, *Miletus nymphis fictus* of the family Lycaenidae (the blues, coppers, & hairstreaks), *Amathusia perakana perakana*, *Bassarona teuta goodrichi*, *Elymnias saueri saueri*, *Elymnias nesaea*, *Mycalesis horsfieldi hermana*, *Mycalesis distanti*, *Ypthima pandocus tahanensis* of the family Nymphalidae (the brush-footed or four-footed), *Celaenorrhinus ladana*, *Erionota sybirita*, *Matapa aria*, *Matapa cresta*, *Matapa druna*, *Pseudokerana fulger*, *Taractrocera ardonia*, *Taractrocera luzonensis*, *Telicota linna*, and *Unkana mytheca mytheca* of the family Hesperiidae (the skippers). The dominance of family Nymphalidae may be due to several factors, including high species diversity, widespread distribution and occurrence, as well as the type of bait used in this study. Besides the Genting Highlands and Taman Negara Johor Endau Rompin, butterfly species at Chemerong Amenity Forest are more diverse than other study sites in Malaysia such as Gunung Serambu, Ulu Gombak Forest Reserve, Setiu Wetlands, Kuala Lompat, Bukit Hampuan Forest Reserve, Sungai Imbak Forest Reserve, Tabin Wildlife Reserve, and Ulu Senagang Substation. Further investigation of aspects such as stratification distribution patterns, host plants and forest dwelling species are recommended for better understanding of butterfly communities in the Chemerong Amenity Forest.

Keywords: Biodiversity indices, butterflies, forest reserve, Lepidoptera, primary forest, tropical rainforest.

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INTRODUCTION

Studies of butterflies have contributed greatly to the understanding of their ecology, evolution, biogeography, conservation, and usefulness as biodiversity indicators (Sekimura & Nijhout 2019). Knowledge about tropical butterflies is, however, quite limited (Beck 2007; Koh 2007; Bonebrake et al. 2010). In comparison with most temperate ecosystems, tropical forests are characterized by extraordinarily high but poorly- inventoried insect diversity (Bonebrake et al. 2010; Ballesteros-Mejia et al. 2013).

There are 1,182 recorded species of butterfly in Malaysia (Wilson et al. 2015), with 117 being endemic (Tamblyn et al. 2006) and 1,038 species recorded in Peninsular Malaysia (Eliot & Kirton 2000). Continuous monitoring of biodiversity over time is essential to identify changes in species populations. For example, the tradition of recording and monitoring of species occurrences and relative abundance by the Butterfly Monitoring Scheme has provided evidence for declines and losses of some species in the northern temperate zone (Pollard & Yates 1993), while a citizen science project: the 'Peninsular Malaysia Butterfly Count' involved the general public to obtain samples for DNA barcoding of butterflies for monitoring communities in Peninsular Malaysia (Wilson et al. 2015).

Therefore, it is vital to monitor and assess the current status of local biodiversity comprehensively as an action link to the conservation approach and priorities (Green et al. 2003).

Deforestation, together with human population growth increase, have substantial effects on global biodiversity (McKee et al. 2003. Wittmeyer et al. 2008), especially in southeastern Asia. For example, Singapore has recently lost most of its biodiversity due to massive development (Castelletta et al. 2000; Brook et al. 2003; Sodhi et al. 2004; Hau et al. 2005; Sodhi et al. 2010). This concern was also felt in other southeastern Asian countries including Malaysia, which have had high terrestrial degradation in recent years (Sodhi et al. 2010). This is quite worrying as habitat loss is the main cause of butterfly extinction, and diversity is being lost before we can quantify or understand it (Checa et al. 2009).

In the state of Terengganu, butterfly inventory and monitoring were first carried out by Fleming (1975) and also Corbet & Pendlebury (1992). Since then, there have been few studies of butterfly status in the state of Terengganu, and there are deficient sources and publications on this subject (Tamblyn et al. 2006; Yap et al. 2018). Therefore, the diversity and composition of butterfly at the Chemerong Amenity Forest was investigated. The study site chosen for this study was opportune, as it is proclaimed to be an undisturbed tropical rainforest which houses myriads of flora and fauna species. The results of this study will provide a baseline data on butterflies in the Chemerong Amenity Forest.

MATERIALS AND METHODS

Study Site

The research was conducted at Chemerong Amenity Forest (4.651667, 103.001389) located in the Pasir Raja Forest Reserve, Dungun, Terengganu, Malaysia. It is considered as an undisturbed area with pristine forest. The Chemerong Amenity Forest encompassing of at least 292 ha area and is categorized as a hill dipterocarp forest (Forestry Department of Peninsular Malaysia 2022). This area is blessed with various flora and fauna and is rich with a variety of dicotyledonous plants, namely, Dipterocarpaceae, Rubiaceae, and Euphorbiaceae together with monocotyledonous species such as Zingiberaceae and Palmae (Faridah-Hanum et al. 2006). The amenity forest is well known for the Lata Chemerong waterfall, which is about 305 m in height and the presence of the Malaysia's largest and oldest Cengal tree *Neobalanocarpus heimii* with a height of 65 m, girth of 16.75 m and the estimated age of at least 1,300 years old.

The Chemerong Amenity Forest mainly consists of primary forest. However, due to the status of the area as an amenity forest, the local authority has built several facilities for administration and ecotourism such as an office, cafeteria, toilet, prayer room, camping site, hall, and garden. Various trees and floristic plants were also planted at surrounding areas as decoration. Moreover, a walking trail has also been built in the forest to facilitate tourists to reach the waterfall area.

Data Collection

Sweep sampling method, baits method, and modified VanSomeren-Rydon cylinder trap was utilised to investigate butterfly diversity and composition in Chemerong Amenity Forest from July 2010 to January 2011 (14 days sampling) and August 2011 to January 2012 (10 days sampling). The study was conducted once a month for two days, one-night sampling per effort.

Different collection methods have been used to increase the species diversity of butterflies caught. For instance, some members of subfamily Charaxinae and

Nymphalinae tend to be trapped in the canopy, while Morphinae and Satyrinae in the understory (De Vries 1988). Butterfly collecting was conducted from 0830 h to 1100 h and from 1500 h to 1800 h. Sweep sampling method was conducted by walking in the forest interior, along the trails and garden area at the visitors' complex, and sighted butterflies were captured using sweep net. Baits method on the other hand, was conducted by luring the butterflies using bait that consisted of a mixture of rotten fruits of banana, papaya, apple, orange, and pineapples. The bait was placed on the forest floor at several selected spots such as near the trails, forest fringe and at the forest interior. Lured butterflies were then captured using sweep net.

Butterflies were sampled using modified VanSomeren-Rydon cylinder trap, baited with rotten banana following the method of Rydon (1964). However, the original structure of PVC bait case used by Rydon (1964) was replaced with a plastic plate. To reduce the damage to the trapped samples on a rainy day caused by raindrops, a transparent plastic-sheet was used to cover the top of each trap.

Ten traps were used for each sampling attempts and was positioned about 1 m to 4 m above ground at 10 different selected spots, at the interior of the forest and forest edges. The traps were checked and mixed with fresh baits daily in the morning between 0830 h and 1000 h, and in the evening between 1700 h and 1830 h. The bait was renewed daily by mixing the old bait together with the fresh baits in order to produce the homogenous odour of rotten banana. All butterflies were captured by hand through the zipped part of the trap whilst either resting on the netting or hanging from the cone part of the trap. The butterflies were then killed by using the pinching technique and kept in triangle envelopes. Only butterflies caught using the traps and by sweep net were recorded for this study.

Identification

The samples were identified into species taxon by referring to Otsuka (2001), Corbet & Pendlebury (1992), and Fleming (1975). Revisions were also made by referring to van der Poorten & van der Poorten (2020).

Data Analysis

The diversity, evenness and species richness indices of butterfly communities were assessed and pooled over for two years. Shannon diversity index (*H'*) was applied as a measure of species abundance and richness to quantify diversity of butterfly species. The Shannon diversity index formula is shown below:

$$H' = -\sum_{i}\left(\frac{ni}{N} \cdot ln\left[\frac{ni}{N}\right]\right)$$

where (*ni*) is the number of individuals of one particular species found in the community, (*N*) is the total number of individuals for all species found in the community, (*ln*) is the natural log and (Σ) is the sum of the calculations.

Next, as a tool to measure species dominance, Simpson's index ($D_{Simpson}$) was used while Margalef index ($I_{Margalef}$) was used to determine species richness, evenness and dominance. The equation for Simpson's index is as follows:

$$D = \frac{\Sigma_i\, ni(ni-1)}{N(N-1)}$$

Where (*ni*) is the number of individuals found for particular species in the community, (*N*) is the total number of individuals for all species found in the community and (Σ) is the sum of the calculations.

For Margalef index ($I_{Margalef}$), the equation is as follows:

$$I = \frac{S-1}{\ln N}$$

Where (*S*) is the total number of species and (*N*) is the total number of individuals found for all species.

To measure equitability or evenness of spread of individuals for each species of butterflies, Shannon evenness index ($E_{Shannon}$) was applied based on the following equation:

$$-\frac{\Sigma_i\left(\frac{ni}{N} \cdot \ln\left(\left[\frac{ni}{N}\right]\right)\right)}{\ln N}$$

Where (*ni*) is the number of individuals found for particular species in the community, (*N*) is the total number of individuals for all species found in the community, (*ln*) is the natural log and (Σ) is the sum of the calculations. If the value obtained in $E_{Shannon}$ approaching zero, the distribution of individuals in each species is considered highly similar or even. However, if the value approaches 1, the community did not have evenly distributed number of individuals for each species.

Whittaker plot or a rank abundance curve (RAC) was also generated by using excel to show the relative species abundance, richness and evenness.

RESULTS

Butterfly composition

We recorded a total of six families, 198 species and 939 individuals (Table 1). The most abundant family (Nymphalidae), included 577 (61.4%) individuals, followed by Hesperidae 161 (17.1%) individuals, Pieridae 131 (14%) individuals, Lycaenidae 46 (4.9%) individuals, Papilionidae 15 (1.6%) individuals, and Riodinidae 9 (1%) individuals (Figure 1). The richest genus was *Mycalesis* (9 species), followed by *Arophala, Neptis,* and *Eurema* (8 species), *Tanaecia* (7 species), *Amathusia* and *Ypthima* (6 species), *Graphium* (5 species), and *Euthalia, Lexias, Charaxes* and *Athyma* (4 species).

Diversity indices analysis

The diversity of butterflies in the Chemerong Amenity Forest recorded a reading of 0.042 for Simpson's index and 4.1 for Shannon-Weiner index with the evenness or equitability of 0.776. These readings indicate that butterfly community in the Chemerong Amenity Forest have very high diversity, yet the equitability of the species can be considered relatively low. However, for the species richness, Margalef index was 28.78 which

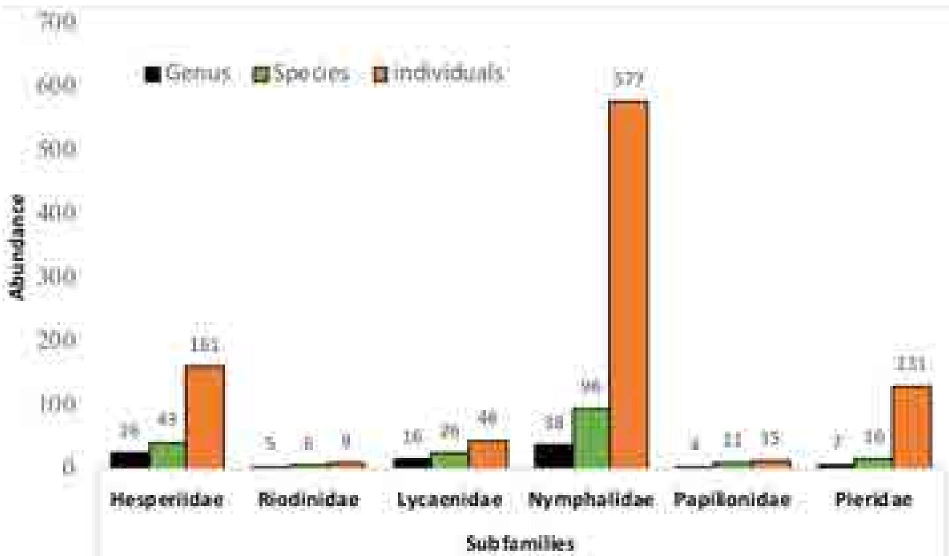

Figure 1. Total number of genus, species, and individuals according to family.

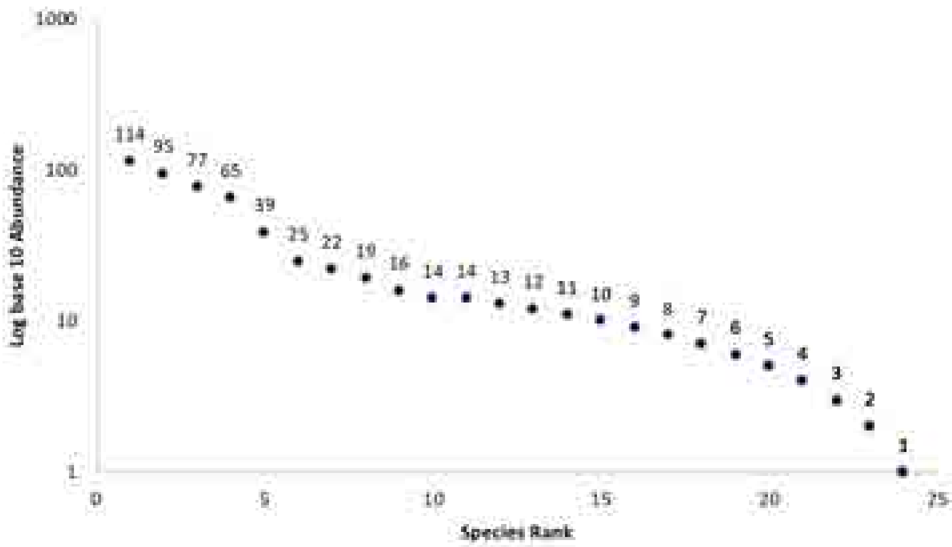

Figure 2. Rank abundance curve of butterfly family's community in Chemerong Amenity Forest.

Table 1. List of butterfly species recorded in Chemerong Amenity Forest, Terengganu, Malaysia.

Taxon	Scientific name	No. of individuals	Voucher code
Hesperiidae			
Hesperiinae	*Ancistroides armatus armatus*	1	UMT/8/2012
	Ancistroides gemmifer gemmifer	1	UMT/4/2012
	Ancistroides nigrita maura	4	UMT/34/2012
	Arnetta verones	1	UMT/61/2012
	Astictopterus jama jama	7	UMT/95/2012
	Baoris oceia	1	UMT/113/2012
	Caltoris brunnea caere	1	UMT/120/2012
	Cephrenes acalle niasicus	65	UMT/130/2012
	Erionota acroleuca apicalis	3	UMT/131/2012
	Erionota sybirita	3	UMT/1/2012
	Gangara lebadea lebadea (syn. *glandulosa*)	1	UMT/77/2012
	Gangara thyrsis thyrsis	1	UMT/78/2012
	Hidari doesoena doesoena	1	UMT/157/2012
	Hyarotis microsticta microsticta	1	UMT/158/2012
	Iambrix salsala salsala	4	UMT/2/2012
	Iambrix stellifer	1	UMT/3/2012
	Isma guttulifera kuala	1	UMT/171/2012
	Isma miosticta	6	UMT/172/2012
	Isma umbrosa umbrosa	1	UMT/173/2012
	Koruthaialos rubecula rubecula	5	UMT/24/2012
	Koruthaialos sindu sindu	4	UMT/96/2012
	Matapa aria	1	UMT/18/2012
	Matapa cresta	2	UMT/144/2012
	Matapa druna	1	UMT/156/2012
	Notocrypta clavata clavata (syn. *devadatta*)	1	UMT/183/2012
	Notocrypta curvifascia corinda	1	UMT/184/2012
	Parnara bada bada	1	UMT/35/2012
	Pelopidas agna agna	4	UMT/5/2012
	Pelopidas assamensis	1	UMT/17/2012
	Pelopidas conjunctus	4	UMT/99/2012
	Polytremis lubricans lubricans	4	UMT/146/2012
	Potanthus juno juno	1	UMT/165/2012
	Potanthus omaha omaha (syn. *maesoides*)	3	UMT/10/2012
	Pseudokerana fulgur	1	UMT/32/2012
	Psolos fuligo fuligo	3	UMT/170/2012
	Tagiades lavata	1	UMT/132/2012
	Taractrocera ardonia sumatrensis (syn. *lamia*)	5	UMT/133/2012
	Taractrocera luzonensis zenia	2	UMT/134/2012
	Telicota linna	1	UMT/164/2012
	Telicota besta bina	2	UMT163/2012
	Unkana ambasa batara	6	UMT/193/2012
	Unkana mytheca mytheca (syn. *harmachis; standingeri*)	1	UMT59/2012
Pyrginae	*Celaenorrhinus ladana*	2	UMT/9/2012

Taxon	Scientific name	No. of individuals	Voucher code
Riodinidae			
	Abisara saturata kausambioides	3	UMT/98/2012
	Paralaxita telesia lyclene	2	UMT/115/2012
	Stiboges nymphidia nymphidia	1	UMT/159/2012
	Taxila haquinus haquinus	1	UMT/160/2012
	Zemeros emesoides emesoides	1	UMT/114/2012
	Zemeros flegyas albipunctus	1	UMT/175/2012
Lycaenidae			
Theclinae	*Arhopala aedias*	1	UMT/186/2012
	Arhopala antimuta antimuta (syns. *davisonii; tana*)	1	UMT/22/2012
	Arhopala lurida	2	UMT/14/2012
	Arhopala major major (syn. *catori*)	1	UMT/15/2012
	Arhopala normani	1	UMT/79/2012
	Arhopala centaurus nakula	1	UMT/80/2012
	Arhopala tropaea	1	UMT/81/2012
	Arhopala wildeyana wildeyana	1	UMT/60/2012
	Drupadia ravindra moorei	1	UMT/30/2012
	Eooxylides tharis distanti	1	UMT/11/2012
	Megisba malaya sikkima (syn. *velina*)	1	UMT/23/2012
	Surendra vivarna amisena	1	UMT/33/2012
Curetinae	*Curetis saronis sumatrana*	1	UMT/162/2012
	Curetis sperthis sperthis	1	UMT/145/2012
Lycaeninae	*Rachana jalindra burbona*	1	UMT/16/2012
Polyommatinae	*Acytolepis puspa* lambi	1	UMT/7/2012
	Catochrysops strabo strabo (syn. *riama)*	1	UMT/57/2012
	Jamides celeno aelianus	2	UMT/58/2012
	Jamides elpis pseudelpis	4	UMT/118/2012
	Jamides zebra lakatti	1	UMT/119/2012
	Prosotas nora superdates	1	UMT/117/2012
	Zizeeria karsandra	5	UMT/161/2012
	Zizina otis lampa	12	UMT/185/2012
Miletinae	*Allotinus horsfieldi permagnus* (syn. *nessus*)	1	UMT/36/2012
	Miletus nymphis fictus	1	UMT/135/2012
Poritiinae	*Simiskina pharyge deolina*	1	UMT/174/2012
Nymphalidae			
Charaxinae	*Agatasa calydonia calydonia*	2	UMT/13/2012
	Charaxes athamas athamas	1	UMT/101/2012
	Charaxes athamas uraeus	1	UMT/21/2012
	Charaxes bernadus crepax	2	UMT/6/2012
	Charaxes echo echo	1	UMT/97/2012
	Doleschallia bisaltide pratipa	1	UMT/102/2012
	Prothoe franck uniformis	11	UMT/191/2012
Amathusiinae	*Amathusia friderici holmanhunti f. utana*	1	UMT/147/2012
	Amathusia ochraceofusca ochraceofusca	6	UMT/148/2012
	Amathusia perakana perakana	1	UMT/12/2012

Taxon	Scientific name	No. of individuals	Voucher code
	Amathusia phidippus phidippus f. *chersias*	1	UMT/116/2012
	Amathusia phidippus phidippus f. *gunneryi*	2	UMT/129/2012
	Amathusia sp.	4	UMT/100/2012
	Amathuxidia amythaon dilucida	4	UMT/31/2012
	Amathuxidia sp.	1	UMT/37/2012
	Discophora sondaica despoliata	2	UMT/40/2012
	Discophora timora perakensis	2	UMT/128/2012
	Faunis canens arcesilas [syn. *taraki*]	6	UMT/177/2012
	Faunis gracilis	1	UMT/178/2012
	Faunis kirata	1	UMT/179/2012
	Thaumantis klugius lucipor	1	UMT/48/2012
	Thaumantis noureddin noureddin	2	UMT/192/2012
	Zeuxidia amethystus amethystus	2	UMT149/2012
	Zeuxidia doubledayi doubledayi (syn. *chersonesia*)	4	UMT/150/2012
	Zeuxidia sp.	1	UMT/151/2012
Limenitidinae	*Athyma nefte subrata (*syns. *urvasi*; *nivifera*)	2	UMT/39/2012
	Athyma pravara helma	1	UMT/49/2012
	Athyma reta moorei	1	UMT/167/2012
	Athyma sinope sinope	1	UMT/166/2012
	Bassarona teuta goodrichi (syn. *johorensis*)	1	UMT/76/2012
	Euthalia phemius phemius (syns *ipona*; *corbeti*)	1	UMT/104/2012
	Euthalia kanda marana	2	UMT/190/2012
	Euthalia merta (syn. *simplex*)	2	UMT/137/2012
	Euthalia monina monina (syn. *ramada*; *perakana*)	5	UMT/138/2012
	Lasippa heliodore dorelia	2	UMT/20/2012
	Lasippa tiga camboja	2	UMT/50/2012
	Lebadea martha malayana (syn. *koenigi*)	1	UMT/51/2012
	Lexias canescens pardalina	3	UMT/52/2012
	Lexias cyanipardus sandakana (syn. *johorensis*)	3	UMT/53/2012
	Lexias dirtea merguia (syn. *maga*)	114	UMT/28/2012
	Lexias pardalis dirteana (syn. *erici*)	95	UMT/103/2012
	Neptis cliniodes gunongensis	1	UMT/126/2012
	Neptis duryodana neisa	1	UMT/63/2012
	Neptis hylas papaja (syn. *mamaja*)	1	UMT/125/2012
	Neptis leucoporos cresina	1	UMT/152/2012
	Neptis magadha charon	1	UMT/41/2012
	Neptis nata gononata	1	UMT/42/2012
	Neptis omeroda omeroda	1	UMT/46/2012
	Neptis soma pendleburyi	1	UMT/127/2012
	Tanaecia aruna aruna (syns. *robertsii*, *satapana*)	8	UMT/47/2012
	Tanaecia flora flora (syn. *maclayi*)	1	UMT/71/2012
	Tanaecia godartii picturatus	5	UMT/72/2012
	Tanaecia iapis puseda (syn. *cocyta*)	6	UMT/73/2012
	Tanaecia munda waterstradti	5	UMT/74/2012
	Tanaecia palguna consanguinea	9	UMT/45/2012

Taxon	Scientific name	No. of individuals	Voucher code
	Tanaecia pelea pelea (syns. *pulsara*; *supercilia*)	4	UMT/56/2012
Heliconiinae	*Cethosia hypsea hypsina*	2	UMT/153/2012
	Cirrochroa orissa orissa	1	UMT/139/2012
	Vindula erota chersonesia	1	UMT/187/2012
Nymphalinae	*Chersonesia rahria rahria*	1	UMT/38/2012
	Cyrestis themire themire (syn. *periander*)	1	UMT/176/2012
	Dophla evelina compta	9	UMT/136/2012
	Hypolimnas bolina bolina	1	UMT/44/2102
	Hypolimnas anomala anomala	1	UMT/29/2012
	Junonia atlites atlites	1	UMT/55/2012
	Junonia iphita horsfieldi	1	UMT/82/2012
	Junonia orithya wallacei	7	UMT/83/2012
Satyrinae	*Elymnias saueri saueri*	1	UMT/105/2012
	Elymnias hypermnestra tinctoria	3	UMT/106/2012
	Elymnias nesaea lioneli	1	UMT/107/2012
	Melanitis leda leda	2	UMT/108/2012
	Mycalesis fuscum fuscum	3	UMT/109/2012
	Mycalesis horsfieldi hermana	2	UMT/110/2012
	Mycalesis distanti	2	UMT/19/2012
	Mycalesis maianeas maianeas	1	UMT/43/2012
	Mycalesis mineus macromalayana	3	UMT/54/2012
	Mycalesis mnasicles perna	1	UMT/124/2012
	Mycalesis orseis nautilus	1	UMT/140/2012
	Mycalesis perseoides	1	UMT168/2012
	Mycalesis sp.	1	UMT/169/2012
	Neorina lowii neophyte	1	UMT/197/2012
	Ragadia makuta siponta	19	UMT/102/2012
	Xanthotaenia busiris busiris	1	UMT/64/2012
	Ypthima newboldi	77	UMT/65/2012
	Ypthima fasciata torone	4	UMT/66/2012
	Ypthima heubneri	39	UMT/67/2012
	Ypthima horsfieldii humei	2	UMT/68/2012
	Ypthima pandocus corticaria (syn. *emporialis*)	25	UMT/69/2012
	Ypthima pandocus tahanensis	3	UMT/70/2012
Danainae	*Danaus melanippus hegesippus*	1	UMT/90/2012
	Euploea mulciber mulciber	1	UMT/195/2012
	Euploea radamanthus radamanthus (syn. *diocletianus*)	4	UMT/196/2012
	Idea hypermnestra linteata	6	UMT/198/2012
	Ideopsis similis persimilis	1	UMT/154/2012
	Ideopsis vulgaris macrina	1	UMT/155/2012
Apaturinae	*Rohana parisatis siamensis*	1	UMT/189/2012
Papilionidae			
Papilioniae	*Graphium agamemnon agamemnon*	1	UMT/26/2012
	Graphium antiphates alcibiades (syn. *itamputi*)	1	UMT/94/2012
	Graphium eurypylus mecisteus	1	UMT/91/2012

Taxon	Scientific name	No. of individuals	Voucher code
	Graphium evemon eventus (syn. *orthia*)	1	UMT/92/2012
	Graphium sarpedon luctatius	1	UMT/93/2012
	Losaria doubledayi doubledayi	1	UMT/121/2012
	Losaria neptunus neptunus	1	UMT/122/2012
	Papilio demolion demolion	2	UMT/180/2012
	Papilio iswara iswara	2	UMT/182/2012
	Papilio memnon agenor	1	UMT/181/2012
	Graphium antiphates alcibiades (syn. *itamputi*)	1	UMT/94/2012
	Trogonoptera brookiana albescens	3	UMT/188/2012
Pieridae			
Pierinae	*Appias indra plana*	1	UMT/194/2012
	Appias lyncida vasava	7	UMT/142/2012
	Appias paulina distanti	1	UMT/143/2012
	Delias hyparete metarete	3	UMT/27/2012
Coliadinae	*Catopsilia pomona pomona*	2	UMT/141/2012
	Eurema ada iona	22	UMT/87/2012
	Eurema andersonii andersonii	16	UMT/88/2012
	Eurema blanda blanda (syn. *snelleni*)	11	UMT/89/2012
	Eurema hecabe hecabe (syn. *contubernalis*)	2	UMT/86/2012
	Eurema lacteola lacteola	13	UMT/62/2012
	Eurema sari sodalis	14	UMT/84/2012
	Eurema simulatrix tecmessa	10	UMT/85/2012
	Eurema nicevillei nicevillei	14	UMT/112/2012
	Gandaca harina distanti	10	UMT/123/2012
	Parenonia valeria lutescens	3	UMT/111/2012
	Saletara panda distanti	2	UMT/25/2012
Total	Species= 198	939	

indicates high species presence in the study site. Figure 2 summarizes the rank abundance curve for six butterfly families at Chemerong which showed that most of the butterfly species from different families were low ranking species where the number of individuals caught were nearly similar with majority of the butterfly species categorized in low ranking species (106 species or 53.5%) being singletons.

Five species of butterfly were ranked as high-ranking species or dominant species namely *Lexias dirtea merguia* (syn. *maga*), *Lexias pardalis dirteana, Ypthima newboldi, Cephrenes acalle niasicus, Ypthima heubneri, Ypthima pandocus corticaria*, *Eurema ada iona*, and *Ragadia makuta siponta*. These dominant species contributed 48% (456 individuals) of the total individuals caught in this study.

DISCUSSION

The dominancy by the family Nymphalidae may be due to the generally diverse group of butterfly species in this family. The Nymphalidae contains 7,200 species occurring in all habitats and continents except Antarctica (DeVries 1987; Shields 1989), with 281 species recorded in Malaysia (van der Poorten & van der Poorten 2020). In addition, the use of fruit baits as attractants such as rotting banana, papaya, apple, orange and pineapple were found to successfully attract the *Lexias* butterflies which contributed 22.9% of the total individuals caught in this study. This was supported by Owen (1975), who reported that the baits were effective only for certain genera.

Furthermore, the usage of rotten fruits especially banana as bait have been practiced by many researchers to trap fruit-feeding butterflies (e.g., Hamer et al. 2006;

Barlow et al. 2007; Bonebrake & Sorto 2009; Sáfián et al. 2010). As the strong odour of fermenting fruits can likely be detected at long distances, and in forest environments, it probably forms a reliable cue for locating a fruit fall by these species (Molleman et al. 2005).

In addition, as Nymphalidae is categorized under the fruit-feeding butterflies' guild, the usage of rotten fruits as bait was felicitous which was manifested through the high number of captured individuals and species. However, although fruit-feeding butterflies are defined as those species attracted to fruit bait, this does not mean that fruits are the main food source for all the species in this guild (Molleman et al. 2005). For instance, most tropical Satyrinae are exclusively fruit-feeders, but Charaxinae and Apaturinae are attracted to both fruit and rotting animal matter and excrement (Fermon et al. 2000). Furthermore, fruit-feeding butterflies (including nymphalids) are among the longest-lived Lepidoptera (Molleman et al. 2008). Therefore, longevity and ability to exploit various food resources may be the reasons why family Nymphalidae was the dominant family in this study.

Besides *Lexias* species, a high number of *Cephrenes acalle niasicus* was also caught in this study. One of the reasons which may have contributed to this might be due to the landscape of the study site where ornamental plants such as the Poison bulb *Crinum asiaticum* and White buttercup *Turnera subulata* were planted at the garden area around the visitor complex. These ornamental plants were some of the plants observed to be frequently visited by many butterfly species and eventually contributed to the ease in capturing *C. accelle* and other fast flyer butterfly species.

Other vegetation structures such as meadows, shrubs, grass and lower ground plants were found to be frequently visited by some butterfly genera, namely: *Ypthima, Eurema, Jamides*, and *Zizeeria*. These butterflies were easily captured at areas close to ground as they obtained protection from winds because of their weaker flight ability. In addition, open areas which offer more light penetration is deemed one of the most visited area by the butterflies to bask under the sun for energy (Van Lien & Yuan 2003). This is proven that, although the developed area and garden area is limited, the occurrence of various surrounding landscape with an array of flora is believed to serve as important habitats for different butterfly species (Asmah et al. 2016; Toivonen 2017).

There were eight species of butterflies categorized as protected under Malaysian legislation, the Wildlife Conservation Act 2010 which were recorded in this study namely *Agatasa calydonia calydonia* (Glorious Begum), *Charaxes athamas athamas* (Common Nawab), *Charaxes athmamas uraeus*, *Charaxes bernadus crepax* (Tawny Rajah), *Charaxes echo echo*, *Idea hypermnestra linteata* (Malayan Tree Nymph), *Prothoe franck uniformis* (Blue Begum), and *Trogonoptera brookiana albescens* (Rajah Brooke).

For *Agatasa calydonia calydonia* (Glorious Begum), it is also considered to be rare in the Malay Peninsula. The two individuals recorded in this study were females and was captured using fruit bait. As for the *Charaxes* recorded, all were singletons except for *C. bernadus crepax* (2 individuals). All individuals were males, and were caught using fruit baits as they are difficult to capture while in flight.

For *Idea hypermnestra linteata* (Malayan Tree Nymph), this species was only seen at some specific trees in the sampling site. Additionally, based on our observation, they are commonly found to be in a group and were caught during mating. Due to their rarity, we speculate that the abundance of this species may depend on its host distribution. Furthermore, the life cycle of this species might also contribute to its rare occurrence as the adults naturally die after laying eggs. Although *I. hypermnestra linteata* has relatively slow flight abilities (Otsuka 2001), it was not an easy task to capture them as they can fly up to very tall trees.

As for *Prothoe franck uniformis* (Blue Begum), 11 individuals of this species were caught during our study with most caught being females (n= 9). Based on our observation, they are strongly attracted to the fruit bait, which is in agreement with Corbet & Pendlebury (1992) whom reported the females to be often seen on fruit bait or on sap from a damaged tree trunk.

The *Trogonoptera brookiana albescens* (Rajah Brooke) population have been reported to be plunging, but the exact status of the population is unknown (Phon & Kirton 2010). The species was rarely observed in this study and only the males were captured. This is since only the males exhibited puddling behaviour by which they tend to aggregate at moist places along forest paths and riverbanks to drink water from which nutrients are obtained (Phon & Kirton 2010). The females by contrast, are forest dwellers and can only be sighted during mating season. This sex disparity is supported by Corbet & Pendlebury (1992). This species is also listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II where the trade in this species is closely regulated.

This study also recorded other rare species such as *Arhopala lucida*, *Curetis saronis sumatrana*, *Miletus nymphis fictus* of the family Lycaenidae (the blues, coppers, & hairstreaks), *Amathusia perakana perakana*, *Bassarona teuta goodrichi*, *Elymnias saueri saueri*, *Elymnias nesaea*, *Mycalesis horsfieldi hermana*, *Mycalesis distanti*, *Ypthima pandocus tahanensis* of the family Nymphalidae (the brush-footed or four-footed), *Celaenorrhinus ladana*, *Erionota sybirita*, *Matapa aria*, *Matapa cresta*, *Matapa druna*, *Pseudokerana fulger*, *Taractrocera ardonia*, *Taractrocera luzonensis*, *Telicota linna*, and *Unkana mytheca mytheca* of the family Hesperiidae (the skippers).

Although both *Arhopala lucida* and *Bassarona teuta goodrichi* are common in Langkawi but they are considered to be rare in the Malay Peninsula (van der Poorten & van der Poorten 2020). Similarly, the two *Mycalesis* species are listed as rare, being uncommon to other parts of the Malay Peninsula although *M. horsfieldi hermana* is found in the Tioman group of islands and along the east coast of Johor while *M. distanti* is more common in Kedawi. *Telicota linna* is another species listed as not common to the Malay Peninsula.

For montane species, *Miletus nymphis cresta* is recorded as a rare montane species while *Ypthima pandocus tahanensis* was recorded from Gunung Tahan at elevation of 1650m (van der Poorten & van der Poorten 2020). *Pseudokerana fulgur* restricted to Neomalaya, is another very rare species which is usually observed in the hills.

As for *Amathusia perakana perakana*, it is a rare species that is only found in primary forest while *Erionata sybirita* and *Unkana mytheca mytheca* are very rare species that are confined in lowland forest. For both *Elymnias saueri saueri* and *Elymnias nesaea*, these are rare species that are restricted to heavy forest as their habitat (van der Poorten & van der Poorten 2020).

For the *Matapa* species, *M. aria* (Common Redeye) is listed by van der Poorten & van der Poorten (2020) as being not common in the Malay Peninsula, occurring in lowland primary and secondary forests, while *M. cresta* and *M. druna* are rare in the Malay Peninsula lowlands.

As for the other rare species, according to van der Poorten & van der Poorten (2020), *Curetis saronis sumatrana* has only been recorded on the edges of mangrove swamps in Singapore, while *Celaenorrhinus ladana* is very rare with its recorded range being only the Malay Peninsula and Borneo. Both *Taractrocera ardonia* and *T. luzonensis* are also rarely recorded in the Malay Peninsula.

Two major factors are believed to impose great pressure on butterfly populations, namely, habitat loss and an extraordinarily high demand for butterflies by collectors and commercial dealers (Phon & Kirton 2010), especially for *T. brookiana albescens*. Habitat loss due to timber industries and conversion of extensive area of natural forest for agricultural activities and urbanization, shrink the habitat as well as diminish the host and nectar-plants of this and many other butterfly species.

Comparison of the Shannon-Weiner index results for this study with Kuala Lompat which consists of primary forest located in the Krau Wildlife Reserve, Pahang showed that the diversity of butterfly species in Chemerong Amenity Forest (*H'*= 4.1) was higher than Kuala Lompat (*H'*= 3.87) (Nur Afny Syazwany & Amirrudin, 2014) (*H'*= 3.37) and (*H'*= 3.37) (Zaidi & Abin 1991). Furthermore, the results of butterfly diversity recorded in the Chemerong Amenity Forest (939 individuals from 198 species) were also highest as compared to other study sites in Malaysia namely Gunung Serambu, Sarawak (377 individuals from 97 species) (Pang et al. 2016), Ulu Gombak Forest Reserve, Selangor (194 individuals from 28 species) (Min 2014), Setiu Wetlands, Terengganu (350 individuals from 45 species) (Tamblyn et al. 2006), Kuala Lompat, Pahang (302 individuals from 90 species) (Nur Afny Syazwany & Amirrudin 2014), Bukit Hampuan Forest Reserve, Sabah (42 species) (Chung et al. 2013), Sungai Imbak Forest Reserve, Sabah (174 species) (Jalil et al. 2008), Tabin Wildlife Reserve (136 species) (Akinori et al. 2001) and Ulu Senagang Substation (147 species) (Haruo et al. 2012) yet lower than what was recorded from Genting Highlands, Pahang (2,876 individuals from 214 species) (Min 2014) and Taman Negara Johor Endau Rompin (349 species).

Based on the comparison with other studies, the Chemerong Amenity Forest environment can accommodate more diverse species of butterflies. This can be proven if the sampling period was extended and the study site not only focuses on the lowlands (not more than 200 m above sea level) but includes different elevations (more than 200m above sea level). Nevertheless, Chemerong can be considered as pristine forest and the introduction of certain ornamental plants in the garden area plays an important role as attractant for the various species of butterflies such as *Papilio memnon agenor*, *Catopsilia pomona pomona*, and many Hesperiidae butterflies.

Conclusion and Recommendations

In general, short-term sampling with limited manpower and equipment was considered satisfactory, although it only provides a snapshot of the butterfly community present in the Chemerong Amenity Forest. The presence of endangered butterfly species which are protected under the Malaysian Wildlife Conservation Act 2010 increases the conservation value of the Chemerong Amenity Forest as a forest reserve in Malaysia. A much longer term sampling is strongly recommended to further observe and examine butterfly species at different elevations, across different seasonality and years, as well as further exploration of forest canopy to reveal more species in that stratum. The rapid loss of primary forest habitats and the growth of oil palm plantations in many areas of Malaysia as well as in the state of Terengganu underline the urgency with which this work needs to be undertaken.

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Author contributions: All authors discussed the results and contributed to the final manuscript. Muhammad Hafiz Sulaiman, Abdul Munir Mohd Zaki and Chong Ju Lian wrote the manuscript with support from the rest of the authors. Muhammad Hafiz Sulaiman and Chong Ju Lian conceived the original idea for this paper and revised the main conceptual ideas, while Abdul Munir Mohd Zaki, Yap Geok Chin and Nur Atiqa Aniruddin gave feedback to improve the paper.

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COMMUNICATION

Ecological niche modeling for reintroduction and conservation of *Aristolochia cathcartii* Hook.f. & Thomson (Aristolochiaceae), a threatened endemic plant in Assam, India

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Abstract: *Aristolochia cathcartii* Hook.f. & Thomson is a medicinal plant species native to Assam (India). Karbi people have traditionally used the plant to treat a variety of ailments. The population stock of this species has been rapidly depleting in its natural habitats due to over-utilization, habitat fragmentation, and other anthropogenic activities. Extensive field surveys were carried out to investigate the population status of *A. cathcartii* in various forest areas of Assam's Karbi Anglong district. In 20 km of transects, a total of 36 quadrats were observed. *A. cathcartii* density, frequency of occurrence, and abundance were recorded to be 0.65, 17.8, and 3.81, respectively. Ecological niche modelling was used to identify suitable habitat for the reintroduction and conservation of this plant in Assam in order to prevent its extinction in the future. The maximum entropy distribution modelling algorithm was used to identify suitable areas and habitat for the species' reintroduction and conservation. Primary data on the occurrence of *A. cathcartii* was gathered from the natural habitat of Karbi Anglong district, Assam, for modelling. The model identified various forest areas in northeastern India that have suitable climatic conditions for plant reinforcement.

Keywords: Abundance, DIVA GIS, forest, habitat, medicinal plant, MaxEnt, NDVI, occurrence, population, survey.

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INTRODUCTION

Aristolochia cathcartii, belonging to the family Aristolochiaceae, is a large climber. Traditionally, *A. cathcartii* has been used by the Karbi community of Assam to treat cholera, stomach pain, fever, and poisonous bites (Sarma et al. 2015, 2017). Overexploitation, climate change, habitat fragmentation and loss, and rapid urbanization cause gradual depletion of this medicinally important plant from its natural habitat. Species reinforcement is the best technique for the restoration of depleted species populations and degraded habitats and ecosystems (Leaper et al. 2006; Martinez-Meyer et al. 2006; Kuzovkina & Volk 2009; Ren et al. 2009; Rodríguez-Salinas et al. 2010; Polak & Saltz 2011). Ecological niche modeling helps in identifying sites of species occurrence and also helps to spot other suitable habitats for reintroduction. Ecological niche modeling (ENM) is a tool in geographic information system (GIS) software that uses occurrence data of a species across landscapes and correlates them with digital raster GIS coverage to develop a model of environmental conditions that meet ecological requirements and identify the suitable environment of the species (Guisan & Zimmermann 2000; Elith et al. 2006; Kozak et al. 2008). ENM facilitates interpolation as well as the extrapolation of species distributions in geographic space across different periods and it helps to prepare habitat distributional maps by spotting areas suitable for reintroduction of threatened species (Irfan-Ullah et al. 2006; Kumar et al. 2009; Ray et al. 2011). For conservation strategy, it is essential to identify areas which bear appropriate environmental conditions suitable for the species persistence. Therefore, the present work was undertaken to study the population distribution status of *A. cathcartii* and to model the habitat distributional map in its native range.

MATERIALS AND METHODS

Plant material

A. cathcartii Hook.f. & Thomson belonging to the family Aristolochiaceae is a large climber, with corky furrowed bark; young branchlets, and petioles villous. Leaves 5.5–10 by 3.5–6.5 inch, broadly ovate, sometimes ovate-lanceolate, acute or acuminate, entire; base cordate, sometimes slightly lobed along the sinus, 3-nerved or pedately 5-nerved, thinly coriaceous, pubescent along the midrib and larger nerves especially towards the base, otherwise glabrous above, clothed, often felted with long silky hairs beneath; lateral nerves excluding the basal 5–6 on either side; petioles 1.5–4 inch long, sometimes twining. Flowers usually in short brown villous cymes from axils of existing or fallen leaves; pedicels 0.6–1 inch long, villous. Perianth yellowish-white, with purple veins clothed with spreading hairs outside, 2.5–3 inch long along the bends, sac bent near the short neck, mouth square, densely purple papillose along the edge and the recurved lip. Capsule about 6.5 by 1.7 inch, linear-oblong, bluntly apiculate, softly tomentose, 6-ribbed, grooved between the furrows; seeds about 0.4 inches long, not winged, obovate, acute at the base, margins slightly incurved on the inner face, dorsally more or less truncate and margined (Kanjilal & Bor 1940). This plant is native to Assam, Bangladesh, China south-central, eastern Himalaya, Myanmar, Nepal, and Tibet (Plants of the world online, Royal Botanic Gardens, Kew).

Survey of the plant species and its population status

A frequent field visit was carried out to record the population status of *A. cathcartii* in Dhansiri, Kalioni, Nambar, Lahorijan, and Matipung Reserve Forest of KarbiAnglong district, Assam (India). The forest of KarbiAnglong is moist semievergreen and moist mixed deciduous type. The total population of *A. cathcartii* was calculated through a direct count method for all individuals. The grid size was taken 250 Ï 250 m and individuals were categorized as seedlings (<1 m height), saplings (>1 m height), and matured individuals (≥1.37 m height). The density, frequency, and abundance of the plant species were calculated with the following formulae:

$$\textit{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats studied}}$$

$$\textit{Frequency}\ (\%) = \frac{\text{Number of quadrats in which the species occured x 100}}{\text{Total number of quadrats studied}}$$

$$\textit{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats in which the species occured}}$$

Ecological niche modeling

Primary locations of the species were collected through field surveys. To record the coordinates of occurrence points of the species global positioning system (GPS) was used to an accuracy of 10–40 m. Then the coordinates were translated to decimal degrees to be used in habitat distribution modeling software (Adhikari & Barik 2012). For ecological modeling different types of environmental datasets are available in public domain websites. In our study, the index of normalized difference vegetation (NDVI) was used to model the distributional pattern of *A. cathcartii* in northeastern India (Table 2). The NDVI was obtained from Global Land Cover Facility (GLCF, University of Maryland). All the analyses were conducted at the spatial resolution of 250 m.

Validation of model robustness

For habitat modeling of *A. cathcartii*, the NDVI and the maximum entropy modeling (MEM) was used to develop the model (Adhikari & Barik 2012). MaxEnt uses presence-only data to predict the geographic location of a species based onthe principle of maximum entropy (Phillips et al. 2006; Elith et al. 2011). For the calibration, we used the presence and background data locations where 75% of the records were used for training the model and 25% for the test (Adhikari & Barik 2012). We conducted 20 replicated model runs and the replicated run type was cross-validation with a 10-percentile threshold rule of training presence to validate the model robustness (Adhikari & Barik 2012; Sarma et al. 2018). Since the program is already calibrated, therefore, other parameters were set as default (Adhikari & Barik 2012). Replicated runs generated average, maximum, minimum, median, and standard deviation. Quality of the model was assessed based on area under curve (AUC) value and the model was classified according to Thuiller et al. (2007) as very good (0.95 < AUC < 1.0), good (0.9 < AUC < 0.95), fair (0.8 < AUC < 0.9), and poor (AUC < 0.8).

Population status vis-à-vis model thresholds

Extensive field visits were executed to investigate the robustness and relevance of the model in predicting the population status of *A. cathcartii* in each occurrence area as predicted under various model thresholds. The total population of the species was calculated by direct count of all individuals of seedlings, saplings, and mature individuals in each 250 × 250 m grid of occurrence within the predicted localities. The population data of *A. cathcartii* in each occurrence area was then correlated with the corresponding threshold level of the distribution models to check whether regions fell under higher threshold level sustain higher populations thus favoring improved habitat conditions for species establishment and vice versa.

Analysis of habitat status and recognition of areas for reintroduction

We analyzed the habitat type in the occurrence areas of the species as well as the predicted potential areas through repeated field surveys. To identify the actual habitat of the species, we imported the ASC (Action Script Communication) file of the model output to Diva GIS ver. 7.3, and then we exported the Grid file as KMZ (Keyhole Markup Language Zipped) format for display in Google Earth (Adhikari & Barik 2012; Sarma et al. 2018; Baruah et al. 2016; Deka et al. 2018). Then we superimposed the exported KMZ files on Google Earth Pro satellite imageries to determine the actual habitat condition of the areas of occurrence and areas that prevailing the same habitat for the reintroduction of the species (Thuiller et al. 2007; Adhikari & Barik 2012; Baruah et al. 2016; Deka et al. 2017; Deka et al. 2018; Sarma et al. 2018).

RESULTS

Population distribution status of *Aristolochia cathcartii*

The population distribution status of a species indicates its importance in conservation. Species with a limited range of distribution needs to be protected more than a wide range of distribution. Considerable field surveys were conducted to explore the population status of *A. cathcartii* in each occurrence area. A total of 36 numbers of quadrats were observed along 20 km of transects. The density, frequency of occurrence, and abundance of *A. cathcartii* are shown in Table 1. The observation tabulated below depicted the mean density of *A. cathcartii* as 0.65, frequency of occurrence 17.77, and abundance concerning other associated species as 3.81.

Calibration of models

The model calibration test for *A. cathcartii* yielded satisfactory results (AUC test= 0.96 ± 0.002).

Response curves

The response curves (Figure 1) reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other variables. The curves show the mean response of the 20 replicate Maxent runs (red) and the mean +/- one standard deviation (blue, two shades for categorical variables).

Analysis of variable contributions

The table 2 gives estimates of relative contributions of the environmental variables to the Maxent model. Figure 2 shows the results of the jackknife test of variable

Table 1. Population status of *A. cathcartii*.

Grid no.	No. of adult plants within 250 m² grid	No. of saplings within 250 m² grid	No. of seedlings within 250 m² grid	Total no. of quadrats of occurrence of *A. cathcartii* within 250 m² grid	Density within 250 m² grid	Frequency within 250 m² grid	Abundance within 250 m² grid
1	15	4	0	5	0.53	13.9	3.8
2	17	7	5	8	0.81	22.2	3.6
3	17	6	2	6	0.69	16.7	4.2
4	13	7	3	6	0.64	16.7	3.8
5	16	8	0	4	0.67	11.1	6
6	10	9	2	7	0.58	19.4	3
7	14	9	6	9	0.81	25	3.2
8	18	11	5	8	0.94	22.2	4.3
9	16	10	0	7	0.72	19.4	3.7
10	17	9	0	7	0.72	19.4	3.7
11	12	10	6	9	0.78	25	3.1
12	10	9	0	6	0.53	16.7	3.2
13	11	5	0	5	0.44	13.9	3.2
14	11	7	3	8	0.58	22.2	2.6
15	16	9	2	6	0.75	16.7	4.5
16	13	4	0	7	0.47	19.4	2.4
17	15	9	4	6	0.78	16.7	4.7
18	13	5	0	6	0.5	16.7	3
19	15	10	5	8	0.83	22.2	3.8
20	11	7	2	7	0.56	19.4	2.9
21	13	6	4	6	0.64	16.7	3.8
22	12	6	3	4	0.58	11.1	5.3
23	11	7	2	6	0.56	16.7	3.3
24	14	8	2	4	0.67	11.1	6
25	15	5	1	5	0.58	13.9	4.2

importance. The environmental variable with the highest gain, when used in isolation, is eu5_1_eur (May), which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is eu4_1_eur (April), which therefore appears to have the most information that isn't present in the other variables. Values shown are averages over replicate runs.

Population status vis-à-vis model thresholds

A total of 589 number of individuals were recorded within the area of occurrence spread over 25 250 x 250 m grids. Of these 345 numbers of individuals were adults, 187 numbers of individuals were sapling and 57 numbers of individuals were seedlings (Table 3). The analysis of population structure at each locality revealed that the highest number of adult individuals were in Dhansiri (78), Daldali (75), Lahorijan (67), Matipung (65), and Nambar (60). The population size including all adults, saplings, and seedlings was larger in the areas under the high suitability threshold category followed by amedium to low category (Table 3). Areas predicted as a medium to high suitable classes represent 84% of the total population followed by a low threshold. This establishes the strong correlation between population size and level of the model threshold. Of the 25 localities, nine localities fell under high class, 11 localities under medium, and five localities fell under low habitat suitability class.

Saplings were poorly represented in most of the areas. The number of seedlings was also very poor even absent in some areas. The number of seedlings was highest in Daldali with 13 seedlings, followed by Matipung with 12 seedlings, Nambar, and Lahorijan

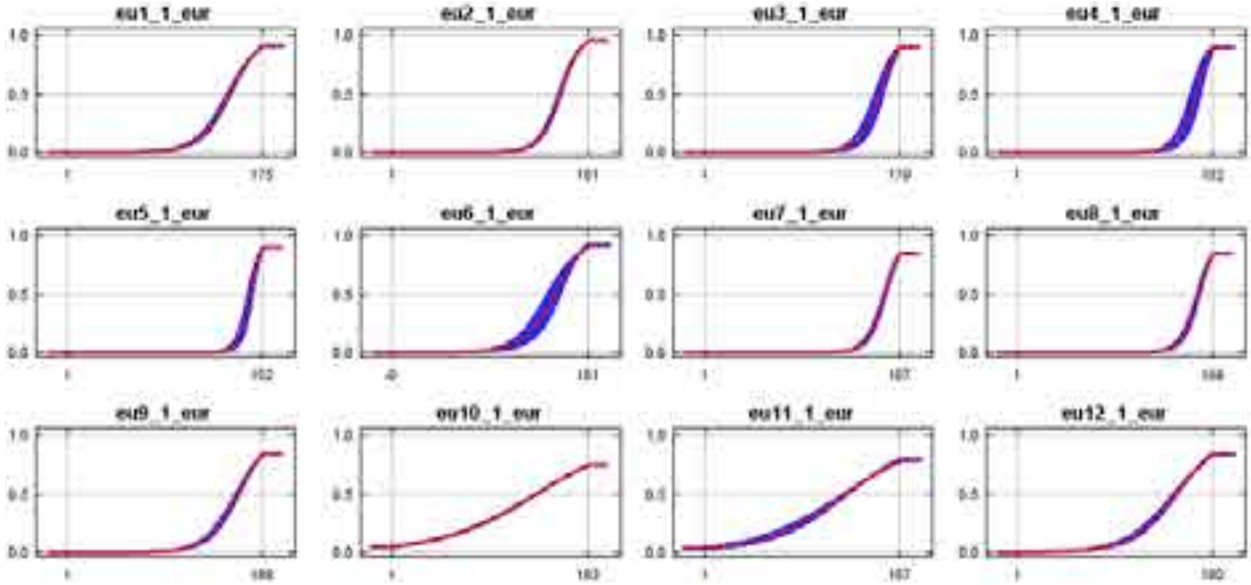

Figure 1. Response curves reflect the dependence of predicted suitability both on the selected variable and on dependencies induced by correlations between the selected variable and other variables.

with 11 seedlings each, and Dhansiri with 10 seedlings. Similarly, the number of saplings also highest in Daldali with 48 individuals, followed by Nambar with 40 individuals, Lahorijan with 35 individuals, and Dhansiri and Matipung with 32 individuals each. The population structure based on a seedling, sapling, and adult individuals revealed that good regeneration takes place in the moist semi-evergreen habitat followed by mixed deciduous habitat whereas in other habitats it depicted poor regeneration (Table 3).

Habitat status assessment and identification of areas for reintroduction

Field surveys for assessing the habitat type of *A. cathcartii* in the predicted potential areas revealed that the species occurred in moist semi-evergreen and mixed deciduous forests. Superimposition of the predicted potential habitat distributional map of the species on Google Earth Pro, satellite imageries showed that the areas with high habitat suitability for the species were moist semi-evergreen and evergreen forests. The areas with medium habitat suitability were mixed deciduous forests and grasslands. The areas with low habitat suitability were degraded open forests and homestead gardens (Table 4).

The superimposition of predicted potential habitat distribution map on Google Earth Pro imageries identified different forest areas of northeastern India, viz., KarbiAnglong (Rangapahar, Bokajan) district of Assam, foothills of Assam-Nagaland border (Mokokchung, Wokha, Kohima), Meghalaya (West Khasi Hills, Ri Bhoi), Arunachal Pradesh (East Siang, Papumpare) (Image 1). These areas could be used as in situ conservation and reintroduction of *A. cathcartii* in the wild.

Table 2. List of NDVI and variable contribution used in the model.

Variable	Description of the variable	Percent contribution	Permutation importance
eu5	NDVI May	38.9	45.5
eu4	NDVI Apr	20.9	15
eu8	NDVI Aug	11.6	11.9
eu3	NDVI Mar	9.7	9.5
eu6	NDVI June	7.8	0.5
eu10	NDVI Oct	6.7	15.8
eu7	NDVI Jul	2.2	1.2
eu2	NDVI Feb	2.1	0.6
eu9	NDVI Sep	0	0
eu1	NDVI Jan	0	0
eu12	NDVI Dec	0	0
eu11	NDVI Nov	0	0

DISCUSSION

A. cathcartii, is best known among the Karbi community of Assam for its high medicinal value. Locally this plant is called ChongaLota. Due to overexploitation of this plant by the local community, and other natural,

Table 3. Population status of *A. cathcartii* related to model thresholds.

Occurrence localities	Habitat suitability thresholds	Current habitat status	Number of individuals in occurrence localities			
			Adult	Sapling	Seedling	Total
Dhansiri	Low	Degraded open forest	15	4	0	19
Dhansiri	High	Moist semi evergreen	17	7	5	29
Dhansiri	High	Moist semi evergreen	17	6	2	25
Dhansiri	Medium	Mixed deciduous	13	7	3	23
Dhansiri	Medium	Mixed deciduous	16	8	0	24
Daldali	Low	Degraded open forest	10	9	2	21
Daldali	Medium	Mixed deciduous	14	9	6	29
Daldali	Medium	Mixed deciduous	18	11	5	34
Daldali	High	Moist semi evergreen	16	10	0	26
Daldali	High	Moist semi evergreen	17	9	0	26
Nambar	High	Moist semi evergreen	12	10	6	28
Nambar	High	Moist semi evergreen	10	9	0	19
Nambar	Low	Degraded open forest	11	5	0	16
Nambar	High	Moist semi evergreen	11	7	3	21
Nambar	Medium	Mixed deciduous	16	9	2	27
Lahorijan	Medium	Mixed deciduous	13	4	0	17
Lahorijan	Medium	Mixed deciduous	15	9	4	28
Lahorijan	Low	Degraded open forest	13	5	0	18
Lahorijan	Medium	Mixed deciduous	15	10	5	30
Lahorijan	High	Moist semi evergreen	11	7	2	20
Matipung	High	Moist semi evergreen	13	6	4	23
Matipung	Medium	Mixed deciduous	12	6	3	21
Matipung	Medium	Mixed deciduous	11	7	2	20
Matipung	Medium	Mixed deciduous	14	8	2	24
Matipung	Low	Degraded open forest	15	5	1	21
Total			**345**	**187**	**57**	**589**

Table 4. Habitat types of *A. cathcartii* identified through field surveys and high resoultion Google Earth Pro satellite imageries.

Habitat suitability thresholds	Habitat types identified using high resolution Google earth satellite imageries
High	Moist semi evergreen forests and evergreen forests
Medium	Mixed deciduous forests and grasslands
Low	Degraded open forests and home stead gardens

as well as anthropogenic activities, the population stock of this plant, has been exhausting very fast from its natural habitat. In primary field surveys in different forest areas of KarbiAnlong district, we found the mean density 0.65, frequency 17.77, and abundance 3.81 of *A. cathcartii* concerning other associated species. To save this plant species from extinction from its near future, we conducted ENM to improve the conservation status of this plant. In our present study, ENM gave a good result in its native range. NDVI parameters used in the modeling algorithm offered a reasonable explanation in the determination of the habitat suitability of the species. In determining the boundaries of the potential habitat of species, NDVI acts as powerful and informative alternate variables, which represent the complex formulations of the underlying environmental factors (Baruah et al. 2016; Deka et al. 2017; Sarma et al. 2018; Baruah et al. 2019). Overall, the results of actual habitat assessment through Google Earth superimposition and field surveys were identical. The ENM in the present study showed a good overall result (based on Area Under Curve (AUC) value and threshold test) in its native range. The high AUC value, i.e., 0.96 ± 0.002 indicates the good performance of the model. Habitat status analysis through primary field surveys

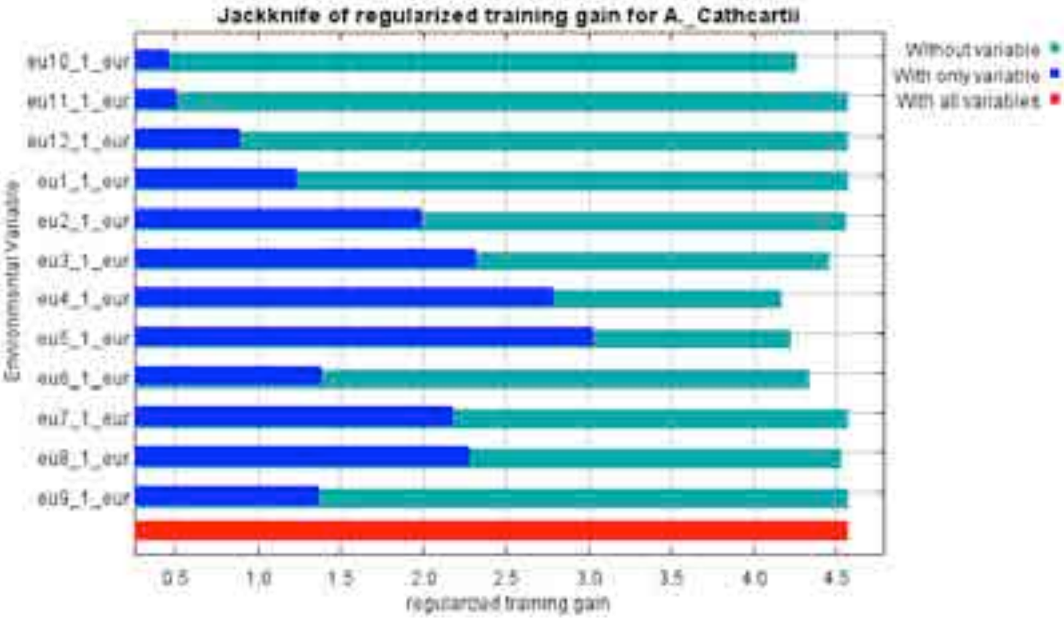

Figure 2. Jacknife test of variable importance for *A. cathcartii* individual variable contribution (blue bar), contribution when a given variable is excluded (green bar), whole set of variables (red bar).

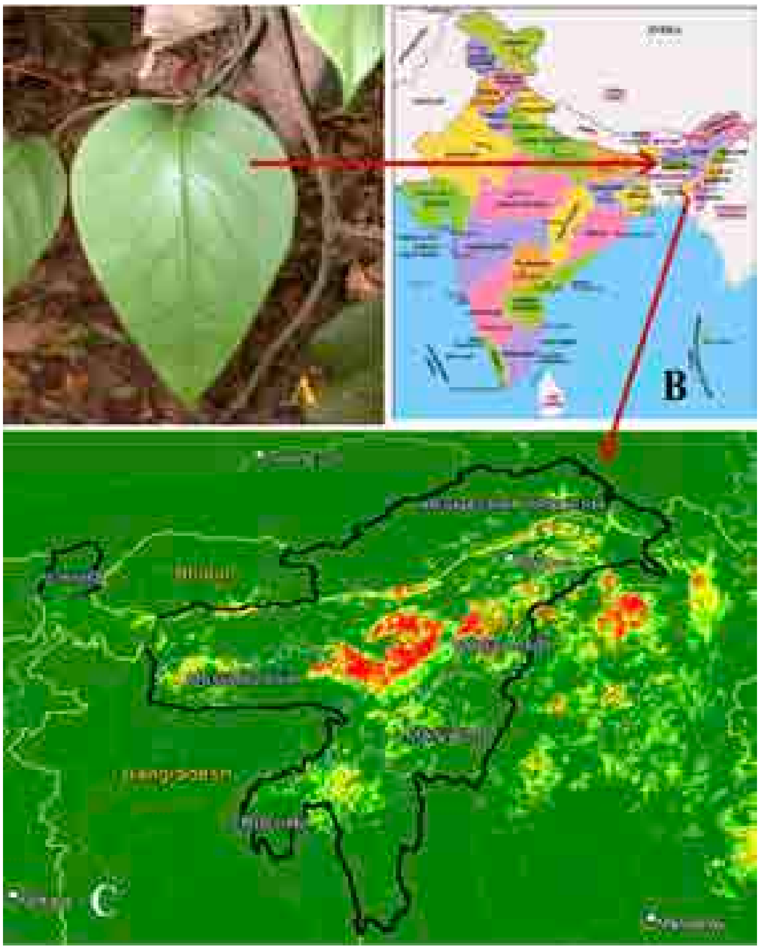

Image 1. A—*Aristolochia cathcartii* plant | B—Map of India | C—Map showing potential habitat distribution of *A. cathcartii* in northeastern India. The red patches in the map indicating suitable habitat conditions for the species.

and secondary surveys using Google Earth Pro satellite imageries established that the predicted potential areas of the species fell under all suitability threshold levels, i.e., low to high suitability. Within 25 250 x 250 m grids, 589 individuals were counted, of which 345 were adults, 187 saplings, and 57 seedlings. The number of saplings and seedlings were very poor in most of the occurrence areas of the species. Areas identified as medium to high suitable classes represent 84% of the total population and it establishes a strong correlation between the population size and the model thresholds. In the present study, evergreen, moist semievergreen, and mixed deciduous forests offer potential habitats at higher levels of probability. Hence, for in situ conservation and reintroduction of *A. cathcartii*, such forest areas could serve as suitable habitats. The present study demonstrates that habitat distribution modeling serves as an important tool in identifying the potential habitats for the reintroduction of threatened species. The areas identified in the present study for reintroduction would help in the improvement of the conservation status of species population of *A. cathcartii*. Therefore, the results would be quite helpful in the management of this species in its natural habitat and conservation of overall biological diversity in the region.

CONCLUSIONS

We present an ecological niche model of *Aristolochia cathcartii* Hook.f. & Thomson, a potential medicinal plant found in some forest pockets of Assam's KarbiAnlong district. We were able to create a distributional map of *A. cathcartii* using our modelling approach. The areas identified in this study for reintroduction would aid in improving the conservation status of the *A. cathcartii* species population. As a result, the findings would be extremely useful in the management of this species in its natural habitat as well as the conservation of the region's overall biological diversity.

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COMMUNICATION

New host plant records of Fig Wax Scale *Ceroplastes rusci* (Linnaeus, 1758) (Hemiptera: Coccomorpha: Coccidae) from India

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Abstract: A survey for the host plants of Fig Wax Scale *Ceroplastes rusci* (Linnaeus, 1758) was conducted in the Uttarakhand province, India. Among the six new host plants recorded during the study, four are new host records of *C. rusci*. A global check list of host plants of *C. rusci* was also prepared.

Keywords: Biological stages, checklist, infestation, morphological characters, scale insect.

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Author contributions: AK has surveyed the region and collected the host plants in the Garhwal region, identified the insect species, photography, and prepared this manuscript. RP has collected the host pants from Kumaun region of Uttarakhand and contributed to prepare this manuscript.

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INTRODUCTION

Members of the genus *Ceroplastes* Gray, 1828 (Hemiptera: Coccomorpha: Coccidae), known as wax scale insects are pest of numerous fruit and other plants of economic importance (Pellizzari & Camporese, 1994). The genus has a worldwide distribution including India (Kumar 2013). Among the species belonging to this genus, *Ceroplastes rusci* (Linnaeus, 1758), Fig Wax Scale, is of immense economic importance with a wide range of host species across the world (Morales et al. 2016). *Ceroplastes rusci* is one of the earliest species reported from the Mediterranean region and has been known since Theophrastus' era, i.e., 370–285 BCE (Silvestri & Martelli 1908). Primarily it is native to the Afrotropical region (Qin et al. 1994, 1998) and has also been reported from Palearctic, Neotropical, Oriental, Ethiopian, and Australian regions (Ben-Dov 1993; Waterhouse & Sands 2001). *Ceroplastes rusci* was first reported in Britain from *Ficus carica* fruits imported from Italy (Green 1917). It has a wide range of host plants in Algeria, Cyprus, Egypt, Greece, Israel, Italy, Lebanon, Morocco, Spain, Tunisia, Turkey, and India (Talhouk 1975; Kumar 2013). Apart from fig, *Nerium oleander*, *Pistacia lentiscus*, and *P. terebinthus* are its common host plants (Balachowsky & Mesnil 1935). About 100 per cent plant infestation by *C. rusci* in *Annona muricata* was recorded with 100 per cent of its shoot infestation (Vu et al. 2006). *Ceroplastes rusci* infestation in fig was recorded with about 500 nymphs per twig (Bodkin 1927; Balachowsky & Mesnil 1935; Khasawinah & Talhouk 1964; Talhouk 1969; Argyriou & Santorini 1980; Mustafa-Al-Antary & Al-Momany 1990; Mustafa-Al-Antary & Sharaf 1994). In India *C. rusci* has been reported infesting *Mangifera indica*, *Dalbergia sissoo, Syzygium* sp., *Ziziphus mauritiana*, *Citrus* sp., *Ficus benghalensis, F. religiosa*, *F. rubiginosa, F. acrocarpa*, *F. retusa*, and *F. carica* (Del Guercio 1906; Balachowsky & Mesnil 1935; Talhouk 1975; Morsi & Mousa 2003; Vu et al. 2006; Mifsud et al. 2012; Kumar 2013). *Ceroplastes rusci* is also reported as a vector of plant viruses (La Notte et al. 1997). Ben-Dov (1993) reported 39 plant species hosting *C. rusci* and subsequently, Morales et al. (2016) listed 137 host plant species belonging to 48 families of the world. The finding of the workers proves that *C. rusci* has wide range of host plants worldwide. The present survey was carried out to find out the host-plant species and infestation intensity in Uttarakhand, India and subsequently check list of host plant of the world was also prepared.

MATERIAL AND METHODS

The present study was carried out in foothill regions of Uttarakhand province, India at an elevation range of 200–1,200 m. The plant species infested with *C. rusci* were observed from Dehradun (30.349N, 79.002E), Haridwar (29.934N, 77.938E), Udham Singh Nagar (29.022N, 79.484E), Nainital (29.150N, 79.582E), and Champawat (29.078N, 80.101E) districts during the years 2018 and 2019. The infestation intensity of *C. rusci* on each host plant species was recorded and plant samples were collected and identified by taxonomists at the Systematic Botany Discipline. Digital photo of morphological characters and biological stages of *C. rusci* (Figure 2) were taken under Leica M-205 microscope fitted with a photographic camera MC190 HD at the Insect Systematic Laboratory, Forest Research Institute, Dehradun. Subsequently, identification of *C. rusci* also referred to the reports of Gimpel et al. (1974), Williams & Watson (1990), and Hodgson & Peronti (2012). Infestation data was statistically analysed for their mean and standard deviation using Microsoft Excel.

RESULTS AND DISCUSSION

In the present survey of host plants of *C. rusci* in Uttarakhand, India, *Chrysanthemum* sp., *Ocimum gratissimum* L., *Ficus benjamina* L., *Ficus natalensis* Hochst., *Grevillea robusta* A.Cunn. ex R.Br. and *Geijera parviflora* Lindl. were found to be infested with *C. rusci* (Table 1 & Figure 1). These host plants were also recorded as new hosts in India. Kumar (2013) has reported eight host plants of *C. rusci*, viz., *Citrus* sp., *D. sissoo*, *F. benghalensis*, *F. religiosa*, *F. carica*, *M. indica, Psydium* sp., *Syzygium* sp., and *Z. mauritiana* from India. *Ficus benjamina* (Balachowsky, 1927) and *Grevillea robusta* (Ben-Dov, 1970) were also reported from Israel. The

Table 1. New host plants of *Ceroplastes rusci* and its population intensity in Uttarakhand, India.

Botanical name	Family	Population (mean ±SD) m^{-2}
*Chrysanthemum sp.**	Asteraceae	24.60±3.91
Ocimum gratissimum L.*	Lamiaceae	3.67±1.47
Ficus benjamina L.	Moraceae	27.34±4.53
Ficus natalensis Hochst.*	Moraceae	32.10±3.89
Grevillea robusta A.Cunn. ex R.Br.	Proteaceae	3.34±1.39
Geijera parviflora Lindl.*	Rutaceae	2.70±1.02
*New records for the world		

Image 1. New host species (a–f) with *Ceroplastes rusci* infestation: a— *Chrysanthemum* sp. | b—*Ocimum gratissimum* L. | c—*Ficus benjamina* L. | d—*Ficus natalensis* Hochst. | e—*Grevillea robusta* A.Cunn. ex R.Br. | f—*Geijera parviflora* Lindl.

Image 2. Growth stages of *Ceroplastes rusci* (a–d): a—Nymphal stages | b—Dorsal view of nymph | c—Ventral view of female adult | d—Dorsal view of female adult.

Table 2. Check list of host plant species of *Ceroplastes rusci* of the world.

	Family	Botanical name	References
1	Anacardiaceae	*Mangifera indica* #	Carnero Hernandez & Perez Guerra (1986), Malumphy (2010), Kumar (2013)
2		*Pistacia lentiscus*	Bodenheimer (1928)
3		*Pistacia terebinthus*	Balachowsky & Mesnil (1935)
4		*Pistacia vera*	Ülgentürk & Dokuyucu (2019)
5		*Rhus coriaria*	Marott (1987)
6		*Schinus terebinthifolius*	Ben-Dov (1970)
7		*Schinus molle*	Bodenheimer (1928)
8		*Searsia gerrardii*	Brain (1920)
9		*Spondias purpurea*	Lincango et al. (2010)
10	Annonaceae	*Annona cherimoya*	Nakahara (1983)
11		*Annona muricata*	Ben-Dov (1993)
12		*Annona reticulata*	Malumphy & Anderson (2011)
13		*Annona squamosa*	Nakahara (1983)
14	Apocynaceae	*Alstonia scholaris*	Wu and Wang (2019)
15		*Cascabela thevetia*	Ben-Dov (1970)
16		*Nerium oleander*	Balachowsky & Mesnil (1935)
17		*Thevetia peruviana*	Malumpy & Anderson (2011)
18	Aquifoliaceae	*Ilex aquifolium*	Ben-Dov (1993)
19	Araliaceae	*Hedera helix*	Ben-Dov (1993)
20	Arecaceae	*Brahea armata*	Malumphy (2010)
21		*Chamaerops humilis*	Marotta (1987)
22		*Cocos nucifera*	Chua (1997)
23		*Dictyosperma album*	Malumphy (2010)
24		*Dypsis lutescens*	Wu & Wang (2019)
25		*Mascarena* sp.	Malumphy (2010)
26		*Phoenix canariensis*	Malumpy & Anderson (2011)
27		*Phoenix roebelenii*	Malumphy (2010)
28		*Trachycarpus fortunei*	Wu & Wang (2019)
29	Asparagaceae	*Ruscus aculeatus*	Marotta (1987)
30	Asteraceae	*Argyranthemum frutescens*	Crnero & Perez (1986)
31		*Chrysanthemum* sp. #	New Record
32	Balsaminaceae	*Impatiens sultani*	Ben-Dov (1993)
33	Boraginaceae	*Cordia lutea*	Lincango et al. (2010)
34		*Cordia myxa*	Ben-Dov (1970)
35	Buxaceae	*Buxus balearica*	Balachowsky (1939)
36	Cannaceae	*Canna* sp.	Ben-Dov (2012)
37	Clusiaceae	*Psorospermum* sp.	Malumpy & Anderson (2011)
38	Compositae	*Artemisia* sp.	Crnero & Perez (1986)
39		*Artemisia monosperma*	Ben-Dov (2012)
40	Convolvulaceae	*Convolvulus* sp.	Ben-Dov (1993)
41		*Ipomoea sp.*	Borg (1932)
42		*Ipomoea batatus*	Nakahara (1983)
43	Cyperaceae	*Cyperus* sp.	Hall (1922)

	Family	Botanical name	References
44		*Cyperus diffusus*	Malumpy & Anderson (2011)
45		*Cyperus involucratus*	Ben-Dov (1970)
46	Ebenaceae	*Diospyros austro-africana*	Hodgson & Peronti (2012)
47		*Diospyros glabra*	Hodgson & Peronti (2012)
48		*Euclea* sp.	Hodgson (1969)
49		*Euclea schimperi*	Hodgson & Peronti (2012)
50	Ericaceae	*Arbutus unedo*	Balachowsky (1931)
51	Euphorbiaceae	*Codiaeum variegatum*	Malumpy & Anderson (2011)
52		*Euphorbia longan*	Ben-Dov (1993)
53	Fabaceae	*Albizia* sp.	Malumpy & Anderson (2011)
54		*Dalbergia sissoo #*	Kumar (2013)
55		*Phaseolus caracalla*	Malumpy & Anderson (2011)
56		*Tamarindus* sp.	Gomez (1958)
57		*Vigna caracalla*	Borg (1932)
58	Heliconiaceae	*Heliconia* sp.	Malumphy (2010)
59	Hypericaceae	*Psorospermum* sp.	Hodgson (1994)
60		*Psorospermum febrifugum*	Hall (1931)
61	Juncaceae	*Juncus acutus*	Carnero & Perez (1986)
62	Lauraceae	*Laurus nobilis*	Ben-Dov (1993)
63		*Persea americana*	Ben-Dov (1970)
64	Lamiaceae	*Ocimum gratissimum*	New Record
65	Loranthaceae	*Plicosepalus acaciae*	Ben-Dov (2012)
66	Lythraceae	*Lawsonia inermis*	Hall (1923)
67	Malvaceae	*Gossypium* sp.	Carnero & Perez (1986)
68		*Hibiscus rosa-sinensis*	Lincango et al. (2010)
69	Moraceae	*Ficus amplissima*	Marotta (1987)
70		*Ficus benghalensis #*	Hodgson & Peronti (2012) Kumar (2013)
71		*Ficus benjamina #*	Balachowsky (1927) New record
72		*Ficus carica #*	Green (1917) Balachowsky (1939) Kumar (2013)
73		*Ficus concinna*	Wu & Wang (2019)
74		*Ficus elastica*	Marotta (1987)
75		*Ficus infectoria*	Hodgson & Peronti (2012)
76		*Ficus macrophylla*	Balachowsky (1927)
77		*Ficus microcarpa*	Wu & Wang (2019)
78		*Ficus natalensis*	New Record
79		*Ficus obliqua*	Ben-Dov (1970)
80		*Ficus pseudosycomorus*	Hall (1922)
81		*Ficus religiosa #*	Kumar (2013)
82		*Ficus retusa*	Ben-Dov (1970)
83		*Ficus rubiginosa*	Ben-Dov (1970)
84		*Ficus sycomorus*	Ben-Dov (1970)
85		*Ficus thonningii*	Hodgson (1994)
86		*Ficus virens*	Bodenheimer (1924)

	Family	Botanical name	References
87		*Morus alba*	Ben-Dov (1970)
88		*Morus nigra*	Marotta (1987)
89	Musaceae	*Musa* sp.	Hall (1924)
90		*Musa acuminata*	Marotta (1987)
91		*Musa cavendishi*	Ben-Dov (1993)
92		*Musa paradisiaca*	Hall (1922)
93		*Musa sapientum*	Ben-Dov (1993)
94	Myrtaceae	*Myrtus* sp.	Bodenheimer (1928)
95		*Myrtus communis*	Aziz (1977)
96		*Psydium* sp. #	Kumar (2013)
97		*Psydium guajava*	Hodges et al. (2005)
98		*Syzygium cumini #*	Ben-Dov (1993) Kumar (2013)
99	Ochnaceae	*Ochna* sp.	Malumpy & Anderson(2011)
100		*Ochna ciliata*	Williams & Matile (2009)
101	Oleaceae	*Olea europaea*	Ulgenturk & Dokuyucu (2019)
102	Phyllanthaceae	*Bischofia javanica*	Wu & Wang (2019)
103	Pinaceae	*Cedrus deodora*	Malumpy & Anderson (2011)
104	Piperaceae	*Piper* sp.	Hall (1924)
105		*Piper nigrum*	Gomez (1958)
106	Pittosporaceae	*Pittosporum tobira*	Marotta (1987)
107	Platanaceae	*Platanus orientalis*	Ben-Dov (1993)
108	Proteaceae	*Grevillea robusta #*	Ben-Dov (1970) New Record
109	Punicaceae	*Punica granatum*	Bodenheimer (1926)
110	Ranunculaceae	*Clematis cirrhosa*	Ben-Dov (2012)
111	Rhamnaceae	*Ziziphus mauritiana #*	Kumar (2013)
112	Rosaceae	*Amygdalus communis*	Malumpy & Anderson (2011)
113		*Crataegus azarolus*	Ben-Dov (1970)
114		*Crataegus vulgaris*	Hodgson & Peronti (2012)
115		*Cydonia* sp.	DeLotto (1978)
116		*Cydonia oblonga*	Ben-Dov (1970)
117		*Mespilus germanica*	Marotta (1987)
118		*Mespilus monogyna*	Pierce (1917)
119		*Mespilus oryneantha*	Pierce (1917)
120		*Mespilus cocinea*	Pierce (1917)
121		*Pyrus communis*	Ben-Dov (1970)
122		*Prunus dulcis*	Carnero & Perez (1986)
123		*Prunus domestica*	Hodgson & Peronti (2012)
124	Rubiaceae	*Pavetta* sp.	DeLotto (1978)
125		*Ixora* sp.	Hamon & Mason (2017)
126	Rutaceae	*Citrus aurantium*	Ben-Dov (1970)
127		*Citrus limon*	Nakahara (1983) Talhouk (1975)
128		*Citrus maxima*	Ben-Dov (2012)
129		*Citrus paradisi*	Ben-Dov (1993)
130		*Citrus reticulata*	Argyriou & Mourikis (1981)

	Family	Botanical name	References
131		*Citrus sinensis*	Argyriou & Mourikis 1981)
132		*Geijera parviflora#*	New Record
133	Salicaceae	*Populus alba*	Marotta (1987)
134		*Populus deltoides*	Ben-Dov (1970)
135		*Populus nigra*	Pierce (1917)
136		*Populus tremula*	Pierce (1917)
137		*Salix* sp.	Ben-Dov (2012)
138		*Salix babylonica*	Hall (1923)
139	Santalaceae	*Osyris alba*	Kozar et al. (1991)
140	Sapindaceae	*Dimocarpus longan*	Carnero & Perez (1986)
141		*Dodonaea viscosa*	Hodgson (1994)
142		*Litchi chinensis*	Carnero & Perez (1986)
143		*Nephelium lappaceum*	Ben-Dov (1970)
144		*Sapindus saponaria*	Marotta (1987)
145	Sapotaceae	*Sideroxylon oxyacanthurm*	Hodgson (1994)
146		*Mimusops roxburghiana*	Hamon & Mason (2017)
147	Smilacaceae	*Smilax aspera*	Kozar& Franco (1995)
148	Strelitziaceae	*Strelitzia reginae*	Carnero & Perez (1986)
149		*Strelitzia nicolai*	Malumpy & Anderson (2011)
150	Umbelliferae	*Bupleurum* sp.	Gomez (1946)
151		*Bupleurum subfructicosum*	Malumpy & Anderson (2011)
152	Vitaceae	*Vitis vinifera*	Balachowsky (1927)
153	Thymelaeaceae	*Synaptolepis alternifolia*	Hodgson (1969)

Host records of *Ceroplastes rusci* in India.

population intensity (Table 1) of *C. rusci* was recorded to be maximum in *F. natalensis* (132.10 insects m^{-2}) followed by *F. benjamina* (27.34 insects m^{-2}), *Chrysanthemum* sp. (24.60 insects m^{-2}), *O. gratissimum* (3.67 insects m^{-2}), *G. robusta* (3.34 insects m^{-2}), and *G. parviflora* (2.70 insects m^{-2}). *Ceroplastes rusci* was recorded to be infesting to *D. sissoo* tree with an intensity of about 23.33 insects per twig and up to 10.00 insect per leaf (Kumar 2013). The present study also revealed that plants of Moraceae family were preferred hosts of *C. rusci* in the study area. Six new host plant species of *C. rusci* recorded from India, indicated that *C. rusci* is a polyphagous species and there are additional host plants yet to be detected.

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COMMUNICATION

Seasonal variations influencing the abundance and diversity of plankton in the Swarnamukhi River Estuary, Nellore, India

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Abstract: An integrated approach was used to study the seasonal influence on the abundance and diversity of phytoplankton and zooplankton in the Swarnamukhi River Estuary (SRE) and the adjacent coast covering five stations by collecting monthly samples from the years 2014 to 2017. A total of 54 phytoplankton species conforming to four families and 58 zooplankton species conforming to nine families were recorded. Phytoplankton abundance and richness were high during pre-monsoon (PRM - 56410 cells/L) followed by monsoon (MON – 42210 cells/L). A similar trend was observed in the case of zooplankton, where abundance was recorded high during PRM (124261 ind./m^3) followed by MON (111579 ind./m^3). Moreover, phytoplankton and zooplankton were dominated by the diatoms and copepods, respectively. Both phytoplankton and zooplankton exhibited significant temporal (F= 26.4, p <0.05) and spatial (F= 32.1, p <0.05) variations. The higher density and abundance were recorded in the inner stations compared to the open sea. The present study reveals that the SRE have a rich diversity which could be attributed to a higher nutrient influx in the inner stations. The anthropogenic discharge from the surrounding aqua farms, agricultural land, and human settlement area could cause concerns for the local flora and fauna if a proper mitigation plan is not evolved through long-term monitoring study in this coastal region.

Keywords: Abundance, diversity, estuary, indices, Nellore, Phytoplankton, zooplankton.

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INTRODUCTION

Estuaries act as transitional zones and support the coastal economy in the form of fishing, aquaculture, transport, and tourism activities. They are also known to be highly productive ecosystems that provide shelter and breeding grounds for various marine aquatic organisms (Nybakken & Bertness 2005). Unlike salt marshes and backwaters, estuaries are complex and highly dynamic and their structure and function are influenced by anthropogenic inputs (e.g., aquaculture, agriculture, and industrial discharges) from the land and get transferred to the sea (Shenai-Tirodkar et al. 2016). Such anthropogenic activities can alter the physicochemical properties of water and immensely influence the migration, richness, distribution, diversity, and feeding of the associated marine aquatic organisms (Unanam & Akpan 2006). Plankton are aggregates of organisms (plants and animals) passively floating, drifting, or somewhat motile occurring in aquatic ecosystems (Lalli & Parsons 1993). Phytoplankton is grazed upon by zooplankton and other higher aquatic organisms (nektons) (Calbet 2008). Nutrient enrichment through, riverine inputs, and discharge from anthropogenic activities can significantly alter the phytoplankton growth and in turn affect the zooplankton grazing pressure (Berdalet et al. 1996). Therefore, plankton assemblages are usually helpful in assessing the water quality as they quickly respond to the environmental changes, hence; act as ecological indicators of an ecosystem (Hays et al. 2005; Longhurst 2007).

In the Indian scenario, most of the estuarine ecosystems are under stress due to natural and anthropogenic inputs from the surrounding environment. With the increase in nearby aquaculture, agricultural, and anthropogenic activities, the effluent discharges find their way into the nearby coastal areas which provides an advantageous environment to the organisms for proliferation. Similar activities have been reported in the Swarnamukhi River Estuary (SRE) region, fewer studies have been carried out to assess the tidal variations (Reddi et al. 1993), hydrographic properties of water (Sreenivasulu et al. 2015), contamination studies on the presence of heavy metal in seawater, sediments, & organisms (Reddy et al. 2016; Sreenivasulu et al. 2018; Jha et al. 2019), and the benthic organisms (Pandey et al. 2021). However, an elaborate study for the plankton communities is not available for the SRE region. A long-term study (2014–2017) was conducted to analyze the planktonic (phytoplankton and zooplankton) assemblages. This study can serve as baseline information for future ecological assessment related to the SRE and other similar tropical ecosystems.

MATERIALS AND METHODS

Study area

The SRE region (14.072–14.077 °N and 80.126–80.154 °E), situated in the Vakadu Mandal of Nellore district, Andhra Pradesh. This estuarine runs about 1.5 km in length perpendicular to the Bay of Bengal with an average depth of 1.0 m and an area of 6.25 km^2 (Reddi et al. 1993). Nellore receives the majority of the rainfall during the north-east monsoon (October to December) than the south-east monsoon (Kannan et al. 2016). Altogether, five sampling stations were fixed; four stations covering SRE and a reference station in the open sea (OS) about a kilometer from the shore. The coordinates were fixed using GPS (Garmin) covering the study area and the surrounding coast. The selected sampling stations are shown in (Figure 1), covering the Buckingham canal (BC), near to (SR1), away from mouth (SR2), mouth (SRM), and open sea (OS). The monthly sampling was carried out covering low and high tides at all the stations. The data was categorized seasonally as pre-monsoon [PRM (January–May)], monsoon [MON (June–September)], and post-monsoon [POM (October–December)] from May 2014 to December 2017 for analysis (5 stations × 43 months × 2 tides = 430 samples).

Temperature and rainfall

The temperature and rainfall data for the sampling period were obtained from the Indian Meteorological Department, Ministry of Earth Sciences, Government of India. The obtained data (monthly) was plotted for better interpretation (refer to Figure 2).

Biological parameters

For phytoplankton sampling, 5.0 L of surface seawater samples (in triplicate) were collected in a polyethylene container and preserved with 4% formalin and Lugol's iodine. Phytoplankton analysis was carried out using Utermöhl (1931) sedimentation technique. The samples were allowed to settle in a measuring cylinder for a period of 48 hours and siphoned (using a 10 µ mesh) to obtain 50 mL concentrate (Hasle,1978). For phytoplankton enumeration, 1 mL of the concentrated sample was taken onto a Sedgewick rafter plankton counting chamber and the total number of organisms was examined under a compound microscope. Phytoplankton was identified using standard identification keys (Subrahmanyan

Figure 1. Sampling stations at Pamanji, Nellore.

1946, 1959; Santhanam et al. 1987; Tomas 1997). For chlorophyll-*a* (chl-*a*) analysis, 1,000 mL of the water sample was filtered through Whatman GF/F filter paper and chl-*a,* was extracted by following the modified acetone extraction method (Parson et al. 1984). The extracted chl-*a* samples were analyzed using a spectrofluorometer (make Hitachi model F-4600) and obtained results were expressed in mg/m^3. The surface zooplankton samples were collected using a zooplankton net (150 µm mesh size, 0.5 m diameter, 1.8 m length) fitted with a digital flow meter (make Hydro-Bios). The surface hauls were made from the stern side of the boat running at a speed of 1 km/hr and the collected plankton was transferred to 500 mL polythene containers and preserved using 5% buffered formalin. In the laboratory, triplicate subsamples were taken onto a Sedgewick rafter plankton counting chamber and the total numbers of organisms were enumerated under the compound microscope (Nikon model SMZ 1500). The zooplankton was identified following the standard identification key of Kasturirangan (1963) and Santhanam & Srinivasan (1994). The zooplankton biomass was determined by the settled volume method, where the collected sample was allowed to settle and the obtained biomass was expressed as mL/m^3.

Statistical analysis

PRIMER v6.1 was used for univariate indices, e.g., species richness (S), abundance, Margalef's diversity (d), Shannon-Wiener diversity index (H', $\log_2$), Simpson's diversity (1-λ), and Pielou's evenness (J') (Clarke & Gorley 2006). The sitewise variation between the environmental parameters were analyzed using one way analysis of variance (ANOVA) in Microsoft Excel 2007. To determine the phytoplankton diversity and dominance in different seasons and the stations, univariate diversity indices were applied. The abundance of phytoplankton and zooplankton was represented using a box plot using SPSS v10 software.

RESULTS AND DISCUSSION

Temperature and rainfall

The rainfall data were analyzed for the years 2014–2017 and it indicates that maximum rainfall was recorded from September to December (Figure 2). It ranged 6.2–221.1 mm (2014), 8.0–767.2 mm (2015), 10.6–149.0 mm (2016), and 1.1–218.0 mm (2017). Maximum rainfall of 767.2 mm was recorded in November 2015. The lowest rainfall was recorded in 2016 during the north-east monsoon (December 149.0 mm). The atmospheric temperature (AT) ranged 22.1–40.2 °C, 21.4–39.7 °C, 22.0–39.5 °C, and 21.8–40.9 °C in 2014, 2015, 2016, and 2017, respectively. The AT peaked during the summer, i.e., April and May. The SRE region is continuously fed with tidal water and keeps the ecosystem comparatively in good condition; however, every year during the MON when the precipitation is less, the mouth of the river gets closed for a few months (Sreenivasulu et al. 2016; Pandey et al. 2021). During this period, the concentration of some of the parameters changed drastically due to stagnation. It has been reported that the rainfall can significantly affect the phytoplankton composition in the river (Jeong et al. 2007), estuaries (D'silva et al. 2012), and reservoirs (Zhou et al.,2012) worldwide.

Phytoplankton diversity, density, and chlorophyll-a

A total of 54 phytoplankton species include 38 diatoms, nine dinoflagellates, three green algae, and four blue-green algae. Diatoms (Bacillariophyceae) were the dominant group consisting of 70%, 69%, and 76% in PRM, MON, and POM, respectively. The next dominant was dinoflagellates (dinophyceae) registering 20%, 14%, and 18%, in PRM, MON, and POM, respectively. Green algae (Cyanophyceae) were recorded during PRM (6%) and MON (7%) seasons. Blue-green algae (Chlorophyceae) were 4%, 10, and 6%, in PRM, MON, and POM, respectively (Figure 3).

During the study period, the highest phytoplankton density was recorded in the SRM (56,410 cells/L) and it was lowest in the OS (2,440 cells/L). Phytoplankton density in the inner riverside stations, BC, SR2, and SR1 ranged 9,605–50,160 cells/L, 7,785–56,340 cells/L, and 10,500–55,850 cells/L, respectively. In SRM and OS, phytoplankton density ranged 10,033–56,410 cells/L and 2,440–37,100 cells/L, respectively. The mean phytoplankton density recorded in the inner stations BC, SR2, and SR1 were 19,785, 21,005, and 18,815 cells/L, respectively (Figure 4a). In the SRM and OS region, the mean phytoplankton density was 20000 and 17864 cells/L, respectively. The maximum density recorded in PRM, MON, and POM was 56,410, 42,210, and 24,480 cells/L, respectively. The phytoplankton density in PRM ranged 13,647–23,217 cells/L, in MON it ranged 18,585–22,746 cells/L, and in POM it ranged 9,492–16,973 cells/L (Figure 4a). Among diatoms, *Rhizosolenia* sp. was the dominant species in all the stations, followed by *Thalassiosira subtilis* and *Navicula* sp. The *Protoperidinium* sp. dominated the dinoflagellates community followed by *Ceratium* sp. and *Prorocentrum* sp. during the study period. All the three species of green algae (*Chlorella* sp., *Oocystis* sp., and *Pediastrum* sp.) were present during MON, while only *Chlorella* sp. and *Oocystis* sp. were represented during PRM and none of the three species mentioned above were present during POM. Among the four blue-green algae recorded during the study, *Trichodesmium* sp. and *Spirulina* sp. were observed during PRM, *Microcystis* sp. and *Oscillatoria* sp. were observed during POM, and all the four species were present during the MON. The SRE received precipitation during the POM (north-east monsoon) which could enhance the land-driven run-off from the aqua farms, agricultural land, and domestic discharge which consequently could have attributed higher nutrient inputs helping phytoplankton to proliferate and bloom. Higher phytoplankton density in the inner stations could be attributed to higher nutrient input in those stations from the surrounding regions (aquaculture runoff) (Mckee et al. 2000; Roberts & Prince 2010).

The chl-*a* in PRM ranged 2.11 ± 0.12 mg/m^3 (OS & SRM)–10.71 ± 2.08 mg/m^3 (BC). In MON, it ranged 2.10 ± 0.49 mg/m^3 (OS)–8.46 ± 1.76 mg/m^3 (BC). In POM, it ranged 0.78 ± 0.17 mg/m^3 (SRM)–3.41±0.24 mg/m^3 (BC) (Figure 4b). The data indicates that the phytoplankton exhibited significant variations between seasons (F= 26.4, p <0.05), while variation was insignificant between the stations (F= 1.026, p >0.05). The diversity indices between the five stations did not vary significantly (F= 1.026, p >0.05). An increase in phytoplankton abundance and chl-*a* was on par with previous studies observed during the PRM and MON (Achary et al. 2014; Baliarsingh et al. 2016).

Univariate diversity indices have shown variations between the three different seasons (Table 1). Throughout the study, maximum phytoplankton species were recorded in the BC station in the monsoon (45 species). Marglef's species richness (d) was the highest in MON, followed by PRM whereas it was lowest in POM. This could be attributed to the high species diversity in MON compared to the other two seasons. Pielou's evenness (J') and Simpson's dominance (D)

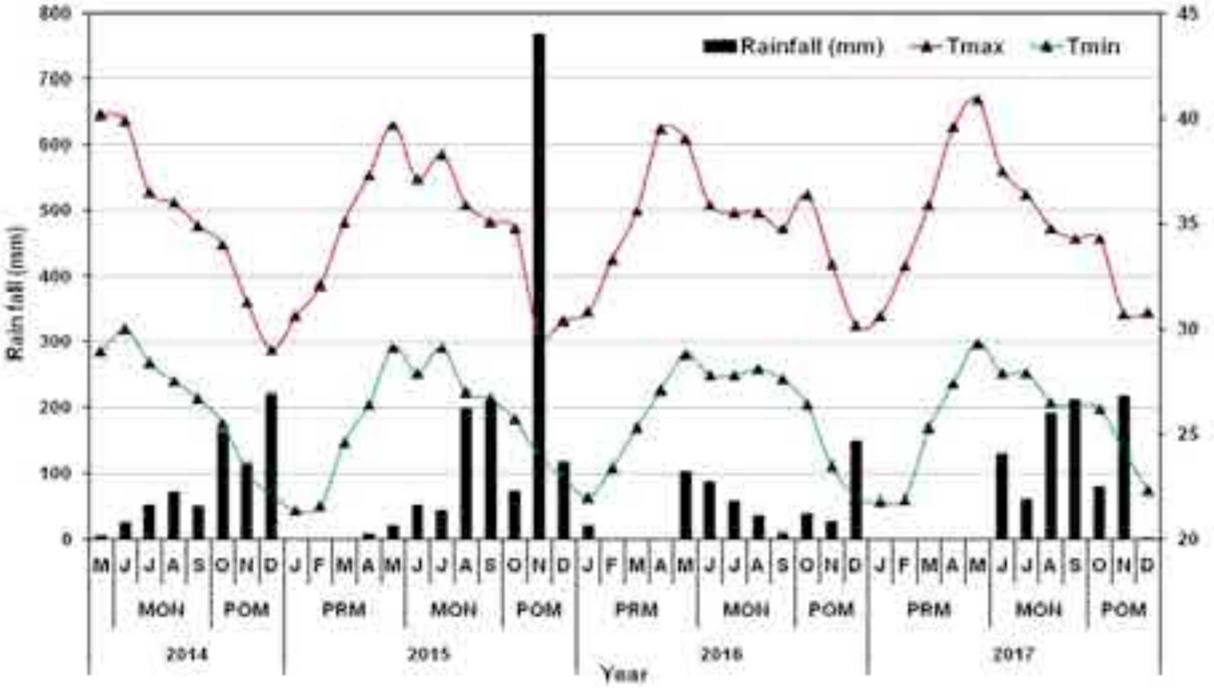

Figure 2. Temperature (°C) and rainfall (mm) data from 2014 to 2017 in Nellore (Tmax= maximum temperature, Tmin= minimum temperature).

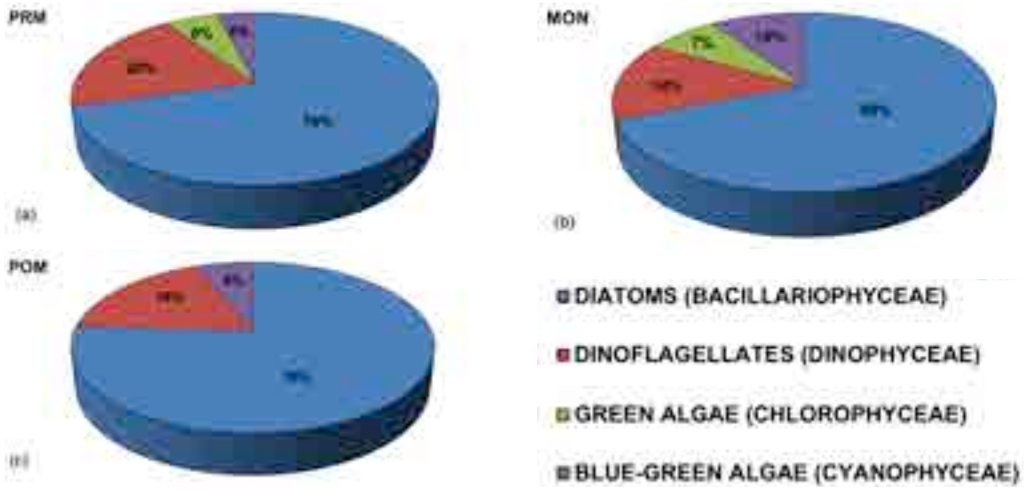

Figure 3. Seasonal variation (a) PRM, (b) MON, and (c) POM showing phytoplankton groups at Pamanji.

were relatively higher in the PRM and POM compared to the MON season. The relatively low value in MON can be attributed to the high species diversity during this season. In general, the high species dominance in PRM and POM can be related to the low species richness in these seasons. The maximum phytoplankton abundance and chl-*a* biomass were recorded during the PRM followed by MON season. The highest phytoplankton abundance and biomass was recorded during 2014 and 2015.

Zooplankton density and diversity

A total of 58 different species of zooplankton conforming to nine different phyla, i.e., Sarcomastigophora, Ciliophora, Ctenophora, Cnidaria, Chordata, Chaetognatha, and Arthropoda were recorded. The increased diversity of zooplankton especially the copepods observed in the estuarine region was on par with previous reports from the east coast of India (Madhupratap et al. 1992; Thippeswamy & Malathi 2009). However, the number of copepod taxa

Table 1. Spatio-temporal univariate diversity indices for phytoplankton.

Season	Station	Total species (S)	Total Individuals (N)	Marglef's species richness (d)	Pielou's evenness (J')	Shannon Wiener Diversity index (H')	Simpson's dominance (D)
PRM	BC	36	23217	3.27	0.93	3.36	0.96
	SR2	35	22493	3.13	0.91	3.25	0.94
	SR1	36	18980	3.26	0.93	3.35	0.95
	SRM	35	21054	3.16	0.93	3.34	0.95
	OS	35	13647	3.28	0.91	3.25	0.95
MON	BC	45	22746	4.54	0.71	2.70	0.87
	SR2	40	22409	3.99	0.73	2.72	0.87
	SR1	41	18585	4.15	0.73	2.71	0.88
	SRM	42	20040	4.12	0.82	3.09	0.93
	OS	41	18906	3.90	0.78	2.90	0.91
POM	BC	30	14959	3.05	0.88	2.99	0.93
	SR2	27	16378	2.75	0.92	3.05	0.94
	SR1	29	10521	3.03	0.92	3.11	0.94
	SRM	29	16973	2.94	0.91	3.07	0.94
	OS	18	9492	1.87	0.91	2.64	0.90

Table 2. Spatio-temporal univariate diversity indices for zooplankton.

Season	Station	Total species (S)	Total Individuals (N)	Marglef's species richness (d)	Pielou's evenness (J')	Shannon Wiener Diversity index (H')	Simpson's dominance (D)
PRM	BC	19	27100	1.759	0.7223	2.13	0.8415
	SR2	19	27793	1.828	0.7863	2.32	0.8749
	SR1	19	26655	1.874	0.7829	2.31	0.8615
	SRM	19	29114	1.827	0.7811	2.30	0.8694
	OS	19	20090	1.873	0.7468	2.20	0.8447
MON	BC	23	24006	2.306	0.7836	2.46	0.8493
	SR2	21	16390	2.057	0.7903	2.41	0.8460
	SR1	19	24330	1.932	0.7172	2.11	0.7880
	SRM	22	21521	2.019	0.6835	2.11	0.8170
	OS	19	16691	1.793	0.5965	1.76	0.6701
POM	BC	16	16576	1.463	0.5105	1.42	0.5485
	SR2	9	22426	0.714	0.2415	0.53	0.2313
	SR1	8	14828	0.783	0.6151	1.28	0.6249
	SRM	14	19619	1.184	0.4009	1.06	0.4726
	OS	13	13286	1.045	0.3664	0.94	0.3983

reported during the present survey was comparatively less than previous reports in the Andhra coast (Rakhesh et al. 2006).

In BC, density varied 2,722–82,540 ind./m^3. In SR1, it varied 2,871–84,230 ind./m^3. In SR2, the density of zooplankton varied 1,645–105,558 ind./m^3. In SRM, it varied 7,551–131,579 ind./m^3. Similarly, in OS, it varied 1,523–96,872 ind./m^3. It was observed that zooplankton density was maximum at SRM (131,579 ind./m^3) (Figure 5a). Zooplankton density in PRM, MON, and POM ranged 20,090–29,114 ind./m^3, 16,390–24,330 ind./m^3, and 13,286–22,426 ind./m^3, respectively. Maximum

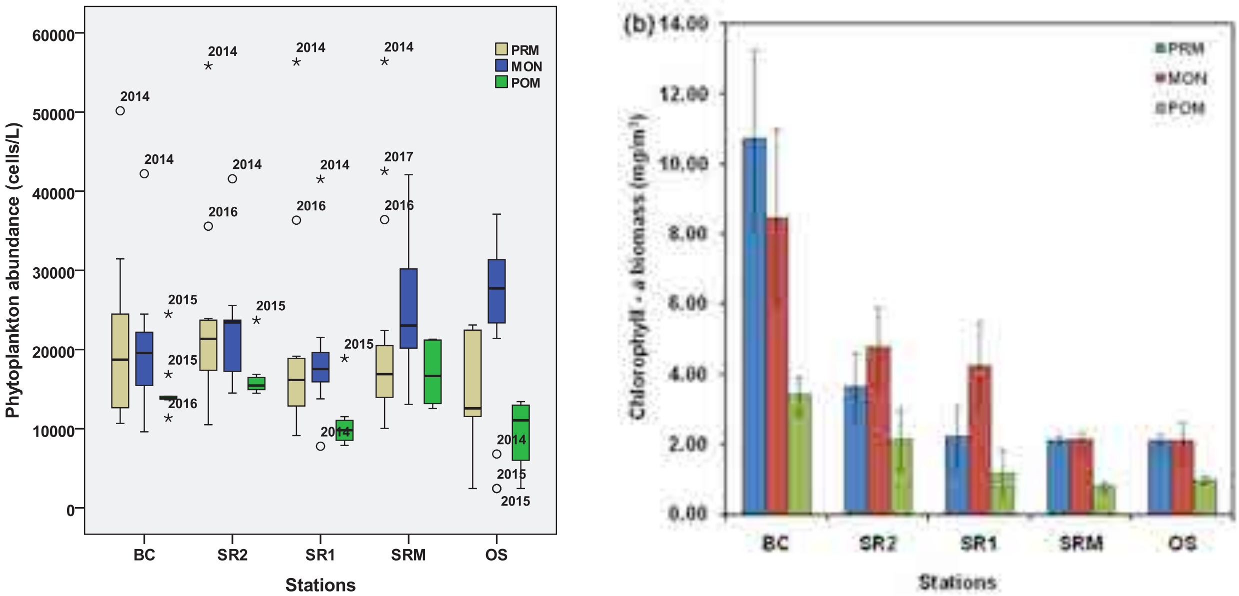

Figure 4. Box-plot representing the seasonal variation in: a—phytoplankton abundance observed at Pamanji. Each box plot with the central point represents the median, the box gives the interval between the 25% and 75% percentiles, the whisker indicates the range, mild outliers are marked with a circle (o) and extreme outliers are marked with an asterisk (*) | b—chlorophyll-a, is expressed in mg/m³.

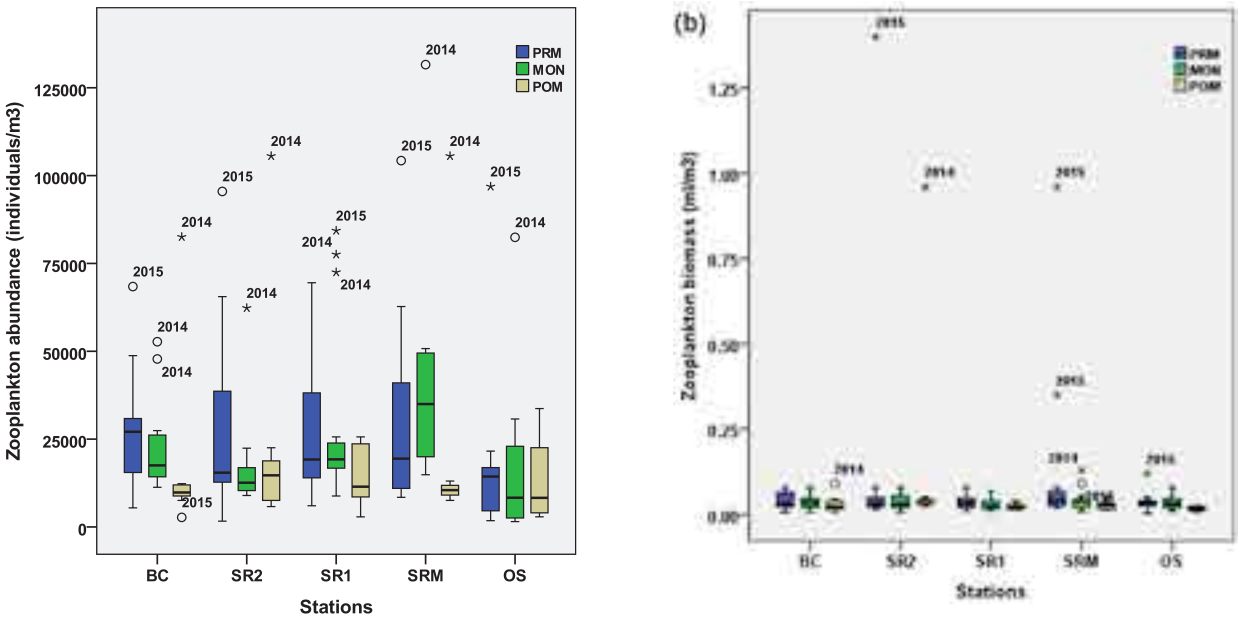

Figure 5. Box-plot representing the seasonal variation in: a—zooplankton abundance | b—biomass observed at Pamanji during 2014–2017. Each box plot with the central point represents the median, the box gives the interval between the 25% and 75% percentiles, the whisker indicates the range, mild outliers are marked with a circle (o) and extreme outliers are marked with an asterisk (*).

zooplankton abundance was observed during PRM followed by MON and POM during the study period. The OS recorded the least abundance throughout the seasons (PRM: 20,091 ind./m³, MON: 16,390 ind./m³ & POM: 13,286 ind./m³, respectively). Maximum zooplankton biomass was observed in SR2 ranging from 0.04 to 0.13 ml/m³ throughout the study period (Figure 5b). OS recorded the least biomass (0.02 to 0.04 ml/m³) throughout the sampling period. Overall PRM followed by MON season exhibited favourable conditions for zooplankton growth in the SRE region.

Zooplankton exhibited a typical season-specific

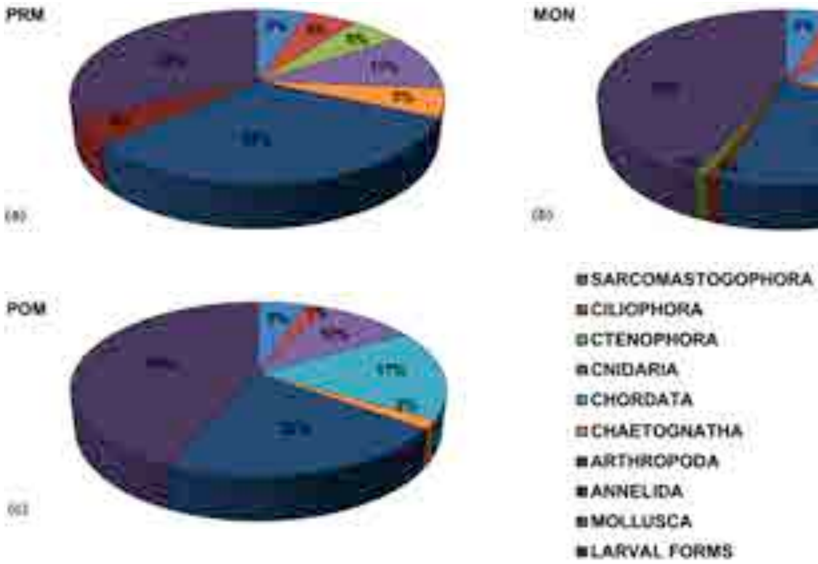

Figure 6. Seasonal variation (a) pre-monsoon, (b) monsoon, and (c) post-monsoon in percentage composition of zooplankton groups at Pamanji.

and site-specific variation. Copepods followed by invertebrate larval forms dominated the zooplankton community during all three seasons. A total of 37 species of copepods were recorded during the survey, with the major species being *Acartia danae*, *A. spinicauda*, *A. clausii*, *Paracalanus parvus*, *Acrocalanus gibber*, *A. longicornis*, *Corycaeus danae*, *C. catus*, *Oithona rigida,* and *Euterpina acutifrons* were recorded throughout the year irrespective of seasons. Copepods followed by larval forms dominate the entire zooplankton community irrespective of seasons (Figure 6). The least contributing groups (less than 10%) include organisms belonging to phyla/group Sarcomastigophora, Ciliophora, Ctenophora, Cnidaria, Chordata, Chaetognatha, and Annelida. Copepods species such as *Eucalanus* sp., *Subeucalanus* sp., *Onacaea* sp., *Centropages* sp., and *Copilia* sp. were present only during POM season in higher numbers in all stations which correlates with the lowering salinity in all stations due to the north-east monsoon. Apart from the copepods, some other larval forms exhibited seasonality such as bivalve (PRM and MON) and gastropod veligers (MON and POM). Larval forms belonging to phylum Mollusca, e.g., *Creisis* sp. and the Ophiothrix larva were exclusively present only in monsoon. Copepod nauplius, crustacean nauplius, and polychaete larvae were present throughout the year in all the stations.

Univariate diversity indices have shown variations between the three seasons (Table 2). Marglef's species richness (d) was the highest in MON, followed by PRM and POM. Among the five stations, a significant difference in the diversity indices was observed during the POM. BC region was more diverse and recorded maximum zooplankton species (19–23). This could be attributed to anthropogenic activities in the surrounding environment (Pandey et al. 2021).

The zooplankton community exhibited significant differences between the seasons (F= 191.1, p <0.001) as well as the stations (F= 224.5, p <0.001). The present investigation has shown the presence of discrete assemblages of zooplankton communities observed in the SRE and coastal region indicating a strong seasonal fluctuation with lower abundances in POM and higher during the PRM and MON season. A similar study conducted elsewhere suggested that phytoplankton abundance plays a very important role in regulating zooplankton population in estuaries (Jagadeesan et al. 2013; Nandy & Mandal 2020).

The coast is prone to heavy rainfall, the likely discharges from the nearby aquaculture activities in the inner stations (BC, SR2, and SR1) of the SRE region which was supported with previous studies (Sreenivasulu et al. 2018). The results of this study are in agreement with Jha et al. (2019) and Pandey et al. (2021) in the same region.

CONCLUSION

The present long-term study reveals the spatial and temporal variations of phytoplankton and zooplankton in the SRE and the adjoining coast. The study also highlights that the SRE region receives very little rainfall during the MON period and most of the rainfall occurred only during the POM period, i.e., during the north-east monsoon (NEM) period. The SRE region is known to have a good cover of mangroves swamps and is usually impacted by anthropogenic activities, such as, aquaculture farms, agriculture activities, and discharge areas from nearby vicinity. The increased nutrient concentration significantly affected the plankton community in the SRE region. Our study indicates that the phytoplankton community exhibited significant variations between seasons. The zooplankton density also showed significant variation and revealed the anthropogenic impact in the study. The present study suggests that phytoplankton and zooplankton are important indicators of a healthy ecosystem which was evident in the present study. Moreover, the study also suggests that a long-term monitoring could help in understanding the ecosystem and planning the mitigation management strategy for the tropical coastal environment.

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Threatened Taxa

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SHORT COMMUNICATION

First record of *Prosoponoides* Millidge & Russell-Smith, 1992 (Araneae: Linyphiidae) from India, with the description of a new species

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Abstract: The genus *Prosoponoides* Millidge & Russell-Smith, 1992, is reported for the first time from India. A new species, *Prosoponoides idukkiensis* sp. nov., is described from the Western Ghats of Kerala. Distally pointed paracymbium, the structure of parmula, arrangement of coils of copulatory duct, and position of spermatheca are the features that differentiate *P. idukkiensis* sp. nov. from its congeners. Description, illustrations, and distribution map are provided.

Keywords: Distribution, Kerala, Idukki, taxonomy, Western Ghats.

Abbreviations: ALE—anterior lateral eye | AME—anterior median eye | DMCKLIN—Deva Matha College Kuravilangad Linyphiidae | DSA—distal suprategular apophysis | PLE—posterior lateral eye | PME—posterior median eye.

A total of 94 linyphiid species belonging to 39 genera have been reported in India so far (Sharma et al. 2020). Millidge & Russell-Smith established *Prosoponoides* in 1992 under the subfamily Linyphiinae Blackwall, 1859 with the type species, *Prosoponoides hamatum* Millidge & Russell-Smith, 1992. *Prosoponoides* comprises of six species, namely: *P. hamatum* Millidge & Russell-Smith, 1992, *P. kaharianum* Millidge & Russell-Smith, 1992, *P. simile* Millidge & Russell-Smith, 1992, *P. sinense* Chen, 1991, *P. jambi* Tanasevitch, 2017, and *P. youyiensis* Liu & Chen, 2020 (WSC 2022). The genus is endemic to Asia, with its distribution in China, Thailand, Vietnam and Indonesia (WSC 2022). The current study deals with the report of *Prosoponoides* from India with the discovery of a new species.

Materials and Methods

A study on linyphiids in central Kerala was conducted from January 2020 to October 2021. Specimens were hand collected from various sites and were preserved in 70% ethyl alcohol. The specimens were examined using a compound microscope and a Leica SAPO Automontage stereozoom microscope. Microphotographs were captured with Flexacam–C1 and processed with Leica Application Suite X (Las X) software. Leg and palp measurements are given in the following order: total (femur, patella, tibia, metatarsus (except palp), and tarsus). Female epigyne was cleared by boiling in 10% KOH for five minutes. All measurements are in millimeters. The distribution map was prepared using an online tool available at https://mapmaker.nationalgeographic.org/. The type specimens are deposited in the Arachnology Lab, Deva Matha College, Kuravilangad, Kottayam, Kerala. The terminology used follows Liu et al. (2020).

ZooBank: urn:lsid:zoobank.org:pub:3D42B1EC-2F4B-4156-ABBE-824163BB3F10

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Taxonomy

Family Linyphiidae Blackwall, 1859

Genus *Prosoponoides* Millidge & Russell-Smith, 1992

Type species: *Prosoponoides hamatum* Millidge & Russell-Smith, 1992

Diagnosis: Males of *Prosoponoides* have a small paracymbium, filiform embolus and also a second membrane which is situated on the lamella. Female epigynum possess atrium with a septum, a highly cuticularized parmula (Li et al. 2018) and a bold projecting scape/socket posteriorly (Millidge & Russell-Smith 1992).

***Prosoponoides idukkiensis* sp. nov.**

(Images 1–11; Figures 1–4)

urn:lsid:zoobank.org:act:FAE465EB-B07F-4A8C-8D8A-6EDF419052ED

Material examined: Holotype: DMCKLIN023, male, 20.xi.2020, Munnar (10.085°N, 77.058°E), Idukki, Kerala, India, coll. A. Domichan.

Paratypes: DMCKLIN003, female, 30.i.2020, Idukki (9.909°N, 76.918°E), Kerala, India, coll. A. Domichan; DMCKLIN080, male & DMCKLIN027, female, 24.iv.2021, Cherthala (9.652°N, 76.318°E), Alappuzha, Kerala, India, coll. A. Domichan; (DMCKLIN084, male & DMCKLIN018, female, 20.vii.2021, Mailadumpara (9.889°N, 77.155°E), Idukki, Kerala, India, coll. A. Domichan; DMCKLIN079, DMCKLIN082, DMCKLIN085, 3 males, 03.x.2021, Ponkunnam (9.575°N, 76.760°E), Kottayam, Kerala, India, coll. A. Domichan.

Etymology: The species is named after the district 'Idukki' in Kerala, which is the type locality.

Diagnosis: The males of *P. idukkiensis* sp. nov. can be distinguished by the distally pointed paracymbium, anterior part of paracymbium which is positioned upward and posterior tip which is not arched (arched in *P. hamatum* Millidge & Russell-Smith, 1992 and *P. youyiensis* Liu & Chen, 2020 (Liu & Chen 2020)); suprategular apophysis not curved (curved in *P. hamatum*). The structure of tegulum and subtegulum is similar to that of *P. youyiensis* but is different in the shape of the lamella; lateral side of lamella narrow (broad in *P. hamatum* and *P. youyiensis*); the U–shaped curve between lateral and anterior ends of lamella found in *P. hamatum*, *P. simile* Millidge & Russell-Smith, 1992, *P. sinense* Chen, 1991, and *P. youyiensis* is absent in *P. idukkiensis* sp. nov.

The females of *P. idukkiensis* sp. nov. possess copulatory ducts with one and a half coils as in *P. hamatum* and *P. youyiensis* (*P. sinense* has two-and-a-half coils); parmula with a shallow depression at the centre (deep in *P. hamatum*), the depression wider than long and semicircular as in *P. sinense* (tongue-shaped in *P. hamatum* and as wide as long in *P. youyiensis*); spermathecae located medially as in *P. youyiensis* (lateral in *P. hamatum*).

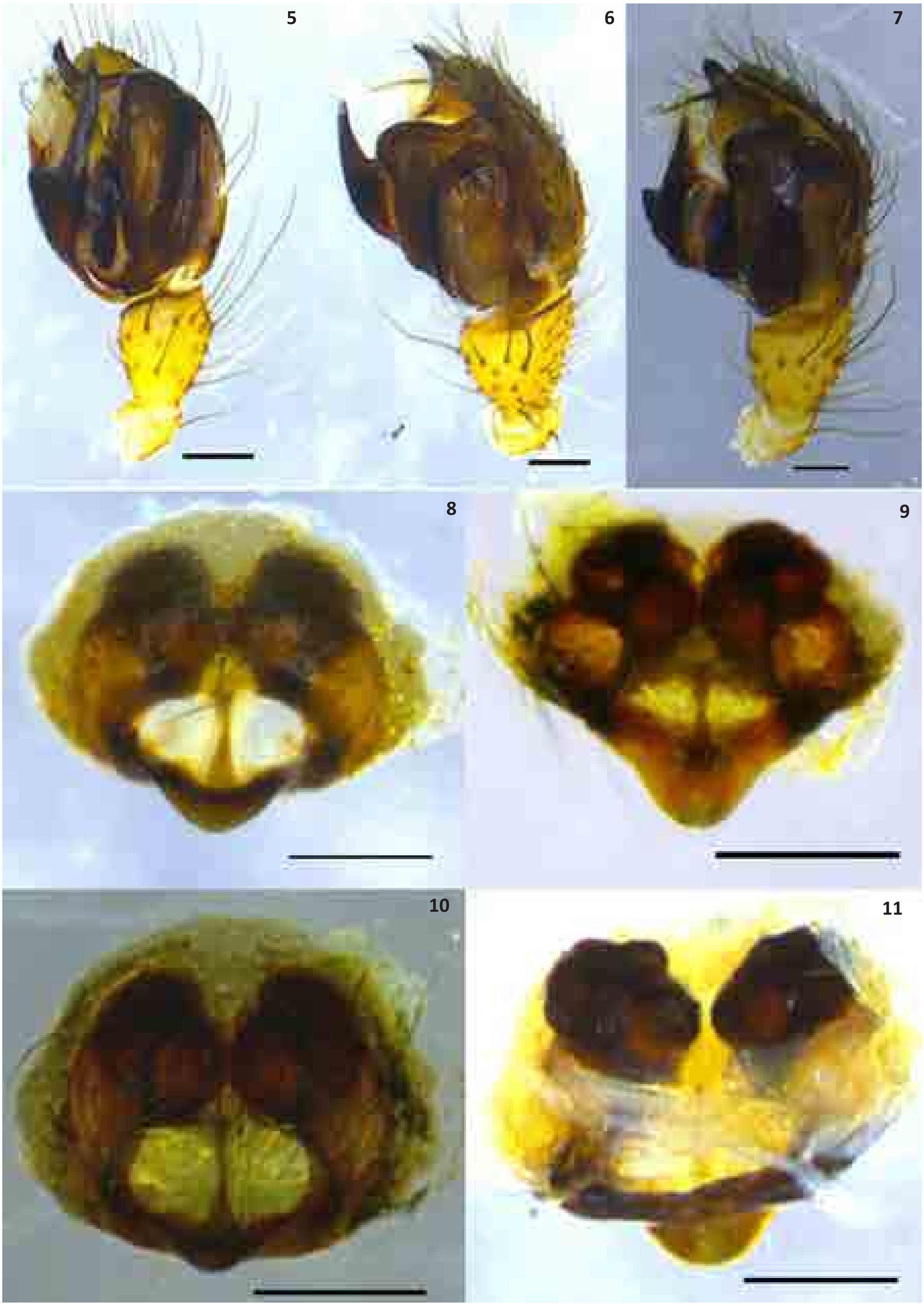
Description: Male: total length: 2.38. Cephalothorax length: 1.08, width: 0.71. Abdomen length: 1.29, width: 0.82. Chelicerae length 0.52. Eye interdistances: AME–ALE 0.05, AME–AME 0.03, PME–PLE 0.10, PME–PME 0.04. Eye diameter (PME) 0.08. Measurements of legs and palp: I 4.88 (0.93 + 0.17 + 0.87 + 0.68 + 0.23), II 4.38 (1.24 + 0.26 + 1.06 + 1.32 + 0.5), III 1.75 (0.64 + 0.14 + 0.34 + 0.43 + 0.2), IV 4.04 (1.17 + 0.27 + 0.86 + 1.29 + 0.45), palp 1.53 (0.45 + 0.35 + 0.39 + 0.34).

Cephalothorax yellowish-brown. Ocular area raised with long hairs. Eyes heterogeneous. White eyes placed in black rings; ALEs and PLEs juxtaposed. Stridulatory ridges not visible on lateral sides of chelicerae. Chelicerae with three promarginal teeth and two retromarginal teeth. Legs yellowish-brown with spines and short hairs. Leg formula 1243. Sternum blackish, heart-shaped (Image 2). Abdomen elongated oval, with white dorsal portion and black medial portion, postero-lateral half with pairs of dark brown spots (Image 1). Palp: anterior tip of paracymbium pointed, directed upwards; embolus and DSA elevated above cymbium; embolus long, originating near base of cymbium; pointed tip of DSA extends upwards; tegulum wide, bulges medially on ventral side; subtegulum bulges medially, with a pointed thin tip that curves anteriad; radix small, gradually narrows medially, like a minor constriction; lamella well-developed, thin and narrow, lateral side projecting apically with pointed tip, anterior portion small without projection, posterior portion narrow and pointed (Images 5–7, Figures 1–2).

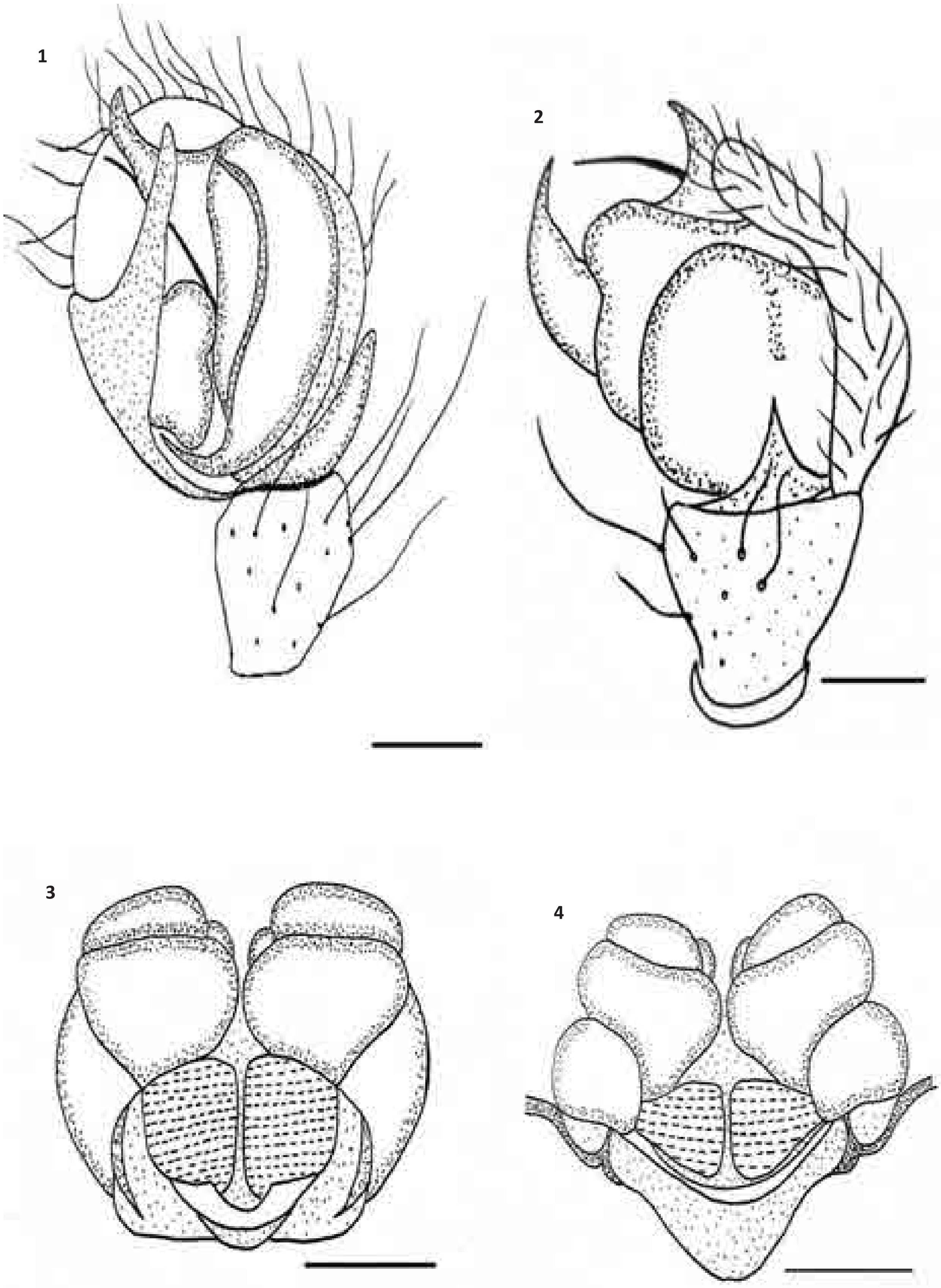
Female: total length: 2.55. Cephalothorax length: 1.2, width: 0.84. Abdomen length: 1.33, width: 0.91. Chelicerae length 0.46. Eye interdistances: AME–ALE 0.05, AME–AME 0.04, PME–PLE 0.05, PME–PME 0.06. Eye diameter (PME): 0.04. Measurements of legs and palp: I 2.69 (0.99 + 0.24 + 0.93 + 0.28 + 0.25), II 2.31 (1.06 + 0.19 + 0.42 + 0.38 + 0.26), III 1.35 (0.43 + 0.16 + 0.36 + 0.23 + 0.17), IV 2.06 (1 + 0.22 + 0.25 + 0.36 + 0.23), palp 0.75 (0.29 + 0.13 + 0.19 + 0.14).

Cephalothorax brownish. Ocular region dark brown, V-shaped. Eyes heterogenous; anterior row recurved and posterior row procurved. ALEs and PLEs juxtaposed. Legs yellowish-brown. Leg formula 1243. Tarsus of palp orangish with many long black spines. Sternum dark brownish, heart-shaped (Image 4). Chelicerae dark brownish with three promarginal teeth and two retromarginal teeth. Abdomen brownish with white

Images 1–4. *Prosoponoides idukkiensis* sp. nov.: 1—male habitus, dorsal view | 2—same, ventral view | 3—female habitus, dorsal view | 4—same, ventral view. Scale: 1–4, 1mm.



Images 5–11. ***Prosoponoides idukkiensis*** **sp. nov.: 5—male palp, ventral view | 6—male palp, retrolateral view | 7—male palp, ventro-lateral view | 8–10—epigyne, ventral view | 11—vulva, dorsal view. Scale: 5–11, 0.1mm.**



Figures 1–4. *Prosoponoides idukkiensis* sp. nov.: 1—male palp, ventral view | 2—same, retrolateral view | 3—female epigyne, ventral view | 4—vulva, dorsal view. Scale: 1–4 = 0.1mm.

Image 12. Distribution map showing collection sites of *Prosoponoides idukkiensis* sp. nov. in central Kerala, India.

markings; brown patches present on either side postero-medially (Image 3). Epigynal atrium semi-elliptical, separated by a short septum, arises from dorsal wall; parmula semicircular, wider than long, with a shallow, wide depression at centre; scape shallow; copulatory ducts starts from the openings of atrium with one and a half coils; fertilisation ducts run downwards from spermathecae (Images 8–11, Figures 3–4).

Distribution: India (Kerala) (Image 12).

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SHORT COMMUNICATION

Rediscovery of *Platerus pilcheri* Distant (Hemiptera: Reduviidae), a forgotten assassin bug from India, with comments on its range extension

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Abstract: *Platerus pilcheri* Distant, 1903, a harpactorine reduviid, is rediscovered from India after more than a century since its original description. A brief diagnosis of this species, a note on its range extension, a distributional map, and images of live habitus are provided along with the images of a syntype preserved in the Natural History Museum, London (BMNH). We also present a comparison with the other Indian congeneric species, *Platerus bhavanii* Livingstone & Ravichandran, 1991, and show that this latter species does not belong in the genus *Platerus* and is to be treated as species inquirenda. The issue of the subsequent documentation of *Platerus bhavanii* from Karnataka is also discussed.

Keywords: Harpactorinae, *Nagusta*, *Nagustoides*, Oriental region, China.

A single male harpactorine assassin bug was carefully studied and photographed in the Talle Valley Wildlife Sanctuary (Ziro, Arunachal Pradesh), in September 2019. It showed the main diagnostic characters of the genus *Platerus* Distant, 1903, viz., the head about as long as the pronotum; a long oblique suberect spine at the base of the antenna; a posterior pronotal lobe with two long, discal, tuberculous, erect, acute spines and lateral pronotal angles spinously produced (Distant 1903, 1904; Zhao et al. 2006b). It was subsequently identified as *P. pilcheri* Distant, 1903 based on the original description and an illustration provided by Distant (1903, 1904), as well as the redescription, illustrations and key provided by Zhao et al. (2006b). A further comparison with images of a male syntype of *Platerus pilcheri,* preserved in the BMNH, confirmed the identity of the bug photographed in Arunachal Pradesh.

Platerus Distant, 1903 is a small genus in Reduviidae (Hemiptera), with only three species, all described from the Oriental region (Zhao et al. 2006b). Distant (1903) established *Platerus* with *P. pilcheri* as the only species, based on an unspecified number of male specimens, collected by J.G. Pilcher in Sikhim [= Sikkim], India; later Distant (1904) included this genus in Harpactorinae, division Euagorasaria and also provided a figure of the dorsal habitus of this species. While Distant's 'divisions' of Harpactorinae are no longer used, Distant (1904) still proves useful for the identification of the Indian

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hemipteran fauna. The division Euagorasaria has been merged in the tribe Harpactorini, which includes species with a curved labium. The subfamily Harpactorinae is the largest reduviid subfamily, with over 300 genera and more than 2,800 species (Schuh & Weirauch 2020).

The other two species of the genus *Platerus*, viz., *P. bhavanii* Livingstone & Ravichandran, 1991 and *P. tenuicorpus* Zhao, Yang & Cai, 2006 are known from India and China (Tibet), respectively. *Platerus pilcheri* has never been documented in detail from any part of India since its original description, although it has been collected, as can be vouched by specimens in the collections of the BMNH (see 'Material studied') and the Zoological Survey of India (ZSI, see Biswas et al. (1994)). More recently, one female specimen was reported from Xizang (Tibet), China, by Zhao et al. (2006b), who described the female of the species for the first time. Agarwal (2019) made images of a specimen available on the iNaturalist website; this was recently identified as *P. pilcheri.* The present report is based on this sighting made on 7 September 2019 at the Talle Valley Wildlife Sanctuary, Arunachal Pradesh (27.545614N & 93.830229E). The specimen was studied in detail and released back into nature; no collections were permitted in that area during the study.

Since the genus and the species have been originally, and subsequently, described in detail, we are here only presenting recent images of this species with brief comments on the other Indian congeneric species, *P. bhavanii.* We are also providing images of a syntype of *P. pilcheri* and documenting other specimens deposited in the BMNH.

Taxonomy

Reduviidae Latreille, 1807

Harpactorinae Amyot & Serville, 1843

***Platerus* Distant, 1903**

Platerus Distant, 1903: 247 (type species *Platerus pilcheri*, by monotypy); Maldonado Capriles 1990: 258; Ambrose 2006: 2399; Zhao et al. 2006b: 25; Biswas et al. 1994: 398; Biswas & Mitra 2014: 14; Bhagyasree 2017: 67.

Diagnosis

Division Euagorasaria, sensu Distant (1904), which includes the genus *Platerus*, is characterized by an elongate body, the head with a distinct tubercle or spine behind the base of each antenna and lateral pronotal angles spinous or at least prominent. Within Euagorasaria the genus *Platerus* is diagnosed by the following characters: anterior tibia not curved at the tip and without a spine, anterior lobe of pronotum without any prominent tubercles at the sides, the posterior lobe of pronotum with discal spines and the head about as long as the pronotum.

Diagnostic characters of the genus

The genus *Platerus* has been described thoroughly by Distant (1903) and some more details were added by Zhao et al. (2006b); for this reason, we do not reiterate those characters. Only some characters that are relevant for the subsequent discussion are given below:

Head long, about or almost as long as the pronotum, postocular portion a little longer and slenderer than the anteocular portion; pronotum subtriangular, the anterior lobe obsoletely tuberculate, its anterior angles moderately prominent, its posterior area profoundly and broadly sulcate; abdomen long, scarcely wider than the hemelytra, the fifth [visible] segment a little dilated on each side.

***Platerus pilcheri* Distant, 1903** (Image 1 & 2)

Platerus pilcheri Distant, 1903: 248, 1904: 375; Maldonado Capriles 1990: 258 (catalogued); Ambrose 2006: 2399 (in checklist); Zhao et al. 2006b: 25 (redescription, key, description of female); Biswas et al. 1994: 398 (listed); Biswas & Mitra 2014: 14 (checklist, misspelling: *P. pilchen*); Bhagyasree 2017: 67 (as type species of *Platerus*, similar misspelling).

Material studied

1 male, India, Arunachal Pradesh, Ziro (Image 1); specimen not collected.

Other material for which images are provided:

Type material. Syntype, male, India, Sikkim, with the following labels: red-bordered "Type" disc; "♂"; "Platerus pilcheri Dist."[Distant's handwriting]; "Sikkim/ 7000 [ft]/ June 1895/ J.G. Pilcher // 97/ 120"; "BMNH(E) 1255121"; "NHMUK 013588826" (BMNH) (Image 2).

Additional material: (known from the literature / examined in the BMNH)

1 male, India, West Bengal, Jalpaiguri, with the following labels: "♂", "Gopaldhara, Bw./ Darjeeling./ 4,720 ft. 29.ix.14./ H. Stevens.", "At light.", "NHMUK 013588827" (BMNH); "1 ex., Darjiling, Brich hills.,? coll. M. Banerjee; 2 exs., Darjiling, vii.1912, coll.?" (ZSI, fide Biswas et al., 1994, not seen); 1 female, China, Yunnan: Dulong Valley, with the following labels: "♀", "Upper Burma:/ Taron Valley./ 16.x.1938./ R. Kaulback./ B.M.1938-741.", "Alt.5,000 ft./ lat.N.28° 08'/ Long. E 98° 20'.", "NHMUK 013588828" (BMNH) (Although one label reads 'Upper Burma', i.e., northern Myanmar, the

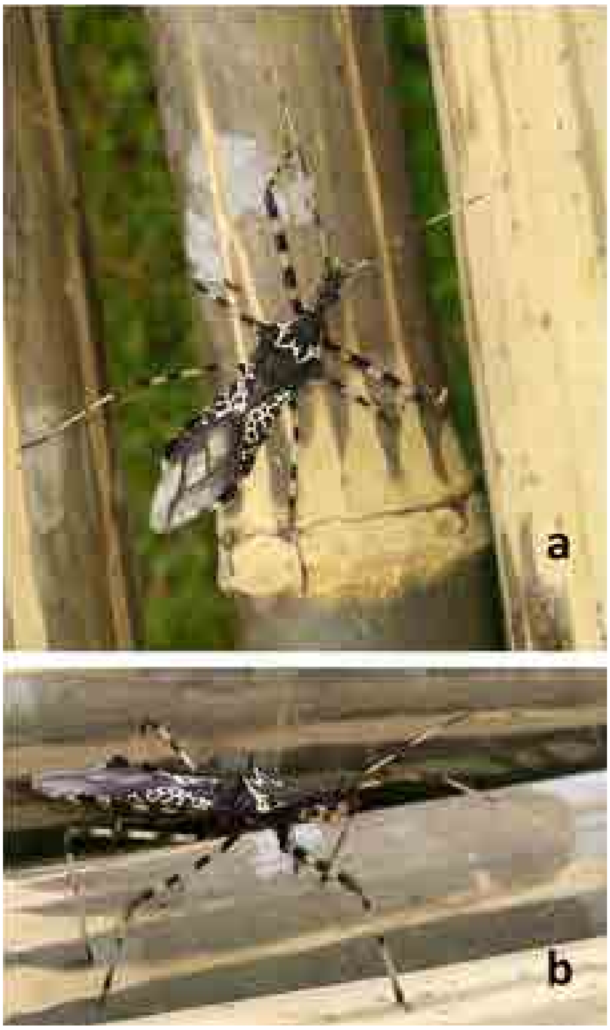

Image 1. ***Platerus pilcheri*** **Distant, 1903 from Talle valley, Arunachal Pradesh: A—dorsal view | b—lateral view. © H. Sankararaman.**

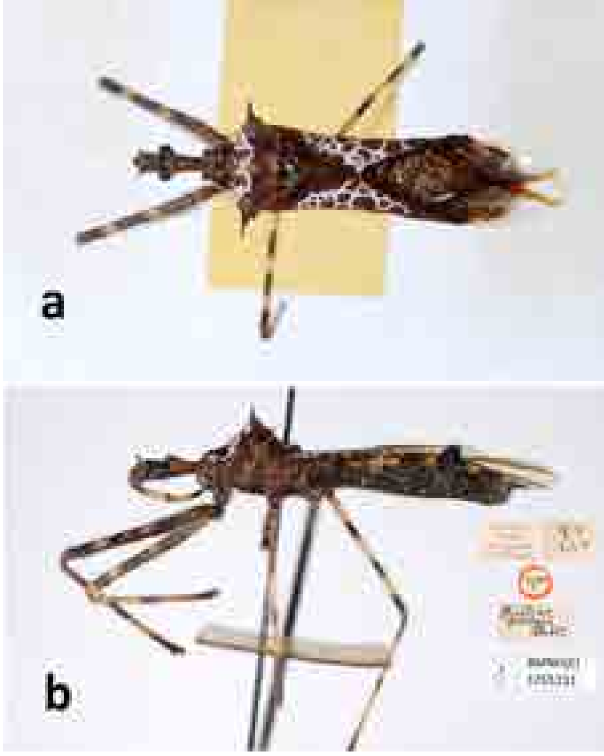

Image 2. *P. pilcheri* Distant, 1903 (syntype & labels): a—dorsal view | b—lateral view. © The Trustees of the Natural History Museum, London. Imaged by T. Ishikawa.

coordinates on another label indicate a locality in China; this may be explained by the instability of the Burma-Yunnan frontier (see McGrath 2003). Ronald Kaulback trekked in Tibet (see Kaulback 1934) and "Tibet" is what was recorded in the BMNH accession register under entry 1938-741, when he presented the specimen to the BMNH in December 1938); 1 female, China, Xizang (Tibet), "Motuo; 29-viii-2003, collector unknown; kept in CAU [China Agricultural University, Beijing]" (fide Zhao et al. 2006b, not seen); A further two males, without any data, are deposited in the BMNH.

Brief description

Coloration: Body dorsally mostly black with symmetrical pattern of white markings on pronotum and corium. Antennae and legs with alternate black and yellow annulations. Anterior pronotal lobe, discal and lateral spines of posterior lobe black; a white fine marking on lateral margins of anterior lobe of pronotum continued as a wavy 'W'-like transverse fascia on posterior lobe, just in front of discal spines. Three broad black annulations on all femora are also clearly visible; clavus entirely black, membrane fuliginous with basal half partly brownish-black, apical half pale hyaline; conspicuous white reticulate markings on corium (Image 1a). Apical segment of labium, fine tibial annulations and connexival coloration black, showing a well-defined black anterior part of each abdominal segment (Image 1b)

Structure: Head about as long as pronotum, with long, anterolaterally directed spine at base of antenna. First visible labial segment longer, slightly passing posterior border of eye and longer than second. Pronotum with the anterior lobe short, posterior lobe more than twice as long as anterior lobe; lateral pronotal angles spinously produced, their posterior margin distinctly notched near base; posterior pronotal lobe with discal, long erect, tuberculous spines; fore femur slightly incrassate; abdomen with sixth connexival segment dilated laterally (Image 1a,b).

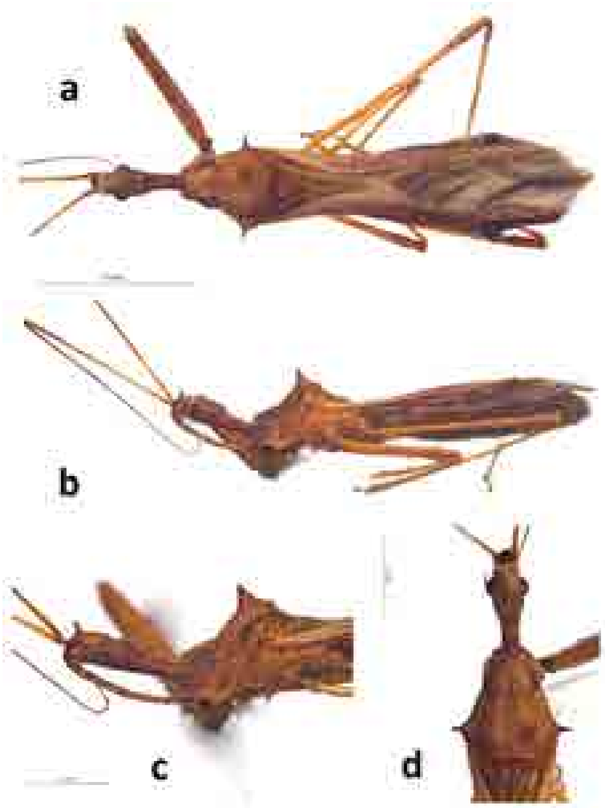

Image 3. *P. bhavanii* sensu Bhagyasree (2017): a—dorsal view | b—lateral view | c—head & pronotum magnified, lateral view | d—same, dorsal view. © University of Agricultural Sciences, GKVK, Bengaluru, India. Imaged by H.M. Yeshwanth.

Remarks

Validity of our identification: The single male from Ziro, Arunachal Pradesh, exactly matches the original description and the subsequent habitus figure given by Distant (1903, 1904), as well as the syntype of *P. pilcheri* preserved in the BMNH, as can be seen from the images provided (Image 2). This species can also be identified, according to the recent key in Zhao et al. (2006b).

***Platerus bhavanii* does not belong in *Platerus*:** *P. pilcheri* was the only species known under this genus until Livingstone & Ravichandran (1991) described a new species *Platerus bhavanii* Livingstone & Ravichandran, 1991, collected from the Botanical Garden near Bhavani Dam, Periyar, Tamil Nadu, southern India. The specimens examined by them included one female (holotype), one male and another female (paratypes); our attempts at locating these types and obtaining images remained unsuccessful. The authors gave a brief description and only a dorsal habitus line drawing, without any information on male / female genitalia. Considering the description and illustration given by Livingstone & Ravichandran (1991), it is important to point out here that *P. bhavanii* has some characters that are distinctly different from the original diagnostic characters of the genus *Platerus* given above. For example: (i) the pronotum is of a very different shape in *P. bhavanii*, (ii) the broadly sulcate area in the posterior part of the anterior lobe described in the genus *Platerus* is neither mentioned in the original description of *P. bhavanii* nor visible on the line drawing provided and (iii) in *Platerus*, only abdominal segment V is dilated on either side, as per Distant (1903), while in *P. bhavanii* segments V to VII are dilated (Distant (1903) had stated: 'the fifth segment a little dilated on each side'; this must refer to a visible segment V, i.e., segment VI, as Zhao et al. (2006b) have described the sixth connexival segment as expanded in the female and our specimens show expansion on the sixth connexival segment). Finally, Livingstone & Ravichandran (1991), while describing *P. bhavanii*, had stated: "…anteocular area with a median 'Y'-shaped, smooth brown streak, posteriorly confluent with the transverse fissure connecting the eyes"; this character is not found in the genus *Platerus*.

Because of these differences alone we strongly reckon that *P. bhavanii* does not belong in the genus *Platerus* and that the type material must be re-examined to settle its identity. We therefore suggest that until the types are located, the species *P. bhavanii* should be treated as species inquirenda, i.e., a species of doubtful identity.

Specimens identified as *P. bhavanii* may not be this species and do not belong in *Platerus*: Bhagyasree (2017) examined seven females collected from various parts of Karnataka, identified those as *Platerus bhavanii* and photographically illustrated one of them. Looking at the original line drawing in Livingstone & Ravichandran (1991) and the photo provided by Bhagyasree (2017), it seems that the specimens in Karnataka are again different and a detailed re-examination of these specimens is essential. It is certain that Bhagyasree's specimen, photographed anew for this study (Image 3), does not belong in *Platerus* either as it also lacks the diagnostic characters of the genus *Platerus*; in addition, a lateral view of the head of this specimen shows the first visible segment of the labium to be passing much beyond the posterior border of the eye (Image 3b,c), a feature not seen in the similar view of the live specimen (Image 1b) or of the syntype (Image 2b) of *P. pilcheri*. In the absence of the type material of *P. bhavanii*, it is also difficult to tell with certainty if Bhagyasree's specimens are conspecific with what was originally described as *P. bhavanii.*

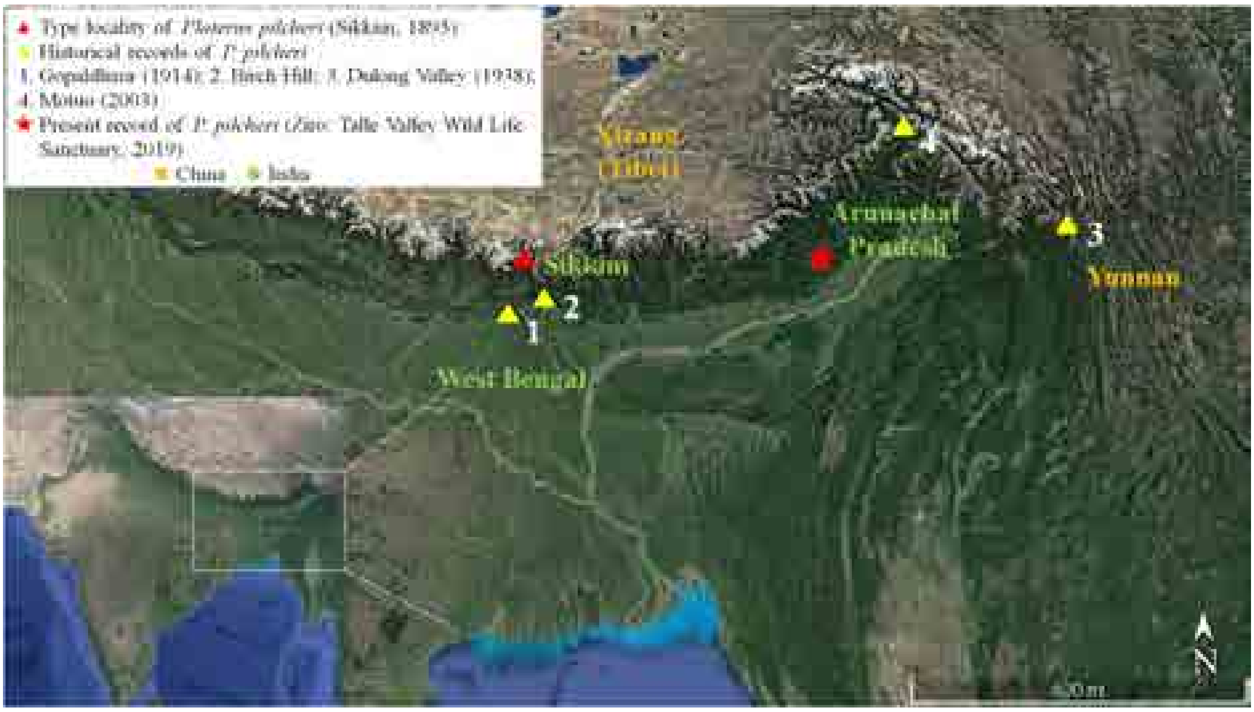

Image 4. Map showing the distribution of *P. pilcheri* Distant.

***P. bhavanii* and specimens identified as such could belong to either *Nagustoides* or *Nagusta*:** Some of the aforementioned characters that preclude *P. bhavanii* and specimens identified as such by Bhagyasree (2017) to be placed in *Platerus* are, however, seen in the genera *Nagustoides* and *Nagusta*: (i) the 'Y'-shaped smooth brown streak and more than one expanded abdominal segments are seen in the genus *Nagustoides* Miller, 1954 (Miller 1954 (Fig. 43 A); Zhao et al. 2006a (Fig. 1); Ishikawa & Naka 2016 (Fig. 3)) although, in *Nagustoides*, only abdominal segments (connexivum) V and VI are laterally expanded (and the external apical angle of segment V is spinous) and the 7th abdominal sternite has only a small median spine on the posterior border. In some species of *Nagusta* Stål, 1859, one or more abdominal segments are expanded or dilated as well (Villiers 1967). (ii) the first visible segment of the labium is passing much beyond the posterior margin of the eye in Bhagyasree's *P. bhavanii* (Image 3b,c), which is another character seen in the genera *Nagusta* and *Nagustoides* (as a matter of fact, in *Nagustoides*, the first visible labial segment is longer than the second and third combined; this is one of the characters that separates it from the genus *Nagusta* Miller, 1954). For these reasons, we suspect that the originally described *P. bhavanii* and the specimens identified as *P. bhavanii* by Bhagyasree (2017) possibly belong in either *Nagusta* or *Nagustoides* and certainly not in *Platerus.*

Miller (1954: 52) separated *Nagustoides* from *Nagusta* thus: "Allied to *Nagusta* Stål, [...] but it differs in having the basal segment of the rostrum longer than the remaining segments together, the anterior pronotal lobe tuberculate, the posterior lobe without subdorsal spines or gibbosities and the expanded 5th connexival segment spinous". Despite this, subsequent papers have illustrated *Nagustoides* with discal tubercles on the posterior lobe of pronotum (Zhao et al. 2006a; Ishikawa & Naka 2016), a character seen in Bhagyasree's specimens, and, even described in *P. bhavanii*. To better define *Nagusta* and *Nagustoides* a detailed study of their types species need to be carried out.

Thus, we firmly state that our discovery of *P. pilcheri* in Arunachal Pradesh becomes the first authentic record of this genus and species from India, after a gap of over 100 years. This discovery also indicates that this handsome predatory bug is still inhabiting northeastern India. Besides this, we also maintain that *Platerus pilcheri* is the only species under the genus *Platerus* in India; the other described species from India is of doubtful identity.

Distribution: China (Xizang, Yunnan), India (Sikkim, West Bengal, Arunachal Pradesh).

Distant's historical record of *P. pilcheri* was from Sikkim, Zhao et al. (2006b) reported it from Xizang (Tibet), China, the present record is from Ziro, Arunachal

Pradesh, while specimens found in the collections of ZSI and BMNH allow us to add to the distribution West Bengal and the Yunnan province of China (Image 4), altogether showing the northward and eastward extension of the range of this species. No specimens were collected during the present study. The species was diagnosed based on the original description and subsequent illustrations.

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OPEN ACCESS

SHORT COMMUNICATION

First Indian DNA barcode record for the moth species *Pygospila tyres* (Cramer, 1780) (Lepidoptera: Crambidae: Spilomelinae) distributed in Asia and Australia

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Abstract: The species *Pygospila tyres* was described from the Coromandel region of India about 240 years ago, accommodated in the family Crambidae having immense importance. The species is morphologically cryptic and is known to have 10 extant species under the genus. Earlier mt DNA Barcodes for the species were available from Pakistan, Korea, and Australia, here we report the first barcode of the species from the country of its type locality. Morphological details for the collections with the male and female genitalia are provided for the taxonomic identification. Identities of the mt COI DNA sequences for the genus in the GenBank are discussed.

Keywords: *Holarrhena*, host plant, India, Maharashtra, *Wrightia*.

The members of the superfamily Pyraloidea are known to cause crop yield loss between 10 to 100 per cent across the world (Jotwani & Young 2007). Earlier the family Crambidae was originally a part of the family Pyralidae, but separated from it by Munroe (1972). They are of immense economic importance as they are the pest on many agricultural important cash crops like sugarcane and other crops like maize, brinjal, tomato, cabbage, cotton, oil seed, and bamboo (Solis 1997). Most of the crambid moths are morphologically cryptic (cryptic species is a group of individuals that are morphologically identical to each other but belong to different species) and difficult to study. The moths of the subfamily are characterized by the absence of chaetosemata, presence of bilobed subcostal retinaculum in male, praecinctorium fornix tympani projecting and pointed spinula. Corpus bursae in the female genitalia lack signum and gnathos absent (Minet 1981; Solis & Maes 2003; Solis 2007; Kumar et al. 2013).

The genus *Pygospila* was established by Achille Guenée in 1854 and in 1896 Hampson subsequently designated the type species for this genus as *Pygospila tyres* Cramer, 1780, which was included by Guenée (1854) as *Pygospila tyresalis* Cramer, 1780. Earlier, Hampson (1896) has recognized four species under the genus namely, *Pygospila octomaculalis* Moore, 1867; *Pygospila tyres* Cramer, 1780; *Pygospila cuprealis*, (Swinhoe, 1892); *Pygospila costiflexalis*, Guenée, 1863. Further *Pygospila bivittalis* Walker, [1866]; *Pygospila hyalotypa* Turner, 1908; *Pygospila imperialis* Kenrick, 1907; *Pygospila marginalis* Kenrick, 1907; *Pygospila macrogastra* Meyrick, 1936; *Pygospila minoralis* Caradja, 1937; *Pygospila yuennanensis* Caradja, 1937 were

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Competing interests: The authors declare no competing interests.

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added. As of now a total of eleven species (Hampson 1896; Kenrick 1907; Turner 1908; Caradja 1916; Meyrick 1937; Caradja & Meyrick 1937; Kitching et al. 2020) are considered extant in the genus of which, five species are reported from India (Kitching et al. 2020). Hampson (1896) mentioned the distribution of *P. tyres* as throughout India (having type locality in the Coromandel region of southern India).

For easy identification of the morphological cryptic species, mt DNA barcoding are being used as an alternative tool for insect species identification and documentation of new species (Hebert et al. 2003). Although DNA barcode-based species identification works are in infancy in the developing countries, the technique provides robust and rapid approach for biodiversity analysis (Ashfaq et al. 2017), exploiting low conspecific and high interspecific genetic variation principle (Hebert et al. 2003). DNA barcodes have been constructively utilized for diverse aims in addition to serving as an aid to conventional slow-paced taxonomic delimitation approaches (Ashfaq et al. 2017). DNA barcodes having effectively applied to unpin species identity for numerous animal taxa, the order Lepidoptera has seen particularly intensive barcode analysis (Ashfaq et al. 2017). The identification using DNA barcoding approach exclusively depends on the quality of reference library, which is strengthened if the barcodes are linked to registered voucher specimens. Identification of moths using mt DNA barcode has been introduced in the moth groups of *Olepa* (Kalawate et al. 2020a,b). Despite its widespread distribution there are no genetic data available for the species from India. Hence, during one of our exercise of generation of mt DNA barcodes for the moth species, here we report the first mt DNA barcode for the species *P. tyres* from India, having a wide range of distribution.

Materials and Methods

The specimens were collected by installing light trap during night, and were euthanized by ethyl acetate vapours. The specimens were transferred to the laboratory in insect packets under dry conditions. They were stretched, pinned, labelled, and dry-preserved in fumigated entomological boxes for further study. For morphological studies the specimens were studied under Leica EZ4E stereomicroscope. The map of the collection locality was prepared using open free QGIS software. The details of collection locality are given under material examined and also shown in Figure 1. The identification was done with the help of Hampson (1896). The genitalia of male and female were studied following Robinson (1976). The identified materials are deposited at the National Zoological Collections of the Zoological Survey of India, Western Regional Centre,

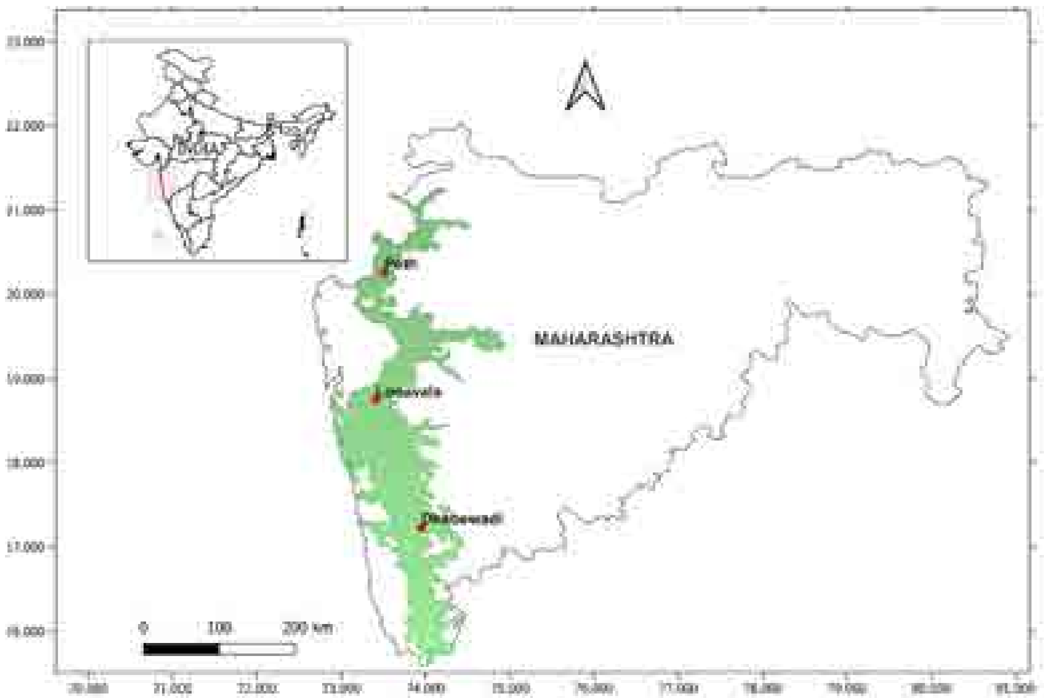

Figure 1. Collection localities of *Pygospila tyres* from northern Western Ghats, India.

Pune, Maharashtra, India (ZSI, WRC).

DNA extraction and purification were performed using leg and thoracic muscle from dried specimen, followed by quantitation utilizing HS dsDNA assay kit on Qubit 2.0 fluorometer. Amplification of mt COI gene was attempted using universal primer (Folmer et al. 1994), LCO1490 and HCO2198 in 25µL reaction volume constituted by 12.5 µL of Master Mix (Promega), 10 pmol of each forward and reverse primer along with Nuclease free water up to Q.S. thermal cycling profile as per Kalawate et al. (2020a). Amplified PCR product was confirmed by gel electrophoresis stained by SYBR safe DNA gel stain (Invitrogen), visualized under UV by gel documentation system, followed by purification of amplified product by Invitrogen's Pure Link PCR Purification Kit. Purified PCR product was sequenced bidirectionally by Sanger's method on ABI 377 (Applied Biosciences) sequencer.

Both the forward and reverse sequences generated in the current study were verified manually for corrections. From the GenBank 21 mt COI gene sequences available for the *Pygospila* were downloaded (Table 1) and were aligned with Clustal W algorithm in MEGA 5.2 software (Tamura et al. 2011). For phylogenetic reconstruction, Maximum Likelihood tree was built with RaxML (Silvestro & Michalak 2012) for thorough bootstrap 1,000 replicates under the GTR+GAMMA+I model and the final consensus tree was visualized by Fig Tree v1.4.0 treating species *Pycnarmon* as out groups (Figure 2).

Result and Discussions

Morphologically the collected samples were identified as *Pygospila tyres* (Cramer, 1780) (Image 1).

Taxonomic account

Superfamily Pyraloidea Latreille, 1809
Family Crambidae Latreille, 1810
Subfamily Spilomelinae Guenée, 1854
Genus *Pygospila* Guenée, 1854
1854. *Pygospila* Guenée, Delt. and Pyr.: 312.
Type species: *Pygospila tyres* (Cramer, 1780)
Species *Pygospila tyres* (Cramer, 1780) (Image 1A–D)
1780. *Phalaena tyres* Cramer, *Pap. Exot*., 3: 263.
Type Locality. Coromandel, southern India.

Morphological description Adult (Image 1A): Wing expanse: 40–45 mm. Olive-brown with purple tinge reflects in light; palpi white underside; frons with lateral white lines; white line on thorax and patagia; abdomen slender, long with paired white spots placed dorsal and lateral. Forewing olive brown with several nacreous spots, these spots shine with a purple tinge in light. Hindwing with nacreous streaks in and below the cell. A pair of spots present between origin of vein 3 and 5, three submarginal spots and a spot present below vein 2; cilia brown and white towards anal angle. Underside exactly same pattern on both fore and hindwings. Hind wing of male with vein 8 widely separated from 7, 6 bent downward, the veins beyond the cell roughly scaled.

Male genitalia (Image 1B): Uncus thin, bulbous with hairs; tegumen well developed with a process resembles feather of peacock; valvae broad, laterally surrounded by long hairs, ampulla thin, sclerotized and hooked; saccus relatively well developed, broad u-shaped, with two curved process. Aedeagus (Image 1C) very long, thin, whip-like, with swollen apex.

Female genitalia (Image 1D): Apophyses thin, both anterior and posterior are of equal length; Corpus bursae membranous, elongated, devoid of signum; papillae anales large, setosed.

Material examined: 01 #, Peth, Nashik (N 20.259; E 73.513, altitude 593 m), 28 viii 2013, Coll. P.S. Bhatnagar & Party (L-1465); 04 #, Dhebewadi, Satara (N 17.229; E 73.952, altitude 731 m), 17 vii 2017, Coll. A.S. Kalawate & Party (L-1630); 01 #, Dhebewadi, Satara (N 17.229; E 73.952, altitude 731 m), 12 vii 2017, Coll. A.S. Kalawate & Party (L-1706); 01 #, Dhebewadi, Satara (N 17.229; E 73.952, altitude 731 m), 13 vii 2017, Coll. A.S. Kalawate & Party (L-1716); 04 #, Dhebewadi, Satara (N 17.229; E 73.952; altitude 731 m), 15 vii 2017, Coll. A.S. Kalawate & Party (L-1759); 01 #, Lonavala, Pune (N 18.742; E 73.405, altitude 622 m), 23 viii 2017, A.S. Kalawate & party (L-1583).

Distribution in India: Bihar, Chhattisgarh, Himachal Pradesh, Jharkhand, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Sikkim, Tamil Nadu, and West Bengal.

Outside India: Africa, Australia, Borneo, China, Indonesia, Java, Japan, Malaysia, Myanmar, Nepal, New Guinea, Pakistan, Philippines, Sri Lanka, Thailand, and Vietnam.

Host plants: *Wrightia tinctoria*, *Wrightia arborea*, *Holarrhena antidysentrica*, *Tabenaemontana heyneana* (Apocynaceae) (ICAR-NBAIR 2020).

DNA Barcode diagnosis

The genetic sequence of sample of *P. tyres* from Pune, Maharashtra matches completely with the *P. tyres* sequences from Pakistan, Korea, and Australia. The clade composing the *P. tyres* is homologous without any genetic distance variation. One of the sequences (JX017862.1) from Australia is labelled as *P. tyres*, where the identity should be rechecked with the voucher

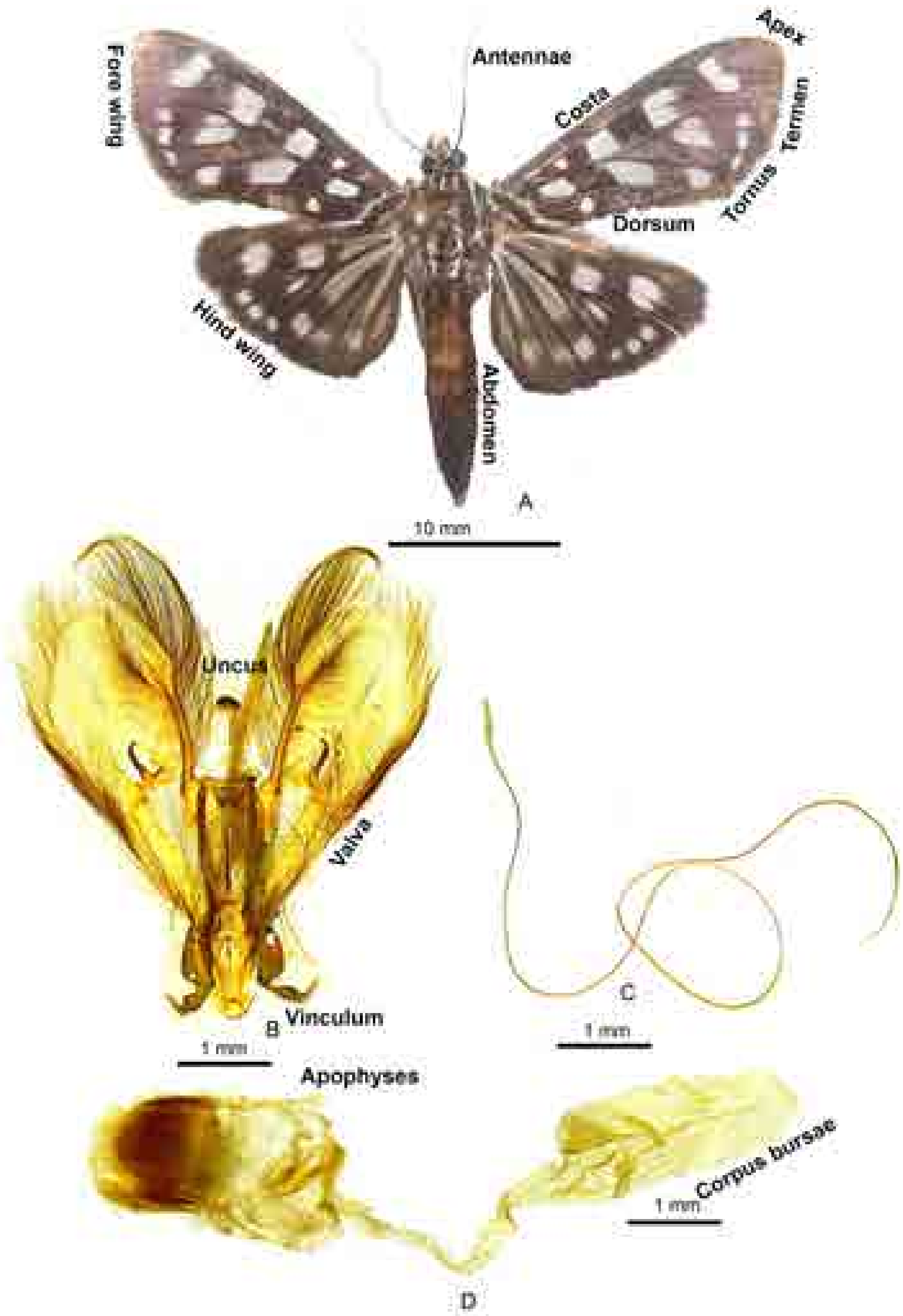

Image 1. *Pygospila tyres*: A—Adult | B—Male genitalia | C—Aedeagus | D—Female genitalia.

specimens as the sequence is forming monophyletic clade with the members of *P. bivittalis* from Australia. Although there are limitations with the phylogenetic inferences of mt COI DNA barcode trees, our studies could discern three clear clades for the species *P. tyres, P. bivittalis* and *P. hyalotypa.* Of the extant eleven species of *Pygospila*, we could include data of three species in the phylogenetic studies including our sequences from India for *P. tyres*.

Since the species *P. tyres* is of economic importance, the present mt DNA Barcode data generated is expected to be helpful in building a reliable DNA barcode library for the country intimated with a voucher specimen and helpful in addressing the taxonomic problems as the morphological characters are cryptic. Interestingly *P. tyres* was described almost 240 years ago from India

Table 1. GenBank details for the mt DNA COI sequences utilized in the construction of the phylogenetic tree.

	GenBank Accession No.	Locality	Species name as per NCBI	Publication details as per NCBI
1	HQ953036.1	Australia: Northern Territory	*Pygospila tyres*	Unpublished
2	HQ953033.1	Australia: Northern Territory	*Pygospila tyres*	Unpublished
3	KF392550.1	Australia: New South Wales, Mt. Lewis	*Pygospila tyres*	Hebert et al. 2013
4	MT776312.1	India: Maharashtra	*Pygospila tyres*	This study
5	KX862292.1	Pakistan: Kashmir, Peer Chinassi, Azad Kashmir	*Pygospila tyres*	Ashfaq et al. 2017
6	KT988774.1	Korea	*Pygospila tyres*	Unpublished
7	HQ990826.1	Pakistan	*Pygospila tyres*	Unpublished
8	HQ953034.1	Australia: Queensland, Keating Gap,3 km SW of Cooktown	*Pygospila tyres*	Unpublished
9	HQ990827.1	Pakistan	*Pygospila tyres*	Unpublished
10	HQ953035.1	Australia: Western Australia, 18 km from Fitzroy Crossing	*Pygospila tyres*	Unpublished
11	HQ990825.1	Pakistan	*Pygospila tyres*	Unpublished
12	HQ990824.1	Pakistan	*Pygospila tyres*	Unpublished
13	HQ990828.1	Pakistan	*Pygospila tyres*	Unpublished
14	HQ953031.1	Australia: Queensland, Gordon`s Mine, Claudie Riv	*Pygospila hyalotypa*	Unpublished
15	HQ953030.1	Australia: Queensland, Moses Ck 4km Nby E of Mt. Finnigan	*Pygospila hyalotypa*	Unpublished
16	HQ953032.1	Australia	*Pygospila hyalotypa*	Unpublished
17	HQ953029.1	Australia: Queensland, Gap Creek, rainforest	*Pygospila bivittalis*	Unpublished
18	HQ953028.1	Australia: Queensland, Gap Creek, rainforest	*Pygospila bivittalis*	Unpublished
19	HQ953027.1	Australia: Northern Territory, Solar Village Humpty Doo	*Pygospila bivittalis*	Unpublished
20	JX017862.1	Australia	*Pygospila tyres*	Hains & Rubinoff 2012
21	GU695393.1	Papua New Guinea	*Pygospila marginalis*	Unpublished
22	KY370911.1	Papua New Guinea: Madang, Mis village	*Pycnarmon jaguarali*s	Unpublished
23	KF394279.1	Australia: Queensland, Mt. Bartle Frere, east base	*Pycnarmon jaguaralis*	Hebert et al. 2013
24	KF391152.1	Australia: Queensland, Etty Bay	*Pycnarmon jaguaralis*	Hebert et al. 2013
25	MK459732.1	China	*Pycnarmon pantherata*	Mally et al. 2019
26	KF492066.1	Japan: Chubu, Shizuoka-shi, Honkawane, Kaminagao	*Pycnarmon pantherata*	Unpublished
27	KF390443.1	Australia: Queensland	*Pycnarmon meritalis*	Hebert et al. 2013

and now the species is known to have a wide range of distribution in Asia and Australia. Original description of the species *P. tyres* from Coromandel region and our multiple collections from the parts of Deccan plateau and the northern Western Ghats are similar in morphological characters. Genetic homogeneity with mt COI DNA gene studies across the two continents (Asia and Australia) reestablishes the wide distribution across these landscapes.

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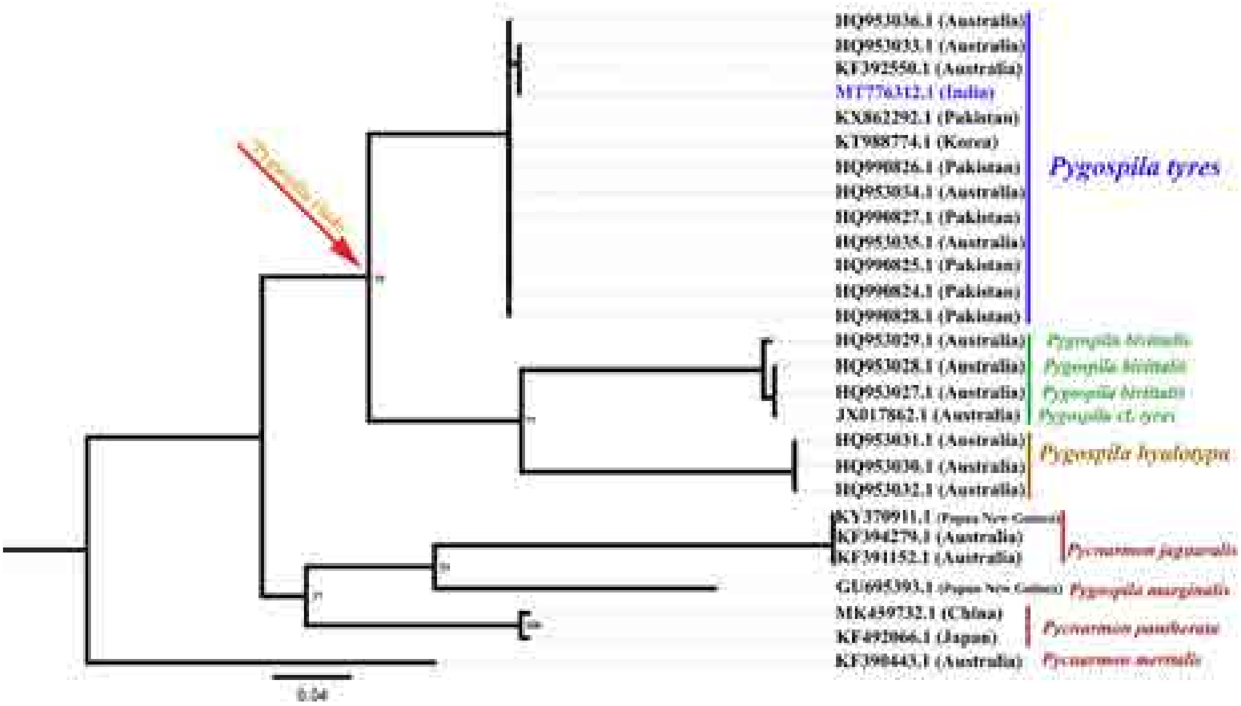

Figure 2. Maximum likelihood (ML) tree for the species of *Pygospila* based on 599 bp of mt COI DNA.

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SHORT COMMUNICATION

First record and description of female *Onomarchus leuconotus* (Serville, 1838) (Insect: Orthoptera: Tettigoniidae) from peninsular India

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Abstract: The members of family Tettigoniidae, commonly called katydids, generally exhibit mimicry and camouflage with shapes and colours similar to leaves. The genus *Onomarchus* Stal is mainly distributed in temperate and tropical Asia, and was earlier reported from Assam and West Bengal in India. The species *Onomarchus leuconotus* (Serville, 1838) is reported here for the first time in peninsular India from the Western Ghats (Chandoli National Park, Kolhapur, Maharashtra). This record extends the known geographical range of this species by about 1630 km. As its holotype is not described from India, the female of *O. leuconotus* is described here via detailed diagnostic characters, colour photographs and illustrations.

Keywords: Distribution, female description, katydid, *leuconotus*, Phaneropterinae.

During a survey of Orthoptera from the Western Ghats area, we came across a green Tettigonid at Chandoli National Park of Kolhapur district, and identified it as *Onomarchus leuconotus,* not previously reported from peninsular India.

The genus *Onomarchus* Stal, 1874 is spread across temperate and tropical Asia, and so far represented by five species (http://orthoptera.speciesfile.org, accessed on 7 May 2021). From India, Shishodia et al. (2010) listed *Onomarchus bisulacatus* from Mizoram, and *Onomarchus leuconotus* from Assam and West Bengal. Subsequently, Srinivasan and Prabakar (2012) reported *Onomarchus uninotatus* from Arunachal Pradesh. Serville (1838) described the male of *O. leuconotus*, while Barman (1993) provided minimum information about the diagnosis of this species and mentioned its locality as West Bengal (Kolkata) and Assam of India, as did Shishodia et al. (2010) who made a checklist without diagnosis and deposition records. Our report is the first record for the Western Ghats and peninsular India. Here we describe female *O. leuconotus* by giving detailed diagnostic characters, colour photographs and illustrations.

Materials and Methods

Material examined: ZSUK.E.TT.07, 1 female, 15.xi.2012, Ukhalu, Chandoli National Park, Kolhapur, Maharashtra, India (Figure 1), 17.126^{0}N and 73.860^{0}E, 844 m, coll. Y.J. Koli, deposited in Department of Zoology, Shivaji University, Kolhapur. The specimen was studied under a Nikon stereozoom (SMZ 800) microscope and photographed using a Canon 550D camera with 100 mm lens. Measurements were done with digital Vernier

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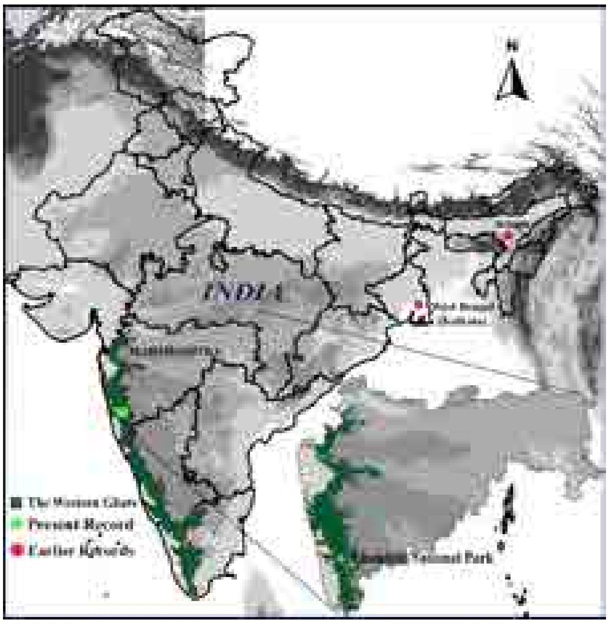

Figure 1. Distribution records of *Onomarchus leuconotus* in India.

calipers. The specimen was identified as *O. leuconotus* by using the original description (translated from French to English) of Serville (1838), De Jong (1939), Barman (1993), and images of the type specimen and keys on the website Orthoptera Species File (http://orthoptera.speciesfile.org). Dr. Sigfrid Ingrisch from The Alexander Koening Zoological Research Museum in Germany confirmed the identification based on images of the specimen.

Results

Description Female (Image 1 & 2):

Measurements (in mm): body length 82; pronotum 11; tegmen 75 & width 26; fore femur length 10, mid femur 12, hind femur 25, hind tibia 24; ovipositor length 30 & width 7 mm.

Diagnostics

Head: Lateral margins, starting from the lower margin of the eyes and antennal socket downwards along the genae, broadly yellowish-white; labrum and mandibular base whitish (Image 1A, E).

Pronotum: short, disc white, hind margin acutely angular, centrally one long and one slightly short transverse groove running downwards and short vertical groove intersect posterior transverse suture vertically (Image 2A).

Meso and Metasternum: mesosternum somewhat quadrate, metasternum subquadrate narrows posteriorly; two large pits are situated nearly in the central area in both meso and metasterna and one very fine additional pit found near mesosternal caudal margin medially; pits in the metasternum joined by nearly straight grooves, mesosternal lateral pits joined to the medial pit by oblique grooves (Image 2B).

Legs: yellowish, fairly short; fore and mid femur barely dented below; fore femur bearing three spines on internal carina and 6 spines on external carina; mid femur bearing five spines on external carina and seven spines on internal carina; hind femur bearing five strong spines, broad at the base and hooked at tip and four small spines on external carina and 10 small spines on internal carina; hind tibia armed with five spines on the upper side and ventrally seven pairs of moderate spines, 4^{th} pair separated.

Forewing: slightly leathery, undulating anteriorly, large, more than twice the length of the body (Image 1A). *Venation* (Image 2C)*:* The costa (C) fine, unbranched, long, runs along the anterior margin; subcosta (Sc), branched into anterior short subcostal (Sc1) and long posterior subcostal (Sc2); the radius (R), most prominent, runs 2/3 distance and branched into anterior radius (R1) and posterior radius (R2); median (M) long runs parallel to radius for a short distance and then separates, reaching to the apical region; cubitus (Cu) forks at the base into long cubitus 1 (Cu1) and short cubitus 2 (Cu2), continues with a hind margin of tegmen; anals short, unbranched, 4 in number (A1, A2, A3, and A4).

Hindwing: large, hyaline, protruding beyond the tegmina at rest (Image 1A).

Abdomen: Last abdominal tergite short, transverse, subfused with epiproct; epiproct semicircular with shallow Y shaped furrow; cerci cylindrical, narrower towards the apex, sinuately curved outside before apex, apex obtuse dark coloured with a minute spinule; subgenital plate roughly triangular with basal angles rounded, basal half portion strongly raised in the midline, apical half portion with fine medial furrow, apex subtruncate, crenulated and obtusely projecting short lateral lobes (Image 1C,D); ovipositor large about four times longer than broad, sabre like, dorsal valves with seven oblique furrows at apex, 2/3 ventral valve and 1/3 dorsal valve dark black (Image 1B).

Discussion

This species is distributed in India, Malaysia, Sumatra, Papua New Guinea, Java, China, Maluk, Indo-China, and Vietnam (http://orthoptera.speciesfile.org, accessed on 30 April 2021). This is the first illustrated report of this species from Western India, and the present record extends its known geographical range from Kolkata

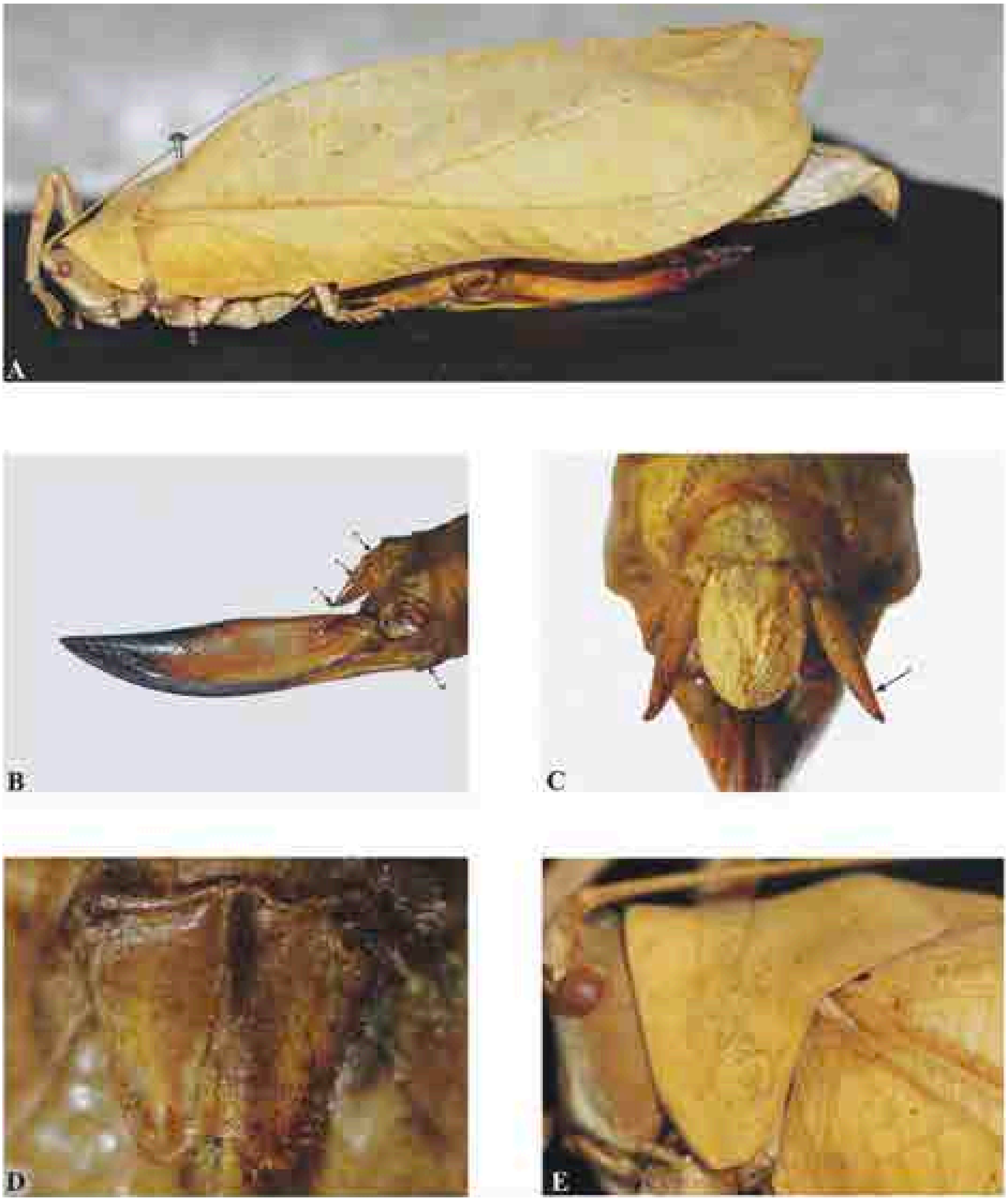

Image 1. A—*Onomarchus leuconotus* (lateral habitus of female) | B—Ovipositor | C—epiproct & abdominal apex with cerci (dorsal view) | D—subgenital plate (ventral view) | E—head- whitish gena & pronotum (lateral view). Abbreviation: tt—tenth abdominal tergite | e—epiproct | c—cercus | sg—subgenital plate. © Sunil Gaikwad.

to western India, a distance of about 1,630 km by air (Figure 1).

The holotype of *Onomarchus leuconotus* is from Java, and the type specimen of this species is in the Natural History Museum, London. Serville originally described the *O. leuconotus* (male) in 1838 as *Pseudophyllus*

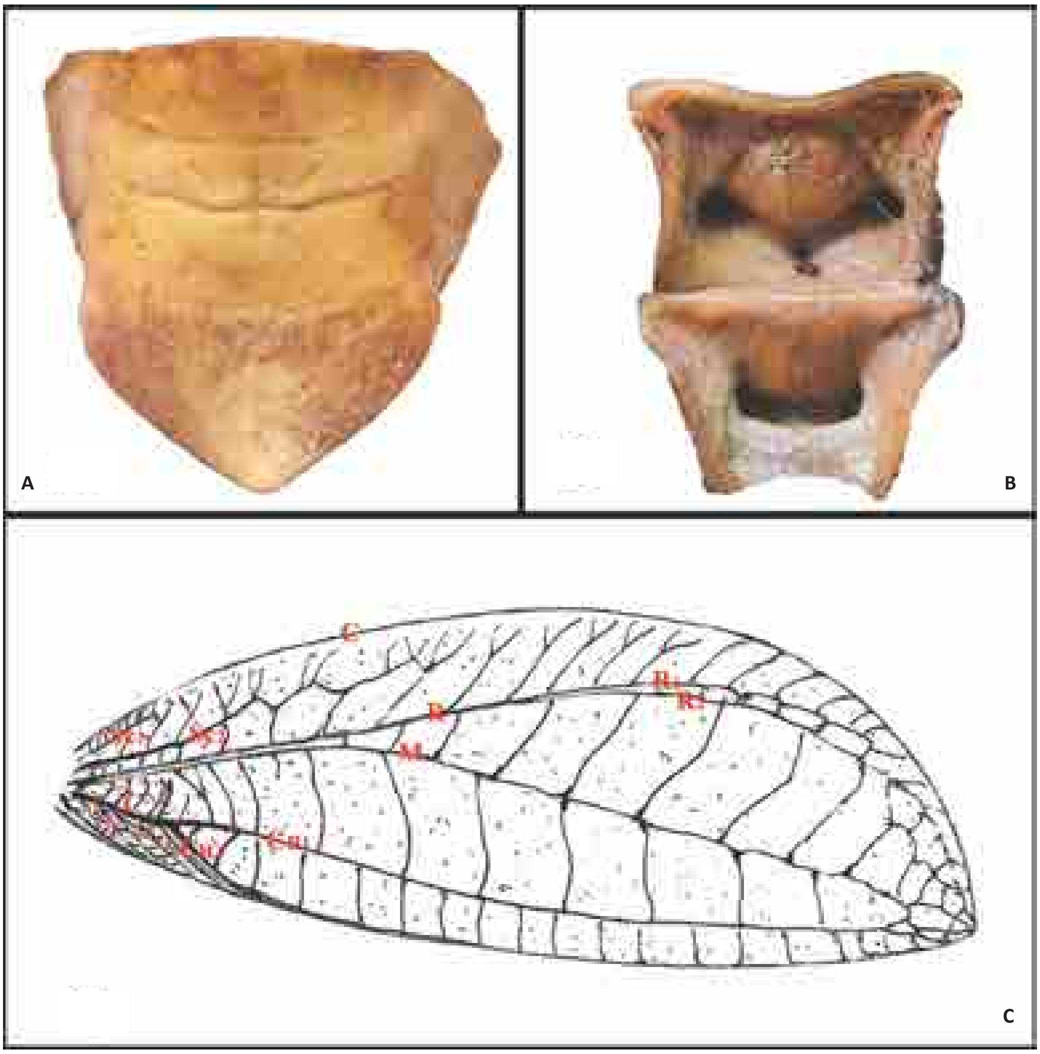

Image 2. ***Onomarchus leuconotus*****: A—pronotum with two horizontal & one vertical groove and acute angular hind margin (dorsal view) | B—meso and metasternum with deep pits | C—line drawing depicts right forewing venation- Costa (C); Subcosta 1 (Sc_1), Subcosta 2 (Sc_2); Radius (R), Radius 1 (R_1), Radius 2 (R_2); Median (M); Cubitus (C), Cubitus 1 (Cu_1), Cubitus 2 (Cu_2); Anals (A_1, A_2, A_3, A_4). © Sunil Gaikwad.**

leuconotus in French. The same species was later described with three synonyms: *O. albisellatus* (Walker 1870), *O. latipennis* (Pictet & Saussure 1892) and *O. nobilis* (Brunner 1895), none described from India. However, Barman (1993) recorded *O. leuconotus* from India with scant diagnostics.

According to the original description by Serville (1838), elaborative diagnostics of de Jong (1939), images and keys on http://orthoptera.speciesfile.org, the specimen recorded from Chandoli National Park is treated here as *O. leuconotus*. The whitish genae, part of mouth and labrum; pronotal colour and shape; structure of meso- and metasternum; hind tibiae with strong 5 spines dorsally; broad tegmina and ovipositor in the present specimen are identical with *O. leuconotus*.

de Jong (1939) mentioned important characters for identifying the three species of Serville. If hind tibia has five strong thorns on the dorso-internal margin, pronotum dorsally white, broad tegmen and ovipositor: *O. leuconotus*; if seven strong thorns on the dorso-internal margin of hind tibia, a white spot near the base of the tegmen and ovipositor five times as long as broad: *O. uninotus* and if six small thorns on hind and lot of white spots on tegmen and ovipositor is about six times longer than its thickness: *O. cretaceus*. Since the characters suggested for *O. uninotus* and *O. cretaceus*, are not found in our specimen and since our specimen contained the characters mentioned for *O. leuconotus* by de Jong (1939), our specimen proves to be *O. leuconotus.* Considering the thorns on the feet, it appears that only the large spines on the hind tibia are counted, mainly for *O. leuconotus*. However, while describing our specimen, it has been found that in addition to large thorns, many small and blunt thorns are also found on femur and tibiae. It seems that the counting of the small spines has not been given importance thus information on this count is given here. Moreover, he mentioned additional character for *O. leuconotus* that narrow strip of little pits running from the lower margin of the eyes downwards along the genae, which is not found in the other species and the shape of the meso- and metasternum by line drawings. The characters and line drawings of meso- and meta-sternum given by de Jong (1939) are clear in our specimen. In addition, as per the revision of the Pseudophyllinae by Beier (1954), our specimen agrees best with *O. leuconotus* (Serville 1838). The smooth pronotum, the sinuate shape of the dorsal margin of the tegmen and its venation, and the white band at the genae agree with that species.

The pronotum has only one transverse groove in the anterior half of the disc, and the hind margin is acutely angular (de Jong 1939). The line drawing of pronotum on the website of Orthoptera species File (http://orthoptera.speciesfile.org) shows one transverse and one vertical groove, which intersect horizontal one. However, the pronotum of the specimen under study is having an additional short transverse groove. This is probably because our specimen is female, it may have another groove in it, or it may not have been noticed, as the anterior transverse groove is indistinguishable.

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SHORT COMMUNICATION

New records of odonates (Insecta: Odonata), *Archibasis oscillans* Selys, 1877 and *Merogomphus tamaracherriensis* Fraser, 1931 from Maharashtra, India

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Abstract: *Archibasis oscillans* Selys, 1877 is reported for the first time from Maharashtra, India; and first record of *Merogomphus tamaracherriensis* Fraser, 1931, based on photographic evidence taken from Sindhudurg, Maharashtra. We report the range extension of both the species in the northern Western Ghats.

Keywords: Kalse stream, Kudal taluka, photographic evidence, Sindhudurg.

The genus *Archibasis* Kirby, 1890 is distributed from India to northern Australia including Sri Lanka, southeastern Asia, Papua New Guinea, Solomon Islands (Connif & Bedjanic 2013). *Archibasis oscillans* Selys, 1877 is the only species currently known from India (Subramanian et al. 2018; Kalkman et. al 2020). Initially, this species was described as *A. mimetes praeclara* by Fraser, 1933. Later it was revised by Lieftinck (1949) as *A. oscillans*. Including this, Lieftinck (1949) listed six more species, which included *A. incisura* Lieftinck, 1949, *A. melanocyana* Selys, 1877, *A. mimetes* Tillyard, 1913, *A. tenella* Lieftinck, 1949, and *A. viola* Lieftinck, 1948 (Conniff & M. Bedjanič 2013). A few years later, *A. rebeccae* was described by Kemp (1989). Recently in 2013, *A. lieftincki* and *A. oscillans hanwellanensis* was described by Conniff & M. Bedjanič (2013).

Genus *Merogomphus* comprises a total of 11 species worldwide which includes *M. chaoi* Yang & Davies, 1993, *M. femoralis* Laidlaw, 1931, *M. parvus* Kruger, 1899, *M. pavici* Martin, 1904, *M. tamdaoensis* Karube, 2001, *M. torpens* Needham, 1930, *M. vandykei* Neddham, 1930, and *M. vespertinus* Chao, 1999. Among these, Fraser (1933) introduced three species from India, *M. longistigma*, Fraser 1922, *M. tamaracherriensis* Fraser, 1931, and *M. martini* Laidlaw, 1930. Recently, Kosterin (2016) rearranged the species *M. martini* and described a new combination *Euthygomphus martini* (Kalkman et al. 2020). However, only two Western Ghats endemic species of this genus have been currently known from India (Kalkman et al. 2020).

Till date various worker surveys Odonate fauna of Maharashtra and succeeded to enlist about 134 species (Kulkarni et al. 2012; Tiple et al. 2013; Tiple & Koparde 2015). In this paper we report the first record of *A. oscillans* and new distributional record of *M. Tamaracherriensis* from Maharashtra.

Material and Methods

In July 2021, Akshay Dalvi (Hereafter AD) first observed and photographed *Archibasis oscillans* at Kalse

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INDIA

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stream (16.024N & 73.601E), situated in Kudal taluka, Sindhudurg, Maharashtra. The specimen was preserved in 70% alcohol and deposited at the Zoological Survey of India (ZSI), Pune. At the same time in July 2021, Amol Kambli first observed and photographed a female of *Merogomphus tamaracherriensis* at Varavde, Kankavali, Sindhudurg district (16.268N & 73.677E). In August 2021, an additional field record of a male was taken by AD at Bambarde, Dodamarg taluka and successively at Koloshi, Devgad taluka, on 08 October 2021. All the field photographs were taken using Canon 760D camera and 100 mm micro. Microscopic photos of *A. oscillans* male were taken using model LM-52-3621 at Shivaji University, Kolhapur. The morphological characters of the collected specimen matched with that of the male specimen described earlier by Fraser (1933, 1934). Morphological terms refer to Garrison et al. (2006). Map used in Image 5 is created using QGIS v3.10.2.

Archibasis oscillans **Selys, 1877 (Image 1 & 2)**

Material examined: Ent.4/2934, 12.viii.2021, male, Kalse, Kudal Taluka, Sindhudurg District, Maharashtra, India (16.024N & 73.601E), Akshay Dalvi leg.

Brief description of male (Image 1, 2)

Description: Head (Image 1a–d): Labium, labrum, base of mandibles pale blue; postclypeus blue with two small broad black circles joined each other, two triangular blue postocular spots connected with a thin blue band; eyes black above and blue beneath. Thorax*:* prothorax (Image 1d) blue with a combination of broad black bands making an 'M' shape structure at the middle lobe; synthorax (Image 1c,d) broadly black on dorsum with azure blue ante humeral stripes. Wings (Image 1f, g): hyaline, 10 to 15 post nodal nervures in the fore wing. Abdomen (Image 1a,e): segment 1 entirely blue, segment 2 black on dorsum and blue laterally, segment 3 to 6 black on dorsum and yellowish on sides, last three segments entirely blue with black apical ring. Caudal appendages (Image 2a,b): black, superiors as long as segment 10, apical notch at the tip, inferiors two-third the length of superiors.

Diagnosis: Diagnostic characters are based on available literature (Fraser 1933; Connif & Bedjanic 2013) and after comparing our specimen with the original description and photographic evidence available on the website 'Odonata of India'. This genus can be easily differentiated from *Pseudagrion* Selys, 1876 by following characters: (i) Pterostigma almost square and slightly convex (Image 1f) in *Archibasis* Kirby, 1890 and rectangular in shape, longer than broad in *Pseudagrion*; (ii) 8 to 15 postnodal nervures in *Pseudagrion* whereas *Archibasis* have 10 to 13 post nodal nervures; (iii) *Archibasis* has distinct blue colouration with black markings and species included in the genus *Pseudagrion* are found in various colours like red, blue, orange and green with black markings; (iv) Superior anal appendages in *Archibasis* are shorter with tiny apical notch (Image 2b) whereas in the case of *Pseudagrion*, they are longer and deeply notched (Image 2d).

It can be distinguished from *A. melanocyana* by: (i) Inferior two thirds the length of superior in *A. oscillans* whereas inferiors are less than half of superior in *A. melanocyana*; (ii) In case of *A. Melanocyana*, inferiors have a small spine on the inner side which is absent in *A. oscillans*. However, the markings on the head, synthorax, and abdomen (Image 1a,e) appear to be more or less the same among these two species. *A. oscillans*is morphologically very similar in comparison with the original description of *A. oscillans hanwellaanensis* Conniff & Bedjanič, 2013 and *A. lieftincki* Conniff & Bedjanič, 2013. The tip of superior anal appendages in *A. oscillans*is flat hollow and curved inwards (Image 2a) which is similar with *A. lieftincki.* Two main differences that distinguish *A. lieftincki* from *A. oscillans* are: (i) They have considerably expanded flap-like superiors which is never seen in case of *A. oscillans*; (ii) Also, inferiors are less than half of superiors which are the same as in the case of *A. melanocyana* whereas *A. oscillans* have inferiors two thirds of the length of the superior. *A. viola* Lieftinck, 1948 and *A. rebeccae* Kemp, 1989 can also be distinguished from the *A. oscillans* by their distinct violet colour and clubbed cerci, respectively.

Distribution (Image 5a,b): The previous western limit of this species was confined to Coorg, South Kanara, southern Malabar, and parts of the Wynaad (Fraser, 1933) (Image 5a). Further records of this species were taken by iNaturalist from several other locations in Kerala, Karnataka as well as Goa (Image 5b). Our records extend the range of this species further north. Apart from India, this species is also found in Indonesia, Lao People's Democratic Republic, Sri Lanka, and Thailand (Subramanian et al. 2018).

Habitat (Image 4a): This species was found in a small seasonal stream in Kalse village, Sindhudurg district. This locality is situated close to the Karli River, surrounded by paddy fields and wetland. Five to six males were found near small shrubs adjacent to this stream.

Merogomphus tamaracherriensis **Fraser, 1931 (Image 3)**

Material examined: Male, 25.viii.2021, Bambarde,

Image 1. ***Archibasis oscillans*** **(Selys, 1877) male: a—habitus, lateral view | b—face | c—thorax, lateral view | d—thorax, dorsal view | e—abdomen, lateral view | f—pterostigma, left FW| g—left FW and HW | h—secondary genitalia | © a–h—Akshay Dalvi.**

Dodamarg, (16.268N, 73.677E); male, 8.x.2021, Koloshi, Devgad (16.384N, 73.625E); female, 29.vii.2021, Varavade, Kankavali (16.024N, 73.601E).

Brief description of male (Image3a–d)

Head (Image 3b): Eyes apple green; labium, labrum, and occiput entirely black; broad yellow stripe above frons. Thorax (Image 3a): prothorax black with yellow marking, synthorax (Image 3a) black with yellow antihumeral stripes running along the dorsal carina. Mesepimeron and Metepimeron with broad yellow stripes with thin yellow line on metepisternum. Abdomen (Image 3a): segment 1 to 3 with broad yellow stripe on dorsum and quadrate or triangular spot-on lateral, Segment 4 to 6 with no mid dorsal spot. Segment 7 has its basal half broadly yellow; segment 8 with small diamond shaped spot-on dorsal side; segment 9 to 10 unmarked. Caudal appendages (Image 3d): cerci milky

Image 2. Caudal appendages of *Archibasis oscillans* (Selys 1877) male: a—dorsal view | b—lateral view. *Pseudagrion microcephallum* (Rambur 1842): c—dorsal view | d— lateral view | © a–d—Yogesh Koli.

Image 3. *Merogomphus tamaracherriensis* (Fraser, 1931): a—male, habitus, lateral view | b— male, habitus, frontal view, | c— female, habitus, dorsal view| d— male, caudal appendages | © a—Gurunath Kadam | © b, d—Akshay Dalvi | © c—Amol Kambli.

Image 4. Habitat photos of: a—Kalse stream | b—Bambarde| c— Koloshi | d—Varavde | © a—c Akshay Dalvi © d—Amol Kambli

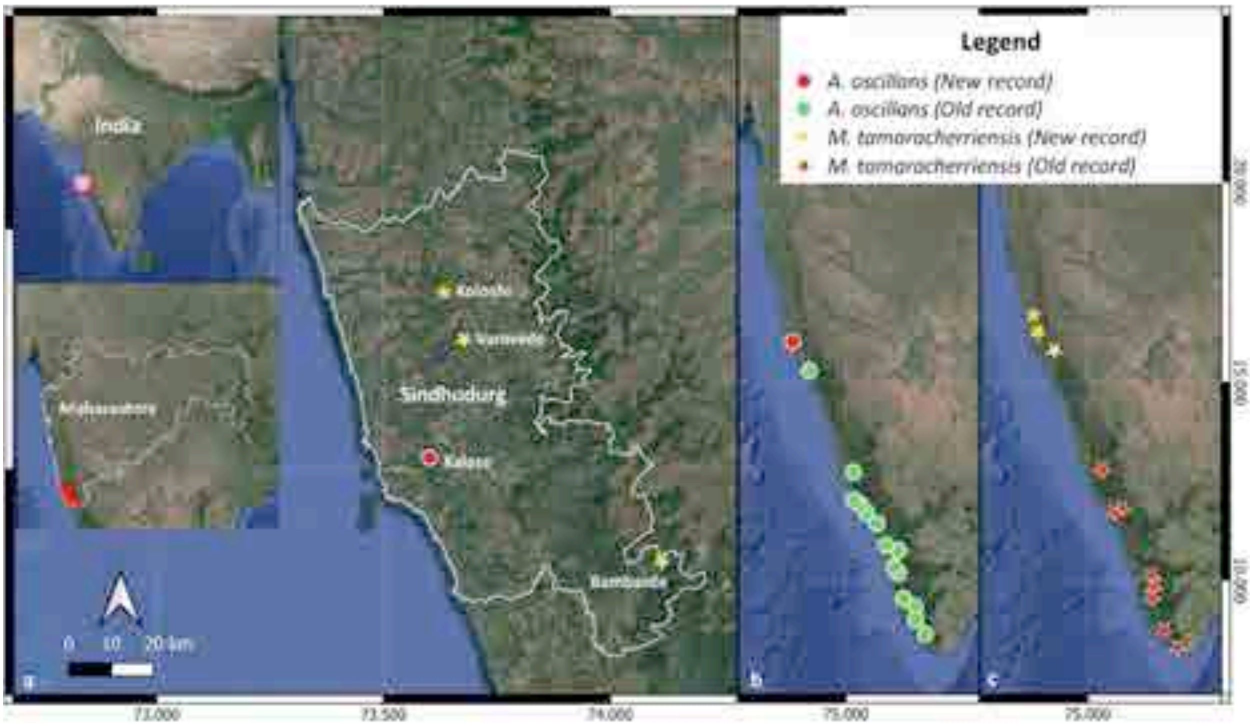

Image 5. Mpas of: a—Sindhudurg District with distribution of *Archibasis oscillans* (Selys 1877) and *Merogomphus tamaracherriensis* (Fraser, 1931) | b—*A. oscillans* | c—*M. tamaracherriensis.* Map created using QGIS v3.10.2 by Akshay Dalvi.

white pointed at the tip with finely distributed black hairs, curled like the horns of a bull; base slopes sharply away from the inner side;

Female (Image 3c): very similar to the male as far as head, thorax and abdominal colour pattern. Abdomen is broader at the base and shorter as compared to the male. Anal appendages simple, white, and pointed.

Diagnosis: Fraser initially described this species as a subspecies of *Merogomphus longistigma* in 1931. Later he revised it in 1953 as advised by D.E. Kimmans (Fraser 1953). Following diagnostic characters are based on Fraser 1934 and specimens that we observed during the survey. *M. tamaracherriensis* can be distinguished by *M. longistigma* by following characters: (i) Occiput entirely black, while greenish-yellow in *M. longistigma*, (ii) Mid dorsal spot-on segment 3 is isolated and absent on segment 3 to 6 in *M. tamaracherriensis*, present in others, (iii) A diamond-shaped yellow spot appears on segment 8, no marking is seen on segment 9 and 10, whereas in *M. longistigma* only mid dorsal carina appears on segments 8 to 10, (iv) Lateral spine of cerci is more pointed than *M. longistigma* and base sharply away on the inner side, while depressed for the distal half and apices turn sharply upwards in others.

Habitat (Image 4b,c,d): This species prefers slow moving streams, marshy land or riverside habitat. Female of this species firstly observed near the riverside area in Varavade village Kankavli. This region is surrounded by seasonal flowing streams with tree canopy and small patches of paddy field surrounding it. First male record of this species was taken in Bambarde village, Dodamarg. This particular locality is surrounded by Myristica swamp on one side and paddy fields on the other. More records were also taken from Koloshi stream, Devgad. It is a seasonal stream surrounding the tree canopy and grassland at the edges. Male specimen was found resting on vegetation along the stream and small rocky areas between the stream.

Distribution (Image 5a,c): Earlier records were limited to parts of Karnataka, Kerala, and Tamil Nadu. These records extend the distribution range of this species to the further north.

Discussion: We recorded two odonate species from northern Western Ghats, both are in addition to the Odonata fauna of Maharashtra. The presence of *Archibasis oscillans* in northern Western Ghats is not quite surprising as it was already reported near Goa in recent years (Subramanian et al. 2018). This study area was never surveyed before by any means and surprisingly this species was found in a human disturbed area. More surveys will surely reveal the actual geographical distribution of this cryptic species in northern Western Ghats.

M. tamaracherriensis is a Western Ghats endemic species whose earlier records were confined to southern parts of the Western Ghats only. For the first time since then, a female and successively a male were found in Sindhudurg district, Maharashtra. The male of this species was found just outside the Myristica swamp, Dodamarg. The government of Maharashtra has already declared this region as a Biodiversity heritage site in the year 2021 which would definitely help protect such infrequent species. Many new records and newly described odonata species from Sindhudurg district greatly signify the true potential of this region (Joshi & Sawant 2019, 2020; Koli & Dalvi 2021; Koli et al. 2021). Coastal regions including the Sindhudurg and Ratnagiri district harbor many wetlands, small seasonal streams and water bodies on rocky plateaus. Exclusive surveys of these habitats may reveal many new observations, therefore more work has to be done to study the diversity of odonates in the entire northern Western Ghats.

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SHORT COMMUNICATION

A checklist of dragonflies & damselflies (Insecta: Odonata) of Kerala, India

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Abstract: A checklist of odonates of Kerala State is presented in this paper. Scientific binomen, vernacular names in Malayalam, IUCN Red List status, and endemism are also given. A total of 174 species of odonates have been recorded from Kerala till date, 65 of which are endemic to the Western Ghats, and 10 to India. Five species fall under various threatened categories of IUCN. None of the odonates occurring in Kerala is listed in the schedules of the Indian Wildlife (Protection) Act or the appendices of CITES.

Keywords: Biodiversity, endemism, odonates, Western Ghats, IUCN Red List.

A total of 6,324 species of odonates from 45 families have been described from around the globe till date (Paulson & Schorr 2021). In India, 493 species from 18 families are known. The Western Ghats, which forms part of a global biodiversity hotspot has 196 species of odonates (Subramanian & Babu 2020). High endemism and diversity is seen in the southern Western Ghats (Subramanian & Sivaramakrishnan 2002), of which Kerala is a part. Odonatology in India can be traced back to Carl Linnaeus and Selys-Longchamps who described some of the first species from India. During the British Raj, Laidlaw started the systematic documentation of odonates which was taken to its pinnacle by F.C. Fraser. In his three volume treatise (Fraser 1933, 1934, 1936) on the odonates of the Indian subcontinent, Fraser gave a detailed account of the odonates of Kerala also. After independence, the documentation of odonate fauna in India was taken up mostly by the scientists of Zoological Survey of India (ZSI) and some regional universities, with many papers being published on new species descriptions, life histories and distribution of Odonata. Prasad & Varshney (1995) published a checklist of Odonata of India which was a major landmark in Indian Odonatology.

After Fraser, there was a significant gap in the study of Odonata in Kerala which was gradually filled by the works of Peters (1981), Rao & Lahiri (1982), Prasad (1987), Mathavan & Miller (1989), Radhakrishnan (1997), Emiliyamma & Radhakrishnan (2000, 2002), Palot et al. (2002), Radhakrishnan & Emiliyamma (2003), Emiliyamma (2005), and Subramanian & Sivaramakrishnan (2005). Odonata watching was popularized with the publication of field guides by Emiliyamma et al. (2005), Subramanian (2005, 2009), and Kiran & Raju (2013). The conservation of odonates of the Western Ghats was highlighted in the works of Subramanian (2007) and Subramanian et al. (2011). ZSI has been publishing updated checklists of Odonata of India periodically and the latest version has listed 488 species (Subramanian & Babu 2017). A systematic study of Odonata of the southern Western Ghats was

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done by Emiliyamma (2014) in which 169 species were listed from the region. The first checklist of Odonata of Kerala was compiled by Kiran & Raju (2011) in which 148 species were included. Subramanian et al. (2018) gave a detailed account of the distribution of odonates in the Western Ghats. However, there has been no bona fide attempt to update the checklist of Odonata of Kerala with species that were newly described (Subramanian et al. 2013; Kiran et al. 2015; Emiliyamma & Palot 2016b; Joshi & Sawant 2019; Rangnekar et al. 2019; Joshi & Sawant 2020; Emiliyamma et al. 2020; Joshi et al. 2020) and whose range extensions were published (Das et al. 2013; Emiliyamma et al. 2013; Emiliyamma & Palot 2016a; Rison & Jose 2019; Varghese 2019; Rison & Chandran 2020; Muneer & Chandran 2020; Chandran et al. 2021; Haneef et al. 2021). Besides, citizen science portals have helped to document the occurrence of some rare odonates in Kerala (Anonymous 2021; Ueda 2021a,b,c). Nair et al. (2021) reported 181 species of Odonata from Kerala, but many of these records lack taxonomic, or even photographic evidence (Chandran & Sherif in press). Here, we list Odonata species whose occurrence in Kerala have been confirmed either from earlier published records or by presenting new evidence.

Studies on the geographical distribution of Odonata are a prerequisite for their conservation (Moore 1997). This paper attempts to provide a comprehensive and up-to-date list of odonates known from Kerala. We have omitted three species, *Asiagomphus nilgiricus* (Laidlaw, 1922), *Heliogomphus kalarensis* Fraser, 1934, and *Idionix nadganiensis* Fraser, 1924 from the previous list for want of evidence of their occurrence in Kerala. Moreover, Subramanian et al. (2018) have not shown records of these species from Kerala. We have desisted from using English common names in this list because multiple names are prevalent for many species. Malayalam names widely used in the state and listed in the website of Society for Odonate Studies (2021) have been added. The taxonomy and systematic arrangement follows Kalkman et al. (2020). A total of 174 species from 14 families belonging to two suborders are listed with their Malayalam names, references, IUCN Red List status and endemicity. Of the species listed, 65 are endemic to the Western Ghats and 10 to India. None of the species are protected under the Indian Wildlife (Protection) Act or come under the appendices of CITES. The sole Endangered species, *Idionyx galeata* Fraser, 1924 is a rare forest insect endemic to the Western Ghats. All the four species classified as Vulnerable are also endemic to the Western Ghats (IUCN 2021). It must be noted that out of the 174 species of Odonata recorded from Kerala till date, 27 are Data Deficient and 21 remain Not Evaluated in the IUCN Red List of Threatened Species.

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Table 1. Checklist of dragonflies & damselflies (Insecta: Odonata) of Kerala, India.

	Scientific name	Malayalam name	References	IUCN	END
	Order: Odonata				
	I. Suborder: Zygoptera	**സൂചിത്തുമ്പികൾ**			
	1. Family: Lestidae	**ചേരാച്ചിറകൻ തുമ്പികൾ**			
1	*Indolestes gracilis* (Hagen in Selys, 1862)	കാട്ടു വിരിച്ചിറകൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
2	*Indolestes pulcherrimus* (Fraser, 1924)	ചതുപ്പ് വിരിച്ചിറകൻ	Muneer & Chandran (2020)	DD	EN WG
3	*Lestes concinnus* Hagen in Selys, 1862	തവിടൻ ചേരാച്ചിറകൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
4	*Lestes dorothea* Fraser, 1924	കാട്ടു ചേരാച്ചിറകൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
5	*Lestes elatus* Hagen in Selys, 1862	പച്ച ചേരാച്ചിറകൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
6	*Lestes malabaricus* Fraser, 1929	മലബാർ ചേരാച്ചിറകൻ	Kiran & Raju (2011); Subramanian et al. (2018)	NE	
7	*Lestes nodalis* Selys, 1891	പുള്ളി വിരിച്ചിറകൻ	Emiliyamma & Palot (2016a); Subramanian et al. (2018)	LC	
8	*Lestes patricia* Fraser, 1924	കരിവരയൻ ചേരാച്ചിറകൻ	Subramanian et al. (2018)	NE	EN WG
9	*Lestes praemorsus* Hagen in Selys, 1862	നീലക്കണ്ണി ചേരാച്ചിറകൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
10	*Platylestes kirani* Emiliyamma, Palot & Charesh, 2020	കിരണി ചേരാച്ചിറകൻ	Emiliyamma et al. (2020)	NE	EN WG
11	*Platylestes platystylus* (Rambur, 1842)	പച്ചക്കണ്ണൻ ചേരാച്ചിറകൻ	Rison & Chandran (2020); Emiliyamma et al. (2020); Chandran et al. (2021)	LC	
	2. Family: Platystictidae	**നിഴൽത്തുമ്പികൾ**			
12	*Indosticta deccanensis* (Laidlaw, 1915)	കുങ്കുമ നിഴൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	VU	EN WG
13	*Protosticta antelopoides* Fraser, 1931	കൊമ്പൻ നിഴൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	NE	EN WG
14	*Protosticta cyanofemora* Joshi, Subramanian, Babu & Kunte 2020	നീലക്കാലി നിഴൽത്തുമ്പി	Joshi et al. (2020)	NE	EN WG
15	*Protosticta davenporti* Fraser, 1931	ആനമല നിഴൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
16	*Protosticta gravelyi* Laidlaw, 1915	പുള്ളി നിഴൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
17	*Protosticta hearseyi* Fraser, 1922	ചെറു നിഴൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
18	*Protosticta monticola* Emiliyamma & Palot, 2016	മാമല നിഴൽത്തുമ്പി	Emiliyamma & Palot (2016b)	NE	EN WG
19	*Protosticta mortoni* Fraser, 1924	നീലക്കഴുത്തൻ നിഴൽത്തുമ്പി	Kiran & Raju (2011); Joshi et al. (2020)	NE	EN WG
20	*Protosticta ponmudiensis* Kiran, Sadasivan & Kunte, 2015	പൊന്മുടി നിഴൽത്തുമ്പി	Kiran et al. (2015); Subramanian et al. (2018)	NE	EN WG
21	*Protosticta rufostigma* Kimmins, 1958	അഗസ്ത്യമല നിഴൽത്തുമ്പി	Joshi et al. (2020)	DD	EN WG
22	*Protosticta sanguinostigma* Fraser, 1922	ചെമ്പൻ നിഴൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	VU	EN WG
23	*Protosticta sholai* Subramanian & Babu, 2020	ചോല നിഴൽത്തുമ്പി	Joshi et al. (2020)	NE	EN WG
	3. Family: Calopterygidae	**മരതകത്തുമ്പികൾ**			
24	*Neurobasis chinensis* (Linnaeus, 1758)	പീലിത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
25	*Vestalis apicalis* Selys, 1873	ചുട്ടിച്ചിറകൻ തണൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
26	*Vestalis gracilis* (Rambur, 1842)	ചെറിയ തണൽതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
27	*Vestalis submontana* Fraser, 1934	കാട്ടു തണൽതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	NE	EN IND
	4. Family: Chlorocyphidae	**നീർരത്നങ്ങൾ**			
28	*Calocypha laidlawi* (Fraser, 1924)	മേഘവർണ്ണൻ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
29	*Heliocypha bisignata* (Hagen in Selys, 1853)	നീർമാണിക്യൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN IND

	Scientific name	Malayalam name	References	IUCN	END
30	*Libellago indica* (Fraser, 1928)	തവളക്കണ്ണൻതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	NE	EN IND
	5. Family: Euphaeidae	**അരുവിയന്മാർ**			
31	*Dysphaea ethela* Fraser, 1924	കരിമ്പൻ അരുവിയൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN IND
32	*Euphaea cardinalis* (Fraser, 1924)	തെക്കൻ അരുവിയൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
33	*Euphaea dispar* Rambur, 1842	വടക്കൻ അരുവിയൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
34	*Euphaea fraseri* (Laidlaw, 1920)	ചെങ്കറുപ്പൻ അരുവിയൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
	6. Family: Platycnemididae	**പാൽത്തുമ്പികൾ**			
35	*Caconeura gomphoides* (Rambur, 1842)	കാട്ടുമുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	NE	EN WG
36	*Caconeura ramburi* (Fraser, 1922)	മലബാർ മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN IND
37	*Caconeura risi* (Fraser, 1931)	വയനാടൻ മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
38	*Copera marginipes* (Rambur, 1842)	മഞ്ഞക്കാലി പാൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
39	*Copera vittata* (Selys, 1863)	ചെങ്കാലി പാൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
40	*Disparoneura apicalis* (Fraser, 1924)	ചുട്ടിച്ചിറകൻ മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	VU	EN WG
41	*Disparoneura quadrimaculata* (Rambur, 1842)	കരിഞ്ചിറകൻ മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN IND
42	*Elattoneura souteri* (Fraser, 1924)	ചെങ്കറുപ്പൻ മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
43	*Elattoneura tetrica* (Laidlaw, 1917)	മഞ്ഞക്കറുപ്പൻ മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
44	*Esme cyaneovittata* Fraser, 1922	പഴനി മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
45	*Esme longistyla* Fraser, 1931	നീലഗിരി മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
46	*Esme mudiensis* Fraser, 1931	തെക്കൻ മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
47	*Melanoneura bilineata* Fraser, 1922	വടക്കൻ മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	NT	EN WG
48	*Onychargia atrocyana* Selys, 1865	എണ്ണക്കറുപ്പൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
49	*Phylloneura westermanni* (Hagen in Selys, 1860)	ചതുപ്പു മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	NT	EN WG
50	*Prodasineura verticalis* (Selys, 1860)	കരിഞ്ചെമ്പൻ മുളവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
	7. Family: Coenagrionidae	**നിലത്തന്മാർ**			
51	*Aciagrion approximans* (Selys, 1876)	നീലച്ചിന്നൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
52	*Aciagrion occidentale* Laidlaw, 1919	നീലച്ചുട്ടി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
53	*Agriocnemis keralensis* Peters, 1981	പത്തി പുൽച്ചിന്നൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
54	*Agriocnemis pieris* Laidlaw, 1919	വെള്ളപ്പുൽച്ചിന്നൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
55	*Agriocnemis pygmaea* (Rambur, 1842)	നാട്ടുപുൽച്ചിന്നൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
56	*Agriocnemis splendidissima* Laidlaw, 1919	കാട്ടുപുൽച്ചിന്നൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
57	*Amphiallagma parvum* (Selys, 1876)	ചെറുനീലിത്തുമ്പി	Muneer & Chandran (2020); Anonymous (2021)	LC	
58	*Archibasis oscillans* (Selys, 1877)	അരുവിത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
59	*Ceriagrion cerinorubellum* (Brauer, 1865)	കനൽവാലൻ ചതുപ്പൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
60	*Ceriagrion chromothorax* Joshi & Sawant 2019	സിന്ധുദുർഗ് ചതുപ്പൻ	Varghese (2019)	NE	EN WG

	Scientific name	Malayalam name	References	IUCN	END
61	*Ceriagrion coromandelianum* (Fabricius, 1798)	നാട്ടുചതുപ്പൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
62	*Ceriagrion olivaceum* Laidlaw, 1914	കരിമ്പച്ചചതുപ്പൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
63	*Ceriagrion rubiae* Laidlaw, 1916	തീച്ചതുപ്പൻ	Kiran & Raju (2011); Subramanian et al. (2018)	NE	
64	*Ischnura rubilio* Selys, 1876	മഞ്ഞപ്പുൽമാണിക്യൻ	Kiran & Raju (2011); Subramanian et al. (2018)	NE	
65	*Ischnura senegalensis* (Rambur, 1842)	നീല പുൽമാണിക്യൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
66	*Mortonagrion varralli* Fraser, 1920	കരിയിലത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN IND
67	*Paracercion calamorum* (Ris, 1916)	ചുട്ടിവാലൻ താമരത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
68	*Paracercion malayanum* (Selys, 1876)	മലയൻ താമരത്തുമ്പി	Ueda, K. (2021b)	LC	
69	*Pseudagrion australasiae* Selys, 1876	കുറുവാലൻ പൂത്താലി	Chandran et al. (2021)	LC	
70	*Pseudagrion decorum* (Rambur, 1842)	ഇളനീലി പൂത്താലി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
71	*Pseudagrion indicum* Fraser, 1924	മഞ്ഞവരയൻ പൂത്താലി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
72	*Pseudagrion malabaricum* Fraser, 1924	കാട്ടുപൂത്താലി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
73	*Pseudagrion microcephalum* (Rambur, 1842)	നാട്ടുപൂത്താലി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
74	*Pseudagrion rubriceps* Selys, 1876	ചെമ്മുഖപ്പൂത്താലി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
	II. Suborder: Anisoptera	**കല്ലൻത്തുമ്പികൾ**			
	8. Family: Aeshnidae	**സൂചിവാലൻ കല്ലൻത്തുമ്പികൾ**			
75	*Anaciaeschna jaspidea* (Burmeister, 1839)	തുരുമ്പൻ രാജൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
76	*Anaciaeschna martini* (Selys, 1897)	ചോലരാജൻതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
77	*Anax ephippiger* (Burmeister, 1839)	തുരുമ്പൻ ചാത്തൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
78	*Anax guttatus* (Burmeister, 1839)	മരതകരാജൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
79	*Anax immaculifrons* Rambur, 1842	നീലരാജൻതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
80	*Anax indicus* Lieftinck, 1942	പീതാംബരൻതുമ്പി	Ueda, K. (2021c)	LC	
81	*Anax parthenope* (Selys, 1839)	തവിട്ട്രാജൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
82	*Gynacantha dravida* Lieftinck, 1960	സൂചിവാലൻ രാക്കൊതിച്ചി	Kiran & Raju (2011); Subramanian et al. (2018)	DD	
83	*Gynacantha millardi* Fraser, 1920*	തത്തമ്മത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	NE	
	9. Family: Gomphidae	**കടുവാത്തുമ്പികൾ**			
84	*Acrogomphus fraseri* Laidlaw, 1925	പൊക്കൻ കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
85	*Burmagomphus laidlawi* Fraser, 1924	ചതുരവാലൻ കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
86	*Burmagomphus pyramidalis* Laidlaw, 1922	പുള്ളി ചതുരവാലൻ കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
87	*Cyclogomphus flavoannulatus* Rangnekar, Dharwadkar, Sadasivan & Subramanian, 2019	മഞ്ഞ വിശറിവാലൻ കടുവ	Rangnekar et al. (2019)	NE	EN WG
88	*Cyclogomphus heterostylus* Selys, 1854	വിശറിവാലൻ കടുവ	Subramanian et al. (2018)	DD	EN WG
89	*Davidioides martini* Fraser, 1924	സൈരന്ധ്രിക്കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
90	*Gomphidia kodaguensis* Fraser, 1923	പുഴക്കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
91	*Heliogomphus promelas* (Selys, 1873)	കൊമ്പൻ കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	NT	EN WG
92	*Ictinogomphus rapax* (Rambur, 1842)	നാട്ടുകടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	

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93	*Lamelligomphus nilgiriensis* (Fraser, 1922)	നീലഗിരി നഖവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
94	*Macrogomphus wynaadicus* Fraser, 1924	വയനാടൻ കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
95	*Megalogomphus hannyngtoni* (Fraser, 1923)	പെരുവാലൻ കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	NT	EN WG
96	*Megalogomphus superbus* Fraser, 1931	ചോര പെരുവാലൻ കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
97	*Melligomphus acinaces* (Laidlaw, 1922)	കുറു നഖവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
98	*Merogomphus longistigma* (Fraser, 1922)	പുള്ളിവാലൻ ചോലക്കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
99	*Merogomphus tamaracherriensis* Fraser, 1931	മലബാർ പുള്ളിവാലൻ ചോലക്കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	NE	EN WG
100	*Microgomphus souteri* Fraser, 1924	കടുവാച്ചിന്നൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
101	*Nychogomphus striatus* (Fraser, 1924)	വരയൻ നഖവാലൻ	Subramanian et al. (2018)	DD	EN WG
102	*Onychogomphus malabarensis* (Fraser, 1924)**	വടക്കൻ നഖവാലൻ	Subramanian et al. (2018)	DD	EN WG
103	*Paragomphus lineatus* (Selys, 1850)	ചൂണ്ടവാലൻ കടുവ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
	10. Family: Chlorogomphidae	**മലമുത്തന്മാർ**			
104	*Chlorogomphus campioni* (Fraser, 1924)	നീലഗിരി മലമുത്തൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
105	*Chlorogomphus xanthoptera* (Fraser, 1919)	ആനമല മലമുത്തൻ	Kiran & Raju (2011); Subramanian et al. (2018)	VU	EN WG
	11. Family: Macromiidae	**നീർക്കാവലൻമാർ**			
106	*Epophthalmia frontalis* Selys, 1871	പുള്ളി നീർക്കാവലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
107	*Epophthalmia vittata* Burmeister, 1839	നാട്ടു നീർക്കാവലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
108	*Macromia annaimallaiensis* Fraser, 1931	കാട്ടു പെരുങ്കണ്ണൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
109	*Macromia bellicosa* Fraser, 1924	വഴക്കാളിപ്പെരുങ്കണ്ണൻ	Subramanian et al. (2018)	LC	EN WG
110	*Macromia cingulata* Rambur, 1842	ആറ്റു പെരുങ്കണ്ണൻ	Subramanian et al. (2018)	LC	EN IND
111	*Macromia ellisoni* Fraser, 1924	നാട്ടു പെരുങ്കണ്ണൻ	Subramanian et al. (2018)	LC	EN WG
112	*Macromia flavocolorata* Fraser, 1922	മഞ്ഞപ്പെരുങ്കണ്ണൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
113	*Macromia ida* Fraser, 1924	മാമലപ്പെരുങ്കണ്ണൻ	Subramanian et al. (2018)	LC	EN WG
114	*Macromia indica* Fraser, 1924	ഇന്ത്യൻ പെരുങ്കണ്ണൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
115	*Macromia irata* Fraser, 1924	ചൂടൻ പെരുങ്കണ്ണൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
	12. Family: Corduliidae	മരതകക്കണ്ണന്മാർ			
116	*Hemicordulia asiatica* Selys, 1878	കാട്ടു മരതകൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
	13. Family: Libellulidae	**നീർമുത്തന്മാർ**			
117	*Acisoma panorpoides* Rambur, 1842	മകുടിവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
118	*Aethriamanta brevipennis* (Rambur, 1842)	ചോപ്പൻ കുറുവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
119	*Brachydiplax chalybea* Brauer, 1868	തവിട്ടുവെണ്ണിറൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
120	*Brachydiplax sobrina* (Rambur, 1842)	ചെറുവെണ്ണീറൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
121	*Brachythemis contaminata* (Fabricius, 1793)	ചങ്ങാതിത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
122	*Bradinopyga geminata* (Rambur, 1842)	മതിൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
123	*Bradinopyga konkanensis* Joshi & Sawant, 2020	ചെങ്കൽത്തുമ്പി	Haneef et al. (2021)	NE	EN WG

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124	*Cratilla lineata* (Brauer, 1878)	കാട്ടുപതുങ്ങൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
125	*Crocothemis servilia* (Drury, 1773)	വയൽത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
126	*Diplacodes lefebvrii* (Rambur, 1842)	കരിനിലത്തൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
127	*Diplacodes nebulosa* (Fabricius, 1793)	ചുട്ടിനിലത്തൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
128	*Diplacodes trivialis* (Rambur, 1842)	നാട്ടുനിലത്തൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
129	*Epithemis mariae* (Laidlaw, 1915)	തീക്കറുപ്പൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
130	*Hydrobasileus croceus* (Brauer, 1867)	പാണ്ടൻ പരുന്തൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
131	*Hylaeothemis apicalis* Fraser, 1924	നീലനീർത്തോഴൻ	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN IND
132	*Indothemis carnatica* (Fabricius, 1798)	കരിമ്പൻ ചരൽമുത്തി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
133	*Indothemis limbata* (Selys, 1891)	പാണ്ടൻ കരിമുത്തൻ	Muneer & Chandran (2020); Ueda, K. (2021a)	LC	
134	*Lathrecista asiatica* (Fabricius, 1798)	ചോരവാലൻതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
135	*Lyriothemis acigastra* (Selys, 1878)	കുള്ളൻ വർണ്ണത്തുമ്പി	Emiliyamma et al. (2013); Subramanian et al. (2018)	DD	
136	*Lyriothemis tricolor* Ris, 1919	മഞ്ഞവരയൻ വർണ്ണത്തുമ്പി	Das et al. (2013); Subramanian et al. (2018)	LC	
137	*Macrodiplax cora* (Kaup in Brauer, 1867)	പൊഴിത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
138	*Neurothemis fulvia* (Drury, 1773)	തുരുമ്പൻതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
139	*Neurothemis intermedia* (Rambur, 1842)	പുൽത്തുരുമ്പൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
140	*Neurothemis tullia* (Drury, 1773)	സ്വാമിത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
141	*Onychothemis testacea* Laidlaw, 1902	കാട്ടുപുള്ളൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
142	*Orthetrum chrysis* (Selys, 1891)	ചെന്തവിടൻ വ്യാളി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
143	*Orthetrum glaucum* (Brauer, 1865)	നീലവ്യാളി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
144	*Orthetrum luzonicum* (Brauer, 1868)	ത്രിവർണ്ണൻ വ്യാളി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
145	*Orthetrum pruinosum* (Burmeister, 1839)	പവിഴവാലൻ വ്യാളി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
146	*Orthetrum sabina* (Drury, 1770)	പച്ചവ്യാളി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
147	*Orthetrum taeniolatum* (Schneider, 1845)	ചെറുവ്യാളി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
148	*Orthetrum triangulare* (Selys, 1878)	നീലക്കറുപ്പൻ വ്യാളി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
149	*Palpopleura sexmaculata* (Fabricius, 1787)	നീലക്കുറുവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
150	*Pantala flavescens* (Fabricius, 1798)	തുലാത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
151	*Potamarcha congener* (Rambur, 1842)	പുള്ളിവാലൻതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
152	*Rhodothemis rufa* (Rambur, 1842)	ചെമ്പൻതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
153	*Rhyothemis triangularis* Kirby, 1889	കരിനീലച്ചിറകൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
154	*Rhyothemis variegata* (Linnaeus, 1763)	ഓണത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
155	*Sympetrum fonscolombii* (Selys, 1840)	കുങ്കുമച്ചിറകൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
156	*Tetrathemis platyptera* Selys, 1878	കുള്ളൻതുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	

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157	*Tholymis tillarga* (Fabricius, 1798)	പവിഴവാലൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
158	*Tramea basilaris* (Palisot de Beauvois, 1817)	ചെമ്പൻ പരുന്തൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
159	*Tramea limbata* (Desjardins, 1832)	കരിമ്പൻ പരുന്തൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
160	*Trithemis aurora* (Burmeister, 1839)	സിന്ദൂരത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
161	*Trithemis festiva* (Rambur, 1842)	കാർത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
162	*Trithemis kirbyi* Selys, 1891	ചോപ്പൻ പാറമുത്തി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
163	*Trithemis pallidinervis* (Kirby, 1889)	കാറ്റാടിത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
164	*Urothemis signata* (Rambur, 1842)	പാണ്ടൻ വയൽതെയ്യൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
165	*Zygonyx iris* Selys, 1869	നീരോട്ടക്കാരൻ	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
166	*Zyxomma petiolatum* Rambur, 1842	സൂചിവാലൻ സന്ധ്യാത്തുമ്പി	Kiran & Raju (2011); Subramanian et al. (2018)	LC	
	14. *Genera Incertae sedis*	**കോമരത്തുമ്പികൾ**			
167	*Idionyx corona* Fraser, 1921	നീലഗിരിക്കോമരം	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
168	*Idionyx galeata* Fraser, 1924	മിനാരക്കോമരം	Kiran & Raju (2011); Subramanian et al. (2018)	EN	EN WG
169	*Idionyx gomantakensis* Subramanian, Rangnekar & Naik, 2013	ഗോവൻ കോമരം	Subramanian et al. (2013); Subramanian et al. (2018)	NE	EN WG
170	*Idionyx minima* Fraser, 1931	ചിന്നൻ കോമരം	Kiran & Raju (2011); Subramanian et al. (2018)	NE	EN WG
171	*Idionyx rhinoceroides* Fraser, 1934***	കൊമ്പൻ കോമരം	Kiran & Raju (2011); Subramanian et al. (2018)	LC	EN WG
172	*Idionyx saffronata* Fraser, 1924	കാവിക്കോമരം	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
173	*Idionyx travancorensis* Fraser, 1931	തെക്കൻ കോമരം	Kiran & Raju (2011); Subramanian et al. (2018)	DD	EN WG
174	*Macromidia donaldi* (Fraser, 1924)	നിഴൽക്കോമരം	Kiran & Raju (2011); Subramanian et al. (2018)	LC	

Checklist of Odonata of Kerala. IUCN Red List Status: NE—Not Evaluated | DD—Data Deficient | LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered | Endemicity: EN WG—Endemic to the Western Ghats | EN IND—Endemic to India.
*According to Kalkman et al. (2020), *Gynacantha bayadera* is known from the northeast of Indian subcontinent and it is unclear if its distribution overlaps with that of *G. millardi*. We did a thorough study of citizen science portals and found numerous photographs of *G. millardi* from Kerala, but none of *G. bayadera*.
** *Onychogomphus malabarensis* (Fraser, 1924) is known only from a female holotype collected at Palakkad, Kerala in the Western Ghats (Fraser 1934). It has been suggested by Kalkman et al. (2020) that it could belong to a different genus and its present taxonomic status is temporary.
*** *Idionyx rhinoceroides* Fraser, 1934 is known only from a female holotype collected at Palakkad, Kerala in the Western Ghats (Fraser 1936).

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Image 1. *Indolestes pulcherrimus*.

Image 2. *Protosticta cyanofemora*.

Image 3. *Amphiallagma parvum*.

Image 4. *Ceriagrion chromothorax*.

Image 5. *Paracercion malayanum*.

Image 6. *Cyclogomphus flavoannulatus* (female).

Image 7. *Indothemis limbata*.

Image 8. *Idionyx gomantakensis*.

Image 9. *Disparoneura apicalis*.

Image 10. *Heliogomphus promelas*.

Image 11. *Indosticta deccanensis*.

Image 12. *Megalogomphus hannyngtoni*.

Image 13. ***Melanoneura bilineata*.**

Image 14. ***Phylloneura westermanni*.**

Image 15. ***Protosticta sanguinostigma*.**

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SHORT COMMUNICATION

Aldama macbridei (Heliantheae: Compositae): notes on its distribution and vulnerable habitats in central Peru

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Abstract: *Aldama macbridei* (S.F.Blake) E.E. Schill. & Panero (Heliantheae: Compositae), endemic to Peru is updated in terms of its distribution in the Central Andes. Also presented is a brief description of the species and the environments it inhabits. It is proposed its conservation status according to IUCN Red List categories be upgraded to 'Near Threatened' (NT).

Keywords: Central Andes, conservation status, distribution, endemic, IUCN Red List.

The genus *Aldama* La Llave (1824: 14) (Heliantheae, Compositae) is native to tropical and subtropical areas and comprises 118 species extending from southwestern North America and Mexico to South America (Schilling & Panero 2011; Magenta et al. 2017). In Peru, the genus is represented by eight species (Schilling & Panero 2011) mainly distributed in subtropical dry and humid montane forests across the Andes.

During ongoing floristic studies in archaeological sites in the boundaries of the Alto Marañon region in Central Peru (Montesinos-Tubée 2016, 2017), some interesting specimens of *Aldama* were collected. These plants occur on rock crevices and steep slopes in the boundaries of Pasco and Huánuco departments at 2,300–2,450 m elevation. After examination the specimens were identified as *Aldama macbridei* (S.F.Blake) E.E.Schill. & Panero, which is endemic to Peru (Beltrán et al. 2006) and has not been recorded in the studied region so far. The habitat of the type locality, near Huacachi, Mito (Blake 1926), has been modified by agriculture conversion, forestation with exotic species, and burning of the slopes (Image 1). The objective of this study is to present a brief description of *Aldama macbridei* along with photo plates and other relevant information, to facilitate the correct identification of this species and define its conservation status in the light of present field observations and the diminishment of native ecosystems.

Materials and Methods

This contribution is the result of a review of the published bibliography, field work in southern Peru, and the revision of Peruvian herbarium specimens. Additionally, digital specimens from USA herbaria were studied. Herbarium acronyms follow Thiers (2020). Frequent field surveys were carried out during the period from 2016–2017 in Marañon region in Central Peru

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(South America) and specimens of *Aldama macbridei* were collected, identified using relevant literature (Magenta et al. 2017; Pruski & Robinson 2018), and also compared with specimens from different herbaria (CPUN, COL, F, GH, HSP, HUT, K, MH, MOQ, OXA, TX, US). All voucher specimens are deposited in the herbaria of Cajamarca University (CPUN), Michael Dillon Institute (HSP), La Libertad-Trujillo National University (HUT), Moquegua National University (MOQ), and San Marcos National University (USM). Pictures of living individuals are presented.

Sampling strategy

After the study of herbarium specimens from Huánuco (Macbride 4078), Huancavelica (Tovar 1884), and Ancash (Cerrate 2135 & 3746), several expeditions to those provinces and neighboring areas allowed us to collect individuals from a population located 60 km from the type locality of *Aldama macbridei*. Based on data from sheet labels we were able to contrast the current variability of some morphological characters in the field, and to observe the typical habitats and ecological features for this taxon. Early and reproductive stages were measured for vegetative characters to assess phenotypic plasticity associated with soil characteristics and slope inclination. Juvenile, sexually immature but well-developed plants (>1.5 m tall) and adults, sexually mature plants, and flowering individuals were characterized at least once. An estimation of the number of individuals composing the population sampled was done. The species has been assessed for its conservation status based on the 14th version of the IUCN Red List (IUCN 2019). The locality sampled was recorded by Garmin Global Positioning System, allowing the first georeferenced population of *Aldama macbridei*.

Results and Discussion

The description of the species with notes on its distribution, phenology, ecological aspects, details of specimens examined and conservation status along with colour photographs to facilitate accurate identification are given below.

Taxonomic treatment and amplified description

Aldama macbridei (S.F.Blake) E.E.Schilling & Panero
(Figure 1; Images 2 & 3)

in *Bot. J. Linn. Soc.* 167(3): 324 (2011). *Viguiera macbridei* S.F.Blake. in J. Wash. Acad. Sci. 16: 218 (1926).

Synonym

Rhysolepis macbridei (S.F.Blake) H.Robinson & A.J.Moore in *Proc. Biol. Soc. Washington* 117(3): 429 (2004).

Holotype: 4078, 20.v.1923–1.vi.1923, Peru, Huánuco, Pachitea, Huacachi, near Muña, at about 1,980 m, coll J.F. Macbride (F-535145!). Isotypes: GH barcode 00014012 image!, S-R6483 image!, US-1191485 image!.

Perennial herbs with multiple stems, densely ramified at the base, 0.5–2 m tall. Stems and leaves densely covered by sericeous trichomes of about 2 mm long. Alternate arrangement of leaves, sessile, narrowly lanceolate to linear-lanceolate, blades 2–11 cm long, 3–15 mm wide, subcoriaceous, upperside bright dark green to yellowish-green at maturity, shallowly bullate, mostly glabrous except by a few, scattered glandular trichomes resembling resinous dots, underside densely sericeous, base truncate, apex acute, margins revolute, subentire. Capitulescences in paniculiform cymes, pedicels 3–15 cm long, densely sericeous. Capitula radiate, 2.8–5 cm wide including ray corollas. Involucre campanulate with phyllaries arranged in 4 or 5 series, lanceolate, 2–3 mm long, acute-mucronate, fimbriate, underside densely pubescent and upperside glabrous except at the margins. Ray florets 8–18, corolla 13–26 mm long, 40–75 mm wide, limb oblong, bilobulated or trilobulated (slightly curved towards the tip), golden yellow, bearing 11–13 dark yellow parallel veins; disk florets fertile ca. 55–65, 1.2–1.8 long, tubular, tube shortly pubescent; stamens 4–5.5 mm long, anthers black, styles 2.5–3.5 mm long, bifurcated, yellow, apex glabrous and acute. Cypselae 4 mm long, narrowly obovate, black, pappus of 2 awns, unequal, and several squamellae in between.

Flowering: Flowers and fruits were observed between March and May.

Ecology: This species was found on the lower mountain slopes close to the Huertas river, tributary of the Huallaga river, between the cities of Ambo (Huánuco) and Yanahuanca (Pasco) at an altitudinal range of 2,320–2,410 m. The species inhabits the tropical dry low montane forest (bs-MBT, MINAM 2009), considered a life zone located in the Meso-Andean region and characterized by the predominance of mountainous steep slopes. The prevailing climate is characterized by its dryness during several months of the year. The total annual precipitation fluctuates between 500 and 600 mm. The vegetation cover is deciduous as well as evergreen shrub species, and there is evidence of fire occurrence (mostly by anthropic action), influenced by the dominance of grasses. The following species were observed in the environment of *Aldama macbridei* in the boundary of the Huánuco-Pasco departments: *Caesalpinia spinosa* (Molina) Kuntze (Fabaceae), *Dodonaea viscosa* Jacq.

Figure 1. Distribution map of *Aldama macbridei*. The yellow asterisks indicate the distribution of the species according to the herbarium specimens examined (Ancash, Huancavelica, Huánuco, and Pasco departments). The red asterisk indicates the approximate location of the type specimen in the Huánuco department.

(Sapindaceae), *Espostoa huanucoensis* H. Johnson ex F. Ritter (Cactaceae), *Furcraea andina* Trel. (Asparagaceae), *Heliotropium arborescens* L. (Boraginaceae), *Myriopteris myriophylla* (Desv.) J. Sm. (Pteridaceae), *Schinus molle* L. (Anacardiaceae), *Spermacoce remota* Lam. (Rubiaceae), *Tillandsia usneoides* (L.) L. (Bromeliaceae), among others. Three additional specimens were observed at USM herbarium, two of them are from Bolognesi province, Ancash department, between 2,900 and 3,060 m in tropical dry low montane forest (bs-MBT). The other specimen corresponds to the Colcabamba district, Tayacaja province, Huancavelica department, in humid montane forests (bh-MT, tropical montane humid forest), at 2,300 m. An altitude of 1,980 m is indicated on the label of the type specimen, in Pachitea, Huánuco. Considering new collections, it is therefore concluded that the altitudinal distribution range for *Aldama macbridei* is from 1,980 to 3,060 m in tropical dry low montane forests (Figure 1).

Distribution: Central Peru, new to Ancash, Huancavelica and Pasco departments. Prospections on herbaria out from Peru (example COL) allow us to reaffirm that the taxon does not surpass the Peruvian

Image 1. Burning of slopes in the boundary of the Huanuco and Pasco departments, near the Huertas river, June 2018.

Image 2. *Aldama macbridei* growing in the boundaries of the Huánuco-Pasco departments (2,320–2,410m): A—Environment near the Huertas river were the species grows | B—Habit near the road from Yanahuanca to Ambo, close to the Huertas river | C—Suberect flowering stems | D—Detail of the underside of the capitulescens | E—Upperside of the capitulescens | F—Size of a collected stem (ruler reference of 1m) | G—Detail of the underside and upperside of the leaves (in mm) | H—Detail of a capitules cut were the florets and inmature pappi are observed (in mm) | I—Detail of the capitules rays with bilobulated tips (in mm). © Daniel B. Montesinos Tubée

territory and is endemic to the mountains of the Central Andes. According to our ongoing expeditions in these geographic high-altitude systems, the species distribution boundaries lie between Huánuco province to the north, and Huancavélica province to the south, and is limited to the high altitude plateaus or Andes mountains.

Specimens examined: 4078 (F), Peru, Huánuco, Pachitea, Huacachi, near Muña, 1,980 m, 20.v.1923–1.vi.1923, coll. J.F. Macbride; 1884 (USM), Peru, Huancavelica, Tayacaja, Colcabamba, Hacienda Villa Azul, abajo de Colcabamba, 2,300 m, 17.iv.1954, coll. O. Tovar; 2135 (USM), Peru, Ancash, Bolognesi, Pacllon, Mashcash, punto de unión de los ríos Llamac y Chiquián, 3,060 m, 18.v.1954, coll. E. Cerrate; 3746 (USM), Peru, Ancash, Bolognesi, Huaraumapata, 2,900 m, 15.iv.1961, coll. E. Cerrate (USM); 7357 (CPUN, CUZ, HSP, HUT, TX), Peru, Huánuco, Ambo, San Francisco, road between San

Francisco de Mosca and Parcoy, Lat. 10.27, Long. 76.33, 2,317 m, 14.v.2018, coll. D.B. Montesinos & G. Sancho; 7537 (CPUN, HSP, HUT, MOQ, OXA, USM, TX), Peru, Pasco, Daniel Alcides Carrión, Santa Ana de Tusi, Centro Poblado de Antapirca, roadside vegetation, Lat. 10.308, Long. 76.32, 2,406 m, 25.iv.2019, D.B. Montesinos (Figure 2).

Conservation status: With nearly 724 endemic Composite species, Asteraceae is the second biggest family in terms of endemicity, in Perú (León et al. 2006). Endemism is a significant attribute of any taxon with reference to its restricted distribution, and endemic species of Peruvian Andes mountains located between Huancabamba deflection, an important biogeographic boundary, and Atacama Desert, hold immense significance. An assessment of their geographical distribution within remote Andean areas is of great conservation concern. Assessments are always done using the best available information, however, there is a dearth of knowledge in the case of the distribution pattern for many high-altitude endemic species, especially those in some Andean mountains with difficult access, as those explored as part of the ongoing prospection of Asteraceae from Perú.

The study by Beltrán et al. (2006) regarding conservation status on Peruvian Asteraceae has provided valuable information for most of endemic Composites in the country. In the present survey, an attempt has been made to assess the population and conservation status of one of the species omitted from this work (Aldama macbridei), because of the scarce exploration of some remote Andean areas, as those considered and sampled here.

Also, a perusal of herbarium consultation in local (CPUN, HSP, HUT, MOQ, OXA, USM, TX) and international herbaria has revealed interesting new information about the species distribution. A new record from Huancavelica province (Tovar 1884) allows us to broaden the current knowledge for the distribution of the species, thought to be limited to Andean high-altitude plateaus located to the North of Lima, the Capital city (provinces of Ancash, Huánuco, and Pasco).

According to the criteria and categories of IUCN (2019), it is proposed as 'Near Threatened' (NT) following Red List criteria. This taxon has a reduced distribution area (less than 10,000 km²). For the locality sampled, less than 500 individuals were counted for the whole population at this site. Only four other populations are known, and the absence of other collections allow us to consider that the species may be restricted to the localities referenced in this work. Nevertheless, one

Image 3. *Aldama macbridei* type specimen stored at (Swedish Museum of Natural History)

of these populations is located near the Huayhuash reserve, in a private protected area (Sernanp 2021), so the category NT is defined preliminarily, to move to an eventual threatened category (ex. EN B1-b) if future assessments of population dynamics firmly establish a high risk of extinction. Suitable habitats for *Aldama macbridei* are regarded as near threatened because of slope burning in all the areas where its occurrence is known. Also, agriculture expansion, changes in annual rainfall, landslides, and forestation with exotic species are quite common ongoing processes outside the protected area where one occurrence is registered. These factors, together with exploitation of natural resources (especially mining in Ancash, Huanuco, and Pasco provinces) and the expansion of roads (MTC, 2020) due to the explosive demographic growth of Lima's vicinities (the capital city) may all potentially reduce the current extent of *Aldama macbridei*'s populations. Interestingly, several degraded areas with steep slopes (the current habitat for *Aldama macbridei*, ex. Figure 3B) documented during our expeditions, present a potential for reforestation with native species for watershed protection purposes.

Notes: *Aldama macbridei*, was originally described by Blake (1926) under the species *Viguiera macbridei* S.F.Blake from Pachitea region, Huánuco province. According to Schilling & Panero (2011), *Aldama macbridei* was better placed into Aldama group than within Viguiera traditional concept. *Aldama macbridei* is allied to *Aldama linearifolia* (Chodat) E.E.Schill. & Panero (2011: 324), differing by the glabrous stems, narrower leaves, glabrous pedicels, larger phyllaries and ray limbs, and by the distribution of the latter in Brazil and Paraguay. *Aldama macbridei* also differs from *Aldama linearis* (Chodat) E.E.Schill. & Panero (2011: 324), another similar species, by its relatively shorter leaf size, hispidolous pubescence of leaves, broader phyllaries, shorter capitules and by the distribution of the latter in Mexico. Lastly, it differs from *Aldama tenuifolia,* (Gardner) E.E.Schill. & Panero (2011: 325), a brazilian representative of the genus, by the narrower leaves, glabrous underside of the leaf blades, glabrous stems, and pedicels.

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SHORT COMMUNICATION

Lichens and animal camouflage: some observations from central Asian ecoregions

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Abstract: Camouflage is a fitness-relevant trait that supports survival and fosters evolutionary adaptation by which animals match their body pattern to a background setting. Lichens are among the most common of these backgrounds that several animal species use for camouflage. Lichens are omnipresent and grow in wide arrays of colorations and compositions. Their composition and phenotypic diversity might facilitate cryptic coloration and habitat matching by various animal species. Here, we describe the role of lichens in providing camouflage to various animal species in central Asian and Caucasus mountain ecoregions, which are categorized as global biodiversity hotspots. Despite multiple ecological studies, no information is available on the role of this regions' lichen diversity in providing animal camouflage. Casual field observations of lichen camouflage are reported for four (one mammal and three reptile) species: the Persian Leopard's *Panthera pardus saxicolor* body coat seems to closely match the colors and patterns of saxicolous lichens (*Acarospora* sp. and *Circinaria* sp.) in their habitat. A similar background matching pattern was observed in both morphs of the Caucasian Rock Agama *Paralaudakia caucasia* upon crustose lichens: *Caloplaca* spp., *Circinaria* spp., and the Radde's Rock Lizard *Darevskia raddei* to the crustose lichens *Acarospora* sp. and *Caloplaca* sp. Likewise, the Horny-scaled Agama's *Trapelus ruderatus* grey matches with the color of multiple lichens (*Lecanora* spp., *Circinaria* spp., *Protoparmeliopsis* spp., *Rinodina* spp., and *Anaptychia* spp.). Our observations preliminarily suggest that lichens play an important role for species of different trophic levels, ensuring adaptation and survival through camouflage. We call for more field-based empirical and experimental studies in various terrestrial ecosystems in other parts of the world to test the role of lichens in local adaption and evolutionary plasticity of regional species.

Keywords: Caucasus, climate change, cryptic coloration, dry ecosystems, Irano-Anatolian, mammals, plasticity, phenotypic traits, reptiles, saxicolous.

Wildlife populations of various taxa are experiencing an unprecedented loss worldwide. The 2020 Global Living Planet Index reported an average 68% decline in the populations of mammals, birds, amphibians, reptiles, and fishes within a period of 46 years (1970–2016). Many of the listed species are subjected to anthropogenic impacts and environmental alterations such as climate change, pollution, disease, invasive species, and land degradation (Kettlewell 1955; Gomulkiewicz & Holt 1995; Gonzalez et al. 2013; Maxwell et al. 2016). Species persistence may also depend on phenotypic plasticity or adaptive evolution (Carlson et al. 2014). The inherent

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genetic variation in a species may help species to adapt towards stressors if these exert strong selection pressure (Gonzalez et al. 2013).

One of the fitness-relevant traits that support survival and foster evolutionary adaptation is camouflage (Pèrez i de Lanuza & Font 2016; Cuthill 2019; Price et al. 2019; Smith & Ruxton 2020). Camouflage is a trait or mechanism by which animals match or tune their body pattern to the background of their habitat, often varying over time and space and across populations (Baling et al. 2019; Cuthill 2019; Smith & Ruxton 2020). Animals employ camouflage in multiple ways to facilitate various strategies including; background matching (i.e., animals resemble the shape of the habitat background) and disruptive coloration (i.e., developing high contrast patches to break up the body's edge). Cryptic coloration and display of specific behaviours may reduce visual detection or recognition by predators (Cuthill 2019). Cryptic coloration can occur seasonally (e.g., as in the form of change of coat colour from brown in summer to white in winter) and may change with patterns and color of habitat, affecting the selection of phenotypic traits for crypsis (Mills et al. 2013). A recent study identified polymorphic regions for some color molting mammal species (e.g., Snowshoe Hare *Lepus americanus*, Arctic Fox *Vulpes lagopus*), suggesting that these regions can function as evolutionary rescue sites in the rapidly changing world due to climate change (Mills et al. 2013).

The most quoted classic example of rapid plasticity in response to anthropogenic climate change affecting the effectiveness of camouflage is that of the Peppered Moth *Biston betularia* (Grant & Howlett 1988; Majerus et al. 2000; Cuthill 2019). During the industrial revolution (ca. 1760–1840), the Silver Birch Trees' *Betula pendula* bark became darker due to pollution (Grant & Howlett 1988). As a result, the melanic forms of the Peppered Moth (dark) in polluted regions had low predation pressure over lichen-like individuals (pale speckled), which were easily spotted by their avian predators due to contrasting dark background. When pollution levels in these regions declined, and the lichens grew back on the trees, the pale speckled morphs regained abundance (Kettlewell 1955; Grant & Howlett 1988). In an experimental study Walton & Stevens (2018) showed that the pale-speckled form of the Peppered Moth closely resembles the crustose lichen found on tree barks, making them less vulnerable to predation by birds, compared to melanic forms. This example provides striking evidence about the importance of the rapid evolutionary response of animals to environmental alterations under the influence of strong selection pressure. It also emphasizes the role of lichens in sustaining populations by providing important ecosystem services such as camouflage that helped reversing population decline (Walton & Stevens 2018).

There are several other examples reported from various parts of the world, where lichens were employed by various species not only as habitat and food source, but also for camouflage (Zedda & Rambold 2011). The larvae of insect species such as Lacewing (Neuroptera: Chrysopidae) and Bagworm (Lepidoptera: Psychidae) use lichens as food and camouflage to escape from predators (Skorepa & Sharp 1971; Cannon 2010). Another interesting case of lichen camouflage is reported in the nymph of the katydid *Lichenodraculus matti* that mimics epiphytic lichens. A species of beetle *Gymnopholus lichenifer* and a land snail species *Napaeus barquini* use lichens as food and cover their body with live lichen to actively carry the camouflage with them (Gressit 1977; Allgaier 2007). The Lichen Huntsman Spider *Pandercetes gracilis* hides among lichens for predation (Botsford-Comstock 1986; Mukherjee et al. 2010). There are several other species of frogs and lizards that use tree and rock lichens for camouflage (Braun et al. 1997; Hocking & Semlitsch 2007; Zedda & Rambold 2011; Sumotha et al. 2012).

Lichens and animal camouflage in central Asian mountain ecoregion

Lichens are a symbiotic group of organisms that occur in terrestrial ecosystems. They cover approximately 8% of the global land surface (Nash 2008), and grow in wide arrays of colorations, compositions and patterns on substrates such as rocks, trees or shrubs' bark, and even anthropogenic material such as concrete (Nash 2008). They are specifically more diverse and abundant in dry high altitude grasslands and tundra ecosystems (Asplund & Wardle 2017). Lichens are sensitive to a wide range of pollutants and climatic alterations and thus serve as indicators of ecosystem health (Munzi et al. 2014; Root et al. 2015). For instance, the depletion of lichens also indicates population decline of Caribou in the arctic ecosystem (Joly et al. 2009).

Here, we describe the importance of lichens in providing camouflage to various animal species of central Asian mountain ecoregion. The Irano-Anatolian, Caucasus, and central Asian mountains ecoregions are mainly characterized by vast dry scrublands, grasslands and steppic mountainous landscapes and are categorized amongst the global biodiversity hotspots (Olson & Dinerstein 2008; Marchese 2015). These ecoregions are vulnerable to climate change as well as intense human use (Stone 2015). Despite several long-term ecological studies on many species from this region, no information is available on the role of regional lichen species in providing animal camouflage. We here present examples from four animal species (one mammal and three reptilian) that represent and occupy different trophic levels in the Irano-Anatolian, Caucasus, and central Asian mountains ecoregions.

The Persian Leopard *Panthera pardus saxicolor*, synonym: *P. p. tulliana* was described by R.I. Pocock in 1927. The etymological meaning of '*saxicolor*' in its scientific name is 'stone-grey' or 'stone-color' (Pocock 1927). Persian Leopard has a grey and yellowish-buff coat interspersed with black rosette patterns (Pocock 1927) that seem to closely match and merge with the colors and patterns of regional saxicolous lichen species such as *Acarospora* sp. (Ascosporaceae) and *Circinaria* sp. (Megasporaceae) (Image 1), and other families of lichens including Candelariaceae, Collemataceae, Lecanoraceae, Lecideaceae, Lichinaceae, Megasporaceae, Parmeliaceae, Physciaceae, Rhizocarpaceae, Teloschistaceae, Umbilicariaceae, and Verrucariaceae that are also found in their habitat in these ecoregions. The Persian Leopard is an apex predator of these ecoregions, that inhabits rocky mountainous habitats in western and central Asia (Jacobson et al. 2016). Their arid and rocky habitat is covered by saxicolous lichens that help them in camouflage, which is often useful in their ambush hunting technique. It reduces their chances of visual detection by their prey species and might improve their ambush predation success.

To further illustrate the importance of lichens in

Image 1. a—Persian Leopard (*Panthera pardus tulliana*, synonym *P.p. saxicolor*) resting on the calcareous rocks in Golestan National Park, Iran. Its coat colors and patterns closely resemble the crustose lichens: *Acarospora* sp. and *Circinaria* sp. (© J. Hasanzadeh) | b—represents the background matching of Radde's Rock Lizard (*Darevskia raddei*) on the volcanic rocks in Arasbaran National Park, the lesser Caucasus ecoregion in Iran (© B. Safaei-Mahroo) and the crustose lichens *Acarospora* sp. and *Caloplaca* sp. | c—shows Caucasian Rock Agama (*Paralaudakia caucasia*) in an alert position on the calcareous rock, in Iran-Turkey border (Sero). The background matching is enhanced by several crustose lichens: *Circinaria* sp. and *Protoparmeliopsis* sp. and *Rinodina* sp. (© B. Safaei-Mahroo) | d—represents the Caucasian Rock Agama in an alert position, its dorsal coloration resembling the crustose lichens *Caloplaca* sp. and *Circinaria* sp. (© J. Hasanzadeh).

Image 2. a—illustrates a summer morph of the Horny-scaled Ground Agama (*Trapelus ruderatus*), Zagros mountains, Iran. Its body scales closely match with lichens covered rocks: fire-dot lichen *Caloplaca* sp., lim lichen *Lecanora* sp., sunken disk lichen *Circinaria* sp., *Protoparmeliopsis* sp., *Rinodina* sp., and *Anaptychia* sp. Whereas | b—shows the early spring morph of the Horny-scaled Ground Agama (Kabir-kuh, Malekshahi, Zagros mountains, Iran), matching finely lichens: *Verrucaria* sp. or *Anema* sp. or *Peccania* sp. (© B. Safaei-Mahroo).

animal camouflage, we present examples of three species of reptiles, which are adapted to rocky high steppe habitats. They are Radde's Rock Lizard *Darevskia raddei* (Lacertidae), Caucasian Rock Agama *Paralaudakia caucasia* (Agamidae) and Horny-scaled Ground Agama *Trapelus ruderatus* (Agamidae) (Images 1, 2). The Radde's Rock Lizard is a polymorphic group of lizards. Their dorsal coloration largely corresponds to the lichen-covered rocks on which they live. A similar background matching pattern occurs in both morphs of the Caucasian Rock Agama *Paralaudakia caucasia*. The dorsal coloration of both morphs matches to the crustose lichens *Caloplaca* sp. and *Circinaria* sp. (Image 1c,d). Several crustose lichens *Circinaria* sp. (Megasporaceae) and *Protoparmeliopsis* sp. (Lecanoraceae) and *Rinodina* sp. (Physciaceae) appear to enhance their background matching (Image 1c). Likewise, the Horny-scaled Agama's grey head matches with the color of the following lichens: lim lichen *Lecanora* sp. (Lecanoraceae), sunken disk lichen *Circinaria* sp. (Megasporaceae), *Protoparmeliopsis* sp. (Lecanoraceae), and *Rinodina* sp. and *Anaptychia* sp. (Physciaceae). The dark-orange spots on the dorsal side correspond to the color and pattern of *Caloplaca* sp. (Teloschistaceae) (Image 2a). The dorsal coloration of the Horny-scaled Ground Agama can change seasonally, which also corresponds to growth stage changes in *Verrucaria* sp. (Verrucariaceae), or *Anema* sp., and or *Peccania* sp. (Lichinaceae) (Image 2b).

We acknowledge that the camouflage of various animal species as described above due to the lichen species in their habitat might just be a perception due to limitations of human vision, which is different from what these animal species and their predators or prey perceive. An experimental study by Majerus et al. (2000) compared the ultra-violate characteristics of both forms of the Peppered Moths in the backdrop of foliose and crustose lichens. They report that the colour patterns of the pale-speckled moth is an effective cryptic match to the crustose lichen *Lecanora conizaeoides,* in both human-vision and ultra-violate visions to the crustose lichens. However, the camouflage behaviour in animals via matching habitat does not essentially depend on lichens (Walton & Stevens 2018), because habitat types and their background characteristics can largely vary across time and space and other factors like vegetation might play a role in camouflage as well (Baling et al. 2019). For example, the melanic form of the peppered moth is adapted closely to plain tree barks, whereas the speckled form adapted to the crustose lichens (Walton & Stevens 2018). In urban ecosystems, even the plain anthropogenic substrates such as roads and pavements are voluntarily selected by animal species that can play a crucial role in their adaptation and population persistence (Camacho et al. 2020).

We conclude that despite several examples of the role of lichens in animal camouflage for a handful of faunal species from a few selected ecosystems, there is insufficient knowledge about lichens and their role in animal camouflage in various terrestrial ecosystems of the world. Lichens are omnipresent and their species composition, richness, and phenotypic diversity might facilitate crypsis coloration and habitat matching by various animal species across different trophic levels. Under variable environments and changing climate scenarios, these traits would also be able to ensure adaptation and survival of those species. We therefore call for more field and experimental studies in various terrestrial ecosystems in other parts of the world to document more examples of habitat matching by animals utilizing local lichen species, and the role of lichens in local adaption and evolutionary plasticity.

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NOTE

First photographic evidence of Asiatic Black Bear *Ursus thibetanus* in Kaziranga Tiger Reserve, India

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The Asiatic Black Bear *Ursus thibetanus*, also commonly known as the Himalayan Black Bear and sometimes known as 'Moon Bear' due to the presence of a characteristic crescent shaped white mark on the upper portion of the chest. It is listed as 'Vulnerable' in the Red Data Book (Garshelis & Steinmetz 2020), in Appendix I of CITES in India since 1990 and in Schedule I of the Indian Wild Life (Protection) Act (as amended in 2006). The Asiatic Black Bear occupies a variety of forested habitats, both broad-leaf and coniferous, from near sea level to an elevation up to 4,300 m (Sathyakumar et al. 2013). It is distributed in southern and eastern Asia from Afghanistan and Baluchistan Province of Iran, east through Indo-China, much of China, Korea, Japan, and Taiwan (Cowan 1972; Servheen 1990). In India, the bear is distributed throughout the Himalaya (Sathyakumar 2001) from the north-west (Jammu and Kashmir, Himachal Pradesh) to the east (Arunachal Pradesh) and in the hills of the other northeastern states (Assam, Meghalaya, Mizoram, Tripura, Nagaland, and Manipur) (Sathyakumar 2006; Sathyakumar & Choudhury 2007; Choudhury 2013). Literature suggests that its range overlaps with that of the Sloth Bear below 1,200 m, the Himalayan Brown Bear above 3,000 m (Prater 1980), and in northeastern India with the Sun Bear (Choudhury 1997a,b). In India, the bear is reported to occur in 83 protected areas and 93 other localities (Sathyakumar & Choudhury 2007).

Kaziranga Tiger Reserve (KTR) is located in the flood plain of the Brahmaputra River, on the foot hills of Karbi Anglong district, spread across the civil districts of Golaghat, Nagaon, Sonitpur, and Biswanath (Figure 1). The Kaziranga-Karbi Anglong landscape consists of the Karbi plateau of Karbi Anglong to the south and the

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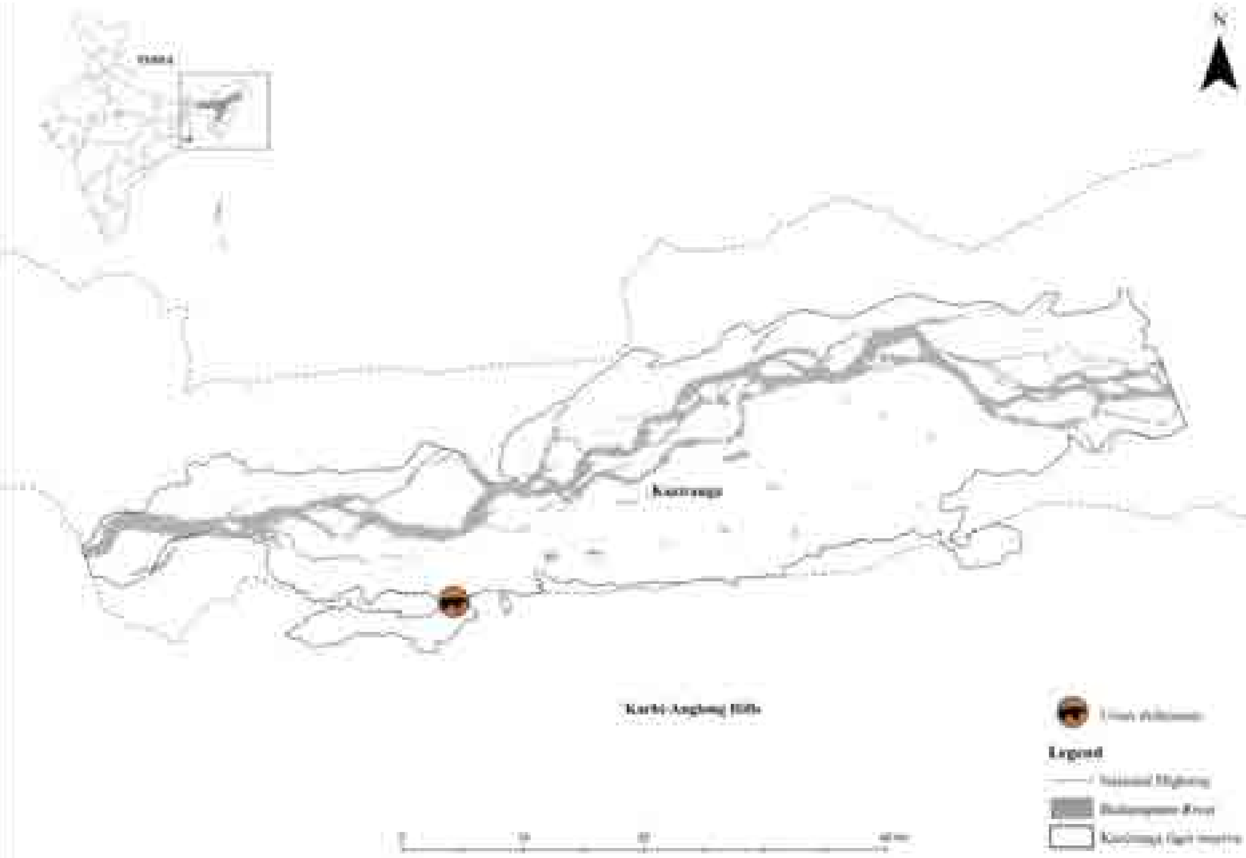

Figure 1. Map showing Kaziranga Tiger Reserve with the location of photo-captured Asiatic Black Bear.

Brahmaputra River to the north in Assam. The hills in Karbi Anglong are part of the Shillong plateau having an average elevation of 300–400 m. The highest peak called 'Singhason Peak' is 1,360 m high located in East Karbi Anglong. The Karbi Anglong forests and grasslands of Kaziranga Tiger Reserve formed one contiguous unit of ideal wildlife habitat.

We carried out camera trap sampling involving several camera traps deployed in a manner so that at least one station falls on each (2 x 2) km^2 grid, as a part of the study to determine the functionality of corridors present in the Kaziranga-Karbi Anglong Landscape. We used infrared Cuddeback (Model: H1453) camera traps during the study.

In 2018, photographs of two rescued cubs from a village called Dokmoka by Karbi Anglong Forest Department were published in the official website of Wildlife Trust of India. In this study, we report, the first photographic evidence of Asiatic Black Bear in the wild of Kaziranga Tiger Reserve. The first deployment of camera traps was started on February 2021 and subsequently the second deployment of camera traps was carried out on May 2021. During this period a single photograph of the species was captured on 12 May 2021 at 2124 h (Image 1). The species was photo-captured at an elevation of 75 m and the location falls under the Bagser Reserve Forest (buffer of Kaziranga National Park). The

Image 1. Camera trap image of Asiatic Black Bear captured on 12 May 2021 in the southern part of Kaziranga Tiger Reserve, India.

location also falls in the junction of Amguri-Kanchanjuri corridor. The habitat was moist mixed deciduous with Teak *Tectona grandis* as the dominant species. The location is approximately 275 m away from the National Highway 37. The proximity of human settlement is about 300 m from the point; hence, it has experienced high human intervention in terms of cutting and lopping of fresh timbers and cane sticks in the area.

Literatures on the Asiatic Black Bear from this landscape are very limited. Choudhury (1997a,b) noted the presence of the species in the foothills and hills of Assam, mostly in the Karbi, NC hills and Cachar district. It was very much common in the eastern Karbi Anglong and Barail Range. Lahan & Sonowal (1973) reported a single record from Kaziranga.

Due to hunting and poaching, the population has decreased globally over the years. Hunting/ poaching of all species of bears is going on at different scales in all the states of northeastern India, especially outside the protected areas for meat (Choudhury & Rengma 2005). In the hilly areas of the region such as Nagaland, Mizoram, parts of Assam, Arunachal Pradesh and Manipur, the village hunters/poachers often keep the skulls as display on their walls (Choudhury 2013). Thus, the presence of the Asiatic Black Bear needs more systematic surveys in the tiger reserve along with the southern landscape.

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NOTE

First record of Small Minivet *Pericrocotus cinnamomeus* (Aves: Passeriformes: Campephagidae) from Kashmir, India

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Minivets are small- to medium-sized, sexually dimorphic and brightly coloured birds belonging to the order Passeriformes and family Campephagidae. They are distributed over mainland Asia in the west and to the Pacific coast and Japan in the east, through the Indonesian archipelago in the south, with the easternmost distribution along Philippines, Borneo, & Flores Island, near east of Wallace's line (Johnsson et al. 2010). Minivets inhabit forests and forest edge habitats and exhibit group foraging in the forest canopy (Dickninson 2003; Taylor 2005). Out of 12 minivet species found across the world (Johnsson et al. 2010), India is home to nine species (Grimmet et al. 2011). Recent work has reported only Long-tailed Minivet *Pericrocotus ethologus* from the temperate region of Kashmir while four species of minivets, including Small Minivet *Pericrocotus cinnamomeus* are known to inhabit subtropical Jammu (Suhail et al. 2020).

Here we report the first record of Small Minivet *Pericrocotus cinnamomeus* with photographic evidence in Kashmir (Images 1–2). The bird was sighted on 02 August 2021 in Hirpora Wildlife Sanctuary (HWS). The authors had been studying mammals in HWS and also documenting bird diversity of the study site. The bird was sitting on a Pine Tree *Pinus wallichiana* adjacent to an open meadow perhaps feeding on something when we sighted a group of four individuals. However, we could capture a photograph of only one (male) as the others flew away. The bird was recorded at 33.631N & 74.631E and altitude of 2,997 m. The male small minivet is distinguished from other minivets as its head and upper parts are grey, orange under parts, yellow fading on the belly, orange tail margins, rump, and wing patches. This species is distributed throughout tropical southern Asia from eastern India to Indonesia (BirdLife International 2021).

Hirpora Wildlife Sanctuary, spanning an area of 341km^2, is in the Shopian district of Kashmir, northwestern Himalaya. It is situated between 33.483–33.683 N and 74.500–74.716 E, with an elevation range of 2,100–4,745m (Image 3). The vegetation of HWS is dominated by alpine meadows with conifer forests confined to lower and middle elevations at 2,100–3,200 m. The alpine scrub and alpine meadows vegetation types occur at 3,200–4,000 m. The area is rich in flora and fauna and is home to Markhor *Capra falconeri* and

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Image 1 & 2. Small Minivet sitting on a pine tree in Hirpora Wildlife Sanctuary. © Zakir Hussain Najar

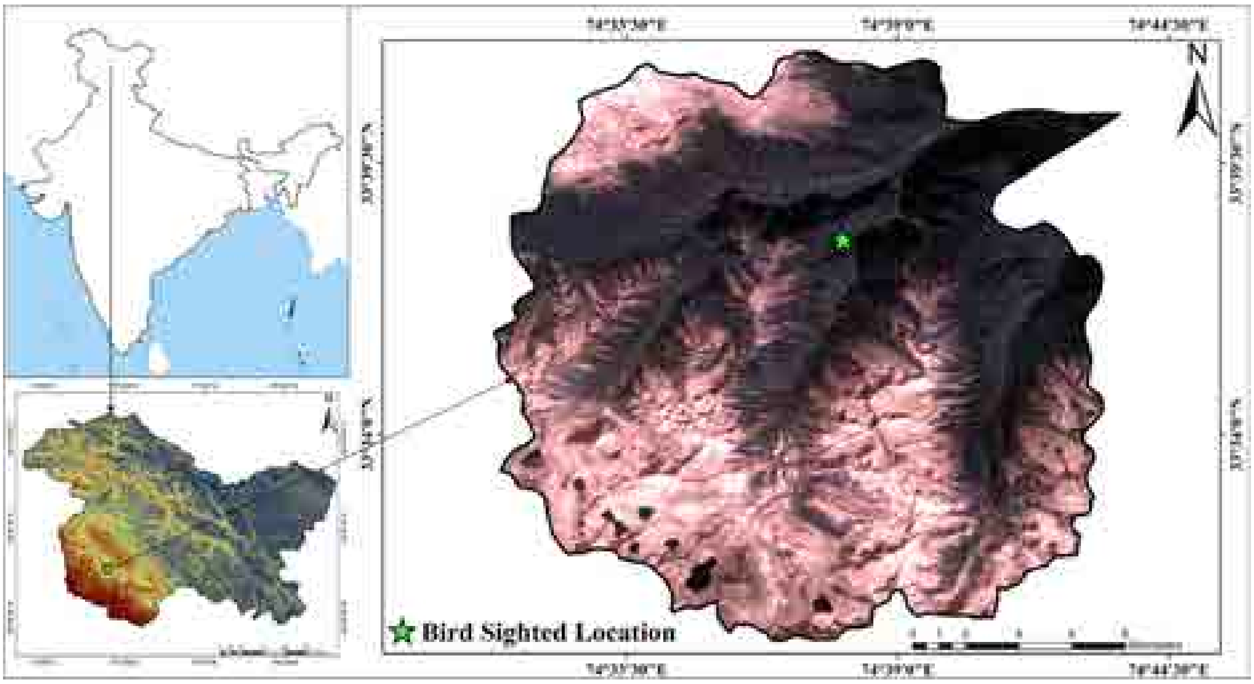

Image 3. Map of Hirpora Wildlife Sanctuary with the location of sighting.

a variety of mammals and birds (Ranjitsinh et al. 2005; Bhatnagar et al. 2009; Kaul et al. 2014).

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NOTE

Cotesia anthelae (Wilkinson, 1928) (Hymenoptera: Braconidae) a natural parasitoid of *Cirrochroa thais* (Fabricius, 1787) (Lepidoptera: Nymphalidae), first report from the Oriental region

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Abbreviations: ICAR—National Bureau of Agricultural Insect Resources, Bengaluru, India | NHMUK—Natural History Museum, London, United Kingdom | NIM (ICAR-NBAIR)—National Insect Museum.

With around 328 species described worldwide (Yu et al. 2016; Fernández-Triana et al. 2020), the genus *Cotesia* Cameron (Hymenoptera: Braconidae) is considered as one of the most hyper diverse and cosmopolitan microgastrine taxa, popular as key players in biological control from all biogeographical regions of the globe. Fernández-Triana et al. (2020) stated that most of the known hosts of *Cotesia* belong to three families: Nymphalidae, Saturniidae, and Sphingidae in Costa Rica. Gupta & Fernández-Triana (2014) while documenting the diversity, hosts and cocoons of Indian Microgastrinae, have reported host species of some 20 morphospecies of *Cotesia.* Based on Gupta et al. (2016) review of the world fauna of *Cotesia*, two species with unusual shape of first tergite (narrowing at midlength), deviating from the original set of generic characters, were compared from India and Africa with their respective hosts belonging to Lasiocampidae and Pieridae, respectively. *Cotesia anthelae* (Wilkinson, 1928) is known to be distributed in Australia from the sole confirmed host *Anthela ocellata* (Walker) (Lepidoptera: Anthelidae) (record from type specimens) with white coloured cocoons (Wilkinson 1928; Fagan-Jeffries & Austin 2020). The present study reports the first confirmed butterfly host species of *C. anthelae* along with its hyperparasitoid *Mesochorus* sp. (Hymenoptera: Ichneumonidae) and the first record of *C. anthelae* from the Oriental region.

Material and Methods

Caterpillars of *Cirrochroa thais* (Fabricius) (Lepidoptera: Nymphalidae) were collected feeding on

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the host plant *Hydnocarpus wightianus* Blume from Nedumpura, Cheruthuruthy, Thrissur district of Kerala in 2020 and during June, 2021 from the same locality. The field collected caterpillars were reared on the natural host plant *H. wightianus*. Parasitoids were collected from the infested caterpillars and were preserved in 70% ethanol for further studies. The voucher specimens of the present study are deposited in the National Insect Museum of ICAR- National Bureau of Agricultural Insect Resources, Bengaluru, India.

Results

Detailed morphological analysis of the gregarious larval parasitoid revealed the primary parasitoid as *C. anthelae* (Image 1) and *Mesochorus* sp. (Image 2) as its hyperparasitoid. The specimens of *C. anthelae* were compared with the images of the holotype (NHMUK 3.c.002) and paratype (NHMUK 3.c.002) illustrated by Fagan-Jeffries & Austin (2020).

***Cotesia anthelae* (Wilkinson, 1928)**

Apanteles anthelae Wilkinson, 1928: 102 (holotype, female, NHMUK).

Cotesia anthelae – Austin & Dangerfield 1992: 21 (transfer from *Apanteles* s.l.).

Diagnosis of *C. anthelae* (Image 1)

Female: Body length 2.5–2.6 mm; general body colour black; legs except coxae, tegulae (light brown), basal ventrites yellowish-brown; apices of hind femora and apical one third of hind tibiae dark brown to black. Hind tibial spurs, palpi and lateral margins of first tergite pale yellow. Pterostigma and wing veins brown. First and second tergites black, rest of metasoma pale at anterior end, darkening towards hypopygium.

Mesosoma: Mesonotum strongly and coarsely punctate, reticulate-rugose punctate near the middle in the apical half; scutellum smooth, sparsely and shallowly punctate, punctures not clearly defined and well separated from each other. Scutoscutellar sulcus with 6–8 pits. Propodeum with well-marked median longitudinal carina and transverse basal carinae, irregular rugose, interspaces shiny. Forewing with first abscissa of radial vein (2.9) subequal to transverse cubital vein (2.9) and shorter than pterostigma width (3–3.1) (relative measurements). Pterostigma almost subequal to metacarp. Hind coxae shallowly punctate. Longer hind tibial spur less than two third length of hind basitarsus.

Metasoma: Metasoma with first tergite strongly and coarsely punctate in apical third, mostly parallel sided, curving inwards at apical corners; sclerotized portion of second tergite rough and ovoid shaped, strongly and distinctly crenulate at posterior margin and lateral edges. Ovipositor sheaths exserted, subequal to length of longer hind tibial spur. Third tergite onwards smooth.

Image 1. Primary parasitoid: Female of *Cotesia anthelae* (Wilkinson).

Image 2. Secondary parasitoid: Female of *Mesochorus* sp.

Cocoons: Gregarious in nature; all the cocoons observed were white in colour and mostly arranged vertically on the host dorsal surface (Image 3).

Host: The butterfly *Cirrochroa thais* (Fabricius) (Lepidoptera: Nymphalidae), commonly known as Tamil Yeoman, is known to be distributed in India and Sri Lanka.

Material examined: 10 females (*C. anthelae*), India: Kerala, 10.729N, 76.263E, 11.viii.2020, ex *Cirrochroa thais* (Fabricius), coll. P. Manoj, specimen code: ICAR/ NBAIR/ Brac/Microg/Cot/11820. 5 females (*Mesochorus* sp.), with same data as above, ICAR/NBAIR/Ich/Meso/11820. Deposited in NIM (ICAR- NBAIR).

Distribution: Australia (Victoria (type) and New South Wales) and Oriental region – Kerala, India (present study).

Image 3. Parasitized caterpillar of *Cirrochroa thais* (Fabricius).

Discussion

Wilkinson (1928) included *C. anthelae* in the 'Indo-Australian species of genus *Apanteles*' hence likelihood of its presence in India is not surprising. However, the more interesting aspect is the discovery of its new butterfly host – *C. thais* as the earlier and the only valid host record was from a species of moth – *A. ocellata* (Anthelidae). According to Fagan-Jeffries & Austin (2020), the other host - *Opodiphthera eucalypti* (Scott) (Lepidoptera: Saturniidae) remains 'doubtful' owing to absence of corresponding specimens. Wilkinson (1928) also mentioned that the cocoons were 'apparently' solitary however as per our observations based on multiple rearings it is confirmed that *C. anthelae* is indeed gregarious in nature.

Conclusion

Our studies substantiate the fact that *C. anthelae* is not a host specific parasitoid species as it is capable to parasitize a butterfly species in addition to moth and with its new distribution record in India the species is no more considered to be endemic to Australia.

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NOTE

Melastoma imbricatum Wall. ex Triana (Melastomataceae): a new addition to the flora of Manipur, India

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Manipur is one of the northeastern states of India lying between 94.31–94.78 E longitudes and 23.83–25.68 N latitude. The state is bounded by upper Chindwin areas of Myanmar in east, Cachar hills of Assam in west, Naga Hills of Nagaland in the north and Chin hills of Myanmar in the south. The state is also a part of the Indo-Burma Biodiversity Hotspot.

The genus *Melastoma* of family Melastomataceae is distributed in southeastern Asia, India, southern China, Japan, northern Australia, Oceania, and Bangladesh. It was reported to comprise about 100 species (Chen 1984), however recent taxonomic revision recognized 22 species (Meyer 2001). While in flora of British India (Vol 2), the genus is represented by six species, viz., *M. malabatricum, M. polyanthum, M. normale*, *M. imbricatum, M. sanguineum*, and *M. houtteanum* (Hooker, 1889), in flora of Manipur (Vol 1), it is represented by two species, viz., *M. malabathricum* and *M. normale* (BSI 2000). And three species were recorded in flora of Assam (Vol 2), viz., *M. malabathricum*, *M. normale*, and *M. imbricatum* (Kanjilal et al. 1938). Among the three species reported from northeastern region (NER) of India, *M. normale* is now designated as *Melastoma malabathricum* ssp. *normale* (D.Don) K. Meyer.

A field survey was carried out at Ukhrul district, Manipur during the month of April 2021. A plant was collected from Lambui (25.015N, 94.294E), Ukhrul district, Manipur which looked similar to *M. malabathricum*. In flora of Manipur (2000), *M. malabathricum* was reported from Sirohee, Imphal, and Uchathol in Manipur. However, the leaves were found to be broader with longer petiole. The plant specimen was brought to Plant Systematic and Conservation Laboratory, Institute of Bioresources and Sustainable Development (IBSD), Imphal, India for proper identification. With the help of floras (Hooker 1889; Kanjilal et al. 1938; Wu et al. 2007), and Literatures (Meyer 2001), the plant specimen was identified as *Melastoma imbricatum* Wallich ex Triana of family Melastomataceae using distinct characters such as hypanthium covered with short appressed golden scales; petiole 1.8–6.5 cm, lamina strigose on both sides, leaf blade broadly ovate to broadly elliptic, 5.5–13.5 cm wide; ovary as long as hypanthium. The herbarium specimen was deposited at Plant systematic and Conservation Laboratory, Institute of Bioresources

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and Sustainable Development, Imphal, India under the voucher number PSCL/C1SP7-35. Since no previous report was found on distribution of *M. imbricatum* in Manipur, India, the present study reports it as a new addition to the flora of Manipur, India. A brief description and colour illustration of the species is provided (Image 1).

Keys to species

1a. Branches covered with scales; hypanthium covered with appressed or slightly spreading golden to red scales; bracts not enclosing the flowers; petiole 0.5–1.9 cm; leaf surface not bullate; leaf blade ovate, elliptic, or elliptic-lanceolate, 1.7–3.5(–6) cm wide; ovary shorter than hypanthium 2

2a. Branches scaly; lamina strigose to slightly pilose below .... ***M. malabathricum***

2b. Branches pilose; lamina pilose below .... ssp. ***normale***

1b. Branches covered with appressed scales; hypanthium covered with short appressed golden scales; petiole 1.8–6.5 cm; bracts not enclosing the flowers; leaf surface not bullate, lamina strigose on both sides, leaf blade broadly ovate to broadly elliptic, 5.5–13.5 cm wide; ovary as long as hypanthium .... ***M. imbricatum***

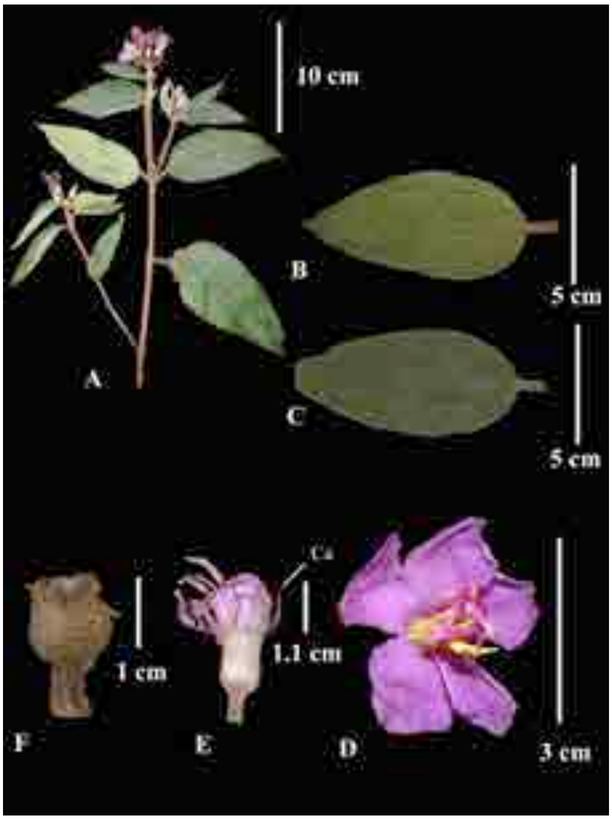

Image 1. *Melastoma imbricatum* Wall. ex Triana: A—Plant | B—Abaxial leaf beneath with very small scabrous hairs | C—Adaxial leaf with 2 secondary veins on each side of midvein, tertiary veins numerous and parallel | D— Flower | E—Bud with calyx (Ca.) | F—Hypanthium. © Rajkumari Jashmi Devi & Mayengbam Aldrin.

Taxonomy description

Melastoma imbricatum Wall. ex Triana, Trans. Linn. Soc. London 28: 60 (1871).

Hooker J.D. Fl. of British India 2: 524.1889; Kanjilal et al. Fl. of Assam 2:299. 1938.

Shrubs, 1 m high. Stems quadrangular, with appressed scales. Leaves broadly ovate to broadly elliptic, 9–11.2 cm × 4.7–5 cm, acute at apex, entire along margin, rounded at base, strigose on both sides, secondary veins two on each side of midvein, tertiary veins numerous and parallel. Petioles 1.5–1.9 cm long. Inflorescences terminal, 8–10 flowered, with two leaf-like bracts at base, overtopped by young branches. Bracts obovate, 1 × 0.4 cm, covered with small appressed scales outside, glabrous inside. Flowers 5-merous. Pedicels 1 cm, strigose; Hypanthium campanulate, 1 × 0.6 cm, covered with short appressed golden scales, 1.2 mm; Calyx triangular, lanceolate 1.12 × 0.2 cm, covered with small appressed scales outside, glabrous inside. Petals violet, obovate, 1.5–2 × 7–10 mm; stamens dimorphic; longer stamens, connective at base 8 mm, ventrally curved, two appendages, 1.5 mm; filaments 6 mm long; anthers 7 mm long, violet; shorter stamens with connective not extended; filaments 5 mm long, two appendages 1 mm long; anthers 6 mm long, yellow. Ovary as long as hypanthium, half inferior, densely bristly at apex. Fruit and seed not seen but noted fruit as a fleshy capsule, rupturing irregularly transversally at maturity exposing soft pulpy orange seeds (Meyer 2001).

Flowering: April–July

Fruiting: Not seen but noted as February to March or December (Flora of China 2007)

Vernacular name: Yachubi (Manipuri)

Distribution: Southeastern Asia, India, southern China, Japan, northern Australia, Oceania (Meyer 2001) and Bangladesh (Uddin 2019)

Habitat: Occurs in disturbed forests and along river banks up to 2,000 m.

Specimen examined: PSCL/C1SP7-35, India, Manipur, Ukhrul, Lambui, 25.015N, 94.294E, 1,420 m, 14.iv.2021 (Image 2).

Image 2. Herbarium sheet of *Melastoma imbricatum* Wall. ex Triana.

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NOTE

Geodorum laxiflorum Griff. (Orchidaceae), a new distribution record for Maharashtra state of India

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Orchidaceae is one of the most diverse and largest families of Angiosperms comprising more than 28,000 recognised plants in around 763 genera (Willis 2017; Jain et al. 2021). In India, around 1,331 species coming under 186 genera represent around 5.98% of the world's orchid flora and 6.83% of the flowering plants in India (De 2020). Recent botanical explorations in Maharashtra, revealed the presence of 32 genera with 106 taxa. The most dominant genus is *Habenaria* with 23 species, followed by *Dendrobium* with 11, *Eulophia* and *Oberonia* with seven, and *Peristylus* with six species (Jalal & Jayanthi 2018). The genus *Geodorum* Jackson is an Indo-Malesian group of about 12 species (Bhatt et al. 2015; Govaerts et al. 2017). In India only six species are found, namely, *Geodorum appendiculatum* Griff., *G. densiflorum* (Lam.) Schlr., *G. laxiflorum* Griff., *G. pallidum* D.Don, *G. recurvum* (Roxb.) Alston., and *G. attenuatum* Griff. (Misra 2007; Kumar et al. 2008; Bhatt et al. 2015; Govaerts et al. 2015). During our exploration we came across a plant which was blooming in the deep forest of Dhanora Tehsil (20.233N, 80.346E) (Figure 1) in Gadchiroli district of Maharashtra, India. The flowering plant looked like pearls spread on the green belt of earth; our curiosity led us to investigate it further.

Markagaon forest range (20.233N, 80.346E) (Figure 1) in the southern part of Dhanora tehsil is well known for its dense dry deciduous forest. Dhanora tehsil is covered with hills and forests and is considered a tribal area. Gadchiroli District mainly receives rain from the south-west monsoon. The average rainfall is 1,562 mm. The climatic conditions are extreme with temperatures reaching 47.3 °C in summer and 9.4 °C in winter.

During our thorough exploration in the Gadchiroli district, we observed the taxa with some interesting characters and is described technically as follows:

Geodorum laxiflorum Griff.

Calcutta J. Nat. Hist. 5: 356 (1845); Hook.f., Fl. Brit. India 6: 18 (1890); G.Seidenfaden, Opera Botanica 72: 51 (1983); S.Misra, Orch. Orissa: 560 (2004); Bhatt et al., Richadiana: 333(2015).

Plant terrestrial, 30–50 cm tall (including leaves); corm 4.5–5 cm, ovoid, slightly compressed, greenish-brown, with scars of fallen leaves; roots few, vermiform, ca. 0.2 cm thick; pseudo stem ca. 10 × 1 cm, enclosed by four foliar imbricating sheaths; leaves 2–4, cauline,

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Figure 1. Distribution map showing the occurrence (red dot) of *Geodorum laxiflorum.*

Image 1. *Geodorum laxiflorum* Griff.: A—habitat | B&C—inflorescence | D—closeup of flower | E—fruiting stage. © Ashish Ravindra Bhoyar

alternate, elliptic lanceolate, acute, undulate, subequal, 13–36 × 8–12 cm, many veined, midvein prominent beneath; inflorescence lateral from the base of newly developed leafy shoot and shorter than it, 20–30 cm; peduncle erect, 20–27 × 0.2 cm, green, decurved at the top, with four membranous tubular sheaths; raceme laxly flowered with 6–12 medium sized flowers; rachis decurved, ca. 2.5– 4 cm long with two sterile bracts; bracts green, oblong lanceolate, ca. 1.1 × 0.3 cm, membranous with acute apex, 3 veined; pedicel with ovary 1.3 cm long, ribbed; flowers white off-white, sepals and petals spreading, 1.5– 2.5 cm across; sepals subequal, 5-veined, oblong lanceolate; dorsal sepal ca. 2.1 × 0.6–0.7 cm; lateral sepals ca. 2.2 × 0.8 cm; petals broader, obovate oblong, ca. 2.3 × 1.2 cm, apex acute obtuse, 7-veined; lip ca. 2.1 × 1.5–1.7 cm, broadly obovate, emarginated, sessile on the base of column, entire, ventricose at the base; sides of the hypochile erect; epichile undulate, edge deflexed, two irregular rows of thick warts starting from the base of the epichile and ending before the apex, hypochile golden brown within, epichile yellow at base and pink at apex; column stout, short, oblong, slightly dilated, ca. 0.5–0.6 × 0.3 cm long; stigma squarish, ca. 0.2 cm long, anther broadly ovate orbicular in outline, ca. 0.3–0.4 cm, off-white with brown tinge, the locules pouch like; pollinia yellow, obliquely oblong ovoid, porate behind, ca. 0.2 × 0.15 cm, stipe hyaline, subquadrate (Image 1).

Flowering: June–July; Fruiting: August–October.

Ecology: Extremely rare in dry deciduous forests, at an elevation range of about 263 m.

Distribution: Endemic to India Assam, Andhra Pradesh, Chhattisgarh, Gujarat, Jharkhand, Odisha, Telangana, and Maharashtra (this report).

Specimen examined: GSC/Gad/Bot.Sp.No. 263, 27.vii.2021, Markagaon forest range, Gadchiroli district, Maharashtra, India, coll. Syed Abrar Ahmed. The specimen is preserved in the Department of Botany, Government Science College, Gadchiroli.

Recently, *Geodorum laxiflorum* was reported from southern peninsular India from Nallamalai hills, part of the Eastern Ghats of Andhra Pradesh (Rao & Prasad 2011) and from the Western Ghats, Waghai taluka of Dangs district, Gujarat state (Bhatt et al. 2015).

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NOTE

Photographic record of *Armillaria mellea* a bioluminescent fungi from Lonavala in Western Ghats, India

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Bioluminescent organisms are one of the most distinctive creations of nature. Several groups of organisms exhibit luminescent properties such as animals, plants, fungi, and even bacteria (Pandey & Sharon 2017). The most commonly found bioluminescent organisms in the oceanic environment are Dinoflagellates (Fleiss & Sarkisyan 2019) while in terrestrial organisms bioluminescence has been observed in a wide range of organisms.

All bioluminescent fungi belong to the division Basidiomycota, except for one, *Xylaria hypoxylan*, which belongs to the Ascomycota division (Becker & Stadler 2021). Amongst this foxfire is a common name for different species of fungi like *Mycena chlorophos* and *Mycena citricolor* (Weitz 2004) while *Armillaria* (Basidiomycota, Physalacriaceae) species infects mostly woody species in natural forests (Baumgartner et al. 2011; Koch et al. 2017). *Armillaria* exhibits a wide range of hosts.

The *Armillaria mellea*, bioluminescent fungi contains an enzyme called Luciferase, causing luciferin substrate to catalyze in presence of oxygen. During these chemical reactions, products are released as excess energy, which is visible as light (Kaskova et al. 2017).

Earlier records suggest the presence of bioluminescent organisms from the Bhimashankar Wildlife Sanctuary in Maharashtra (Pal 2017). To explore the floral and faunal landscape, a survey was conducted from July to September 2021. The sites for the survey were Lonavala (18.694N, 73.386E) and Mulshi (18.459N, 73.406E) in Maharashtra. The survey was opportunistic and focused on the fauna and flora of northern Western Ghats.

The observations were made as the presence of luminescent fungi was seen on rotting substrates like branches, roots, and even leaves. During the day, the fungi appear yellowish-white in color as shown in the image, while at night, the fungi effuse green bioluminescence. During the survey, the observed fungus was noted, by its type of structure (Mushroom or sheet in form) and its presence in an area. During the survey luminescent areas were observed, marked, and documented. The fungi attracted and hosted small flies and insects during the observed period.

The fungus was identified based on the current literature available. The species is *Armillaria mellea*, also referred to as Foxfire or Fairy Fire or even as Wood Destroyer (Mishra & Srivastava 2021).

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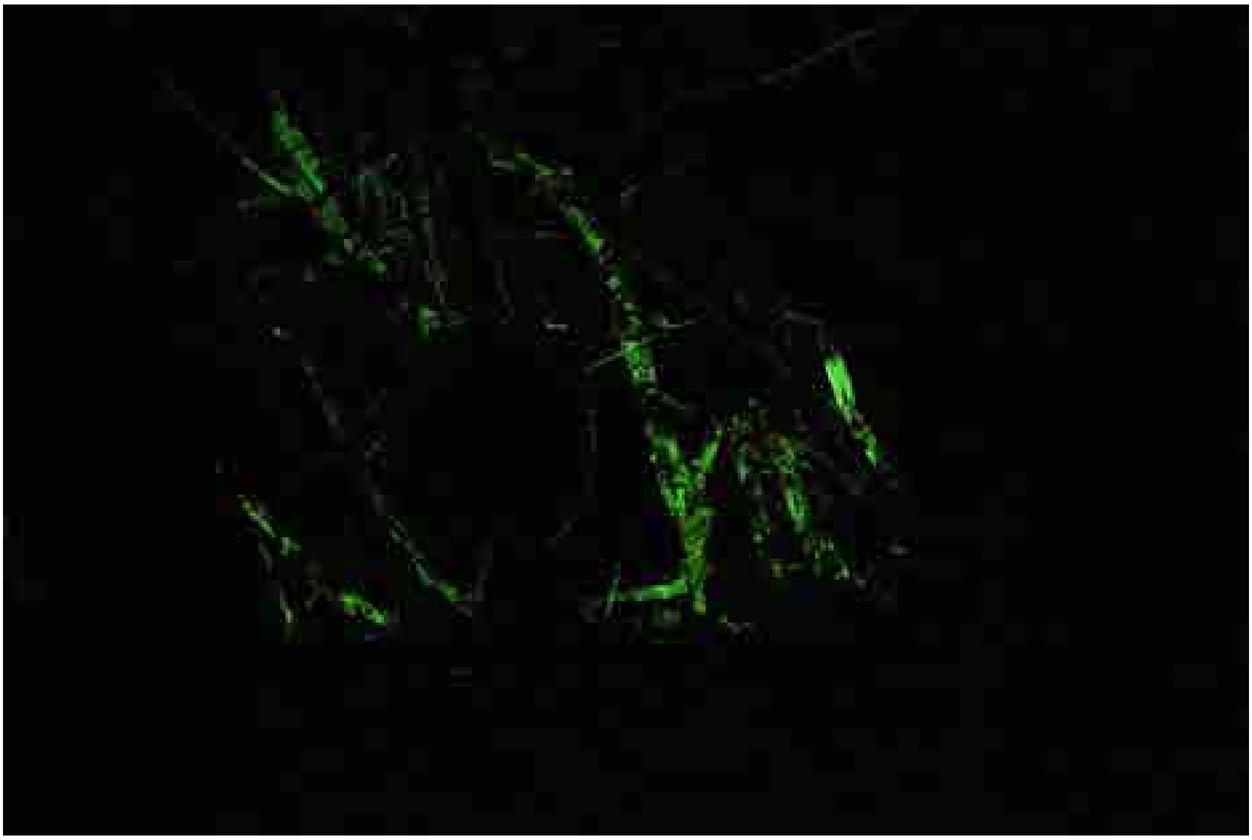

Image 1. Photographic evidence of glowing fungi during the night (bioluminescent fungi). © Arcane Conservancy.

Image 2. Yellowish-white patches on the dead branch is the bioluminescent fungi in light. © Arcane Conservancy.

The observed *Armillaria mellea* fungi were observed on the ground or on rotting on fallen wooden branches of trees. It emits a bluish-green glow and appeared to be abundant in the region. The team didn't come across any other type of bioluminescent fungi.

The functions of these fungi are still unknown. Studies (Fleiss & Sarkisyan 2019) suggest that the luminescent nature of these organisms is for spore dispersal mechanism for attracting insects.

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OPEN ACCESS

RESPONSE

Correction to Catalogue of herpetological specimens from Meghalaya, India at the Sálim Ali Centre for Ornithology and Natural History (SACON)

Pandi Karthik

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The following publication of this article (Journal of Threatened Taxa 13(11): 19603–19610). <https://doi.org/10.11609/jott.7318.13.11.19603-19610>. Chandramouli et al. 2021, in their recent publication on the catalogue of herpetological specimens from Meghalaya, India, at the Sálim Ali Centre for Ornithology and Natural History (SACON), presented imprecise information regarding herpetofaunal collection and its geographical location. However, it is necessary to correct the following inaccuracies and publish corrigenda to help prevent the misleading information from being repeatedly published in the future.

Specimen collection acts as a crucial repository that retains historical information on species dispersal patterns for decades (Da Silva et al. 2017). Therefore, it is essential to keep a check on the original collection material and its datum. Recent, Chandramouli et al (2021) have discussed merely handy specimens, but many more have yet to be documented (Ganesh et al. 2020 and Karthik pers. com.). SACON - *Sálim Ali Centre for Ornithology and Natural History* now houses about 200 species of the herpetological collection. However, the precise number (of samples) is unknown, include the major contribution from Pandi Karthik & R.S Naveen and a renowned herpetologist Dr. (Late) S. Bhupathy's (see Ganesh et al. 2020). Nevertheless, SACON has published two series of catalogues on the care and maintenance of herpetological collections (Ganesh et al. 2020, Chandramouli et al. 2021a & 2021b). As it is catalogued and the specimens are vouchered for future studies, therefore the author ought to disclose the SACON accreditation for upholding a large number of specimens. Hence, in the future other researchers can access the specimens for taxonomical investigation, which will benefit herpetological conservation (Uetz et al. 2019).

(i) The author stated the collector name P. Karthik (instead of Pandi Karthik). The collector name is not included as an author and does not need to be abbreviated; rather, it should be the academic name. (ii) Furthermore, the author failed to follow the word-uniformity (i.e.) on species location and specimen voucher number; a few places the specimen voucher number comes along with institute acronyms (i.e., SACON VA 102) and someplace it does not (i.e., VA 72 & 73). (iii) Also, a paucity of information on preservation methods and collection permit information (follow Al-Razi et al. 2021 & Mirza et al. 2021). As a concurring collector, the specimens were fixed in 7 % formaldehyde solution and later stored in 75 % ethanol. A few specimens of tail tip tissues were preserved in 95% ethanol for molecular work prior to specimen fixation (Mirza et al. 2021). For future taxonomical investigation, the specimens and tissue samples have been deposited in *Sálim Ali Centre for Ornithology and Natural History* (SACON).

Microhylidae Günther, 1858

Microhyla berdmorei (Blyth, 1856)

Location: SACON VA 102 - an adult female from Sasatgre, Meghalaya (coll. Pandi Karthik).

Megophryidae Bonaparte, 1850

Leptobrachium sp.

Location: SACON VA 57 and SACON VA 61 from Mongalgre, Meghalaya (coll. Pandi Karthik)

Comment: The author did not mention sp. collector name. Further, the author has followed Al-Razi et al.

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(2021), based on their syntype specimens and geographic proximity; the author assumes and referred (SACON VA 57, VA 61) as *L. cf. sylheticum*. There is no evidence that Al-Razi et al. 2021 study has a sample widely (including Meghalaya) to prove *L. smithi* complicity. The study involves samples from a single location in Bangladesh named Lawachara National Park (LNP), approximately 220 miles air distance from the location collected by Pandi Karthik. Additionally, a given location has disjunctive biogeographic, it may be a factor attribute to speciosity (Agarwal et al. 2018). It cannot be synonymized with either *L. sylheticum* nor with *L. smithi* as it was referred to as *Leptobrachium* sp. until the integrated taxonomy attempt on the genus.

Amphibia Gray, 1825
Anura Fischer von Waldheim, 1813

Minervarya sengupti (Purkayastha & Matsui, 2012)

Location: Two adult females (SACON VA 89, VA 97) from Mongalgre and Sasatgre, Meghalaya (coll. Pandi Karthik).

Limnonectes khasianus (Anderson, 1871)

Location: An unsexed adult (SACON VA 68) from Selbalgre, Meghalaya (coll. Pandi Karthik).

Comment: Also, the location should be uniform, author had mentioned species collection location Dimitdigre (instead of Dumitikgre).

Rhacophoridae Hoffman, 1932 (1858)

Theloderma cf. albopunctatum

Location: SACON VA 88, VA 69 - an unsexed juvenile from Selbalgre and adult female from Raid Nongbri (coll. Pandi Karthik).

Comment: The author referred (SACON VA 88, VA 96) as *Theloderma baibungense*. I again refer (SACON VA 88, VA 96) as a *Theloderma cf. albopunctatum*. Because, the species resemble to *T. cf. albopunctatum* based on its morphometric characters and other information provided (Mian et al. 2017). Also, conferring the geographic proximity and the molecular nest provided. Therein, I refer to the species again as *T. cf. albopunctatum.* Furthermore, an integrated taxonomic approach would be a substantial in resolving species-level complications.

Reptilia Laurenti, 1768
Sauria Macartney, 1802
Gekkonidae Gray, 1825

Gekko gecko (Linnaeus, 1758)

Location: SACON VR 229 - adult male from Jirang, Meghalaya (coll. Pandi Karthik). Also from Raid Nongbri, Meghalaya (yet to be vouchered).

Agamidae Gray, 1827

Calotes cf. irawadi

Location: SACON VR 205, VR 240, VR 245- six unsexed subadult specimens from Jirang, Dumitdigre, Mongalgre Meghalaya (coll. Pandi Karthik). In addition, each sample sites provided a subset of reference specimen on the genus *Calotes* for future taxonomical investigation. Additionally, reference specimens were collected from each sample site.

Cristidorsa planidorsata (Jerdon, 1870)

Location: SACON VR 185 and VR 169 - two adult males from Sasatgre and Daribokgre Meghalaya (coll. Pandi Karthik).

Ptyctolaemus gularis (Peter, 1864)

Location: SACON VR 238, VR 239, VR 207 - three adult males and, VR 201 - an unsexed juvenile from Lum Jusong, Daribokgre, Meghalaya (coll. Pandi Karthik).

Sphenomorphus sp.

Location: SACON VR 227 - subadult from Dumitikgre, Meghalaya (coll. Pandi Karthik).

Serpentes Linnaeus, 1758
Typhlopidae Merrem, 1820

Argyrophis diardii (Schlegel, 1839)

Location: SACON VR 187, 223 – two adult specimens from North-Eastern Hill University Campus, Shillong and Sasatgre, Meghalaya (coll. Pandi Karthik).

Indotyphlops sp.

Location: An unsexed adult specimen (SACON VA 219) from Dumitikgre, Meghalaya (coll. Pandi Karthik).

Pseudaspididae Cope, 1893

Psammodynastes pulverulentus (Boie, 1827)

Location: SACON VR 152 - a subadult specimen from Mongalgre, Meghalaya (coll. Pandi Karthik).

Colubridae Oppel, 1811

Lycodon sp.

Location: SACON VR 213, VR 215 – two subadult specimens from Padakydeng, Raid Nongbri, Meghalaya (coll. Pandi Karthik).

Oligodon cinereus (Günther, 1864)

Location: SACON VR 214 – unsexed adult from Daribokgre, Meghalaya (coll. Pandi Karthik).

Comment: The author has named SACON VR 214 as *Oligodon juglandifer*, but it is not. The unsexed adult road crush specimen was identified as *Oligodon cinereus*.

Oligodon cyclurus (Cantor, 1839)

Comment: SACON VR 254 – an unsexed adult from Tokpara, Meghalaya. The author did not mention the species collector name (not collected by Pandi Karthik).

Boiga gocool (Gray, 1834)

Location: SACON VR 190, 192 – unsexed subadults from Jirang, Meghalaya (coll. Pandi Karthik).

Dendrelaphis proarchos (Wall, 1909)

Comment: The author had stated the specimen SACON VR 210 - adult from Meghalaya (coll. Pandi Karthik). No such specimen was collected by Pandi Karthik from the genus '*Dendrelaphis*', nevertheless, the author may have been misinformed because one sample from the genus *Dendrelaphis* sp. is available at SACON that perhaps collected lately from the Anaikatty.

Coelognathus radiatus (Boie, 1827)

Location: SACON VR 189 - subadult from Jirang Meghalaya (coll. Pandi Karthik).

Elaphe cantoris (Boulenger, 1894)

Comment: The specimen SACON VR 211 was not collected by Pandi Karthik, was miscommunicated.

Pareidae Romer, 1956

Pareas monticola (Cantor, 1839)

Location: The SACON VR 212 - adult from Selbalgre, Meghalaya (coll. Pandi Karthik).

Natricidae Bonaparte, 1838

Hebius khasiensis (Boulenger, 1890)

Location: SACON VR 162, VR 175, VR 177 four unsexed adults from Sasatgre, SACON VR 209, VR 225, VR 246 - three unsexed sub-adult & juvenile from North-Eastern Hill University Campus, Shillong, Meghalaya (coll. Pandi Karthik),

Fowlea piscator (Schneider, 1799)

Location: SACON VR 156 - adult male road-killed specimen from Nongsangu. SACON VA 202, 203 - adults from Raid Nongbri Meghalaya (coll. Pandi Karthik).

Sinomicrurus macclellandi (Reinhardt, 1844)

Location: SACON VR 159 - one adult from near Padakydeng Village, Meghalaya (coll. Pandi Karthik).

Naja kaouthia Lesson, 1831

Location: One juvenile (SACON VR 157) from Nonsangu, Meghalaya (coll. Pandi Karthik).

Ophiophagus hannah (Cantor, 1836)

Location: SACON VR 252 adult male was collected from Jirang, Meghalaya (coll. Pandi Karthik).

Comment: The specimen SACON VR 252 was killed by humankind, prior to the rescuer's arrival (a local authorization letter was obtained to avoid future consequences).

Viperidae Oppel, 1811

Trimeresurus sp.

Location: One subadult (SACON VR 160) from Selbalgre, Meghalaya (coll. Pandi Karthik).

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REPLY

Reply to the "Correction to Catalogue of herpetological specimens from Meghalaya, India at the Sálim Ali Centre for Ornithology and Natural History (SACON)" by P. Karthik

S.R. Chandramouli [1], R.S. Naveen [2], S. Sureshmarimuthu [3], S. Babu [4], P.V. Karunakaran [5] & Honnavalli N. Kumara [6]

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In a recent issue of the Journal of Threatened Taxa, we published a catalogue of hereptofaunal specimens collected from Meghalaya as a part of an on-going project entitled "Characterization of Community Reserves and Assessment of their Conservation Values in Meghalaya" (Chandramouli et al. 2021a).

Strangely, Karthik (2021) has 'reacted' to our publication with a 'corrigendum' with claims of "imprecise and misleading information" having been presented. Therefore, we are constrained to respond to his allegations in this publication. In principle, errata and corrigenda are published either by the authors of a publication (us) or the publisher (JoTT, in this case). Therefore, Karthik (2021) is not entitled to be titled as a corrigendum to the article that the author was not a part of. To begin with, the author P. Karthik (hereafter PK), who was hired on a temporary basis as a Junior Research Biologist for this project, collected a part of the specimens presented in the catalogue (Chandramouli et al. 2021a) and was initially invited to be a co-author, when the publication was conceived. However, PK voluntarily declined to be a part of this exercise with a request to remove his name from the authors list. His decision was respected by the other principal investigators. We hereby convey the fact that for the publication of another article (Chandramouli et al. 2021b) from the same project, involving the same team, PK was also a co-author (Chandramouli et al., 2021a). Had he not declined our offer of co-authorship for the publication on the catalogue (Chandramouli et al. 2021b), he would have been a part of this publication as well. It is unreasonable on the part of PK to accuse and relegate the efforts of Chandramouli et al. (2021b) in his response. We present our arguments for his allegations below in a point-wise manner:

1. "Recent, Chandramouli et al. (2021b) have discussed merely handy specimens, but many more have yet to be documented (Ganesh et al. 2020 and Karthik pers. com.). SACON - *Sálim Ali Centre for Ornithology and Natural History* now houses about 200 species of the herpetological collection." (sic.)

Response: The title of our article "Catalogue of herpetological specimens from Meghalaya, India at the Sálim Ali Centre for Ornithology and Natural History (SACON)" clearly states that we are dealing only with the herpetological collections from the state of Meghalaya and not the rest.

2. "As it is catalogued and the specimens are vouchered for future studies, therefore the author ought to disclose the SACON accreditation for upholding a large number of specimens." (sic.)

Response: PK himself was a co-author in Ganesh et al. (2020) cataloguing a part of the collections at SACON and hence, the above statement is self-contradictory. The specimens were collected with

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proper permits from the state forest department of Meghalaya. It is an on-going study and hence, all the collected specimens are under the custody of SACON. In future if any taxonomic work on these specimens is addressed then those specimens will be deposited in an accredited repository.

3. The author stated the collector name P. Karthik (instead of Pandi Karthik). The collector name is not included as an author and does not need to be abbreviated; rather, it should be the academic name.
Response: The author (PK) himself has published articles (Ganesh et al., 2020; Chandramouli et al., 2021a) as "P. Karthik" and the same has been followed here. In addition, the official records submitted to SACON by him mentions his name as "P. Karthik". Moreover, it is immaterial and inconsequential to expand his first name, as long as he has been credited for the collection (see Acknowledgements in Chandramouli et al. 2021b).

4. Furthermore, the author failed to follow the word-uniformity (i.e.) on species location and specimen voucher number; a few places the specimen voucher number comes along with institute acronyms (i.e., SACON VA 102) and someplace it does not (i.e., VA 72 & 73).
Response: As the publication deals with the collections from Meghalaya at SACON, it is not necessary to repeat the institutional acronym SACON in each entry and whether or not to mention it is solely at the discretion of the authors and the journal format. To substantiate this, we point out that Karthik (2021) himself mentions the voucher numbers of certain samples e.g. *Calotes* cf. *irrawadi* as "SACON VR 205, VR 240, VR 245", wherein, VR 240, VR 245 do not bear the prefix SACON, and is presumed to be understood.

5. Also, a paucity of information on preservation methods and collection permit information (follow Al-Razi et al. 2021 & Mirza et al. 2021). As a concurring collector, the specimens were fixed in 7 % formaldehyde solution and later stored in 75 % ethanol. A few specimens of tail tip tissues were preserved in 95% ethanol for molecular work prior to specimen fixation (Mirza et al. 2021). For future taxonomical investigation, the specimens and tissue samples have been deposited in *Sálim Ali Centre for Ornithology & Natural History* (SACON).
Response: The concerned authorities: i.e., the Additional Principal Chief Conservator of Forests (Wildlife) and Chief Wildlife Warden (CWLW), Meghalaya, and officers of the Forest and Environment Department, Government of Meghalaya have been duly acknowledged in our publication for according permits for the study, based on which P. Karthik and other researchers of this project were permitted to visit and collect data / specimens from Meghalaya. It is to be noted that the permission was given to the project. In fact, it is to be questioned as to how Karthik (2021) can be published since the scientist to whom permission was granted does not feature in Karthik (2021). The information on whether or not tissues have been extracted and stored at SACON is irrelevant and unnecessary for this publication.

6. Locality information of *Microhyla berdmorei* (SACON VA 102) *Minervarya sengupti* (VA 89, 97), *Limnonectes khasianus* (VA 68), *Hemidactylus frenatus* (VR 222), *Hemidactylus* sp. (VR 171), *Gekko gecko* (VR 229), *Calotes* cf. *irawadi* (VR 205, VR 240-245), *Calotes emma* (VR 150, 151), *Cristidorsa planidorsata* (VR 185 and VR 169), *Ptyctolaemus gularis* (VR 238-239, VR 207, VR 201), *Sphenomorphus* sp. (VR 227), *Argyrophis diardi* (VR 187, VR 223), *Indotyphlops* sp. (VR 219), *Psammodynastes pulverulentus* (VR 152), *Lycodon* sp. (VR 213, VR 215), *Oligodon juglandifer* (VR 124), *Boiga gocool* (VR 190, VR 192), *Dendrelaphis proarchos* (VR 210), *Coelognathus radiatus* (VR 189), *Elaphe cantoris* (VR 211), *Pareas monticola* (VR 212), *Hebius khasiense* (VR 209, VR 225, VR 246), *Fowlea piscator* (VR 202, 203), *Sinomicrurus maclellandi* (VR 159), *Naja kaouthia* (VR 157) and *Ophiophagus hannah* (VR 252) and *Trimeresurus* sp. (VR 160).
Response: Despite being aware of the information on their origin, PK has neither documented and submitted this information to the project PIs, nor informed us when the first draft of the catalogue was shared with him while inviting him to be a co-author. It is unjust and unfair on the part of PK, engaged as a Junior Research Biologist, to have deliberately concealed all this information from the PIs and to raise a query on their origin now, after publication. Nevertheless, as fellow scientists, we are happy that PK has managed to furnish this vital information at least now that we take to be good for the larger benefit of science.

7. "*Theloderma* cf. *albopunctatum*
Location: SACON VA 88, VA 69 - an unsexed juvenile from Selbalgre and adult female from Raid Nongbri

(coll. Pandi Karthik).

Comment: The author referred (SACON VA 88, VA 96) as *Theloderma baibungense*. I again refer (SACON VA 88, VA 96) as a *Theloderma* cf. *albopunctatum*. Because, the species resemble to *T.* cf. *albopunctatum* based on its morphometric characters and other information provided (Mian et al. 2017). Also, conferring the geographic proximity and the species complicity in the molecular nest. Therein, I refer to the species again as *T.* cf. *albopunctatum.* Additionally, an integrated taxonomic approach would be detrimental in resolving species-level complicity."

Response: Frost (2021), under the accounts of *Theloderma albopunctatum* states that "populations from northeastern India, Myanmar, to and including Thailand are provisionally attached to this species but likely represent a complex of unnamed species". Therefore, we disagree with the unsubstantiated claims made by Karthik (2021) who failed to fully substantiate his claims by describing the specimens.

8. "*Oligodon cinereus* (Günther, 1864)

Location: SACON VR 214 – unsexed adult from Daribogkre, Meghalaya (coll. Pandi Karthik).

Comment: The author has named SACON VR 214 as an *Oligodon juglandifer*, but it is not. The unsexed adult road crush specimen was identified as an *Oligodon cinereus*."

Response: Karthik (2021) without any idea of the specimen in question makes an emphatic, premature statement on the identity of SACON VR 214. The road-killed *O. cinereus* which he states to be from Daribokgre, is presently not traceable in the collections and VR 214, which is a totally different specimen has been identified by us as *O. juglandifer*.

9. "*Dendrelaphis proarchos* (Wall, 1909)

Comment: The author had stated the specimen SACON VR 210 - adult from Meghalaya (coll. Pandi Karthik). No such specimen was collected by Pandi Karthik from the genus '*Dendrelaphis*', nevertheless, the author may have been misinformed because one sample from the genus *Dendrelaphis* sp. is available at SACON that perhaps collected from the Anaikatty".

Response: Perhaps the collector information could have been misconstrued. But yet, we could not help ourselves but to wonder, how could PK comment so emphatically about the provenance of a specimen that he himself states to not have collected. Moreover, there has been a team of seven members involved in the project who were at Meghalaya, one of whom could have been its collector.

In conclusion, it is apparent that the intentions of Karthik (2021) have just been defamation of the article published by Chandramouli et al. (2021b) which he voluntarily declined to be a part of. Our explanations clearly point at the personal lamentations rather than scientific concerns of Karthik (2021). We strongly discourage such unethical practices in scientific forums.

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BOOK REVIEW

Book Review: Conservation Kaleidoscope: People, Protected Areas and Wildlife in Contemporary India

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The launching of *The Protected Area Update* (PAU) by Pankaj Sekhsaria in 1994 speaks about the very unique foundation and sustainable foresight for perennial source of information. PAU has grown in its contents and deliverables. At regular interval while it is updating its readers with all that is happening in the country about wildlife, the volume of information the PAU have amassed have developed into a historical data bank.

For a researcher it would have been difficult to go back and search the contents of PAU for crisp and meaningful data pieces, anywhere. In 2013, Sekhsaria brought out *The State of Wildlife in North-East India 1996–2011* within 295 pages, and in 2015 it was the turn for *The State of Wildlife and Protected Areas in Maharashtra*, within xii + 235 pages. I had the opportunity to go through the second masterpiece (Singh 2020).

This time, as a person ever hungry for data and information, I have profound pleasure and satisfaction while going through *Conservation Kaleidoscope: People, Protected Areas and Wildlife in Contemporary India,* compacted within xviii + 412 pages. The book has a simple and attractive cover within 23 x 15 cm. From the small art works, one is able to know the scope within the book.

I reaffirm my own opinion (Singh 2015) that information relating to wildlife and natural history photography have now expanded to people who are beyond full time field researchers, and the platforms used for dissemination of information are often outside impact-loaded journals. One needs to see his observation or writing quickly in the print or electronic media. PAU has very ably harvested upon these changing trends.

Field discoveries, management remarks, instances of policy flouts, and people interfaces are now possible by tourists, amateur photographers, and users of normal mobile phones. Data do not have to wait for confirmation by full time researchers from large institutions or

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Pankaj Sekhsaria (2021). (Ed.)
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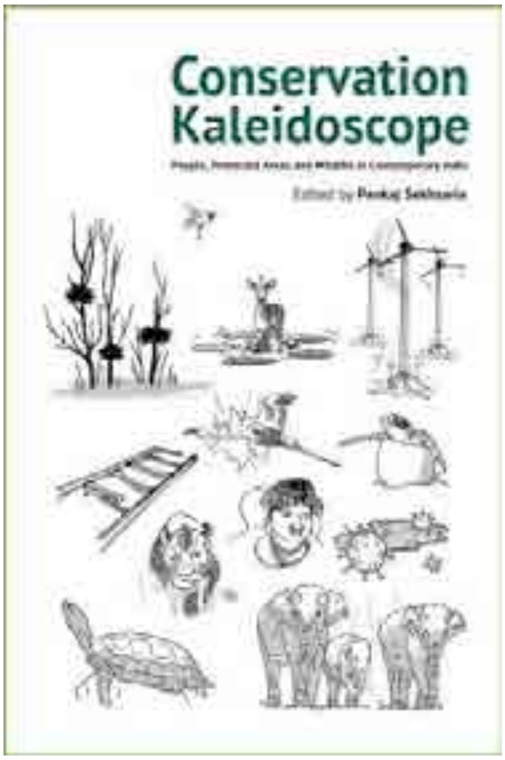

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sophisticated equipment or costly laboratory profiling.

PAU has the pages where these are documented and getting accessibly organised in the compilations edited by Sekhsaria. The data doesn't come only from India, but from the neighbourhood, as well. For example, "Only two rhinos poached in Nepal in 2007" (Page 347). The piece on "Do we want the cheetah back?" (Page 351) from October 2009 is interesting to browse back in the light of present developments. The volume includes more than a hundred editorials from old issues of PAU. Congratulations!

Obtaining authentic information from nook and corner of the country is extremely difficult, time consuming and depends on the level of networking. The editor, Mr. Sekhsaria, has handled these faculties with grit and efficiency so well for nearly two decades. That has made this book possible.

Organising the contents for such a data base is a hard task, considering the range of topics, over historical account of states, and the variety of happenings. Yet, the contents have been well planned and laid out in 14 chapters. Well done! The chapters include 1. Law, Policy, and Governance; 2. Human Rights in Protected Areas; 3. The Developmental Threat; 4. The Linear Infrastructure Nightmare; 5. The Local Context; 6. At the State Level; 7. Specific Geographies; 8. Changing Seasons; 9. Tourism; 10. Communicating Conservation; 11. Tiger and Tiger Reserves; 12. Fate of the Elephant; 13. Rhinos, Bees, Bats, Dolphins; and 14. A Colourful Mosaic. The Editor's Note is very explicit. There is also a very exhaustive list of abbreviations running to 5.5 pages. The entire work is carefully woven. An index would have made usage more at once.

I am confident that the volume will draw references for students, historians, and general readers in India and overseas keen to know the happenings around wildlife in this part of the globe with the scope of a wide-ranging chapter titles.

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