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continued on the back inside cover

Caption: The Himalaya from Kangra by Sanjay Molur.

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Factors affecting diversity and distribution of threatened birds in Chitwan National Park, Nepal

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Abstract: Factors affecting diversity and distribution of globally threatened birds were studied by dividing Chitwan National Park (CNP) into five study blocks consisting of 17 birding routes. CNP provides major habitats for the feeding and breeding of a large number of migratory birds from many parts of the globe and also plays a vital role in the conservation of threatened species. We recorded a total of 437 individuals of globally threatened birds belonging to 19 species of nine families and eight orders. There was considerable variation (F=2.94, df=44.43, p=0.05) in species diversity of threatened birds in different study blocks: the highest diversity was in Block E (Pithauli, Amaltari, and Narayani Island area; H=2.108), followed by Block C (Kasara to Sukibhar area; H=2.047), Block B (Barandabhar Corridor Forest; H=2.033), Block A (Khagendra Malli, Kathar, Sauraha to Old Padampur; H=1.744), and Block D with the least diversity (Madi area; H=1.69). The higher dominance index was found in blocks A (D=0.2407) and D (0.2361) compared to other blocks. The lower diversity of threatened birds was reported in those blocks (A & D) located nearer to human settlements that experienced higher disturbance. Presence of livestock and people caused significantly negative effects on species richness and abundance of threatened birds, mainly in Block A. Distance from roads and villages also had a negative effect on the diversity and abundance of most of the threatened birds. This study suggests that human disturbance caused a significantly negative impact on the presence, distribution, diversity, and abundance of threatened birds in CNP and adjoining areas.

Keywords: Abundance, anthropogenic disturbance, avian diversity, distribution.

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Author Contribution: JNA & BPB designed and carried out research, BPB & TBT performed analyses. JNA, BPB & TBT wrote the paper.

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INTRODUCTION

Nepal, the mountainous country, supports a total of 886 species of birds (8.87% of the global bird species) including 39 globally threatened species, 31 Near Threatened species, and one endemic species, the Spiny Babbler *Turdoides nipalensis* (Grimmett et al. 2016; Inskipp et al. 2016; BCN & DNPWC 2018). The National Red List Series for birds of Nepal shows nearly 19% of Nepal's birds (168 species) as listed in the nationally threatened category. Among them are 68 (40%) Critically Endangered, 38 (23%) Endangered, and 62 (37%) Vulnerable species. Besides this, 62 species are also listed as Near Threatened (Inskipp et al. 2017). Nine species of birds are nationally protected according to the National Parks and Wildlife Conservation Act-NPWC Act 1973 (DNPWC 1973) and 113 birds are listed in CITES category (DNPWC 2018). Eight species (1% of the total threatened) are regionally extinct from Nepal and were not reported since the 19th Century; also, 22 species (2.5% of the total) are considered Data Deficient (Inskipp et al. 2016; DNPWC 2018).

Grasslands, wetlands, and forests not only provide feeding and breeding sites for a large number of threatened birds, mammals, reptiles, amphibians, fish, and invertebrates but also play a vital role in their conservation and in meeting the needs of the local people residing near those areas. Habitat degradation and loss are the major threats (86%) to birds (Baral et al. 2013). Fifty-five per cent of grassland specialist birds of lowland Nepal are threatened, followed by 25% of wetlands birds and 24% of tropical and subtropical forest birds (Inskipp et al. 2016). Most of the protected areas of Nepal face human and livestock pressure, creating continuous disturbance of various levels to wildlife (Bhattarai et al. 2017). Modernization in agriculture practices such as heavy use of pesticides in crops and exotic crop varieties, development activities such as roads and industries, eutrophication of lakes and ponds, succession in grasslands, and the introduction of exotic and alien plant species such as *Mikania micrantha, Chromolena odorata, Lantana camara,* and *Parthenium hysterophorus* are considered as the major threats to wildlife habitats. Shrinking of grasslands due to forest encroachments is the major threat to grassland-dependent birds (Chhetri & Shakya 2016)

Chitwan National Park (CNP) harbours spectacular birdlife due to high habitat heterogeneity (Bhattarai & Kindlmann 2012). The freshwater swamp of Reu, Rapti, and Narayani river floodplain stands with Sal *Shorea robusta,* Sissoo *Dalbergia sissoo*, and Khair *Acacia catcheu* vegetation and the profuse aquatic vegetation is the prime habitat for rich micro and macro living forms including many species of snails, fish, and herpetofauna (Bhattarai 2012; CNP 2018). Such abundant food renewed annually by the floodwater of rivers is a suitable habitat for resident water birds and also attracts thousands of migratory water birds each year. The large patches of grasslands inside the park support many grassland-dependent birds as well as mammals and reptiles. More than 600 species of birds were recorded in Chitwan District in which 544 species were recorded in the CNP (CNP 2018). Wetlands face a serious eutrophication problem that significantly decreases the quantity (shrinking area of wetlands) and quality (physicochemical parameters) of water (Thapa & Saund 2012). Ecologic succession and introduction of exotic and alien species of plants destroy the grasslands (Shrestha 2016). Therefore, the present study was designed to explore the factors associated with the distribution, diversity, and abundance of globally threatened birds of CNP.

MATERIALS AND METHODS

Study area

CNP, the world heritage site, is situated in southern central Nepal in the subtropical lowlands of the inner Terai of Chitwan, Makawanpur, Parsa, and Nawalparasi districts. It lies between 27.276–27.837 ^{0}N & 83.837 –84.770 ^{0}E, covering an area of 952.63km^{2} (CNP 2018). The area of 729.37km^{2} surrounding the park was declared a buffer zone, which consists of forests and private lands including cultivated lands (CNP 2018). The park consists of a diversity of ecosystems including the Churia Hill forests, ox-bow lakes (Tal, including Beeshazari, the Ramsar site; Ministry of Forests and Environment 2018), and the floodplains of the Rapti, Reu, and Narayani rivers (Fig. 1). Churia Hills in Chitwan are characterized by steep, sloppy, and dissected topography, which is made by sedimentary rocks (sandstone, mudstone, and conglomerates). The Churia Hills rise slowly towards the east from 150m to more than 850m and are covered by CNP (DMG 2007; CNP 2018).

The Chitwan Valley consists of tropical and subtropical forests. The CNP is mainly covered by various types of forests (80%) including Sal forest, succession forest, and mixed hardwood forest. Besides, there are grasslands (12%), water bodies (3%), and exposed surface and floodplain (5%) (Thapa 2011). The riverine forests consist of Khair *Acacia catechu*, Sissoo *Dalbergia*

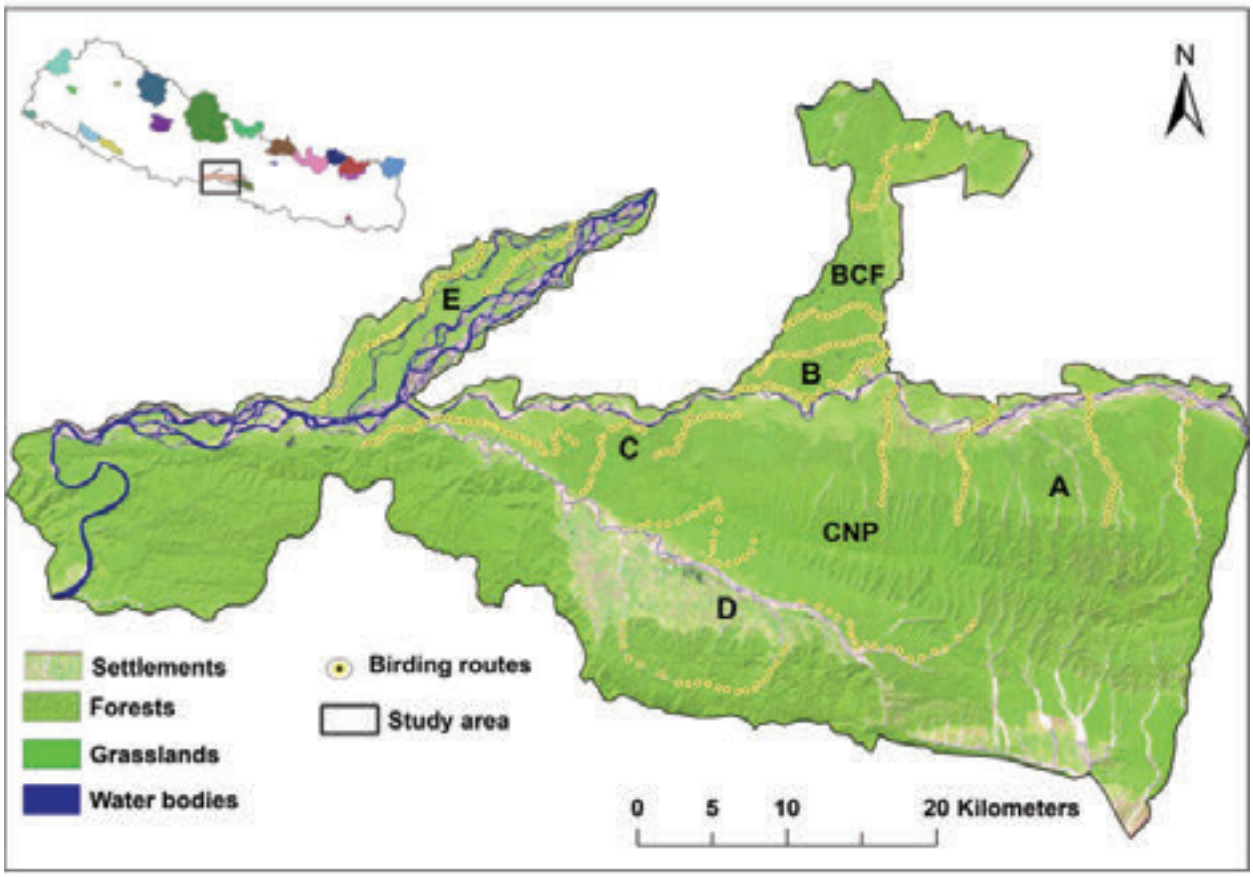

Figure 1. The study area in Chitwan National Park, Nepal, showing major landcover characteristics including study blocks and birding routes. A - Block A (Khagendramalli to Sauraha and old Padampur), B - Block B (Barandabhar Corridor Forest), C - Block C (Kasara to Golaghat), D - Block D (Madi and Someshor hill area), E - Block E (Narayani Island and Pithauli area).

sisoo, and Simal *Bombax ceiba*. There are more than 50 different types of grasses including the elephant grass *Saccharum* spp., renowned for its immense height (Lamichhane et al. 2016; CNP 2018). The CNP supports rare and threatened fauna with more than 68 species of mammals, 544 birds, 56 reptiles and amphibians, and 126 fish (CNP 2018).

Block A: Khagendramalli to Sauraha and old Padampur

This block is located in the eastern part of CNP. The area is mainly covered by riverine forest and grassland. The old Padumpur area is now covered with elephant grass *Saccharum* spp. and water holes, the key habitat of many grassland and wetland birds. The floodplain of the Rapti River near Sauraha is covered with short grass and riverine forest.

Block B: Barandabhar Corridor Forest area

Barandabhar Corridor Forest (BCF) is only the bio-corridor that connects CNP with the Mahabharat range. Most of the area of BCF is covered with Sal forest. This area is rich with lakes including the biologically significant Ramsar site Beeshhazari lake systems, Batulpokhari Lake, Rhino Lake, Tiger Lake, and Ratomate Lake and associates, and small streams such as Rapti, Budi Rapti, Khageri, and Devnagar Khola. The floodplain of Rapti is covered with grassland and riverine forest. Small grass patches are present inside the Sal *Shorea robusta* forest, which provide significant habitats for wildlife.

Block C: Kasara to Golaghat

This block is located in the central part of CNP. Most of the area of this block is covered with Sal forest associated with small patches of grasslands and lakes. The floodplain of the Rapti River is covered with riverine forest. Sukibhar is the largest grassland that provides key habitat for grassland-dependent animals. Tamor Tal, Lami Tal, and Devi Tal and associates provide good shelter for wetland-dependent animals.

Block D: Madi and Someshwar hills

Madi Valley is the floodplain of Reu River, Baghai,

and other small streams. The Someshwor Hill area has Sal forest. This is the holy hill. The floodplain of the Reu River is covered with grassland and provides shelter and feeding and breeding grounds for many grassland specialist birds. Most of the area of this block is covered with Sal *Shorea robusta* forest.

Block E: Narayani Islands and Pithauli

This block is located in the southern part of CNP. This area is mainly covered with the Narayani floodplain and islands. Most of the island is covered with grassland and riverine forest. Pithauli is a buffer zone area of CNP. This area is famous for vultures and other wetland birds. A locally managed vulture restaurant is also located in this block, which provides safe feeding sites for vultures. The habitat of individual birds where they performed their activities such as feeding, nesting, roosting, and breeding was recorded.

Data collection

Threatened birds were recorded by direct observation method ("look-see" counting method) and scanning was used to identify and record the individuals of bird species in birding routes (BR) including the area searches (AS) method for areas considered as bird hotspots between January and December 2017. By including both summer (May–June) and winter (November–January) seasons, the chances of recording migrant species were maximized (Bibby et al. 2000; Dieni & Jones 2002; Siegel 2009; Basnet et al. 2016; Katuwal et al. 2016; Jia et al. 2018). The study area was divided into five different study blocks where 17 birding routes were established. There were four birding routes in Block A, four in Block B, three in Block C, three in Block D, and three in Block E (Fig. 1). In each birding route, the birds were observed at an interval of 100m in all directions and up to the height of the trees with the help of binoculars. The birds were observed by two observers in one birding route, then the list was combined as a single list. We spent 10min on each point. We used two sets of field guide books for birds (Grimmett et al. 2016), GPS (Garmin eTrex 35 and eTrex10), four binoculars (Nikon 20x50), and digital cameras (Nikon Coolpix B700, with 60x zoom) for two observers. All birds seen were recorded and identified using field guide books. Images were taken for identification and documentation. During the field study, most of the birding routes of the blocks were covered on foot for the monitoring of birds. During the survey, the number of individuals, associated habitat types, and human disturbance indicators such as distance to roads (DiR), distance to villages (DiV), number of livestock grazing (LivG), number of people including tourists (Peop), collection of prey animals (fish, snails, crabs) of birds (PrCo), and collection of chick or eggs of birds (ChEc) were recorded in standard field data sheets. Birds were monitored early in the morning from 7.00h to 11.00h and in the evening from 14.00h to 17.00h (Bibby et al. 2000; Siegel 2009; Katuwal et al. 2016; Kandel et al. 2018).

Data analysis

The normality test was performed before calculating the diversity indexes to identify whether the data were normally distributed or not. The various indices of species diversity were calculated in PAST V 3.18 (Hammer et al. 2001).

The diversity of the recorded animals was analysed by using different diversity and dominance indexes such as Shannon's index and Simpson index. A diversity index is a mathematical measure of species diversity in a community.

Shannon's index: The Shannon diversity index (*H*) is commonly used to characterize species diversity in a community (Shannon 1948).

Shannon Index (H) = $\sum_{i=1}^{s} p_i \ln p_i$

where p_i is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

Simpson index: The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect diversity (Simpson 1949).

Simpson Index (D) = $\frac{1}{\sum_{i=1}^{s} p_i^2}$

where p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is still the sum of the calculations, and s is the number of species.

Evenness (e): Evenness is a statistical tool that compares actual diversity value to the maximum possible diversity by using evenness. The evenness of the sample is obtained from the formula:

Evenness = H'/Hmax

By definition, E is constrained between 0 and 1.0. As with H', evenness assumes that all species are represented within the sample.

Jacob's Equitability (J): The equitability is calculated by dividing the Shannon index of diversity by the logarithm of the number of taxa. This measures the

evenness with which individuals are divided among the taxa present.

Equitability (J)= H'/lnS

where, H' is Shannon's index of diversity, and S is the number of taxa.

Fisher's diversity index describes mathematically the relation between the number of species and the number of individuals in those species (Fisher & Yates 1943):

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

where *S* is the number of taxa, *n* is the number of individuals, and *a* is the Fisher's alpha.

In a sample, an ordinary count of the number of species usually gives a biased underestimate of the true number of species found in the environment. Increasing the sampling effort (sampling a larger area or counting more individuals or examining more sampling units) certainly increases the number of species (Nicholas & Anne 2013). This effect is illustrated in a species accumulation curve in which the x-axis is the number of individuals recorded and the y-axis is the number of species observed or species richness. Canonical correspondence analysis (CCA) was used to show the species response to different environment variables in CNP. The significance of the predictors was tested by using a Monte Carlo permutation test in CANOCO 4.52 (ter Braak & Smilauer 2002).

RESULTS AND DISCUSSION

Species diversity

The present study recorded 437 individuals of globally threatened and near threatened birds belonging to 19 species, nine orders, and 10 families in CNP (Table 1). A total of 12 species recorded are globally threatened in CNP (five Critically Endangered, two Endangered, and five Vulnerable) and seven are Near Threatened (Table 1). The highest number of threatened species belonged to the order Accipitriformes (eight species), followed by Ciconiiformes (two species), Psittaciformes (two species), Passeriformes (two species), Otidiformes (one species), Bucerotiformes (one species), Anseriformes (one species), Charadriiformes (one species), and Suliformes (one species) (Table 1). As much as 42 species of birds in Nepal are globally threatened (nine Critically Endangered, nine Endangered, and 24 Vulnerable) and 31 are Near Threatened (BirdLife International 2018). This shows that CNP alone supports around 29% (12 out of 42 species) of globally threatened birds of Nepal. Two (Bengal Florican *Houbaropsis bengalensis* and Great Hornbill *Buceros bicornis*) out of nine nationally protected birds (DNPWC 1973) were also reported in this park during the study. Sharma (2004) recorded 12 nationally threatened species of birds including two Critically Endangered birds in BCF. CNP listed 22 species of threatened birds including Lesser Florican *Eupodotis indica*, Greater Adjutant *Leptoptilos dubius*, Kashmir Flycatcher *Ficedula subrubra*, and Lesser Kestrel *Falco naumanni* (CNP 2018), but these bird species were not recorded during our study.

The species diversity of threatened birds in five different study blocks showed significant variation ($F_{(4, 90)}$ =2.94, p=0.02). The species diversity was significantly highest in Block E (H=2.073), followed by Block B (H=2.056), Block C (H=1.978), Block A (H=1.689), and Block D with the least diversity (H=1.655; Table 2). The species dominance index was more in Block A (D=0.2482) and Block D (D=0.2431), which indicates the low Simpson index of diversity in these areas (1-D=0.7518 and 1-D=0.7569, respectively). Human disturbance was found to be the highest in blocks A and D as these blocks are located nearer to the human settlements. The species evenness of threatened birds (0.4967) and Jacob's coefficient of equality (0.7476) was low in Block E, as this block is the main site for Critically Endangered vultures (Table 2). This area is provided with a vulture restaurant that is located in Namuna Community Forest, Pithauli, Nawalparasi. This area also includes many islands created by the Narayani River and is considered as the prime habitat for many forest, grassland, and wetland birds.

The species diversity profile of the threatened birds at a 95% confidence interval showed that Block E possessed the highest diversity compared to the other blocks. The Fisher alpha diversity index was higher in Block C (α=4.502), as the number of individuals was low in comparison with species number. In Block E, the species diversity was higher, but due to the presence of more individuals of the bird species, Fisher alpha was lower (α=4.121) than that of Block C. Block D had the lowest diversity profile (Fisher alpha=3.322; Fig. 2).

Accumulation or rarefaction curves attained asymptote and signified that the number of individuals of birds we observed was complete enough to cover all the threatened species present in the sampling sites. The accumulation curve of threatened bird species exponentially increased up to 150 individuals, slowly increased up to 250 individuals, very slowly increased up to 350, and remained nearly constant up to 437 (Fig. 3). The encounter rates of Critically Endangered species of birds were very low. The curve continues to rise as more individuals are sampled (Tokeshi & Schmid 2002). These

Table 1. List of threatened birds recorded in Chitwan National Park, Nepal. NRDB - National Red Data Book Nepal; CR - Critically Endangered; EN - Endangered; VU - Vulnerable; NT - Near Threatened; ** - nationally protected birds under NPWC Act 1973; I, II, III - CITES appendices.

	Threatened birds	Species code	Zoological name	Family	Order	NPWC	CITES	NRDB	IUCN
1	Red-headed Vulture	RHV	*Sarcogyps calvus* (Scopoli, 1786)	Accipitridae	Accipitriformes		II	EN	CR
2	Slender-billed Vulture	SBV	*Gyps tenuirostris* Gray, 1844	Accipitridae	Accipitriformes		II	CR	CR
3	White-rumped Vulture	WRV	*Gyps bengalensis* (Gmelin, 1788)	Accipitridae	Accipitriformes		II	CR	CR
4	Long-billed Vulture	LBV	*Gyps indicus* (Scopoli, 1786)	Accipitridae	Accipitriformes		II	VU	CR
5	Bengal Florican	BeF	*Houbaropsis bengalensis* (Gmelin, 1789)	Otididae	Otidiformes	**	I	CR	CR
6	Egyptian Vulture	EGV	*Neophron percnopterus* (Linnaeus, 1758)	Accipitridae	Accipitriformes		II	VU	EN
7	Lesser Adjutant Stork	LAS	*Leptoptilos javanicus* (Horsfield, 1821)	Ciconiidae	Ciconiiformes			VU	VU
8	Asian Woolly-necked Stork	WNS	*Ciconia episcopus* (Boddaert, 1783)	Ciconiidae	Ciconiiformes			NT	VU
9	Grey-crowned Prinia	GCP	*Prinia cinereocapilla* Hodgson, 1854	Cisticolidae	Passeriformes			NT	VU
10	Bristled Grassbird	BrG	*Chaetornis striata* (Jerdon, 1841)	Locustellidae	Passeriformes			VU	VU
11	Pallas's Fish Eagle	PFE	*Haliaeetus leucoryphus* (Pallas, 1771)	Accipitridae	Accipitriformes		II	CR	EN
12	Grey-headed Fish Eagle	GFE	*Icthyophaga ichthyaetus* (Horsfield, 1821)	Accipitridae	Accipitriformes		II	CR	NT
13	Ferruginous Duck	FeD	*Aythya nyroca* (Güldenstädt, 1770)	Anatidae	Anseriformes			VU	NT
14	Great Hornbill	GrH	*Buceros bicornis* Linnaeus, 1758	Bucerotidae	Bucerotiformes	**	I	EN	VU
15	River Lapwing	RiL	*Vanellus duvaucelii* (Lesson, 1826)	Charadriidae	Charadriiformes			NT	NT
16	Alexandrine Parakeet	AlP	*Psittacula eupatria* (Linnaeus, 1766)	Psittacidae	Psittaciformes		II	NT	NT
17	Red-breasted Parakeet	RBP	*Psittacula alexandri* (Linnaeus, 1758)	Psittacidae	Psittaciformes		II	VU	NT
18	Oriental Darter	OrD	*Anhinga melanogaster* Pennant, 1769	Anhingidae	Suliformes			NT	NT
19	Himalayan Griffon	HiG	*Gyps himalayensis* Hume, 1869	Accipitridae	Accipitriformes		II	VU	NT

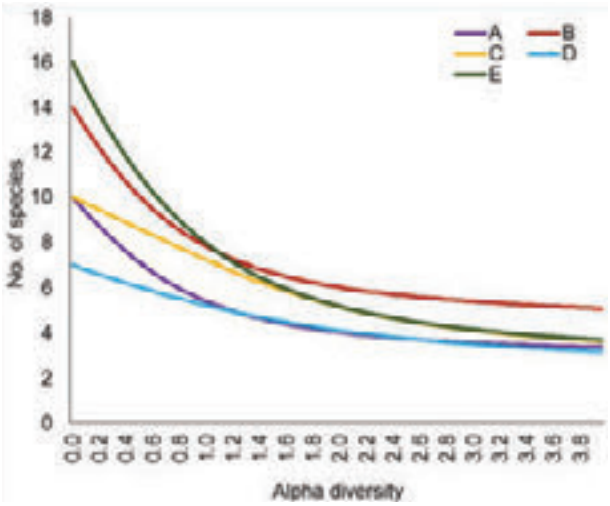

Figure 2. Species Diversity profiles of threatened birds in five study blocks (A–E) in Chitwan National Park, Nepal, at 95% confidence interval (A - Block A (Khagendramalli to Sauraha and old Padampur), B - Block B (Barandabhar Corridor Forest), C - Block C (Kasara to Golaghat), D - Block D (Madi and Someshor hill area), E - Block E (Narayani Island and Pithauli area).

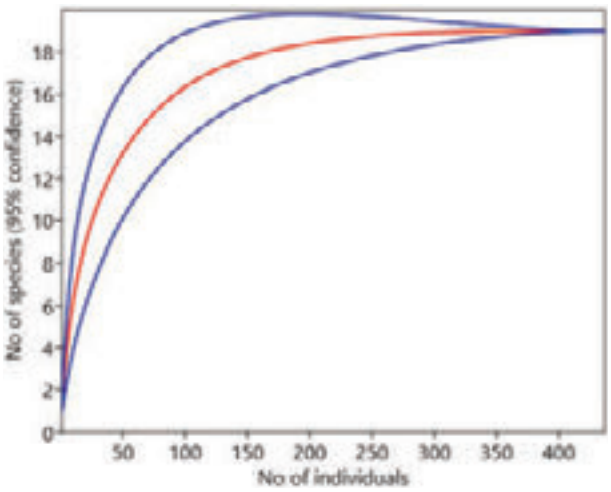

Figure 3. Species accumulation curve. Curve (red) was generated by assuming an assemblage of 19 species whose relative abundances were created from a broken stick distribution (Tokeshi & Schmid 2002). The x-axis is the number of individual recorded and the y-axis is the number of species at 95% confidence interval. Blue lines indicate the 95% confidence interval.

Table 2. Threatened bird diversity and dominance indices in Chitwan National Park, Nepal.

Block	A	B	C	D	E
No. of species	10	14	10	7	16
No. of individuals	63	117	37	24	196
Dominance (D)	0.2482	0.1658	0.1936	0.2431	0.1925
Simpson (1-D)	0.7518	0.8342	0.8064	0.7569	0.8075
Shannon (H)	1.689	2.056	1.978	1.655	2.073
Evenness (e^H/S)	0.5416	0.558	0.7227	0.7477	0.4967
Equitability (J)	0.7337	0.779	0.8589	0.8506	0.7476
Fisher alpha	3.348	4.149	4.502	3.322	4.121

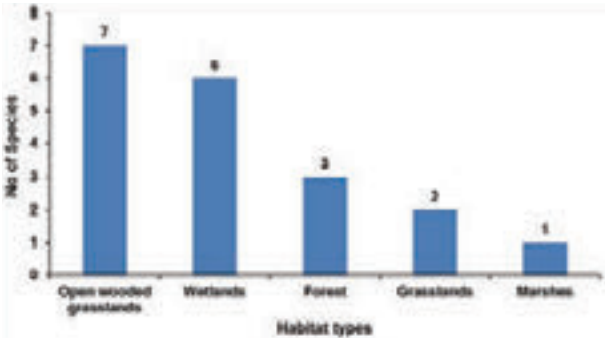

Figure 4. Threatened bird species richness in various habitats showing the preference of different habitats in Chitwan National Park, Nepal.

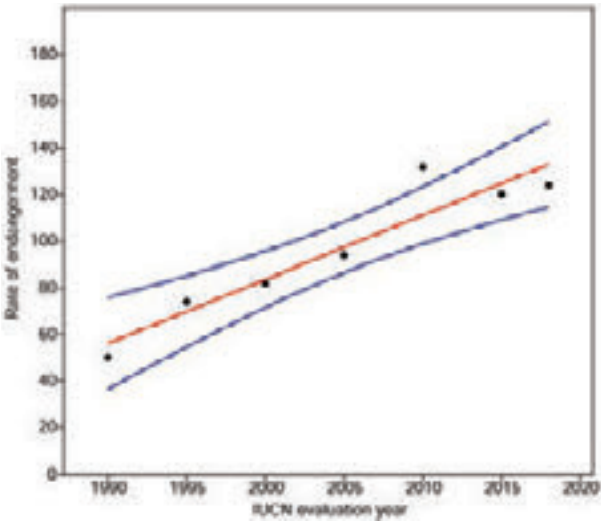

Figure 5. Rate of endangerment of threatened birds of Chitwan National Park, Nepal, as per IUCN Red List categories from 1990 to 2018. The score for each category is assigned as the greatest to the lowest risk: CR=10, EN=8, VU=6, NT=4, and LC=2 (linear regression model: r^2=0.89, t=6.29, p=0.003 at 95% bootstrapped confidence intervals N=1999). The red line shows the rate of endangerment and blue line shows 95% confidence limit.

empirical findings suggest that CNP harbours critical populations of globally threatened birds.

Habitat preference

More than 70% area of CNP is covered by *Shorea* forest and the rest of the area is comprised by grasslands, open wooded forest, riverine forest, floodplains, and wetlands (CNP 2018). This park consists of three rivers of the Gandaki river system and many ox-bow lakes such as Beeshhazari, Lamital, Tamor, Devi, Nandan, Nanda-Bhauju, and Batulpokhari, and many other swampy areas associated with grasslands. Most of the threatened birds were recorded in wetland (wetland birds) and open wooded land (e.g., vultures). Some grassland specialist birds such as Bengal Florican was recorded in the large grass patches of Sukibhar and Pithauli (Fig. 4). A total of 10–14 individuals of Bengal Florican was recorded in the grassland of CNP in 2008 (Poudyal et al. 2008). High habitat diversity may harbour many coexisting species within habitat types, resulting in high species turnover between different habitats (Jankowski et al. 2009; Quintero & Jetz 2018). High habitat diversity of CNP could be another reason for harbouring many threatened bird species (Bhattarai & Kindlmann 2012). Bird species diversity in different habitat types in and around North Nandi Forest, Kenya, reported a significant difference in bird abundance across habitats (indigenous forest, disturbed forest, plantation forest; F=15.141, p≤0.05; Bett et al. 2016) similar to our study.

Conservation threats

We recorded 12 globally threatened (five Critically Endangered, two Endangered, five Vulnerable) and seven Near Threatened birds in CNP (BirdLife International 2018; Table 1). The rate of increase of endangerment of birds according to the IUCN Red List categories from 1990 to 2018 showed rapid increase of endangerment. The linear regression model shows positive increment of the vulnerability of birds from 1990 to 2018 (r=0.991, t=16.622, p=0.0001 at 95% bootstrapped confidence intervals, N=1999; Fig. 5). Risk of extinction of birds in the global scenario increases day by day (White & Bennett 2015). Such cases are also evident in other areas of Nepal. BirdLife International (2018) declared 42 of Nepal's bird species as being in the globally threatened category, including two vagrants (Long-tailed Duck *Clangula hyemalis* and Indian Vulture *Gyps indicus*) and three regionally extirpated species. Inskipp et al. (2016) described a total of 167 bird species (19% of total birds in Nepal) as nationally threatened that included 67 (40%) Critically Endangered, 38 (23%) Endangered,

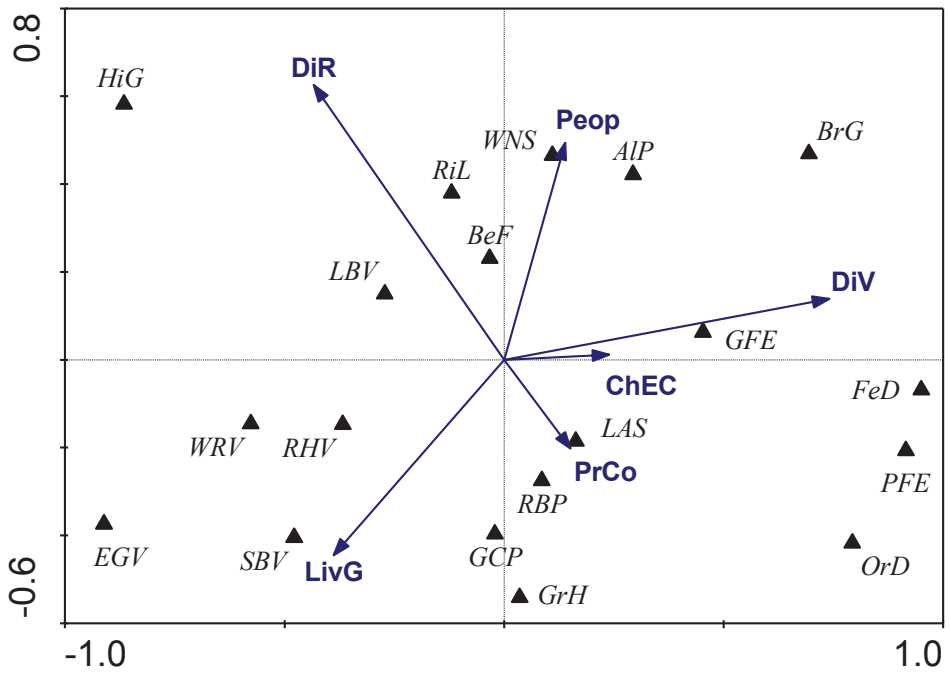

Figure 6. CCA ordination diagram (biplot) showing species response to different environment variables in Chitwan National Park, Nepal. Monte-Carlo permutation test of significance of all canonical axes: Trace=0.643, F=1.464, p=0.01 (with 499 permutations). First two axes are displayed. The first axis accounts for 46% and the second axis for 23.8% of the variability. DiR - distance to road, DiV - distance to village, LivG - livestock grazing, Peop - number of people, PrCo - prey collection, ChEc - chick or egg collection.

and 62 (37%) Vulnerable species. Later, Inskipp et al. (2017) assessed 168 species (19%) of birds of Nepal as nationally threatened species that included 68 (40%) Critically Endangered species, 38 (23%) Endangered species, and 62 (37%) Vulnerable species. As many as eight species of birds were extirpated from Nepal and were not recorded since the 19th Century (Inskipp et al. 2016). Official checklist of CNP listed 22 species of globally threatened birds including Lesser Florican *Sypheotides indicus* (CNP 2018). According to previous observations and reports, however, there was no record of Lesser Florican in CNP since 1999 (BES 2018; Basu Bidari pers. comm. 13 January 2018). There is the potentiality of occurrence of Lesser Florican in Sukibhar and old Padampur areas (this study).

Livestock pressure and human disturbances were the major threats to birds in CNP, mainly in blocks A and D as these blocks are located nearer to human settlements. Numbers of livestock present in the habitats of threatened birds caused a significantly negative effect on species richness and abundance of threatened birds (r=-0.61, t=3.15, p=0.006). The presence of people (both local people and tourists) in the habitats of the birds caused a significantly negative effect on the occurrence and abundance of threatened birds in CNP (r=-0.36, t=1.66, p=0.09). Jia et al. (2018) described flooding phenology, human disturbance, habitat loss and degradation, and declining water quality caused by eutrophication and pollution as the major threats of waterbird communities in Yangtze River floodplain lakes. Similar problems also occurred in Narayani, Rapti River, and Rew floodplains (e.g., loss of a large patch of riverine forest and grasslands). Earlier studies also indicated the same problem. For example, grassland specialist birds in lowlands are the most threatened group of birds (55% of the birds threatened), followed by wetland birds (25%) and tropical and subtropical broadleaved forest birds (24%) (Inskipp et al. 2016). Human pressure was the major cause of habitat disturbance of threatened birds. Collection of grasses, forest products, and snails and fishing from the wetlands were the major activities of the people that disturbed the threatened birds. The CCA shows a significantly close association of Lesser Adjutant Stork and villages as the species commonly visited farmlands for foraging. Most of the threatened birds were recorded from undisturbed areas of CNP (F=1.464, p=0.01; Fig. 6).

Distribution of birds was highly affected by disturbance variables such as distance from roads and distance from settlements or villages. The diversity of birds was found to be low close to villages or roads. As the distance from roads increased, the abundance of

threatened birds was found to significantly increase. There was a strong positive Pearson correlation between the distance from roads and the abundance of threatened birds (r=0.61, t=10.75, p=0.0001). Similar type of strong positive correction was found between distance from villages and the abundance of birds (r=0.73, t=15.14, p=0.0001). These empirical findings showed that there was a negative impact of roads and settlements on threatened birds of this area.

CONCLUSION

This study recorded 437 individuals of 12 globally threatened (five Critically Endangered, two Endangered, five Vulnerable) and seven Near Threatened species of birds in CNP. The diversity and abundance of threatened birds were found to be higher in wetlands, open wooded lands, and grasslands. The species diversity of threatened birds was recorded as the highest in Block E (H=2.073), followed by Block B (H=2.056), Block C (H=1.978), Block A (H=1.698), and Block D with the least diversity (H=1.655). The lower diversities of birds in blocks A and D were due to the high disturbance caused by closer proximities of human settlements as compared to other blocks. The species evenness of threatened birds (0.4967) and Jacob's coefficient of equality (0.7446) was low in Block E, as this block was the main site for Critically Endangered vultures. Livestock and human disturbances were the major threats to the birds in CNP and that was so in blocks A and D. The presence of livestock and people in the habitats of threatened birds caused a significantly negative effect on species richness and abundance. The diversity and abundance of threatened birds were significantly low nearer to human settlements or roads. Therefore, the study suggests that maintaining heterogeneous habitats (forests, grasslands, and wetlands) with low human disturbances could be a better strategy for the long-term survival of resident and migratory threatened birds in CNP.

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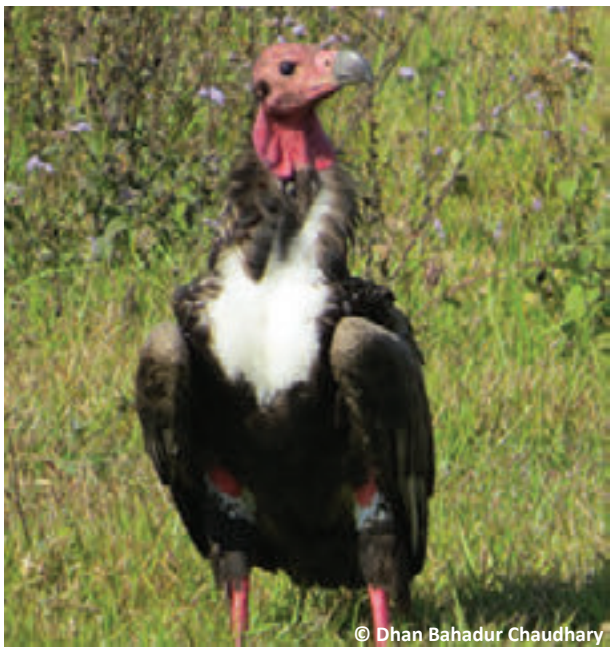

Image 1. Red-headed Vulture *Sarcogyps calvus* (IUCN-CR).

Image 2. Grey-headed Fish Eagle *Icthyophaga ichthyaetus* (IUCN-NT).

Image 3. White-rumped Vulture *Gyps bengalensis* (IUCN-CR).

Image 4. Bengal Florican *Houbaropsis bengalensis* (IUCN-CR).

Image 5. Egyptian Vulture *Neophron percnopterus* (IUCN-EN).

Image 6. Asian Woolly-necked Stork *Ciconia episcopus* (IUCN-VU).

Image 7. Lesser Adjutant Stork *Leptoptilos javanicus* (IUCN-VU).

Image 8. Slender-billed Vulture *Gyps tenuirostris* (in front) (IUCN-CR).

Image 9. Oriental Darter *Anhinga melanogaster* (IUCN-NT).

Image 10. Himalayan Griffon *Gyps himalayensis* (IUCN-NT).

Image 11. Nest of White-rumped Vulture with chicks.

Image 12. Safe feeding site of vultures inside Namuna Buffer Zone Community Forest, Chitwan National Park, Nepal.

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Encounter rates and group sizes of diurnal primate species of Mole National Park, Ghana

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Abstract: Primate species are not widely explored in Ghana's savannah ecosystems. We report data on encounter rates and group sizes of primates at the Mole National Park in Ghana. Forty transects, each of 5km length, were randomly laid in the park for the study. Four species of primates were visually recorded during field surveys: Olive Baboon *Papio anubis*, Patas Monkey *Erythrocebus patas*, Green Monkey *Chlorocebus sabaeus* and *Colobus vellerosus*. The status of *C. vellerosus* is Critically Endangered, the status of the other species is Least Concern according to the IUCN Red List. Encounter rates (groups/km) were 0.98, 0.65 and 0.45 for Olive Baboons, Patas Monkeys and Green Monkeys respectively. The mean group sizes were: Olive Baboon 10.8 (SE=1.1, range=1-38), Patas Monkey 12.2 (SE=3.3, range=1-35), and Green Monkey 10.0 (SE=1.9, range=1-25). Only one group of White-thighed Colobus with a group size of six was encountered. Encounter rates and group sizes of the same species varied in different parts of the park, and factors such as resource distribution and security against secret hunting may have influenced this variation. Authors recommend further studies to facilitate better understanding of these primates.

Keywords: Green Monkey Olive Baboon, Patas Monkey, resource distribution, savannah, White-thighed Colobus.

Dagaare Abstract: Ngmaane par3 nang bei a Ghana dagaw3 paalong zanoo ba maaleng kpare yaga. Te wulee a ngmaane ngabo ane alantaa a Mole National Park nang bei Ghana puo. Sobie lizaanaare ka te da ngmaa ngmaa bare kang zaa na mang ta m3l3 anuu (5km) w3l3 w3l3 ana bang de zani ne. Ngmaane par33 anaare la ka te da ny3 ne nimiri a muo puo zano nga puo: ngmaakpatere (Olive Baboon Papio aubis), ngmaazie (Patas Monkey Erythrocebus patas), ngmaaulmo (Green Monkey Chlorocebus saboeus) ane ngmaapulipilaa (Colobus vellerosus). A ngmaapulipilaa (Colobus vellerosus) par3 pogro la. Ky3 a ngmaane kyelee na eng da ba maaleng fer3 yaga aseng a tendaa dunizu kpaaroo IUCN Red list nang mane l3. A nyaabo nu3 da waa ngaa ane a taalangmo puo meng: 0.98, 0.65 ane 0.45 a ko ngmaakpate3 (Olive Baboon), ngmaapulipi3li (Patas Monkey) ane ngmaaulimo (Green Monkey). A zaa ponsentaa ane a lantaa da la ngaa: ngmaakpatie da waa 10.8 (SE=1.1, ayi bonyeng te ta lizarenepie ne anii (range=1-38), ngmaapulipi3li meng da waa 12.2 (SE=3.3 ayi bonyeng te ta lizarenepie ne anuu (range=1-35) k'a ngmaaulimu meng da waa 10.0 (SE=1.9 ayi bonyeng te ta lizare ne anuu (rang=1-25). Ky3 te da ny3 ngmaagbiepilaa (White-thighed Colobus) meng young k'a da lang taa ayobo (6). A ngmaane nyaabo ane a taa langmo da waa tietie a muo langbo3 min3 puo, bonso kaapag a zukaariba ba seng bong ana tou kaa zu ka nankpaanema ta ku'a, l3 laso aba yitaa nga. A gang segreb3 yeli ka ana viel3 la ka zaano kyaare ne a ngmaane la bang gaa nige a na veng la ka te bang a sie ti3g3.

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INTRODUCTION

Population surveys are important for examining ecosystem functioning, forming the basis for management decisions and providing the means to evaluate the effectiveness of different conservation strategies (Nichols & Williams 2006; Stokes et al. 2010). The global biodiversity decline has not spared primates, and IUCN (2016) indicates primate population decline across large parts of their range. Threats to primate populations in their natural ranges are logging, mining, habitat destruction and hunting. The influx of people increases hunting pressure and causes further habitat loss (Masanja 2014). Primates have received conservation attention, and they are one of the few orders of mammals that have not lost a species or subspecies in the twentieth century (Mittermeier et al. 1997). But the danger of extinction can be particularly acute in the case of taxa that have received little attention and live in parts of the world that are not a major focus of biologists and conservationists (Oates et al. 2000). In Ghana and other countries of Upper Guinea and Dahomey gap, the need to obtain current information on species distribution, encounter rates and population dynamics is critical to the formulation of informed conservation and management plans. Conservation of primates in savannah ecosystems has been on ad-hoc basis without any empirical information on their population dynamics and ecology. Previous studies of the distribution, diversity and conservation of threatened species in Ghana have focused on forest ecosystems (Booth 1956; Asibey 1978; Abedi-Lartey & Amponsah 1999; Curtin 2002; Deschner & Kpelle 2003; Oates 2006; Wiafe 2013; 2016) with little attention given to primates in savannah ecosystems.

In 1958, Mole National Park was established enclosing some traditional hunting grounds and sacred sites. By 1964 all the inhabitants of five villages in the southern part of the Park were resettled elsewhere. Poor road access to and around the Park has limited the number of visitors (Mole Management Plan 2011), however, the main road leading to Mole National Park has recently been substantially improved (personal observation), and this has facilitated the influx of people to the area. This has also increased threats to primates that inhabit the park. For primate populations to be protected effectively, baseline information on encounter rates, distribution and group sizes are essential. Population monitoring enables direct measurement of the effect of local threats and assessment of the effectiveness of conservation measures. Surveying primate populations is also important for identifying priority areas for their protection, developing conservation management strategies, mitigating threats, and balancing economic and conservation priorities (Campbell et. al. 2016). It is against this background that the study of the composition, group sizes and encounter rates of primates at the Mole National Park was taken up. The objectives of the study were to: identify all diurnal primate species at the Park; estimate encounter rates of all identified primate species; and determine the sizes of primate groups encountered. The following were postulated to guide the study: (i) the encounter rates of all species were not the same in different parts of the Park, and (ii) group sizes of the same species found at different parts of the park were not the same.

Theoretical framework

This study was based on the theory of 'Ideal Free Distribution' (Fretwell 1972) which explains the way in which animals distribute themselves among several resources. The theory states that the number of individual animals that will aggregate in various patches is proportional to the amount of resources available in each patch. This indicates that patches in the same landscape may have different levels of intrinsic resource values, yet the same principle of distribution can be applied but the number may differ. This means that populations of individuals of the same species will distribute themselves equally among patches with the same resource values. This study did not evaluate resource distribution, but the encounter rates, group sizes and their distribution pattern was attributed to the distribution of resources within the Park.

METHODS

Study area

Mole National Park is Ghana's largest protected area, covering about 4,577km². It is almost entirely located in the Northern Region and includes parts of West Gonja, Sawla–Tuna-Kalaba, Wa East and West Mamprusi districts. It lies between 9.183–0.166 ^{0}N and 1.367–2.216 ^{0}W (Figure 1). The main access to the Park is currently by road from Fulfulso junction through Damongo to Laribanga, or through Sawla and Larebanga to Mole National Park headquarters (Figure 2). The average annual rainfall is about 1100mm, decreasing to 1000mm in the north of the Park. More than 90% of the rain falls in the rainy season from April to October, with peaks in July and September. The dry season lasts from

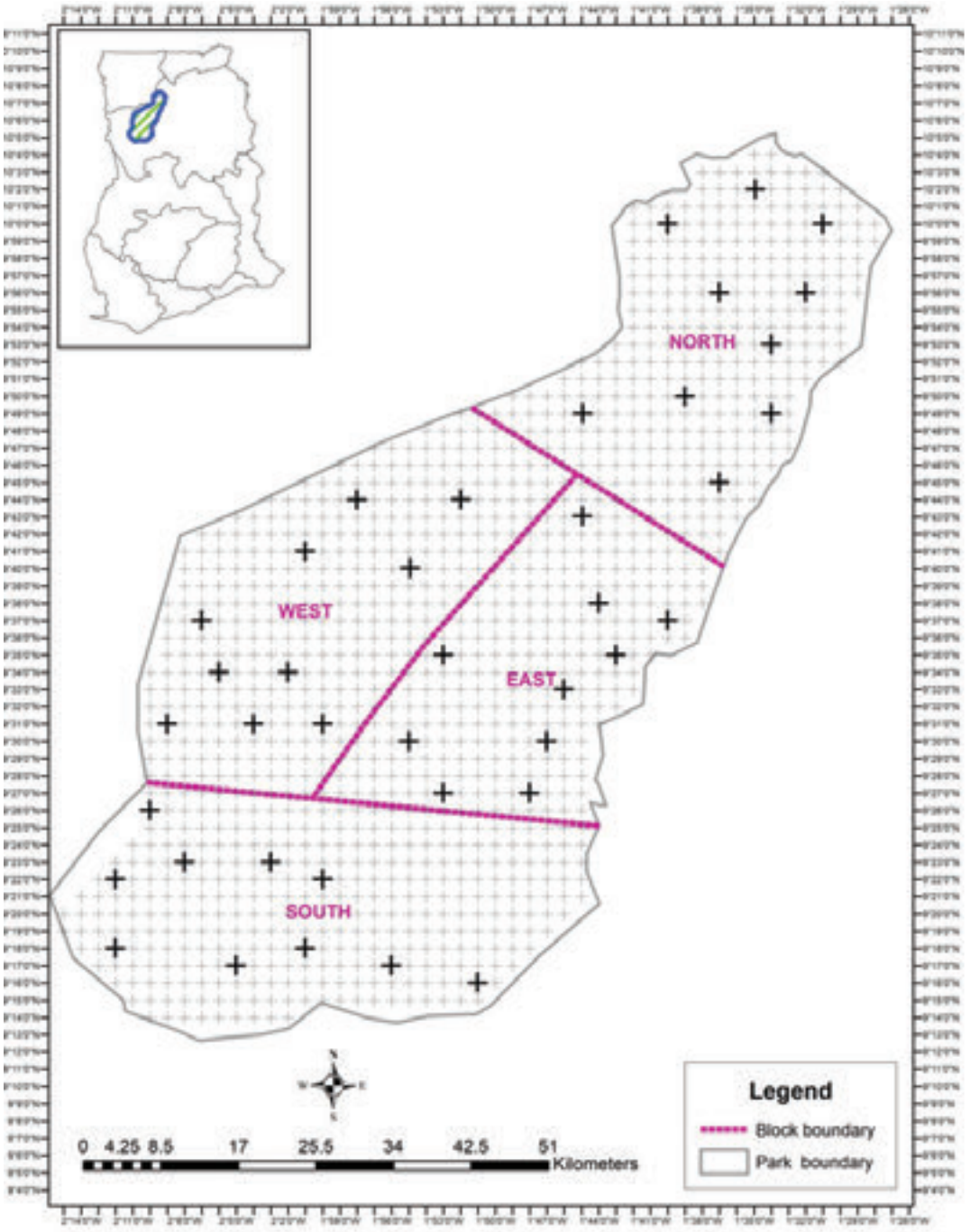

Figure 1. Mole National Park showing the distribution of transects used for the primate's survey (Inset: Ghana map showing the location of Mole National Park).

November to March. The mean annual temperature of 28°C varies from 26°C in December to 31°C in March. The average range from day to night is 13°C. It can be hot in March and April, with temperatures sometimes at 40°C (Mole Management Plan 2011). The Harmattan - the dry wind from the Sahara – may blow during December to February bringing dusty, hazy weather. The relative humidity reaches 90% at night in the rainy season and falls to about 70% in the afternoons. In the dry season the figures are 50% and 20% respectively (Mole Management Plan 2011; Wildlife Department, Ghana 1994). The topography is mostly flat, with the narrow Konkori Escarpment running north-south. The elevation ranges from 120—490 m. Most of the rivers are seasonal and drain into the White Volta (Mole Management Plan 2011).

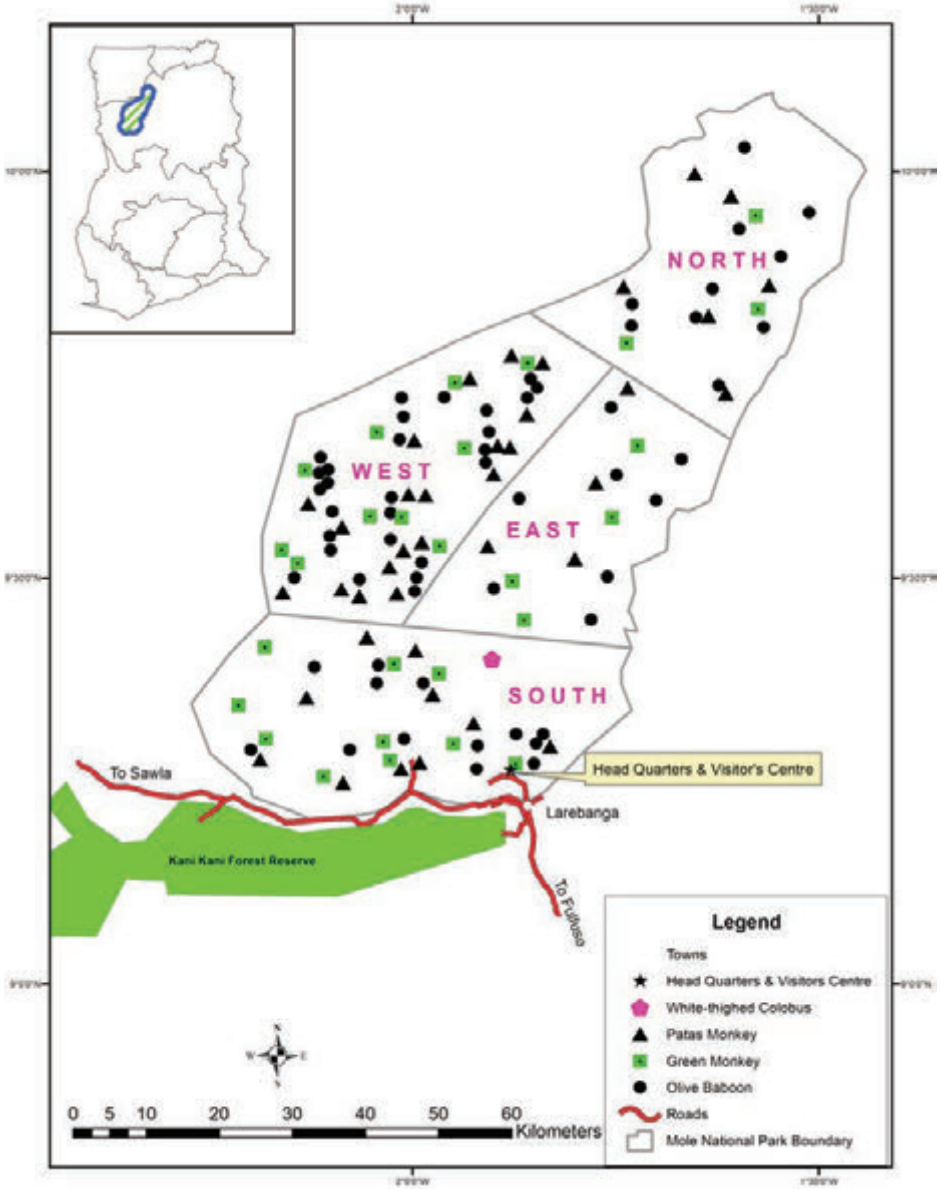

Figure 2. Mole National Park showing distribution of diurnal primates.

Stratification of the study area and distribution of transects

To equalize sampling effort, the entire park was divided into four blocks of approximately 1,140km² each based on the existing management systems used by the Park management. These were Northern sector (Ducie range), Western sector (Jang range), Southern sector (Headquarters range) and Eastern sector (Bawena range) (Figure 1). Latitudinal and longitudinal grids at one-minute intervals were placed over the map of the study site and the intersections of the lines formed the mid-point of each transect. In each block, 10 transects were laid at random with at least 2km apart as shown in Figure 1. Each transect was straight and ran for a length of 5km (Campbell et al. 2016). Transects were surveyed twice, therefore the total transect walk was 400km. Navigation was conducted using a compass and a Geographical Positioning System (GPS) gadget to reach the starting point of each transect. Transects which followed compass lines were measured with a GPS gadget, laid out with minimal cutting or disturbance (Peres 1999) and oriented northwards as a rule of the thumb (Campbell et al. 2016).

Determination of group density, group size and distribution of primates

A three-person survey team was maintained at every section or block throughout the survey to ensure

consistency in data collection procedures. During the census, the observers moved along a transect line and stopped at every 200m to listen and scan the surrounding area, at optimal walking-pace of about 1 km/h. At the beginning of each transect, the location, habitat type, date, weather, starting time and participating personnel were recorded as standard items. When a primate group was seen, 10 minutes was spent observing it, and the observer remained on the census route without following the animals away from the line. The information recorded followed the guidelines of National Research Council (1981) and Peres (1999) which included identification of species, number of individuals, the group size and other relevant information.

Data Analysis

Kilometric Indices of Abundance (KIA), which is the ratio of the number of animals encountered to the distance covered, was used to present the frequency of group encounters (Groupe 1991; Gatti 2010).

RESULTS

Species composition

We confirmed the presence of four diurnal primate species in the Mole National Park. Apart from the White-thighed Colobus that has been classified as Critically Endangered, Olive Baboon, Green Monkey and Patas Monkey have been classified as Least Concern (IUCN 2016).

Olive Baboons *Papio anubis* were the most widespread diurnal primates encountered at the Mole National Park. They were found in all parts of the park with majority (27) groups encountered at the western part; 13 groups at the southern part; 10 and eight groups encountered at the northern part and eastern parts respectively (Table 1) as shown in Figure 2.

The number of groups of Patas Monkeys *Erythrocebus patas* found in the western part of the Park was 19; 10 groups were at the southern, four at the eastern and six at the northern part of the Park (Table 1) (Figure 2).

The Green monkeys *Chlorocebus sabaeus* encountered were 10 groups at the western and southern parts each, while the eastern and northern parts encountered four and three groups respectively (Table 1) shown in Figure 2.

The White-thighed Colobus *Colobus vellerosus* group was encountered only once at the southern part of the Park (Table 1). The group was made up of six individuals along a riverine forest (Figure 2).

Encounter rates of primates identified in Mole National Park

The most encountered primate in the park was the Olive Baboon with a mean encounter rate of 0.98/km (SE=0.29, Min. = 0.5, Max. = 1.8). This was followed by the Patas Monkey with a mean encounter rate of 0.68/km (SE = 0.13, Min. = 0.2, Max. =0.3) and the Green Monkey with a mean encounter rate of 0.48/km (SE =0.23, Min. =0.3, Max. =1.3). The White-thighed Colobus was encountered only once with six individuals. At the eastern part of the park, the KIA of the Olive Baboon was 1.8, Green Monkey was 0.7 and Patas Monkey was 1.3. At the southern part, the KIA of Olive Baboon was 0.9, Green Monkey was 0.7, Patas Monkey was 0.7 and White-thighed Colobus was 0.07. At the western part, the KIA for Olive Baboon was 0.5, and Green Monkey and Patas Monkey was 0.3 respectively; while KIA of 0.7, 0.2 and 0.4 were for Olive Baboon, Green Monkey and Patas Monkey respectively for northern part (Table 2). However, no significant difference was found in the KIA of all species encountered (ANOVA: F=1.21, df =5.39, p=0.37).

Group size of primates encountered

Members of each group of primates were encountered as follows:

(i) Relatively higher mean group sizes of *P. anubis*

Table 1. Number of groups of primates observed in each range.

Common name	Scientific name	Number of groups				Mean	*SE
		western	southern	eastern	northern		
Olive Baboon	*Papio anubis*	27	13	8	10	14.5	4.3
Patas Monkey	*Erythrocebus patas*	19	10	4	6	9.8	3.3
Green Monkey	*Chlorocebus sabaeus*	10	10	4	3	6.8	1.9
White-thighed Colobus	*Colobus vellerosus*	-	1	-	-		

*SE represents standard error

Table 2. Kilometric Indices of Abundance (KIA) of primates encountered at Mole National Park.

Common name	Scientific name	KIA				Mean	SE
		Eastern	Southern	Western	Northern		
Olive Baboon	*Papio anubis*	1.8	0.9	0.5	0.7	0.98	0.29
Patas Monkey	*Erythrocebus patas*	1.3	0.7	0.3	0.4	0.68	0.13
Green Monkey	*Chlorocebus sabaeus*	0.7	0.7	0.3	0.2	0.48	0.23
White-thighed Colobus	*Colobus vellerosus*	-	0.07	-	-	-	-

Table 3. Mean group sizes of primate species identified in Mole National Park.

Name of species	Eastern			Southern			Western			Northern		
	Mean	SE	Range	mean	SE	Range	mean	SE	Range	Mean	SE	Range
Olive Baboon	16.8	2.3	7–30	17.1	3.4	4–38	7.8	1.1	1–19	6.8	1.1	3–15
Patas Monkey	26.7	4.6	14–35	13.1	3.2	3–34	9.5	1.4	1–19	2.7	0.6	1–5
Green Monkey	14.5	4.7	3–25	12.9	2.3	6–25	9.5	1.4	3–18	1.7	0.3	1–2
White-thighed Colobus	0	0	0	6	0	0	0	0	0	0	0	0

were recorded at the southern part 17.1 (SE=3.4), than the eastern, 16.8 (SE=2.3); western, 7.8 (SE=1.1) and northern, 6.8 (SE=1.1) (Kruskal-Wallis: H=15.07, p=0.0017) parts (Table 3).

(ii) The mean group size of *E. patas,* at the southern part was 13.1 (SE=3.2); western part, 9.5 (SE=1.4); eastern part, 26.7 (SE=4.6); and northern part, 2.7 (SE=0.6) (Table 3). The group sizes of patas monkey in the eastern part was found to be higher than all other parts, followed by the southern, western and northern parts (H=19.43, p=0.0002).

(iii) The mean group size of *C. sabaeus* at the southern part was 12.9 (SE=2.3); eastern part, 14.5 (SE=4.7); western part, 9.5 (SE=1.4) and northern part, 1.7 (SE=0.3) (Table 3). The average group size of Green Monkey in the eastern part was significantly higher than all other parts, followed by the southern and the western parts. The least group size was encountered at the northern part of the Park. (H=9.09, p=0.03)

(iv) C. vellerosus recorded only six individuals during the survey.

DISCUSSION

The population ecology and behaviour of savannah non-human primates have been extensively studied in east and southern Africa (e.g., Struhsaker 1967; Henzi & Lucas 1980; Isbell et al. 1991; Barrett et al. 2006). There is, however, a paucity of information on savannah primates in Ghana. This is probably because almost all the species occurring in this area are classified as Least Concern by IUCN, and also are not endemic in the sub-region. Much attention has therefore been paid to those species facing extinction spasm and in critical condition. Species of primates living in Ghana's premier national park have enjoyed the peace of being situated in a low human populated area, and the main road to the place was in deplorable condition until recently when it was improved and brought in large influx of people. The presence of White-thighed Colobus *Colobus vellerosus* in the Park is quite strange, as it does not typically occur in Guinea savannah area. There could equally be similar forest related species in the savannah park that an organized thorough survey could encounter.

Olive baboons were common, and the most conspicuous primate species in the Park. Early primate studies reported a total of 34 groups through aerial survey in the Mole National Park (Wilson 1993). The mean of the groups of Olive Baboons was 14.5 (SE=4.3) and encounter rate of 0.98 group/km in Mole National Park is high when compared to Gashaka Gumti National Park (Nigeria) of 0.17 groups /km (Isabell et al. 2002); 0.2-1.4 groups/km^2 (Dunn 1993). The mean group size of the Olive Baboon was 10.8 (SE=1.1, range=1-38), but there was variations in group sizes at different parts of the Park (Table 3). It was observed that the mean group size was higher in the southern part than all other areas with the least group size found in the northern part (Table 3). This is probably because of variations

in resources distribution and the security situation at a particular locality in the Park. The Olive Baboon groups were found to be very conspicuous at every part of the Park and sometimes two or more troops of Olive Baboons group around the visitors centre to forage most of the time. They used to search for feed everywhere, even in the refuse containers, and also posed for cameras when they came closer to tourists. In a zoological study in Mole National Park, Wilson (1993) observed that Olive Baboons were easily seen from helicopter, but was afraid that the population could become a nuisance that require culling or translocation.

Patas Monkeys, with an average group of 9.8 (SE=3.3) and an encounter rate of 0.68 group/km were also relatively common. The 1993 aerial survey could not give accurate groups of monkey in Mole because the species would 'freeze' or take cover as soon as they heard the noise of the helicopter; therefore, the number of groups was under-estimated to be 15 (Wilson 1993). In Comoé National Park in Côte d'Ivoire, Fisher et al. (2000) observed groups of between 3-17; W national park, 3-38 groups by Poche' (1976) and 16-45 groups at Kalamaloue' National Park in Cameroon (Nakagawa et al. 2003). The mean group size of the Patas Monkey was 12.2 (SE=1.5, range= 4 – 19).

Green Monkeys were also found in all parts of the Park with mean group size of 10 (SE=1.2, range=1-25) and encounter rate of 0.48 group/km as compared to 18 groups in 1993 (Wilson 1993). In Mali, Green Monkeys were found to be 1.2 groups/km^2 in Bafing Faunal Reserve (Pavy 1993).

The hypotheses that the encounter rates of all species were not the same in different parts of the Park was rejected. This indicates that there was not much variation in the encounter rates of the species which may imply that the factors controlling encounter rates of the species might be the same for all primate taxa. However, the hypothesis that the group sizes of the same species found at different parts of the park were not the same was supported by the study. Variations in group sizes were found to occur in the same species at different localities in the same park, and this could be attributed to unstudied differences in the habitat (Kruger et al. 1998); security situation at the locality against poaching (Wiafe 2016) or other unknown factors. Mole National Park might be heterogeneous in terms of habitat (resources) richness, distribution and pressure from other users. It is worth noting that the three primates encountered in the northern part recorded smaller numbers in the group sizes than all other parts. This might be attributed to the narrowness of that part of the park or probably its proximity to the regional capital city (Wa); with the assumption that human presence and pressure is higher in that area than in all other areas. It has been suggested that the size of many animals are the result of the local ecology interacting with the species' adaptation (Dunbar 1988). It could then be inferred that the variations in the group sizes observed in Mole National Park are a consequence of cost and benefits of some particular local environmental factors and inequality of resource distribution.

This study confirmed the presence of four diurnal monkey species in the savannah protected area of Ghana. Among these monkeys, one is classified as Critically Endangered by IUCN (*Colobus vellerosus*) and three others as Least Concern (*Papio anubis*, *Chlorocebus sabaeus* and *Erythrocebus patas*). With the exception of *Colobus vellerosus*, these monkeys were encountered everywhere in the national park and were abundant.

Mole National Park could be considered a high conservation area and the park can be regarded as a natural laboratory for research and conservation of biodiversity. Studies of inter-specific and intra-specific relationships are required to strengthen understanding of these primates in the park. Promotion of primate-focused eco-tourism is suggested to boost the socio-economic lives of the humans living in the fringe communities of the park, and promote conservation of the primates.

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Estimating Leopard *Panthera pardus fusca* (Mammalia: Carnivora: Felidae) abundance in Kuno Wildlife Sanctuary, Madhya Pradesh, India

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Abstract: Reliable population estimate of apex predators, such as the Leopard *Panthera pardus fusca*, is important as they indicate ecosystem health, enable evaluation of the effectiveness of conservation efforts and provide a benchmark for future management decisions. The present study is the first to estimate abundance of Leopard along with possible prey profile in Kuno Wildlife Sanctuary (KWLS), in central Madhya Pradesh (M.P.), India. For systematic sampling, two study habitats, 15km² each, were identified, one close to the park entrance and the other away from the park entrance. Sampling was carried out between March and April 2017, for a period of 18 days in each of the two study habitats, 'good' and 'poor', initially based on situation in reference to park-entry. Each habitat was divided into five blocks each, and each block subdivided into three, 1km² observation units. In all, 16 trail cameras were placed in pairs, one set at a time in five of the blocks, over a six–day period. The total sampling effort was 180 trap-nights. The trigger speed was set to 3 frames per 10 seconds, and repeated only after 20 minutes interval on infra-red detection of object. The data was analysed using closed population capture–recapture analyses in Program MARK, to estimate Leopard abundance. Seventy-eight Leopard detections representing eight unique individuals were found in the 30km² study site. Seven Leopards were detected in the good habitat and one in the poor habitat. The estimate for Leopard abundance for the good habitat was 11 Leopards (SE 4.6, 95% CI = 8 – 31 individuals). Due to limited captures/recaptures in the poor habitat, abundance could not be estimated for this habitat class.

Keywords: Camera trap, capture-recapture, Kuno Wildlife Sanctuary, Leopard abundance, prey diversity.

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INTRODUCTION

The Kuno watershed and the Kuno Wildlife Sanctuary (KWLS) form an important stepping-stone ecosystem between the Ranthambore National Park in Rajasthan, the Madhav and the Panna national parks, in Madhya Pradesh, India (Johnsingh et al. 2007). Historically, Kuno was known to support populations of both the Bengal Tiger *Panthera tigris* and Asiatic Lions *Panthera leo persica* (Kinnear, 1920). However, lions have been extirpated from Kuno in the last century due to excessive hunting (Kinnear 1920), and in recent years, poaching is one of the prime threats to the survival of Leopards and tigers in India (Wildlife Protection Society of India, 2017). A solitary male tiger was recorded in the sanctuary after it moved into Kuno from Ranthambore Tiger Reserve in December 2010 (Sharma et al. 2013). Based on verbal communication with the forest department, Leopards *Panthera pardus fusca* are thought to be the primary apex predator at this site.

KWLS is one of the sites selected for Asiatic Lion reintroduction (Johnsingh et al. 2007). In 2009, the sanctuary was considered for reintroduction of Cheetah (Ranjitsinh & Jhala 2010). There is always a possibility that the tiger population may grow as more animals immigrate into the sanctuary from the neighbouring Ranthambore Tiger Reserve (Sharma et al. 2013). Therefore, an estimate of the Leopard abundance could provide useful baseline against which the distribution of all three large cats can be compared in the future. No published studies could be traced by the authors on Leopard abundance in KWLS.

Leopard studies have acquired greater urgency with increased incidents of human–wildlife conflict due to increasing human encroachment around sanctuaries (Athreya 2006, 2012; Athreya et al. 2013). Leopards are also listed Vulnerable by the International Union for Conservation of Nature (IUCN) and have been consistently poached in large numbers over the years (Edgaonkar 2008; Wildlife Protection Society of India, 2017).

Although the method of pugmark tracking has been refined for determining the spatio-temporal distribution and population structure of a minimum number of tiger and Leopard (Singh 2000), the primary method used for estimating large carnivore abundance was the traditional system of pugmark detection and analysis (Choudhary 1970, 1971, 1972; Sawarkar 1987; Sharma et al. 2001). The pugmark method has been replaced by camera trapping and associated mark and recapture analysis, which yield robust estimates of population parameters (Otis et al. 1978; Pollock et al. 1990; Karanth & Nichols 1998, 2000a). However, problems persist in accurate population estimation due to factors such as low numbers, poor detection probability, hardware, logistics and manpower cost (Smallwood & Fitzhugh 1995).

Capture–recapture studies on Leopards using camera traps have been conducted in many parts in India previously, as well as in other countries (Khorozyan 2003; Balme et al. 2007; Henschel 2009; Gray & Prum 2012). The studies in India on Leopard abundance were performed in Sariska (Chauhan et al. 2005), Manas (Borah et al. 2014), Sanjay Gandhi (Surve 2017) and Satpura National Parks (Edgaonkar 2008). A study in Rajaji National Park (Harihar et al. 2009), reported on the density of Leopards. The goal of the present study was to use remotely triggered camera traps and closed population estimators (Otis et al. 1978; Pollock et al. 1990), to assess the abundance of Leopards in KWLS.

MATERIALS AND METHODS

Study site

The 345km² Kuno Wildlife Sanctuary, established in 1981, lies between -25.500^{0}N and 77.433^{0}E longitude (Figure 1). It extends over the districts of Sheopur and Morena in north-west Madhya Pradesh, and is a part of the Sheopur-Shivpuri forested landscape, about 6800km^2. An area of 890km² buffer zone was added to the sanctuary later to form the 1,235km² Kuno Wildlife Division (Sharma et al. 2013). Between 1996 and 2001, a total of 24 villages with 1547 families got voluntarily relocated outside the protected area to leave behind a pristine area for wildlife conservation, on which the KWLS was established (Johnsingh et al. 2007). The Kuno River, one of the main tributaries of river Chambal, flows south to north across almost the entire length of the sanctuary and bisects it into the Palpur West and Palpur East ranges (Figure 1) (Johnsingh et al. 2007; Sharma et al. 2013). The altitude varies from 238–498 m above sea level, with temperature ranging from 47.4^{0}C in the summer to a minimum of 0.6^{0}C during the winter, and the average annual precipitation is 760mm (Sharma et al. 2013). Ecologically, KWLS falls within the Kathiawar-Gir dry deciduous forest eco-regions, which include northern and southern tropical dry deciduous forests, *Anogeissus pendula* forests and scrub, *Boswellia* forests, *Butea* forests, dry savannah forests and grasslands, and tropical riverine forests (Champion & Seth 1968).

KWLS hosts a diverse mammalian community

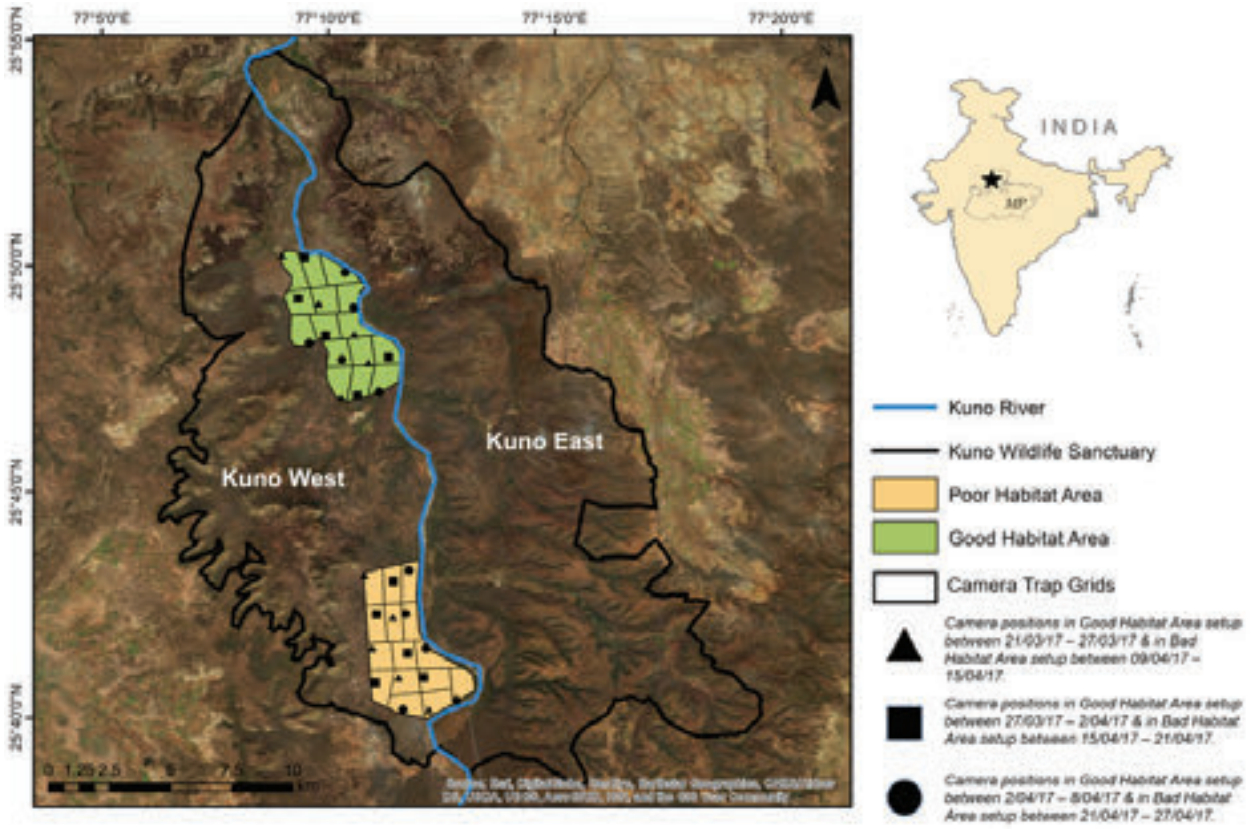

Figure 1. Outline of Kuno Wildlife Sanctuary showing the camera trap locations, river Kuno and the two good and poor study habitats selected for the study.

including Chital *Axis axis*, Sambar *Rusa unicolor*, Nilgai *Boselaphus tragocamelus,* Wild Pig *Sus scrofa*, Chinkara *Gazella bennetii*, Chousingha or Four-horned Antelope *Tetracerus quadricornis* and Indian crested-porcupine *Hystrix indica*. Other carnivorous species, apart from the Leopards recorded at KWLS include Sloth Bear *Ursus melursinus*, Striped Hyaena *Hyaena hyaena,* Indian Fox *Vulpes bengalensis* and Honey Badger *Mellivora capensis*. Additionally, a large population of feral cattle, which were left by the villagers behind during the relocation, also roam the forests and number around 700, that has come down from a high of 2500 cattle recorded in 2005 (Johnsingh et al. 2007).

The dominant tree species here include Khair *Acacia catechu*, Kardhai *Anogeissus pendula*, Salai *Boswellia serrata*, Tendu *Diospyros melanoxylon*, Palash *Butea monosperma*, Dhok *Anogeissus latifolia* and Ber *Zizyphus mauritiana* (Sharma et al. 2013).

Field surveys and 'observation units'

The study was conducted over a 40–day period from 18 March to 26 April 2017 during the summer season when the average temperature was 42° C during the day and 22^{0}C during the night. Confined to the administrative jurisdiction of Palpur West Forest Range of KWLS data were obtained from 30 observation units in 10 observation blocks under two study habitats each of 15km^2 (Figure 1). The size of each observation unit was 1km^2 and the blocks of about 3 km^2 each. The basis for considering study habitats of 15km^2 each was inspired from Odden & Wegge (2005) who mentioned the smallest home range of a female Leopard as 15–17 km^2.

One of the two study habitats, the 'poor study habitat' was identified close to the entrance of KWLS and the other, the 'good study habitat' was approximately 7km apart and away from the park entrance. Unpublished Forest Department reports were consulted and a preliminary survey was conducted for three days from 18 March to 20 March in 2017 to distinguish and demarcate the two 'good' and 'poor' study habitats. The distinction was based on previously used criteria such as carnivore signs, prey species abundance, proximity to the park boundary, signs of human interference, poaching evidence, predation by domestic dogs and water availability (Chauhan et al. 2005; Borah et al. 2014;

Thapa et al. 2014; Hedges et al. 2015). The poor habitat had reduced evidence of prey species, with presence of domestic dogs, increased human activity and signs of forest fire. On the other hand, the good habitat was away from the park entrance, had increased prey base, absence of domestic dogs, reduced human activities and had more patrolling posts in the forest (Image 1). The boundaries of each 15km² 'study habitat' were demarcated using GPS (Garmin Etrex 10) and imported into Google Earth (Google Earth, Digital Globe, version 2017).

Trail camera placements

Sixteen trail cameras, with PIR (passive-infra-red) motion sensor (Bushnell Trophy Cam HD Aggressor No-Glow, 20 MP resolution, 0.2 second trigger, Kansas, USA), were used. The cameras were deployed in pairs, either on trees or on wooden stakes at a height of approximately 40cm, and angled slightly away from each other, four to six metres apart. Paired camera ensured capture of both flanks of an animal under normal conditions, and the availability of at least one functional camera in case of malfunctioning of the other camera (Ancrenaz et al. 2012). Vegetation was cleared between the camera pairs to enable a clear line of sight. Trigger motion was physically checked by crouching in front of the camera before leaving the camera site (Karanth & Nichols 1998; Ancrenaz et al. 2012). The trigger speed was set to 3 frames per 10 seconds to balance the detection probability and conserve battery power. To minimise the possibility of double counting, an interval of at least 20 minutes was taken before recording the same object again.

Within each observation unit the camera traps were fixed so that inter-camera distances during a six–day trapping session were between 1.25km and 2.5km. Where the theoretical sites for fixing a camera were impractical because of locations like ponds, rocky cliffs etc., the cameras were shifted within 100–150 m. The cameras were moved to nearby locations with evidence of Leopard presence ascertained from scats, pugmarks, roads and water holes (Sankar et al. 2005). This reduced the probability that any Leopard in the survey-grid went undetected. Most camera sites were either accessible by road or by walking a distance of less than 2km.

Due to time constraints and the unavailability of cameras, trapping was conducted over two survey periods of 18 days for each habitat. Each 18–day period was further sub-divided into three episodes of six days each. This study approach is similar to a study by Chauhan et al. (2005) in Sariska National Park in which 10 camera traps were deployed for a comparable period of 10 days. In the present study, the camera traps were inspected once every alternate day for the good study habitat and once every three days for the poor study habitat.

Data analysis

Estimation of Leopard abundance from closed population capture–recapture model was performed using Program MARK version 8.2 (Otis et. al. 1978; White 2008). As the surveys were carried out within a relatively short period of approximately five weeks the Leopard population was assumed to be closed geographically and as there was no permanent migration of the animals into or off the grid, we also assumed that there was demographic closure, i.e., no deaths occurred in the population during the survey (White 2008).

Several alternate parameterisations of closed population capture–recapture models were fit to account for variation in detection probability. Various models such as the Mt model (time-varying capture probability), Mh model (individual heterogeneity in capture probability) and M0 model (null model) were considered (White 2008). The data was analysed using modelling procedures that were suitable for small sample sizes (Gerber et al. 2014). The model support was evaluated using Akaike information criterion (AICc).

Individual animals were identified based on rosette patterns, using images of both flanks (Trolle & Kerry 2003; Jackson et al. 2006; Harihar et al. 2009; Hedges et al. 2015) and observing the sexual organs in the images. To minimise identification error, independent verifications of identifications, based on rosette patterns, was undertaken by four observers. These data were entered into a matrix with individuals along the rows, and occasion-wise capture events in columns, with a one or zero representing capture and non-capture respectively for each 18–day period.

RESULTS

In total, 78 photographs of Leopards were taken in both good and poor study habitats. Of these, 38 were of sufficient quality to enable identification of individual Leopards. All the Leopards except one were captured nocturnally. In all photographs but one, Leopards were solitary.

In the good study habitat, on the basis of the rosette patterns on the right and left flanks, a total of six Leopards were identified and one Leopard was identified on the

Table 1. Identification of individual Leopards by Right, Left and both Right & Left Flanks in good study habitat.

Leopard ID	Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Dates	21/03	22/03	23/03	24/03	25/03	26/03	27/03	28/03	29/03	30/03	31/03	01/04	02/04	03/04	04/04	05/04	06/04	07/04
L1 M		None	None	Left	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None
L2 M		None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Right Left	Right Left
L3 M		None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Right Left
L4 F		None	Right	None	None	None	None	None	None	None	None	Right Left	None	None	None	None	None	None	None
L5 F		None	None	None	Left	Right Left	None	None	None	None	None	None	None	None	None	None	None	None	None
L6 F		None	None	None	None	None	Right Left	None	None	None	None	None	None	None	None	None	None	None	None
L7 F		None	None	None	None	None	Right Left	None	None	None	None	None	None	None	None	None	None	None	None

Table 2. Capture-recapture (CA-RC) history of individually identified, sex determined Leopards in good study habitat. L - Leopard | M - male | F- female | CA - capture | RC - recapture

Date	March 21 – March 26						March 27 – April 1						April 2 – April 7					
Day	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
L1 M	0	0	CA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L2 M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	RC	RC
L3 M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CA
L4 F	0	RC	0	0	0	0	0	0	0	0	RC	0	0	0	0	0	0	0
L5 F	0	0	0	RC	RC	0	0	0	0	0	0	0	0	0	0	0	0	0
L6 F	0	0	0	0	0	CA	0	0	0	0	0	0	0	0	0	0	0	0
L7 F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CA

basis of the rosette pattern on the left flank only (Table 1). Therefore, a total of seven Leopards were identified in the good study habitat (Table 2; Images 2-8). Only one individual was identified based on its left flank rosette pattern in the poor study habitat (Table 3,4; Image 9). One Leopard was unable to be classified into the good or poor study habitat due to the poor quality of the captured image.

In the good study habitat, three of seven Leopards were recaptured including one male and two females (Table 2). Of the remaining four Leopards, which were not recaptured, two were males and two were females (Table 2). There was only a single capture of a male Leopard in the poor study habitat (Table 4).

During the camera trapping exercise, a total of nine Leopard sightings also occurred on eight occasions in the good study habitat and two were sighted in the poor study habitat (directly seen by the team) (Figure 2).

Leopard Abundance

The estimate for Leopard abundance for the good study habitat was 11 Leopards (SE4.6, 95% CI = 8 – 31 individuals). Due to the small sample size and sparse recaptures, M0 (null) was the only model that converged. Consequently, the estimate was associated with wide confidence intervals. In the poor study habitat due to the capture of only a single Leopard, analysis could not be performed. For both the good and poor study habitat the detection/capture probability was 0.15 (SE= 0.07, 95% CI= 0.05–0.35).

Details of pictures from camera traps

A total of 1,95,408 pictures were clicked during the camera trapping exercise, out of which 97,270 pictures were clicked in the good study habitat and 98,138 pictures were clicked in the poor study habitat. False trigger images were obtained in majority across both the study sites. Among carnivores, photos of Indian jackals (112) were the highest followed by those of Striped Hyena (26) (Table 5; Images 10–12).

Among prey species, chital (736+86) and cattle (194+141) were the most frequently detected on

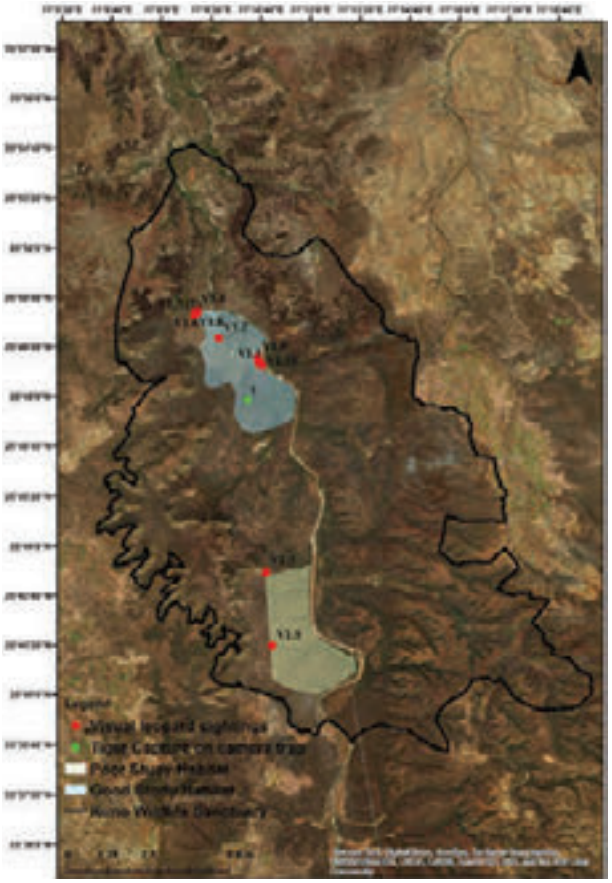

Figure 2. Locations of Leopards visually encountered during drives and on foot in Kuno Wildlife Sanctuary. In the map, L denotes Leopards and the number denotes the sighting number of the Leopard. The location of the camera trap on which the tiger was captured is also indicated in the map and is denoted by T.

the camera traps in both the good and the poor study habitats (Table 5; Images 10–12). Based on the locations of the camera traps and visual sightings in the good study habitat, chital numbers were concentrated around water holes, grassland and riverbank while cattle were concentrated around water holes and open forest habitats. In the poor study habitat, cattle were mostly concentrated in grasslands, open forests and hilly scrub forests, followed by chital which were concentrated around riverbanks.

Some of the rarer species detected by the camera traps included the sole known tiger in the sanctuary (Figure 2), a honey badger, an Asiatic Wildcat/Indian Desert Cat *Felis silvestris ornata* and a slightly darker morph of Jungle Cat *Felis chaus*, perhaps a male. A four feet long Marsh Crocodile *Crocodylus palustris* was also detected at a small stream, away from the Kuno River. The total number of times the animals were photographed support the distinction of the two study habitats into good and poor study habitats (Image 1), i.e., 22 species (mammals, reptiles and bird) yielded 1644 images in the good study habitat while, 23 species (mammals and bird) yielded 475 images in the poor study habitat (Table 5; Image 10).

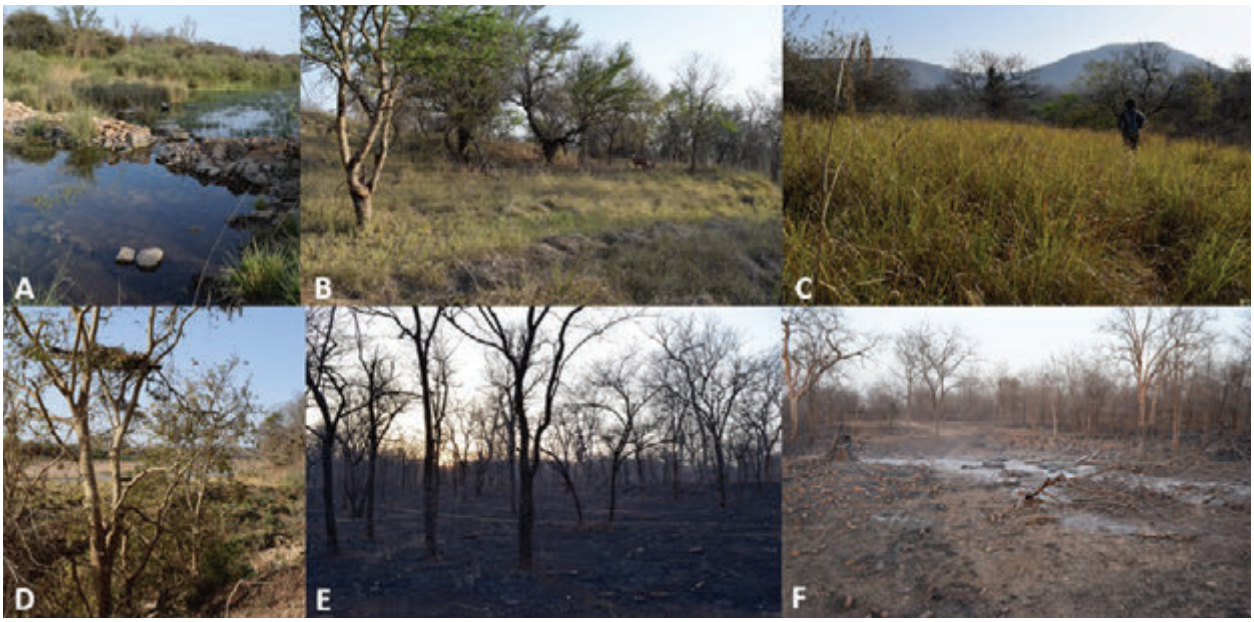

Image 1. Top panel shows representative images indicating the condition of the good study habitat with presence of water sources (A) and vegetation (B, C). On the other hand, the bottom panel shows representative images from the poor study habitat which showed signs of human activities such as the presence of a machan (tree-top platform made for animal observation) (D) and extensive forest fires (E, F).

Table 3. Identification of individual Leopards by Right, Left and both Right & Left Flanks in poor study habitat.

Leopard ID	Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Dates	9/04	10/04	11/04	12/04	13/04	14/04	15/04	16/04	17/04	18/04	19/04	20/04	21/04	22/04	23/04	24/04	25/04	26/04
Leopard 8 M		None	None	None	Left	None	None	None	None	None	None	None	None	None	None	None	None	None	None

Image 2.L1 M - male, captured in the good study habitat.

Image 4. L3 M - male, captured in the good study habitat.

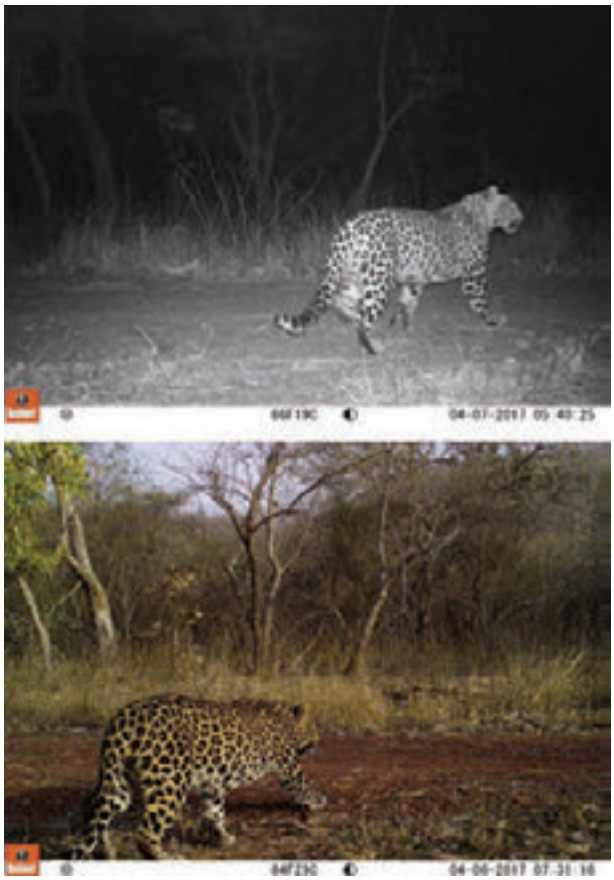

Image 3. L2 M - - male, captured in the good study habitat.

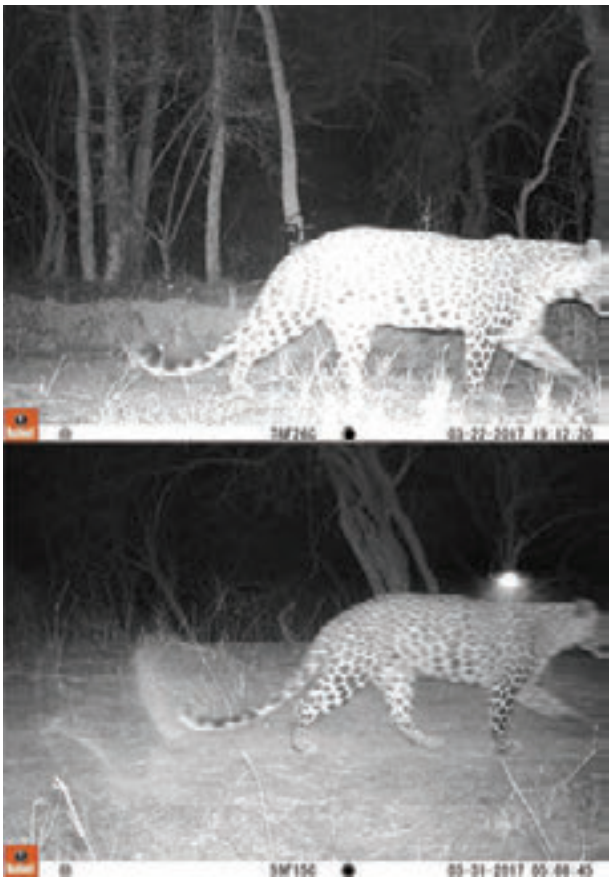

Image 5. L4 F - female, captured in the good study habitat.

Table 4. Showing capture–recapture history of individually identified, sex determined Leopards in poor study habitat.

Date	April 9 - April 14						April 15 -April 20						April 21 - April 26					
Day	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
L8 M	0	0	0	CA	0	0	0	0	0	0	0	0	0	0	0	0	0	0

DISCUSSION AND CONCLUSION

In adjunct to previously unpublished work by the Forest Department of Madhya Pradesh, this study is the first on Leopard abundance in KWLS. Previous studies have focussed on estimating herbivore populations as prey available for future introduction of lions, and baseline population estimates of existing carnivore populations have remained unpublished (Johnsingh et al. 2007; Sharma et al. 2013).

To increase the probability of detection for all Leopards and to avoid violations of closure norms we sampled over six–day periods to cover the entire area chosen, and used a small size of observation units covered by each camera trap location – 1km² each and small inter-trap distances of around 2km (Hedges et al. 2015). However, a paucity of time, equipment and the adoption of an experimental design to interpret for the full area of KWLS limited the applicability of the capture–recapture computer modelling, leading to a high level of standard error. Despite these limitations, the present study revealed the number of Leopards inhabiting the study areas in KWLS along with indices of prey base. As shown in Table 1, seven individual Leopards were captured in the good study habitat and the estimate for Leopard abundance was found to be 11 ± 4.6 for an area of 15km². As shown in Table 3, only one Leopard was captured in the poor study habitat.

Previous studies provide estimates of abundance of 16 ± 6.85 Leopards in an area of 68km² in Sariska National Park (Chauhan et al. 2005), 35.60 ± 5.50 in an area of 500km² in Manas National Park (Borah et al. 2014) and 35.59 + 0.51 in an area of 140km² in Sanjay Gandhi National Park (Surve 2015). The Leopard estimate (11 ± 4.6) in the present study in 15km² of KWLS appears high, which might be due to the absence of other predators such as tigers and dholes/wild dogs *Cuon alpinus* (Chauhan et al. 2005; Edgaonkar 2008).

During the study, only one tiger was captured on a single camera trap in the good study habitat. Throughout the duration of the study, no other tiger captures were recorded and thus it is possible that the captured tiger's movement was transient in the area. Additionally, the relatively high Leopard abundance suggests that the presence of the tiger did not affect the presence of Leopards in the good study habitat based on the visual sightings of Leopards and the number of camera trap captures of the Leopard (Figure 2; Table 5).

Image 6. L5 F - female, captured in the good study habitat.

The prey base photos captured in the study support the reflection in this study on Leopard abundance in KWLS. The high captures of Leopards in the good study habitat could have been influenced due to the presence of a large number of chital (736) and feral cattle (194) (Table 5). The number of feral cattle (141) in the poor habitat was about 73% that of the good habitat, but the number of chital (86) was significantly low, only 12% of the good habitat (Table 5). Low prey base in the poor habitat may have attributed to the reduced captures of Leopard. According to a previous study, chital and cattle are a part of Leopard's diet (Ramesh 2010; Forest

Image 7. L6 F - female, captured in the good study habitat.

Image 8. L7 F - female, captured in the good study habitat.

Image 9. L8 M- male, captured in the poor study habitat.

Table 5. The numbers of pictures obtained for varying species from the camera trapping study in Kuno Wildlife Sanctuary.

	Species captured	Good habitat area (21/03/2017 to 8/04/2017 - 18 days)	Poor habitat area (09/04/2017 to 27/04/2017 - 18 days)	Total Captures
		Number of Pictures	Number of pictures	
1	Leopard	12	1	13
2	Tiger	2	0	2
3	Cattle	194	141	335
4	Asian Palm Civet	1	7	8
5	Asiatic Wild Cat	0	1	1
6	Bengal Fox	6	18	24
7	Blue Bull	62	11	73
8	Chinkara	7	0	7
9	Chital Deer	736	86	822
10	Feral Dog	0	1	1
11	Four Horned Antelope	1	5	6
12	Gray Langur	21	63	84
13	Honey Badger	2	3	5
14	Indian Boar	118	20	138
15	Indian Crested Porcupine	21	9	30
16	Indian Grey Mongoose	1	0	1
17	Indian Hare	61	3	64
18	Indian Jackal	88	24	112
19	Jungle cat	17	20	37
20	Rhesus Macaque	0	2	2
21	Ruddy Mongoose	0	3	3
22	Sambar Deer	42	21	63
23	Sloth Bear	0	3	3
24	Small Indian Civet	15	10	25
25	Striped Hyena	21	5	26
26	Indian Peafowl	214	18	232
27	Marsh Crocodile	2	0	2
	Total	**1644**	**475**	**2119**

department of KWLS). In the poor habitat, the number of cattle were the highest compared to the other species, which may be due to increased human activity in this area.

The dry summer season, human activities (Image 1) and extensive forest fire noticed during the study may have resulted in outflux of the prey animals from the poor study habitat into the good study habitat, and subsequently movement of Leopards to the good area.

As the study was conducted during summer, the high temperatures of 40° C - 44° C may have influenced the movement of the animals towards the water sources, as a result in both the good and poor study habitats, the highest numbers of animals were recorded in association with water.

The goal of this study was to provide baseline population data for the Leopards in KWLS, thereby providing a useful starting point for future studies. Since KWLS has been considered at different times for possible reintroduction of Asiatic lion and Cheetah (Johnsingh et al. 2007, Ranjitsinh & Jhala 2010), it was important to understand the existing profile of carnivores and prey base of the sanctuary. Future studies may lead to better understanding of predator-prey coexistence, competition interfaces, behaviour and prey selection in the context of their distribution and abundance in KWLS.

There is rapid evolution and adoption of methods of estimating occurrence, abundance, densities and associated behavioural-patterns of cryptic carnivores (Singh 1999; Karanth & Sunquist 2000b; Sharma et al. 2001; Wang & Macdonald 2009; Jhala et al. 2011). Advances in camera trapping equipment, theory, computer modelling, softwares and analysis tools (e.g., via Mark, Capture, R, etc.), have led to increased accuracy, replicability and comparability in data obtained from various locations and time frames (Otis et al. 1978; Pollock et al. 1990; Karanth & Nichols 1998, 2000). O'Brien et al. (2003) were the first to demonstrate that the relative abundance of tigers and their prey, as measured by camera traps, is directly related to independently derived estimates of densities for these species. However, challenges remain.

The current study was limited by financial and logistical constraints and the loss of two cameras towards the end of the study due to theft and damage by wildlife. Despite these limitations we expect that the present study provides a baseline. It is suggested that future studies may deploy a substantial number of cameras and allow for a large number of detections in an extensive area over prolonged periods of time repeated in different seasons to discern long-term trends.

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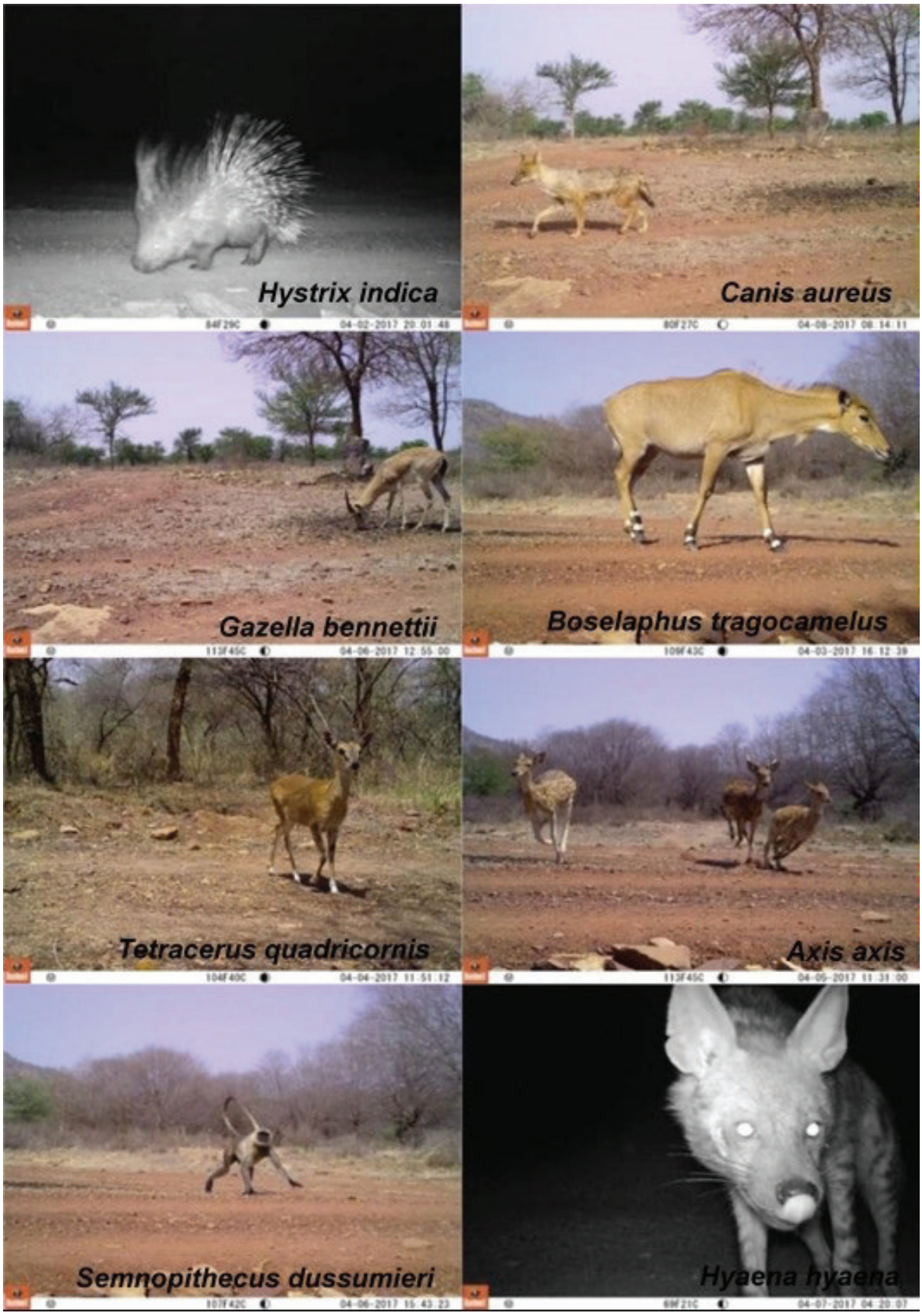

Image 10. Other species recorded from the camera trapping study in Kuno Wildlife Sanctuary.

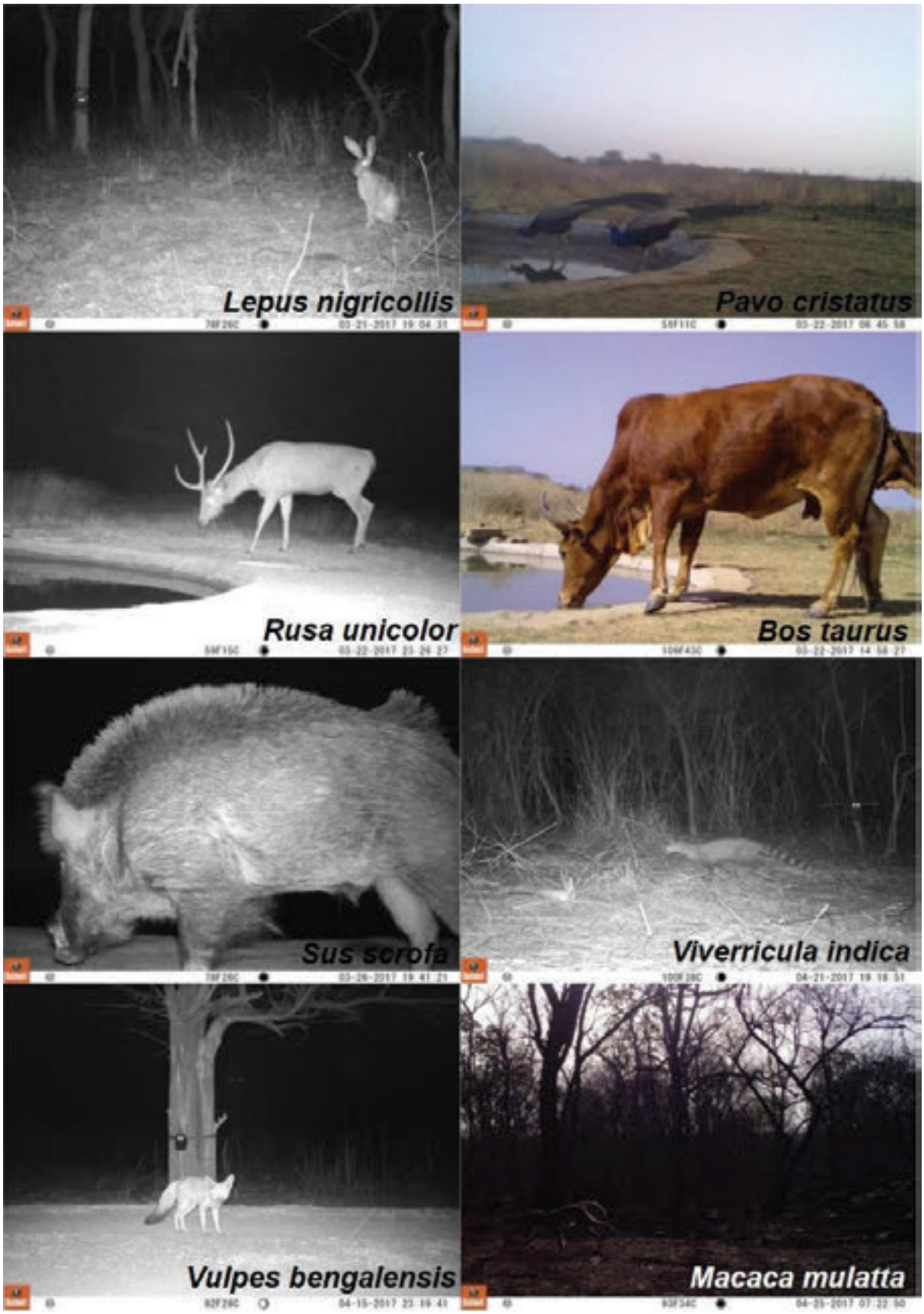

Image 11. Other species recorded from the camera trapping study in Kuno Wildlife Sanctuary.

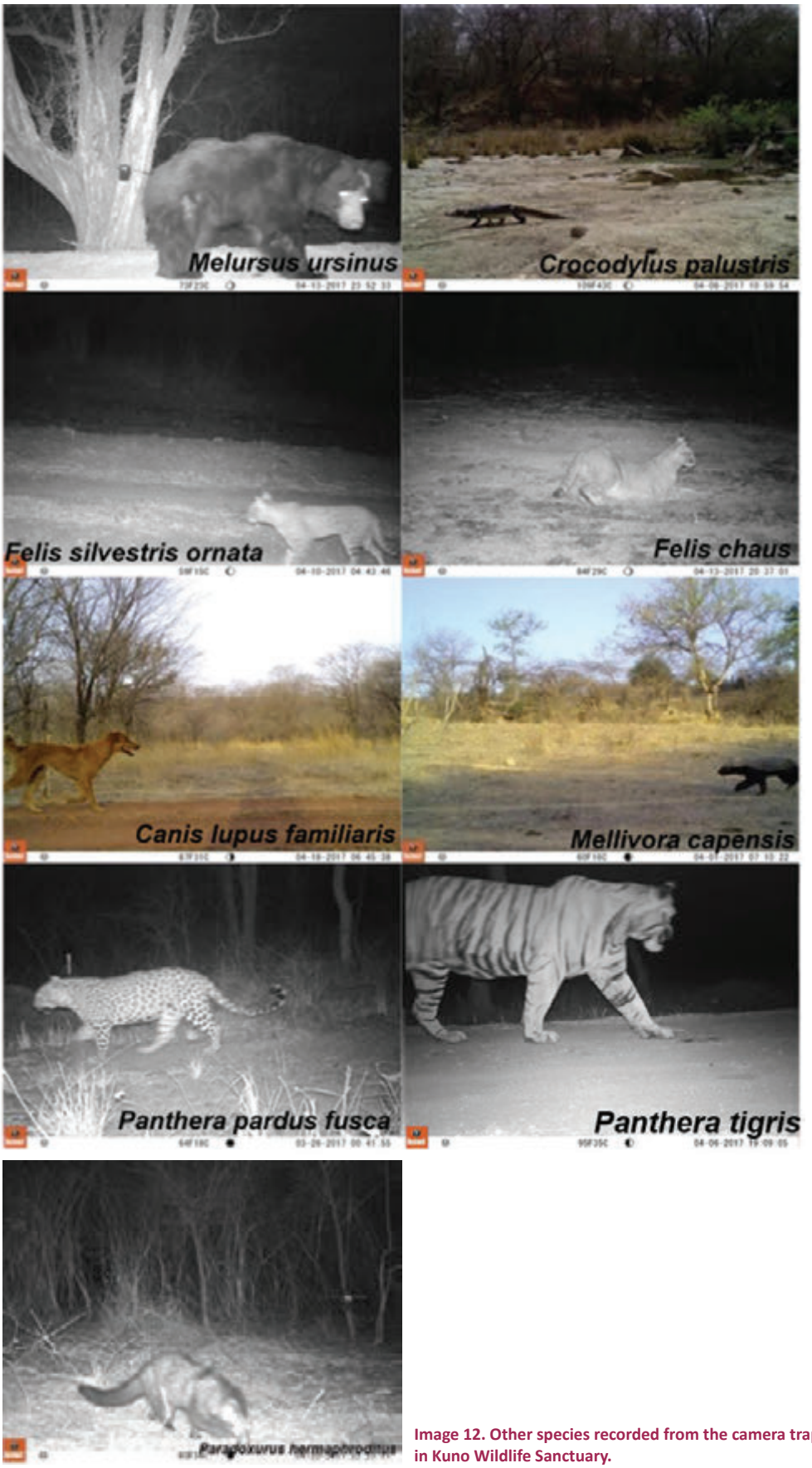

Image 12. Other species recorded from the camera trapping study in Kuno Wildlife Sanctuary.

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Food composition of Indian Eagle Owl *Bubo bengalensis* Franklin (Aves: Strigiformes: Strigidae) from Tiruchirappalli District, Tamil Nadu, India

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Abstract: The diet of the Indian Eagle Owl was studied from April to September 2017 in Tiruchirapalli District, Tamil Nadu, India. Analysis of 1082 regurgitated pellets yielded 2077 prey items; the mean prey items/ pellet was 1.91. The diet constituted 65.1% of rodent prey and the remaining 34.83% of other groups of both vertebrate and invertebrate animals. The mean percentage of prey composition was 31.15% *Millardia meltada* Soft-furred Field Rat, 12.95% *Bandicota bengalensis* Lesser Bandicoot Rat, 10.25% *Mus booduga* Indian Field Mouse, and 10.24% of other rodent species. Of the 34.83% of non-rodent prey, the owls ingested insects (Rhinoceros beetles, 9.58%), Arachnida (Solifugae or Sun spider, *Galeodes* sp., 9.58%), reptiles (*Calotes* sp., 3.7%), amphibians (3.56%), shrews (*Suncus murinus,* 2.84%), and others (5.57%). The Indian Eagle Owls consumed more than one prey per day and chiefly foraged in agricultural crop fields and consumed both small mammals and insects of agricultural importance under crop ecosystems.

Keywords: Amphibians, arachnid, *Bandicota bengalensis,* insects, *Millardia meltada*, pellet analysis, prey composition, reptiles, rodents, shrew.

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Author contribution: TS collected and analysed Data. PNN and VVR prepared the article.

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INTRODUCTION

Owls are nocturnal birds and there are 241 (BirdLife International 2017) living species in the world. The Indian Eagle Owl *Bubo bengalensis* is one of the nocturnal raptors distributed only in the Indian subcontinent. Owls have evolved with many adaptations to occupy the top of the food chain in the ecological niche. Owls feed mainly on field rats, mice, shrews, bats, birds, reptiles, frogs, crabs, scorpions, and insects. The Indian Eagle Owls are terrestrial nesters of rocky hillocks of hill slopes, earth cuttings and bushes. Their hunting grounds consist of agricultural crop fields, water bodies, hills and rural habitats. Regurgitated pellets of owls have undigested body parts of prey like bones, fur of vertebrate and exoskeleton of invertebrate animals. These undigested food materials are oval in shape and greenish black or grey coloured and dropped in the nesting and roosting/perching sites of owls. Regurgitated pellets are analyzed to understand and document the prey composition of Indian Eagle Owls and to find out the variations in their food habits over a period of time. Earlier studies have been carried out on Indian Eagle Owls such as information on the long call (Ramanujam 2003); methods of analyzing rodent prey (Ramanujam 2004); auditory and visual communicatory traits (Ramanujam 2007), morphometric development of young Indian Eagle Owl (Penteriani et al. 2005; Ramanujam & Murugavel 2009; Pande & Dahanukar 2011a); breeding biology, nesting habitat, and diet (Ramanujam 2006; Pande et al. 2011; Pande & Dahanukar 2011b); spread-winged agonistic displays (Ramanujam 2010); the time budget and behavioural traits of young and adult (Ramanujam 2015); and a comparative study on the diet (Ramanujam & Singh 2017). In India, prey spectrum of this species have been studied and reported from Tamil Nadu – Puducherry (ravines and gullies habitats) in southern India (Ramanujam 2006, 2015) and Maharashtra (Pande et al. 2011; Pande & Dahanukar 2011b) in central India. It is understood from the review of literature that there is limited published information on the diet composition of Indian Eagle Owls from Tamil Nadu and hence the present study.

MATERIALS AND METHODS

The Study Area

The present study was carried out in Musiri Taluk of Tiruchirappalli District, Tamil Nadu. The area consists of many hillocks, interspersed with villages and agricultural fields (Image 1). In the past, studies by Nagarajan et al. (1993), Taylor (1994) and Santhanakrishnan (1995) suggested use of indirect signs such as regurgitated pellets, milky white droppings and prey remains of Barn Owls for the identification of roosting/nesting sites. The same indirect signs were utilized in the present study for the identification of Indian Eagle Owls' nesting/roosting sites. Information given by the local residents was also useful in locating the roosting/nesting sites of Indian Eagle Owls. It is apparent from the survey that the hillocks are the prime nesting and roosting/

Image 1. A typical roosting habitat of Indian Eagle Owls in Thuraiyur Puthupatti hillock and adjoining agricultural crop fields.

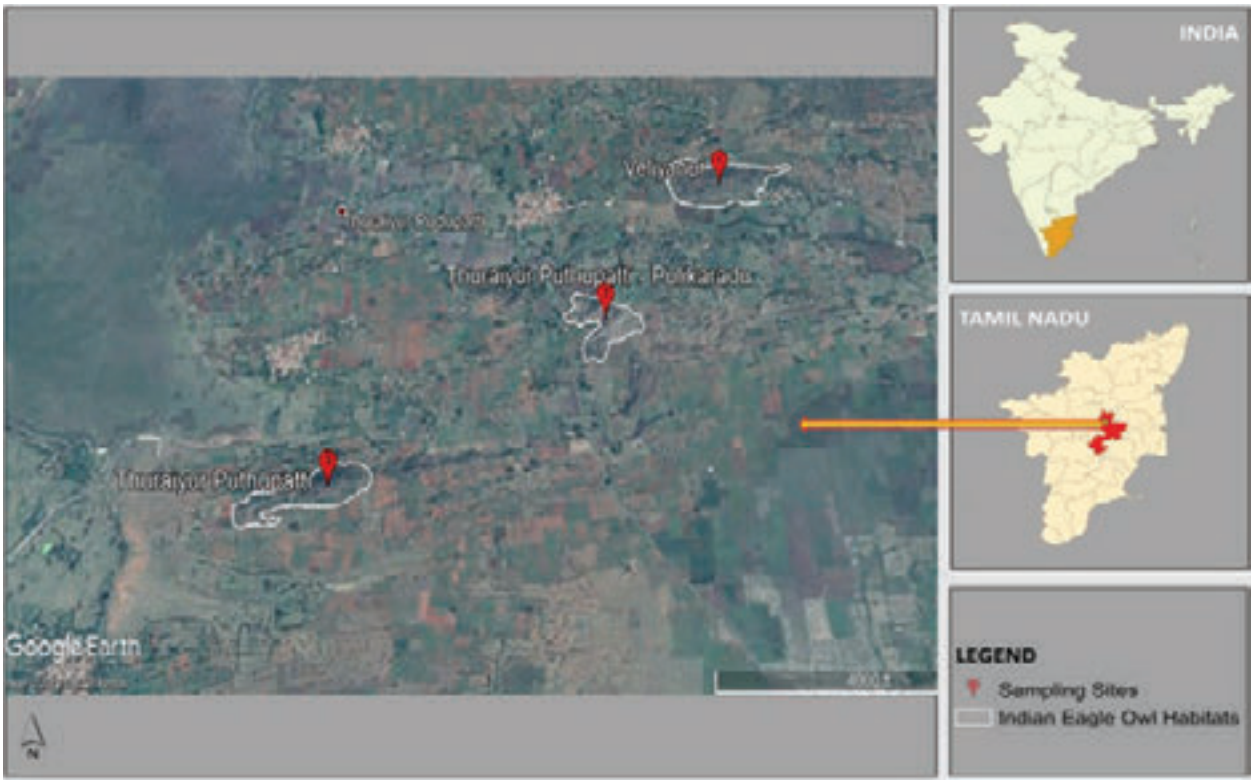

Figure 1. Location of the identified Indian Eagle Owl's roosting sites in the chosen study area.

perching habitats of Indian Eagle Owls (Image 2). The pellets of Indian Eagle Owls were collected from hillocks near three villages - Veliyanur (11.049^{0}N & 78.586^{0}E), Thuraiyur-Puthupatti-Pulikaradu (11.043^{0}N & 78.580^{0}E) and Thuraiyur-Puthupatti (11.037^{0}N & 78.568^{0}E) (Fig. 1) between April and September 2017. In total, 1082 pellets were collected during the study period.

Pellet Analysis

The pellets (Images 3 & 4) were collected once a month, and bagged in separate polybags, labelled and brought to the laboratory for analysis. Before analysis, the pellets were kept in an oven at 70^{o}C for 24h to kill the associated invertebrate parasites (Neelanarayanan et al. 1995; Santhanakrishnan 1995). The pellets were then placed in separate washing cups, containing 8% NaOH (by weight) sodium hydroxide solution, and then analysed (Neelanarayanan et al. 1998). Fur and other debris were dissolved in the 8% NaOH solution leaving only the osteous and chitinous remains of vertebrates and invertebrates, respectively. The solution was then carefully decanted by using a filter and the osteous remains were collected, oven dried at 60°C, labelled, bagged and preserved for prey species identification.

Vertebrate prey items were identified on the basis of lower jaws, skull, limb bones and pectoral and pelvic girdles (Neelanarayanan et al. 1998; Talmale & Pradhan 2009). We determined the number of prey individuals consumed per pellet based upon the number of skulls, lower jaws, or fore and hind limb bones found in each pellet. One set of lower jaws (left and right) (Image 5) or one skull or one pair of fore and hind limb bones were counted as remains of one prey item. In the absence of mandibles, other bones like skulls, limb bones, pectoral and pelvic girdles and synsacra (in the case of birds) were useful, especially for identifying and quantifying the mammalian, avian and amphibian prey (Neelanarayanan 2007). Insect prey items were identified up to order level on the basis of undigested pieces such as chitinous exoskeleton, heads, wings, legs, and stings (Images 6 & 7). A hand lens or low power binocular microscope was employed to identify insect exoskeleton (Marti 1987; Neelanarayanan 2007). In order to know the contribution of each prey species in the Indian Eagle Owl's diet, they were converted into proportions and presented in tables. The mean prey items per pellet were calculated as follows:

$$\text{Mean prey items/pellet} = \frac{\text{Total no. of prey items observed in a month}}{\text{Total no. of pellets collected in a month}}$$

Image 2. A pair of Indian Eagle Owl observed in the Thuraiyur Puthupatti-Pulikaradu hillock.

RESULTS AND DISCUSSION

Analysis of 1082 regurgitated pellets yielded 2077 prey items (Table 1). The analyzed pellets revealed—small mammals such as *Bandicota bengalensis, B. indica, Funambulus palmarum, Millardia meltada*, *Mus booduga, Rattus rattus, Suncus murinus* & *Tatera indica*, and bats; amphibians; reptiles; birds; and invertebrates such as Rhinoceros beetle *Oryctes rhinoceros*, *Galeodes indicus*, Scorpion—the constituents of the diet of Indian Eagle Owls. Of these 2077 prey items, rodents constituted 1353 of the prey and the remaining 724 of other prey species like *S. murinus,* amphibians, reptiles, birds, bats, Rhinoceros beetle, among others.

Earlier, Pande & Dahanukar (2011b) and Pande et al. (2011) reported *B. bengalensis, B. indica, M. meltada, R. rattus*, *T. indica, M. musculus* and *Golunda ellioti* as the major constituents of the Indian Eagle Owls' diet in terms of frequency, proportion and biomass. Besides these they also reported Rhinoceros beetles, long-horned beetles, grass hoppers, mantids, snakes, scorpions formed the diet of Indian Eagle Owl. The diet of the Indian Eagle Owl in and around Puducherry and a part of Tamil Nadu comprised of prey such as *S. murinus, T. indica*, Chiroptera, *F. palmarum, R. rattus, M. meltada, B. indica, B. bengalensis, Mus* spp., *Lepus nigricollis*, Aves, *Varanus bengalensis, Amphiesma stolata,* Anura, *Paratelphusa* sp., *Heterometrus swammerdami, Scolopendra morsitans*, Orthoptera, Coleoptera (Ramanujam 2006; Ramanujam & Singh 2017). The results of these studies corroborate the findings of the present study. It is obvious from the results of the present investigation that these owls hunt both commensal and field rodent pests and insect pests (particularly Rhinoceros beetle) from agricultural crop fields around their nesting/roosting habitats.

The Rhinoceros beetle is found on Coconut palms, occurring throughout the country and many regions of the world. Detection can be difficult due to the beetles' nocturnal activity within the trees. In the present study, rhinoceros beetle accounted for 9.58% of the Indian Eagle Owl's diet. In Maharashtra, 11.9% of this beetle was recorded in the owl diet (Pande & Dahanukar 2011b). *Galeodes indicus* was found to be 9.58% of the diet in this study, however, Pande & Dahanukar (2011b) reported it at 0.2%. The presence of the diurnal Three-striped Palm Squirrel *F. palmarum* in the diet may be due to the owls hunting behaviour during day time. Bats are also potential prey of owls, not surprising considering that both these animal groups are nocturnal (Marks et al. 1999). The other prey species groups like birds, reptiles including *Calotes* sp., amphibians, and scorpion

Table 1. Prey composition (month-wise) of Indian Eagle Owls revealed from pellet analysis.

Month and Year		April 2017	May 2017	June 2017	July 2017	August 2017	September 2017	Total	Percentage	Proportion of rodents, insects & other prey	Proportion of major prey groups (pest & non-pest)
Prey species/ total number of pellets		**158**	**177**	**191**	**207**	**167**	**182**	**1082**			
Bandicota bengalensis		46	42	47	38	53	43	269	12.95	65.1	74.68
Millardia meltada		93	108	126	111	89	120	647	31.15		
Mus booduga		18	27	36	53	36	43	213	10.25		
Tatera indica		2	5	4	11	7	9	38	1.82		
Rattus rattus		0	0	1	1	0	0	2	0.096		
Bandicota indica		0	2	1	6	0	2	11	0.52		
Funambulus palmarum		0	1	0	2	1	1	5	0.24		
Unidentified Rodents		28	21	31	38	21	29	168	8.08		
Rhinoceros beetle		23	51	42	34	17	32	199	9.58	9.58	
Galeodes indicus		36	47	44	23	17	32	199	9.58	25.25	25.25
Scorpion		2	1	4	2	5	2	16	0.77		
Amphibians		17	10	4	16	22	5	74	3.56		
Reptiles	*Calotes* sp.	12	7	9	21	18	10	77	3.7		
	Others	7	2	6	12	14	8	49	2.35		
Birds		3	5	9	17	8	5	47	2.26		
Suncus murinus		4	11	6	17	9	12	59	2.84		
Bats		0	1	2	0	1	0	4	0.19		
Grand Total		**291**	**341**	**372**	**402**	**318**	**353**	**2077**	100	**100**	**100**

Image 3. A pellet of Indian Eagle Owl observed in its roosting site.

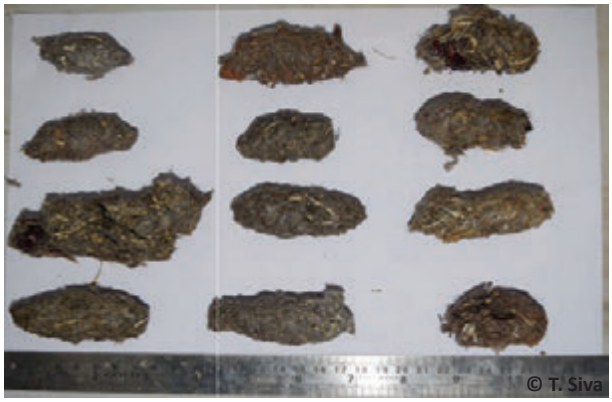

Image 4. Different sizes of Indian Eagle Owls' pellets collected during the present study.

were rarely hunted by owls.

In the present study, a maximum of 1.94 prey items/ pellet was observed during June and July 2017 while a minimum of 1.84 prey items/pellet was observed during April 2017 (Table 2). The results of the present study indicate that the Indian Eagle Owls consumed more than one prey per day.

CONCLUSION

In conclusion, the results of the present study reveal that the Indian Eagle Owls are hunters of both rodent and insect pests. Steps should be initiated to protect and conserve Indian Eagle Owls in their natural habitats to increase their population and make use of their services in managing the pest populations in cropping ecosystems.

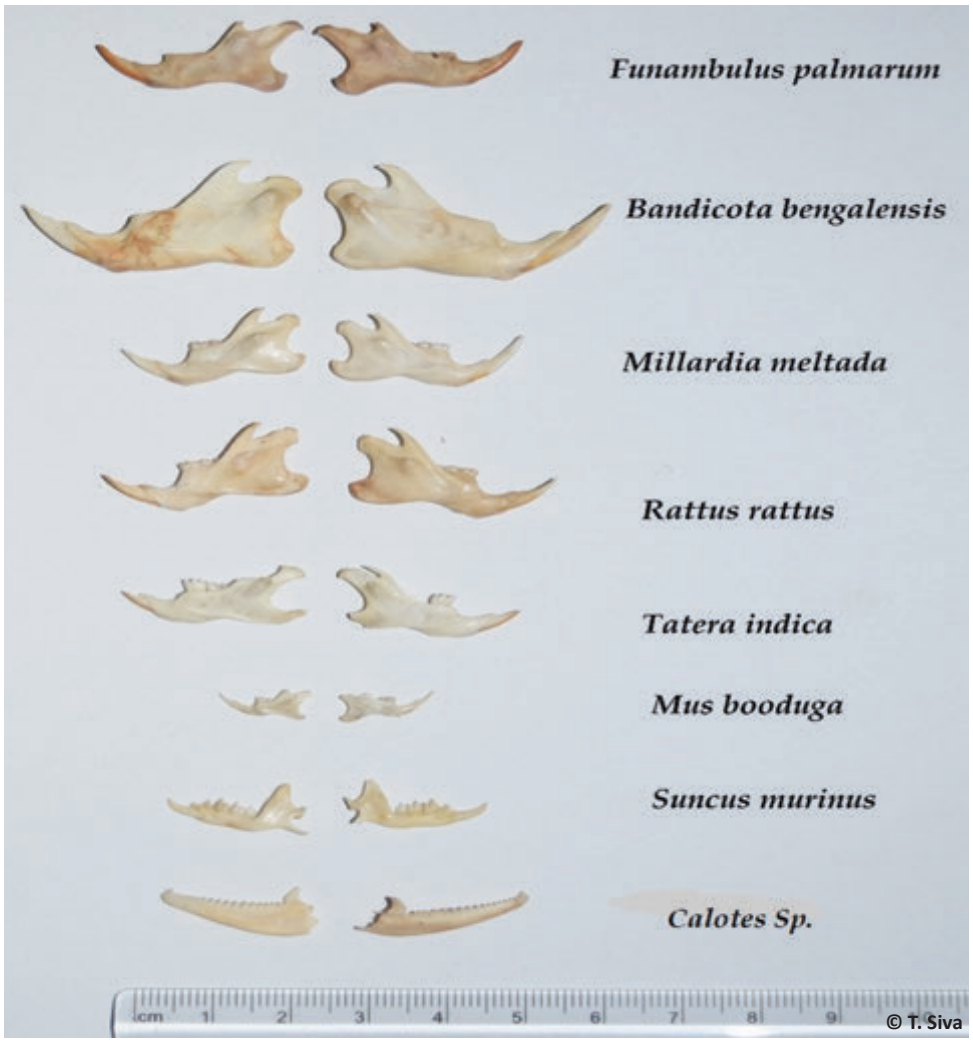

Image 5. The lower jaws or mandibles of rodents, an insectivore and *Calotes* sp.

Image 6. Entire exoskeleton of Rhinoceros Beetle observed in the pellets.

Image 7. Chelicerae of *Galeodes indicus* observed in the Indian Eagle Owl pellets.

Table 2. Mean prey items/ pellet observed during the study period.

	Month & year	Total number of pellets collected	Total number of prey items enumerated	Mean prey items/ pellet
1	April 2017	158	291	1.84
2	May 2017	177	341	1.92
3	June 2017	191	372	1.94
4	July 2017	207	402	1.94
5	August 2017	167	318	1.90
6	September 2017	182	353	1.93
Total		**1082**	**2077**	**1.91**

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Short Communication

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Sunda Pangolin *Manis javanica* (Mammalia: Pholidota: Manidae) of Gaya Island, Sabah

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Abstract: The Sunda Pangolin *Manis javanica* is naturally present in Gaya Island, Sabah, but its population status is largely unknown. Results from a recent survey using camera traps indicated the presence of a few individuals, who were strictly nocturnal. There is a strong indication that the population in Gaya Island is in danger of local extinction. There is also an urgent need to conduct an in-depth study to gather scientific information for further conservation action.

Keywords: Camera trap, Gaya Island, North Borneo, population, Sunda Pangolin.

The Sunda Pangolin *Manis javanica* (Pholidota) is one of eight extant species of pangolins, with a home range in Southeast Asia (Lim & Ng 2008; Phillipps & Phillipps 2016). All pangolin species have recently been classified from schedule II to schedule I in CITES, as they have become Critically Endangered due to poaching and international illegal trade (CITES 2017), including the Sunda Pangolin (Phillipps & Phillipps 2016). Payne et al. (1985) reported that the Sunda Pangolin can be found in the mainland and throughout the islands of Borneo. Phillipps & Phillipps (2016) reported that Sunda Pangolin population in Sabah is on the verge of extinction due to poaching. The status of the Sunda Pangolin population of Gaya Island is still largely unknown. This paper documents the presence of the Sunda Pangolin on Gaya Island and describes their activity patterns based on the results of a recent camera trap survey.

Materials and Methods

Study area

Gaya Island is 1,465ha in size, and more than three quarters falls under the jurisdiction of Sabah Parks (Figure 1), one of the five islands gazetted as the Tunku Abdul Rahman Marine Park. Gaya Island is a 15 minute boat ride from the Capital of Sabah, Kota Kinabalu City. It is well known as a tourist destination for its beautiful beach, marine life and water activities such as scuba diving and snorkelling. Terrestrial habitat on this island

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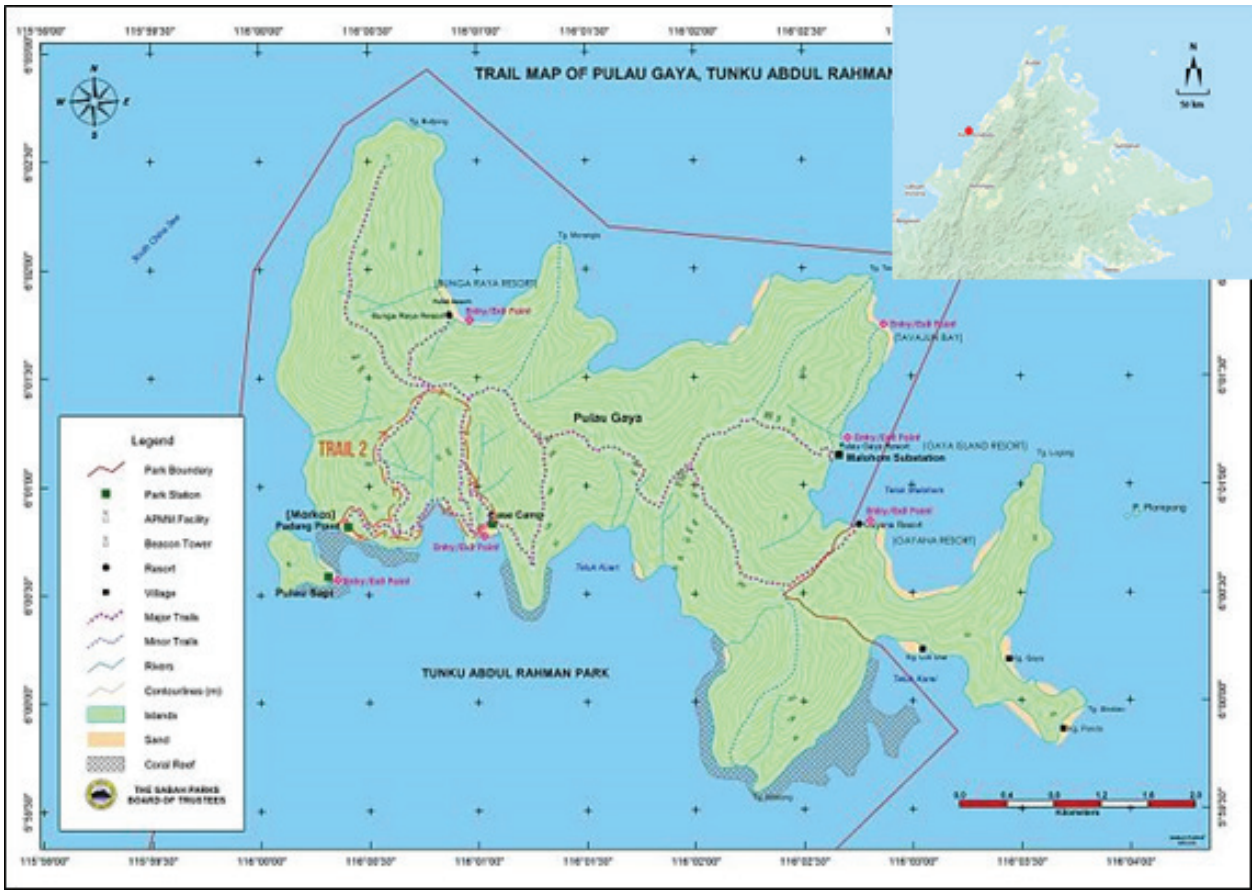

Figure 1. The National Park Boundary in Gaya Island in Sabah, East Malaysia (Sabah Parks 2013).

consists of primary forest and a small patch of mangrove (Said 2008).

Data collection

Ten Bushnell trophy Aggressor Brown (Model #119776) camera traps were deployed for a survey from 01 September 2016 to 30 June 2017. Camera traps were borrowed from Sabah Parks under the Research Unit. The camera traps were installed according to the techniques recommended by Acrenaz et al. (2012). In order to effectively survey pangolin, camera traps were frequently shifted to new locations. A total of 69 camera-trapping stations were established to cover most of the park area. The number of trapping days for each station varied from 22 to 109 days, with an average of 36.9 (SD=19.6) days. A total of 2,545 trapping days were undertaken by all stations.

Nine images of Sunda Pangolin were recorded during the 2,545 trapping days. The earliest image was recorded a day after the installation of the camera trap. The encounter rate was calculated using the number of images recorded per 1,000 camera working hours (the Occurrence Index, OI-value; Pei & Chiang 2004). Sunda Pangolin encounter rate in Gaya Island was 0.147 for this survey. They were strictly nocturnal, and all the images were recorded between 8.21 night to 2.22 past midnight (Table 1).

All nine images of Sunda Pangolin are shown in Figure 2. Good images of a pangolin that was probably searching for food at the decomposing large tree trunk were successfully recorded (Figure 2A and 2G). Figure 2.B shows an individual near a large tree that has a burrow at its base. The third image captured a single Sunda Pangolin walking towards the base of a large tree with a protruding large root (Figure 2C). The fourth image recorded an individual Sunda Pangolin that was coming out from a burrow at the base of a large tree (Figure 2D).

The locations of the Sunda Pangolin images that were recorded during the survey were scattered within an area approximately 310ha in size (Figure 3). The pangolins were distributed almost throughout the whole park area.

This study conclusively shows that a Sunda Pangolin

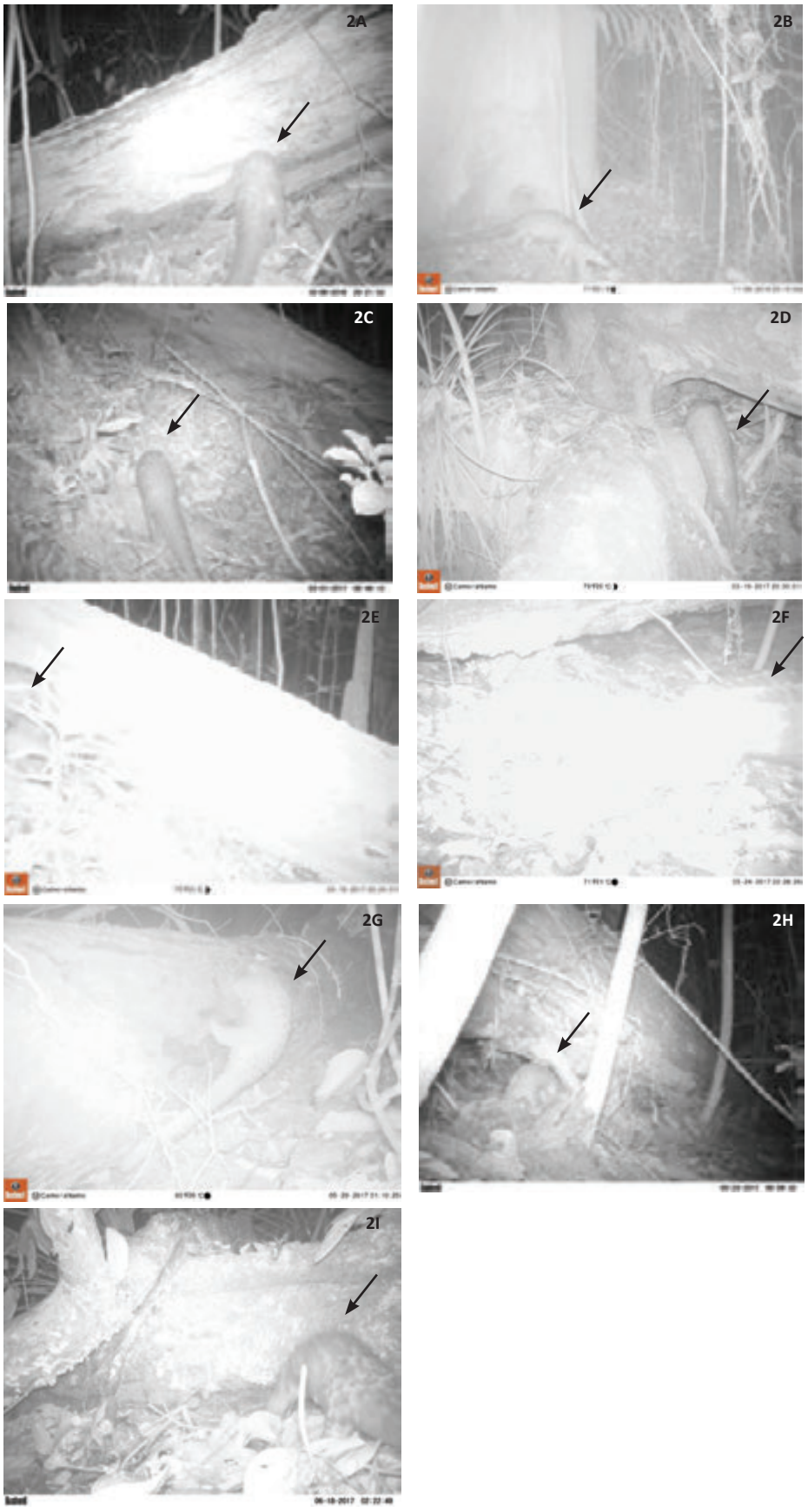

Figure 2. Nine images of Sunda Pangolin that were recorded during the survey.

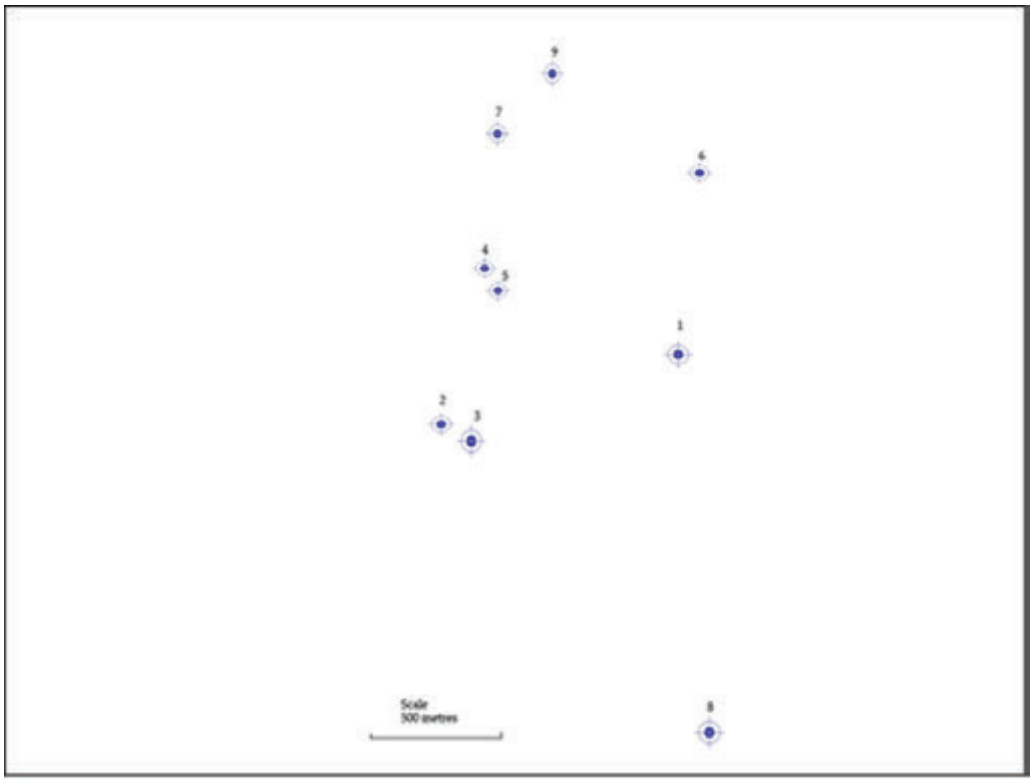

Figure 3. The planimetric locations of Sunda pangolins recorded during the six months surveys.

population still exists in most parts of Gaya Island. According to one of the Sabah Park staff stationed at Gaya Island, a decade ago Sunda Pangolins were commonly seen walking around at night within the staff quarters compound (Victor Siam pers. comm. 17 October 2016). Nowadays, they can no longer be sighted that way, indicating a reduced population of Sunda Pangolin. Although its encounter rate (OI-value) was higher than that of the Formosan Pangolin (*M. pentadactyla pentadactyla*) in Taiwan, 0.147 versus 0.016-0.078 in Alishan area (Pei & Weng 2017), it was similar to the low density site of 0.179 in northern Coastal Mountain Range (Kurtis Jai-Chyi Pei unpub. data). The IO-value for high density area (12.8/100ha) in Eastern Taiwan was 0.38 (Pei 2010). The body weight of the Sunda Pangolin (up to 10kg) is larger than that of the Formosan Pangolin (up to 6kg), therefore more resources are required. The number of pangolins in Gaya Island park area might be present in a small population if there is 300-350 ha pangolin habitat on the island. A requirement for proper conservation action is indicated.

The Gaya Island Sunda Pangolins were strictly nocturnal, with most activity concentrated in the first two-thirds of the evening/night. This observation is consistent with Payne et al. (1985); Phillipps & Phillipps (2016). However, Lim & Ng (2008) reported that a female Sunda Pangolin that they studied in Singapore had peak activity between 03.00h and 06.00h.

Table 1. Sunda Pangolin data from camera trap survey.

Camera No.	Date of pangolin image that was recorded	Time capture (hrs)	Trapping days	Days to the pangolin image taken
1	6 October, 2016	08.21	35	11
2	9 November, 2016	23.15	109	9
3	1 March, 2017	00.48	29	11
4	19 March, 2017	08.30	24	1
5	19 March, 2017	08.26	24	1
6	29 May, 2017	01.10	31	11
7	25 May, 2017	00.09	30	7
8	18 June, 2017	02.22	30	30
9	24 May, 2017	22.28	30	7

All of the Sunda Pangolin images taken during this survey were of animals near large trees. Their survival is closely associated with large trees that have hole/burrow at their root, which provide refuges (Bhandari & Chalise 2014; Wu et al. 2004). Decomposing trees are also important sources of food in the form of ants and

termites that make up the pangolins entire diet, making them important regulators of insect populations in forest ecosystems (Li et al. 2011; Mohapatra & Panda 2014).

Sabah Parks do not have a comprehensive data on the presence of Sunda Pangolins on all of the islands in Sabah. To date, Gaya Island is the only island in the west coast of Sabah known to have Sunda Pangolin, although pangolins have also been reported on the Banggi Island. However, the villagers in Banggi Island have also reported that Sunda Pangolin sightings have become uncommon due to poaching.

The terrestrial treasure that resides in Gaya Island is less emphasized as it is overshadowed by marine tourism. As such, there is an imminent danger that the island will be converted into a terrestrial ecosystem of built environment that solely focuses reaping the revenues from marine tourism at the expense of the island's terrestrial natural ecosystem. The terrestrial ecosystem of the island is also an important transit location for winter migratory bird, as reported by Sompud et al. (2016). There is an urgent need for a detailed study of the Sunda Pangolin to gather comprehensive scientific information; such as number of individuals left, their sex ratio, age-group ratio, reproduction, habitat use and preferences, to support further effective conservation actions.

Conclusions

The Sunda Pangolin occurs in low numbers on Gaya Island, and long-term studies and monitoring are required for its conservation. The Island has a potential to become a Sunda Pangolin rescue and conservation centre.

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Distribution and morphometric measurements of Blanford's Fox *Vulpes cana* (Mammalia: Carnivora: Canidae) of the Kingdom of Saudi Arabia

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Abstract: A study on Blanford's Fox was conducted from Tabuk Province, a poorly studied area of the Kingdom of Saudi Arabia (KSA), from December 2015 until May 2016. This study adds to our knowledge, where two survey methods were used, which are the live trapping and camera trapping methods. Five specimens were captured alive, in addition to a dead specimen reported during the survey period. Measurements of live, captured specimens were obtained and the skull of the dead specimen was measured. The information provided will serve as a basis for future monitoring of Blanford's Fox in Saudi Arabia, and it will provide the foundation for future research in the species' range of occurrence in the Arabian Peninsula. In addition, more attention shall be paid to establish a joint collaboration between scholars from Saudi Arabia and Jordan to assess the status of Blanford's Fox along the sandstone escarpments Hisma plateau.

Keywords: Blanford's Fox, distribution, morphometric measurements, skull, Tabuk Province.

The Blanford's Fox is a small canid species, which is associated with mountainous habitats (Smith et al. 2003; Eid et al. 2015). This species was categorized as Least Concern by the IUCN, as evidence suggests that it has a relatively wide distribution despite being largely confined to mountainous regions (Hoffmann 2015). Studies on the Blanford's Fox's distribution, morphological characteristics, and behavior from the arid mountainous regions of the Arabian Peninsula has expanded with records from Jordan, Oman, Palestine, Saudi Arabia, Yemen and the United Arab Emirates (Mendelssohn et al. 1987; Al Safadi 1990; Kingdon 1990; Nader 1990; Harrison & Bates 1991; Geffen et al. 1992; Al-Khalili 1993; Geffen et al. 1993; Stuart & Stuart 1995; Qumsiyeh 1996; Al Jumaily 1998; Al Jumaily et al. 1998; Disi & Hatough-Bouran 1999; Spalton & Willis 1999; Llewellyn- Smith 2000; Cunningham & Howarth 2002; Drew 2003; Abu Baker et al. 2004; Al Jumaily et al. 2012; Eid et al. 2013, 2015).

Information from Saudi Arabia, however, is still limited due to limited research attempts and monitoring programs. J. Gasperetti reported a road-killed specimen 40km south east of Biljurshi in Saudi Arabia, and another specimen was found in the vicinity of Asir photographed by Mrs. Collenette at Jabal Shada (Harrison & Bates 1989). Cunningham & Wronski (2009) from Saudi Arabia obtained further records and despite the available information, records are sparse and often limited. Williams et al. (2004) studied the basal metabolic rate and total evaporative water loss of the Blanford's Fox in the Arabian Peninsula. Cunningham & Wronski (2009) updated the distribution map of the Blanford's

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Fox in Saudi Arabia and provided new range expansion in northern and central Saudi Arabia. Despite these efforts, more details are needed on this species from Saudi Arabia.

This paper contributes to our understanding of the Blanford's Fox from Bajdah at Tabuk governorate in the northwestern region of Saudi Arabia. The information provided improves our knowledge about the distribution range of this species, and its activity period. Although single skull morphometric measurements were provided, it could be used for comparison purposes with other regions, and could lead to future investigations on evolutionary significance.

Study Area

Bajdah is located at the northwestern side of the Tabuk governorate in Saudi Arabia (28.399^{0}N & 36.571^{0}E) with an elevation exceeding 1,167m (Figure 1). It is part of the Hisma plateau (28.666^{0}N & 35.7^{0}E) in the Arabian Shield, which covers around 3,699.29km^2 and its geology is composed mainly of late Cambrian and Ordovician sandstone (Image 1). The surveyed area in Bajdah was approximately 42km^2, which overlie the metamorphosed Precambrian volcanic and volcaniclastic basement rocks of the Arabian Shield, mixed with green schist and sedimentary rock (Llewellyn et al. 2010). The flora composition is represented by several species including *Ferula assafoetida, Ficus populifolia, Retama raetam* and *Capparis cartilaginea* (Llewellyn 2013; Aloufi pers.

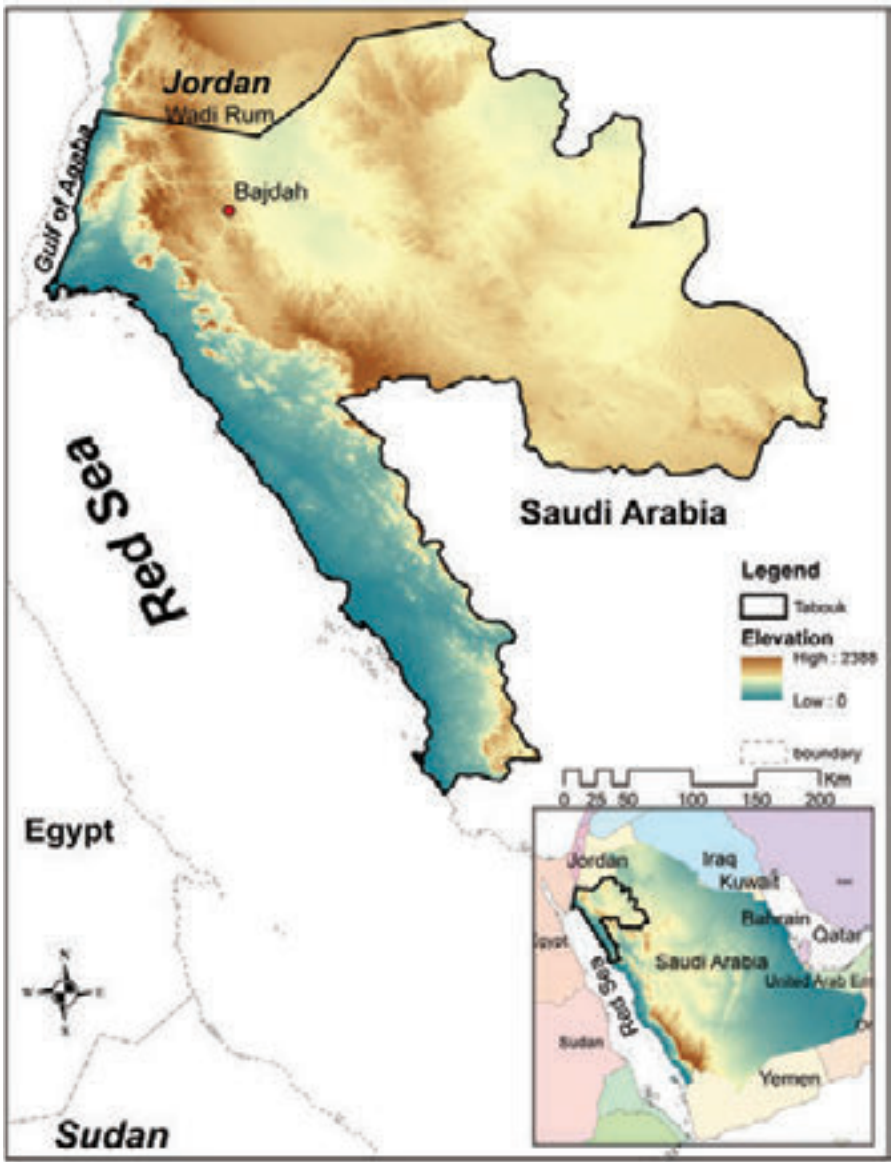

Figure 1. The location of Bajdah in Tabuk Province.

comm. 2016). In addition, the site is also important for mammals where several species were recorded including the Rock Hyrax *Procavia capensis*, Nubian Ibex *Capra nubiana*, Striped Hyaena *Hyaena hyaena*, and the Arabian Wolf *Canis lupus* (Llewellyn 2013)

Methods

Live-trapping Method

Live-traps manufactured locally, with a dimension of 100 x 40 x 40cm mesh size were used from December 2015 to May 2016. During a total of 432 trapping nights, all traps were placed in the field for three successive nights, and distributed in different locations depending on accessibility. Traps were hidden as much as possible to provide shelter for the captured animals as well as to prevent the traps from being taken by local people. Traps were checked every morning and reset late in the afternoon using chicken and sheep viscera as bait. When a specimen was captured, it was marked by cutting some hair from different parts of the body, identified, sexed, measured morphometrically using a digital caliper and a measuring tape, after which the captured specimens were released at the same capture site (Eid et al. 2015).

Camera-trapping Method

HCO NightXplorer UWAY-NX50 cameras were used with a total of 192 camera-trapping nights. Cameras were programmed for still photos, and they were fixed to stones at different locations, which were selected randomly. The bait was placed in front of the cameras at a distance of approximately five meters to increase capturing probability. Cameras were fixed in the late afternoon and removed in the early morning of the following day to upload photos for analysis (Eid et al. 2015).

Results

A total of five specimens of Blanford's Fox (2 females, 3 males) were captured live, with no recaptured attempts. In addition, a single killed male specimen was recorded at a Bedouin tent. Morphometric measurements were obtained for all specimens including the dead one (Table 1; Image 2).

In addition, authors obtained the skull measurements from the killed specimen following Onar et al. (2005) (Table 2). Camera traps have confirmed the presence of the Blanford's Fox with a maximum of two foxes per photo (Image 3). According to the camera trap results, the peak of activity was analyzed based on photos uploaded, and it started after 19:00h with the highest peak at around 05:00h followed by 24:00h. In addition,

Image 1. Topography of Bajdah Village in Saudi Arabia.

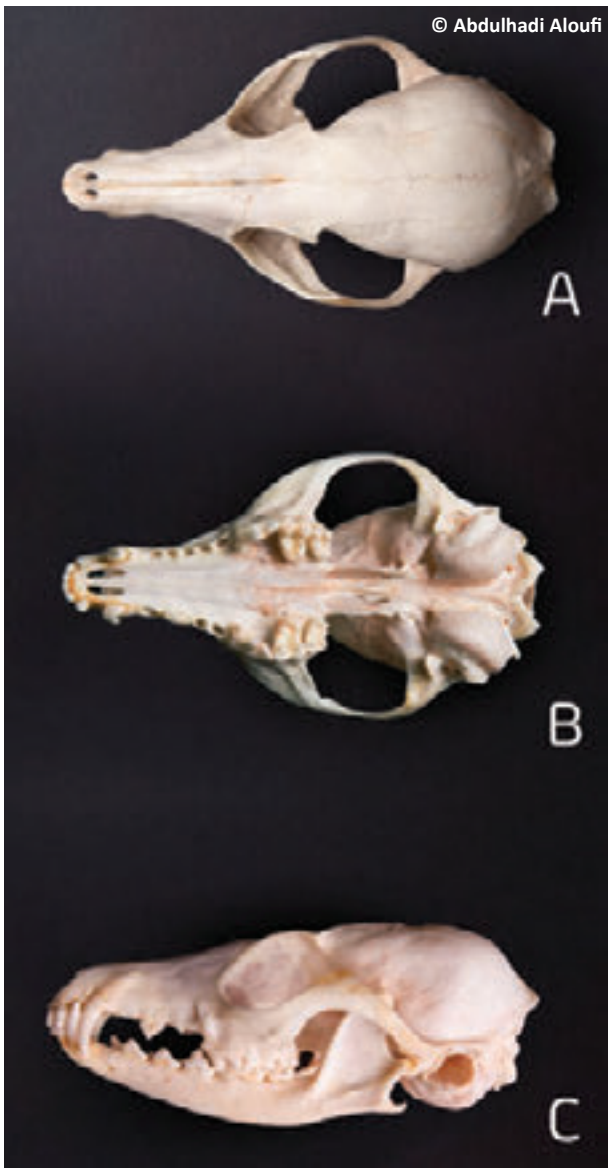

Image 2. A - dorsal view | B - ventral view | C - lateral view of the Blanford's Fox skull.

Image 3. Camera-trap images showing Blanford's Fox. *Vulpes cana* (Left) and Red Fox *Vulpes vulpes* (Right).

Table 1. Morphometric measurements of live captured Blanford's fox (W – weight | HB - Head and Body Length | T - Tail Length | E - Ear Length | FA - Forearm Length | HF - Hind arm Length).

	Sex	W (kg)	HB (mm)	T (mm)	E (mm)	FA (mm)	HF (mm)
1	Female	1.32	410	300	80	49.4	88
2	Male	1.80	430	335	82	53	89.7
3	Male	1.25	450	310	77	55	90.45
4	Female	1.04	440	330	80	40	100
5	Male	1.2	412	300	70	50.5	91.71
6	Male-killed	NA	415	330	75	51	90.2

the Red Fox was captured by photo, where it has an activity period commencing at 01:00h, with a peak after 05:00h.

Discussion

This research is significant since it enhanced our knowledge on the Blanford's Fox from a poorly surveyed region in Saudi Arabia. This survey revealed a new distribution range and provided more evidence on the habitat preferences of this species (Amr 2000; Smith et al. 2003; Eid et al. 2015). Authors believe that the extent of occurrence of this species is large, and extend from the current locality at Bajdha in Saudi Arabia to Wadi Rum in Jordan. However, the area of occupancy is small, referring to the small population collected from Jordan and Saudi Arabia where five specimens were captured in 432 trapping nights in Saudi Arabia, compared to six individuals collected in 520 trapping nights from Wadi Rum (Abu Baker et al. 2004). The low trapping frequency highlights the necessity for more research on population size as well as reconsidering the most recent Red List status of this species as Least Concern (Hoffmann et al. 2015). In addition, the most recent assessment for carnivores in the Arabian Peninsula stated that the Blandfor's Fox is a vulnerable species (Mallon & Budd 2011), which indicates the necessity for a global review to the status of this species. Potential collaboration between scholars from Saudi Arabia and Jordan might reveal more interesting information, and cross-border protected areas may provide a possible solution.

The dead specimen of Blanford's Fox was found near a Bedouin tent killed by accident, since the shooter considered it as a threat, after it approached the herd late at night (A. Aloufi pers. comm. 03 July 2017). It is believed that the fox approached the vicinity of the herd for feeding on insects present at the site. Cunningham & Howarth (2002) stated that Blanford's Fox's diet consists mainly of invertebrates and fruits in the United Arab Emirates. Geffen et al. (1992) and Ilany (1983) found the Blanford's Fox to be primarily insectivorous and frugivorous, whereas Roberts (1977) found them to be largely frugivorous in Pakistan. Eid et al. (2015) stated that Coleopterans, goat hair, and unidentified bones were also present in the fox's diet, in addition to Juniper fruits. Human persecution is a major threat to Blanford's Foxes in Jordan (Abu Baker et al. 2004), as Eid et al. (2013) stated that Jordanians do not differentiate between fox species. Aloufi & Eid 2016 stated that foxes flesh is used in treating diabetes mellitus and jaundice in Saudi Arabia. However, the killed specimen was not used for folk medicine according to our survey.

The skull of the Blanford's Fox is intermediate in size between the Sand Fox, *Vulpes rueppelli,* and the Fennic Fox, *Vulpes zerda*. Our survey records obtained from the killed specimen's skull was in accordance to Harrison

Table 2. Skull measurements of the Blanford's Fox.

A - Dorsal view		
1.	Skull length	91.73mm
2.	Facial length	53.63mm
3.	Upper neurocranium length	43.41mm
4.	Cranial length	57.60mm
5.	Viscerocranial length	36.31mm
6.	Greatest length of the nasals	27.65mm
7.	Snout length	33.51mm
8.	Least breadth between the orbits	17.31mm
9.	Frontal breadth	22.58mm
10.	Least breadth of skull	17.33mm
11.	Maximum width of neurocranium	34.20mm
12.	Maximum zygomatic width	50.81mm
B - Ventral view		
1.	Condylobasal length	88.51mm
2.	Basal length	80.98mm
3.	Median palatal length	45.84mm
4.	Length of the horizontal part of the palatine	16.65mm
5.	Length of the horizontal part of the palatine-1	16.17mm
6.	Palatal length	45.07mm
7.	Greatest breadth of the palatine (P4 level)	26.29mm
8.	Least palatal breadth	9.56mm
9.	Breadth at the canine alveoli	12.49mm
10.	Length of the premolar row	24.90mm
11.	Length of the molar row	9.77mm
12.	Length of the cheektooth row	33.05mm
13.	Greatest diameter of the auditory bulla	16.71mm
14.	Breadth dorsal to the external auditory meatus	32.75mm
A - Left-Lateral view		
1.	Greatest inner height of orbit	17.19mm
2.	Neurocranium length	51.36mm
3.	Braincase length	38.69mm
4.	Skull height	26.04mm
B - Occipital view		
1.	Height of the occipital triangle	20.24mm
2.	Height of the foramen magnum	9.48mm
3.	Maximum width of the foramen magnum	10.86mm
4.	Maximum width of occipital condyles	16.97mm
5.	Greatest breadth of the bases of the jugular process	23.34mm
6.	Greatest mastoid breadth	29.63mm

Table 3. Comparison between skull measurements as stated by Harrison & Bates (1991) and Mendelssohn et al. (1987).

Measurement	Source	
	Current Survey	Harrison & Bates (1991) and Mendelssohn et al. (1987)
Greatest skull length	91.73	94.1 ± 3.1
Condylobasal length	88.51	87.0 ± 5.1
Zygomatic width	50.81	49.1 ± 3.0
Width of Braincase	38.69	35.8 ± 0.9
Interorbital constriction	17.31	16.9 ± 0.8

& Bates (1991) with a dental formula obtained from the killed Blanford's Fox skull was i 3/3, c 1/1, p 4/4, m 2/3, with a total of 42. In addition, all measurements are in the range described by Harrison & Bates (1991), though the greatest skull measurement is smaller when compared to the measurements obtained and indicated in Table 3 below. It is important to note that the skulls from the Oman population are the largest with lengths reaching 99.8mm. However, specimens described from Mendelssohn et al. (1987) showed a skull range of 90.7 to 94.4mm for the six specimens measured. These results enhanced our understanding, and provided a new reference for skull measurements for this species from the Arabian Peninsula.

Data obtained from photo surveillance cameras indicated that the Red and Blanford's Fox do not appear within the same time duration. The peak for the nocturnal Blanford's Fox was around 05.00h followed by 24.00h compared with a peak at 05.00h for the Red Fox. Eid et al. (2015) indicated a peak activity at 04.00 in the early morning, and Geffen et al. (2004) stated that the onset of activity was triggered by dim light (sunset). The conversation with the Bedouin indicated that the specimen was killed after 04.00h. These results confirm that the Blanford's Fox is a strictly nocturnal species, and strengthens the hypothesis proposed by Geffen et al. (1992) that the nocturnal activity period is to avoid predation, including from the Red Fox. The knowledge obtained from this survey is important, and support earlier research attempts (Eid et al. 2015), though more specific research should be conducted to get more details about this secretive species.

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SHORT COMMUNICATION

Sebaceous gland adenoma in a free-ranging Baird's Tapir *Tapirus bairdii* (Tapiridae: Perissodactyla)

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Abstract: An external mass was observed on the ear of a free-ranging Baird's Tapir *Tapirus bairdii*. The mass was surgically removed under general anesthesia and was histopathologically identified as sebaceous gland adenoma. Hematological and biochemical analyses were also performed. The animal showed a mild anemia and the other values were unremarkable. Only few cases of tumors have been reported in tapirs and this is the first report of a tumor in a free ranging Baird´s Tapir. The presence of any disease in free-ranging wildlife should call our attention in order to develop a better understanding of disease ecology, especially in threatened species.

Keywords: Histopathology, neoplasia, tumor.

The Baird´s Tapir *Tapirus bairdii* is classified as an Endangered species on the IUCN Red List (García et al. 2016) due to threats like habitat fragmentation, hunting, and increasing roadkills (Brenes-Mora 2017). It ranges from southern Mexico to northwestern Colombia, with the population comprising less than 6000 individuals within the entire distribution range (García et al. 2016; Schank et al. 2017). Tapirs' habitats in the wild include a great diversity of ecosystems from sea level to altitudes of 3600m (González-Maya et al. 2012; Schank et al. 2017).

The health status of free-ranging tapirs is a very important aspect to take into account when developing conservation strategies for this endangered species in the wild (Mangini et al. 2012). In the past, neoplasia in wildlife was not considered to be a conservation concern, however, with the identification of the Tasmanian Devil facial tumor disease, the sea turtle fibropapillomatosis and the sea lion genital carcinoma, it has become apparent that highly prevalent tumors can have considerable effects on a species and that anthropogenic activities can contribute to the development of such tumors (McAloose & Newton 2009). Hence the presence of any disease in free-ranging species should call our attention in order to develop a better understanding of disease ecology, especially in threatened species.

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Sebaceous gland adenomas are benign, can be surgically excised and are not life-threatening (Knottenbelt et al. 2015). To the authors' knowledge, this is the first report of a sebaceous gland adenoma in a tapir species.

Materials and Methods

An approximately 15-year-old free-ranging female Baird´s Tapir, that often came by a private natural reserve in Guápiles, Limón, Costa Rica, was observed to have a protruding multifocal to coalescing, pink, hairless, ulcerated mass on the inner surface of the left ear (Image 1).

This animal was accustomed to feed from an artificial feeder at the reserve and by positively reinforcing the tapir with food and scratches it was possible to lure it into a chute (Image 2). Once the animal was comfortable in the chute, a biopsy was taken in a first approach in order to establish if the lesion was a malignant neoplasia. Therefore, lidocaine (Lidocaina HCl 2%, Laboratorios Faryvet S.A., Apdo. 55-3006, Barreal, Heredia, Costa Rica; 20mg) was locally infiltrated into the mass, and a biopsy (1cm x 0.5cm) was resected and fixed in 10% buffered formalin and submitted for histopathologic examination to the Department of Pathology at the Faculty of Veterinary Medicine at the National University of Costa Rica. The histopathological examination of the biopsy revealed a sebaceous gland adenoma.

Surgical removal of the mass was scheduled. The estimated weight of the animal was 230kg. The tapir was restrained in the same chute for manual injection. The anesthetic combination used consisted of Butorphanol tartrate (Butormin, Holliday Scott S.A.) at 0.18mg/kg and a total amount of 40mg intramuscular, Xilacine (Procin Equus, Pisa Agropecuaria S.A.) at 0.44mg/kg and a total amount of 100mg intramuscular, injected 10 minutes after Ketamine (Ketamin 10%, Bremer Pharma GMBH) given at 0.65mg/g with a total amount of 150mg intramuscular. Ketoprofen (Dolfen, Laboratorio Hispanoamericano S.A.) at 1mg/kg with a total amount of 230mg intramuscular was used for additional analgesia and a long-acting Enrofloxacin (Baytril Max, Bayer S.A.) at 7.5mg/kg with a total amount of 1725mg intramuscular was used as antibiotic. Anesthesia was reversed with tolazoline (Tolazine, Lloyd Laboratories, USA) at 4mg/kg with a total volume of 920mg injected intravenously.

A section of the excised tumor of 4.5cm x 4cm x 2cm was fixed in 10% buffered formalin (Image 3) and processed for histopathological analysis (Veterinarian pathology Services Dr Guevara laboratories), which

Image 1. Clinical appearance of the ear mass in the Tapir.

Image 2. Chute built for positive reinforcement with food to get the tapir to give anesthetic injection.

Image 3. Macroscopic appearance of the mass (fixed in 10% buffered formalin).

Image 4. Post-surgical appearance after sebaceous gland adenoma was removed from the Tapir´s ear.

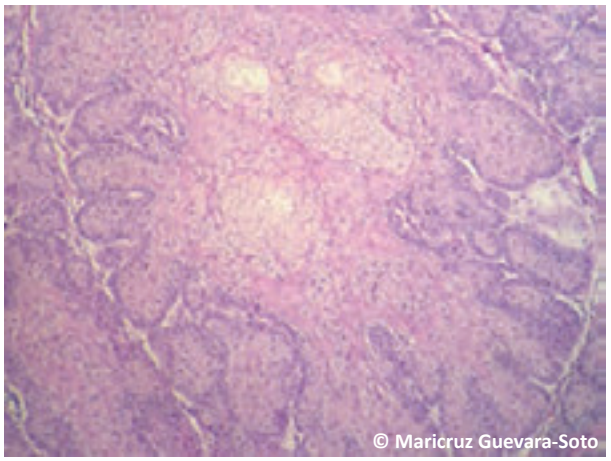

Image 5. Microscopic appearance of the sebaceous gland adenoma. Hematoxilin-Eosin Stain. 100x.

confirmed the previous result of a sebaceous gland adenoma.

The surgical incision area was cauterized and left without any sutures (Image 4).

Results

The histopathological examination revealed a multinodular neoplasia with the presence of a moderate amount of reserve cells at the periphery of the tumor. At the center of the multifocal nodules are mature regular sebaceous cells with a vacuolated cytoplasm and an eccentric nucleus. The nodules are separated by a thin layer of fibrovascular tissue (Image 5).

A complete hematological examination was performed and a number of biochemical blood values were also analyzed; asparte aminotransferase, creatinine, urea, total protein and albumin. The animal showed mild anemia (PCV 20.9%, Hb 8g/dl, RBC 4.0 x 10^{12}/l), the other values were unremarkable. Though the anemia was probably not directly related to the neoplasia, the tumor can cause pain or lack of comfort and the animal might therefore not have been eating well. Another explanation for the anemia might have been the heavy tick infestation and we recommended appropriate treatment.

Discussion

Few tumor cases have been reported in tapirs this far (Karpinski & Miller 2002; Kidney & Berrocal 2008; Mangini et al. 2012; Bonar et al. 2016; Miller et al. 2016). Ear tumors specifically have been reported in captive tapirs in Costa Rica, but they were classified as sarcoid tumors, related with Bovine Papillomavirus type 1 or 2 (BPV1 and BPV2) (Kidney & Berrocal 2008).

Among domestic animals, sebaceous gland adenomas are very common in dogs, and uncommon in cats (Meuten 2017). Microscopically, the sebaceous gland adenoma is comprised primarily of mature sebaceous cells. These cells are arranged more basal than in a hyperplasia, there is marked lobular proliferation and cell organization is asymmetrical. Adjacent structures are frequently involved often including melanocytes, giving pigmented characteristics to the tumor (Maxie & Youssef 2007). Sebaceous gland adenomas are benign and should be surgically excised (Knottenbelt et al. 2015).

Although sebaceous cell adenomas are fairly common in mammals, there is no prior report of these tumors in tapirs and we hope that our findings are a valuable source of information for continuing tapir conservation efforts.

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Recent records of the Banded Racer *Argyrogena fasciolata* (Shaw, 1802) (Reptilia: Squamata: Colubridae) from southern Coromandel Coast, peninsular India

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Abstract. We report the Banded Racer *Argyrogena fasciolata* from the Coromandel Coast in peninsular India, where its occurrence remained doubtful. This is based on four specimens—two live, uncollected ones from Tambaram and Auroville, respectively, and two preserved specimens from Tuticorin. The sighting points span a distance of 500 airline km north-south across the eastern coastal plains. Both juvenile and adults were included in these records, which underscores that breeding populations exist in the regions dealt with. Our records highlight the need for faunal surveys even in reportedly depauperate or well-studied ecoregions, an element that points out a hidden diversity including species that are not ecologically cryptic.

Keywords: Diurnal species, dry forests, eastern coastal plains, land snake.

The Banded Racer *Argyrogena fasciolata* (Shaw, 1802) is a species of non-venomous colubrid snake found in the Indian subcontinent. General accounts on Indian herpetology state this species to be widespread, distributed more or less throughout the country (Daniel 2002; Das 2002; Whitaker & Captain 2004). The most comprehensive review of this species is the one by Wilson (1967). Aside from late 18th and early 19th centuries classical taxonomic treatises, very few regional works focusing on a certain geographic region dealt with this species. In one such historic regional monograph, Jerdon (1853) stated that this species was not uncommon in Madras and elsewhere in the Carnatic. Whether Jerdon meant Madras Presidency (i.e., the region now inclusive of entire southeastern India) or the actual city of Madras (= Chennai) per se, however, is not clear. Similarly, Günther (1858) recorded a "half-grown" specimen collected from "Madras" by Walter Elliot. Jan (1863) listed the distribution of this species as "Indie Orient" (also see Günther 1864). Theobald (1868) recorded this species from Ramri (in Rajasthan) based on a purchased specimen and from "South India" based on Jerdon's material.

Boulenger (1893) clearly gave the distribution as "Madras Presidency" while acknowledging the origin and locality of specimens of *Argyrogena fasciolata* in the British Museum, presented as "Madras" by Jerdon and Elliot. Wall (1914) gave its distribution from Cape Comerin to the Himalayan foothills, except perhaps in

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Travancore. Smith (1943) stated that its distribution extended from peninsular India northwest as far as a line drawn from Baroda through Gwalior to the Himalaya south of Nepal, east to West Bengal, and northern Ceylon. Wilson (1967) reviewed this species and gave its range similarly. Whitaker (1976) gave its distribution as plains throughout most of India. Daniel (2002) enumerated its geographic range as peninsular India, up to Sind in Pakistan, north to the Himalaya and in the east to West Bengal, and northern Sri Lanka. Das (2002) gave its range as peninsular India, besides Bangladesh and Nepal; Sri Lanka was not mentioned. Its record from Jaffna by Haly is considered doubtful (Wall 1921; Taylor 1950).

Whitaker & Captain (2004) described its range as most of the peninsular plains, to the Himalaya, in the east to Bengal and south to Tirunelveli, except the southeastern coast. The precise mention of the southeastern coast probably stems from the remarks of Wall (1914) (see below) and the authors' own personal observations of its non-detection in the region. Studies on snakes in southeastern India (Madras: Kalaiarasan & Kanakasabai 1999, Ganesh et al. 2005, Tsetan & Ramanibai 2011; Kalpakkam: Ramesh et al. 2013; Mayiladuthurai: Ganesh & Chandramouli 2007, Nath et al. 2012; Ramnad: Annandale 1906; Tuticorin: Sondhi 2009) did not document this species, and such evidence does attest to its rarity there. Specimen holdings in regional museums do not reveal any specimen collected from this region (Ganesh & Asokan 2010). Secondary sources and literature compilations also do not furnish any precise records from this part of the Coromandel Coast (Srinivasulu et al. 2014). A note that reported a live specimen from Tuticorin stands short of better substantiation (Rameshwaran 2008). Therefore, the occurrence of *Argyrogena fascioalata* in southeastern India along the southern parts of the Coromandel Coast remains unclear. To clarify this situation, we here elaborate on our recent field sightings and describe older voucher specimens of *A. fasciolata* from the region.

Material and Methods

We studied live and preserved specimens of *A. fasciolata* stemming from the Coromandel Coast. We followed Whitaker & Captain (2004) for morphologic examination terminology and scoring protocols. We followed Dowling (1951) for counting ventral scales and Dowling & Savage (1960) for hemipenial terminologies. We measured body length using a standard measuring tape (L.C. 1mm) and other smaller measurements using vernier callipers (L.C. 0.1mm). Where necessary, we observed scales and hemipenis, viewing through magnifying illuminated hand lens (5x optic zoom). Scalation and distribution data were compared with the literature. Images were taken using Canon EOS 5D digital camera. GPS coordinates were sourced from Google Earth software and projected on WGS-84 map datum. Sighting points were represented in decimal degrees, corrected to three decimal digits. Habitat classification followed Champion & Seth (1968).

Results

***Argyrogena fasciolata* (Shaw, 1802)**

(Image 1; Table 1)

Specimens examined: A live uncollected juvenile (Image 1a) observed by JR, NA, and RR on 7 May 2018 in Tambaram (12.916^{0}N & 80.123^{0}E; elevation 33m) [Tamil Nadu State], Coromandel Coast, peninsular India.

A live uncollected adult (Image 1b) observed by NA on 26 July 2017 at 15.55h in Auroville (12.005^{0}N & 79.813^{0}E; elevation 60m) [Tamil Nadu State], Coromandel Coast, peninsular India (Fig. 1).

CSPT/S-50 a, b [Chennai Snake Park Trust] (Image 1c) coll. late M.V. Rajendran from Tuticorin (ca. 8.765^{0}N & 78.135^{0}E; elevation 1m), [Tamil Nadu State], Coromandel Coast, peninsular India.

Morphology: Head fairly distinct from neck; snout declivous; rostral pointed, protruding further beyond mental; body fairly slender, cylindrical; tail long and tapering. Scales elongate, smooth, slightly glossy laterally, in 21–23:21–23:17 rows; ventrals 199–226; subcaudals on complete tail 86–88 pairs; supralabials 8 (4, 5 touching eye); infralabials 8 (1–5 touching genials); anterior genials slightly larger than posterior ones; preocular 1, reaching upper surface of head, touching prefrontal; postoculars 2; loreal 1, small, subequal to nasal; temporals 2+2/3 (Table 1).

Colouration in life (based on live uncollected individuals): Dorsum sandy fawn brown; upper labial, lateral region, and chin ivory white; top of head variegated with white random markings; back with a series of 33–39 distinct white cross bars extending from nuchal region till two-thirds of the body; anteriorly bold and conspicuous, posteriorly obscure and disintegrated; crossbars mildly edged with thin black border; ends of crossbars diverging basally along ventrolateral region, often confluent on to the nearby bar forming ovoid pattern; posterior part of body variegated with black and whitish-cream specklings randomly on the brown ground colour; interscalar skin white; iris golden brown with black circular pupil; body pattern more intense in juvenile than in the adult snake.

Image 1. *Argyrogena fasciolata*: a - living, uncollected adult from Auroville © N. Anandan | b - living, uncollected juvenile from Tambaram © S. Janani | c - CSPT/S-50b from Tuticorin © S.R. Ganesh | d - habitat showing dry evergreen vegetation in Tambaram © S. Janani.

Colouration in formalin: Dorsally brownish-grey to pale creamy-white, with off-white cross bars bordered with ashy black, visible or obscure; labia, lateral region, and venter white; eye black with greyish circular pupil.

Hemipenis (based on CSPT/S-50a): Everted; organ smooth, not forked; extending to third subcaudal scales; organ length (including lobe head and pedicel) 8mm; organ width 3mm; pedicel smooth, as thick as apex; lobe head with a small dent at apex; sulcus spermaticus single, clearly visible throughout its length in sulcate view; sulcul lips simple, without much folds; lobe head not spinose, but papillated with small villi; asulcate side calyculate, calyses small and dense.

Field observations: The juvenile from Tambaram was sighted inside Madras Christian College campus with relict patches of scrub vegetation. It was seen actively moving around on ground near grass patches abutting a small ephemeral water body surrounded by scrub thickets. The adult from Auroville in Puduchery was sighted in a community forest with dry evergreen vegetation type. The sighting of the juvenile (<300mm total length) in May implies the breeding season of this species in the region to be around January. Both snakes were observed in pre-monsoon season during May–July. Further observations are needed to confirm if this part of the year is the peak activity period of this species in the region.

Discussion

Wall (1914) was perhaps the first to explicitly state the apparent rarity of this species in the Coromandel region, in writing thus, "Though Jerdon remarks that it [*A. fasciolata*] is not uncommon in the Carnatic, this has not been my experience. I have never obtained one when in residence in southern India (Trichinopoly, Madras, Cannanore, and Bangalore)". Studies in southern India, in aptly dry forests, did not record this species. Ganesh & Asokan (2010) mention a specimen from Coimbatore,

Figure 1. Map of southern India, depicting areas of new records of *Argyrogena fasciolata* from across the Coromandel Coast: Tambaram, Auroville and Tuticorin (black diamonds).

abutting the Ghats, with no further data. The Madras Christian College, where this species was now sighted, once donated specimens to the Madras Government Museum (Ganesh & Asokan 2010). It is surprising that when this happened half a century ago, no *A. fasciolata* specimen was obtained. Its occurrence in the related and nearby region of northern Sri Lanka is also debatable at best (Taylor 1950; Das 2002; Bauer & de Silva 2007; Abyerami & Sivashanthini 2008). Therefore, we hypothesize that the lack of sightings of *A. fasciolata* anywhere from southeastern India prompted literature (Whitaker & Captain 2004) to exclude the southeastern coast of India from the distribution of this otherwise widespread species. Our own field experience in the Coromandel Coast for nearly two decades did not yield a sighting of this species (SRG pers. obs.), attesting to its rarity here. Though relict forests here are rich, they are simply underexplored, as exemplified by the recent discoveries of elusive wild cats (Guptha & Ramanujam 2017). At least Tambaram is relatively special in its snake fauna, unlike Madras City by and large, as exemplified by the much more frequent occurrence of *Lycodon striatus* instead of the usual *L. anamallensis* and *L. aulicus* (SRG pers. obs.).

Snakes entering into human settlements and the consequent human-snake negative interactions are quite characteristic of many Indian cities. *Argyrogena fasciolata*, by virtue of its large size (1.2m), active

Table 1. Morphologic characters of live and preserved *Argyrogena fasciolata* from the southern Coromandel Coast, peninsular India.

Characters	Live individual from Tambaram	Live individual from Auroville	CSPT/S-50a from Tuticorin (male)	CSPT/S-50b from Tuticorin (female)
Scale rows	21:21:17	23:23:17	21:21:17	21:21:17
Supralabials	8 (4, 5 touch eye)	8 (4, 5 touch eye)	8 (4, 5 touch eye)	8 (4, 5 touch eye)
Preocular	1	1	1	1
Postoculars	2	2	2	2
Loreals	1	1	1	1
Temporals	2+2	2+2	2+3	2+2/2+3
Ventrals	199	223	226	206
Anal shields	2	2	2	2
No. of white bars	37	33	faded	42
Subcaudal pairs	88	86	88	72+?
Head length	-	-	20mm	24mm
Head width	-	-	12mm	18.5mm
Eye diameter	-	-	3mm	4mm
Inter-ocular distance	-	-	7mm	9mm
Eye-snout tip distance	-	-	3.5mm	6mm
Snout-vent length	240mm	-	725mm	760mm
Tail length	50mm	-	210mm	220+?mm
Total length	290mm	790 mm	935mm	980+?mm

+? denotes cut tail.

foraging nature, and diurnal habits, is expected to be certainly present, if not prevalent, in snake rescue data sets from cityscapes. Indeed, this was the case in some data from places where this species is known to be common (Urfi 2005; Nande & Deshmuk 2007; Vyas 2013; Deshmukh et al. 2015). There are, however, areas where this species is not absent but still never featured in snake-rescue data. In Bengal, this species was recorded from city fringes, but was reported to be rare (Gayen et al. 2017). In Madras and its surrounding, this species was not encountered during rescue operations (Shravan Krishnan pers. comm. 2018). A single juvenile roadkill of *A. fasciolata*, however, was sighted in Tambaram in 2012 (identified by Ashok Captain based on image, Nishanth Nich pers. comm. 2018). Thus, though there are mixed opinions on the occurrence or the propensity of the species entering human settlements in the Madras region, past sightings attest to a relict population at least in rocky forested scapes of this area.

We believe that our report herein of this species including a breeding population will alleviate, to a large extent, the paucity of published records of *A. fasciolata* from the Coromandel Coast. Though many works (both published and unpublished) on snakes of this region exist, they involve almost always searching in rice fields with Irula tribals, and very few surveys were done in the remnant forest belts of this region. In the past, novelties resulted from studies on ecologically (Aengals & Ganesh 2013) and behaviourally (Vogel & Ganesh 2013; Guptha et al. 2015) cryptic groups of snakes in eastern peninsular India. In our case, the live individuals dealt with here were found in remnant dry scrub forest patches in the outskirts of two cities, Madras and Puduchery. Thus, this work adds to an increasing reports of large-growing diurnal land snakes that remained obscure due to lack of surveys in dry forests (Ganesh et al. 2017) and even in well-accessible and populated city fringes (Narayanan & Satyanarayanan 2012; Seetharamaraju & Srinivasulu 2013; Viswanathan 2015; Visvanathan et al. 2017; Narayana et al. 2018).

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A new species of *Simulium* (*Simulium*) (Diptera: Simuliidae), with keys to *S. striatum* species-group from India

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Abstract: *Simulium* (*Simulium*) *yanaense* sp. nov. is described based on the male, larva, and pupa. It is characterized by having a maxillary palp with a small sensory vesicle, and the subcosta and basal portion of the radius bare in the male; the gill with 10 short slender filaments and short common basal stalk in the pupa; and the thorax and abdomen without a pair of dorsolateral protuberances in the larva. Keys are provided to the species of the *S. striatum* species group of the subgenus *Simulium* known from India.

Keywords: Black fly, central Western Ghats, Karnataka, new species, *Simulium* (*Gomphostilbia*) *cauveryense*, *Simulium* (*Simulium*) *striatum*, taxonomic survey.

Black flies (Diptera: Simuliidae) are widely distributed on all continents except Antarctica. Approximately, 10–20 % of the species are of medical and veterinary importance due to their habit of biting humans and domestic animals (Adler & McCreadie 2009; Andrade-Souza et al. 2017). The immature stages of black flies inhabit lotic environments and play an important role in nutrient turnover in streams (Currie & Adler 2008). In India, 81 species of black flies were recorded, all of which are classified in six subgenera of the genus *Simulium* Latreille (Anbalagan et al. 2017). Around 24% of these species are recorded from southern India (Kerala, Karnataka, and Tamil Nadu states), whereas the remaining species are recorded from northeastern India.

To explore the black fly fauna in southern India, we surveyed larvae and pupae in the central Western Ghats in November 2016 and January 2017 and collected two described species, *Simulium* (*Simulium*) *striatum* Brunetti, 1912 and *S.* (*Gomphostilbia*) *cauveryense* (Anbalagan et al. 2015), along with a new species of the same genus herein described based on the male, pupa, and larva. We also provide keys to the *S. striatum* species-group known from India.

Materials and Methods

A taxonomic survey was conducted in the central Western Ghats between November 2016 and January 2017. We collected pupae and larvae from the streams at Yana and Balur, Kumta Taluk, Uttara Karnataka District, Karnataka State, India. The physical and chemical characteristics of the river at the type locality of the new species were as follows: dissolved oxygen 8.2mg/L, pH 6.4, conductivity 145µ/s, total dissolved solids 101.3ppm, width 2–3.5 m, depth 5–30 cm, water current 0.03–0.06 m/s. River substrates included bedrock, boulders, pebbles, gravel, and sand.

Larvae and pupae were collected manually from submerged leaf litter and woody debris in the water. Mature pupae were removed from substrates with a fine

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brush and forceps and reared to adults. We obtained males but no females. The descriptions and illustrations and terms for morphologic features follow those of Takaoka (2003) and partially those of Adler et al. (2004). The holotype and paratypes were deposited in the Department of Zoology, Government Arts College, Melur, Madurai, Tamil Nadu, India.

Results

Simulium (*Simulium*) *yanaense* Anbalagan sp. nov.

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(Figs. 1 & 2)

Description

Male: Body length 2.8mm. Head somewhat wider than thorax. Upper eye yellowish-brown, consisting of 12 vertical columns and 16 horizontal rows of large facets. Face brownish-black, greyish-white pruinose. Clypeus black, whitish pruinose, densely covered with golden-yellow scale-like medium-long hairs (directed upward and lateral) interspersed with several dark brown simple longer hairs. Antenna composed of scape, pedicel, and nine flagellomeres, yellow to brown; first flagellomere elongate, twice as long as second. Maxillary palp light to medium brown with five segments, proportional lengths of segments 3, 4, and 5 are 1.00:1.46:3.13; segment 3 (Fig. 1A) widened apically; sensory vesicle (Fig. 1A) globular, small (0.19 times as long as segment 3) and with small opening. Thorax: scutum slightly darker and short hairs on scutum golden yellow. Legs: foreleg coxa yellow; trochanter yellow with some portions light brown; femur light brown except apical cap brown; tibia brown with median 2/3 light brown and covered with dark brown hairs; tarsus brown to dark brown; basitarsus moderately dilated 6.75 times as long as its greatest width. Midleg: coxa yellowish-brown; trochanter yellow to brown; femur yellow except apical one-fourth brown; tibia medium brown to dark brown; tarsus dark brown to brownish-black except anterior surface of little less than basal half of basitarsus dark yellow to light brown. Hindleg: coxa dark yellow to brown; trochanter yellow; femur light brown except apical half dark brown; tibia (Fig. 1B) brown except base and apex dark brown; tarsus medium to dark brown except basal half (or little less) of basitarsus whitish-yellow and little less than basal one-third of second tarsomere white; basitarsus (Fig. 1C) enlarged, spindle-shaped, 4.1 times as long as wide, and 0.73 and 0.68 times as wide as greatest width of tibia and femur, respectively; calcipala (Fig. 1C) nearly as long as wide, and 0.36 times as wide as greatest width of basitarsus. Pedisulcus (Fig. 1C) well-defined. Wing: length 1.92mm. Costa with dark brown spinules as well as dark brown hairs except for basal portion with patch of yellowish hairs. Subcosta bare and basal portion of radius bare. Halter yellowish-brown except outer surface ochreous, basal stem darkened and apex white. Abdomen: basal scale dark brown with fringe of light to medium brown hairs. Dorsal surface of abdomen dark brown except segment 2 light brown (though posterior one-fourth of dorsal surface brown), covered with dark brown short to long hairs; segments 2–7 each with shiny dorsolateral or lateral patches; ventral surface of segment 2 yellow, those of segments 3 and 4 yellow except sternites medium brown, and those of other segments medium to dark brown. Genitalia: coxite in ventral view (Fig. 1D) nearly rectangle, 1.2 times as long as its greatest width. Style in ventral view (Fig. 1D) bent inward, slightly tapered from base toward middle, then nearly parallel-sided, rounded apically and with apical spine; style in medial view (Fig. 1E) longer than coxite (1.4 times as long as coxite), somewhat flattened dorso-ventrally, with short basal protuberance directed dorso-medially; style in ventrolateral view (Fig. 1F) with short basal protuberance having several spines near anterior margin. Ventral plate in ventral view (Fig. 1G) with body transverse, 0.66 times as long as wide, slightly narrowed posteriorly, without anterior margin produced anteromedially, and posterior margin convex medially, without microsetae on ventral surface; basal arms small, directed forward, convergent apically; ventral plate in lateral view (Fig. 1H) moderately produced ventrally; ventral plate in end view (Fig. 1I) concave ventrally, densely covered with microsetae on lateral surface. Median sclerite (Fig. 1H) thin, plate-like, wide. Paramere (Fig. 1J) of moderate size, with three distinct long and stout hooks and several smaller ones. Aedeagal membrane moderately setose, slightly sclerotized at base but dorsal plate not well-defined. Ventral surface of abdominal segment 10 without distinct hairs near posterior margin. Cercus in lateral view (Fig. 1K) small, rounded, with 9–11 hairs.

Pupa: Body length 3.1–3.3 mm. Head: integument dark yellow, moderately covered with small round tubercles; antennal sheath with protuberance; face with pair of simple long trichomes with uncoiled apices, and frons with three pairs of simple long trichomes with coiled or uncoiled apices; two frontal trichomes on each side arising close together, subequal in length to one another and slightly longer than facial one. Thorax: integument yellow, without covered round tubercles, with three simple long dorsomedial trichomes with uncoiled apices, one simple long anterolateral trichome with coiled apex, one simple long mediolateral trichome with uncoiled

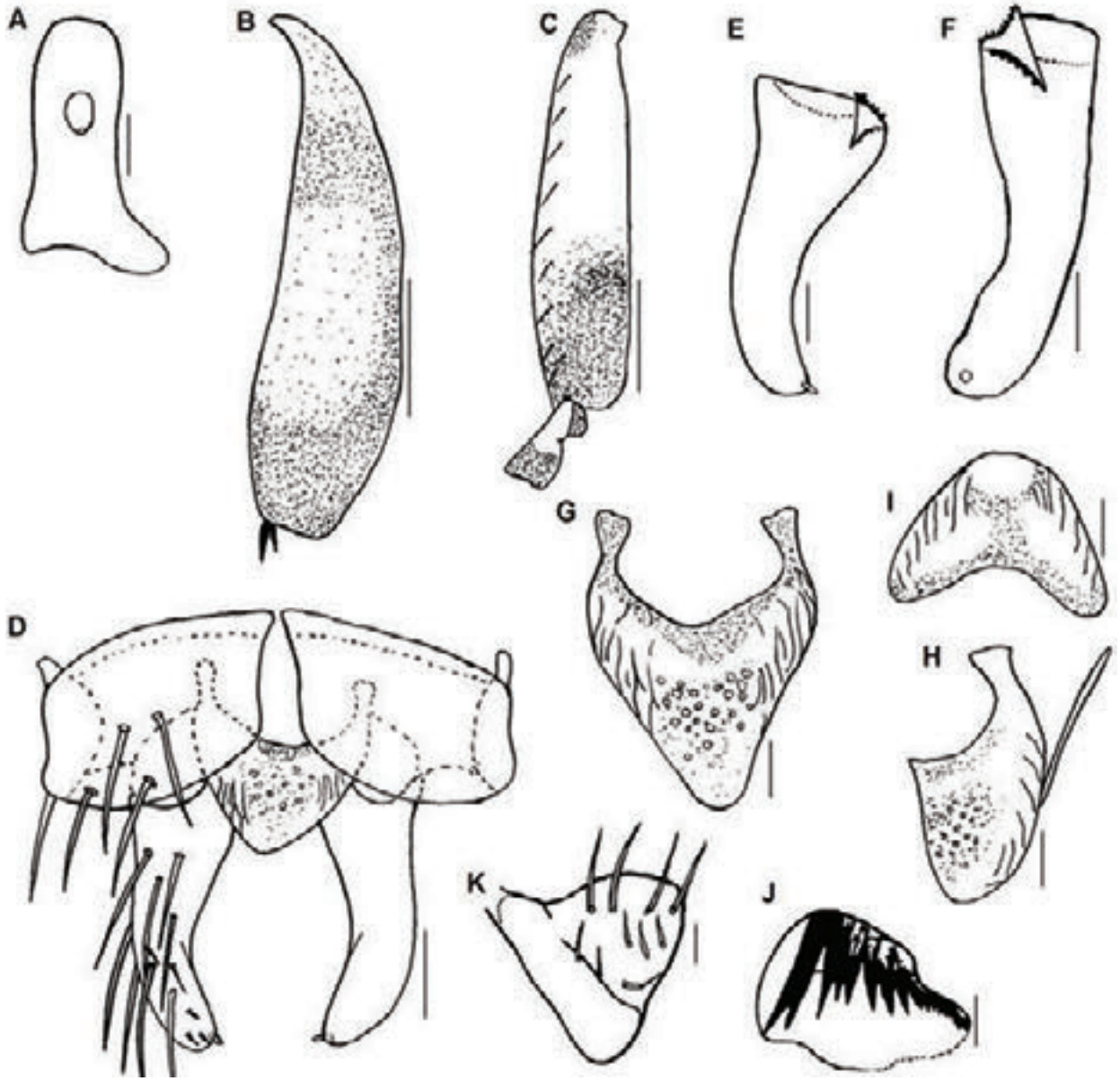

Figure 1. Male of *Simulium* (*Simulium*) *yanaense* sp. nov.: A - frontal view of third segment of left maxillary palp showing small sensory vesicle | B - outer view of left hind tibia | C - outer view of basitarsus and second tarsomere of left hind leg showing calcipala and pedisulcus | D - ventral view of coxites, styles, and ventral plate | E - medial view of right styles | F - ventrolateral view of right styles | G - ventral view of ventral plate | H - lateral view of ventral plate and median sclerite | I - end view of ventral plate | J - end view of left paramere and aedeagal membrane | K - right side and lateral view of tenth abdominal segment and cercus. Scale bars: 0.01mm for A; 0.1mm for B & C; 0.02mm for D–K.

apex, and three simple ventrolateral trichomes with coiled apices (one medium-long and two short) on each side. Gill (Fig. 2A) composed of 10 short slender filaments, arranged as [(2+3)+(1+2)]+2 or {[2+(2+1)]+(1+2)}+2 filaments from dorsal to ventral, with short common basal stalk having somewhat swollen transparent basal fenestra ventrally at base; common basal stalk 0.33 times length of interspiracular trunk; both dorsal and ventral stalks short, length of primary stalks of dorsal filaments combined slightly nearly subequal to stalk of ventral pair; stalk of ventral pair short, 0.6–0.7 times length of common basal stalk and 0.22–0.24 times length of interspiracular trunk; stalk of ventral pair 0.6–0.64 times as thick as primary stalk of dorsal pair, 0.38–0.4 times as thick as primary stalk of first dorsal triplet, and 0.6–0.7 times as thick as primary stalk of second dorsal triplet; primary stalk of dorsal pair lying against stalk of ventral pair at angle of 180° or little more when viewed laterally; all filaments yellowish-brown, decreasing their thickness toward apex; entire length of filaments (measured from base of gill to

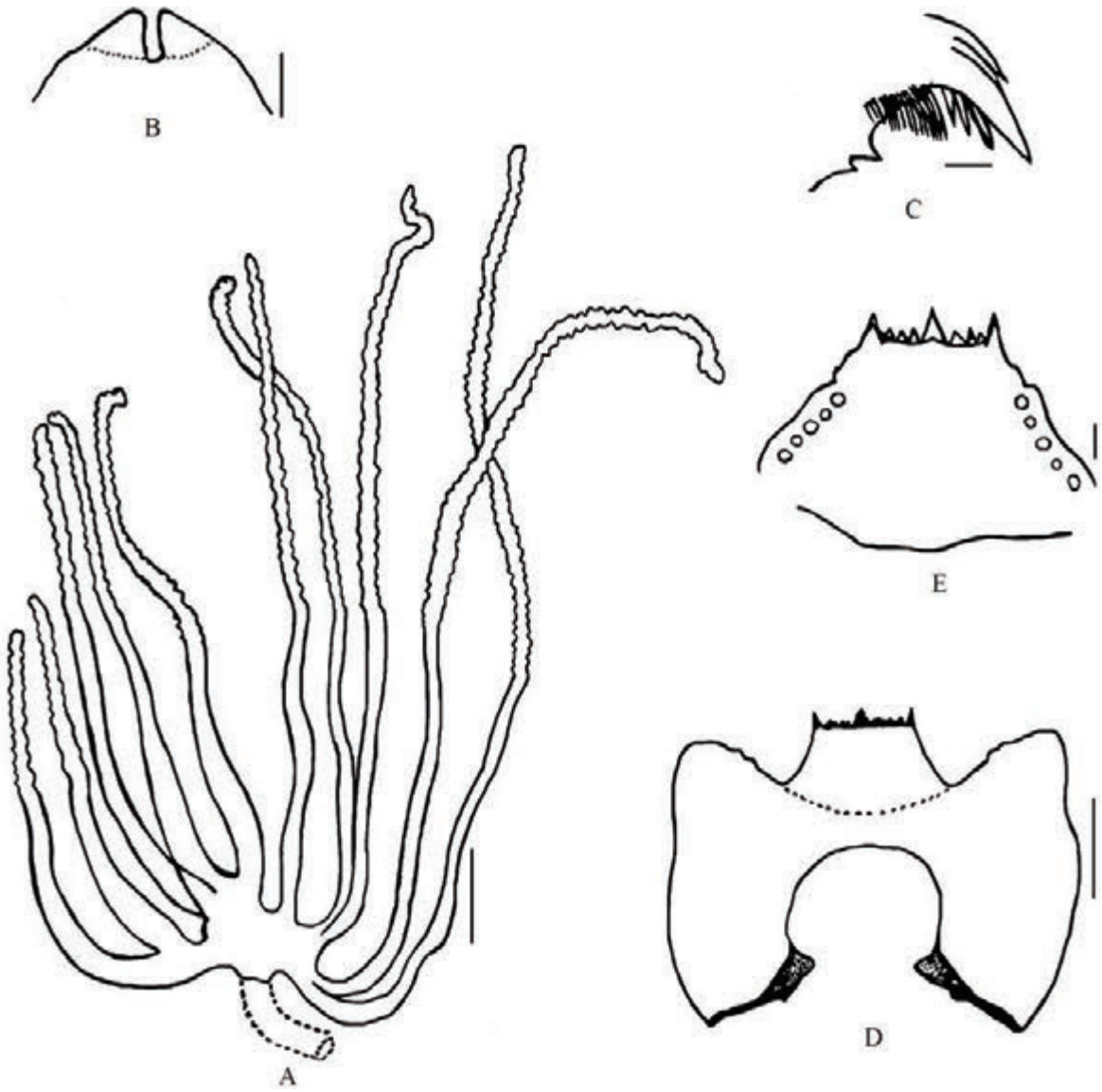

Figure 2. Pupa and larva of *Simulium* (*Simulium*) *yanaense* sp. nov.: A - outer view of left gill of pupa | B - dorsal view of terminal hooks of pupa | C - lateral view of right mandible of larva | D - ventral view of hypostoma of larva | E - ventral view of head capsule showing postgenal cleft and hypostoma of larva. Scale bars: 0.1mm for A & D; 0.01mm for B, C & E.

tips of filaments) based on one pupa as follows: 0.38–0.41 mm for dorsal pair, 0.63–0.72 mm for first dorsal triplet, 0.9–1.1 mm for second dorsal triplet, and 1.2–1.3 mm for ventral pair; cuticle of all filaments with indefinite annular ridges and furrows from base to apex, densely covered with minute tubercles. Abdomen: dorsally, segments 1 and 2 brownish-yellow and with tubercles; segment 1 with one simple slender medium-long hair-like seta on each side; segment 2 with one simple medium-long and three short hair-like setae on each side; segments 3 and 4 each with four hooked spines and one short hair-like seta on each side; segment 5 lacking spine–combs and one short hair like seta on each side; segments 6–9 each with spine-combs in transverse row (though those on segment 9 slightly smaller than those on segment 8) and comb-like groups of minute spines on each side; segment 9 with pair of triangular flat terminal hooks, of which outer margin slightly longer than inner margin and not crenulated (Fig. 2B). Ventrally, segment 4 with one simple hook and few simple slender short setae on each side; segment 5 with pair of bifid hooks submedially and few short simple slender setae on each side; segments 4–8 each with comb-like groups of minute spines. Each side of segment 9 without grapnel-shaped hooklets. Cocoon: shoe-shaped, thinly and moderately woven, anterior margin somewhat thickly woven, with dorsal portion slightly produced anteriorly when viewed dorsally; posterior half with floor roughly or moderately woven; individual threads visible;

Keys to the species of *S. striatum* species group of the subgenus *Simulium* reported from India.

Adult females [1]

1. Frons dull black ..... *S.* (*S.*) *kapuri*
- Frons dull grey or greyish-black 2
2. Scape and two basal flagellar segments of antenna yellow or brownish-yellow ..... *S.* (*S.*) *pallidum*
- Scape and two basal flagellar segments of antenna brown or dark brown 3
3. Fore basitarsus slightly less than 5 times as long as its greatest width ..... *S.* (*S.*) *striatum*
- Fore basitarsus about 5 times as long as its greatest width 19
4. Basal section of radial vein fully haired ..... *S.* (*S.*) *grisescens*
- Basal section of radial bare ..... *S.* (*S.*) *consimile*

[1] Females of *S.* (*S.*) *palmatum* and *S.* (*S.*) *yanaense* sp. nov. are unknown.

Adult males [2]

1. Fore basitarsus 6 to 7 times as long as its greatest width 2
- Fore basitarsus 5 to 5.5 times as long as its greatest width 3
2. Hind basitarsus parallel-sided ..... *S.* (*S.*) *pallidum*
- Hind basitarsus spindle-shaped ..... *S.* (*S.*) *yanaense* sp. nov.
3. Hind coxae brownish-black ..... *S.* (*S.*) *consimile*
- Hind coxae black 4
4. Middle femur black ..... *S.* (*S.*) *grisescens*
- Middle femur grayish-yellow ..... *S.* (*S.*) *striatum*

[2] Males of *S.* (*S.*) *kapuri* and *S.* (*S.*) *palmatum* are unknown.

Pupae

1. Gill with eight filaments ..... *S.* (*S.*) *kapuri*
- Gill with 10 filaments 2
2. Thoracic integument yellow ..... *S.* (*S.*) *yanaense* sp. nov.
- Thoracic integument brown 3
3. Anterior of cocoon without spaces ..... *S.* (*S.*) *palmatum*
- Anterior of cocoon with large spaces 4
4. Cocoon loosely woven ..... *S.* (*S.*) *striatum*
- Cocoon closely woven ..... *S.* (*S.*) *consimile*, *S.* (*S.*) *grisescens* & *S.* (*S.*) *pallidum*

Larvae[3]

1. Pharate pupal gill with 8 filaments ..... *S.* (*S.*) *kapuri*
- Pharate pupal gill with 10 filaments 2
2. Labral fan with 33 main rays ..... *S.* (*S.*) *yanaense* sp. nov.
- Labral fan with 50 main rays ..... *S.* (*S.*) *grisescens*

[3] Larvae of *S.* (*S.*) *consimile*, *S.* (*S.*) *pallidum*, *S.* (*S.*) *palmatum*, and *S.* (*S.*) *striatum* are unknown.

3.2mm long by 1.35mm wide.

Mature larva: Body length 4.3–4.5 mm. Body creamy with markings as follows: thoracic segment one greyish dorsally, laterally encircled with a transverse band (though disconnected ventrally), proleg greyish-black, thoracic segments 2 and 3 grayish dorsally and each with distinct ochreous wide areas ventrally, abdominal segments 1–4 each encircled with yellowish-brown broad band, abdominal segments 5–8 almost entirely covered by yellowish-brown transverse broad band on dorsal and dorsolateral surfaces; abdominal segments 5 and 6 each with W-shaped broad transverse band on dorsolateral surfaces of posterior half of each segment; abdominal segment 7 and 8 with transverse yellowish-brown band on ventral surface; cephalic apotome yellowish-brown and sparsely covered with simple minute setae; head spots indistinct. Lateral surface of head capsule yellowish-brown except eye-spot region yellow and sparsely covered with simple minute setae; spots indistinct. Ventral surface of head capsule yellowish-brown except somewhat darkened area near posterior margin on each side of postgenal cleft and sparsely covered with simple minute setae. Antenna composed of three articles and apical sensillum, 1.23 times longer than stem of labral fan; proportional lengths of segments 1, 2, and 3 are 1.00:1.20:0.76. Labral fan with 33 main rays. Mandible (Fig. 2C) with three comb-teeth decreasing in length from first to third; mandibular serrations composed of two teeth (one medium-sized and one small); major tooth at acute angle against mandible on apical side. Hypostoma (Fig. 2D) with row of nine apical teeth; median and each corner tooth prominent (though median tooth slightly longer than corner teeth) and much longer than three intermediate teeth on each side; lateral margin weakly serrate apically; five hypostomal bristles per side lying parallel to lateral margin. Postgenal cleft (Fig. 2E) arrow-head-shaped, 3.1 times as long as postgenal bridge; sub-esophageal ganglion moderately pigmented. Thoracic cuticle finely covered with minute dark spinules. Thorax and abdomen without pair of dorsolateral protuberances.

Thoracic cuticle almost bare. Abdominal cuticle almost bare except few posterior segments sparsely to moderately covered with simple minute setae dorsally and dorsolaterally and last segment densely covered with colourless simple setae on each side of anal sclerite, and with dorsal pairs of conical protuberances. Rectal scales present. Rectal papillae compound, each of three lobes with five finger-like secondary lobules. Anal sclerite of usual X-form, with anterior arms slightly shorter (0.91 times as long as posterior arms) than posterior ones, broadly sclerotized at base; accessory sclerite absent. Last abdominal segment expanded ventrolaterally but lacking ventral papillae. Posterior circlet with 78 rows of hooklets with up to 22–24 hooklets per row.

Type series: Holotype: BYH19, male, 19.xi.2016, Yana downstream, Kumta Taluk, Uttara Kannada District, Karnataka State, India, 14.522^{0}N & 74.320^{0}E , 55m, coll. S. Vijayan & S. Anbalagan.

Paratype: 2 males, 8 pupae, 41 mature larvae, same data as the holotype (catalogue number BY003).

Etymology: The species is named after the place of collection, Yana.

Habitat: The larvae and pupae of *Simulium* (*Simulium*) *yanaense* sp. nov. are mainly found in leaf litter and on woody debris submerged in water.

Diagnosis: This new species is characterized by having a maxillary palp with a small sensory vesicle (0.19 times as long as segment 3), hind basitarsus 4.1 times as long as its greatest width, and coxite 1.2 times as long as its greatest width in the male; gill with 10 short slender filaments and a short common basal stalk in the pupa; and five hypostomal bristles per side lying parallel to the lateral margin, thorax, and abdomen without a pair of dorsolateral protuberances, and the posterior circlet with 78 rows of hooklets in the larvae.

Discussion

This new species is assigned to the subgenus *Simulium*, defined by Takaoka & Choochote (2004), by having the katepisternum bare and coxite shorter than the style in the male, absence of grapnel-like hooklets on the last abdominal segment in the pupa, and lack of ventral papillae on the last abdominal segment in the larva. This new species is placed in the *Simulium striatum* species-group, redefined by Takaoka (2017), on the basis of the saddle-shaped ventral plate of the male.

The morphologic features of the male genitalia and arrangement of the pupal gill filaments of this new species are similar to those of *S*. (*S*.) *grisescens*, *S*. (*S*.) *kapuri*, and *S*. (*S*.) *striatum* from India, and *S*. (*S*.) *baliense* from Indonesia (Takaoka et al. 2017). The new species, however, is distinguished from *S*. (*S*.) *striatum* by the following characters (those of *S*. (*S*.) *striatum* in parentheses): in the male by the hind basitarsus 0.73 and 0.68 times as wide as greatest width of tibia and femur, respectively (0.75 and 0.26 times as wide as greatest width). The new species is indistinguishable in the male from *S*. (*S*.) *kapuri* but is distinguished in the pupa by the gill with 10 filaments (eight filaments). The new species is distinguished in the pupa from *S*. (*S*.) *grisescens* by having the stalk of the ventral pair of filaments 0.6 times as thick as the primary stalk of the dorsal pair (1.6 times as thick as the primary stalk of the dorsal pair).

This new species is distinguished from *S*. (*S*.) *baliense* by the following characters: in the male by the large upper eye facets in 12 vertical columns and 16 horizontal rows (15 vertical columns and 15 horizontal rows), hind basitarsus 4.1 times as long as wide (5.64 times as long as its greatest width), and coxite in ventral view 1.2 times as long as wide (0.75 times as long as wide), and in the larva by the posterior circlet with 78 rows of hooklets (104 rows of hooklets).

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New host records of polyphagous Lepidoptera on Ban Oak *Quercus leucotrichophora* A. Camus (Fabaceae) in the Garhwal Himalaya, India

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Abstract: The paper provides information on the life history stages of 12 species of Lepidoptera recorded for the first time feeding on Ban Oak *Quercus leucotrichophora* in Garhwal Himalaya, supported by images along with their distribution range and host plants recorded across the globe. A comprehensive list of all the Lepidoptera recorded so far feeding on *Q. leucotrichophora* is also provided.

Keywords: Arctiinae, Chakrata, Dehradun, Erebidae, Geometridae, Lycaenidae, Pyralidae, Zygaenidae.

Mathur & Singh (1959) were the first to give a comprehensive list of 35 species of Lepidoptera feeding on Ban Oak *Quercus leucotrichophora* (Fabaceae), which occurs in the moist temperate forest zone from the western to the central Himalaya (Table 1). Recently, the life cycle of the Indian Gypsy Moth *Lymantria obfuscata* Walker, 1865 was studied on the host *Q. leucotrichophora* by Verma et al. (1979) and Thakur et al. (2015) in Himachal Pradesh, and two other species were later recorded as hosts on this oak (Smetacek & Smetacek 2011; Table 1) in the Kumaon region of Uttarakhand. Beeson (1941) had earlier recorded *Antheraea roylei* Moore, 1858 (Satruniidae) feeding on *Q. leucotrichophora* along with seven other species of Lepidoptera, which were later reported by Mathur & Singh (1959). Besides these 39 species that belong to 16 families, there are no other records of Lepidoptera feeding on *Q. leucotrichophora* from the Himalayan region of India. The present study reports for the first time 12 new species of Lepidoptera feeding on *Q. leucotrichophora* from the Garhwal region of the Uttarakhand State of India. An account of each species is given below.

Common Onyx *Horaga onyx onyx* (Moore, [1857]) (Papilionoidea: Lycaenidae: Theclinae: Horagini) (Image 1)

A fifth instar larva (12mm; Image 1a) was collected on 14 September 2018 while feeding on the foliage of *Q. leuco trichophora* in the plantation in New Forest Campus of the Forest Research Institute (FRI), Dehradun. The larva was bred in the laboratory (Image 1b) FRI, Dehradun, on *Q. leucotrichophora* leaves. The mature larva (16mm) fed on the entire oak leaf leaving only the midrib. Pupation took place on 20 September 2018 (pupa:

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Image 1. Life history stages of the Common Onyx *Horaga onyx onyx* Moore, 1857: a - larva | b - feeding pattern | c - pupa | d - adult (female).

10mm) on the leaf stalk. The shape of the pupa, being oval and light green in colour with dark spots, resembled the eyes on a human face (Image 1c). The emergence of the butterfly (female; wingspan: 28mm; Image 1d) took place on 28 September 2018.

This species occurs throughout the Indian subcontinent up to 2,000m in hilly tracts (northern, northeastern, central, and southern India) with a flight period throughout the year (Wynter-blyth 1957), while the subspecies *O. h. onyx* occurs from Kangra in Himachal Pradesh up to Myanmar (Evans 1932). The larval food plant recorded for the subspecies is *Coriaria nepalensis* Wall. (Coriariaceae) in the Himalaya (Wynter-blyth 1957). The other subspecies *O. h. cingalensis* feeds on *Mangifera indica* L. (Nitin et al. 2018) in southern India and Sri Lanka. Other larval food plants for this species are *Durio zibethinus* L. (Malvaceae) in Thailand and *Glochidion rubrum* Blume, Bijdr. (1825) (Euphorbiaceae) in Taiwan (Robinson et al. 2010). The life cycle of the early stages of this species were photographed by Chandrasekharan (2018) in Kannur District of Kerala but was not described.

***Eterusia aedea aedea* (Clerck, 1759) (Zygaenoidea: Zygaenidae: Chalcosiinae) (Image 2)**

A dark reddish-brown larva (42mm; Image 2a,b) was recorded feeding on the foliage of *Q. leucotrichophora* plantation and was collected on 12 April 2018 from the New Forest Campus of FRI, Dehradun. Pupa (30mm) formed on 16 April 2018, inside an arch-shaped pale coloured cocoon (Image 2c,d) with one end flat and the rest of the curved surface shaped like a purse; it was stuck to the surface of a half-curled oak leaf. The moth (wingspan: 62mm; Image 2e,f,g) emerged on 14 May 2018 from the mouth of the cocoon which was covered with a lid-like structure (Image 2d) in the laboratory at FRI, Dehradun.

The larvae of *E.a. aedea* were recorded feeding on a wide range of plants, including *Bischofia javanica* Blume, *Aporosa lindleyana* (Wright) Baill., *A. villosa* (Lindl.) Baill., *Cornus florida* L., *Lagerstroemia* sp., *Melastoma candidum* D. Don, *Myrica rubra* Siebold & Zucc., *Sloanea formosana* Li., *Rhododendron* sp., *Symplocos glauca* (Thunb) Koidz, *Camellia* spp. (including *C. japonica* L., *C. sasanqua* Thunb., *C. sinensis* (L.) Kuntze, *C.abel*, and *C. oleifera*), *Eurya japonica* Thunb., *E. septata* Wu, Hsu & Tsou, *Cleyera japonica* Thunb. and *Buddleja* sp. The *Eterusiaaedeas* spp. *aedea*, *sinica*, *formosana*, *cingala*, and *virescens* were reported as pests on tea (Yen 2004; Robinson et al. 2010). The species is found in Sri Lanka, India, Taiwan, Japan, and China.

Image 2. Life history stages of *Eterusia aedea aedea* (Clerck, 1759): a - second instar larva | b - fifth instar larva | c - cocoon | d - cocoon with operculum | e - upper side of adult | f - underside of adult | g - upper side of adult.

The subspecies *E. a. aedea* occurs in the northeastern regions of India including Sikkim, Assam, Nagaland, Manipur, and Meghalaya during the months of April, May, July, August, and October (Hampson 1892; Shubhalaxmi et al. 2011; Anonymous 2018a).

***Artena dotata* (Fabricius, 1794) (Noctuoidea: Erebidae: Erebinae: Ophiusini) (Image 3)**

The larvae (2.3–2.5 mm; Image 3a) of this moth were collected from the terminal tips of new shoots of *Q. leucotrichophora* plantation on 11 October 2017 from the New Forest Campus of FRI, Dehradun. Dark brownish pupa (26–28 mm; Image 3b) formed on 29 October 2017 and the moth (wingspan: 50mm; Image 3b,c) emerged on 9 November 2017 in the laboratory at FRI, Dehradun.

Artena dotata occurs from the Indian subregion to Sri Lanka, Taiwan, Japan, Sumatra, and Borneo. Habitat preference is for lowland forest areas, including those with much secondary vegetation after logging. The pupa is typically ophiusine in form while the larva has a series of thin white lines running longitudinally along the body and was described by Bell (Holloway 2005). The flight period recorded is from April to June and August to December in Borneo. It was recorded in the Himalayan region from Himachal Pradesh, Uttarakhand, and Arunachal Pradesh and in northeastern India from Manipur and Nagaland (Hampson 1894a; Sondhi & Sondhi 2016; Anonymous 2018b). Larval food plants recorded are *Combretum latifolium* Bl.*., Getonia floribunda* Roxb.*, Quisqualis indica* L.*, Terminalia bellirica* (Gaertn.) Roxb.*, T. paniculata* Roth., and *T. tomentosa* (Roxb.) Wight &

Image 3. Life history stages of *Artena dotata* (Fabricius, 1794): a, b - mature larvae | c - upper side of moth | d - pupa and moth.

Image 4. Life history stages of *Artaxa guttata* Walker, 1855: a - dorsal view of larva | b - ventral view of larva | c - cocoon | d - moth | e - upper side of adult.

Image 5. Life history stages of *Orgyia postica* (Walker, 1855): a - larva | b - apterous female with pupa | c - upperside of winged male.

Arn.in India and *Vitis* sp. in Korea (Robinson et al. 2010).

Yellow Tussock Moth *Artaxa guttata* Walker, 1855 (Noctuoidea: Erebidae: Lymantriinae: Nygmiini) (Image 4)

A fourth instar larva (10mm; Image 4a,b) was collected on 24 August 2018 while feeding on the foliage of *Q. leucotrichophora* in the plantation in the New Forest Campus of FRI, Dehradun. The larva underwent one moulting into final instar on 26 August 2018 (11–27 mm). Pupation (pupa: 18mm; Image 4c) on the surface of an oak leaf took place on 04 September 2018. The emergence of the moth (wingspan: 42mm; Image 4d) took place on 13 September 2018 in the laboratory at FRI, Dehradun. Another larva of the same moth collected on 16 May 2018 from the same location on the oak emerged from its pupa on 18 May 2018 in the laboratory.

This species is found in northern India (Sondhi & Sondhi 2016). The known host plants of this species are *Ricinus communis* L., *Jasminun* sp., *Lantana camera* L., *Mangifera indica* L., *Terminalia* spp., *Ziziphus mauritiana* Lam., *Shorea robusta* Roth., *Maesa lanceolata* Forssk, *Mallotus philippensis* (Lam.) Muell. Arg., *Anogeissus acuminata* (Roxb. Ex. Candolle) Guillemin et al., *Barringtonia acutangula* (L.) Gaertn., *Carissa carandas* L., and *Lagerstroemia indica* (L.) Pers. It occurs in India, Bangladesh, Nepal, and Sri Lanka (Robinson et al. 2010).

***Orgyia postica* (Walker, 1855) (Noctuoidea: Erebidae: Lymantriinae: Orgyiini) (Image 5)**

One larva was collected on 29 October 2017 (15mm) while feeding on the foliage of *Q. leucotrichophora* in the plantation in the New Forest Campus of FRI, Dehradun. The larva was bred in the laboratory at FRI and pupated on 28 September 2017, with the moth (male; wingspan: 22mm) emerging on 6 October 2017 (Image 5a). Larvae were again collected on 15 and 22 October 2018 and 8 and 20 November 2018 from the Ban Oak foliage in the same locality. The length of the larvae (Image 5b) just before pupation in October and November varied from 24mm to 40mm and the pupal length varied from 24mm to 38mm (Image 5c). Emergence of one apterous female took place on 24 October 2018 (Image 5d) and one male on 10 November 2018, while two pupae remained under hibernation until January 2019.

This species commonly occurs from the Oriental tropics east to New Guinea and the larvae are known to feed on *Buchanania*, *Mangifera*, *Durio*, *Ochroma*, *Casuarina*, *Terminalia*, *Shorea*, *Hevea*, *Ricinus, Pelargonium*, *Cinnamomum*, *Acacia*, *Albizia*, *Caesalpina*, *Cajanus*, *Cassia*, *Dalbergia*, *Erythrina*, *Pithecellobium*, *Pterocarpus, Sesbania, Xylia*, *Lagerstroemia*, *Eucalyptus*, *Tristania*, *Zizyphus*, *Malus*, *Coffea*, *Citrus*, *Santalum*, *Dimocarpus*, *Litchi*, *Nephelium*, *Theobroma*, *Camellia*, *Grewia,* and *Tectona* (Holloway, 1999) species and also *Populus deltoides* W. Bartram ex. Marshall (Singh 1991).

***Rhypotoses drepanioides* Kishida, 1995 (Noctuoidea: Erebidae: Lymantriinae: Nygmiini) (Image 6)**

The larvae (15mm) were collected on 11 October 2017 while feeding on the foliage of *Q. leucotrichophora* in the plantation in the New Forest Campus of FRI, Dehradun. Dark coloured pupa (18mm) formed on 15 October 2017 and the emergence of the moth (wingspan: 30mm; Image 6a,b) took place on 09 November 2017 in the laboratory at FRI, Dehradun.

The moth is not so rare in nature. It is not attracted to light and traps as frequently as other moths. The distribution of *Rhypotoses drepanioides* Kishida, 1995 is extended westwards upto the Kumaon Himalaya, in India with larval food plant recorded as *Quercus floribunda* Lindl. ex A. Camus (Smetacek & Smetacek 1995, 2011).

***Thyas juno* (Dalman, 1823) (Noctuoidea: Erebidae: Erebinae: Ophiusini) (Image 7)**

Fifth instar larva (65mm; Image 7a) was collected

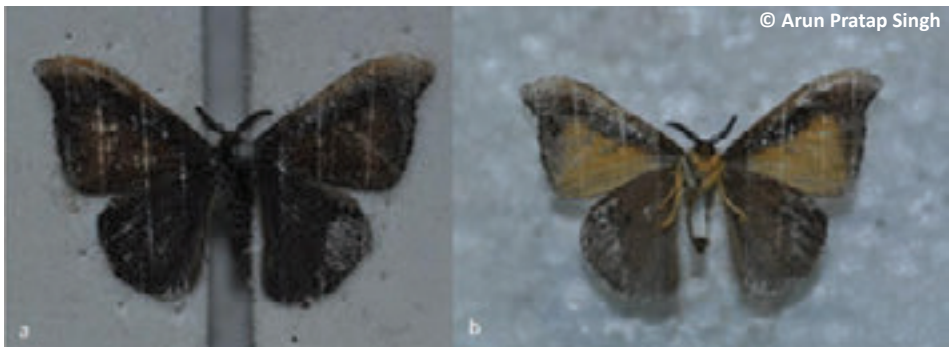

Image 6. Moth of *Rhypotoses drepanioides* Kishida, 1995: a - dorsal view | b - ventral view.

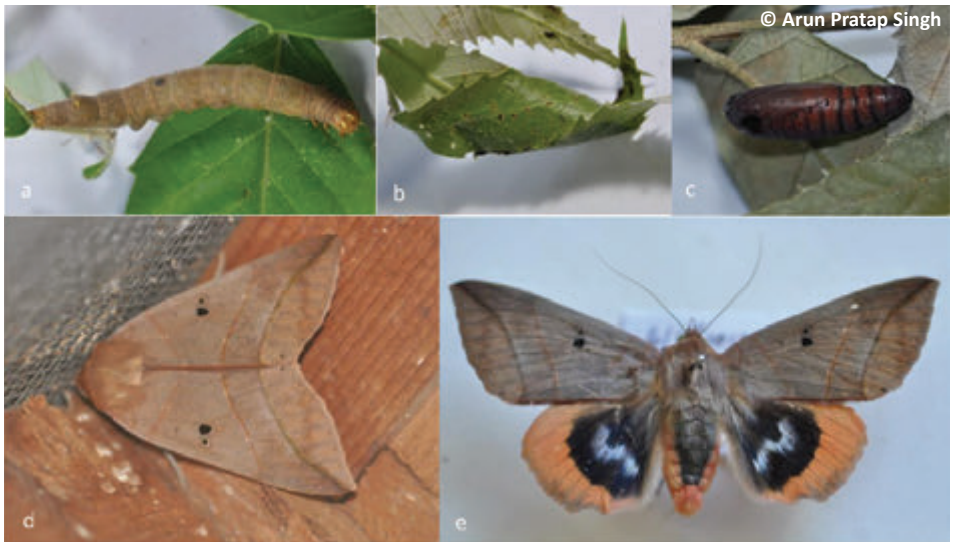

Image 7. Life history stages of *Thyas juno* (Dalman, 1823): a - mature larva | b - cocoon in folded leaves | c - pupa | d - moth in rearing cage | e - upper side of adult.

Image 8. Life history stages of *Cyana coccinea* (Moore, 1878): a - larva | b - pre-pupa | c - pupa inside cocoon | d - lateral view of moth.

on 7 October 2018 while feeding on leaves of *Q. leucotrichophora* in the plantation in New Forest Campus in FRI, Dehradun. The mature larva (70mm; Image 7b) underwent pre-pupation on 12 October 2018 by the formation of a hairy mass of body hairs by twining together three leaves and finally formed a pupa (38mm; Image 7c) on 15 June 2018. The emergence of the moth (wingspan: 90mm; Image 7d,e) took place on 5 November 2018 in the laboratory at FRI, Dehradun.

The moth is known to occur in the Indian subregion, China, Japan, Korea, Thailand, Borneo, Java, Sulawesi, and on southern Maluku. The larvae feed on *Castanea, Quercus*, *Juglans*, and *Pterocarya* species (Holloway 2005). The oak species infested are *Quercus acutissima* Carruth., *Q. phillyraeoides* A. Gray, *Q. serrata* Murray, and *Q. variabilis* Blume in Japan (Robinson et al. 2001). The adult is a fruit-piercer in Thailand (Kuroko & Lewvanich 1993). There are, however, no reports of

it infesting the genus *Quercus* in India. The species is known to be in flight in April and August–September in Mussoorie, Uttarakhand, and Eaglenest Wildlife Sanctuary in Arunachal Pradesh in the Himalaya (Anonymous 2018c).

***Cyana coccinea* (Moore, 1878) (Noctuoidae: Arctiidae: Lithosiinae: Nudariini) (Image 8)**

The fifth instar larva (30mm; Image 8a) was collected on 19 June 2018 while feeding on leaves of *Q. leucotrichophora* plantation in the New Forest Campus of FRI, Dehradun. The larva underwent pre-pupal stage (20mm; Image 8b) on 20 June 2018 by the formation of a hairy dome (40mm) from the mass of body hairs on the upper surface of a leaf and finally formed a pupa (20mm; Image 8c) on 21 June 2018. The emergence of the moth (female; wingspan: 30mm; Image 8d) took place on 28 June 2018 in the laboratory at FRI, Dehradun.

The species is distributed in India from the Himalaya (Uttarakhand, Nepal, and Sikkim) to northeastern India (Sikkim, Assam, West Garo Hills in Meghalaya, and Nagaland) and the Andaman in October–November (Anonymous 2018d). It also occurs in China, Thailand, Malaysia, Vietnam, Laos (Hampson 1894b; Strand 1922; Ghosh & Chaudhury 1998; Chaudhury 2003; Tangmitcharoen et al. 2006; Sondhi & Sondhi 2016). Host plants recorded for this species are *Dimocarpus* sp. (Kuroko & Lewvanich 1993), *Camellia sinensis* (L.) Kuntze (Theaceae), *Dalbergia sissoo* Roxb. (Leguminosae), *Shorea robusta* Roth. (Dipterocarpaceae), *Tectona grandis* (Verbenaceae), *Mangifera indica* L. (Anacardiaceae), and *Dimocarpus longan* Lour. (Sapindaceae) (Robinson et al. 2010). San-

Image 9. Life history stages of *Hyposidra talaca* (Walker, 1860): a - second stage larva | b- fifth instar larva | c - pre-pupa | d - pupa | e - live moth | f - upper side of pinned moth.

Image 10. Life history stages of *Hypomecis infixaria* (Walker, 1860): a, b - second instar larva | c, d - fifth instar larva | e - uppe rside of live moth | f - underside of live moth | g - upper side of pinned moth.

yal et al. (2013) studied the life history of this moth on *S. robusta* in Dehradun and reported its outbreak in Rajaji National Park in Uttarakhand, India.

***Hyposidra talaca* (Walker, 1860) (Geometroidea: Geometridae: Ennominae: Boarmiini) (Image 9)**

A second instar larva (12mm; Image 9a) was collected on 20 June 2018 while feeding on leaves of *Q. leucotrichophora* plantation in the New Forest Campus of FRI, Dehradun. Moulting into the fifth instar larva took place on 25 June 2018 (30–43 mm; Image 9b); pre-pupa (Image 9c) was formed on 2 July 2018, finally turning into a dark brown pupa (18mm; Image 9d) on 4 July 2018. The emergence of the moth (female; wingspan: 32mm; Image 9e,f) took place on 10 July 2018 in the laboratory at FRI, Dehradun.

The species is distributed from India to Indo-China, Sundaland, Sulawesi, the Philippines, Sri Lanka, the Solomon Islands, Thailand, Taiwan, New Guinea, and Australia (Queensland). It is a major defoliating pest in tea plantations. In India, the species was reported from Assam, Meghalaya, Himachal Pradesh, Uttarakhand, Goa, Madhya Pradesh, and Karnataka with flight throughout the year. The flight period in the western Himalaya is during the monsoons (July–September; Sondhi & Sondhi 2016; Singh 2018). Host plants include *Anacardium, Bombax, Terminalia, Chromolaena, Gynura, Mikania, Cupressus, Aleurites, Aporusa, Bischofia, Breynia, Glochidion, Hevea, Manihot, Ficus, Morus, Psidium, Polygonum, Rubus, Cinchona, Coffea, Mussaenda, Citrus, Schleichera, Theobroma, Perilla-frutescens* (L.) Britton, *Camellia*, and *Tectona* (Holloway, 1993a). The larva was described by Singh (1953).

Image 11. Life history stages of *Hypomecis transcissa* (Walker, 1860). a, b - mature larva | c - pupa shell and moth.

***Hypomecis infixaria* (Walker, 1860) (Geometridae: Ennominae: Boarmiini) (Image 10)**

A second instar larva (Image 10a,b; 8mm) was collected on 5 July 2018 from the leaves of *Q. leucotrichophora* from the plantation in the New Forest Campus of FRI, Dehradun. A fifth instar larva (36mm) was formed on 18 July 2018 (Image 10c,d), while a dark brown pupa (16mm) was formed on 31 July 2018. The emergence of the moth (male; wingspan: 30mm; Image 10e,f) took place on 6 August 2018 in the laboratory at FRI, Dehradun.

Host plants in India include *Bauhinia divaricate* L., *Carissa spinarum* L., *Dalbergia sissoo* Roxb., *Derris scandens* Roxb. (Benth.), *Planchonia careya* (F. Muell.) R. Knuth, *Platycladus orientalis* (L.) Franco, *Schleichera oleosa* (Lour) Oken, *Shorea robusta* Roth, *Xylia xylocarpa* Roxb. Taub., and *Tectona grandis* L.f. (Robinson et al. 2010). Another species of the same genus, *Hypomecis punctinalis* (Scopoli, 1763), is known to feed on the family Fagaceae and the genus *Quercus*, in Japan and British Isles (Robinson et al. 2010).

***Hypomecis transcissa* (Walker, 1860) (Geometridae: Ennominae: Boarmiini) (Image 11)**

A fifth instar larva (38–40 mm; Image11a,b), dark brown and black, was collected on 24 August 2018 feeding on the foliage of *Q. leucotrichophora* in the plantation in the New Forest Campus of FRI, Dehradun. Pupation took place (pupa: 17mm; dark brown; Image 11c) between two oak leaves on 30 August 2018 and the

Image 12. Life history stages of *Ephestiodes* sp. (Pyralidae: Phycitinae). a - feeding pattern of skeletonizing the oak leaf | b, c - larva | d - mass of cocoons | e - pupa inside cocoon | f - moth | g, h - upperside of moth | i - lateral view of moth.

moth (wingspan: 42mm; Image 11d) emerged on 6 September 2018 in the laboratory at FRI, Dehradun.

The host plant recorded is *Aleurites* (Euphorbiaceae) species. The moth occurs in the Indian subregion, from Sri Lanka to Sundaland (Holloway 1993b). Its distribution is in India (Dharamsala, Sikkim, Assam, and Nilgiris), Bhutan, Sri Lanka, Burma, and Java (Hampson 1895). The species is also found in Malaysia and Hong Kong (Robinson 2010). Host plants recorded outside India are *Aleurites Montana* Lour., *Castanopsis fissa* (Champ. ex. Benth.) Rehd. & Wils., *Cinnamomum zylanicum* Blume, *Nephelium lappaceum* L., *Hevea* sp., *Theobroma cacao* L., and *Vernicia fordii* (Hemsl.) Airy Shaw (Robinson et al. 2010). Flight period is from August to December in Himachal Pradesh, Maharashtra, Assam, Tripura (Anonymous 2018d), and Uttarakhand (Sondhi & Sondhi 2016).

***Ephestiodes* (Ragonot, 1887) sp. (Pyraloidea: Pyralidae: Phycitinae) (Image 12)**

The larvae of this moth were recorded feeding on *Q. leucotrichophora* in Chakrata Forest Division, Uttarakhand, on 22 May 2018. Feeding took place by scratching and skeletonizing the oak leaf surface (Image 12a). Two pale-coloured larvae (32mm; Image 12b,c) and a mass of 11 dark brown pupae (14–15 mm; Image 12d,e) within interwoven leaves were collected from the Chakrata Cantonment Forest (30.743^{0}N & 77.871^{0}E; 2,610m). Four moths (wingspan: 24–32 mm; Image 12f) emerged on 24 and 25 May 2018 in the laboratory at FRI, Dehradun. The moths (Image 12g,h,i) were slender with light brown forewings with yellowish shading in the basal third and darker reddish-brown in distal two-thirds. The hind wings were much wider than the forewings and were pale with a brown terminal line and having long pale fringe scales.

An allied species of the same genus, *Ephestiodes infimella* Ragonot, 1887, is native to North America (Wikipedia contributors, 2018, April 5) and feeds on wild cherry and *Ambrosia* sp. with adults on the wing from June to September (Stegmaier 1971), besides *Prunus* sp. and *Smilax rotundifolia* L. in the Nearctic region (Robinson et al. 2010).

Except for *H. o. onyx* and *Ephestiodes* sp., all other

Table 1. Past records of Lepidoptera feeding on Ban Oak *Quercus leucotrichophora* A. Camus in the western Himalaya.

	Family/Species	Nature of damage	References
Family: Nolidae			
1	*Nola* sp.	Larva defoliates	Mathur & Singh (1959)
2	*Meganola nitida* (Hampson, 1894)	Larva defoliates	Mathur & Singh (1959)
3	*Garella ruficirra* (Hampson, 1905)	Larva defoliates	Mathur & Singh (1959)
4	*Nycteola revayana* (Scopuli, 1772)	Larva defoliates	Mathur & Singh (1959)
Family: Bombycidae			
5	*Mustilizans hepatica* (Moore, 1879)	Larva defoliates	Mathur & Singh (1959)
Family: Tortricidae			
6	*Enarmonia disperma* Meyrick, 1931	Larva defoliates	Beeson (1941); Mathur & Singh (1959)
Family: Gelechiidae			
7	*Dichomeris quercicola* Meyrick, 1921	Larva feeds on leaves	Beeson (1941); Mathur & Singh (1959)
8	*Telphusa tetragrapta* Meyrick, 1937	Larva defoliates	Mathur & Singh (1959)
Family: Geometridae			
9	*Mixochlora vittata* (Moore, [1868])	Larva defoliates	Mathur & Singh (1959)
Family: Lasiocampidae			
10	*Pyrosis undulosa* (Walker, 1855)	Larva defoliates	Mathur & Singh (1959)
11	*Euthrix inobtrusa* (Walker, 1862)	Larva defoliates	Mathur & Singh (1959)
12	*Malacosoma indica* Walker, 1855	Larva defoliates	Beeson (1941); Mathur & Singh (1959)
13	*Trabala vishnou* (Lefèbvre, 1827)	Larva defoliates	Beeson (1941); Mathur & Singh (1959)
Family: Lycaenidae			
14	*Arhopalado donaea* Moore, [1858]	Larva defoliates	Mathur & Singh (1959)
15	*A. ganesa* (Moore, [1858])	Larva defoliates	Mathur & Singh (1959)
16	*A. rama* (Kollar, [1844])	Larva defoliates	Mathur & Singh (1959)
17	*Acytolepis puspa gisca* (Fruhstorfer, 1910)	Larva defoliates	Smetacek & Smetacek (2011)
Family: Erebidae			
18	*Callitera grotei* (Moore, 1859)	Larva defoliates	Mathur & Singh (1959)
19	*C. strigata* (Moore, 1879)	Larva defoliates	Mathur & Singh (1959)
20	*C. varia* (Walker, 1855)	Larva defoliates	Mathur & Singh (1959)
21	*Somena scintillans* Walker, 1856	Larva defoliates	Mathur & Singh (1959)
22	*Euproctis varians* (Walker, 1855)	Larva defoliates	Mathur & Singh (1959)
23	*Lymantria concolor* Walker, 1855	Larva defoliates	Beeson (1941); Mathur & Singh (1959)
24	*L. mathura* Moore1866	Larva defoliates	Beeson (1941); Mathur & Singh (1959)
25	*L. obfuscata* Walker, 1865	Larva defoliates	Verma et al. (1979); Thakur etal. (2015)
26	*Ophiusa olista* (Swinhoe, 1893)	Larva defoliates	Mathur & Singh (1959)
27	*Hypocala rostrata* Fabricius, 1794	Larva defoliates	Mathur & Singh (1959)
28	*H. subsatura* Guenée, 1852	Larva defoliates	Mathur & Singh (1959)
Family: Tineidae			
29	*Opogona iolychna* Meyrick, 1920	Larva feeds on dead bark	Mathur & Singh (1959)
Family: Pyralidae			
30	*Syllepta lunalis* (Guenée) [1970]	Larva defoliates	Beeson (1941); Mathur & Singh (1959)
31	*Heterocrasa expansalis* Warren, 1896	Larva defoliates	Smetacek & Smetacek (2011)
Family: Noctuidae			
32	*Goniocras pidumennomoides* Hampson, 1894	Larva defoliates	Mathur & Singh (1959)
Family: Nymphalidae			
33	*Euthalia patala* (Kollar, [1844])	Larva defoliates	Mathur & Singh (1959)
34	*Sephisa dichroa* (Kollar, [1844])	Larva defoliates	Mathur & Singh (1959)

	Family/Species	Nature of damage	References
Family: Elachistidae			
35	*Agonopterix taciturna* (Meyrick, 1910)	Larva bores into green shoots	Mathur & Singh (1959)
Family: Oecophoridae			
36	*Promalactis calathiscias* Meyrick, 1937	Larva feeds on dead bark	Mathur & Singh (1959)
Family: Saturniidae			
37	*Antheraea roylei* Moore,1858	Larva defoliates	Beeson (1941)
Family: Sphingidae			
38	*Pergesa acteus* (Cramer, [1779])	Larva defoliates	Mathur & Singh (1959)
Family: Zygaenidae			
39	*Tasema bipars* Walker, 1856	Larva defoliates	Mathur & Singh (1959)

new Lepidoptera recorded feeding on *Q. leucotrichophora* are polyphagus in nature with these species occurring across either the entire Himalaya and/or the Indian subcontinent.

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Short Communication

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A preliminary study of the hawkmoth diversity (Lepidoptera: Sphingidae) of Kanyakumari District, Tamil Nadu, India

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Abstract: Kanyakumari District is situated at the southernmost tip of peninsular India in Tamil Nadu State and is bounded by the Western Ghats and the coasts of three seas. There are no detailed historical records of the moths of this region, which, before India's independence, was part of Travancore State. This paper presents a brief account of the 27 species of hawkmoths of Kanyakumari District, recorded during surveys conducted from 2011-2015, and is the first formal record of the hawkmoths of this region. A list of the species from the collection of the Natural History Museum, UK, collected in the erstwhile Travancore State that are likely to be found in the Kanyakumari region is also included.

Keywords: Kanyakumari Wildlife Sanctuary, species checklist, Suchindrum.

Abbreviations: FW - Forewing | HW - Hindwing | KK(WS) - Kanyakumari (Wildlife Sanctuary) | NHMUK - Natural History Museum, London, UK | UP - Upperside | UN - Underside.

The Western Ghats, recognized as a Natural World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO 2012), is a mountain chain approximately 1,600km in length running along the western side of peninsular India. Kanyakumari District, the southernmost region of Tamil Nadu State, is situated between the mountain ranges of the Western Ghats and the Arabian Sea to the west, between 8.083°-8.583°N and 77.167°-77.0°E. Rivers here are perennial and rain-fed, and the district is criss-crossed by canals and ponds to facilitate storage of rainwater draining from the Ghats. Habitats range from coastal to estuarine and freshwater and from wetlands and mangroves to forests, and support diverse ecosystems and biodiversity. About 30% of the region is forest (Rehamathulla 1970), which serves as the catchment area for 10 reservoirs (Gopala Krishnan 1995), which in turn feed into almost 1500 large and small ponds serving to sustain paddy, coconut and flower cultivation, many also being used to grow lotus.

The moths of Tamil Nadu State remain relatively less studied, with only a very few published studies on their diversity. Ramkumar et al. (2010) and Sivasankaran & Ignacimuthu (2014) both reported on the family Erebidae; Sivasankaran et al. (2011) recorded 154 species of noctuid moths from the Western Ghats; and Rathikannu & Chitra (2017) discussed crambid moths from a few localities in Tamil Nadu. Elanchezhian et al. (2014) reported 105 moth

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species from the Maruthamalai Hills, however, none of these studies included Kanyakumari District. Indeed, a literature survey of the older Indian records in Moore (1858), Cotes & Swinhoe (1887), Hampson ([1893]) and Bell & Scott (1937) found mention of "Madras", "Nilgiris" and "Ceylon" but not Kanyakumari District. It is worth mentioning that until India's Independence Kanyakumari was part of what was then Travancore State and can be found described as the "South Travancore District" (Menon & Padmanabha 1929). Soon after independence, it became Kanyakumari District in the state of Tamil Nadu. Although there are records for some moth species from "Travancore" (see Appendix 1) as a geographical region, generally there is no specific mention as to what part of Travancore. Hence this paper presents, for the first time in nearly a century, a dedicated survey of moths in this unique part of the Western Ghats.

The focus of the present paper is the hawkmoths of the family Sphingidae. Adult hawkmoths are generally active at night, although some are diurnal or crepuscular in habit. They are mostly strong fliers that imbibe nectar from flowers while hovering, and many are important pollinators of night-blooming flowers. They are often robust moths, with elongate, triangular forewings and small hindwings, which makes them agile fliers. They have large eyes, antennae that are thick, hooked and apically pointed, and strong legs with well-developed spurs and numerous spines on the tarsi. The most comprehensive study of Indian sphingids, which focused on NW India and Kanara, remains that of Bell & Scott (1937), which included 75 species, subspecies and forms belonging to 27 genera. More recent faunal studies of sphingid moths in southern India are those of Sondhi et al. (2017) (Kerala; 29 species recorded over 31 nights' sampling), Gurule (2013) (Maharashtra; 23 species from 67 nights' sampling), Melichar (2012) (NW Karnataka; 49 species from surveys during the period 2008-2012) and Shubhalaxmi & Chaturvedi (1999) (Maharashtra; 21 species from surveys during the years 1994-1997).

Materials and Methods

Study sites

The forests of Kanyakumari District and the village Suchindrum form the sites for the present survey. About 30% of Kanyakumari District is forest, occupying an area of about 40,000ha between 8.083° and 8.583°N, and 77.167° and 77.0°E. In 1996, Veerapuli and Klamalai Reserve Forests in this district came under the authority of the newly created Kalakad Mundanturai Tiger Reserve. In 2002, the remaining parts of the reserve forests were declared as Kanyakumari Wildlife Sanctuary (KKWS). The sanctuary includes several different forest types, wet evergreen, moist and dry deciduous, shola, montane and riparian (Fig. 1, Table 1). The village of Suchindrum, at 8.15°N, 77.45°E, is located on the banks of the Pazhayar River and is surrounded by paddy, fields, coconut groves, irrigation tanks, and temple ponds. The Suchindrum, Theroor and Vembanoor irrigation tanks have been declared Important Bird Areas by BirdLife International (IBA-IN279) and from 2015 the Forest Department has maintained Suchindrum tank as a Conservation Reserve (Vismiju Viswanathan, former DFO, pers. comm. 01 May 2015)

Moths were surveyed at the following locations during the years 2011-2015. The surveys at Kalikesam, Maramalai, Balamore estate and Upper Kothayar were dependent upon the availability of accommodation at the sites and permissions from the forest department, so were quite unsystematic with regard to their scheduling.

Moths were surveyed primarily using a light trap consisting of a 160W mercury vapour bulb hung above a 3x5 feet white cotton sheet stretched between either two posts or trees, or sometimes nails on a wall. In case electricity was not available (Balamore and Maramalai), a petrol-powered Honda generator was used. The white screen was illuminated from 18.00h or 18.30h, depending upon sunset time, till 02.30h. Where electricity was available, the light was switched off at 03.30h. At Suchindrum, daytime moth activity was also recorded.

Unlike the neighbouring states of Kerala and Karnataka, the Tamil Nadu Forest Department actively discourages collecting, which is one of the contributory factors to the poor faunal record from this part of the Western Ghats. Although repeated requests were made and photographic evidence of new range records provided, permission to collect voucher specimens was not granted. Consequently, digital photography and manual observation notes were the only options available for recording. Digital photographs were taken using a Panasonic FZ 200 and a Panasonic FZ 35 with a Lumix lens. The studies were self-funded by the first author.

Identification of moths and compilation of distribution ranges were undertaken using the following literature sources: Cotes & Swinhoe (1887), Hampson ([1893]), Rothschild & Jordan (1903), Bell & Scott (1937), Holloway (1987), Pittaway & Kitching (2014) and Kitching (2018).

This paper presents a brief description of 27 hawkmoths recorded from KKWS and Suchindrum, Kanyakumari District, Tamil Nadu, India, supplemented by a list of hawkmoths from "Travancore" region, compiled from published records and specimens in the

Figure 1. India showing the state of Tamil Nadu - specific study sites in Kanyakumari District.

collection of the NHMUK (Appendix 1).

The moth species recorded in this study are discussed below in taxonomic sequence.

Subfamily Macroglossinae Harris, 1839
Tribe Macroglossini Harris, 1839

Subtribe: *Sphingonaepiopsis* genus-group

1. *Neogurelca hyas* (Walker, 1856)

Diagnosis: Head, thorax and abdomen grey-brown; patagia and tegulae edged in red brown; several pairs of reddish-brown lateral segmental on the abdomen. FW UP grey brown with a black basal spot; with two indistinct, curved antemedial lines, two highly angulate postmedial lines, a curved submarginal line, and a subtriangular dark marginal patch below the apex. HW UP basally yellow; annular spot present at apex of discal cell; marginal band broad, brown and evenly curved. FW UN and HW UN ochreous and mottled brown, with a broad irregular, marginal grey brown band; inner margin of HW yellow.

Kanyakumari District locality: Suchindrum.

Distribution: Southern India & Sri Lanka; NW India along the southern edge of the Himalayas, east to southeastern China, Taiwan and southern Ryukyu Islands (Japan: Ishigaki-shima), then south to the Philippines, Sumatra and Java. Apparently absent from Borneo.

Similar species in southern India: none.

Table 1. Location of study sites along with elevation, habitat, and timeline.

	Place	Latitude	Longitude	Elevation in metres	Habitat type	Date
1	Kalikesam	8.4°N	77.383°E	115m	riparian	2011-2014
2	Maramalai	8.45°N	77.4°E	500m	mixed forest/estates	2012, 2015
3	Balamore	8.767°N	77.65°E	459m	wet deciduous & estates	2013
4	Upper Kothayar	8.533°N	77.45°E	950m	evergreen and montane	2012-2014
5	Suchindrum	8.25°N	77.767°E	0m	village near a river	2011-2017

Subtribe: Acosmerygina Tutt, 1904

2. *Acosmeryx akanshi* Melichar, Řezáč, Manjunatha & Horecký, 2014

Diagnosis: FW UP grey, with transverse scalloped antemedial, postmedial and submarginal lines; discal spot inconspicuous; oblique dark band from middle of costa to tornus; outer margin excavated below the apex and again below the apex of vein M1. HW UP dark grey brown, slightly paler over basal half.

Kanyakumari District locality: KKWS, Maramalai. First record for Tamil Nadu

Distribution: Endemic to southern Western Ghats and Sri Lanka.

Similar species in southern India: none.

Subtribe: Choerocampina Grote & Robinson, 1865

3. *Hippotion celerio* (Linnaeus, 1758)

Diagnosis: UP: Ground colour brown green; thorax with a white lateral stripe; abdomen with a pale white dorsal stripe, highlighted with spots on the segmental margins, and a white dorsolateral spot on each segment; FW with an oblique silvery band from the apex to the inner margin, with several more distal oblique brown lines and a whitish submarginal line; veins beyond the discal cell streaked black up to the black discal spot, followed by silvery streaks to the wing base; HW basal and tornal area bright pink; broad black medial and narrow submarginal bands separated by a row of broad pink patches, separated by the veins highlighted in black.

Kanyakumari District locality: Suchindrum.

Distribution: Widespread across the entire Old World tropics and subtropics, migratory into northern temperate regions.

Similar species in southern India: none.

4. *Hippotion rosetta* (Swinhoe, 1892)

Diagnosis: FW UP brown, with a pattern of indistinct, oblique lines across the centre of the wing, the heaviest of which are the basal most, which runs from the costa to the inner margin, and that which runs in from the apex as far as vein M3. HW UP pink with dark brown scaling along the costa and a similar narrow marginal band; tornus cream-buff.

Kanyakumari District locality: KKWS, Maramalai.

Distribution: Widespread is southeastern Asia, from Pakistan east to Taiwan, the southern Ryukyu Islands (Japan) and Palau, then south and east through the Philippines and Sunda Islands, to New Guinea, the Solomon Islands and Queensland (Australia). Also recorded from the Maldives, Cocos-Keeling Islands and the Andaman Islands in the Indian Ocean. Introduced into Hawaii (USA).

Similar species in southern India: *Hippotion boerhaviae* (Fabricius, 1775), from which *H. rosetta* can be distinguished with certainty only by the shape of the juxta of the male genitalia. However, *H. rosetta* is in general less striped and has a slightly shorter forewing than *H. boerhaviae*. *Hippotion rafflesii* (Moore, [1858]) is also similar but has a richer brown ground colour to the FW UP and the tornus of the HW UP is pinkish, rather than the cream-buff of *H. rosetta* and *H. boerhaviae*. *H. boerhaviae* has yet to be recorded from Tamil Nadu but has been reported from other states in southern India.

5. *Hippotion velox* (Fabricius, 1793)

Diagnosis: Head, thorax, abdomen and HW UP dark brown; tegulae edged in cream; abdomen with black dorsal and subdorsal lines with cream/white lateral patches on abdominal segments 5-8. FW UP brown, with a series of oblique pale, slightly waved lines; discal spot black, conspicuous; dark brown spot near the tornus and three dark brown lines extending in from the apex as far as vein M2; fringe chequered cream and brown. HW UP brown, tornus and inner margin paler.

Kanyakumari District locality: Upper Kothayar.

Distribution: South India and Sri Lanka; from Nepal east to Taiwan and the Ryukyu Islands (Japan), then south and east through the Philippines, Sunda Islands, New Guinea, the Solomon Islands and Queensland (Australia) to Vanuatu, New Caledonia, Fiji, Tonga and Tokelau. Also recorded from the Maldives, Cocos-Keeling Islands, the Andaman Islands and Christmas Island in the Indian Ocean.

Similar species in southern India: none.

6. *Theretra castanea* (Moore, 1872)

Diagnosis: Overall ground colour bright reddish-brown to deep chestnut brown. Opening between segment 1 and 2 of the labial palps covered by single long scales. Antennae and legs white. FW UP with an irregular grey marginal band and a black discal spot. HW UP tawny; white fringes between veins CuA_2 and A. FW UN bright rufous with a broad but irregular marginal band.

Kanyakumari District locality: Upper Kothayar.

Distribution: Endemic to the Western Ghats.

Similar species in southern India: none.

7. *Theretra latreillii lucasii* (Walker, 1856)

Diagnosis: UP: Ground colour buff with tinges of olive brown or (when fresh) olive green; markings on abdomen indistinct. Forewings noticeably less elongate

than most other species of the genus. First segment of labial palp with slightly irregular scaling; apical cavity partly concealed by this scaling. FW UP with a series of faint to well-developed oblique lines, the first and fourth stronger than the others; discal spot black. HW UP dark brown. UN: Both pairs of wings with a pinkish tinge of wings; HW with a submarginal row of black spots on the veins.

Kanyakumari District locality: Suchindrum.

Distribution: Southern India and Sri Lanka; Nepal east to eastern China and Taiwan, then south through Burma, SE Asia and the Philippines, to Sumatra, Borneo, Java and the Lesser Sunda Islands. The nominotypical subspecies, *Theretra latreillii latreillii* occurs east from Sulawesi and the Moluccas, through New Guinea, to the Solomon Islands and Australia.

Similar species in southern India: *Theretra clotho clotho* (Drury, 1773) *Theretra gnoma* (Fabricius, 1775) and *Theretra shendurneensis* Sondhi, Kitching, Basu & Kunte, 2017. However, *T. latreillii lucasii* is easily distinguished from these three species by its relatively shorter forewings and the lack of a pair of lateral black spots near the base of the abdomen.

8. *Theretra nessus nessus* (Drury, 1773)

Diagnosis: UP: Head, thorax and centre of abdomen green, fading to brown. Second segment of labial palp strongly triangular in comparison to those of other species in the genus; opening between segments 1 and 2 large. FW UP olive brown with a green band along the costal margin, a pale medial band, a wavy postmedial band and a black discal spot; apex strongly falcate. Abdomen with conspicuous and diagnostic broad, golden yellow lateral stripes. HW UP: base black, with an irregular buff submarginal band. UN: Body and wings russet with a green streak at the base that extends to thorax; FW and HW postmedial bands and lines black, wavy and incomplete and a thin submarginal line extending to the apex.

Kanyakumari District locality: Upper Kothayar; KKWS, Kalikesam.

Distribution: Southern India and Sri Lanka; northwestern India east to Taiwan (migratory into southern Japan), then south through southeastern Asia, the Philippines and Indonesia as far as New Guinea. A second subspecies, *Theretra nessus albata* Fukuda, 2003, occurs east from New Guinea and eastern Australia, through the Solomon Islands, Vanuatu and New Caledonia to Fiji.

Similar species in southern India: none.

9. *Theretra silhetensis silhetensis* (Walker, 1856)

Diagnosis: Upperside of abdomen with a diagnostic single, solid white line. FW UP with a broad, oblique, brown discal band that narrows towards the apex; immediately distal and parallel to this, in the space between the third and fourth postmedial lines, is a narrow silvery line running from near the apex to the inner margin; space between the fourth and fifth postmedial lines beige and broader; fifth postmedial line broader than the sixth; discal spot black.

Kanyakumari District locality: Suchindrum.

Distribution: Southern India and Sri Lanka; NW India east to Taiwan (migratory into southern Japan), then south through southeastern Asia, to Borneo, Sumatra, Java and the Lesser Sunda Islands. A second subspecies, *Theretra silhetensis intersecta* (Butler, [1876]), occurs east from the Philippines and Sulawesi and eastern Australia, through the Solomon Islands, Vanuatu and New Caledonia to Fiji.

Similar species in southern India: *Theretra oldenlandiae oldenlandiae* (Fabricius, 1775). However, *T. silhetensis* is easily distinguished from this species by the single, rather than double, dorsal abdominal line.

Subtribe: Macroglossina Harris, 1839

10. *Angonyx krishna* Eitschberger & Haxaire, 2006

Diagnosis: UP: Head, thorax (except metanotum), abdomen and wings bright green, but fading to brown in old specimens or dead specimens exposed to high humidity; metanotum russet. Labial palps large, obtuse, second segment longer than the first. FW UP with a pink-grey medial band running from the costa to the inner margin; black submarginal spot present between veins M1 and M3, black colour extending to the outer margin; a pale green oblique patch from the base from costal margin to R1(?). HW UP blackish with a pinkish- or orange-grey submarginal band and a thin white band on the margin. UN: Wings russet with a brown submarginal band.

Kanyakumari District locality: KKWS, Maramalai; Kalikesam. First record for Tamil Nadu

Distribution: Endemic to the Western Ghats and Sri Lanka.

Similar species in southern India: none.

11. *Daphnis nerii* (Linnaeus, 1758)

Diagnosis: UP: Ground colour bright green, with wavy bands of grey and pink, but often fading to brown in old specimens or dead specimens exposed to high humidity. Head rufous in front, green behind, with a grey band on vertex; thorax green; patagia grey posteriorly; abdomen

Image 1a. *Neogurelca hyas* - UN

Image 1b. *Neogurelca hyas* - UP

Image 2. *Acosmeryx akanshi*

Image 3. *Hippotion celerio*

Image 4. *Hippotion rosetta*

Image 5. *Hippotion velox*

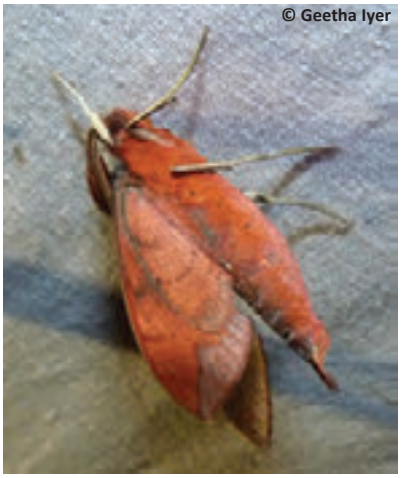

Image 6a. *Theretra castanea* - UN

Image 6b. *Theretra castanea*

Image 7. *Theretra latreillii lucasii*

Image 8. *Theretra nessus nessus*

Image 9. *Theretra silhetensis silhetensis*

Image 10. *Angonyx krishna*

pale green with dark green lateral oblique stripes. FW with a conspicuous small green spot surrounded by a paler halo; basal patch solid green; antemedial line closer to basal patch than to the proximal edge of the medial green area; green and pink oblique bands from costa to M3 and an oblique streak from apex to M1. HW UP greenish, with brown scaling along the costa and a thin white postmedial line. FW and HW UN with a strong pale postmedial line bordered distally by an orange band.

Kanyakumari District locality: Suchindrum.

Distribution: Widespread across the entire Old World tropics and subtropics, migratory into northern temperate regions

Similar species in southern India: *Daphnis hypothous crameri*. However, *D. nerii* is readily distinguished from *D. hypothous* by its brighter green ground coloration and the lack of a conspicuous white spot near the apex of the forewing upperside.

12. *Daphnis hypothous crameri* Eitschberger & Melichar, 2010

Diagnosis: UP: Ground colour dark olive-green. Head and patagia dark purple brown; thorax pale grey; tegulae and first two abdominal segments dark green, the remaining segments dark olive brown, with the streaks and spots as in *D. nerii*. FW UP ground colour dark olive green; pattern elements similar to those of *D. nerii* but with a conspicuous white apical spot (visible also on the underside). FW and HW UN postmedial line inconspicuous and often diffuse and incomplete.

Kanyakumari District locality: KKWS, Maramalai.

Distribution: Southern India and Sri Lanka; NW India east to Taiwan (migratory into southern Japan), then south through southeastern Asia, the Philippines, Borneo and Sulawesi, to Sumatra, Java and the Lesser Sunda Islands. The nominotypical subspecies, *Daphnis hypothous hypothous* (Cramer, 1780) occurs in the Moluccas.

Similar species in southern India: *Daphnis nerii*. However, *D. hypothous crameri* is readily distinguished from *D. nerii* by its darker, olive green ground coloration and the presence of a conspicuous white spot near the apex of the forewing upperside.

13. *Macroglossum assimilis* Swainson, 1821

Diagnosis: UP: Overall ground colour brown and grey. Abdomen with orange yellow lateral patches on segment 2-4 and dark brown lateral patches on segments 5 and 6. FW UP flushed with grey medial and submarginal bands, antemedial and postmedial bands dark brown; antemedial band broadening from costa to inner margin; conspicuous and diagnostic dark brown or black ovate spot apically between veins Rs4 and M1; the grey costal area on its proximal side not sharply limited posteriorly but continuous with the grey submarginal area. HW upperside orange-yellow with a dark brown/black base and broad marginal band. FW and HW UN ground colour brown, greyish towards the base; HW inner margin with a sharply delimited chrome yellow patch.

Kanyakumari District locality: KKWS, Maramalai.

Distribution: Endemic to southern India and Sri Lanka.

Similar species in southern India: *Macroglossum belis*, from which *M. assimilis* differs primarily in the more conspicuous dark brown or black spot near the apex of the forewing upperside.

14. *Macroglossum belis* (Linnaeus, 1758)

Diagnosis: UP: Head, thorax and abdomen brown with tinges of red. Labial palps dirty white. Abdomen with orange yellow lateral marks segments 2-4; dark brown/black patches laterally on segment 5, dorso-laterally on segment 6 and mesally on segment 7; lateral white tufts on distal segments. FW UP: antemedial band narrowing slightly towards the costa; postmedial lines converging slightly on the costa and diverging slightly on the inner margin; subapical brown spot between veins Rs4 and M1 not prominent and proximal grey patch sharply delimited by vein M1. HW UP: orange-yellow medially, with a dark brown basal patch and a dark brown marginal band. UN: Labial palps, head and thorax dirty white; legs and abdomen brown; FW and HW UN ground colour brown (slightly darker than in *M. assimilis*), greyish towards the base; HW inner margin with a sharply delimited chrome yellow patch.

Kanyakumari District locality: KKWS, Maramalai.

Distribution: Pakistan, east through the southern Himalaya to southeastern China, then south to Thailand, Cambodia and Vietnam. Records from Sumatra, Java, Taiwan and the Ryukyu Islands remain to be confirmed.

Similar species in southern India: *Macroglossum assimilis*. from which *M. belis* differs primarily in the inconspicuous (or absent) brown near the apex of the forewing upperside.

15. *Macroglossum gyrans* Walker, 1856

Diagnosis: UP: Head, thorax, and basal half of abdomen and forewing grey-brown; metanotum tawny laterally. Abdominal segments 2-4 with three large confluent orange patches; white patch with a black central spot on the base of segment 7. FW grey; paired

antemedial and postmedial lines with spaces between them ground colour; postmedial lines sinuate, strongly directed distally between veins M1 and M3. HW orange, with a brown marginal band, one merging gradually into the other. UN: Labial palps, head, thorax, and legs, except tarsomeres, pure white, this coloration extending onto the first three abdominal segments; laterally, thorax and legs brown; abdomen a mix of white and brown scaling, with white lateral tufts on segment 4. FW and HW UN grey brown; basal half of FW tinged with orange; HW inner margin with a chrome yellow patch that gradually becomes orange then brown distally.

Kanyakumari District locality: Suchindrum. First record for Kanyakumari District and Tamil Nadu.

Distribution: From the Maldives and India, east to Thailand, Laos and Vietnam; also reported from Borneo, Java, the Lesser Sunda Islands and Sulawesi.

Similar species in southern India: *Macroglossum affictitia* Butler, 1875, from which *M. gyrans* differs in the brownish (rather than orange) medial band of the hindwing with a diffuse outer edge.

Tribe Macroglossini Harris, 1839

Subtribe: Clarinina Tutt, 1904

16. *Enpinanga assamensis* (Walker, 1856)

Diagnosis: Strongly sexually dimorphic. Male UP: Head, thorax, abdomen and wings pale greyish-brown. A pair of divergent, broad, dark-brown stripes from the head to the tegulae, continuing as paler patches to abdominal segment 2. FW strongly excavated below the apex, outer margin sinuate from vein M3 to tornus. FW UP with a small black basal spot followed by two faint antemedial lines; four contiguous black patches from vein CuA_1 to costa at end of discal cell; postmedial band pale brown, running from inner edge to M2, gradually fading. HW mostly uniformly dark brown, with an indistinct orange buff medial band across wing from near tornus to vein Rs. UN: Body and legs pinkish-grey; small patches of pinkish-orange enclosing a yellow-white spot on abdominal segments 4-8 and white tufts apically. FW and HW UN mostly pinkish-orange; postmedial lines mostly faint, strongest between vein M1 and costa on; marginal bands on both wings greyish-brown, inner edges highlighted in brown (more strongly on the FW than the HW), that on the FW with a median pale grey band.

Female (not yet observed in southern India): UP: ground colour brown; pair of divergent, broad, dark brown stripes from the head to the tegulae, continuing as paler patches to abdominal segment 2, as in male but much less conspicuous against the darker ground colour. FW outer margin less strongly sinuate than the male. FW UP lacking the four dark brown patches of the male, instead with a conspicuous dark brown discal spot and narrow medial band. HW UP: orange suffused with brown scales; marginal band brown. FW and HW undersides similar to the male but brighter orange with few scattered brown scales.

Kanyakumari District locality: KKWS, Kalikesam. First record for Tamil Nadu.

Distribution: Southern India; NE India and Bangladesh, east through Thailand, Laos and Vietnam, to SE China; also, the Andaman Islands. A new record for southern India and a range extension for the species. However, it remains to be critically determined whether this population is conspecific with *E. assamensis* from elsewhere or a separate species, a study that cannot be undertaken in the absence of voucher specimens.

Similar species in southern India: none.

Subfamily Smerinthinae Grote & Robinson, 1865

Tribe Ambulycini Butler, 1876

17. *Ambulyx matti* (Jordan, 1923)

Diagnosis: UP: Tawny coloured moth with long wings. Labial palps, foretibiae and foretarsi yellow. Outer edges of tegulae and metathorax laterally dark chocolate brown. Abdomen with a distinct brown longitudinal dorsal line. FW: inner margin shallowly excavated before the tornus. FW UP: a small circular spot and a prominent dark brown spot on the costa subbasally; a diffuse black patch near the tornus; antemedial and postmedial lines indistinct; veins distal to discal spot highlighted in dark brown; submarginal line dark brown with an indistinct yellowish inner edge. HW UP yellow with a diffuse black basal patch and blackish-brown antemedial, postmedial and submarginal lines extending from inner margin to costa.

Kanyakumari District locality: KKWS, Maramalai. First record for Tamil Nadu.

Distribution: Endemic to the Western Ghats.

Similar species in southern India: *Ambulyx auripennis* Moore, 1879, *Ambulyx belli* (Jordan, 1923) and *Ambulyx substrigilis aglaia* (Jordan, 1923). *Ambulyx matti* differs from *A. belli* in the presence of a strong brown dorsal line along the abdomen (very faint or absent in *A. belli*) and from *A. auripennis* and *A. substrigilis aglaia* in the presence of a conspicuous dark brown spot on the costa near the base on the forewing upperside. However, these features are rather individually variable, and dissection of the male genitalia and DNA barcoding is

advised for confirmation of identifications in this difficult genus.

18. *Amplypterus panopus karnatakaensis* Melichar & Řezáč, [2014]

Diagnosis: UP: Head and thorax chocolate brown, anterior half of abdomen pale grey, distal half brown with paired subdorsal greyish patches. FW UP: Basal area chocolate brown with two narrow, zigzag basal lines and a broader, more even subbasal band; middle part of the wing pale grey with a purplish tinge; postmedial line narrow, chocolate brown, straight; rudimentary eye-spot pattern at the tornus. When at rest, the basal lines are continuous across with the dark posterior margin of the thorax, and the postmedial lines are continuous with the dividing line across the abdomen. The effect is to cut the moth into three parts with straight lines and is effective camouflage among leaves. HW UP medially pink, distal to which are narrow dark brown postmedial and submarginal lines and a brown marginal band, all crossed by dark brown highlights along the veins. FW and HW UN mostly pale yellow (FW distally orange) with irregular pale grey brown bands and spots.

Kanyakumari District locality: Upper Kothayar. First record for Tamil Nadu.

Distribution: Endemic to the Western Ghats. Other subspecies occur from NW India, east to SE China, the Philippines, Timor and the Moluccas.

Similar species in southern India: none.

Tribe Sichiini Tutt, 1902

19. *Marumba dyras dyras* (Walker, 1856)

Diagnosis: UP: Body and wings pale greyish-brown, with a darker brown dorsal line running from the head to the tip of the abdomen; FW outer margins strongly scalloped. FW UP: Wing crossed by 10 narrow brown transverse lines, representing the subbasal (1), antemedial (4), postmedial (2) and submarginal (3) bands. The antemedial lines converge towards the inner edge and may meet before or on the edge or not meet, this being individually variable. Two dark brown spots near the tornus, one anterior and more basal than the other, which is on the inner margin; the submarginal lines converge distal to these spots and then are sharply reflexed back and around each side of the spots. HW UP: Ground colour orange brown, tornal pale grey, containing two dark brown spots. UN: Body rusty brown. FW UN: marginal area darker than the rest of the wing with a few indistinct lines and an orange patch at the tornus. HW UN: pinkish-brown, with two postmedial and two submarginal dark brown lines; tornus with an orange patch similar to that on the FW.

Kanyakumari District locality: Upper Kothayar; KKWS, Maramalai; Kalikesam.

Distribution: Southern India and Sri Lanka; northern Pakistan and northwestern India, east to eastern China and Taiwan, then south through southeastern Asia and Borneo, to Sumatra and Java.

Similar species in southern India: none.

20. *Marumba nympha* Rothschild & Jordan, 1903

Diagnosis: UP: Body and wings orange-brown, with a lilac flush on the thorax and FW; labial palps, uppersides of legs and antenna brownish black; black mesial line on head and thorax; thorax crested. FW UP: Transverse lines and bands as in *M. dyras* but much less conspicuous; areas between these bands flushed with lilac; dark brown tornal spots small, edged in lilac. HW UP: Ground colour similar to the FW but slightly greyish and lacking the lilac flush except near the tornus around the dark brown spots. UN: Head dark brown; thorax and abdomen orange. FW and HW UN: Similar in ground colour to upperside but flushed with pink, particularly on the body and HW.

Kanyakumari District locality: Upper Kothayar.

Distribution: Endemic to the Western Ghats.

Similar species in southern India: none.

Subfamily Sphinginae Latreille, [1802]

Tribe Sphingini Latreille, [1802]

Subtribe "*Psilogramma* genus-group"

21. *Psilogramma vates* (Butler, 1875)

Diagnosis: UP: Ground colour of head, thorax, abdomen and FW pale grey; outer edges of tegulae and metathorax laterally and posteriorly dark brown/black, the latter with a yellowish anterior margin and two small lateral pale blue patches; abdomen with a dorsal and two lateral, black longitudinal stripes that fade out by the sixth and seventh segments respectively. FW UP: Subbasal, antemedial, postmedial and submarginal bands generally represented by short, dark brown lines that extend across the wing no further than the discal cell; two short, longitudinal stripes below the discal cell between veins M3 and CuA_1 and CuA_1 and CuA_2; a black zigzagged streak extending in from the apex as far as the submarginal line. Occasionally, the entire area between the antemedial and submarginal lines may be filled in black. HW UP uniformly brown, except for some pale grey scaling at the tornus. Fringes of both wings chequered black and white. UN: Abdomen pure white, with only slight brownish colour on segments 5-8.

Image 11. *Daphnis nerii*

Image 12. *Daphnis hypothous crameri*

Image 13. *Macroglossum assimilis*

Image 14. *Macroglossum belis*

Image 15a. *Macroglossum gyrans* showing HW

Image 15b. *Macroglossum gyrans*

Image 16. *Enpinanga assamensis*

Image 17. *Ambulyx matti*

Image 18. *Amplypterus panopus karnataka-ensis*

Image 19. *Marumba dyras*

Image 20. *Marumba nympha*

Image 21. *Psilogramma vates*

Kanyakumari District locality: KKWS, Kalikesam. First record for Tamil Nadu.

Distribution: Sri Lanka and the Western Ghats, north to Maharashtra; also, N and NW Pakistan.

Similar species in southern India: *Psilogramma renneri*, from which *P. vates* differs in its generally smaller size, overall grey ground colour to the forewing upperside and pure white underside to the abdomen.

22. *Psilogramma renneri* Eitschberger, 2001

Diagnosis: UP: Similar in pattern to *P. vates* but ground colour dark brown with grey brown elements replacing the pale grey (the degree of development of which is subject to much individual variation); in particular, in most specimens the triangle between the outer antemedial line, the inner postmedial line and vein CuA_2 is much darker than the surrounding areas and as a result, the pale discal spot is very prominent. UN: Abdomen with scattered brown scales on all segments, rendering it a rather dirty brown-white overall.

Kanyakumari District locality: KKWS, Kalikesam. First record for Tamil Nadu.

Distribution: Endemic to the Western Ghats and Sri Lanka.

Similar species in southern India: *Psilogramma vates*, from which *P. renneri* differs in its generally larger size, overall brown ground colour to the forewing upperside and a brownish suffusion of scales on the underside of the abdomen.

Subtribe: Acherontiina Boisduval, [1875]

23. *Acherontia styx* Westwood, 1847

Diagnosis: UP: Head brown; thorax pale brown with grey shades and a pair of black dots centrally; tegulae dark blue- grey with a longitudinal dark brown line medially and the inner edge highlighted in dark brown. Together these form the characteristic "skull mark" of *Acherontia* species, hence the common name of 'Death's head hawkmoths'. Abdomen yellow with black bands on segments and a blue-grey dorsal band. FW UP: brown and grey, with three discontinuous antemedial lines and two curved postmedial lines. HW UP: yellow with a narrow black postmedial and submarginal band, neither of which reach the costa or inner margin.

Kanyakumari District locality: Upper Kothayar.

Distribution: From Syria, Jordan and western Saudi Arabia, east to the Korean Peninsula and Japan (migratory into Manchuria and the Russian Far East), the Philippines, Sulawesi and Timor

Similar species in southern India: *Acherontia lachesis*, from which *A. styx* differs in its generally smaller size, yellow base to the hindwing upperside and lack of red scaling below the "skull-mark" on the thorax.

24. *Acherontia lachesis* (Fabricius, 1798)

Diagnosis: Larger and darker than *A. styx*. UP: Metathorax, posterior margin of mesothorax and edges of the "skull mark" with red hairs; "skull mark" more contrastingly patterned, with a longitudinal median yellow line and yellow surrounds to the pair of dark spots. Abdomen predominantly dark brown/grey with thick black segmental bands; medial blue grey band and yellow lateral patches greatly reduced. HW UP: Yellow coloration greatly reduced by the dark brown basal patch and the broad medial and postmedial bands.

Kanyakumari District locality: Upper Kothayar.

Distribution: Pakistan, east to Japan, Taiwan, the Philippines, New Guinea and the Bismarck Archipelago. Also recorded from the oceanic island groups of Chichijima, Palau and the Chagos Archipelago, with a single record from Socotra.

Similar species in southern India: *Acherontia styx*, from which *A. lachesis* differs in its generally larger size, black base to the hindwing upperside and presence of red scaling below the "skull-mark" on the thorax.

25. *Agrius convolvuli* (Linnaeus, 1758)

Diagnosis: Sexually dimorphic grey moth. UP: Abdomen with a broad grey, dorsal band and a thin darker central line, segment 1 with lateral black patches, those on segments 2-6 anteriorly dirty pink and posteriorly black. FW UP: in male, light to dark grey with extensive contrasting dark grey and brown markings; in female, uniformly pale grey, with few or no contrasting markings. HW UP ground colour pale grey with brown antemedial, (double) postmedial and submarginal bands.

Kanyakumari District locality: Upper Kothayar.

Distribution: Widespread across the entire Old World tropics and subtropics, migratory into northern temperate regions.

Similar species in southern India: none.

26. *Megacorma obliqua obliqua* (Walker, 1856)

Diagnosis: Proboscis longer than the body. Labial palp structure distinctive: apex of segment 1 with a large cavity, segment 2 shorter than segment 1, triangular and narrow at the base. Thorax very long, more than half length of the abdomen. FW with outer and inner margins strongly excavate before tornus, making the tornal angle more produced. FW UP: Ground colour pale grey/white; a dark brown/black line crossing the wing

Image 22. *Psilogramma renneri*

Image 23. *Acherontia styx*

Image 24. *Acherontia lachesis*

Image 25. *Agrius convolvuli Female*

Image 26. *Megacorma obliqua obliqua*

Image 27. *Dolbina manjunatha*

from the costa to the outer margin above the tornus; the area between this and the postmedial band pale brown. HW UP: Brown, marginal area either side of the tornus pale grey.

Kanyakumari District locality: Upper Kothayar. First record for Tamil Nadu.

Distribution: Southern India and Sri Lanka; NE India and Bangladesh, east to the Philippines, Borneo and Java; also, the Moluccas and New Guinea. Replaced by other subspecies in Sulawesi, the Bismarck Archipelago and the Solomon Islands.

Similar species in southern India: none.

Tribe Sphingulini Rothschild & Jordan, 1903

27. *Dolbina manjunatha* Haxaire & Melichar, 2013

Diagnosis: UP: Head, thorax and abdomen dark brown. Thorax with a 'skull mark' (though not as conspicuous as that of the *Acherontia* species due to the much darker and more uniform coloration). Fore tibia without an apical thorn. Abdomen with a dark brown central line as far as segment 7, bisected by a transverse brown black band at the posterior margin of each segment that has a small white central spot. FW UP: ground colour dark brown, with a complex pattern of zigzag transverse black and pale grey lines. UN: ground colour dirty white, abdominal segments 2-6 with large median brown patches, posterior segments all brown. FW & HW UN: anthracite grey; transverse pattern elements extremely inconspicuous or absent.

Kanyakumari District locality: KKWS, Maramalai. First record for Tamil Nadu.

Distribution: Endemic to the Western Ghats.

Similar species in southern India: none.

Conclusion

The present survey reports on 27 species of hawkmoths, all new records for Kanyakumari District, of which nine are also new records for the state of Tamil Nadu. Although the survey was conducted opportunistically over a relatively short time period, this nevertheless clearly indicates that the district has appropriate habitats- not only in forests but also in villages and other anthropogenic environments - where hawkmoth diversity can thrive. A more thorough survey for longer periods of time throughout the year is likely to reveal the presence of not only greater diversity but also endemism. It is hoped that the results of the present study will encourage conservation activities to save the diverse habitats in Kanyakumari District.

Species in the collection of the Natural History Museum, UK, collected in the erstwhile Travancore State that are likely to be found in the Kanyakumari region. Names in parentheses are the collectors of the specimens.

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Appendix 1. Species from the collection of the Natural History Museum UK, collected from the erstwhile Travancore State and likely to be found in the Kanyakumari District.

1. *Theretra gnoma* (Fabricius, 1775): Travancore (Place)
2. *Theretra lycetus* (Cramer, 1775): Travancore (Place)
3. *Theretra oldenlandiae oldenlandiae* (Fabricius, 1775): Travancore (Place)
4. *Pergesa acteus* (Cramer, 1779): Travancore
5. *Macroglossum divergens heliophila* Boisduval, [1875]: Travancore (Place)
6. *Macroglossum mitchellii imperator* Butler, 1875: Travancore, 1932 (C. Rowson)
7. *Leucophlebia lineata* Westwood, 1847: Travancore (Place); Travancore, Peermaade; Travancore, Peermaade (Mrs Imray); Travancore, Pirmad (R.S. Imray)

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SHORT COMMUNICATION

Calamus pseudoerectus (Arecaceae), a new species from the eastern Himalaya, India

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Abstract: *Calamus pseudoerectus* (Arecaceae or Palmae), a new species of rattan from the hilly slopes of Mukti and Mahananda rivers at Darjeeling District of West Bengal in the eastern Indian Himalaya, is described and illustrated. This species closely resembles two Indo-Myanmar species, *C. erectus* Roxb. and *C. arborescence* Griff. It, however, is distinguished by its short and extremely slender stem, spine ornamentation, pendulous, long-branched inflorescence, and minute fruits with fimbriate scales. A comparative study among *C. pseudoerectus* sp. nov., *C. erectus* Roxb., and *C. arborescence* Griff. is provided. Conservation status of this species is proposed as Endangered (EN) as per IUCN.

Keywords: *Calamus arborescence*, *Calamus erectus*, new taxa, Palmae, Rattans.

Calamus L. is the largest genus of the family Arecaceae (Palmae) with about 520 species worldwide, mostly distributed in the Asia-Pacific region and Africa (Dransfield et al. 2008; Baker 2015; Baker & Dransfield 2016). The spiny climbing and non-climbing rattans, the source of the commercial rattan cane, are distributed from tropical Africa, India to Fiji, southern China through Malay Archipelago to northern Australia (Baker & Dransfield 2014). *Calamus* is most species-rich in the southeastern region of Asia, with 183 species occurring across the Malay Peninsula, Philippines, Borneo, Sumatra, and Java (Baker & Couvreur 2012; Govaerts et al. 2013) and 52 species recognized from New Guinea (Baker et al. 2002; Baker & Dransfield 2006). Baker & Dransfield (2014) added 14 more species of *Calamus* from New Guinea. The lower hills of the eastern Himalaya and the Terai parts are quite rich in *Calamus* species, with 28 species reported from China (Pei et al. 1991), seven from Bangladesh (Alam 1990), eight from Bhutan (Noltie 1994), and nine from Nepal (Paudel & Chowdhary 2005). In India, Beccari (1894) reported 72 species of *Calamus* from undivided British India for the first time; presently, around 36 species and three varieties of *Calamus* are recorded from various parts of the Himalaya, Western Ghats, and the Andaman & Nicobar Islands (Basu & Basu 1987; Renuka 1987; Basu 1992). A total of 18 species of the genus *Calamus* L., *Plectocomia* Mart. ex. Bl., and *Daemonorops* Bl. were reported from various altitudes of West Bengal (Mondal & Chowdhury 2018). During exploration of palms and canes in the various lower hills and riverine forests along small streams ('khola') and rivers of the Darjeeling Himalaya, a few interesting specimens of *Calamus* were collected from Muktikhola (26^{0}49'26"N & 88^{0}13'22"E, 822m) and Choklong riverine

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forests (26°51'42"N & 88°21'45"E, 609m) of Mahananda Wildlife Sanctuary on the hillslopes of the Mukti and Mahananda rivers, respectively. After extensive morphologic comparisons in key herbaria (Herbarium, BSI, Central National Herbarium (CAL), Hebarium, BSI, Eastern Regional Centre, Shillong (ASSAM), Herbarium, BSI, Sikkim Himalya Regional Center, Gangtok (BSHC), and Herbarium, University of North Bengal (NBU), matching with some digital herbarium of Herbarium, Royal Botanical Garden, Kew (K), Herbarium, National Taiwan University (TAI) Herbarium, Royal Botanical Garden, Edinburgh (E), and extensive literature search (Renuka 1987; Alam 1990; Pei et al. 1991; Basu 1992; Noltie 1994; Paudel & Chowdhary 2005; Baker & Couvreur 2012; Govaerts et al. 2013; Baker & Dransfield 2014), it was found that it is a new species for science. The new taxon is carefully described and illustrated and a comparison of diagnostic morphologic characters with two allied Indian species, *C. erectus* Roxb. (Hort. Bengal. 72. 1814) and *C. arborescence* Griff. (Calcutta J. Nat. Hist. 5.33.1845), are presented (Table 1). Of the 36 species in India, two species, *C. erectus* and *C. arborescence*, are completely different from the others in respect of lack of knee, cirrus, and flagella. Similar character-bearing species from southeastern Asia are *C. acaulis* A.J. Hend., N.K. Ban & N.Q. Dung from Vietnam and *C. oxycarpus* Becc., *C. macrorhynchus* Burret, *C. erectus* Roxb., and *C. dianbaiensis* C.F. Wei from China. The new species is close to this group and lacks knee, cirrus, and flagella.

Taxonomic treatments

Calamus pseudoerectus sp. nov.

S. Mondal, S.K. Basu & M. Chowdhury,
Betgara, Otla bet [Nepali] (Image 1; Fig. 1).

Similar to *Calamus erectus* Roxb. and *C. arborescence* Griff. in respect of having similar types of ocrea and devoid of knee, flagella, and cirri, but distinct by big, branched inflorescence, minute and scattered spines, and very small fruits with fimbriate fan-shaped scales. It further differs by having scattered spines on leaf sheath and rachis, while in *C. erectus* and *C. arborescence*, spines are clustered and whorled. It is further characterized by pendulous big inflorescence, sheath with white and brownish-black powdery dust, conspicuous ocrea, oblong fruits, 5mm × 1mm, brown.

Holotype: 10044 (CAL), 08.ii.2018, India, West Bengal, Darjeeling District, Muktikhola hillslopes, 26°49'26"N & 88°13'22"E , 822m, coll. S. Mondal & M. Chowdhury.

Isotype: Calcutta University Herbarium (CUH), NBU (10044).

Cluster-forming rattan, erect up to 11m long. Stem solid, with sheaths 18–20 cm diameter, without sheaths 12–13.5 cm diameter; internodes 5–9.8 cm long, 12.1–13.2 cm diameter. Leaf ecirrate, 1.56–3.37 m long; flagella absent; sheath blackish-brown, caducous scales, sparsely variable sized blackish-brown armed with minute and few long flat spines along zone of adnation between inflorescence and sheath; knee absent; petiole 1–1.2 m long, young petiole with white powdery dust, mature petiole base with dense brown dust, covered with irregular small spines, base flat, leaf sheath closed with spongy, thick sheath fibers on both edges; leaflets 38–43 on each side of rachis; rachis 1.3–1.8 m long; glabrous, rarely spines on both edges, leaflets linear-ensiform, 41–75 cm × 2.1–4.1 cm, leaflets alternate in equidistance at base and terminal part, but opposite at middle; green beneath, narrowly elliptic to linear, mid leaflets 71–76.5 cm × 4.8–5.6 cm; apical leaflets 39.6–41.8 cm × 1.6–2.1 cm, apical leaflet scarcely united at base; fine spines 3–6 mm long, on major veins of both abaxial and adaxial surfaces; inflorescences long, looping, 2.10–2.40 m long, non-flagelliform, branched to 1 order, one pistillate and one staminate flower lies in each node; pistillate flowers deeply embedded on rachis node, sterile staminate flowers lies at base of pistillate flowers; prophyll strictly tubular, 14–32 cm × 4.8–3.1 cm tightly sheathing, opening asymmetrically at apex, with brown indumentums similar to that of the sheath, very sparsely armed with minute recurved spines, sometimes with fine bristles around bract opening; peduncular bracts one or two, peduncular up to 1.12m long, 1.3cm diameter, with irregular spine on margin and adaxial surface, rachis bract 5.6–14.4 cm × 3.3–5.2 cm, similar to prophylls; primary branches (rachillae) 25.6–134.2 cm apart, rachillae 2–3 at each nodes; rachillae alternate, straight, 10.3–27.6 mm × 1.6–2.5 mm; rachilla bracts 1.3–1.6 cm × 2.3–2.8 cm, similar to prophylls; floral bracteoles tubular, 0.7–1.4 cm × 1.8–2.5 cm, asymmetrically opened; pistillate flowers oval, 0.6–0.4 cm × 0.4–0.5 cm, sessile, lacking indumentums; calyx 0.4cm diameter, connate at base, three-lobed; lobes 0.6cm × 0.4cm; corollatubular at base, 0.4–1.1 cm × 1.6cm long, tip three-lobed; lobes triangular, 0.6mm long; ovary globose; stigma three, prominent; sterile staminate flower narrow, 0.7cm × 0.3cm, solitary, sessile, attached at base of pistillate flowers, calyx 0.4cm diameter, connate at base, three-lobed; lobes 0.6cm × 0.4cm; tubular at base, corolla 0.4–1.1 cm × 1.6cm, tip three-lobed; lobes triangle, 0.6cm long; sterile stamens six; separate fertile male plants not seen. Fruits very

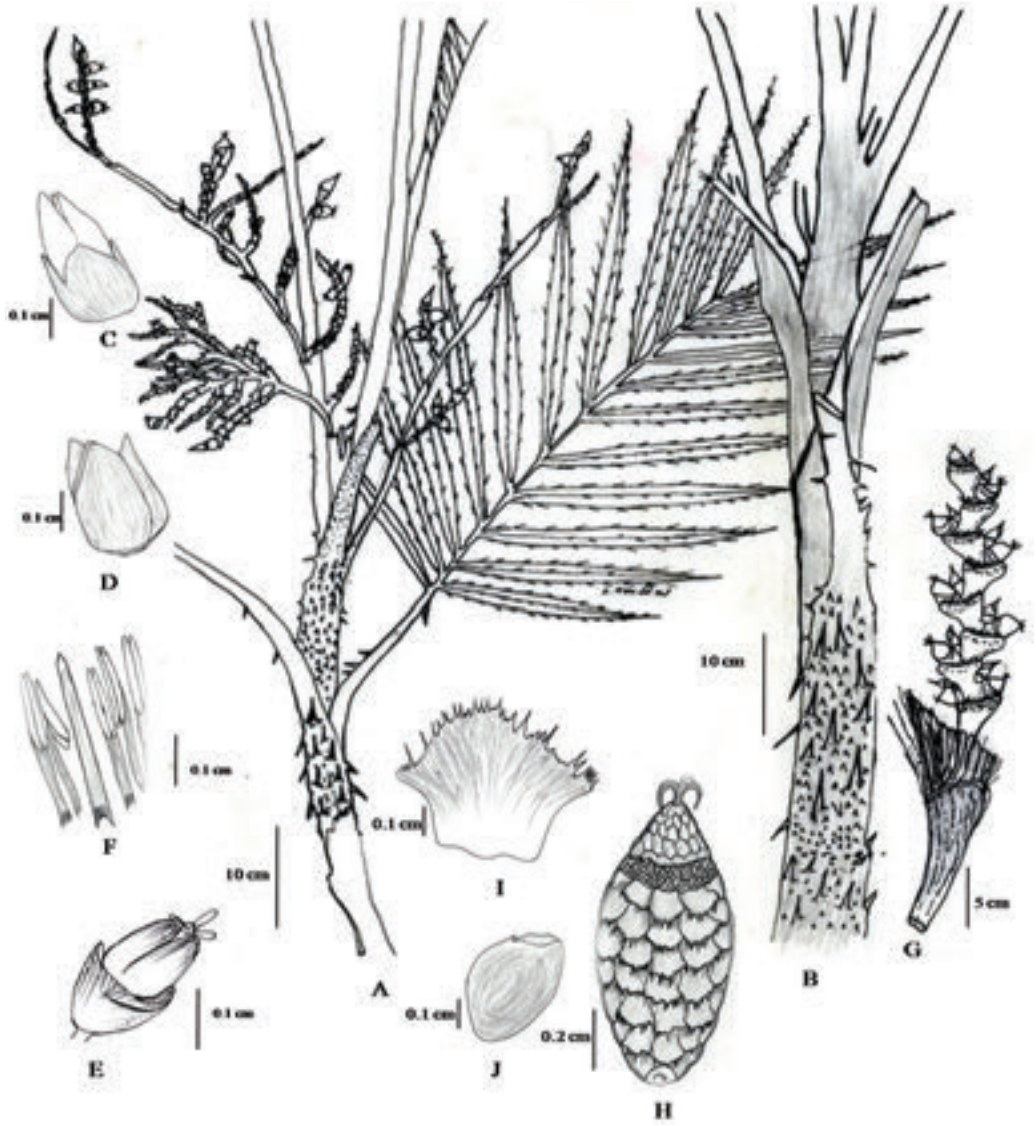

Figure 1. ***Calamus pseudoerectus*** **sp. nov.: A, B - habit with leaf sheaths, leaves, and inflorescence | C - sterile staminate flower | D - calyx | E - pistillate flowers | F - sterile stamens | G - rachilla with female and sterile male flower | H - mature fruit | I - scales | J - seed. © Sujit Mondal.**

small, ellipsoid, 0.7–0.8 mm × 0.3–0.4 mm, rusty brown, with three distinct stigmatic projection, 0.1–0.2 mm long, covered with longitudinal rows of scales, reddish brown, 0.4–0.8 mm × 0.3–0.5 mm, scales not regular, fan-shaped, margins fimbriate, arranged in nine rows; one-seeded. Seeds oblong, 0.5cm × 0.1cm, brown.

Phenology: Flowering: December–February; Fruiting: February–May.

Distribution: India (West Bengal, Darjeeling District).

Habitat: Hill slopes of riverine forests at lower hills, associated with bushes of *Lantana camara* L., *Mikania micrantha* Kunth, *Pandanus nepalensis* H. St. John, *Curcuma aromatica* Salisb., *Alstonia neriifolia* D. Don, and *Wallichia caryotoides* Roxb.

Uses: Leaves are used as thatch; local peoples use fruits for diabetes.

Etymology: The specific epithet is given as the new species is quite closer to the Indian rattan *C. erectus*.

Additional specimen examined (paratypes): 10212 (NBU), one specimen collected on 12.iv.2018, West Bengal, Darjeeling District, Shivkhola hillslopes, 26^{0}51’42”N & 88^{0}21’45”E , 609m, coll. S. Mondal & M. Chowdhury.

Notes: This species was discovered from the lower hills of Darjeeling District of India around 16km away from Siliguri City. *Calamus pseudoerectus* is presently known from four populations in the lower hill forests of Darjeeling District of West Bengal in the eastern Himalaya. Three populations were found at Murtikhola and one population at Shivkhola area of Mahananda WS.

Table 1. Morphologic comparison among *Calamus erectus* Roxb., *C. arborescens* Griff., and *C. pseudoerectus* sp. nov.

Characters	*Calamus erectus* Roxb.	*Calamus arborescens* Griff.	*Calamus pseudoerectus* sp. nov.
Sheath	With yellow powdery dust	Powdery dust absent	Whitish at young and blackish-brown powdery dust, sparsely variable sized armed or spines
Spines	Dense, in oblique rows	Dense, in oblique rows	
Pattern	Comb-like, whorl, dense	Comb-like, whorl	
Size (cm)	4–7	1–4	2–3
Colour	Yellow	Black	Blackish-brown
Rachis			
Size (m)	3–3.5	2–2.5	1.3–1.8
Spine type	Dense long spines	Dense long spines	Glabrous or rarely spines
Pattern	Spine 1–2 or whorled, comb-like	Whorled, comb-like	Rarely on both edge
Petiole			
Size (m)	0.5–1.5	0.5–1.5	0.5–1.2
Spines	Whorled, comb-like	Whorled, comb-like	Single, rarely on edge
Leaves			
Leaflets	25–40	25–39	38–43
Number (pair)	60–80 × 3.5–5	80–100 × 5–6	41–75 × 2.1–4.1
Size (cm)	Leaflets alternate in equidistance, green beneath	Leaflets opposite in equidistance, white beneath	Leaflets alternate in equidistance at base and terminal part, but opposite at middle; green beneath
Arrangement			
Terminal leaflets	Joined at half of their length	Joined at half of their length	Joined at one-fourth of their length
Prophyll	Tubular, short	Tubular, very long	Tubular, long
Sizes (cm)	7–10	20–30	14–32
Type	Uniform, upper parts soft, lacerate	Uniform, lacerate above	Opening wider, upper parts fibrous,
Colour	Green	Green	Whitish-greenish-brown
Spines	Thickly	Thickly	Absent
Texture	Papery, tattering apices	Papery, tattering apices	Leathery, strong
Inflorescence	Short, round	Pendulous, compressed	Pendulous, compressed
Size (m)	1–2	1.6–2	2.10–2.40
Peduncle	Round, strongly armed with black comb-like spines	Compressed, strongly armed with black comb-like spines	Compressed, pedicle unarmed, smooth
Rachillae	Rachillae 1 at each node, female flower rarely with sterile male flower	Rachillae 1 at each node, female flower rarely with sterile male flower	Rachillae 2–3 at each node, each female and sterile male flower together in each node throughout
Pistilate flowers			
Stigma	Deciduous	Deciduous	Persistent
Fruit	Big	Big	Very small
Shape	Ovoid-ellipsoid	Obovoid-ellipsoid	Ellipsoid
Size (cm)	3–5 × 2–2.5	2–2.2 × 0.5–0.7	0.7–0.8 × 0.3–0.4
Colour	Brown	Brown	Rusty brown
Stigmatic projection	Absent	Absent	Present
Scales			
Shape	Boat-shaped	Boat-shaped	Fan-shaped
Size (mm)	6–7 × 9–11	6–7 × 9–11	0.4–0.8 × 0.3–0.5
Margin	Brown, entire	Reddish, entire	Reddish-brown, fimbriate
Vertical rows	12	12	9
Seed			
Size (cm)	Big, 2.7 x 1.3	Big, 1.2 x 0.6	Small, 0.5 x 0.1
Colour	Yellow	Yellow	Brown

Each population is with an average of 10–15 individuals. Altogether, 40–60 individuals were observed. We examined several pistillate inflorescences and every time found minute fruits with seeds and fimbriate scales. The present study did not record staminate specimens.

Given the size of the area is about 60km^2 (area of occupancy <500km^2 and area of occurrence <5000km^2), number of locations four (≤5), and threats to the habitat, we recommend *Calamus pseudoerectus* under the status of Endangered (EN; IUCN Standards & Petitions Subcommittee 2014). The type locality is the part of the Himalayan hotspot (Myers et al. 2000) and faces tremendous adverse anthropologic pressure including tea gardens, road and house construction, huge forest resource collections by local people, and ecotourism. As *C. pseudoerectus* grows in the open forest of Mahananda WS where human infiltration is huge due to the presence of nearby tea gardens and ecotourism sites, the existing habitat needs to be protected by the forest department for the sake of in situ conservation of this new species.

Image 1. ***Calamus pseudoerectus*** **sp. nov. at Darjeeling District of West Bengal, India: A, B - habit | C - stem | D - inflorescence | E - sheath | F - petiole | G, H - sheath with fiber | I - rachilla | J - pistillate flower | K - sterile staminate flower | L - sterile stamens | M - mature fruit | N - fimbriate scales | O - seed. © Sujit Mondal.**

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Weed diversity in rice crop fields of Fatehgarh Sahib District, Punjab, India

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Abstract: A total of 31 species of weeds belonging to 11 families was collected from rice fields in Fatehgarh District of Punjab between June and November 2017. Of the 31 species, 15 were dicots and 16 were monocots. Of the 11 families, six (Portulacaceae, Lythraceae, Solanaceae, Scrophulariaceae, Polygonaceae, and Commelinaceae) were represented by only one species each. Poaceae was the largest family represented by 10 species, followed by Asteraceae and Cyperaceae with five species each. The largest genus was *Cyperus* with four species, followed by *Euphorbia, Echinochloa*, and *Eragrostis* with two species each. Of the 31 weed species, 29 were annual and only two, *Cyperus rotundus* and *Parthenium hysterophorus*, were perennials. More detailed survey work is required on a regular basis to identify possible problematic weeds and new or improved control measures.

Keywords: Documentation, ethnobotany, identification.

Researches indicate that more than 10% of the global agriculture production is reduced as a result of the competition of weeds with crop species mainly for space, nutrients, light, and water (Parker & Fryer 1975). Weeds tolerate adverse edaphic, climatic, and biotic factors as compared to other plants. They have characteristic modifications that help in their perpetuation, multiplication, dissemination, stabilization, and overall adaptation (Vasic et al. 2012). Many weeds bear special structural modifications to reduce water loss during drought conditions, such as thick cuticle, sunken stomata, and waxy coating (Ram & Gupta 1997). The root system of *Convolvulus microphyllus* is coiled to increase its surface area and length for increased absorption efficiency. Grass such as *Cyanodon dactylon* and sedges like *Cyperus* spp. are known to survive under very dry conditions. Some weeds like *Parthenium hysterophorus* are photo-periodically and thermo-periodically neutral. *Parthenium hysterophorus* contains allelochemicals that inhibit the germination of the seeds of other plants; an invasive, it grows mainly in wastelands, and is reported to infest crop fields (Kumar & Varshney 2010).

For better management of weeds, it is necessary to study their morphology, physiology, systematics, ecology, and ethnobotany. The study of weed plants also provides knowledge about their importance as some of them have a large number of ethnobotanic uses and can be used to develop new products for pharmaceutic and food industries (Kendler et al. 1992). *Eclipta alba*, a common weed of the Punjab plains, is widely used as a medicinal plant. *Echinochloa crus-galli, Cynodon dactylon, Cyperus rotundus, Amaranthus viridis*, and *Poa annua* are commonly used as fodder for animals. Some weed species are threatened and their purging affects the biologic diversity of the area. Biodiversity is strongly related to the survival and function of the ecosystem

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(Hooper et al. 2005). Integrated management method is very helpful to control weeds without loss of biodiversity.

Many reports are available on the flora of Punjab (Sharma 1990; Sidhu & Singh 1993; Kaur et al. 2017). No report, however, is available on the diversity of weeds in the rice fields of Fatehgarh Sahib District in Punjab. The main objective of this study was to gain knowledge about the availability of the total number of weeds during the rice season of the area. Identification and documentation of weed species from rice fields will be helpful to prepare effective strategies for weed management.

Materials and Methods

Study area

Collection of weed plants was done from seven rice growing regions (Sirhind, BassiPathana, MandiGobindgarh, Khamanon, Charnarthal, Amloh, and Chunnikalan) of Fatehgarh Sahib (Fig. 1) District in Punjab. The selected sites were surveyed periodically for the collection of weeds. The specimens were collected from within as well as the edges of crop fields. Local people were interviewed to obtain the common or vernacular names of weeds.

Collection of weeds

The study was conducted during the rice growing season of 2017, i.e., between June and November, to explore the weed diversity of the selected area. The standard methods for collection of plant specimens and preservation and preparation of herbarium (Jain & Rao 1977) were followed. Small herbs were collected as a whole with roots, stems, leaves, flowers, and fruits, while larger shrubs were sampled as twigs that included stems, leaves, flowers, and fruits.

Herbarium preparation

After collection, plant specimens were dried using blotters and then pressed using a herbarium press. The blotting papers were changed at regular intervals. After proper drying and pressing, the plant specimens were mounted on sheets for preparation of herbarium specimens. Herbarium sheets were protected against damages from insect and fungal attack by poisoning them with a saturated solution of mercuric chloride in ethyl alcohol. Naphthalene balls were also placed to protect the specimens from insects.

Identification

The collected plant specimens were identified using the available literature, i.e., Bentham & Hooker (1876), Sidhu & Singh (1993), and Kaur et al. (2017), and various websites. The herbarium specimens of identified plant species were arranged on the basis of plant classification

Figure 1. Collection sites in Fatehgarh Sahib District, Punjab, India. (Source: www.google.com).

of Bentham & Hooker (1876) and kept in the Herbarium, Department of Botany and Environmental Science, Sri Guru Granth Sahib World University, Fatehgarh Sahib.

Results and Discussion

During the present study, a total of 31 weed species were collected and identified from rice crop fields of selected localities in the district of Fatehgarh Sahib (Table 1; Images 1 & 2). Collected weed species belong to 25 genera under 11 families of angiosperms (Table 2). Of the 31 species, 15 belong to dicot families (Potulacaeae, Lythraceae, Asteraceae, Solanaceae, Scrophulariaceae, Amaranthaceae, Polygonaceae, and Euphorbiaceae) and 16 belong to monocot families (Commelinaceae, Cyperaceae, and Poaceae). Only one representative species per family was found for six families, namely, Portulacaceae, Lythraceae, Solanaceae, Schrophulariaceae, Polygonaceae, and Commeliaceae. Poaceae was the largest family containing 10 species, followed by Asteraceae and Cyperaceae with five species each. The largest genera were *Cyperus* represented by four species, followed by *Euphorbia, Echinochloa*, and *Eragrostis* with two species each. The genera such as *Portulaca, Ammannia, Eclipta, Parthenium, Tridax, Vernonia, Vicoa, Physalis, Mazus, Polygonum, Amaranthus, Digera, Phyllanthus, Commelina, Fimbristylis, Digitaria, Paspalum, Ischaemum, Setaria, Acrachne*, and *Dactyloctenium* were represented by one species each (Table 1). Of the 31 weed species, 29 were annuals and two species, namely, *Cyperus rotundus* and *Parthenium hysterophorus*, were perennials (Table 1). Manandhar et al. (2007) reported 52 weed species (22 dicots and 25 monocots) belonging to 32 genera under 15 families in the paddy fields of Kirtipur, central Nepal. Hakim et al. (2011) recorded 39 weed species belonging to 15 families, of which 23 were annuals and 16 were perennials, 10 grassy weeds, nine sedges, and 20 broad-leaved weeds associated with rice crop in the coastal

Table 1. Taxonomic position, life form, and habit of weeds identified in the study from rice crop fields in Fatehgarh Sahib District, Punjab, India.

Botanical name	Family	Local name	Life form	Habit	Image	Voucher number
Portulaca oleracea L.	Portulacaceae		Annual	Herb	1a	WU-101
Ammannia baccifera L.	Lythraceae		Annual	Herb to shrub	1b	WU-102
Eclipta alba L.	Asteraceae	Bhringraj	Annual	Herb	1c	WU-103
Parthenium hysterophorus L.		Gajjer Ghass	Perennial	Herb to shrub	1d	WU-104
Tridax procumbens L.			Annual	Herb	1e	WU-105
Vernonia cinerea (L.) Less.			Annual	Herb	1f	WU-106
Vicoa indica (L.) DC.			Annual	Herb to shrub	1g	WU-107
Physalis minima L.	Solanaceae	Jungli rusbhari	Annual	Herb	1h	WU-108
Mazus japonicus (Thunb) Kuntze	Scrophulariaceae		Annual	Herb	1i	WU-109
Polygonum plebeium R. Br.	Polygonaceae		Annual	Herb	1j	WU-110
Amaranthus viridis L.	Amaranthaceae	Chauli	Annual	Herb	1k	WU-111
Digera arvensis Forssk.		Tandla	Annual	Herb	1l	WU-112
Euphorbia hirta L.	Euphorbiaceae	Dhohdak	Annual	Herb	1m	WU-113
E. microphylla Lam.			Annual	Herb	1n	WU-114
Phyllanthus niruri L.		Hazardani	Annual	Herb	1o	WU-115
Commelina benghalensis L.	Commelinaceae		Annual	Herb	1p	WU-116
Cyperus rotundus L.	Cyperaceae	Murk	Perennial	Herb	1q	WU-117
C. iria L.		Chhatriwaladila	Annual	Herb	1r	WU-118
C. difformis L.		Mothi	Annual	Herb	1s	WU-119
C. compressus. L.		Motha	Annual	Herb	1t	WU-120
Fimbristylis tenera Schult.			Annual	Herb	2a	WU-121
Digitaria sanguinalis (L.) Scop.	Poaceae	TatriGhas	Annual	Herb	2b	WU-122
Echinochloa colona (L.) Link		Swanki	Annual	Herb	2c	WU-123
E. crus-galli (L.) P. Beauv		Swank	Annual	Herb	2d	WU-124
Paspalum conjugatum P.J. Bergius			Annual	Herb	2e	WU-125
Eragrostis japonica (Thunb.) Trin.			Annual	Herb	2f	WU-126
E. tenella (L.) P. Beauv. ex Roem. & Schult.		Chirian da dana	Annual	Herb	2g	WU-127
Ischaemum rugosum Salisb.		Kanki	Annual	Herb	2h	WU-128
Setaria glauca (L) P. Beauv.			Annual	Herb	2i	WU-129
Acrachne sp.			Annual	Herb	2j	WU-130
Dactyloctenium aegyptium (L.) Willld.		Madhana	Annual	Herb	2k	WU-131

Image 1. Weed plants of rice crop fields in Fatehgarh Sahib District, Punjab, India: a - *Portulaca oleracea* | b - *Ammannia baccifera* | c - *Eclipta alba* | d - *Parthenium hysterophorus* | e - *Tridex procumbens* | f - *Vernonia cinerea* | g - *Vicoa indica* | h - *Physalis minima* | i - *Mazus japonicas* | j - *Polygonum plebeium* | k - *Amaranthus viridis* | l - *Digera arvensis* | m - *Euphorbia hirta* | n - *E. microphylla* | o - *Phyllanthus niruri* | p - *Commelina benghalensis* | q - *Cyperus rotundus* | r - *C. iria* | s - *C. difformis* | t - *C. compressus.* © Mr. Rai Singh.

Table 2. Taxonomic data of weed plants identified from rice crop fields in Fatehgarh Sahib District, Punjab, India, with their families, genera, and species.

Family	Genera	Species
Portulacaceae	01	01
Lythraceae	01	01
Asteraceae	05	05
Solanaceae	01	01
Scrophulariaceae	01	01
Amaranthaceae	02	02
Polygonaceae	01	01
Euphorbiaceae	02	03
Commelinaceae	01	01
Cyperaceae	02	05
Poaceae	08	10
Total	**25**	**31**

region of peninsular Tanjong Karang in West Malaysia.

During the present study, *Cyperus rotundus* was reported from all the localities of rice crop fields. *Portulaca oleracea, Euphorbia microphylla*, and *Tridax procumbens* were commonly found on the bunds of the crop fields. *Cyperus iria, C. difformis, C. compressus, Ammannia baccifera*, and *Eclipta alba* were found in the crop fields. These plant species commonly occur in aquatic habitats. Rabbani & Bajwa (2001) surveyed the rice fields of five districts of Punjab, namely, Gujarnawala, Sialkot, Gujrat, Kasur, and Sheikhupura, and reported *Cynodon dactylon*, *Cyperus rotundus*, *C. difformis*, *Echinochloa colona*, and *E. glabrescens* as highly abundant and widely distributed throughout the surveyed areas. *Parthenium hysterophorus* was also found on the edges of the studied rice fields. There are reports that *Parthenium hysterophorus* has become a

Image 2. Weed plants of rice crop fields in Fatehgarh Sahib District, Punjab, India: a - *Fimbristylis tenera* | b - *Digitaria sanguinalis* | c - *Echinochloa colona* | d - *E. crus-galli* | e - *Paspalum conjugatum* | f - *Eragrostis japonica* | g - *E. tenella* | h - *Ischaemum rugosum* | i - *Setaria glauca* | j - *Acrachne* sp. | k - *Dactyloctenium aegyptium*. © Mr. Rai Singh.

problem in crop fields in India (Evans 1997). *Parthenium hysterophorus* was reported in rice fields from different districts of India (Oudhia 2000). *Cyperus rotundus* is a common weed species in the study area. This species attains dominance in cultivated land and poses a serious problem for rice crops. It appears immediately after rice sowing and competes heavily with the crop for nutrients and water. *Cyperus rotundus* is recognized as the world's worst weed (Holm et al. 1977). In the Indo-Gangetic plains, adoption of zero tillage has resulted in an increase in the population of globally-significant perennial weeds such as Purple Nut Sedge *Cyperus rotundus* and Bermuda Grass *Cynodon dactylon* (Malik & Kumar 2014). Some of the weeds reported from the study area also have some positive aspects. *Eclipta alba* is good for hair and is used for commercial purposes nowadays. *Cyperus rotundus, C. iria, C. difformis, Fimbristylis tenera, Digitaria sanguinalis, Echinochloa colona, E. crus-galli, Paspalum conjugatum, Eragrostis japonica, Dactyloctenium aegyptium*, and *Acrachne* spp. are commonly used as fodder for animals. *Amaranthus viridis* is used as a vegetable commonly called 'Sagg' by local people. Some previous studies also reported medicinal, industrial, and allelopathic uses of obnoxious weeds (Chopra et al. 1956; Memon & Shahani 1986; Hassan & Marwat 2001; Ibrar et al. 2003).

Conclusion

The present study was a first from the region to explore and identify the weeds present in rice crop fields. This study will help the farmers and agriculturists of the study area to identify weeds and thus help in planning a suitable strategy for their control.

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SHORT COMMUNICATION

Observations on the female flowers and fruiting of Tape Grass *Enhalus acoroides* from South Andaman Islands, India

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Abstract: Documenting phenologic events is crucial in obtaining deeper insights into the life cycle of seagrasses. We documented and compared the flowering and fruiting of the seagrass *Enhalus acoroides* from multispecies seagrass meadows at two sites, Henry Lawrence and Tarmugli islands located inside the marine national parks in South Andaman Islands. At these two locations, the average density of shoots ranged between 30.9/m^2 and 18.16/m^2, fruits between 5/m^2 and 2.33/m^2, and flowers between 6.7/m^2 and 3.83/m^2, whereas the mean length of the peduncles ranged from 40.59cm at Henry Lawrence to 32.44cm at Tarmugli Island. We observed significant differences between the densities of shoots and fruits and peduncle lengths in the two sites. The density of flowers, however, did not vary significantly. These observations of fruiting and flowering in *E. acoroides* establish an important reproductive stage in the life cycle of the species and open avenues for further seagrass research in the Andaman Islands. We describe the findings and emphasize on the need to establish a long-term phenology monitoring program for *E. acoroides* in the Andaman Archipelago.

Keywords: Andaman Islands, flowering, Henry Lawrence Island, marine national park, phenology, seagrass, Tarmugli Island.

Seagrasses are marine angiosperms usually confined to sandy substrates in shallow temperate and tropical waters throughout the world (Vermaat et al. 2004; Fortes 2013). Sixty seagrass species are reported globally, of which 14 species are found in the Indo-Pacific (Short et al. 2007). Throughout their distribution, seagrasses are threatened by trawl fishing, sand mining, coastal construction, nutrient enrichment, sewage, and other terrestrial pollutants (Duarte 2002; Baden et al. 2003; Short & Waycott 2010). One of the consequences of these pressures is meadow fragmentation, which lowers seed output and is considered one of the reasons for seagrass declines worldwide (Green et al. 2003; Unsworth & Cullen 2010). Realizing their ecologic importance, many countries have provided varying degrees of protection to seagrass meadows (Short & Waycott 2010).

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Amongst these, the Tape Grass *Enhalus acoroides* (L.f.) Royle, which is distributed throughout the Indo-Pacific (Short & Waycott 2010), is the tallest species with leathery leaves which can grow up to 150cm. Due to its large shoot size, *E. acoroides* forms one of the major contributors to the productivity and biomass of seagrass meadows (Brouns & Heijs 1986; Rollón 1998). Clumps of this species form important habitats for juvenile fish, benthic invertebrates, and scores of burrowing organisms (Nakamura & Sano 2004, 2005). It is a source of nutrients for the Green Sea Turtle *Chelonia mydas* and a few reports indicate feeding of Dugong *Dugong dugon* on its shoots (Nair et al. 1975; Erftemeijer et al. 1993; Andre et al. 2005; Adulyanukosol & Poovachiranon 2006; D'Souza et al. 2013). *Enhalus acoroides* is dioecious, flowering twice a year from March to July and November to December (Rollón 1998; Rollón et al. 2003; Vermaat et al. 2004). In view of *Enhalus*' hydrophobic mode of pollination (Rattanachot & Prathep 2011), this flowering, when compared to that of other seagrass species, is unique in that the male flowers are released for surface pollination whereas the female flowers have to extend their coiled peduncles (stalk bearing the fruit or flower) to the water surface to capture pollen (Johntone 1979; Rollón et al. 2003). Once the pollination is complete, the female peduncle coils back towards the bottom (Sulochanan & Korabu 2009). The length of the peduncle increases with increase in depth (Johnstone 1979; Rollón 1998) and the peduncles terminate into pinkish-green flowers, the ovaries of which pollinate into green, bulbous fruits (Sulochanan & Korabu 2009).

In India, *Enhalus acoroides* is reported from the Palk Bay and Gulf of Mannar in the state of Tamil Nadu and along the Andaman & Nicobar Islands (Mahalingam & Gopinath 1987; Das 1996; Manikandan et al. 2011). In the Andaman & Nicobar Islands, before the tsunami of 2004, *E. acoroides* was reported from Paschim in Bihar, North Reef, Inglis, Henry Lawrence, Havelock, and Cinque islands in the Andaman group and Camorta, Trinket, Nancowry, Katchal, Pilomilow, Little Nicobar, and Great Nicobar islands in the Nicobar group (Das 1996). Post-tsunami, however, its presence was reported only from Henry Lawrence and Tarmugli in the Andaman Islands and Kamorta and Nancowry in the Nicobar Islands (Thangaradjou et al. 2010; D'Souza et al. 2015). This could be attributed either to lack of focused studies on the distribution of *E. acoroides* meadows or the loss of these meadows to natural disturbances (tsunami and cyclones). Owing to their ecosystem services, documenting and understanding various life cycle events of *E. acoroides* is necessary to obtain deeper insights into their ecology and to develop effective conservation strategies.

Sexual reproduction (characterized by flowering and fruiting) is an important event in the life history of *Enhalus acoroides* as they release floating propagules into the water column, which helps in recolonization of new areas (Rollón et al. 2003). This also helps in mixing of genes, which is an important evolutionary adaptation to cope with environment changes (Marbà & Walker 1999; Alexandre et al. 2006). Thus, understanding the flowering season in *E. acoroides* is of particular importance. There, however, is limited information on the flowering and fruiting of *E. acoroides* and most studies are limited to taxonomic documentation and distribution of the species across the island chain. In such a scenario, opportunistic natural history observations of *E. acoroides* can act as baselines and probe hypothesis-driven studies on the phenology, ecology, and biology of the species. We report the observations on the flowering and fruiting phenomenon of *E. acoroides* at two important seagrass meadows, Henry Lawrence and Tarmugli islands in the South Andaman group of islands.

Material and methods

Study area

The study was carried out at Henry Lawrence (12.130^{0}N & 93.099^{0}E) and Tarmugli (11.589^{0}N & 92.531^{0}E) islands in the Andaman Archipelago (Fig. 1). Henry Lawrence Island is part of the Rani Jhansi Marine National Park (RJMNP) in Ritchie's Archipelago, South Andaman, and covers an area of 54.7km^2 (Singh 2003). The coast is lined by a thick mangrove forest, whereas coral reefs and seagrass meadows are found in the shallow coastal waters surrounding the island. The seagrass meadow at Henry Lawrence is composed of multiple seagrass species including a large patch of *Enhalus acoroides* (c. 600m^2). Similarly, Tarmugli Island, with a total area of 12.6km^2, is part of the Mahatma Gandhi Marine National Park (MGMNP) in Wandoor, South Andaman (Fig. 1). The island has a dense coastal forest along with coral reefs and nearshore seagrass meadows. Unlike Henry Lawrence, however, the seagrass meadow at Tarmugli is exposed to the open ocean and the *E. acoroides* patch is significantly smaller (c. 150m^2). The meadows at both sites are relatively shallow, ranging from 1–3 m at Tarmugli and 2–6 m at Henry Lawrence, and the substrate is sand mixed with coral rubble, which is an ideal habitat for the seagrass associated faunal communities such as sea cucumbers, sea anemones, juvenile fish, and burrowing worms (Image 1).

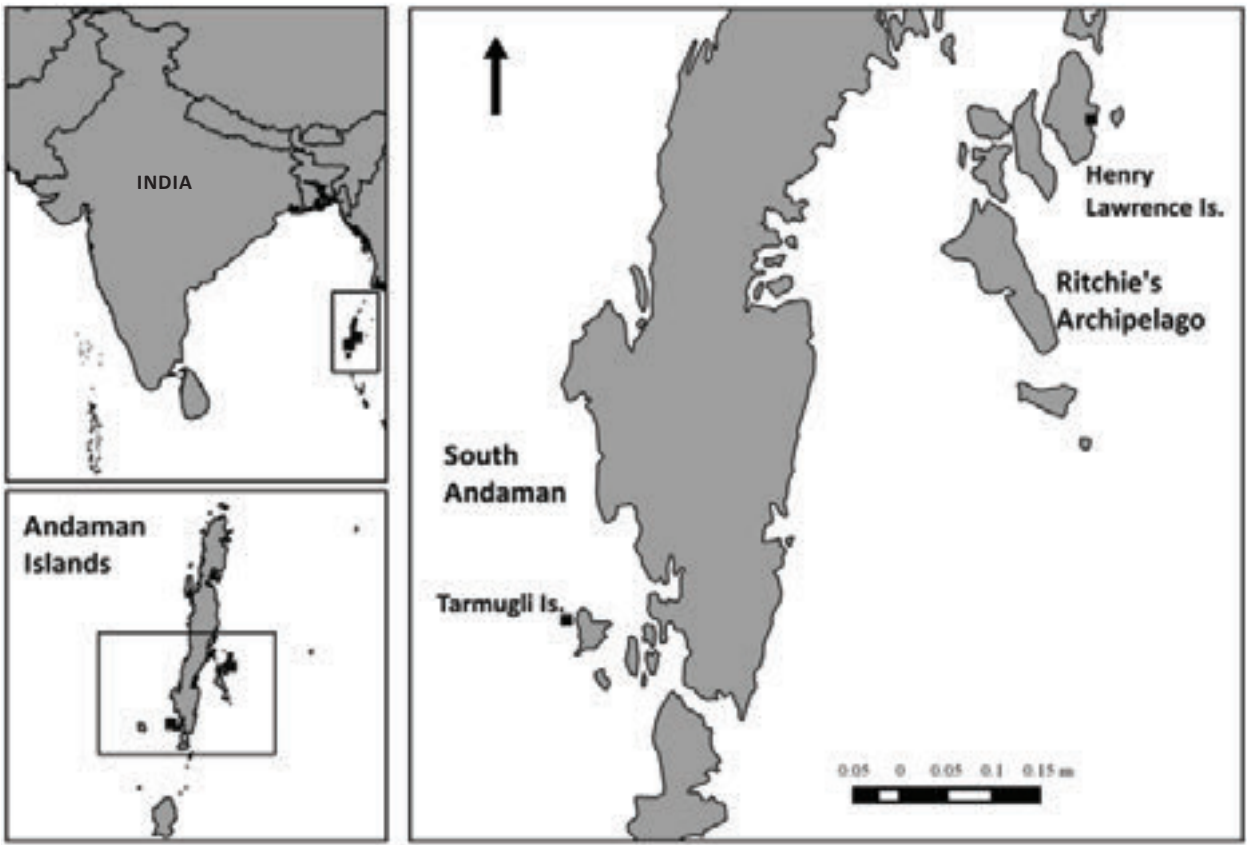

Figure 1. Study area showing sampling locations in South Andaman. Black cells indicate *Enhalus acoroides* patches at the sites.

Sampling protocol

We carried out data collection after incidental observation of flowering and fruiting of the species between 02 and 27 May 2016, using snorkelling and scuba gear at depths of 1–6 m at high tide. We placed 10 random 1m x 1m quadrats in the *E. acoroides* meadow at Henry Lawrence at depths of 2–4 m and six quadrats at Tarmugli Island at depths of 1–3 m. Due to the relatively smaller size of the *E. acoroides* meadow at Tarmugli Island, we limited the number of replicate quadrats to six. Within these quadrats, we counted the number of shoots, fruits, and female flowers and estimated their density per square metre. For the morphometric data, we measured the length of the peduncles, i.e., the distance from the base of the peduncle to the base of the fruit, and the female flower using a measuring tape. The average number of shoots, fruits, and flowers, and the mean lengths of the peduncles were compared between the two sampled sites by performing Welch's two sample t-test to account for unequal sample sizes. Data was explored in Microsoft Excel v.2016 and analyzed using R v3.2 (R Development Core Team 2015).

Results and Discussion

We observed a significant difference between peduncle lengths and the number of shoots and fruits between the two sites, whereas we did not observe significant difference in the number of female flowers between the two sampled sites (Table 1). The male flowers were not observed during the sampling.

We observed a wide variation in the number of shoots and fruits and the peduncle lengths of *E. acoroides* across the two meadows, which can be attributed to several inherent processes. The meadow at Henry Lawrence Island is considerably larger, deeper, surrounded with mangroves, and shielded from the open ocean, which could be some of the reasons for the longer peduncle lengths and higher density and abundance of the species as compared to Tarmugli Island. The variation across these two meadows shows the importance of local environment factors (location, meadow size, depth, exposure) in influencing the *E. acoroides* meadow dynamics (Rollón 1998; Marbà et al. 2005).

As our study was necessarily opportunistic and conducted on incidental observations, we were unable to document the male flowers and monitor the extent

Table 1. Difference in the abundance of shoots, fruits, and flowers and the mean length of the peduncles at Henry Lawrence and Tarmugli islands in South Andaman. Significance between sites was tested using Welch's two sample t-test (T).

Attributes	Henry Lawrence	Tarmugli	T	df	*p*-value
	Mean				
Length of peduncle	40.59±1.67	32.44±1.73	3.3866	77.519	**0.001114***
No. of shoots	30.9±3.11	18.16±1.53	3.6633	12.568	**0.003018***
No. of fruits	5±0.61	2.33±0.55	3.2129	13.476	**0.006528***
No. of flowers	6.7±0.76	3.83±0.60	2.9567	13.956	0.01044

*Significance at alpha=0.05, *P*<0.01
All the attributes are expressed as mean±standard error.

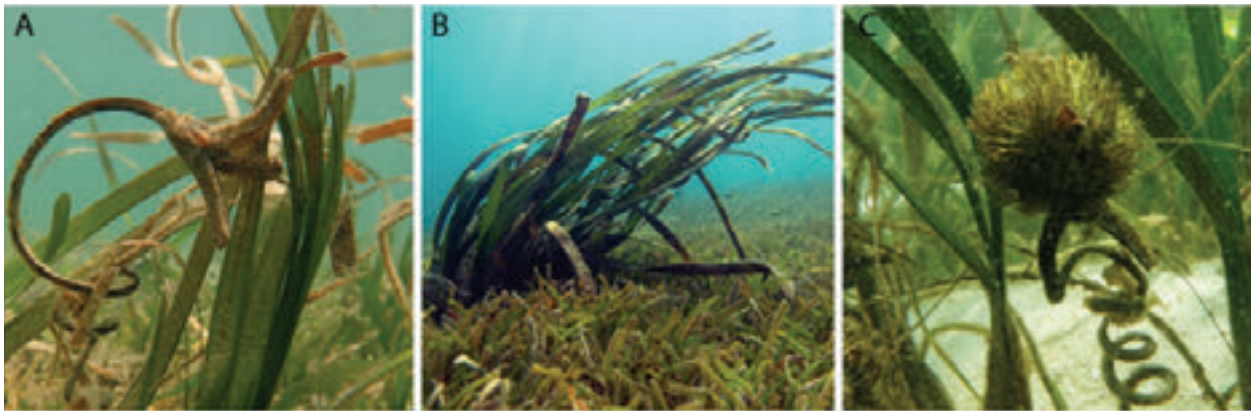

Image 1. *Enhalus acoroides* at South Andaman: A - flower at Henry Lawrence Island | B - meadow at Tarmugli Island | C - fruit with coiled peduncle. © Vardhan Patankar.

of the flowering season of *E. acoroides* in our study area. Previous studies carried out on the flowering of *E. acoroides* from the Philippines and Thailand recorded March to July and November to December as the flowering season (Rollón 1998; Vermaat et al. 2004; Rattanchot & Prathep 2011) whereas in the Gulf of Mannar flowering was reported in June (Sulochanan & Korabu 2009). Our observation of flowering of the female plant in May is within the flowering season recorded at Philippines, Thailand, and the Gulf of Mannar.

Various studies showed that *E. acoroides* forms an important refuge for juvenile fish populations (Nakamura & Sano 2004); therefore, protecting these sites should be of utmost importance especially as climate change increases the frequency and intensity of benthic disturbances (Hoegh-Guldberg et al. 2007). We recommend that extensive surveys be carried out in all potential seagrass meadows of the Andaman & Nicobar Archipelago to understand the phenology of all 11 seagrass species (Das 1996; Savurirajan et al. 2015; Immanuel et al. 2016). The state forest department in collaboration with research institutions should establish long-term monitoring programs to collect specific data on seagrasses as well as to assess potential seed banks, seed dispersal, meadow connectivity, genetic variability, and gene flow. The detailed studies and long-term monitoring of *E. acoroides* meadows in Henry Lawrence and Tarmugli islands will help establish the flowering season and increase our understanding of the factors controlling sexual reproduction, the time of release of male flowers, dispersal abilities, colonisation strategies, and resilience to natural catastrophes. Such research will not only provide new information on the phenology, ecology, and biology of *E. acoroides* and other seagrass species, but also provide empirical and technical support for seagrass meadow conservation in the face of rapid climate change and expanding threats to seagrasses and coastal areas in the Andaman Islands.

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PLATINUM OPEN ACCESS

First records of *Agnidra vinacea* (Moore, 1879) (Lepidoptera: Drepanidae: Drepaninae) from the western Himalaya, extending its known range westwards

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The genus *Agnidra* Moore, [1868] has an oriental distribution and there are four species of this genus recorded from India till now; *A. specularia* (Walker, 1866), *A. corticata* (Warren, 1922), *A. vinacea* (Moore, 1879) and *A. discispilaria* (Moore, [1868]) all of them distributed in NE India, Sikkim, Darjeeling (West Bengal) and from Uttarakhand, only *A. discispilaria* has been reported from the Gangotri Landscape (Sanyal 2015; Uniyal et al. 2016). This paper reports the first distribution records of *A. vinacea* from Uttarakhand, western Himalayas.

Agnidra vinacea (Moore, 1879) is a member of the family Drepanidae, subfamily Drepaninae. It was described as *Drepana vinacea* by Moore,1879 from Darjeeling, West Bengal. Hampson (1892) lists the species distribution as "Sikkim". Subsequently, in a series of publications on Indo-Australian Drepanids, Watson (1961; 1968) lists records of this species from Darjeeling (West Bengal), Khasis (Meghalaya), Naga Hills (Nagaland), Pedong (Sikkim) and Kambaiti (NE Burma). Haruta (1992) reports this species from Nepal, extending its range westwards. Digital Moths of Asia (http://www.jpmoth.org) reports this species from Thailand as well. *Agnidra vinacea* has an ochreous-brown upperside; suffused with purple. A narrow black band from the apex crosses to the middle of the abdominal margin, which bends indistinctly at the costa. A black streak extends from apex to below the angle of the band. Both fore and hindwing have indistinct transverse sub-basal and sub-marginal wavy darker lines and two black-speckled grey-bordered spots are there at the end of the cell. Underside is ochreous-yellow, with indistinct spots at the end of the cell; forewing has a dusky-brown fascia from the apex. Forelegs above and the antennae are blackish in colour (Moore 1879).

Discussion: On 15 April 2018 at 21.06h, during an opportunistic visit to Koti Kanasar village, near Chakrata in Dehradun District (29.702^{0}N & 79.734^{0}E, 1,682m) SS recorded the moth species *Agnidra vinacea* (Moore, 1879) at the Kanasar Ecolodge. The moth was sighted on the wall of the Kanasar Ecolodge, near an incandescent light bulb. Subsequently, PD recorded *Agnidra vinacea* (Moore, 1879) at Gondi, near Mandal Village (30.007^{0}N & 79.004^{0}E, 1,600m) and Kanchula Kharak (30.007^{0}N & 79.75^{0}E, 2,600m) in Kedarnath Wildlife Sanctuary during April-May, 2018. PD did the study by sheet-light method using lepiLED (Brehm 2017) as a part of a study funded by the Rufford Foundation, United Kingdom. Image 1

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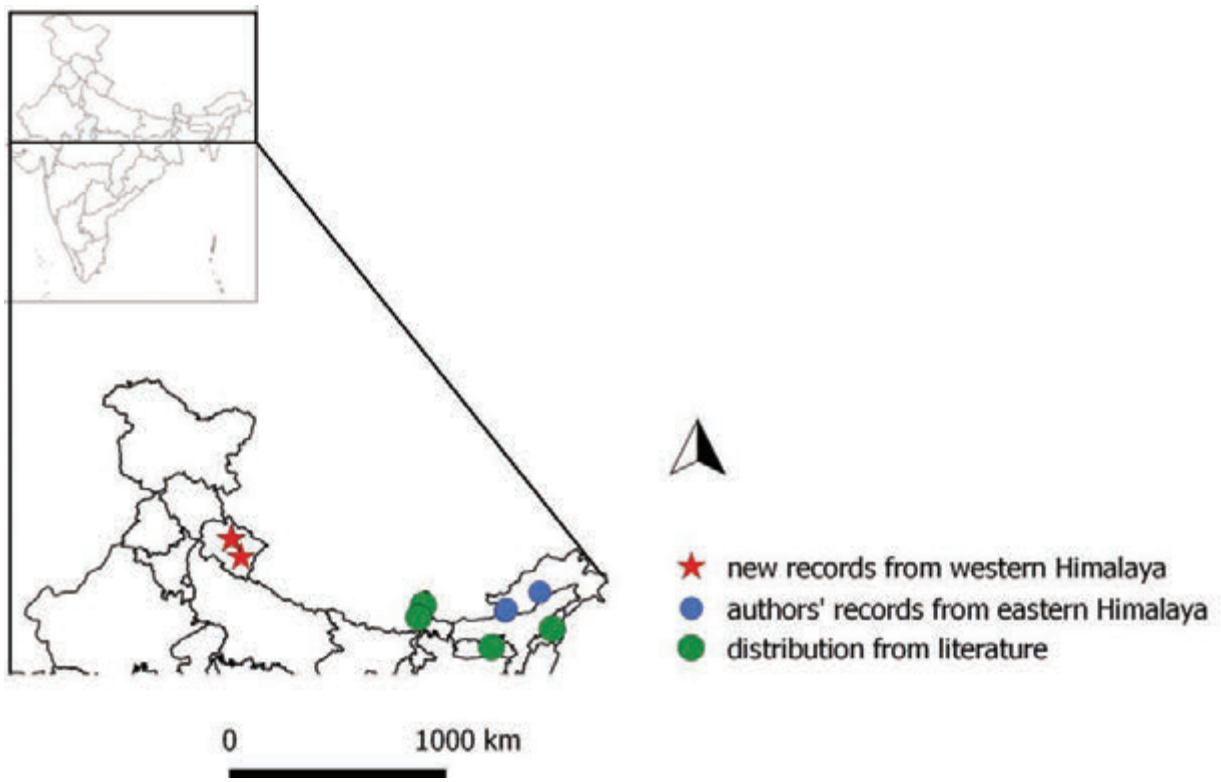

Figure 1. Map showing the different locations of *A. vinacea* from the literature and recorded by the authors.

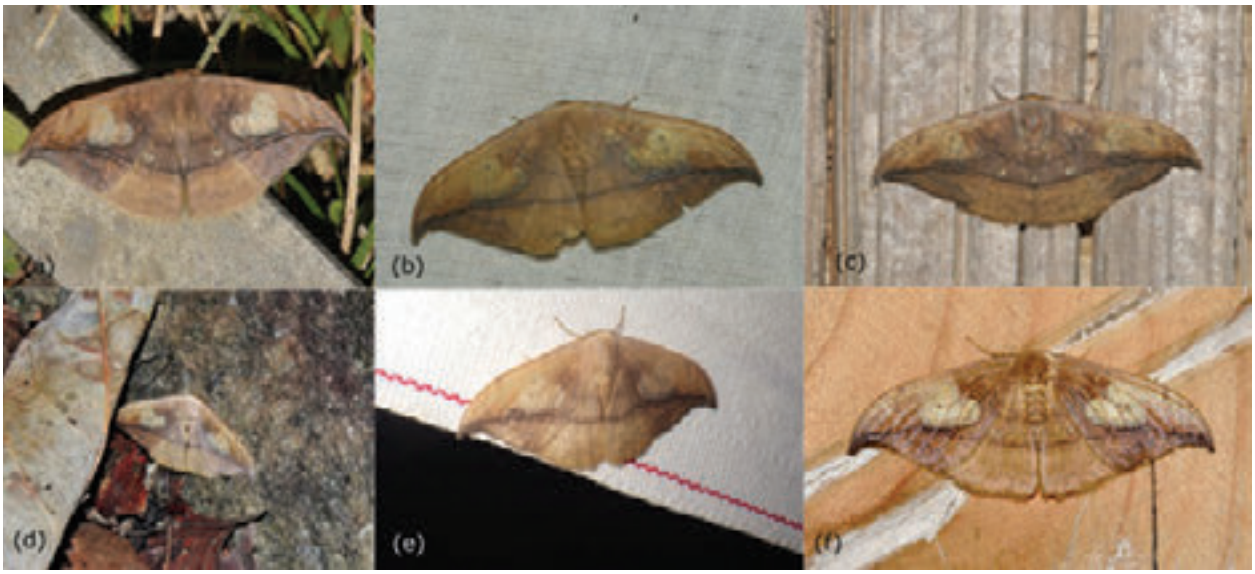

Image 1. Photos of individuals of *A. vinacea* recorded by authors at different locations. From eastern Himalaya (a-c): Lama, Bompu (Eaglenest WS); Talle, Pange and from the western Himalayas (new distribution records) (d-f): Gondi, Kanchula Kharak (Kedarnath WLS); Koti Kanasar, Chakrata. © a–c,f - Sanjay Sondhi | d,e - Pritha Dey.

shows the individuals photographed from different locations in eastern and western Himalayas. Fig. 1 shows locations of *A. vinacea* known from literature, recorded by SS from eastern Himalayas and new records by PD and SS from western Himalayas.

The moths of the western Himalayan state of Uttarakhand are not well studied and documented. Amongst the earliest publications that included

information on the moths of Uttarakhand was a report out on the entomological collection of the Forest Research Institute (Roonwal et al. 1963). Subsequently, Arora et al. (1977) reported on some moths of Garhwal during a Swiss expedition. Arora (1997) reported on Lepidoptera, including moths during an expedition to Nanda Devi Biosphere Reserve. Peter Smetacek, Butterfly Research Center, Bhimtal published numerous papers on the moths of Nainital (Smetacek 2002; 2004; 2008; 2009; 2011). In more recent years, Sanyal et al. (2013; 2017), Sanyal (2015), Sondhi & Sondhi (2016), Uniyal et al. (2016), and Dey (2018) reported on the moths of Uttarakhand. Despite these sporadic documentations, much needs to be studied and understood in the world of moths in Uttarakhand, as well as across the country.

Smetacek (2002) reported on Drepanid moths from Garhwal and Kumaon but makes no mention of records of *Agnidra vinacea* (Moore 1879). Subsequent publications of Smetacek (2004; 2008; 2009; 2011), too, do not make any mention of this species from Uttarakhand. Other more recent publications from Uttarakhand by Sanyal et al. (2013) and Sondhi & Sondhi (2016), which cover Drepanids, too, do not report the presence of *Agnidra vinacea* (Moore, 1879) from Uttarakhand.

Hence, the three recent records of *Agnidra vinacea* (Moore, 1879) from Uttarakhand are the first records of this species from the state, extending its range to the western Himalayas. SS has also recorded this species from numerous locations in Eaglenest Wildlife Sanctuary in West Kameng District (Sondhi et al. 2019) and Talle Valley Wildlife Sanctuary in Lower Subhansiri District of Arunachal Pradesh. SS did not record this species from the Naga Hills, Nagaland and Garo Hills, Meghalaya, which he has surveyed extensively, despite reports in literature of this species from Nagaland and Meghalaya. With these new records, the revised Indian distribution of this species should include Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya and Nagaland.

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Pollinators of Sikkim Mandarin Orange *Citrus reticulata* (Sapindales: Rutaceae)

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Sikkim Mandarin Orange (*Citrus reticulata* Blanco, 1837) is a member of the Rutaceae family and a commercially desirable variety of the mandarin group native to Sikkim. The Sikkim Mandarin Orange (SMO) growing area lies at an altitudinal range of 700–1,500 m and it is an annual flowering plant. Mandarin orange is dependent on bees for its pollination and pollinators help in higher yield and increased fruit set (ICIMOD 2003). Irrespective of large cardamom yield decline due to pollinator deficiency in Sikkim (Sinu & Shivanna 2007), till date there exists no systematic study on the range of pollinators for SMO. This study aims to bridge this gap especially when a large proportion of farmers are dependent on the SMO for cash income.

Our study area spanned the East, West and South districts of Sikkim. The southern part of the state, which lies in the altitude range of 600–1500 m provides an ideal climate for SMO cultivation (DHCCD 2015). Data was collected across 72 SMO orchards from 2011 to 2013. These orange orchards were selected within an altitudinal gradient of 700–1,452 m and were spread across 316km^2 (Fig. 1).

Pollinator visitation: At each site, 150 flowers were tagged and observed from 08.00–17.00 h to record insect species that visit them. Intra-floral foraging behavior of each insect species was carefully observed to note whether it is a pollinator or a forager. SMO bear self-fertile, bisexual flowers and pollen movement is facilitated by pollinators. Transparent plastic bags were used to trap insects visiting the flowers to avoid any fruit loss during their collection. Collected samples were preserved in 70% ethanol and subsequently identified in the laboratory. Insects which were not seen touching the flower reproductive parts were not collected for identification.

We recorded 24 species of insects during the study period (2011–2013). Common Honey Bee *Apis cerana* was the most dominant pollinator followed by hoverflies belonging to eight genera, namely, *Episyrphus* sp., *Melanostoma* sp., *Ischiodon* sp., *Eristalis* sp., *Eristalinus* sp., *Scaeva* sp., *Episyrphus* sp., and *Eupeodes* sp. (Image 1,2) . This was followed by stingless bees (Hymenoptera), seed bug (Hemiptera), and beetles (Coleoptera) that were sparse visitors. Recorded insects were both pollen and nectar feeders. Bees (Hymenoptera) and hoverflies (Diptera) visited flowers in groups while most of the

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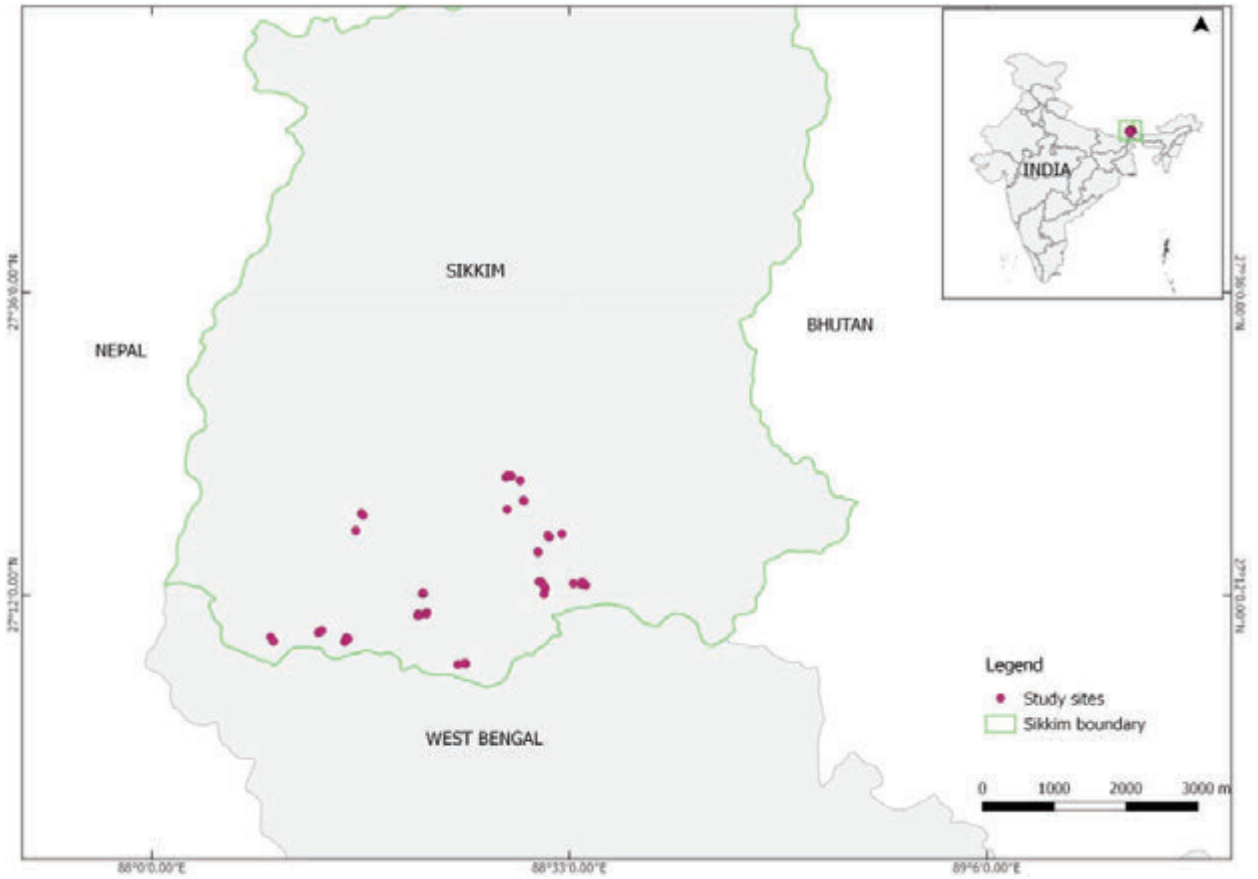

Figure 1. Location of orchards (in red dots) within the northeastern Indian state of Sikkim.

beetles and seed bugs visited individually. All the insects landed on the petal and foraged for pollen placed on top of the flower and nectar at the flower base. In this process all the insects invariably touch both anther and stigma of SMO flower. An insect visitor was called a pollinator when the ventral side of insect's body containing pollen load touched the reproductive part of flowers.

SMO is an evergreen plant showing flowering response to early monsoon shower starting in the mid of February. Flowering period lasts for a month, from late February to early April. Orchards in the lower altitude starts flowering earlier followed by orchards in the higher altitudes. Flowers are white in colour with strong scent attracting a range of insects for pollination. Highlighting the importance of pollinators of the mandarin orange, in a study conducted by the International Center for Integrated Mountain Development (2003), pollination was seen to increase the yield of mandarin orange by four times compared to pollinator excluded flowers. Honey bee (*Apis* sp.) has been reported as a major pollinator of different varieties of *Citrus* sp. from across the world, for example, Mandarin orange *Citrus reticulata* in Nepal is pollinated by *A. cerana, A. dorsata, A. florea,* and *A. mellifera* (International Center for Integrated Mountain Development 2003). Kinnow *Citrus reticulata*, a hybrid between mandarin orange and sweet lime, was reported to be pollinated by *A. dorsata* and *A. florea* in Pakistan (Manzoorul-Haq et al. 1978). Results of our study show only *A. cerana* visited mandarin orange flowers, while *A. dorsata* or *A. florea*, which were recorded in other studies, were not observed even outside our experiment sites during the study period. Hoverflies, although not reported as pollinators of mandarin oranges earlier, are known to pollinate rapeseed oil (Jauker & Wolters 2008), apple (Solomon & Kendall 1970), and strawberries (Kendall et al. 1971). Both bees and flies visited flowers in groups and visited more than one flower at a time, possibly aiding in cross/sexual pollination (Raju et al. 2012). Visits by other taxa such as butterflies, stingless bees, and beetles to orange flowers were less in comparison to bees and flies. However, the importance of these wild pollinators in sustaining pollination of SMO needs further exploration.

Table 1. Pollinators of Sikkim Mandarin Orange.

	Order	Family	Sub family	Genus	Species	Altitude range	Forage collected
1	Coleoptera	Coccinellidae	Coccinellidae	*Oenopia*	*kirbyi* (Mulsant)	700–1400	nectar + pollen
2		Scarabaeidae	Rutelinae	*Anomala*	sp.	700–1400	nectar + pollen
3		Scarabaeidae	Citoniinae	*Clinteria*	sp.	700–1400	nectar + pollen
4		Chrysomelidae	Eumolpinae	*Chrysonopa*	sp.	700–1400	nectar + pollen
5		Chrysomelidae	Galerucinae	*Galerucinae*	sp.	700–1400	nectar + pollen
6	Diptera	Calliphoridae	Chrysomyinae	*Chrysomya*	sp.	1000–1400	nectar + pollen
7		Rhiniidae	Rhiniinae	*Rhinia*	sp.	0800–1400	nectar + pollen
8		Sarcophagidae	Paramacronychiinae	*Wohlfartia*	sp.	0800–1400	nectar + pollen
9		Syrphidae	Syrphinae	*Episyrphus*	sp.	0800–1400	nectar + pollen
10		Syrphidae	Syrphinae	*Melanostoma*	sp.	900–1400	nectar + pollen
11		Syrphidae	Syrphinae	*Ischiodon*	*scutellaris* (Fabricius)	0800–1400	nectar + pollen
12		Syrphidae	Eristalinae	*Eristalis*	*tenax* (Linnaeus)	0800–1400	nectar + pollen
13		Syrphidae	Syrphinae	*Scaeva*	*pyrastri* (Linnaeus)	900–1400	nectar + pollen
14		Syrphidae	Syrphinae	*Eupeodes*	*confrater* (Wiedemann)	900–1400	nectar + pollen
15		Syrphidae	Eristalinae	*Eristalinus*	*taeniops* (Wiedemann)	900–1400	nectar + pollen
16		Syrphidae	Syrphinae	*Episyrphus*	Viridaureus	900–1400	nectar + pollen
17		Syrphidae	Eristalinae	*Eristalis*	*basifemorata(*Brunetti)	700–1400	nectar + pollen
18	Hemiptera	Lygaeidae	Lygaeinae	*Spilostethus*	*pandurus* (Scopoli)	700–1400	nectar + pollen
19		Lygaeidae	Lygaeinae	*Graptostethus*	*incertus* (Walker)	700–1400	nectar + pollen
20		Largidae	Physopeltinae	*Physopelta*	*gutta gutta* (Burmeister)	700–1400	nectar + pollen
21	Hymenoptera	Halictidae	*Halictinae*	*Seladonia sp*	sp.	700–1200	nectar + pollen
22		Halictidae	Halictinae	*Lasioglossum*	sp.	700–1200	nectar + pollen
23		Apidae	Apinae	*Apis*	*cerana*	700–1500	nectar + pollen
24		Apidae	Apinae	*Tetragonula*	sp.	800–1200	nectar + pollen

Image 1. *Apis cerana* pollinating Sikkim Mandarin Orange flower.

Image 2. *Apis cerana* and *Eristalis* sp. visiting Sikkim Mandarin Orange flowers.

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A holistic look on birds in urban areas

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Birds are the prominent representative of the animal kingdom in urban areas and some of them live in close association with humans. It is generally believed that certain birds did acclimatize and adapt to living along with humans. Researchers have proved that rapid changes in urban areas do have an impact on these birds. One good example is the common House Sparrow. Despite the well-known implications, much of the research has been carried out in North American and European countries. There is a need for long term studies on this aspect of avifauna. In this scenario, this book is an excellent summarization of the research done, so far.

This 511 paged book, with 24 chapters is divided into six sections. The first and last sections contain the introduction and conclusion chapters written by the editors Enrique Murgui, Spain and Marcus Hedbolm, Sweden. Chapters in the second section narrate about large-scale abundance pattern and adaptation of birds in urban areas across the globe. Meanwhile, chapters 5, 6 and 7 also look at the evolutionary adaptations in birds due to urban conglomerates. Chapter 4, written by two Chinese authors from the Zhejiang Museum of Natural History, is indeed remarkable for its details about the changes in avifaunal diversity in China - one of the rapidly urbanized countries of the 20th century. Chapter 5 may provide a valid explanation of how exotic birds can be successful in urbanized areas. After reading this chapter, I could perceive some more reasons for the predominance of the Common Myna in Indian cities.

The third section of this book deliberates on the fundamental approaches for understanding bird ecology i.e. in spatial and temporal scale. While chapter 8 discusses the influence of urban factors on bird diversity and it concludes on the need for repeated studies for understanding the influence of urban factors on bird community. It appeared to me that the authors were stressing on the need for long term research. The editors understood it; for next chapter deliberates on 'The trends in Long Term Urban Bird Research'. This is followed by a review chapter on different methods for estimating abundance of urban birds and the subsequent chapter discuss on 77 bird atlas developed in 66 different European towns. Due credits to the editors for this cogent arrangement of chapters.

The fourth section deliberates about the human and bird interaction - starting with the effect of pollution on birds (chapter 12 and 13), human's role in synurbization (chapter 14) and finally on ecosystem services from urban birds (chapter 15). Chapter 13 on Light pollution needs to be highlighted here. The chapter details on the need to manage it efficiently, for its impact can be deleterious for birds.

The fifth Section has 8 chapters that brief on the urban bird habitats; with chapters 16 and 17 specifically narrating the urban habitat prevalent in African and Australian metropolis. Quite differently, chapter 18 reviews the global research on the diversity and

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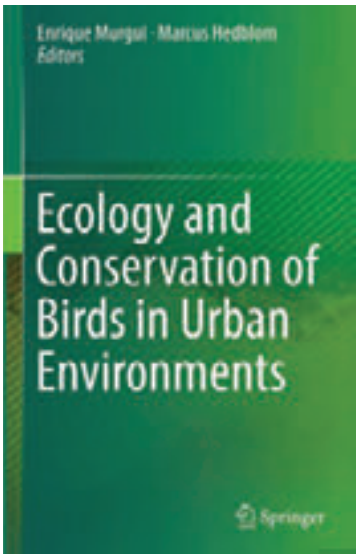

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adaptation of birds in urban residential complexes. This chapter emulates the theme of the book very well. The authors stress on the need for field actions as well as coordinated research to conserve urban bird diversity. In this juncture, I am reminded of the Dr Eugene Schieffelin attempts in 1890's to protect urban bird diversity in New York which turned out to be havoc. Incidents like these stress on the need for coordinated research. In chapter 19, the author uses the term 'Urban Wastelands' which in Indian context refers to a dump yard or landfill. On the contrary, Peter J. Meffert from Germany refers to abandoned warehouses and vacant plots as wastelands and he narrates the significance of these short duration habitats for urban birds. Recently, bird's feedings on the fruits of *Lantana camara* and thereby indirectly aiding in the dispersal has caught the attention of ecologists (Carrión-Tacuri et al. 2012; Thabethe 2014). And chapter 20 focuses on the invasive plant species in North America and their influence in birds' breeding and feeding behaviour. Chapters 21 and 22 are case studies from Italy and Barcelona and chapter 23 is a combination of a case study from Sweden. Furthermore, chapter briefs on the management of green areas to maintain and enhance bird ecosystem services. The editors effectively summarize the key points in the concluding chapter. Further, they highlight the research gaps in urban bird ecology and also list out some effective conservation strategies. I would be thoughtless if I did not point out that this book is both well written and scholarly. It offers a lucid account on urban birds and it will be handy for researchers.

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