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continued on the back inside cover

Cover (front & back) — Sally Raulston Walker (12 October 1944–22 August 2019). Photo by B. Ravichandran, ZOO/WILD.

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Wildlife's Wonder Woman

Sally Raulston Walker
(12 October 1944–22 August 2019)

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The origins of the ***Journal of Threatened Taxa*** goes back to ***Zoo's Print***, a magazine to promote zoo and animal management in Indian zoos published since January 1986. Sally Walker founded the Zoo Outreach Organization (ZOO) in 1985. She initiated Zoo's Print as the second big project after setting up ZOO ZEN, another monthly magazine.

Her task of improving the zoo condition in India was complicated. More than 500 zoos existed in India. The animals in the traveling menageries, circuses, performing-animal shows, and street collections were in deplorable conditions of maintenance.

Sally set up the task of tackling this humongous problem systematically. She studied available literature on zoos in India, in the world, and anything related to the zoo world to learn more about the aspect and the situation. She immediately realized the lack of available literature in India, both scientific and popular. Popular material was more easily accessed, for example, Gerald Durrell's books. Scientific articles were a completely different ball game in those days. To tackle the problem of non-availability of scientific articles, she started ZOO ZEN. She compiled photocopies of materials from different parts of the country and the world (of course, having received permissions for this) under different broad categories of animal and zoo management, and sent these out at no cost to all the zoos in India. She also traveled around the country investigating and compiling a list of all the different kinds of animal collections and finally prepared the first comprehensive list of zoos in India. Her database of the zoos updated the existing one with the government of India by increasing their number several times over. And that study led her to start a process to initiate a national zoo policy, which eventually led to the amendment of the Indian Wildlife (Protection) Act and the setting up of the Central Zoo Authority (CZA).

Sally's methods were not haphazard. Although she was from a non-science background, her keen scientific temper helped her process through the rough and separate factual data from the fictional chaff. It was an era where record-keeping in Indian zoos was nil (unfortunately, it continues to be abysmal). She, however, set up studbook-like records for tigers, lions, rhinos, Lion-tailed Macaques, and Sangai. She visited various Indian zoos and meticulously sifted through old communications, talking with the keepers and querying long-time zoo staff. The studbook-like listing provided critical insights into the provenance of the collections, movement of animals between zoos,

hybridization, among other critical components. While she painstakingly compiled all the records, she also reached out to well-managed zoos around the world for help. She sought help in keeping logs, training possibilities, exchange programs for zookeepers, and capacity building to promote scientific captive breeding protocols in Indian zoos. She trained herself in animal record-keeping and studbook-keeping with the International Species Information System. She traveled around the zoos to train mid-level officers, biologists, veterinarians, and zookeepers on maintaining careful animal records. She was setting the stage for the next push — minimum standards for zoos under the newly formed CZA.

Sally's quest for improving standards were stoked from an emotional bond with the animals in zoos. She hated animals in captivity and didn't like zoos. She did not blindly beat her chest about closing down zoos, nor acted dangerously by promoting the release of animals into the wild. She took on a rational and scientific approach to help alleviate the unfortunate animal and zoo management practices in India. One might not find many scientific papers published by Sally. But, if one were to look at some of the science communications in Zoo's Print, it's clear how well she understood scientific concepts. For example, her illustration of the principles of small populations provides glimpses into the principles of conservation biology.

Immediately after setting up the CZA and being a member of it for the first six years, Sally pulled ZOO from pursuing just zoo matters. She shifted the organization's focus into conservation planning by setting up the first network of the Captive Breeding (now Conservation Planning) Specialist Group (CPSG) of SSC IUCN in India. The scientific approach by CPSG paved the way for Sally to incorporate scientific tools and models to meta-population management. She introduced aspects such as reproductive physiology and genetic procedures for captive animals in Indian zoos. Simultaneously, using the predictive models and tools developed by CPSG, Sally initiated stakeholder-led conservation planning exercises for some of the more charismatic animals. Some examples included the Manipur Brow-antlered Deer, Lion-tailed Macaque, Asiatic Lion, One-horned Rhinoceros, Gharial, Barasingha and Hoolock Gibbon. These workshops determined the probability of extinction of the species in the wild. They also provided specific management actions to be undertaken for habitats and populations, and initiate a comprehensive conservation breeding program at the national level.

By 1995, after I had joined ZOO, Sally and I introduced and conducted a series of Conservation Assessment & Management Plan (CAMP) workshops, a process developed by CPSG. We modified the taxon datasheet from the many experiences of CAMP workshops. We incorporated more aspects of data collection to ease species assessments and included the conservation needs portion into the evaluations. Our experience in those workshops helped us shape the conservation engineering strategy we developed and practice to this date. The conservation strategy included identifying people, building taxonomic networks, training and capacity building, fund field projects, gather data, publish in scientific journals, feed into species assessments, use the data to promote education and outreach, and follow up the strategies in the loop. Sally bought this concept immediately, and we developed everything from training techniques to set up a scientific peer-review journal. The ***Journal of Threatened Taxa*** owes its roots to that thought process and conservation engineering strategy.

Sally's most significant push was education and outreach. She did that with élan. I remember the days when I'd walk into the office in the morning, and Sally would present a complete educational packet that she had worked on the previous night. While I loved to nit-pick, I would often feel bereft of not being able to change anything. Sally, in her typical gesture, would say that she picked up all the facts from the scientific reports I had generated; hence, the product was perfect. We sent out innumerable education packets to many zoos, NGOs, conservationists, educators, forest departments, academics, institutions, individuals, and others. Each of them developed from the data compiled from evidence in our workshops, publications, and processes. Science was the basis for all of Sally's actions; hence, I dedicate this issue in her honor and remembrance. The ***Journal of Threatened Taxa*** would not be possible without Sally's encouragement and complete support. And her philosophy of keeping scientific knowledge free is the reason why ***JoTT*** remains a platinum open access international journal.

Sanjay Molur
Founder & Chief Editor, JoTT

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Species diversity and spatial distribution of amphibian fauna along the altitudinal gradients in Jigme Dorji National Park, western Bhutan

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Abstract: This paper presents the results of a study conducted on the diversity and spatial distribution of amphibian fauna in two different habitat types along the elevation gradients of Mochu River valley in Jigme Dorji National Park, Bhutan. The survey was conducted from November 2017 to February 2019. The study aimed to assess the diversity and distribution of amphibians using an opportunistic visual encounter survey technique. A total of 16 species of amphibians belonging to nine genera distributed among seven families were documented during the study period. The Shannon diversity index was relatively higher in the primary forest habitat than in the agro-ecosystem, however, there was no statistically significant difference of species abundance. The decreasing trend of diversity and abundance of amphibian fauna was noticed towards higher altitudinal zones. About 56% of species were recorded in the lower sampling sites (1200–1600m) indicating more favourable climatic conditions and habitat types for amphibian assemblages at lower elevations.

Keywords: Abundance, amphibian diversity, habitats, spatial distribution.

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Author contribution: BKK—field surveys, and data collection, and manuscript writing; KC—data analysis & editing; TP—manuscript writing and data analyses.

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INTRODUCTION

The current number of amphibian species is 8,043 as of 2019 (Frost, 2019). Of the 8,043 described amphibian species worldwide, 6,771 are evaluated and 2,157 of them are classified as threatened (IUCN 2019). More than 700 species of amphibians are known to exist in southern Asia (IUCN Red List 2009) and as per Global Amphibian Assessment (GAA) records 285 amphibian species are endemic to the region. The discovery of Himalayan Newts *Tylototriton verrucosus* (Anderson 1871), by Frost (1985) unfolds the very first chapter of history of Bhutan's amphibians. It was not until the 2000s, however, that the scientific documentation of amphibian fauna occurred when Das & Palden (2000) reported seven amphibians from three families (one megophryid, one bufonid, and five ranids) which were all new records for Bhutan (Wangyal 2014). According to Das & Palden (2000) and Ahmed et al. (2009), the total number of amphibian species so far recorded from Bhutan then was 13. Later, in 2012, five more species—*Duttaphrynus* cf. *stuarti* (Smith 1929), *Amolops* cf. *monticola* (Anderson, 1871), *Megophrys nankiangensis* (Liu & Hu, 1966), *Polypedates maculatus* (Gray, 1830), and an inadequately described species of *Nanorana* were added to the list of amphibians of Bhutan, pushing the number of species from Bhutan to 18 (Wangyal & Gurung 2012). According to the IUCN Red List (2013), seven families of amphibians (2 Bufonidae, 2 Dicroglossidae, 1 Megophryidae, 1 Rhacophoridae and 1 Salamandridae) are known from Bhutan, of which, five are Least Concern, one Vulnerable and one Data Deficient. After a comprehensive review of the Bhutanese herpetological records, today 58 species of amphibians (56 anurans, one caudata, and one caecilian) are known to occur in Bhutan (Wangyal 2014). With the latest discovery of *Leptobrachium bompu* byTenzin & Wangyal (2019), Bhutan now has 57 anurans. Some of these taxa, however, are identified only up to the genus level and many are yet to be described with proper taxonomic references.

Among vertebrates, amphibians are currently the most imperiled class, with about 41% of the more than 7,000 amphibian species on the planet threatened with extinction (Collins and Crump 2009; Hoffmann et al. 2010) making amphibians one of the most threatened groups of animals on earth (Hof et al. 2011). The GAA suggests that at least 158 amphibian species are believed to be extinct recently, nearly one in three remaining species is currently threatened with extinction, and one in four is inadequately known that they can only be called Data Deficient (IUCN et al. 2010).

Amphibians are perceived to be one of the most sensitive animal taxa and response very rapidly to substantial changes in their environments. Amphibians are sensitive to changes in thermal and hydric environments due to their unshelled eggs, highly permeable skin and unique biphasic life-cycles (Ochoa-Ochoa et al. 2012). For this reason, they are considered "an indicator species" the species that "indicate" the state of the health of their ecosystems (Saber et al. 2017). Amphibians can serve as food for predators in their community and they are voracious predators themselves. Amphibians are an important component of both terrestrial and aquatic ecosystems and play vital role in community ecology by serving as both predators and preys. With the Increasing human population and subsequent impact on the natural environment demand an urgent and immediate conservation intervention to save these least studied but ecologically significant taxa. Nevertheless, when Bhutan is striving forward to study and document its biodiversity, the field of herpetology has always received less priority. The current knowledge of amphibian fauna of Bhutan is scanty and fragmented. There has been no single study conducted on the amphibians in Jigme Dorji National Park (JDNP) despite the park being recognized as an important embodiment of the eastern Himalayan ecosystem. In the present study, an attempt has been made to document the diversity and spatial organization of amphibians in JDNP.

STUDY AREA

Jigme Dorji National Park, one of the 10 protected areas in Bhutan, was gazetted in the year 1995. It is located at (27.81927778 degree latitude and 89.73027778 degree longitude) and altitude ranges from 1200m to 7000m with corresponding vegetation types of warm broadleaved forest, cool broadleaved forest, mixed conifer, and alpine meadows that harbour rich repositories of biodiversity.

Majority of the study area is covered by primary forest (Image 1) with negligible human disturbance. The study area along Mochu River valleys, is characterized by patches of agricultural farmlands (Image 2), and the adjoining forests are used for timber, fire wood, non-wood forest products and livestock grazing.

The dry subtropical zone of the park experiences a hot summer with moderate rainfall, whereas in the warm temperate and cool temperate zones at higher altitudes, the climatic conditions are characterized by

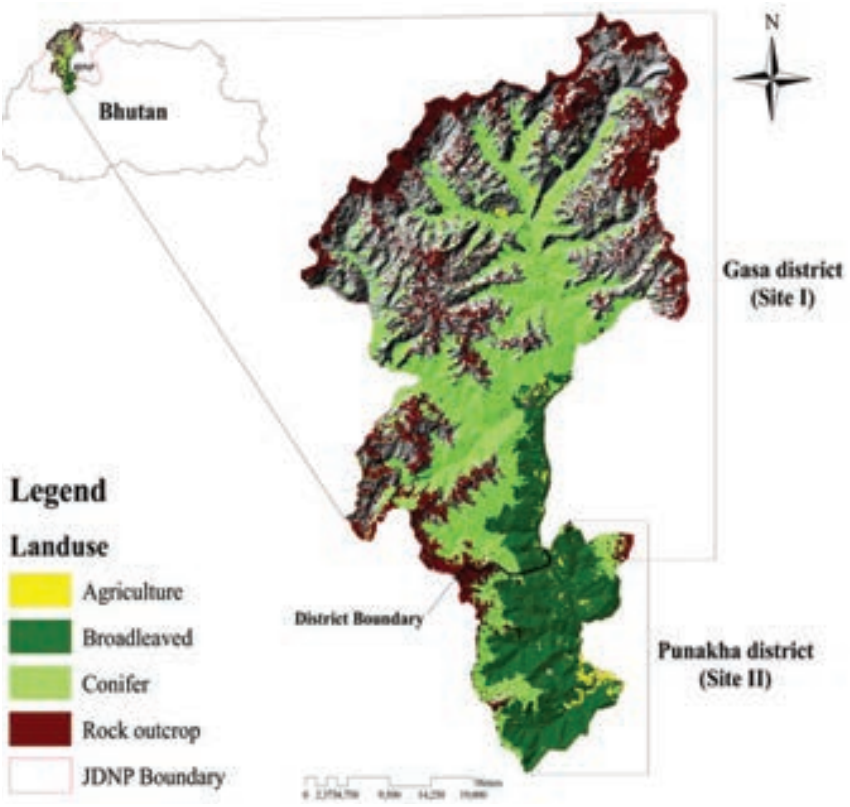

Figure. 1 Jigme Dorji National Park with landuse data.

Image 1. Primary forests habitat of JDNP.

Image 2. Agro-ecosystem habitat of amphibians in JDNP.

warm summers and cold winters. In 2017, the annual total rainfall of Punakha District (which falls under the dry subtropical zone) and Gasa (temperate zone) was 717.6mm and 1,848.1mm respectively (National Statistics Bureau 2018). The higher region of the park is covered by perennial snow; a home of glacial rivers which serves as an important source of water for household use, agriculture and hydropower generation in the downstream valleys. JDNP is a vital watershed covering almost half of northern Bhutan, and is an important natural conservatory of glaciers, alpine meadows and scrublands, sub-alpine and temperate conifer forests, warm and cool temperate broadleaved forests, major rivers and streams, and flora & fauna that inhabit these ecosystems.

METHODS

The survey was conducted from November 2017 to February 2019 in JDNP and adjoining areas in Bhutan. Visual encounter surveys (VES) were conducted by three people during each survey event. The survey was conducted at 08.00–11.00 h in the morning and at

14.00–18.00 h in the afternoon, in order to detect both diurnal and nocturnal species. Considering the rugged terrain with steep slopes and vast elevation range of the study area, specimens were recorded by VES as per Heyer et al. (1994) and Rödel & Ernest (2004), employing randomized walk, carried out along with active searches in day and night. Potential habitats of amphibian fauna, i.e., all microhabitats (rocks and boulders, dead and fallen logs, dense bushes and grass patches, rock and tree crevices, leaf litter, and water bodies) were thoroughly searched.

Standardized road searches were conducted at 14.00–18:00 h twice a month, covering all potential areas with the clearest ground visibility. Four man-hours were spent in each survey event. In total, 48 man-hours were spent to cover the entire study area searching for nocturnal species. The Punakha-Gasa secondary highway which is 85km long was surveyed using a motor vehicle traveling at 10 to 20 k/h.

Every individual specimen was noted and identified to the most specific taxonomic level possible. Identification of species was done using standard field guide books by Daniel (2002), Ahmed et al. (2009), and Vasudevan & Sondhi (2010). Digital photographs taken during the field survey were sent to experts to confirm species identity. Locality data were collected for all specimens that were encountered, live or dead. Whenever possible, the digital photographs were taken for specimens, elevation and geo-spatial location of each species was recorded using GPS. The Shannon diversity indices (H') were used to calculate the diversity, the Hutcheson statistical t-test was performed to compare the diversity index of the two different habitat types, and statistical software SPSS (Statistical Package for the Social Sciences) was used to compare the difference in species abundance of amphibians in two different habitat types.

RESULTS

Diversity

In total, six-day field trips or 300 man-hours were spent searching for amphibians across the various elevation gradients of JDNP, of which, 200 man-hours were spent searching in forests, 48 man-hours for standardized road surveys at night, and 50 man-hours for searching streams.

The amphibian diversity of Bhutan is represented by 58 species belonging to 18 genera distributed among eight families, of which, 16 species belonging to nine genera, distributed from seven families were documented during the field survey from Jigme Dorji National Park (Table 1). Of the observed species, three could not be identified to species level and so they were assigned to closely related species/genus level (e.g., *Amolops* sp., *Hyla* sp., and *Megophrys* cf. *major*).

Table 1. List of amphibian species documented in Jigme Dorji National Park in November 2017–February 2019 including percentage of relative abundance.

Family	Scientific name	Common name	Relative abundance (%)
Bufonidae	*Duttaphrynus himalayanus* (Günther, 1864)	Himalayan Toad	29.52
	Duttaphrynus melanostictus (Schneider, 1799)	Common Indian Toad	5.71
	Duttaphrynus stuarti	Stuart's Toad	8.57
Hyladae	*Hyla* sp.		2.38
Ranidae	*Amolops marmoratus* (Blyth, 1855)	Himalayan Torrent Frog	5.71
	Amolops mantzorum (David, 1872)	Sichuan Torrent Frog	2.85
	Amolops sp.		3.33
	Amolops monticola (Anderson, 1871)	Mountain Torrent Frog	1.90
Rhacophoridae	*Rhacophorus maximus* (Günther, 1858)	Giant Green Tree Frog	2.38
	Polypedates himalayensis (Gray, 1830).	Tree Frog	13.80
Dicroglossidae	*Nanorana liebigii* (Günther, 1860)	Liebigii's Paha	11.42
Megophryidae	*Scutiger sikkimmensis* (Blyth, 1855)	Sikkim Snow Toad	2.38
	Scutiger bhutanensis Delorme & Dubois, 2001	Bhutan Snow Toad	1.42
	Megophrys cf. *major* Boulenger, 1908	Major Horned Toad	3.33
	Megophrys parva Boulenger, 1893	Mountain Horn frog	2.38
Salamandridae	*Tylototriton verrucosus* Anderson, 1871	Himalayan Newt	2.85

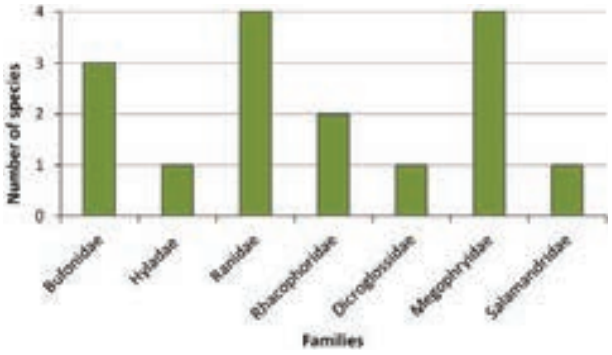

Figure 2. Species richness of amphibians with respect to families recorded during the study period in JDNP.

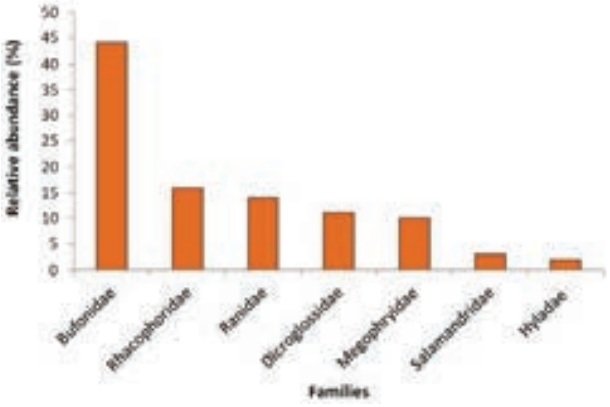

Figure 3. Relative abundance of amphibians with respect to families in JDNP in November 2017–February 2019.

Scutiger bhutanensis is the only species recorded as endemic to Bhutan.

The family-wise distribution of the amphibian fauna of JDNP is given in (Figure 2). Family Megophryidae and Ranidae dominated the amphibian fauna of JDNP each accounting for four species, belonging to three genera, followed by Bufonidae with three species belonging to one genus, Rhacophoridae with two species belonging to two genera. Dicroglossidae, Salamandridae and Hylidae together comprised three species belonging to three genera.

Abundance

At the species level, the abundance of amphibians varied from two to 62 individuals. A total of 210 individuals were recorded during the entire study period. Relative abundance data indicated that *Duttaphrynus himalayanus* was found to be the most common species (n=62, 29.52%) and *Scutiger bhutanensis* was found to be the least abundant species contributing (n=3, 1.42%) (Table 1).

At the family level, the relative abundance of amphibians varied from 2% to 44%. With reference to relative abundance (Figure 3), a deduction can be made that the family Bufonidae was found to be the most dominant family contributing (44%) of the total individuals. This was followed by Rhacophoridae (16%), Ranidae (14%), Dicroglossidae (11%), Megophryidae (10 %), Salamandridae (3%), and only 2% was contributed by Hylidae.

Species composition of amphibians in relation to habitat types

The present study found that amphibian species in Jigme Dorji National Park inhabit both primary forests and agro-ecosystems. Of the 16 species recorded, all 16 were found in primary forest habitats and 11 species were found in agro-ecosystems, however, there were more individuals in the agriculture farm land than in forest habitat. A total of (n=116, 55.24%) were recorded in the agro-ecosystem and a total of (n=94, 44.76%) in the forest habitat. All the four species belonging to the family Megophryidae such as *Scutiger sikkimmensis*, *S. bhutanensis*, *Megophrys* cf. *major*, and *M. parva*, including one species belonging to the family Ranidae such as *A. monticola*, were exclusively found in primary forests, while the remaining 11 species were found inhabiting both the habitats. Although more numbers of individuals were recorded in agro-ecosystems, there was no statistical significance in species abundance between the two different habitats. Mann-Whitney test indicated that the species abundance was not significantly greater for primary forest habitat (Mdn= 4) than for agro-ecosystem (Mdn=2), U=81, p= 0.07 (figure 4).

Most of the species have been found in both the habitat types; the Shannon diversity index (H') for

Table 2. Comparison of Shannon diversity index using the Hutcheson statistical t-test.

	Habitat types	
	Primary forest	Agro-ecosystem
Total individuals	94	116
Richness	16	11
H'	2.639874676	1.739164568
S^2_H	0.00389201	0.007581
t	8.409038716	
df	200	
Critical value	1.971896178	
CI	0.12477195	0.174137876

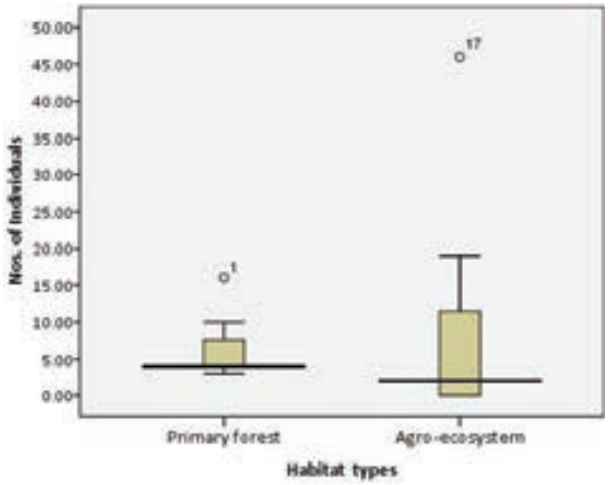

Figure 4. The box plots showing the median of species counts in two different habitat types

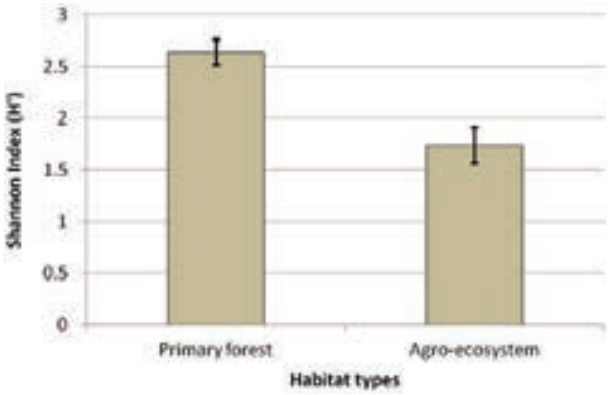

Figure 5. The Shannon diversity index of two different habitat types. Error bars are 95% confidence intervals.

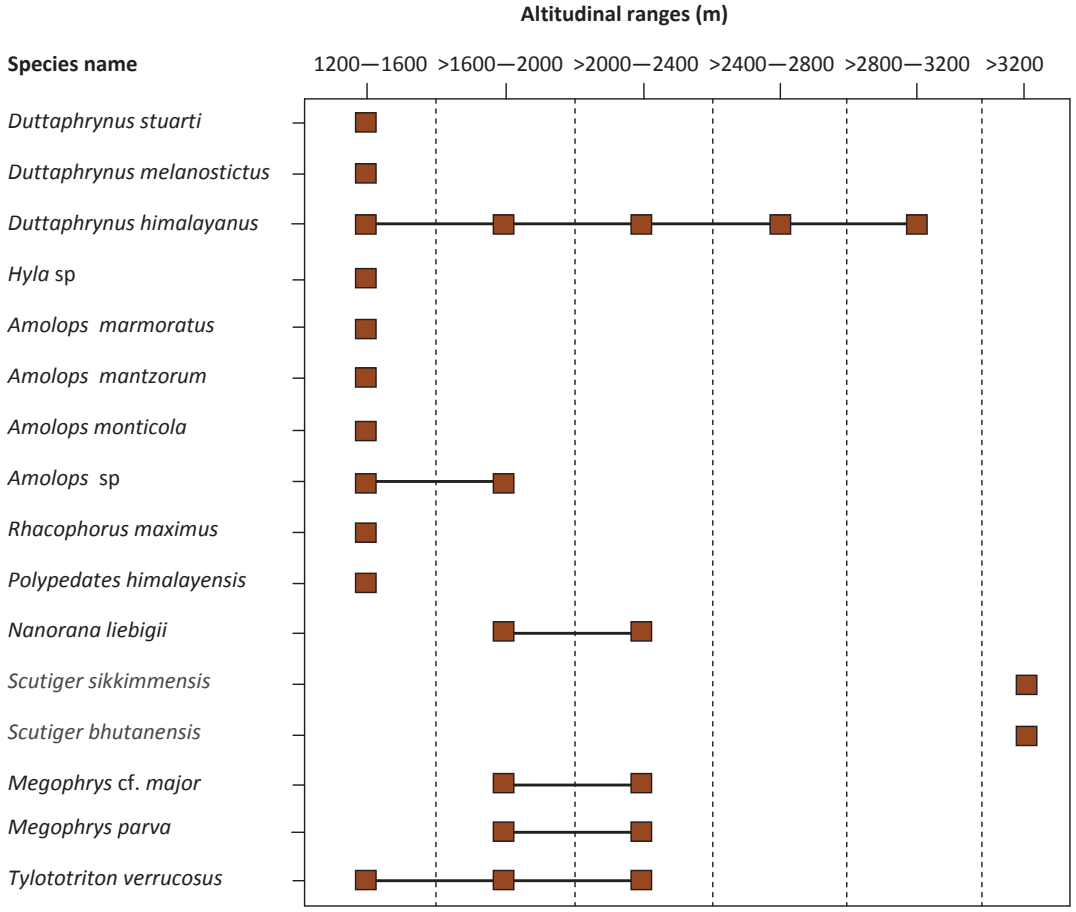

Figure 6. Elevational ranges of each amphibian species documented in JDNP. Brown boxes indicate altitudinal band where individuals were sighted

the primary forest habitat was (n=94, H'=2.63) and (n=116, H'=1.73) for the agro-ecosystem (Figure 5). The Hutcheson statistical t-test suggested that Shannon diversity index (H') between the two different habitats was statistically significant as calculated t-value exceeds the critical value (Table 2). It can, therefore, be deduced that primary forests serve as important habitats for amphibian assemblage in JDNP.

Geo-spatial distribution of amphibians

About 56% of amphibians showed a narrow distribution range and were concentrated in lower elevations, particularly between 1,200m and 1,600m. Both diversity and observed species abundance were found to be relatively higher in this altitudinal zone as compared to subsequent zones towards higher elevations. Of the total 16 recorded species, 11 species were recorded in a lower altitudinal band and nine of them demonstrated the distribution pattern by excluding elevation boundaries above 1,600m. Species such as *P. himalayensis* (Image 3), *A. monticola, A. marmoratus* (Image 4), *A. mantzorum* (Image 5), *Amolops sp* (Image 6), *R. maximus* (Image 7), *Hyla* sp. (Image 8), *D. stuarti*, and *D. melanostictus* (Image 9) were found below 1,600m. Whereas, species such as *N. liebigii* (Image 10) *M.* cf. *major*, *M. parva* (Image 11) were noticed between 1,700m and 2,400m. *Tylototriton verrucosus* (Image 12) was observed in the elevation ranges between 1,300m and 2,200m. *D. himalayanus* (Image 13) was the most widely distributed species across the altitudinal range up to 3,200m. Species such as *S. sikkimmensis* (Image 14) and *S. bhutannensis* were sighted only above 3,500m; both the species were recorded in an alpine ecosystem around 4,000m in JDNP (Figure 6).

DISCUSSION

Jigme Dorji National Park is one of the important conservation areas that encompasses a wide range of habitats from sub-tropical to alpine ecosystems of Bhutan. Considering the limited knowledge on diversity, distribution and natural history of the amphibian fauna of the region, the present study can be considered very significant. Of the eight families and 18 genera of amphibian fauna found in the country, seven families and nine genera were recorded in JDNP. This implies that JDNP is an important repository for amphibian conservation. The park representing a majority of amphibian fauna of the country may be due to the presence of largely-undisturbed forests, altitudinal variation with corresponding habitat types, and an organic farming system practised by park residents. Although most of the species (n=11, 68.78%) were found occupying both the habitat types, relatively more species diversity was observed in the primary forest. Many studies suggest that amphibian species are affected by the degree of canopy cover (Halverson et al. 2003; Skelly & Golon 2003). Most amphibian species tended to be either 'open canopy specialists' or 'canopy generalists' (Skelly et al. 2005). The present finding agrees with Krishnamurthy (2003) who reported that more than 50% of the amphibian species encountered during his study in the Western Ghats, India, were found exclusively in primary forests. Displaying such distribution pattern could be due to amphibians responding to moist condition, numerous perennial streams, marsh lands, and less human disturbance, thus providing potential habitats associated with primary forest. In some cases, however, composition of amphibian fauna might depend on specific ecological requirements of individual species, which is beyond the scope of this study.

The reduced species richness in the agro-ecosystem could be due to disturbances induced by frequent visits of people for farming activities, however, wide distribution of *Duttaphrynus himalayanus, D. melanostictus*, and *D. stuartii* across the human modified landscape and disturbed habitat could be due to the high adaptability of these species to such an environment. The present finding agrees with Ahmed et al. (2009) who claimed that the majority of amphibians and reptiles are sensitive to habitat quality, while only a few species are adaptable to such environments. The number of individuals that represents each species in the community might differ from place to place depending on the amount of rainfall, available habitats and human interference as the structure and diversity of an amphibian community is determined by the availability of food, moisture and microhabitat (Daniels 1992).

The present study has showed that observed species richness and species abundance were found to be comparatively higher in lower altitudinal regions particularly below 1,600m than subsequent zones in higher elevations. Higher species richness at lower elevation sites may be due to more favourable climatic conditions and habitat components for amphibian assemblages at lower elevations. This includes higher average temperatures, evapo-transpiration, productivity and precipitation, which are widely recognized as important for the spatial and temporal distribution pattern of amphibians (Buckley & Jetz 2007). For instance, species such as *S. sikkimmensis* and *S. bhutannensis*

Image 3. *Polypedates himalayensis*.

Image 4. *Amolops marmoratus*.

Image 5. *Amolops mantzorum*.

Image 6. *Amolops* sp.

Image 7. *Rhacophorus maximus.*

Image 8. *Hyla* sp.

Image 9. *Duttaphrynus melanostictus*.

Image 10. *Nanorana liebigii*.

Image 11. *Megophrys parva.*

Image 12. *Tylototriton verrucosus.*

Image 13. *Duttaphrynus himalayanus*.

Image 14. *Scutiger sikkimmensis*.

showing restriction in dispersion range boundary towards lower elevations could be due to their ability to withstand the prevailing cold temperatures of higher elevations and evolutionary adaptation. In contrast, the presence of relatively few amphibian species at higher elevation zones could be due to the inability of most amphibians to withstand cold temperature, limited precipitation, and inadequate food resource in higher elevational region.

This study is the first of its kind on the amphibians of Jigme Dorji National Park. It provides data that could be used to begin to understand local amphibian species' distribution and factors governing such distribution. This research was carried out with the intention of future continuation and long term data collection, to gain a thorough understanding of the species dynamics. Therefore, there is a good future scope to study on amphibian's habitat analyses with addition of more environmental parameters in order to comprehend the complex ecology of these vertebrates.

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COMMUNICATION

The soft-release of captive-born Kaiser's Mountain Newt *Neurergus kaiseri* (Amphibia: Caudata) into a highland stream, western Iran

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Abstract: Captive breeding and reintroduction programs are important conservation tools and are used for increasing the number of plant and animal species worldwide. The endemic Kaiser's Mountain Newt *Neurergus kaiseri* is listed as Vulnerable on the Red List by the International Union for Conservation of Nature (IUCN) and is amended to Appendix I of the Convention of International Trade on Endangered Species (CITES). In the present study, in order to learn about the survival ability of captive-born newts of *N. kaiseri*, we conducted a trial translocation of 15 two-year-old captive-born *N. kaiseri* into the highland stream in Sartakht Village, western Iran. The survival rate of these newts were determined in two stages, involving early acclimatization in mesh bags and direct release in a highland brook. In 12 surveys to the translocation site, a total of 86 individuals were identified during spring and summer. The average survival rate during the acclimatizing phase was 98 ± 0.04 %, while an average survival rate of 12 ± 0.04 % was obtained when the newts were released in the brook. Applying an average diurnal detection probability obtained for the Yellow Spotted Mountain Newt *Neurergus derjugini*, the overall survival rate in September when newts began the autumn withdrawal was 13%. These findings demonstrate that captive-born *N. kaiseri* released into the wild in controlled conditions can survive during spring and summer and provide information for future reintroduction plan of this species.

Keywords: Captive breeding, conservation, CITES, reintroduction, trial translocation, threatened species.

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Author contribution: TS was responsible for field and laboratory works and preparation of the manuscript. VA reviewed the manuscript. MSH conducted field surveys and reviewed and approved the manuscript.

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INTRODUCTION

The list of species categorized as Vulnerable, Endangered, or Critically Endangered has nearly doubled in the past two decades, and 20,000 species are estimated as endangered species on the verge of extinction (Estrada 2014). The release of captive-born individuals is being increasingly used as an important tool for the restoration of endangered and threatened species around the world (Seddon et al. 2007; Okuyama et al. 2010). The reintroduction of captive-bred animals for establishing a viable population often fails due to a range of reasons (Mathews et al. 2005), such as inability to avoid predators, a lack of searching for food and inability to process food, inability to find shelter, lack of predatory abilities, loss of social interactions with conspecifics and orientation in a complex environment (Okuyama et al. 2010).

Various studies conducted on reintroduced species have shown that different environmental and biological factors contribute to the success of reintroduction projects. One of these factors is the type of release; hard (direct) or soft (indirect) release (Serangeli et al. 2012). Based on the hypothesis that soft-release methods will improve the success of reintroduction, they are often included in reintroduction protocols (Moehrenschlager & Macdonald 2003). A common soft-release method is delayed release (or acclimatization) that prevents high rates of mortality that often occur immediately after release (Dickens et al. 2010). In this technique, individuals are placed in a protective enclosure at the release site, so that they can acclimatize to the new environment gradually before the release (Sutherland 2000). In addition, long-term food availability, habitat suitability and the season of release are other factors for the success of reintroduction (Jule et al. 2008; Serangeli et al. 2012).

Over 32% of amphibian species have been known as globally threatened species since the 1970s (Stuart et al. 2004). Different factors including pollution, over-consumption, habitat loss, climate change, and disease (both fungal and viral) play a role in these declines. Therefore, captive breeding programs are used increasingly to counter extinctions of wild populations of frogs and salamanders (Gascon et al. 2007; Bodinof et al. 2012). The drawbacks associated with captive breeding may be less important in amphibian species due to several life history attributes such as small body size with low space requirements, rapid growth and high fecundity (Kinne 2004; Sharifi & Vaissi 2014). There are several reasons to translocate animals that could generally be assigned to experimental research, to mitigate human-wildlife conflict and conservation or population re-establishment (Germano & Bishop 2009). The aim of the experimental reintroduction or research is to survey the best conditions for captive-bred survival in a release site and to improve reintroduction programs in the future (Liu et al. 2016). As a result, an experimental approach can help to provide appropriate guidelines for the success of the reintroduction program (Griffiths & Pavajeau 2008; Santos et al. 2009; Roe et al. 2010).

Kaiser's Mountain Newt *Neurergus kaiseri* is a species that is endemic to the southern Zagros Mountains with a restricted distribution in the Lorestan and Khuzestan provinces. Rapid declines due to its highly fragmented breeding habitat and also because it occupies a small range during its reproductive period implied the extinction of this newt in the wild and is pointed out to be one of the threatened species in Iran (Sharifi et al. 2009). Until recently, studies showed that localities from only four streams (in a single catchment area) increased to 40 new geographical localities. Therefore, this species was listed as Vulnerable by IUCN in 2017 (Mobaraki et al. 2014). Furthermore, this species has been listed in Appendix I of the Convention of International Trade on Endangered Species (CITES, https://www.cites.org/eng/app/appendices.php, Sharifi et al. 2009).

A conservation management plan funded by the Mohamed bin Zayed Species Conservation Fund was initiated for The Yellow Spotted Mountain Newt *Neurergus derjugini* (= *Neurergus microspilotus*) in 2010. Part of this plan included the development of a captive breeding facility (CBF) at Razi University, Kermanshah, Iran (Vaissi & Sharifi 2015). Several laboratory studies in the CBF on *N. derjugini* provided information on growth and development (Vaissi & Sharifi 2016a,b), cannibalism (Vaissi & Sharifi 2016b), ontogenetic changes in spot configuration (Vaissi & Sharifi 2017), a trial reintroduction of captive-bred newts (Sharifi & Vaissi 2014; Vaissi & Sharifi 2018), and comparing the predatory impact of captive-bred and free-living newts (Salehi & Sharifi 2019). Also, this project initiated a program for captive breeding and field studies of the Kaiser's Mountain Newt (Image 1A) aiming to provide critical information for a conservation management plan. These studies included sexual size dimorphism (Sharifi et al. 2012), histomorphological study (Parto et al. 2013; Parto et al. 2014b), reporting chytridiomycosis (Sharifi et al. 2014), and red-leg syndrome (Parto et al. 2014a), delimiting the species range (Sharifi et al. 2013), ageing and growth of species (Farasat & Sharifi 2016), reproductive morphology and sperm storage (Parto et al. 2015), and

population genetic structure (Farasat et al. 2016).

Here we will use translocation as a term referring to the release of individuals from captive origins to areas without conspecifics into the wild for experimental evaluation of post-release survival of captive-reared Kaiser's Mountain Newts. Much of our discourse on translocation here will focus on the captive breeding management and therefore on captive-release programs. However, there was no monitoring work on the survival of the captive-born Kaiser's Mountain Newts into the wild so, here we describe a trial translocation of this species. For this purpose, the experimental release was carried out in two stages during spring and summer. The first stage involved the indirect release of individuals into the environment for acclimatization, and in the second stage, the newts were released directly into the environment.

The main aims of our trial translocation were: (i) whether captive-born newts could survive in the natural habitat during the acclimatization phase, (ii) to determine whether acclimatized newts would be observed at the release site after free release, and (iii) whether reintroduction of captive-born newts could be an effective conservation strategy for the recovery of a viable population in the future.

MATERIALS AND METHODS

Captive breeding

The previous ex situ conservation program on *N. derjugini* and their reintroduction provided relevant experience and information for the current work. In the spring of 2014, the first gravid females (SVL: 173.9–174.2 mm) from Bozorgab Stream (32.933^{0}N & 48.466^{0}E) in the southern Zagros Mountains were transported to CBF. The gravid females were detectable by their swollen bodies. They were introduced together in one aquarium (75 × 45 × 35 cm) with a water level of about 9cm and with small pebbles. Also, the aquaria were filled with mosses and some aquatic plants for egg attachment. Immediately after egg laying, we introduced the eggs (due to cannibalism) into separate rearing aquaria with aerated water. The egg stage lasted 2–3 weeks and then in the first phase of their life they were motionless and attached their mouth regions to plants, stones or other solid objects. In this life cycle, they consumed their internal nutrient reserves and then were fed with Artemia egg and shredded blood worms *Glycera dibranchiate*. The larval period lasted 8–9 months, reaching metamorphosis (loss of gills) and in this stage the young postmetamorphs (mean SVL was 30 ± 0.59 mm and mean body mass was 1.53 ± 0.05 g) left the water and they stayed more in the terrestrial component of their habitat. They were fed with a series of gradually larger food items including blood worms, earthworm *Lumbricus terrestris*, and live mealworms *Teneberio molitor* until they reached the scheduled release size.

Selecting newts for release

We released 15 two-year-old individuals (Image 1B, mean SVL was 35.71 ± 2.46 mm and mean body mass was 1.61 ± 0.48 g) in 2016 because individuals of smaller sizes are vulnerable to predators and environmental factors. In addition, larger individuals acclimatize themselves to the captive condition and likely lose their normal behavior and function. Prerelease protocols included testing for diseases, normal behaviors, and responsiveness to stimulus.

Selecting of the release site

The selected site in the present study was a highland brook in Sartakht Village (34.766^{0}N & 47.150^{0}E) in western Iran (Figure 1, Image 1C), a small highland (1,600m) stream with permanent water discharge. This was partly selected because it was close to a private property to which we had easy and regular access.

Acclimatization and free release

We performed a soft-release reintroduction involving a period of acclimatization in the highland stream to allow the newts to adjust to the environmental conditions and avoid the impact of native predators such as crabs (*Potamon bilobatum*). The newts were placed in mesh bags (46 × 30 × 36 cm) and hid under plants in release site on three occasions (5 individuals per occasion) in 2016: 29 April, 6 May, and 13 May (Image 1D). Periods of acclimatization were 9, 10 and 11 weeks for three occasions. We fed newts with mealworms in the first week of acclimatization to the environmental conditions. The remaining newts from acclimatization period were directly released into the highland brook on 15 July 2016 (Image 1E).

Visual monitoring and detection probability

The newts were monitored on seven occasions when they were in their mesh bags until we made sure of their relative survival during the acclimatization period. Following 70 days of acclimatization, the newts were released in the stream and monitored by visual counts on five occasions until 16 September 2016 when the newts began the autumn withdrawal from the stream. Visual counts conducted by two observers walking along the stream banks between 10.00h and 13.00h where

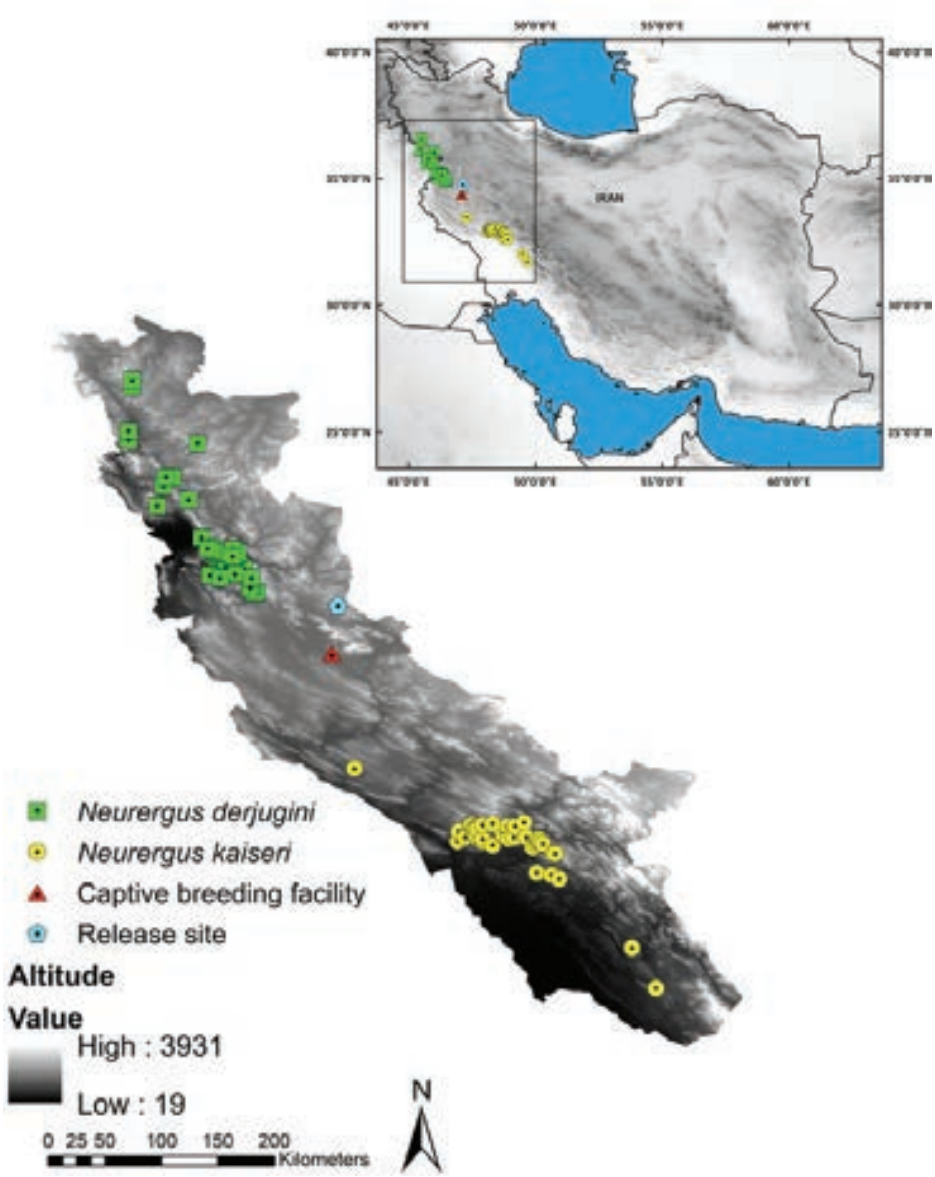

Figure 1. Distribution map of two species of mountain newts in western Iran, the Yellow Spotted Mountain Newt, *Neurergus derjugini* (green square) and the Kaiser's Mountain Newt, *Neurergus kaiseri* (yellow circle). The sites of the captive breeding facility (red triangle) and the translocating (blue pentagon) location between the ranges of the two species.

vegetation cover in the stream was dense and the search involved pursuing them under plants and rocks. Visual counts were conducted on 6 May, 13 May, 20 May, 3 June, 17 June, 1 July, 15 July, 22 July, 5 August, 19 August, 2 September and 16 September. For identification using coloration pattern recognition, we previously photographed the dorsal surfaces of the newts using a digital camera (Sony, DSCHX9V, 3.6V) on a tripod at a fixed height (30cm). After capturing, each newt was identified, measured, weighed, and the health status was checked.

Estimation of the survival rate of the released *N. kaiseri* involved the application of detection probability that was used for measuring *N. derjugini* (Sharifi & Vaissi 2014). This detection probability was obtained when a known number of newts were kept in several stone enclosures. The estimated average detection probability for *N. derjugini* was 0.61 ± 0.19 SD. We used the average detection probability as follows (Bailey et al. 2004): $N = C/\beta$ where C, β, and N are the number of individuals counted, the probability of detection, and we adjusted the visual count respectively.

RESULTS

All of the individuals survived 100% during transportation from the CBF to the release site. Overall, we detected 86 individuals during 12 surveys. At the end of the acclimatization phase, we identified 13 individuals from 15 released newts within mesh bags making the survival rate (mean ± SD) in this period 98 ± 0.04 %. We observed two dead newts on 17 June. At the end of the acclimatization period, the body mass and SVL (mean ± SD) of the surviving newts were 1.69 ± 0.55 g and 38.33 ± 2.56 mm respectively.

In five visits from 22 July 2016 until 16 September 2016, only two released newts were found exactly at the point of release between the mosses and herbs around the stream on 19 August and 16 September 2016. The body mass and SVL of the newts on 19 August and 16 September were 1.56g, 33.36mm and 1.33g, 35.51mm, respectively. The survival rate (mean ± SD) in this period of 12 ± 0.04 % was considerably lower than the acclimatization phase. Based on the detection probability estimated for *N. derjugini*, the observed newts after final release were 13% of reintroduced newts. Table 1 describes the number, SVL, body mass, percent of surviving newts during acclimatization and free release periods and based on detection probability.

DISCUSSION

Release in controlled conditions has revealed the success of the acclimatized animals after release and the higher rates of individual survival (Mitchell et al. 2011). The soft-release of captive-born individuals has shown that this kind of release could provide an opportunity to adapt to the new environment, minimize mortality, and reduces the anxiety (Moseby et al. 2014). In the present study, we tested the survival rate in the acclimatization phase and during free release. The present trial translocation showed that that two-year-old captive-born newts would be able to survive in a natural habitat during acclimatization phase and the average survival rate of two year old newts in this period without humans was 98%. The high rate of survival during the acclimatization period is partly attributable to the protective mesh bags that avoid the impact of native predators and provides more time to adapt to natural conditions. Also, a similar translocation by Sharifi & Vaissi (2014) on *N. derjugini* that is a closely related species to *N. kaiseri* had demonstrated that young captive-born newts (in the relatively protected enclosure) can survive to the second growing season in the wild.

The survival rate in the free release phase was 12% of the released individuals. The present trial translocation showed that the survival of two-year-old captive born newts in the mesh bags remained high in the natural

Table 1. Date and number of the released individuals of *Neurergus kaiseri* into the wild, the age, SVL and body mass of released individuals, number of observed individuals during acclimatization phase, percent of individuals observed after and before free release phase, percent of surviving individuals based on next surveys and an estimate of the survival of newts outside mesh bags based on detection probability (db).

Date	No. released	No. observed	SVL (mm)	Body mass (mg)	% observed	% survived	% survived based on dp
29.iv.2016	5	-	34.31 ± 2.23	1.24 ± 0.16	-		
6.v.2016	5	5	35.62 ± 2.57	1.48 ± 0.22	100%		
13.v.2016	5	10	37.21 ± 2.08	1.65 ± 2.11	100%		
20.v.2016	0	15	35.71 ± 2.46	1.61 ± 0.48	100%		
3.vi.2016	0	15	35.91 ± 2.35	1.57 ± 3.21	100%		
17.vi.2016	0	13	36.04 ±2.49	1.68 ± 3.10	87%		
1.vii.2016	0	13	36.55 ± 2.55	1.69 ± 3.50	100%		
15.vii.2016	13*	13	38.33 ± 2.56	1.69 ± 3.55	100%		
22.vii.2016	0	0			0%	15%	0 %
5.viii.2016	0	0			0%	15%	0 %
19.viii.-2016	0	1			8%	15%	13 %
2.ix.2016	0	0			0%	8%	0 %
16.ix.2016	0	1			8%	8%	13 %

Note: The star mark is the date of free release into the wild outside the mesh bags.

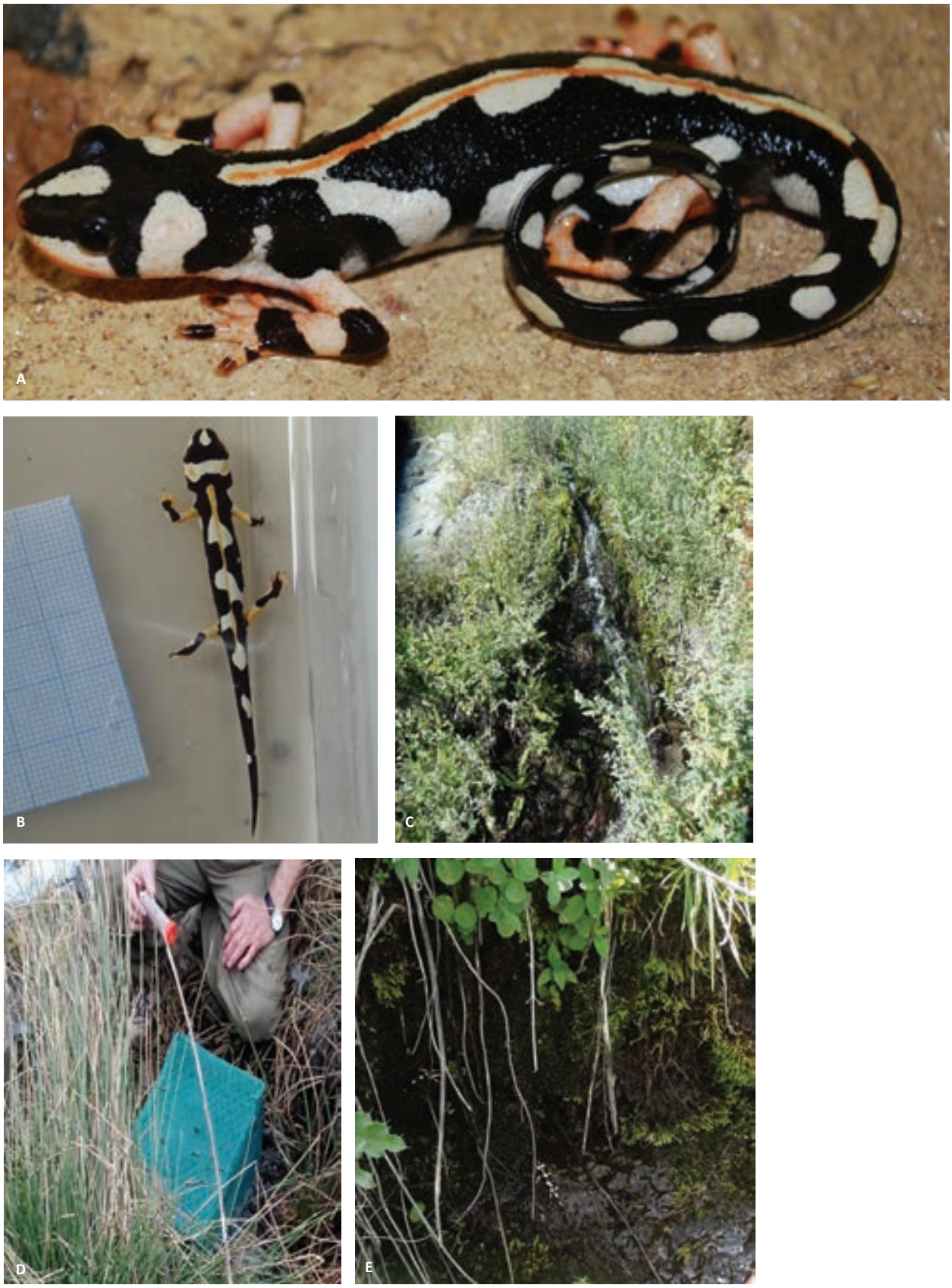

Image 1. A—Kaiser's Mountain Newt *Neurergus kaiseri* | B—two-year- newt in captive breeding facility | C—the release site of *Neurergus kaiseri* into the highland brook | D—acclimatization period in mesh bag | E—direct release to environment. © M. Sharifi & T. Salehi.

habitat during the acclimatization phase. We did not observe any newts on 22 July and 5 August, while in the next surveys two newts were found. Therefore, it is possible that more newts survived and we were not able to find them. Failure to find these newts is likely due to the small size of the released newts and the complexity of the environment. McFadden et al. (2016) encountered major difficulties in finding the Northern Corroboree Frog *Pseudophryne pengilleyi* after reintroduction, due to their small size and cryptic behavior. The study by Randall et al. (2016) on the Northern Leopard Frog *Lithobates pipiens* revealed another major difficulty in the reintroduction program: the low number of individuals released and complexity of the habitat. Also, Bell et al. (2010) carried out the release with low numbers (<30) of the Maud Island Frog *Leiopelma pakeka* and demonstrated that the risk of predators had probably reduced the success of translocation.

We observed that the newts were moving to the wet areas around the water and hiding under vegetation cover at the time of the release. In the next surveys after the free release, some individuals were found close to the release site. Studies show soft-releases can increase site fidelity that is a common aspect of reintroductions with many amphibians (Wanless et al. 2002; Attum et al. 2011). The newts that were observed on 19 August and 16 September after direct release were precisely hidden in the vegetation cover in the initial release site. Moreover, we needed the transmitter for study dispersal and home range of newts after reintroduction while the results show that the use of the transmitter in released individuals can lead to vulnerability and an increase in the likelihood of their death (Miloski & Titus 2008). In addition, studies on salamanders have used few external transmitters because of the movement of salamanders and the complexity of their habitat (Dervo et al. 2010); and internal transmitters have been used in larger species such as the Spotted Salamander *Ambystoma maculatum* (McDonough & Paton 2007) and Chinese Giant Salamander *Andrias davidianus* (Zhang et al. 2018). In a study that was conducted to investigate the survival of 22 Chinese Giant Salamanders after reintroduction the internal transmitter was used. It, however, took too much time for the salamanders to recover from surgery (they needed almost four months to fully recover). Furthermore internal transmitters only last for about one year, and it is difficult to replace expired transmitters with new units, thus longer monitoring plans could not be applied (Zhang et al. 2018). The use of the internal transmitter in this study was impossible due to the low number and small size of the individuals that would increase mortalities at the beginning of release. Sharifi & Afroosheh (2014) have been able to effectively use photographic identification method as a non-invasive method in *N. derjugini*, the sister species of *N. kaiseri* to determine the home range of this newt during a breeding season. The result of this study showed very small home range and high site fidelity of *N. derjugini.*

CONCLUSION

The present trial on the soft-release of two-year-old captive born Kaiser's Mountain Newts in spring and summer involving an acclimatization period and a free release phase showed a high survival rate in the first stage, and a lower survival rate in the second stage. There were major difficulties including small size, cryptic behavior and complexity of habitat, and low number of released newts during direct release. Possible reasons for the failure of translocation can be predation or lack of site fidelity after free release. We hope the findings of this experimental research help future reintroduction programs. We suggest a larger number of newts in a predator-free release environment in future translocations. Also, we encourage comparison of trained and untrained newts in soft-release strategies in future reintroductions. Information on all studies will open the door for a successful reintroduction of *N. kaiseri*.

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COMMUNICATION

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The status of waterbird populations of Chhaya Rann Wetland Complex in Porbandar, Gujarat, India

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Abstract: The present investigation was undertaken to study the diversity of wetland birds in Chhaya Rann (Gujarati: Deserted land) wetland complex, situated in the urban setting of Porbandar City, in the western state of Gujarat, India. Almost 70 species belonging to 21 families of wetland birds have been reported from here with an estimated count of 35,747 and 20,981 in the year 2016 and 2015 respectively. Anatidae and Scolopacidae represent the higher number of species (11 each) followed by Ardeidae (eight species) and Laridae (seven species). The wetland complex supports one IUCN Red Listed Vulnerable species (Common Pochard *Aythya ferina),* six Near Threatened species (Lesser Flamingo *Phoeniconaias minor,* Oriental Darter *Anhinga melanogaster,* Dalmatian Pelican *Pelecanus crispus,* Black-headed Ibis *Threskiornis melanocephalus,* Black-tailed Godwit *Limosa limosa* and River Tern *Sterna aurantia*), and 63 Least Concern species. The wetland meets the Criteria 5 and 6 for listing as a wetland of international importance under the Ramsar Convention.

Keywords: Asian Waterbird Census, Gosabara-Mokarsagar Wetland Complex, Gujarat, IUCN Red List, Porbandar, wetland birds.

Gujarati: હાલની તપાસ ભારત દેશના પશ્ચિમ રાજ્ય ગુજરાતના પોરબંદર શહેરમાં આવેલા છાયા રણ વેટલેન્ડ કોમ્પ્લેક્સમાં પક્ષીઓની વિવિધતાનો અભ્યાસ કરવા માટે હાથ ધરવામાં આવી હતી. વર્ષ ૨૦૧૬અને ૨૦૧૫માં અનુક્રમે ૩૫,૭૪૭ અને ૨૦,૯૮૧ની અનુમાનિત ગણતરી સાથે આર્દ્રથી જલપ્લાવિત ક્ષેત્રના પક્ષીઓના ૨૧ કુટુંબોની ૭૦ પ્રજાતિઓ લગભગ નોંધાયેલી છે. એનાટીડે અને સ્કોલોપેસિડે એ જાતિઓ વધુ સંખ્યા (પ્રત્યેકની ૧૧ પ્રજાતિઓ) રજૂ કરે છે, ત્યારબાદ આર્ડેઈડે (આઠ પ્રજાતિઓ) અને લારિડે (સાત પ્રજાતિઓ) આવે છે. વેટલેન્ડ કોમ્પ્લેક્સ એક આઈયુસીએન રેડ લિસ્ટેડ વલનરેબલ પ્રજાતિ રાખોડી કરચીયા, છ નિયર થ્રેટંડ પ્રજાતિઓ (નાનો હંજ, સર્પ ગ્રીવા, ચોટીલી પેણ, કાળી કાકણસર, અને કેંચી પૂંછ વા-બગલી), અને ૬૩ લિસ્ટ કન્સર્ન પ્રજાતિઓને આશરો આપે છે. રામસર કન્વેશન હેઠળ આંતરરાષ્ટ્રીય મહત્વના જલપ્લાવિત ક્ષેત્ર તરીકેની સૂચિ માટે છાયા વેટલેન્ડ, ૫ અને ૬ ક્રમાંકના માપદંડને પૂર્ણ કરે છે.

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Author contribution: DV—field work, data collection and correspondence with publisher. AC—prepared first draft and provided inputs as and when required.

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INTRODUCTION

Wetlands are the most precious life sustaining water resource of this planet. Some of the vital functions are surface water storage, groundwater recharge, storm water retention, flood control, shoreline stabilization, erosion control, and retention of carbon, nutrients, sediments, and pollutants. Apart from these wetlands are the repository of rich flora and fauna, however, these complex ecosystems only constitute 4% of the earth's ice-free land surface (Panigrahy et al. 2012).

Birds which are fully dependent on wetlands for their physiological and behavioral characters are termed as waterbirds. Natural wetlands are the mainstay of the waterbirds; they are also regarded as the custodian of huge avifauna populations (Weller 1999; Stewart 2001). At present, wetlands in India face tremendous anthropogenic pressure. Almost 38% of inland wetlands in India have been lost during 1971–2001 (Prasad et al. 2004). This has resulted in loss of biodiversity affecting the overall functioning of the wetland ecosystem.

Gujarat occupies 6.2% of the total geographic area in India and has the longest coastline (almost 1,600km) of any state. It is bestowed with 17% of wetlands including intertidal mudflats, mangroves, coral reefs , rivers/ streams, reservoirs/barrages, creeks and salt marsh (National Wetland Atlas: Gujarat 2010).

The Chhaya Rann wetland complex, situated in an urban setting of the coastal Porbandar town, comprises an important part of the Porbandar Bird Sanctuary (officially designated in 1988), however, very few scientific investigations have been published on its birds (Anonymous 2016).

As part of the results of the Asian Waterbird Census conducted in January 2016 in the area, Vargiya et al. (2016) refer to loss of connectivity of the Chhaya Rann wetland complex with the parent wetland and ingress of factory effluents, rapid urbanization, and encroachment inside the wetlands, lack of conservation initiatives and a wetland management authority. They also include images of birds being struck by power lines, affected by fire crackers and DDT spraying.

This paper presents results of baseline information of the waterbirds of the Chhaya Rann wetland complex between January 2015 and January 2016.

STUDY AREA

Porbandar is a coastal district of Gujarat and covers an area of 2,294km^2. It lies in a semi-arid climatic zone with average daily temperatures ranging 21.6–40.4°C, with maximum temperatures being recorded from May to June and minimum from December to January. The average rainfall in Porbandar is 629mm, mainly during July–September. A total of 226 wetlands are mapped in the district by the Indian Space and Research Organization, including 95 small wetlands (< 2.25ha) with a total area of 22,199ha. Inland wetlands contribute 27.3% of the total wetland area while coastal wetlands contribute 72.7%. The major wetland categories of the district are lagoons, rivers/ streams, reservoirs and sand/beach (National Wetland Atlas: Gujarat 2010). Physiogeographically, Porbandar District has two regions, i.e., the Barda Hills forested region and the river plains. The major rivers of the district are Bhadar, Ojat, Minsar and Madhuvanti. Porbandar District is enclosed by Arabian Ocean on the west, by Jamnagar and Devbhumi Dwarika districts on the north, and Junagadh from the east and the south.

The Mokarsagar–Gosabara Wetland Complex in and around Porbandar is a complex of several coastal intertidal and brackish to freshwater wetlands, namely, Medha Creek, Kuchhadi, Chhaya Rann, Subhashnagar, Zavar, Kurly I, Karly II, Vanana, Dharampur, Gosabara, Mokarsagar, and Amipur.

Of these, the Chhaya Rann Wetland Complex (here after Chhaya Wetlands) is a narrow strip of brackish wetland habitat, about 4.5km long and 0.5km wide (2.25km^2) and comprises of Porbandar Rann, Chhaya 1, Chhaya 2 and Chhaya 3 wetlands. Historically, the Chhaya Wetlands were known as the Birla Rann where sea salt was produced several decades ago. Locally the Chhaya and Mokarsagar wetlands are known as 'Rann', i.e., 'Chhaya nu rann' and 'Mokar nu rann', as rann means deserted and non-productive land (a reference to when the wetland dries in summer and looks like barren land).

Over time, much of the wetland area was filled in for construction of housing societies, roads, shops, petrol pumps and educational buildings as part of the urban expansion of Porbandar. With the development of roads, this wetland was fragmented into several small wetlands now named Porbandar Bird Sanctuary (declared in 1988), Porbandar Rann, Chhaya 1, Chhaya 2 and Chhaya 3 near Balwy colony (Map 1 and Table 1). These wetlands are now separated from each other and surrounded by housing colonies and industrial areas. The Porbandar Bird Sanctuary is also separated

Figure 1. Chhaya Rann Wetland Complex, Porbandar City, Gujarat State.

from the rest of the Chhaya Wetlands. Water can flow between Chhaya 1, Chhaya 2 and Chhaya 3 and none are connected to the sea. Chhaya 3 dries out in summer while the other wetlands always retain some water during this period. As Chhaya 3 was previously managed as a salt pan it retains features like bunds, barriers and quadrates which provide roost sites for waterbirds.

The water depth was not measured in any wetland, however, by observing the foraging habits of Lesser Flamingo *Phoeniconaias minor*, which have the longest leg length and by considering the average leg length (as per Mascitti & Castañera 2006), it was possible to roughly calculate the maximum water depth to be about 50cm. Lesser Flamingo can forage at a water depth of 02 to 50cm. Complete legs of the Lesser Flamingo was seen when feeding at the periphery of the wetlands, while in the middle, the flamingos appeared to be floating with their entire legs out of view; here we assume the water depth to be about or at least 50cm in the Chhaya 2 wetland.

Porbandar Bird Sanctuary is a relatively deep water habitat compared to the Chhaya 2 wetland. The state forest department has created around 40 islets within the waterbody to encourage roosting of waterbirds and has planted the Indian Tulip Tree (*Thespesia populnea*) along the periphery of the sanctuary. There are no plantation or habitat creation activities in the Chhaya 1, 2 and 3 wetlands.

Due to increase in salinity in nearby farm areas, salt production was stopped and as a consequence, the wetland currently is maintained by inflows of urban domestic drainage water from the Chhaya municipality area and a limited quantity of rain water during the annual monsoon. In an attempt to combat the breeding of mosquitoes in the area, the Chhaya wetlands was filled with waste material locally called 'datt' from a nearby factory by local municipality (Kishore Joshi, pers. comm. 2016). This dumping created a shallow water wetland and salinity of the datt when mixed with rain water created an algal bloom which appears to have attracted flamingos. The first flock of Lesser Flamingo was seen in the winter of the 1960s (Kishore Joshi, pers. comm. 2016).

METHODS

The Chhaya Wetlands were visited once a month between January 2015 and January 2016 during which a total of 13 counts of birds were made. Surveys were conducted in the mornings at 07.00–10.00 h and in the evenings at 16.00–18.00 h. The species were identified using Grimmett et al. (2015) and birds were counted using block count and individual count methods. The January 2015 and January 2016 counts were linked to the Asian Waterbird Census coordinated nationally by Wetlands International and the Bombay Natural History Society.

RESULTS

A total of 70 species of 21 families of waterbird and wetland bird species were reported in this wetland complex during 2015–2016 (Table 2 and Image 1). Anatidae and Scolopacidae represent the higher number of species (11 each), followed by Ardeidae (eight) and Laridae (seven) (Fig. 2). The Chayya Wetlands support one (1.4% of all species) Vulnerable species (Common Pochard *Aythya ferina)* as per the IUCN Red List of Threatened Species (IUCN 2018), six (8.5%) Near Threatened species (Lesser Flamingo, Oriental Darter *Anhinga melanogaster,* Dalmatian Pelican *Pelecanus crispus,* Black-headed Ibis *Threskiornis melanocephalus,* Black-tailed Godwit *Limosa limosa*, and River Tern *Sterna aurantia*), and 63 (82.9%) species listed as of Least Concern (Fig. 3).

Out of 70 species recorded, seven breed in Chhaya Wetlands, while 27 are resident in the district and have not been recorded to breed here, and 36 are migratory. The estimated counts of waterbird and wetland bird species of the entire wetland complex are 20,981 and 35,747 in January 2015 and January 2016, respectively (Table 2). The Lesser Flamingo was the most abundant species, with 14,649 and 21,611 individuals recorded in 2015 and 2016, respectively. And the species diversity remains the same for the Porbandar Rann for both the survey years (2015 and 2016), i.e., 21 species. While in other sites, the number of species observed dropped from 2015 to 2016; Chhaya 1 & 2 from 39 species in 2015 to 31 in 2016 and at Chhaya 3 from 27 in 2015 to 18 in 2016.

Flocks of 80 to 100 Lesser Flamingos were observed to fly from the Porbandar Rann, Chhaya 2, and 3 to Chhaya 1 wetland only to bathe and after several minutes, to

Table 1. Description of Chhaya Rann Wetland Complex and observed threats to wetlands.

Site No.	Name of wetland	Location (lat. & long.)	Observed threats	Conservation action	Governance
1	Porbandar Bird Sanctuary and associated area	21.636^{0}N & 69.618^{0}E	· Pollution by domestic sewage and garbage · Wetland as inflow of sewage water and no outflow has resulted in an increase in water depth which is not suitable for many wader species. A new municipal sewage system is expected to address this pollution issue.	In April 2019, inflow of municipal sewage water has been reduced. As a result, the water level of the wetland dropped and after 30 years more than 800 Lesser flamingos were seen feeding here.	Porbandar Forest Division & Municipality of Porbandar
2	Porbandar Rann	21.632^{0}N & 69.623^{0}E	· Pollution by domestic sewage and garbage · Dumping zone of waste materials · Industrial effluents · Feral dogs killing birds		Municipality of Chhaya
3	Chhaya 1 & 2	21.630^{0}N & 69.626^{0}E	· Fragmentation and filling of wetland for illegal commercial development and houses · Dumping zone of waste materials · Pollution by domestic sewage and garbage · Invasion of *Prosopis juliflora* on fringes · Annual spraying with DDT along the wetland periphery aimed at controlling mosquitoes	In November 2018, City Survey Porbandar issued 85 notices for illegal construction.	Municipality of Chhaya
4	Chhaya 3	21.622^{0}N & 69.636^{0}E			

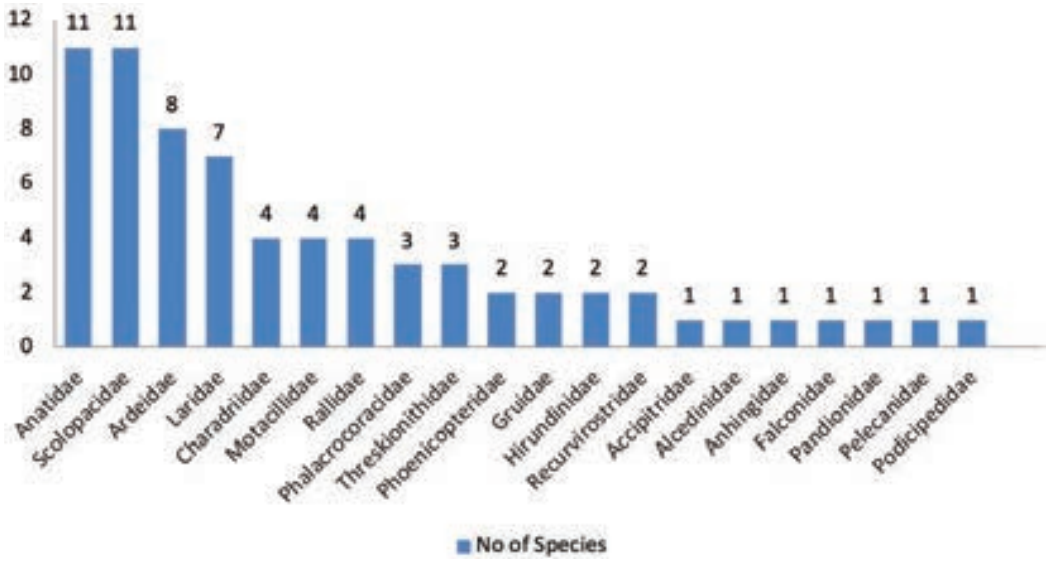

Figure 2. Wetland bird species composition recorded in Chhaya Rann Wetland Complex during the study.

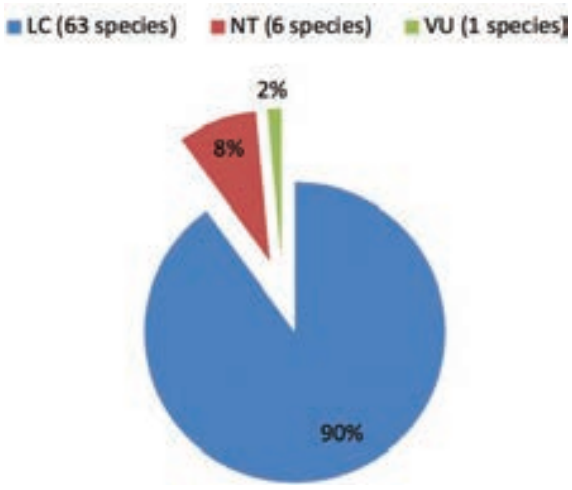

Figure 3. Conservation status (percentage composition) of wetland bird species as per their IUCN Red List category (VU—Vulnerable | NT—Near Threatened | LC—Least Concern).

fly back to the other wetlands. This phenomenon was only observed during afternoons. Greater Flamingo preferred Chhaya 1 for courtship while Lesser Flamingo preferred Chhaya 2 for their courtship activities.

Porbandar Bird Sanctuary: A total of 41 waterbird and wetland bird species were reported in January 2015 and 2016. During the summer, the islets supported nesting of about five pairs of Red-wattled Lapwings *Vanellus indicus* and seven pairs of Black-winged Stilts *Himantopus himantopus*. Tall reeds towards the western side of the sanctuary provided roosting sites for marsh birds like moorhens and waterhens. These reeds were also favored by Demoiselle Cranes *Anthropoides virgo* and Common Cranes *Grus grus* that were injured by kite flying threads and remained throughout the year at the sanctuary as their ability to fly was hampered. The sanctuary appeared to support a number of freshwater fishes, judging from the number of fish-eating birds that were regularly seen feeding. The sanctuary was also the roosting ground of Black-headed Ibis and in summer, a maximum of around 150 were recorded. A pair of Great Cormorants *Phalacrocorax carbo* was observed building a nest although nesting was not successful. In April 2019, inflow of municipal sewage water into the sanctuary was stopped and this reduced the water level of the wetland. These conditions appeared to have been suitable for more than 800 Lesser flamingos that were observed to feed here after a gap of 30 years.

The water at the shallow periphery dried out in Chhaya 1 and 2 which supported roosting birds. Though only 37 Greater Flamingo *Phoenicopterus roseus* were recorded during the January waterbird count, their number was observed to increase up to 500 individuals in Chhaya 1 and Porbandar Rann wetlands after March. One pair of Kentish Plover and two pairs of Little Ringed Plover were recorded nesting in Chhaya 3 wetland in 2016.

The Chhaya wetlands were observed to face various threats, including dumping of solid waste, domestic sewage and garbage. The wetland annually receives a spray of DDT along the periphery to control mosquitoes (Table 1).

Table 2. Wetland bird diversity recorded in Chhaya Rann Wetland Complex during assessment period (with numbers during January 2015 and January 2016).

	English name	Scientific name	Gujarati name	Family	IUCN Conservation status (1)	Status in Study area (2)	AWC January 2015 count	AWC January 2016 count
1	Lesser Whistling-duck	*Dendrocygna javanica* (Horsfield, 1821)	Nani sisoti batak	Anatidae	LC	R	11	10
2	Comb Duck	*Sarkidiornis melanotos* (Pennant, 1769)	Nakto	Anatidae	LC	R	2	4
3	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	Bhagvi surkhab	Anatidae	LC	M	4	7
4	Gadwall	*Mareca strepera* (Linnaeus, 1758)	Luhar	Anatidae	LC	M	0	8
5	Eurasian Wigeon	Mareca penelope (Linnaeus, 1758)	Piyasana	Anatidae	LC	M	0	20
6	Indian Spot-billed Duck	*Anas poecilorhyncha* Forster, 1781	Teelavali batak	Anatidae	LC	R	57	40
7	Northern Shoveler	*Spatula clypeata* (Linnaeus, 1758)	Gayno	Anatidae	LC	M	3292	1190
8	Northern Pintail	*Anas acuta* Linnaeus, 1758	Singpar	Anatidae	LC	M	184	12
9	Garganey	*Spatula querquedula* (Linnaeus, 1758)	Chetva	Anatidae	LC	M	0	5
10	Common Teal	*Anas crecca* Linnaeus, 1758	Murghabi	Anatidae	LC	M	157	45
11	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	Rakhodi Karchiya	Anatidae	VU	M	7	14
12	Greater Flamingo	*Phoenicopterus roseus* (Pallas, 1811)	Moto hanj	Phoenicopteridae	LC	R	37	0
13	Lesser Flamingo	*Phoeniconaias minor* (Geoffroy Saint-Hilaire, 1798)	Nano hanj	Phoenicopteridae	NT	R	14649	21621
14	Little Grebe	*Tachybaptus ruficollis* (Pallas, 1764)	Nani dubki	Podicipedidae	LC	R	25	80
15	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	Matsya bhoj	Pandionidae	LC	M	1	0
16	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	Nano Kajoyo	Phalacrocoracidae	LC	R	10	50
17	Indian Cormorant	*Phalacrocorax fuscicollis Stephens, 1826*	Kajiyo	Phalacrocoracidae	LC	R	0	24
18	Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	Moto Kajiyo	Phalacrocoracidae	LC	R	0	4
19	Oriental Darter	*Anhinga melanogaster* Pennant, 1769	Sarpa griva	Anhingidae	NT	R	0	2
20	Dalmatian Pelican	*Pelecanus crispus* Bruch, 1832	Chotili Pen	Pelecanidae	NT	M	2	2
21	Grey Heron	*Ardea cinerea* Linnaeus, 1758	Kabut Baglo	Ardeidae	LC	R	2	2
22	Purple Heron	Ardea purpurea Linnaeus, 1766	Nadi baglo	Ardeidae	LC	R	0	1
23	Great Egret	*Ardea alba* (Linnaeus, 1758)	Moto baglo	Ardeidae	LC	R	25	40
24	Intermediate Egret	*Egretta intermedia* (Wagler, 1829)	Dhola bagalo	Ardeidae	LC	R	24	0
25	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	Nano Baglo	Ardeidae	LC	R	18	10
26	Western Reef Heron	*Egretta gularis* (Bosc, 1792)	Dariyai baglo	Ardeidae	LC	R	4	2
27	Eastern/ western Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	Dhor baglo	Ardeidae	LC	R	53	73
28	Indian Pond-heron	*Ardeola grayii* (Sykes, 1832)	Kani bagli	Ardeidae	LC	R	33	24
29	Glossy Ibis	*Plegadis falcinellus* (Linnaeus, 1766)	Pan/nani kakansar	Threskiornithidae	LC	M	21	0
30	Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790)	Dholi kakansar	Threskiornithidae	NT	RB	65	54

	English name	Scientific name	Gujarati name	Family	IUCN Conservation status (1)	Status in Study area (2)	AWC January 2015 count	AWC January 2016 count
31	Red-naped Ibis	*Pseudibis papillosa* (Temminck, 1824)	Kali kakansar	Threskiornithidae	LC	RB	1	23
32	Eurasian Marsh-Harrier	*Circus aeruginosus* (Linnaeus, 1758)	Pan pattai	Accipitridae	LC	M	2	1
33	White-breasted Waterhen	*Amaurornis phoenicurus(Pennant, 1769)*	Davak	Rallidae	LC	RB	8	0
34	Grey-headed Swamphen	*Porphyrio poliocephalus* (Latham, 1801)	Nil jalamurgho	Rallidae	LC	R	4	14
35	Eurasian Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	Jal kukadi	Rallidae	LC	R	5	8
36	Eurasian Coot	*Fulica atra* (Linnaeus, 1758)	Bhagatdu	Rallidae	LC	R	100	200
37	Demoiselle Crane	*Anthropoides virgo* Linnaeus, 1758	Karkaro	Gruidae	LC	M	7	10
38	Common Crane	*Grus grus* (Linnaeus, 1758)	Kunj	Gruidae	LC	M	11	7
39	Black-winged Stilt	*Himantopus himantopus* (Linnaeus, 1758)	Gajpau	Recurvirostridae	LC	RB	240	312
40	Pied Avocet	*Recurvirostra avosetta* Linnaeus, 1758	Ulti chanch	Recurvirostridae	LC	M	78	0
41	Pacific Golden-plover	*Pluvialis fulva* (Gmelin, 1789)	Soneri batan	Charadriidae	LC	M	2	15
42	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	Titodi	Charadriidae	LC	RB	159	108
43	Kentish Plover	*Charadrius alexandrinus* Linnaeus, 1758	Bhulamani dhongili	Charadriidae	LC	RB	11	0
44	Little Ringed Plover	*Charadrius dubius* Scopoli, 1786	Vilayati jini titodi	Charadriidae	LC	RB	1	21
45	Terek Sandpiper	*Xenus cinereus* (Güldenstädt, 1775)	Chanchal tutvari	Scolopacidae	LC	M	6	0
46	Common Sandpiper	*Actitis hypoleucos* Linnaeus, 1758	Samanya tutvari	Scolopacidae	LC	M	23	9
47	Common Greenshank	*Tringa nebularia* (Gunnerus, 1767)	Lilapag	Scolopacidae	LC	M	6	1
48	Marsh Sandpiper	*Tringa stagnatilis* (Bechstein, 1803)	Gandapag tutvari	Scolopacidae	LC	M	241	11
49	Wood Sandpiper	*Tringa glareola* Linnaeus, 1758	Van tutvari	Scolopacidae	LC	M	1	4
50	Common Redshank	*Tringa totanus* (Linnaeus, 1758)	Ratapag	Scolopacidae	LC	M	11	33
51	Black-tailed Godwit	*Limosa limosa* (Linnaeus, 1758)	Kali punchh gadero	Scolopacidae	NT	M	45	21
52	Ruff	*Calidris pugnax* (Linnaeus, 1758)	Tiliyo	Scolopacidae	LC	M	177	361
53	Little Stint	*Calidris minuta* (Leisler, 1812)	Kalapag kichadiyo	Scolopacidae	LC	M	119	21
54	Red-necked Phalarope	*Phalaropus lobatus* (Linnaeus, 1758)	Laldok chanchal	Scolopacidae	LC	M	1	0
55	Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	Pankhapunch garkhod	Scolopacidae	LC	M	1	4
56	Black-headed Gull	*Larus ridibundus* Linnaeus, 1766	Kali pith dhomado	Laridae	LC	M	848	1100
57	Brown-headed Gull	*Chroicocephalus brunnicephalus* (Jerdon, 1840)	Ladakhi dhomado	Laridae	LC	M	140	1100
58	Gull sp.	*Larinae sp.*	Dhomado	Laridae	LC	M	13	8000
59	Little Tern	*Sternula albifrons* (Pallas, 1764)	Nani dhomdi	Laridae	LC	M	8	0
60	River Tern	*Sterna aurantia* Gray, 1831	Kenchipunch vabagali	Laridae	NT	R	11	40
61	Whiskered Tern	*Chlidonias hybrida* (Pallas, 1811)	Kashmiri vabagali	Laridae	LC	R	0	21
62	Gull-billed Tern	*Gelochelidon nilotica* (Gmelin, 1789)	Dhomada dhomadi	Laridae	LC	M	2	0

	English name	Scientific name	Gujarati name	Family	IUCN Conservation status (1)	Status in Study area (2)	AWC January 2015 count	AWC January 2016 count
63	Peregrine Falcon	*Falco peregrinus* Tunstall, 1771	Kalo shaheen	Falconidae	LC	M	1	0
64	White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	Safed chhati kalkaliyo	Alcedinidae	LC	R	0	4
65	Wire-tailed Swallow	*Hirundo smithii* Leach, 1818	Tarpunch tarodiyu	Hirundinidae	LC	R	20	550
66	Red-rumped Swallow	*Cecropis daurica* (Laxmann, 1769)	Kanchipunch tharodiyu	Hirundinidae	LC	R	0	400
67	Western Yellow Wagtail	*Motacilla flava* Linnaeus, 1758	Rakhodi mathano pilakiyo	Motacillidae	LC	M	2	1
68	White-browed Wagtail	*Motacilla maderaspatensis* Gmelin, 1789	Khanjan	Motacillidae	LC	R	0	3
69	Citrine Wagtail	*Motacilla citreola* Pallas, 1776	Pila mathano pilakiyo	Motacillidae	LC	M	5	0
70	White Wagtail	*Motacilla alba* Linnaeus, 1758	Diwali ghodo	Motacillidae	LC	M	1	0

IUCN Red List status: VU—Vulnerable | NT—Near Threatened | LC—Least Concern. Status in study area: R—Resident | M—Migrant | RB—Resident and Breeding.

The main threats to waterbirds were injury from kites being flown around the wetlands, predation by feral dogs, fire crackers, and injury & electrocution when flying into power lines. During the study period, a total of 15 flamingos (Lesser and Greater Flamingo) were injured due to kite-flying in the Uttarayan festival celebrated annually on 14 January. The festival was celebrated with rockets and other fire crackers in the evening causing the birds to take flight and risk injury and electrocution from nearby powerlines or injury by flying directly into blast area of rockets. Feral dogs were regularly observed to feed on injured flamingos. A Dalmatian Pelican was also observed to have died after electrocution on a power line at the Chhaya Wetlands in February 2016.

DISCUSSION

The Chhaya Rann Wetland Complex is a natural-cum-man-made wetland located within Porbandar City. This study provides baseline information on the high diversity of waterbirds and wetland birds recorded during two years. This high diversity can be corroborated with the varied microhabitats that appear to provide ideal foraging and roosting sites for migratory and resident species. Studies elsewhere have demonstrated that shallow depth and heterogeneity of habitats often results in higher diversity and abundance (Velasquez 1992; Elphick & Oring 1998, 2003; Svingen & Anderson 1998; Edwards & Otis 1999; Colwell & Taft 2000; Fairbairn & Dinsmore 2001; Riffel et al. 2001; Isola et al. 2002; Taft et. al. 2002; Darnell & Smith, 2004; Zárate–Ovando et al. 2008; Datta 2011).

The main threats observed at these wetlands are similar to those reported from other wetlands in the Indian subcontinent. For example, siltation, eutrophication, risk of DDT and pesticide intoxication, excessive weed infestation and degradation of water quality, encroachment by agriculture and urbanisation were some the main threats to wetlands and waterbirds of Shallabug Wetland in Kashmir (Dar & Dar 2009). While at Rupa Lake in Pokhara, Nepal, threats of habitat destruction by soil erosion, sedimentation and agricultural conversion, human disturbance, water pollution and eutrophication, as well as trapping/hunting and fish farming using nets are reported (Kafle et. al. 2008).

Similarly, the major threats to some of the main waterbird species at the Chhaya Wetlands are reflective of those at other sites. For example, the main threats to the Lesser Flamingo across its global range are the loss and/or the degradation of its specialised habitat at key sites through altered hydrology and water quality, wetland pollution, collision with man-made structures, human disturbance at non-breeding sites and predation (Childress 2008**)**. The recently produced single species action plan for the Dalmatian Pelican lists habitat degradation and collision with powerlines as high threats to the species (Catsadorakis & Portolou 2018) and both threats are recognised at the Chhaya Wetlands.

These wetlands are formed of a single stretch of a wetland that is now separated by roads. Holistically for


Black-tailed Godwit


Black-winged Stilt


Common Redshank


Common Sandpiper


Common Coot


Dalmatian Pelican


Darter


Demoiselle Crane


Glossy Ibis


Golden Plover


Great Cormorant


Great Egret


Greater Flamingo


Grey Heron


Lesser Flamingo


Purple Heron


Purple Moorhen


Red-wattled Lapwing


River Tern


Whiskered Tern


White Ibis


Wood Sandpiper

Image 1. Some waterbirds of Chhaya Wetland Complex. © Dhavalkumar Varagiya.

better management, they should be treated as a single wetland complex and not as separate wetlands. The importance of this is borne out by the observations of the flamingos moving between all four wetlands for feeding, bathing and other behavioural aspects.

Rehabilitation and release of Near Threatened Lesser Flamingos and other species injured due to powerlines and kite-flying threads, habitat restoration and removal of encroachment from the wetlands, control of poaching of birds, removal of solid waste, treatment of sewage water before entry into the wetlands, controlling population of feral dogs, removal of invasive species, especially *Prosopis* and Water Hyacinth *Eichhornia crassipes*, and avoiding spraying of DDT are some of the conservation actions that can be taken to preserve and improve management of the Chhaya Wetlands and its biodiversity.

Additionally, from a management point of view, the lack of formal conservation status (such as a protected area) and absence of comprehensive baseline information on waterbirds may deter science-based decision-making of these internationally important wetlands. Additional studies are required to improve understanding of the ecology of these wetlands and factors to maintain and enhance waterbird diversity and abundance.

The Chhaya Rann wetland complex has been influenced by salt and soda ash from the past salt production. In recent years, the main source of water has been domestic sewage and rain water. As it appears that these conditions are still conducive to attract the flamingos and other waterbirds and in internationally important numbers (>20,000 individuals) as per Criterion 5 of the Ramsar Convention on Wetlands, it is important for the state and national authorities to propose formal designation of the area as a Ramsar site. Development and implementation of a comprehensive management plan is needed to conserve this unique suite of wetlands with such high diversity in the face of rapid urbanization of the city.

Additionally, the Chhaya Wetlands qualify as an Important Bird and Biodiversity Area (IBA). According to global IBA criteria (BirdLife International 2018), criterion A1 states "a site is known or thought regularly to hold significant numbers of a globally threatened species" and criterion A4, "the site is known or thought to hold congregations of ≥1% of the global population of one or more species on a regular or predictable basis".

Finally it should be noted that Lesser Flamingos attempted nesting in Chhaya Wetlands in the 1980s, with around 180 nests; unfortunately heavy rain were reported to have destroyed the colony. It was later identified that they may have been "play-nesting". More recently, in 2015, Lesser Flamingos were seen mating here although they did not nest (Vargiya 2015). It is quite possible that if management of the area is strengthened with conditions created that are conducive for nesting, such as the construction of a flat island for the Lesser Flamingo and disturbance from feral dogs and people is stopped, the Chhaya Wetlands could even provide a unique and safe urban breeding site for the species; as has been demonstrated at the Kampers Dam in Kimberley, South Africa (BirdLife International 2019). Breeding of the flamingo here could provide a unique opportunity for the municipal and state authorities to demonstrate management of urban wetlands and environmental protection can go hand in hand.

The beauty and importance of the Chhaya Wetlands and its flamingos has been highlighted to the local community through various activities, notably 'Pink Celebration' that is organised every year since 2015 by the Mokarsagar Wetland Conservation Committee (Vargiya 2018). Organisation of such activities into the future can help to enhance the local awareness, interest and support for the management of the Chhaya Wetlands.

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Diversity and temporal variation of the bird community in paddy fields of Kadhiramangalam, Tamil Nadu, India

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Abstract: Paddy, a major food crop of India, provides a variety of habitats in a short period of time and supports diverse organisms. Paddy fields also harbour many birds with varying species composition across the different cultivation phases of paddy. This study, conducted in the paddy fields of Kadhiramangalam, Tamil Nadu, India, recorded the bird community composition there during the various cultivation phases of paddy. The bird community data was analysed and a total of 87 bird species were recorded from the study area belonging to 41 families and 13 orders. The growth phase (PS 3) is the most diverse phase. The bird composition showed a significant variation across the paddy cultivation phases with overall average dissimilarity of 71.41%. The patterns shown by graphs of bird species composition across the paddy cultivation phases is based on guild, habitat usage and order overlap and elucidates that the change in bird community composition temporally can be attributed to the niche variability across the paddy cultivation phases. The major species contributing to these changes observed are Black-headed Munia, Baya Weaver, Common Sandpiper, Barn Swallow, Common Myna, and Black Drongo in this region.

Keywords: Agro-ecosystems, aves, habitat usage, paddy cultivation phases, rice fields.

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INTRODUCTION

Birds are known to play a dual role as pests and as bio-controllers of pests in various agro-ecosystems (Borad et al. 2000). But, for decades the focus on birds in agro-ecosystems has been to study their foraging effects on crop yield and their control (Beri et al. 1968; Jotwani et al. 1969; Chahal et al. 1973; Jain & Prakash 1974; Bhatnagar 1976; Dhindsa & Toor 1980; Dhindsa et al. 1984; Parashaya et al. 1986; Subramanya 1987; Saini & Toor 1991). A few studies exist on the beneficial role of birds in agro-ecosystems (Chakravarthy 1988; Parashaya et al. 1994; Asokan & Ali 2010). The attitude on wildlife conservation became inclusive of large man-managed ecosystems (Bambaradeniya et al. 2004; Edirisinghe & Bambaradeniya 2006). Since then, the biodiversity associated with paddy fields is being considered in the light of conservation (Bambaradeniya et al. 1998; Edirisinghe & Bambaradeniya 2008; Elphick et al. 2010). Many studies on the bird use of paddy fields with focus on wetland species have been undertaken in the last two decades worldwide (Elphick et al. 2010; Sicemore & Maine 2012; Nam et al. 2015; Marco-Mendez et al. 2015).

India, being an agrarian economy, produces 21.2% of world's paddy in an area of 3.85 million hectares (Agristat 2016), making it the second largest producer of rice in the world. This large area under paddy cultivation throughout India is known to support 351 bird species (Gopisundar & Subramanya 2010). The bird species using the paddy fields are seen to vary regionally. Paddy fields are dynamic habitats and go through different habitats in a single crop cycle. This temporal variation in biodiversity during a paddy crop cycle is successive (Bambaradeniya et al. 2004). The habitat variations also lead to changes in resource availability for birds. This will have an impact on the bird community composition. As such, the bimodality in the activity pattern of birds in paddy fields during a day is known (Sridhara et al. 1983). In studying the ecological importance of birds in paddy field ecosystems, the understanding of this temporal variability in bird community would be useful. This paper aims to discern the patterns of temporal variation of bird community composition in paddy fields and explores the probable causes for the patterns observed.

Study Area

This study was conducted in Kadhiramangalam Village, Thiruvidaimarudur Taluk, Thanjavur District, Tamil Nadu (11.4'42.63"–11.4'58.24" ^{0}N & 79.31'18.729"–79.31'59.247" ^{0}E). Tamil Nadu is one of the top five rice producing states in India with 2.04 million hectares (4.7% of India's paddy cultivar land) under paddy cultivation, producing 7.65% of India's rice (Agristat 2016). In Kadhiramangalam, the whole of the low lying plains are intensive agricultural areas with the major crop being paddy interspersed with very small patches of sugarcane and timber wood. The main source of water for these paddy fields is from bore wells although it is a part of the fertile Cauvery delta. Farmers used to harvest three crops in the past. In recent years, they harvest only a single crop due to unavailability of water. The fields are flooded before land preparation and later irrigated as required. Chemical fertilizers and urea are used in 80% of the fields. Pesticides are used at the farmer's discretion.

METHODS

Field Methodology

To understand the bird species composition, strip-transect method (Sutherland 2000) was used. Two study sites (A and B) (Images 1–4), that were more than 2-km apart, were selected in the study area. A transect of 1-km was marked in each study site. Bird data was collected for two cropping seasons of paddy cultivated from August 2016 to January 2017 and September 2017 to March 2018 from both sites. Data collected included the bird species, numbers encountered and the field variables such as field conditions (wetland, wet and dry land) and also the paddy cultivation phases.

The data has been compartmentalised into seven phases of paddy cultivation to quantify the variations in bird composition over time (Bambaradeniya et al. 1998; Paliwal & Bhandarkar 2014). The seven paddy cultivation phases identified are

1. Land preparation and sapling phase (paddy stage - PS 1*) – Tilling and levelling are done and seed dispersed for saplings. Inundated wetlands. Around 15 days.
2. Transplantation phase (PS 2) – This stage includes transplantation and crop growth up to one foot in height. Inundated wetlands. Around 20 days.
3. Growth phase (PS 3) – From one ft grown crop till complete growth before flowering. Inundated wetlands. Around 30 days.
4. Flowering phase (PS 4) – Panicle formation and flowering. Wet fields. Pockets of wetlands. Around 10

* Following cultivation phases of paddy will be denoted as PS 1, 2, 3, 4, 5, 6 and 7 respectively.

Image 1. Study area. Source: Google Earth.

days.

5. Milking phase (PS 5) – During the milking period. Wet/ dry fields. Around 15 days.

6. Maturing phase (PS 6) – The panicles get mature. Wet/ dry fields. Around 15 days.

7. Drying and harvesting phase (PS 7) – The crop starts drying. Later harvested. Dry/wet fields. Pockets of wetlands.

Analytical Methodology

Data compiled, tabulated and subjected to basic descriptive statistics for studying the community characteristics. Pair-wise ANOSIM (Analysis of similarity) (Clarke & Green 1988) with Bray-Curtis index was used to test the significance and understand the extent of variation in the bird species composition between the paddy cultivation phases. To explore the species-wise contribution to dissimilarity, SIMPER (Similarity percentage) was used. Richness and diversity indices (Magurran 1988; Morris et al. 2014) were used to understand the temporal variation in the diversity. All these analyses were performed with PAST 3.1 (Hammer et al. 2001). The patterns in temporal variations in bird species composition, feeding guild composition and habitat usage were analysed by constructing relative abundance graphs using MS Excel 2007.

RESULTS

a) Bird Community Composition and Diversity

Eighty-seven bird species belonging to 13 orders and 41 families were recorded from the study area (Figs. 1a & b). Overall data shows that the passerines were the most abundant birds both in terms of species and population abundance. All species are in the Least Concern category of the IUCN Red List except Black-headed Ibis *Threskiornis melanocephalus* and Red-necked Falcon *Falco chicquera* that are in the Near Threatened category. The basic descriptive statistics of the data compiled are summarized in Tables 1 & 2. The maximum variance and standard deviation is observed in PS 5.

The change in relative abundance of the birds as per their taxonomic order (Fig. 2a), broad feeding guild (Fig. 3a) and habitat dependency (Fig. 4a) shows significant patterns.

As the growth of paddy proceeds, a steady decline in the number of birds of Charadriiformes, Pelecaniformes and Coraciiformes was observed. Similarly an increase and steep decline of the birds of Accipitriformes and Falconiformes was also observed with time. A steep

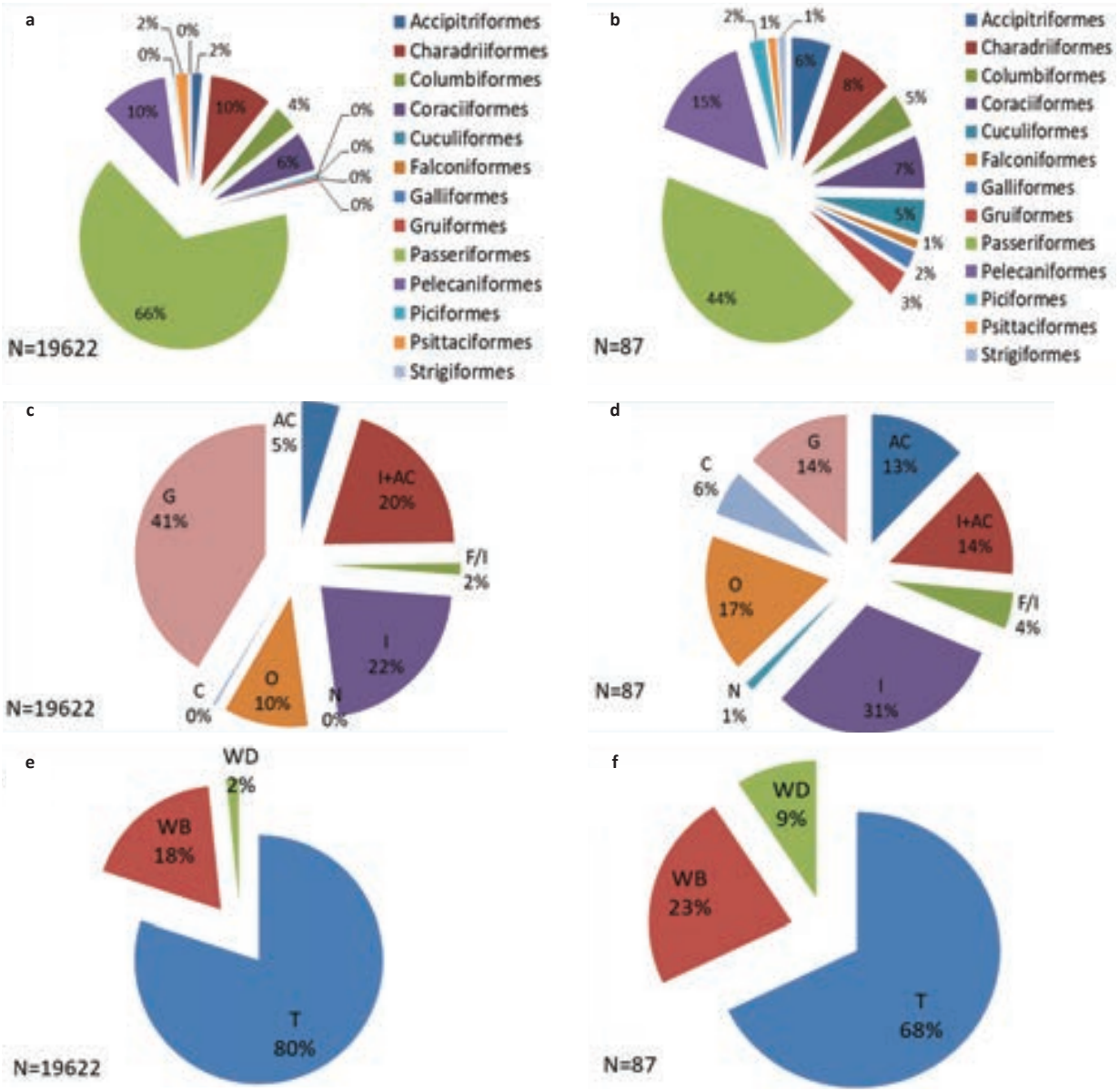

Figure 1. a, c & e—bird community composition in paddy fields based on order, guild and habitat dependency respectively | b, d & f—bird species composition in paddy fields based on order, guild and habitat dependency, respectively. Guild: AC—Aquatic Carnivore | C—Carnivore | F—Frugivore | G—Granivore | I—Insectivore | N—Nectarivore | O—Omnivore. Habitat Dependency: WB—Waterbird | WD—Wetland Dependent | T—Terrestrial.

Table 1. Bird community in paddy fields summary. Descriptive statistics based on species richness.

Paddy growth phases	Species richness	No. of transects	Total encounters	Mean	Standard deviation	Co-efficient of variance in %age	Minimum species/ transect	Maximum species/ transect
PS 1	53	14	2106	19.71	±3.47	17.61	12	27
PS 2	55	16	2536	21.13	±2.7	12.8	15	27
PS 3	60	15	2097	21.86	±4.03	18.44	16	31
PS 4	65	15	3591	25.33	±3.59	14.21	19	32
PS 5	58	10	4296	24.8	±4.75	19.18	18	33
PS 6	62	14	3871	25	±3.78	15.14	20	32
PS 7	54	10	1125	21	±6.43	30.61	9	31

Image 2. Congregation of wetland birds during PS 1.

Image 3. Birds during PS 3.

Image 4. Black-headed Munias and Baya Weaver during PS 5.

increase in Passeriformes and Psittaciformes after PS 4 was seen. Strigiformes increased after PS 3. Galliformes and Gruiformes remained steady across the stages (Fig. 2a).

Diversity and Species Richness indices (Table 3) show that PS 3 (growth phase) is the most diverse with 60 species although PS 4 (flowering phase) has highest species richness and PS 2 (transplanted paddy phase) seems to be the most even. These indices also show that PS 5 (milking phase) is the least diverse with low evenness and high dominance.

The R value of ANOSIM (at 95% confidence) shows that there is a significant difference in the bird species composition between the seven phases of paddy cultivation cycle (Table 4). The average dissimilarity among the seven phases was 71.41% (SIMPER). The R values between two consecutive stages were significant except PS 5 and PS 6 ranging from 0.16 to 0.21. Between two non-consecutive stages the values ranged from 0.21 to 0.71.

Ninety percent of this change is accounted for by 29 species of the total 87 bird species recorded (Appendix 1). The major contributors to this change are, *Lonchura malacca* (19.67%) followed by *Ploceus philippinus* (11.16%), *Actitis hypoleucos* (8.06%), *Hirundo rustica* (6.554%), *Acridotheres tristis* (3.86%), and *Dicrurus macrocercus* (3.499%) (Figs. 5 a & b) contributing to over 50% of the variations seen.

b) Feeding guilds and the temporal variation

The birds were categorised into eight broad feeding guilds based on their feeding preferences in Ali & Ripley (1978) (Figs. 1c & d), viz. insectivores, granivores, carnivores, nectarivores, omnivores, aquatic carnivores (species that feed on aquatic vertebrates and invertebrates), frugivores + insectivores, and aquatic carnivores + insectivores. Considering species richness as the factor, insectivorous guild dominates (32%) as in any terrestrial habitat. Dominance of the gregarious granivorous birds is evident in the abundance pattern showing 41% of total encounters of the granivores.

The relative abundance of these guilds (based on encounter rate) across the paddy growth phases showed a four times increase in granivores from PS 3 to PS 4 (Fig. 3a). More than 50% of the omnivores declined from PS 3 to PS 4. Carnivores also declined from PS 2 onwards. The frugivores are negligible in paddy field ecosystem. The insectivores and aquatic carnivores+insectivores were observed to increase in PS 3, decrease in PS 4 and PS 5 (40% decrease) and again increase in PS 6, probably an artefact of this miscellaneous classification.

c) Wetland birds in paddy fields

Bird community of paddy fields were analysed as per their known habitat association. The 87 bird

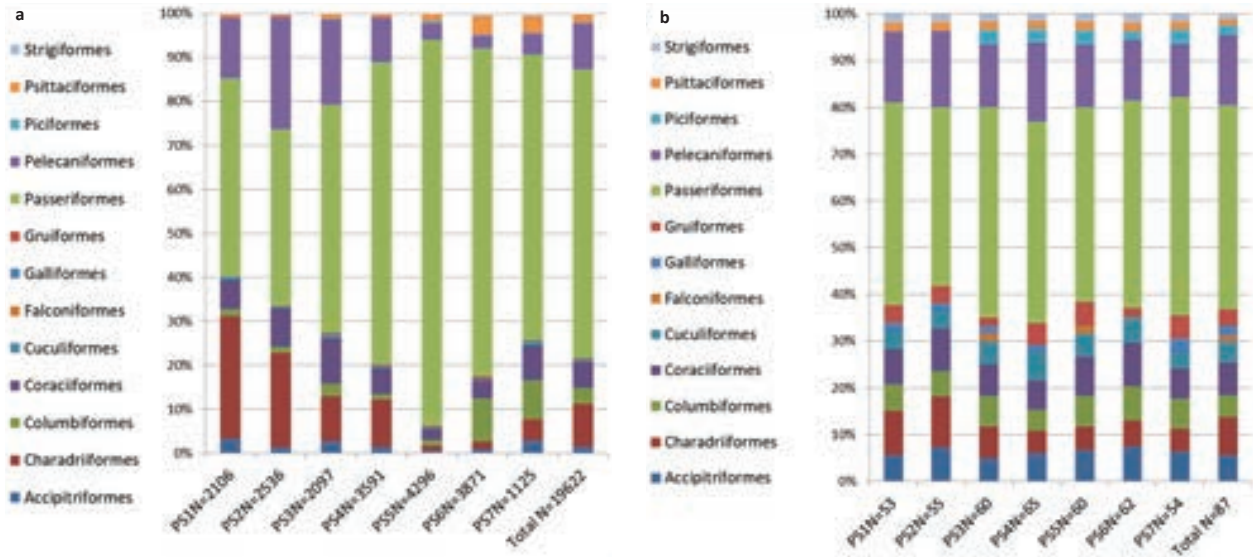

Figure 2. Temporal variation in taxonomic composition of bird community of paddy fields based on order and; a—relative abundance, and b—species richness.

Table 2. Bird community in paddy fields summary. Descriptive statistics based on total encounters.

Paddy growth phases	Species richness	No. of transects	Total encounters	Mean	Standard deviation	Co-efficient of variance in %age	Minimum encounters/ transect	Maximum encounters/ transect
PS 1	53	14	2106	150.42	±68.14	45.2	71	304
PS 2	55	16	2536	158.5	±48.44	30.5	97	264
PS 3	60	15	2097	139.8	±54.33	38.86	88	246
PS 4	65	15	3591	239.4	±149.79	62.56	111	659
PS 5	58	10	4296	429.6	±308.37	71.78	105	1065
PS 6	62	14	3871	276.5	±179.91	65.06	75	784
PS 7	54	10	1125	112.5	±63.07	56.62	32	216

species recorded from the study area were classified into three categories, viz., Waterbirds (wetland birds), wetland-dependent birds, and terrestrial birds; and their response to the changes in paddy stages was analysed. Of these, 28 bird species (relative abundance - 20%) are wetland associated, belonging to seven orders and 13 families. Twenty of these 28 bird species are true water-birds belonging to three orders, viz., Charadriiformes – 6 species (5 families), Gruiiformes – 2 species (1 family), Pelecaniformes – 12 species (4 families). Eight species are wetland dependent belonging to 6 orders, viz., Charadriiformes – 1 species (1 family), Pelecaniformes – 1 species (1 family), Coraciiformes – 3 species (1 family), Accipitriformes – 1 species (1 family), Gruiformes- 1 species (1 family). The rest are terrestrial (Figs. 1 e & f). The relative abundance of these birds across paddy stages shows more than 80% decrease in water-birds and wetland dependent species from PS 2 to PS 6 with a 50% drop between PS 3 and PS 4 (Fig. 4).

Twenty-two species are migrants (25.2%) of which 12 species (54.5%) are wetland dependent. Nineteen species are partial migrants (21.8%) of which 10 species (52.6%) are wetland dependent.

DISCUSSION

According to Subramanya (1987), the bird community in paddy fields are bimodal across paddy cultivation phases with peaks during the tilling/levelling phase and growth phase of paddy. This pattern was observed by considering only the species richness in each of the stages. Along with the species richness the number of birds in each of the species (population abundance) is also a significant factor to explore and understand the bird life of paddy fields. Since availability of prey

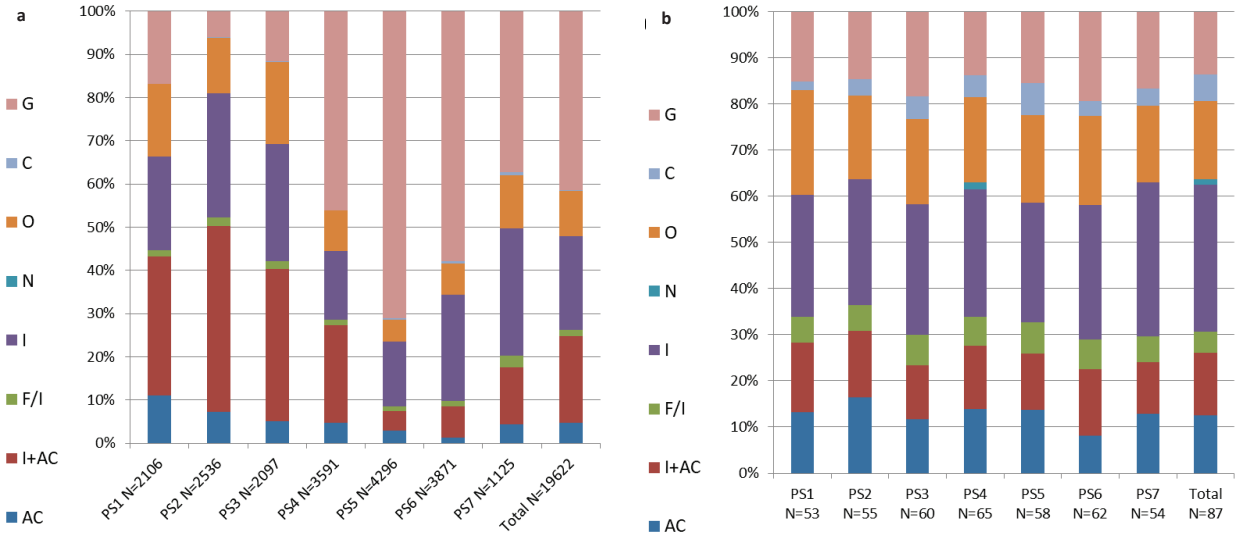

Figure 3. Temporal variations in bird feeding Guild Composition of paddy fields based on a) relative abundance, and b) species richness. AC—Aquatic Carnivore | I—Insectivore| F/I—Frugivore and insectivore | O—Omnivore | C—Carnivore | N—Nectarivore | G—Granivore.

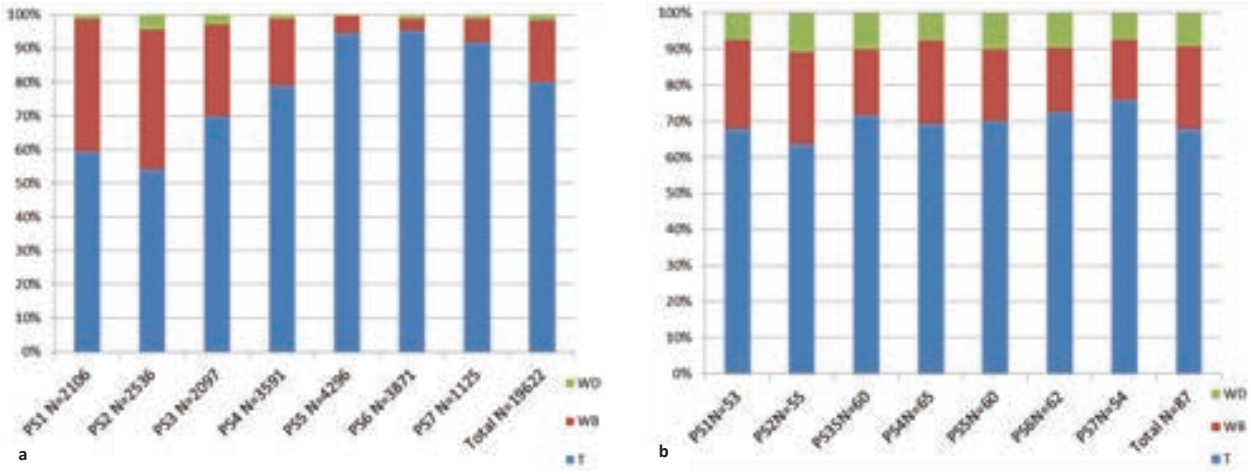

Figure 4. Temporal variations in bird community composition in paddy fields based on habitat dependency and a) relative abundance, and b) species richness: WD—Wetland dependent birds | WB—Waterbirds | T—Terrestrial birds.

Table 3. Richness and diversity indices of birds across paddy growth stages. The highest values of the indices are in bold and the least underlined. * is the most diverse.

	PS 1	PS 2	PS 3	PS 4	PS 5	PS 6	PS 7	Total
Taxa_S	53	55	60*	**65**	58	62	54	87
Individuals	2106	2536	2097	3591	4296	3871	1125	19622
Dominance_D	0.0915	0.0720	0.0606*	0.1294	0.2419	0.1943	**0.0601**	0.0884
Simpson_1-D	0.9085	0.9279	0.9393	0.8706	0.7581	0.8057	**0.9399**	0.9116
Shannon_H	2.885	3.039	3.181	2.7	2.065	2.514	**3.234**	3.073
Evenness_e^H/S	0.3379	0.3796	0.4011*	0.2289	0.136	0.1992	**0.4702**	0.2483
Menhinick	1.155	1.092	1.31	1.085	0.8849	0.9965	**1.61**	0.6211
Equitability_J	0.7267	0.7583	0.7768	0.6468	0.5086	0.609	**0.8108**	0.688
Berger-Parker	0.2023	0.1447	**0.1283**	0.2927	0.3638	0.4141	0.1653	0.2283

Table 4. R values of one-way ANOSIM (Bray-Curtis) between pairs of paddy growth stages. Permutation N = 9999, R= 0.3357, p= 0.0001. p value is less than 0.05 between all pairs in bold.

	PS1	PS2	PS3	PS4	PS5	PS 6
PS2	**0.1787**					
PS3	**0.2151**	**0.1635**				
PS4	**0.2768**	**0.3761**	**0.2106**			
PS5	**0.5038**	**0.6299**	**0.5546**	**0.1823**		
PS6	**0.4555**	**0.6366**	**0.445**	0.0877	0.1128	
PS 7	**0.3778**	**0.7102**	**0.5028**	**0.2252**	**0.3781**	**0.1641**

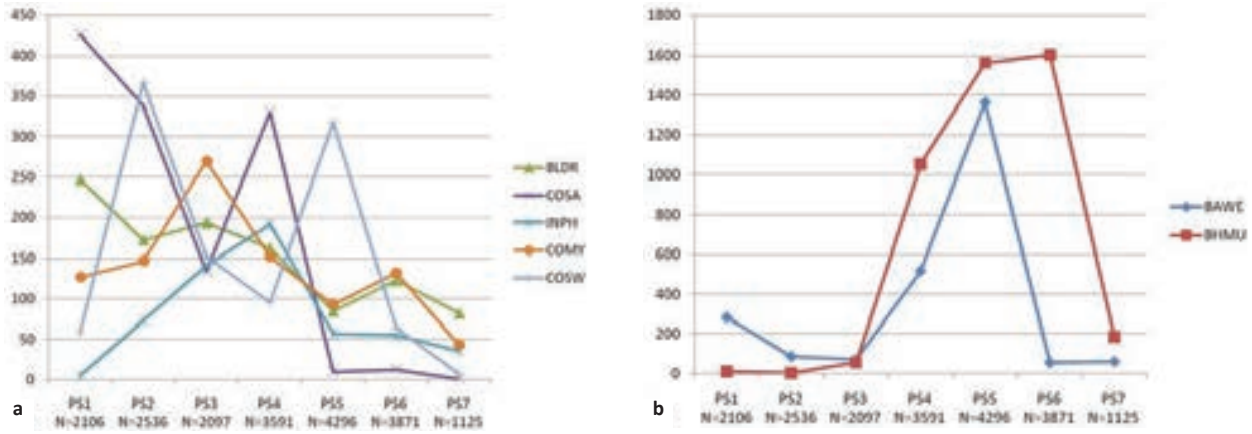

Figure 5. Variation of top contributors to change across paddy cultivation phases. A: COSA- Common Sandpiper | COSW—Barn Swallow | COMY—Common Myna | BLDR—Black Drongo | INPH—Indian Pond Heron. b: BAWE—Baya Weaver | BHMU—Black-headed Munia.

is known to affect bird abundance in paddy fields (Bambaradeniya et al. 1998), it is the feeding guilds and the opportunity provided by the changing ecosystem as a substratum for feeding in the paddy fields that determine the life of birds in this ecosystem. Hence, for the better understanding of temporal variation and its significance, the abundance of each species is important along with the species richness in the paddy fields.

The number of passerines increased across the cultivation phases from PS 1 till PS 5 and reduced in PS 6 and PS 7. Simultaneously, birds belonging to Charadriiformes, Pelecaniformes and Coraciiformes decreased from PS 1 through PS 5 and recovered slightly from PS 6 to PS 7. Columbiiformes showed a fourfold increase from PS 5 to PS 6 and Psittaciformes also showed a threefold increase from PS 5 to PS 7 (Fig. 2a). These results coincide with the trends observed in the guild composition variations where aquatic carnivores and insectivores + aquatic carnivores decreased through PS 2 to PS 5 with peak in PS 2. The same trends can be visualised in the wetland and wetland dependent species from PS 1 through PS 7 (Fig. 4a). The granivores showed a drastic increase from PS 3 with a peak in PS 5 and decreased in PS 6 and 7. The insectivores maintained a minimal of 15% across all the stages although the number increases which denotes their rise in abundance also across PS 1 and PS 7 (Fig. 3a).

Thus, the current study shows that there is a linear (table 3) significant change in bird community composition temporally in paddy fields along with the changes in paddy phases. This change is gradual. The richness (Table 2) did not show significant variation between the seven paddy cultivation phases considered here. So, during a cropping cycle of paddy a variety of niches are available that are also dynamic in nature. Hence, the temporal variation in bird community is due to niche variability across the different paddy cultivation phases.

The differences in bird community observed between two consecutive phases among PS 1–PS 2 and PS 3–PS 4 with R values at 0.178– 0.21 (Table 3) indicate the changes of available niches in the same area during that time frame. This may be because of the sudden change in habitat; (a) in case of PS 1 and PS 2, the presence

of transplanted paddy in an open wetland kind of ecosystem, (b) in the case of PS 3 and PS 4, the changes in crop density and start of panicles and drying of lands, opens avenues for new available niches. Simultaneously the process displaces a few niches already present. Increase in granivores till PS 5 and decrease only 50% till PS 7 seems to coincide with the increase in Columbidae and Psittaculidae that are seen to flock to feed on fallen grains after harvest.

The best examples of the dependency on the availability and accessibility of niches can be seen in PS 5 (milking phase) and PS 3 (growth phase). The high dominance Index value in the milking phase of paddy can be attributed to the increase in relative abundance of Passeriformes especially granivores and decrease of aquatic carnivores + insectivores (Figs. 2a & 3a). The low evenness may also be because of drastic increase in two species—*Lonchura malacca* and *Ploceus philippinus*. The steep decline in omnivores may be due to loss of open wetland conditions (Nam et al. 2015) and the crop density hinders the activities of raptors like *Milvus migrans* and *Haliastur indus*. Insectivores and mixed feeders maintain 20% of the overall abundance across the stages although there is an increase in total encounters. This shows there is an increase in the abundance of insectivores and aquatic carnivores + insectivores along the paddy stages which follow the arthropod abundance in rice fields (Bambaradeniya 1998) and changes with the habitat variations (Fig. 3a).

It can be concluded that there is a significant change in the paddy field bird composition temporarily with peak diversity during the plant growth phase (PS 3) of paddy cultivation phases. This change in bird community composition can be attributed to the dynamic habitat variability happening during paddy cultivation. Twenty-nine bird species contribute to 90% of the bird community changes seen in Kadhiramangalam region. The major contributing species are Black-headed Munia, Baya Weaver, Common Sandpiper, Barn Swallow, Common Myna, and Black Drongo in this region. All these except Black Drongos are colonial/ flocking birds. Hence, their presence or absence gives the major contributions. The temporal variability in the microhabitats of the paddy fields provide varied substratum in support of various bird species of different feeding guilds. This makes paddy fields a good candidate to be considered as a 'keystone habitat' for bird communities.

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Appendix 1. Checklist of birds in Paddy fields of Kadhiramangalam (Praveen et al. 2016).

	Scientific name	Common name	Move-ment	Feeding guild	Habitat	IUCN status	% age contribution to overall dissimilarity (SIMPER)	Relative abundance (%)
I	**Order Galliformes**							
	Family Phasianidae							
1	*Francolinus pondicerianus*	Grey Francolin	R	G	T	LC	0.1729	0.112
2	*Pavo cristatus*	Indian Peafowl	R	O	T	LC	0.04625	0.02
II	**Order Columbiformes**							
	Family Columbidae							
3	*Columba livia*	Rock Pigeon	R	G	T	LC (dec)	2.88	2.461
4	*Streptopelia decaocto*	Eurasian Collared Dove	R	G	T	LC (inc)	0.127	0.076
5	*Streptopelia senegalensis*	Laughing Dove	PM	G	T	LC	0.1919	0.097
6	*Streptopelia chinensis*	Spotted Dove	R	G	T	LC (inc)	0.9167	0.993
III	**Order Cuculiformes**							
	Family Cuculidae							
7	*Eudynamys scolopaceus*	Asian Koel	PM	O	T	LC	0.2126	0.178
8	*Hierococcyx varius*	Common Hawk Cuckoo	PM	I	T	LC	0.09703	0.046
9	*Centropus sinensis*	Greater Coucal	R	C	T	LC	0.0452	0.046
10	*Clamator jacobinus*	Pied Cuckoo	M	I	T	LC	0.1241	0.071
IV	**Order Gruiformes**							
	Family Rallidae							
11	*Gallinula chloropus*	Common Moorhen	M	O	WB	LC	0.05449	0.035
12	*Zapornia fusca*	Ruddy-breasted Crake	PM	O	WD	LC (dec)	0.06516	0.046
13	*Amaurornis phoenicurus*	White-breasted Waterhen	R	O	WB	LC	0.2928	0.245
V	**Order Pelecaniformes**							
	Family Ciconiidae							
14	*Anastomus oscitans*	Asian Openbill	PM	AC	WB	LC	1.895	1.844
	Family Ardeidae							
15	*Ixobrychus flavicollis*	Black Bittern	PM	I+AC	WB	LC (dec)	0.05399	0.04
16	*Bubulcus ibis*	Cattle Egret	PM	I	WD	LC (inc)	0.5555	0.377
17	*Ixobrychus cinnamomeus*	Cinnamon Bittern	PM	I+AC	WB	LC	0.03129	0.015

	Scientific name	Common name	Move-ment	Feeding guild	Habitat	IUCN status	% age contribution to overall dissimilarity (SIMPER)	Relative abundance (%)
18	*Ardea intermedia*	Intermediate Egret	PM	I+AC	WB	LC (dec)	2.691	1.926
19	*Ardeola grayii*	Indian Pond Heron	R	I+AC	WB	LC	3.057	2.84
20	*Ixobrychus minutus*	Little Bittern	PM	I+AC	WB	LC (dec)	0.02426	0.02
21	*Egretta garzetta*	Little Egret	PM	I+AC	WB	LC (inc)	2.249	1.849
22	*Ardea purpurea*	Purple Heron	M	AC	WB	LC	0.07015	0.056
	Family Threskiornithidae							
23	*Platalea leucorodia*	Eurasian Spoonbill	M	AC	WB	LC	0.008825	0.005
24	*Plegadis falcinellus*	Glossy Ibis	M	AC	WB	LC (dec)	0.1489	0.122
25	*Threskiornis melanocephalus*	Black-headed Ibis	PM	AC	WB	NT (dec)	1.437	1.019
	Family Phalocrocaracidae							
26	*Microcarbo niger*	Little Cormorant	PM	AC	WB	LC	0.4764	0.28
VI	**Order Charadriiformes**							
	Family Recurvirostridae							
27	*Himantopus himantopus*	Black- winged Stilt	M	O	WB	LC (inc)	1.522	0.958
	Family Charadriidae							
28	*Charadrius dubius*	Little Ringed Plover	M	I+AC	WB	LC	0.3769	0.28
29	*Vanellus indicus*	Red-wattled Lapwing	R	I+AC	WD	LC	1.591	1.554
	Family Rostratulidae							
30	*Rostratula benghalensis*	Greater Painted Snipe	M	AC	WB	LC (dec)	0.01222	0.01
	Family Scolopacidae							
31	*Actitis hypoleucos*	Common Sandpiper	M	I+AC	WB	LC (dec)	8.067	6.38
32	*Gallinago gallinago*	Common Snipe	M	AC	WB	LC (dec)	0.6628	0.464
	Family Laridae							
33	*Chlidonias hybrida*	Whiskered Tern	M	I+AC	WB	LC	0.02225	0.01
VII	**Order Accipitriformes**							
	Family Accipitridae							
34	*Milvus migrans*	Black Kite	R	O	T	LC	0.7647	0.724
35	*Haliastur indus*	Brahminy Kite	R	AC	WD	LC (dec)	0.6436	0.591
36	*Elanus caeruleus*	Black-winged Kite	R	I	T	LC	0.2424	0.204
37	*Accipiter badius*	Shikra	R	C	T	LC	0.0268	0.025
38	*Butastur teesa*	White- eyed Buzzard	R	C	T	LC	0.009357	0.005
VIII	**Order Strigiformes**							
	Family Strigidae							
39	*Athenebrama*	Spotted Owlet	R	C	T	LC	0.251	0.224
IX	**Order Piciformes**							
	Family Picidae							
40	*Dinopium benghalense*	Lesser Golden-backed Woodpecker	R	I	T	LC	0.09068	0.061
	Family Ramphastidae							
41	*Psilopogon haemacephalus*	Coppersmith Barbet	R	F/I	T	LC (inc)	0.2115	0.102
X	**Order Coraciiformes**							
	Family Meropidae							
42	*Merops philippinus*	Blue-tailed Bee -eater	PM	I	T	LC	0.039	0.015
43	*Merops orientalis*	Green Bee-eater	PM	I	T	LC (inc)	0.2097	0.158

	Scientific name	Common name	Move-ment	Feeding guild	Habitat	IUCN status	% age contribution to overall dissimilarity (SIMPER)	Relative abundance (%)
	Family Coraciidae							
44	*Coracias benghalensis*	Indian Roller	PM	I	T	LC (inc)	0.2962	0.183
	Family Alcedinidae							
45	*Ceryle rudis*	Pied Kingfisher	R	AC	WD	LC	0.2425	0.183
46	*Alcedo atthis*	Common Kingfisher	PM	AC	WD	LC	0.1167	0.076
47	*Halcyon smyrnensis*	White-throated Kingfisher	R	I+AC	WD	LC	2.207	5.172
XI	**Order Falconiformes**							
	Family Falconidae							
48	*Falco chicquera*	Red-necked Falcon	R	C	T	NT (dec)	0.02114	0.01
XII	**Order Psittaciformes**							
	Family Psittaculidae							
49	*Psittacula krameri*	Rose-ringed Parakeet	R	G	T	LC (inc)	1.93	1.824
XIII	**Order Passeriformes**							
	Family Oriolidae							
50	*Oriolus oriolus*	Eurasian Golden Oriole	M	F/I	T	LC (inc)	0.161	0.132
	Family Artamidae							
51	*Artamus fuscus*	Ashy Woodswallow	R	I	T	LC	0.4899	0.326
	Family Dicruridae							
52	*Dicrurus macrocercus*	Black Drongo	R	I	T	LC	3.499	5.407
	Family Laniidae							
53	*Lanius cristatus*	Brown Shrike	M	I	T	LC (dec)	0.07865	0.051
	Family Corvidae							
54	*Corvus splendens*	House Crow	R	O	T	LC	0.2367	0.158
55	*Dendrocitta vagabunda*	RufousTreepie	R	O	T	LC	0.375	0.362
56	*Corvus macrorhynchos*	Large-billed Crow	R	O	T	LC	0.6461	0.189
	Family Monarchidae							
57	*Terpsiphone paradisi*	Asian Paradise Flycatcher	M	I	T	LC	0.01098	0.005
	Family Nectariniidae							
58	*Leptocoma zeylonica*	Purple-rumped Sunbird	R	N	T	LC	0.01199	0.01
	Family Ploceidae							
59	*Ploceus philippinus*	Baya Weaver	R	G	T	LC	11.16	12.491
	Family Estrildidae							
60	*Lonchura malacca*	Black-headed Munia	R	G	T	LC	19.67	22.826
61	*Euodice malabarica*	Indian Silverbill	R	O	T	LC	0.09012	0.066
62	*Amandava amandava*	Red Munia	R	G	T	LC	0.1149	0.076
63	*Lochura punctulata*	Scaly-breasted Munia	R	G	T	LC	0.1346	0.107
64	*Lonchura striata*	White-rumpedMunia	R	G	T	LC	0.2203	0.153
	Family Passeridae							
65	*Gymnoris xanthocollis*	Yellow-throated Sparrow	PM	O	T	LC	0.2035	0.138
	Family Motacillidae							
66	*Motacilla cinerea*	Grey Wagtail	M	I+AC	WD	LC	0.01241	0.01
67	*Anthus rufulus*	Paddyfield Pipit	R	I	T	LC	0.6765	0.464
68	*Motacilla maderaspatensis*	White-browed Wagtail	R	I	T	LC	0.2047	0.132

	Scientific name	Common name	Move-ment	Feeding guild	Habitat	IUCN status	% age contribution to overall dissimilarity (SIMPER)	Relative abundance (%)
	Family Alaudidae							
69	*Mirafra affinis*	Jerdon'sBushlark	R	O	T	LC	0.5862	0.418
	Family Cisticolidae							
70	*Prinia socialis*	Ashy Prinia	R	I	T	LC	1.079	0.902
71	*Orthotomus sutorius*	Common Tailorbird	R	I	T	LC	0.01861	0.01
72	*Prinia hodgsonii*	Grey-breasted Prinia	R	I	T	LC	0.02298	0.01
73	*Prinia inornata*	Plain Prinia	R	I	T	LC	1.592	1.391
74	*Cisticola juncidis*	Zitting Cisticola	R	I	T	LC	2.917	2.899
	Family Acrocephalidae							
75	*Acrocephalus dumetorum*	Blyth's reed Warbler	M	I	T	LC (inc)	0.6365	0.499
76	*Iduna rama*	Syke's Warbler	M	I	T	C	0.008166	0.01
77	*Acrocephalus agricola*	Paddyfield Warbler	M	I	T	LC (dec)	1.595	1.386
	Family Hirundinidae							
78	*Hirundo rustica*	Barn Swallow	M	I	T	LC (dec)	6.554	5.422
79	*Cecropis daurica*	Red-rumped Swallow	M	I	T	LC	2.49	1.62
	Family Pycnonotidae							
80	*Pycnonotus cafer*	Red-vented Bulbul	R	F/I	T	LC (inc)	0.8179	0.958
	Family Leiothrichidae							
81	*Turdoides affinis*	Yellow-billed Babbler	R	O	T	LC	1.961	1.804
	Family Sturnidae							
82	*Sturnia pagodarum*	Brahminy Starling	R	F/I	T	LC	0.3347	0.245
83	*Acridotheres tristis*	Common Myna	R	O	T	LC (inc)	3.858	4.907
	Family Muscicapidae							
84	*Luscinia svecica*	Bluethroat	M	I	T	LC	0.01241	0.01
85	*Saxicola maurus*	Siberian Stonechat	M	I	T	LC	0.002521	0.005
86	*Copsychus saularis*	Oriental Magpie Robin	R	I	T	LC	0.009394	0.005
87	*Saxicola caprata*	Pied Bushchat	PM	O	T	LC	0.01659	0.01

Movement: M— Migrant | PM— Partial Migrant | R— Resident. Habitat: WB—Waterbird | WD—Wetland dependent bird | T— Terrestrial bird. Guild: AC—Aquatic Carnivore | I—Insectivore | F—Frugivore | G—Granivore | C—Carnivore | N—Nectarivore | O—Omnivore. IUCN Status: LC— Least Concern | (dec)—decrease in population | (inc)—increase in population; NT—Near Threatened.

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PLATINUM
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First videos of endemic Zanzibar Servaline Genet *Genetta servalina archeri*, African Palm Civet *Nandinia binotata* (Mammalia: Carnivora: Viverridae) and other small carnivores on Unguja Island, Tanzania

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Abstract: The faunal diversity of the densely populated island of Unguja, Zanzibar archipelago, Tanzania, includes several endemic mammals. Camera-trapping in Jozani-Chwaka Bay National Park and Kiwengwa–Pongwe Forest Reserve in September 2017 captured the first video footage of the Zanzibar Servaline Genet *Genetta servalina archeri*, an endemic subspecies first formally described in 1998. Other native small carnivores were also recorded on video for the first time during this survey, including the African Palm Civet *Nandinia binotata*, which was first documented in print as present in Unguja in 2004. Also camera-trapped in 2017 were the Zanzibar Slender Mongoose *Herpestes sanguineus rufescens* and the Zanzibar Bushy-tailed Mongoose *Bdeogale crassicauda tenuis*. Follow-up camera-trapping in Jozani-Chwaka Bay National Park in August 2018 captured additional video of the Zanzibar Servaline Genet and the African Palm Civet. No images were obtained of the African Civet *Civettictis civetta*, or of the two introduced species—the Banded Mongoose *Mungos mungo* and the Small Indian Civet *Viverricula indica*—in either year. As the remaining natural habitat in Zanzibar shrinks in size and becomes fragmented, it is increasingly urgent to document the archipelago's carnivores and other fauna, so that sound conservation measures can be implemented.

Keywords: *Bdeogale crassicauda,* Bushy-tailed Mongoose, *Herpestes sanguineus*, Slender Mongoose, Tanzania, Zanzibar.

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Author contribution: Both authors took part in the fieldwork in 2017. HVG carried out the fieldwork in 2018. Both authors analyzed the data and interpreted the results. MTW conceived the idea for the paper, HVG wrote the initial draft, MTW gave critical input, and the authors revised it together prior to submission and also following its review. Both HVG and MTW approve the published version of the article.

For **Swahili abstract** see end of this article.

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INTRODUCTION

The island of Unguja, in the Zanzibar archipelago, hosts several native carnivore species (Kingdon 1977; Pakenham 1984; Kingdon & Howell 1993; Van Rompaey & Colyn 1998; Perkin 2004). Three of these are considered endemic subspecies, namely, the Zanzibar Slender Mongoose *Herpestes sanguineus rufescens*, the Zanzibar Bushy-tailed Mongoose *Bdeogale crassicauda tenuis*, and the Zanzibar Servaline Genet *Genetta servalina archeri*, which was first formally described in 1998 (Van Rompaey & Colyn 1998). The remaining two native carnivores on Unguja are the African Civet *Civettictis civetta*, which is the island's largest extant wild carnivore, and the African Palm Civet *Nandinia binotata*. The latter was first observed by a biologist during a survey in 1998–99 and noted as a possible endemic subspecies (Perkin 2004).

The density of the human population of Zanzibar is about 400 per km^2 and as the number of people expands by about 3% per year, 1.2% of the archipelago's forests is lost annually to cultivation and wood extraction for firewood, charcoal production, and building materials (Siex 2011). This lends urgency to investigating the islands' fauna, particularly species at higher trophic levels. Mammalian carnivores, including small-bodied carnivores, may be particularly vulnerable to habitat fragmentation and loss (Di Minin et al. 2016). Though Unguja's natural habitat is diminishing, two elusive species previously not documented on the island were found there in the fairly recent past, as noted above.

The camera-trapping work reported here was undertaken opportunistically, alongside other research and with limited time and equipment, with the objective of obtaining further photographic documentation of Unguja's carnivores 14 years after camera-trapping in some of the same areas by one of the authors (Goldman & Winther-Hansen 2003a, b) and six years after a much larger scale camera-trapping survey carried out by other researchers (Siex 2011).

STUDY AREAS

Zanzibar forms part of Conservation International's Coastal Forests of Eastern Africa Hotspot (Critical Ecosystem Partnership Fund 2016). We set camera-traps in two of Unguja's protected areas: Jozani-Chwaka Bay National Park (JCBNP) and Kiwengwa–Pongwe Forest Reserve (KPFR) (Fig. 1).

JCBNP (ca. 6.183–6.291 ^{0}S, 39.375–39.443 ^{0}E) encompasses the island's only remaining natural, old-growth forest (Robins 1976; Williams et al. 1998; Box 5.5.4 in Rodgers & Burgess 2000) as well as a mosaic of other habitats, including scrub forest, bracken fields, saltmarsh grassland, and mangrove forests. Most of the park's 50km^2 is covered by high and low scrub forest (also known as coral rag forest (Siex 2011)) on ground characterized by numerous outcroppings of fossilized coral (Image 1a). The scrub forest comprises such species as *Euclea racemosa*, *Polysphaeria parvifolia*, *Pachystela brevipes*, *Maytenus mossambicensis*, *Searsia natalensis*, *Macphersonia gracilis*, *Annona senegalensis*, and *Flueggea virosa* (Leskinen et al. 1997). This vegetation cover is classified as Eastern African Coastal Scrub Forest, in Clarke's scheme (Clarke 2000). Some 4km^2 of the park is groundwater forest that floods during the annual heavy rains and is dominated by *Eugenia* sp. and *Calophyllum inophyllum*, with *Pandanus rabaiensis*, *Vitex doniana,* and *Elaeis guineensis* as subdominants (Robins 1976; Beentje 1990; Burgess et al. 1992; Nahonyo et al. 2002). This part of the park can be classed as coastal riverine/swamp/groundwater forest in Clarke's classification scheme (Clarke 2000). Contiguous with the natural old-growth forest is a former *Calophyllum inophyllum* plantation (Image 1b).

KPFR (ca. 5.924–6.041 ^{0}S, 39.33–39.403 ^{0}E) is about 31km^2 in size and is covered by high and low scrub forest, as described above. Camera-traps were placed in the low scrub forest near the Mchekeni caves.

In September 2017, temperatures on Unguja were between 20°C and 32°C. In August 2018, temperatures ranged from 21°C to 30°C. Humidity varies between 75% and 83%. The island receives about 1,575mm of rain annually. Most precipitation falls during rainy seasons in November–December and March–May. During our survey, there were occasional showers. In August, the sun rises at about 06.30h and sets at about 18.24h EAT. In September, the sun rises at about 06.16h and sets at about 18.20h EAT.

METHODS

Between 3 and 15 September 2017, 10 Bushnell Trophy Cam camera-traps were set in JCBNP and KPFR together with bait to attract the island's native carnivore species: the Zanzibar Servaline Genet, the African Palm Civet, the African Civet, the Slender Mongoose, and the Bushy-tailed Mongoose. Most of these species had previously been camera-trapped near JCBNP forestry headquarters and in the scrub forest several kilometres

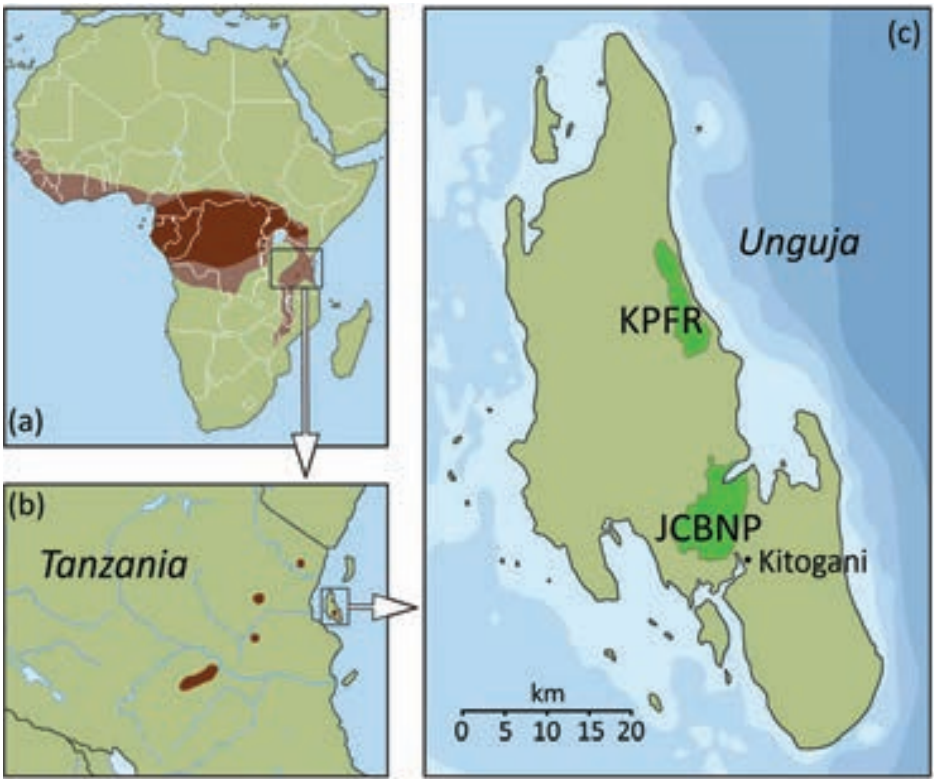

Figure 1. Jozani-Chwaka Bay National Park (JCBNP) and Kiwengwa–Pongwe Forest Reserve (KPFR) on the island of Unguja, in the archipelago of Zanzibar, Tanzania: (a)—The distribution of the Servaline Genet (*Genetta servalina*; dark brown) and, overlapping it, that of the African Palm Civet (*Nandinia binotata*; light brown) | (b)—The distribution of the Servaline Genet in Tanzania (dark brown); African Palm Civet distribution not shown. Maps modified from IUCN Red List of Threatened Species (species assessors and the authors of the spatial data, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=12252776 and https://commons.wikimedia.org/w/index.php?curid=12252756).

to the north, so we set up the traps in those areas. We did not set the traps at pre-set points on a grid or along transects because we were not attempting to estimate population density and did not have the time and resources to do so.

Not all cameras were active for the entire survey period in 2017. Multiple traps were set up at most stations. Counting multiple traps at a single station as a single trap, the number of trap nights in 2017 at JCBNP was 30 and at KPFR nine.

Between 04 and 12 August 2018, a single Bushnell Trophy Cam camera-trap was set in JCBCP (at different locations) for seven trap nights.

RESULTS

In 2017, the Zanzibar Servaline Genet was camera-trapped at four plantation forest stations and three scrub forest stations in JCBNP and at one scrub forest station in KFPR (Image 2; Video 1). The proximity of the plantation forest stations makes it possible for the same individual Servaline Genet to be camera-trapped at several of these stations. It is likely that the patterns of dark markings on the pelage of Servaline Genets permit individual identification, as has been done in capture–recapture studies of such species as Tiger (*Panthera tigris*; e.g., Karanth 1995) and Jaguar (*Panthera onca*; e.g., Silver et al. 2004). Although this would have allowed us to determine how many individual Servaline Genets visited the plantation forest trap stations, it proved difficult to reliably compared images of pelage patterns on account of the different body positions of the animals vis-à-vis the cameras.

Servaline Genets were mostly camera-trapped during the dark hours of the night in 2017, although one individual was camera-trapped in scrub forest habitat in JCBNP in daylight at 08.45h and at 17.48h.

Camera-trap videos of Servaline Genets in 2017 show individuals engaged in behaviours such as ascending and descending a tree, auto-grooming, and rolling on the ground. In one video, a Servaline Genet is chased by a Northern Giant Pouched Rat *Cricetomys gambianus cosensi* (Image 3). The alarm calls of Zanzibar Sykes's

Image 1. a—groundwater forest | b—plantation forest | c—scrub forest, JCBNP.

Monkey *Cercopithicus mitis albogularis* and Red Bush Squirrel *Paraxerus palliatus frerei* were also captured on video in connection with the presence of a male Servaline Genet at one scrub forest station in JCBNP.

In 2017, the African Palm Civet was camera-trapped in the JCBNP at two scrub forest stations. Palm Civets were camera-trapped exclusively at night, in trees and on the ground. In 2018, the Zanzibar Servaline Genet was camera-trapped at one scrub forest station and one plantation forest station and the Palm Civet was camera-trapped at one plantation forest station (Image 4).

Camera-trapping revealed as many as three species of carnivores—Servaline Genet, Palm Civet, and Bushy-tailed Mongoose—visiting a single scrub forest or plantation forest station during the course of a night. They did not overlap on film, suggesting that they avoid one another. The only exception was when a Bushy-tailed Mongoose *Bdeogale crassicauda tenuis* and a Palm Civet visited a station at the same time (Image 5). At two sites, adult Bushy-tailed Mongooses were camera-trapped in pairs.

The Zanzibar Slender Mongoose (*Herpestes sanguineus rufescens)* was camera-trapped—on both the ground and a tree branch, exclusively during daylight—in 2018 but was not camera-trapped in 2017. A Slender Mongoose was observed (by MTW) crossing a dirt road in a cultivated area on the western periphery of Zanzibar Town during the survey in 2017.

The African Civet was the only native species of extant carnivore that was not camera-trapped during either of the surveys. It is the largest of the island's surviving wild carnivores.

In addition to the carnivores that were camera-trapped, the following mammals appeared in the images: Zanzibar Sykes's Monkey *Cercopithicus mitis albogularis*, Zanzibar Four-toed Sengi *Petrodromus tetradactylus zanzibaricus*, Black and Rufous Sengi *Rhynchocyon petersi*, Red Bush Squirrel *Paraxerus palliatus frerei* and, as already mentioned, Northern Giant Pouched Rat *Cricetomys gambianus cosensi*. Unidentified bats and a pair of unidentified small arboreal rodents also made appearances. Outside of the protected areas, near the settlement of Kitogani, Greater Galago *Otolemur garnettii garnettii* and the Zanzibar subspecies of the Tanzania Dwarf Coast Galago *Galagoides zanzibaricus zanzibaricus* were camera-trapped in the same tree at different times.

DISCUSSION

The Zanzibar Servaline Genet was first described in a 1998 publication on the basis of a single skull and damaged skin that came to the attention of a naturalist in 1995 (Van Rompaey & Colyn 1998). No documented scientific observations of the Servaline Genet were made until the animal was camera-trapped in 2003 (Goldman & Winther-Hansen 2003a,b, 2007; Goldman et al. 2004). Servaline Genets were also camera-trapped on Unguja during a survey that lasted from 2008 to

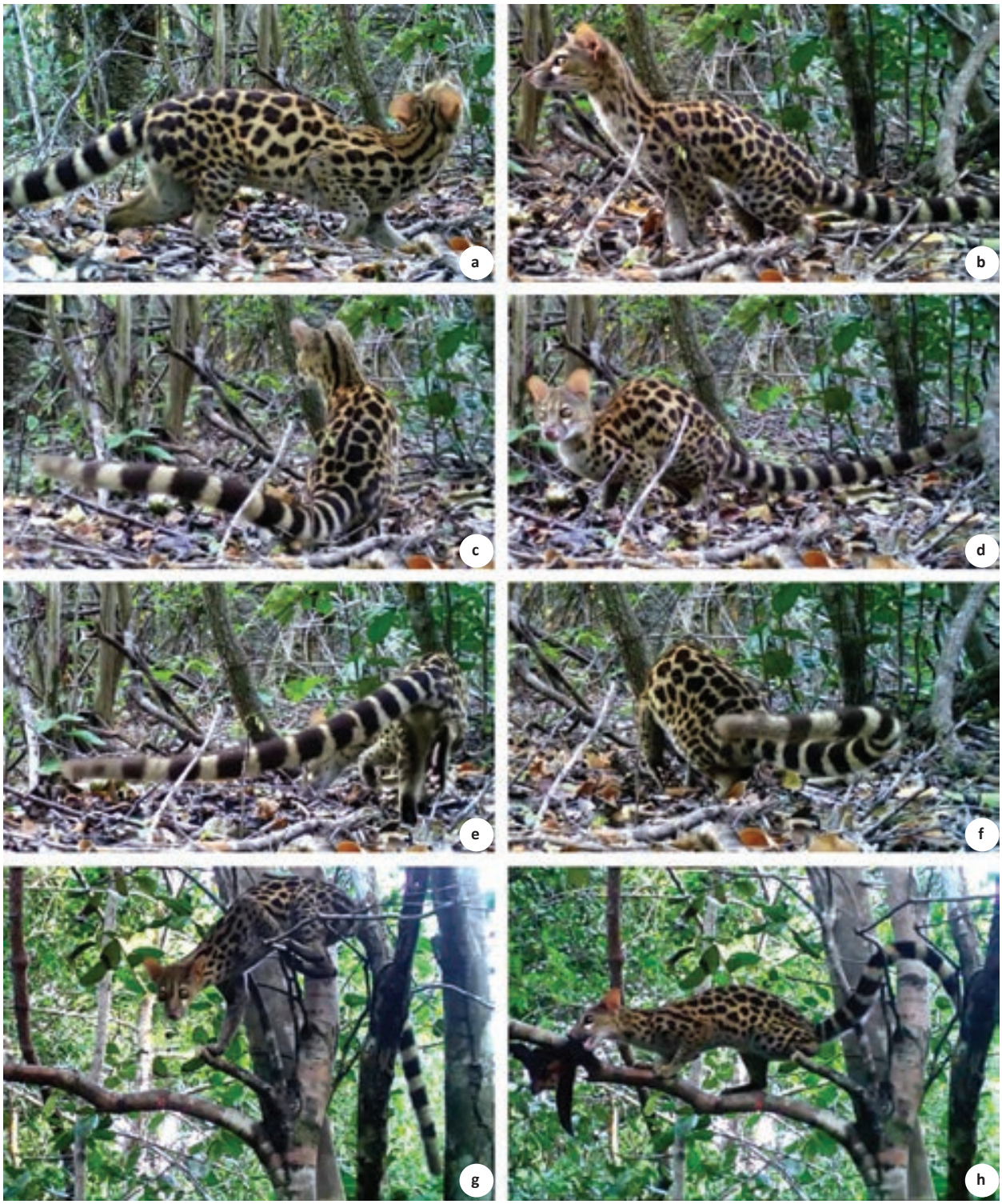

Image 2. Camera-trap video stills of a male Zanzibar Servaline Genet *Genetta servalina archeri* in the scrub forest, JCBNP: a–f - 07.11–08.40 h EAT, 06 September 2017 | g - 17.48h EAT, 08 September 2017 | h - 18.04h EAT, 08 September 2017. The markings on the pelage of the Zanzibar Servaline Genet is described thus: "Nuchal line poorly developed. Spots may tend to fuse near the spine, suggesting a dark mid-dorsal line. Numerous closely groups brownish-black spots on the back and flanks, rarely forming longitudinal lines, weaker and more scattered on the ventral side ... Forelegs may have small spots down to the feet; hindlegs down to the ankle ... [Tail] with 9 – 12 dark rings" (Van Rompaey & Colyn 2013, p. 243). Note the rosette configuration of spots on the dorsal pelage, most clearly seen in (a) and (b). Note also the very long tail (with 12 rings), which is characteristic of the arboreal and semi-arboreal viverrids; in a study comparing nine genet species, Servaline Genets had the longest tails relative to body length (Veron 1999). The long metatarsal pad typical of the arboreal and semi-arboreal species of viverrids (Veron 1999) can be seen on the right hindfoot in (e). The palmar surface of the left forefoot can be seen in (f). In Servaline Genets, "[m]etatarsal and metacarpal pads [are] not connected to interdigital pads" (Van Rompaey & Colyn 2013: 243).

Image 3. Camera-trap video stills showing a Zanzibar Servaline Genet *Genetta servalina archeri* being chased by a Northern Giant Pouched Rat *Cricetomys gambianus cosensi*, scrub forest, JCBNP, 21.09h EAT, 13 September 2017.

Image 4. Camera-trap video stills of the African Palm Civet *Nandinia binotata* in the plantation forest (top photos, both at 20.41h EAT, 10 August 2018) and the scrub forest (bottom left at 22.39h EAT; bottom right at 21.46h EAT, both on 15 September 2017), JCBNP.

Image 5. Camera-trap video still of a Zanzibar Bushy-tailed Mongoose *Bdeogale crassicauda tenuis*, lower left, and an African Palm Civet *Nandinia binotata*, centre, approaching the bait in the plantation forest, JCBNP, 19.47h EAT, 10 August 2018. The mongoose left the scene a moment after this image was captured.

2011 and comprised 316 trap stations and 4,335 trap days (Siex 2011). That study extended the documented range of this species—described as "geographically isolated in Jozani forest" (Van Rompaey & Colyn 2013)—to the corridor between KPFR and JCBNP in the north and, in the south, to the southernmost part of Unguja (Siex 2011). Our own camera-trapping has pushed the Zanzibar Servaline Genet's known range further north, into KPFR.

Servaline Genets are widely distributed in central Africa, from the coasts of Cameroon, Equatorial Guinea, Gabon, and Congo, eastward through Uganda, Rwanda, and Burundi and the wet forests of western Kenya (Van Rompaey & Colyn 2013) (Image 1a). East of this they are confined to small areas of forest in Tanzania's Eastern Arc Mountains and the forests of Unguja (Cordeiro & Seltzer 2012; Van Rompaey & Colyn 2013 and references therein) (Image 1b). The isolation of these pockets hints that the former range of the Servaline Genet in the easternmost part of the continent has undergone severe constriction with climatic and vegetation changes. The extent to which the Zanzibar Servaline Genet may be specially adapted to drier coastal forest is yet to be investigated.

The presence of the African Palm Civet on Unguja first came to light when the species was observed, and subsequently live-trapped, during a survey of nocturnal mammals (primarily galagos) in 1998–99 (Perkin 2004). It was not camera-trapped during the large-scale survey of 2008–2011 (Siex 2011).

In mainland Africa, the distribution of the African Palm Civet largely overlaps that of the Servaline Genet, extending from the Senegambian coast in the west to the coast of Tanzania in the east (Gaubert et al. 2015) (Image 1a). Regarding the African Palm Civet on Unguja, Perkin observed that "more research may show this population of *N. binotata* to be a distinct subspecies because of the effects of isolation of Unguja Island from the mainland" (Perkin 2004). The separation occurred some eight or nine thousand years ago (Prendergast et al. 2016).

The recent scientific discovery of the Servaline Genet and the African Palm Civet in Unguja is notable given the high density of the human population (400 individuals/km^2) and the small size of the island (1,650km^2). When the camera-trapped images of the Servaline Genet and the Palm Civet were shown to Zanzibaris in and around JCBNP, they were familiar with the former, a nocturnal predator with a reputation for killing large numbers of chickens in henhouses and leaving the majority of them unconsumed. In contrast, almost all Zanzibaris who examined our African Palm Civet images professed never to have seen it before, in life or in photographs. This attests to the elusiveness of this species on Unguja.

Pairs of apparently full-grown Bushy-tailed Mongooses were camera-trapped at two locations. According to Taylor (2013), this mongoose is "primarily solitary", although females accompanied by young may be expected. On Unguja, Bushy-Tailed Mongooses are known for carrying Giant African Land Snails *Achatina* spp. to rocks against which the shells are cracked. Broken snail shells accumulate around favoured rocks.

It is noteworthy that images of the African Civet, the island's largest extant carnivore, were obtained during camera-trapping in 2003 (Goldman & Winther-Hansen 2003a,b, 2007) and in 2008–2011 (Siex 2011) but not in 2017 or 2018. Zanzibaris residing in the vicinity of JCBNP believe that the African Civet population has been much reduced in recent years. Hunting for sport and, in some cases, human consumption is said to be the cause. According to local informants, this is a new phenomenon on the island as African Civets are not part of the traditional diet.

Our camera-trapping produced no evidence of the two introduced species of small carnivore included by Pakenham (1984) in his work based primarily on his own observations in Zanzibar in the 1930s and '40s. These species were the Banded Mongoose *Mungos mungo*, which Pakenham noted was "seldom seen now", and the Small Indian Civet *Viverricula indica*, which was "common" and "frequently observed in early morning or late evening in semi-open grassy areas or woodland" (Pakenham 1984). Neither of these species was camera-trapped in 2003 (Goldman & Winther-Hansen 2003a) nor in 2008–2011 (Siex 2011). We were told that both are still present in cultivated areas on the western side of the island, but not in Jozani or on the east coast.

CONCLUSION

Although very little is known about the distribution and population status of Zanzibar's carnivores and other mammal species across the islands of Unguja and Pemba, deforestation can be considered a major threat to the wildlife of the archipelago. Within JCBNP, we saw ample evidence of wood-cutting, poaching, and cattle-grazing in spite of the dedicated efforts of the forestry staff, who work with very limited resources. We have donated camera-trapping equipment to the Department of Forestry and Non-renewable Natural Resources and have trained staff in its use. We have also facilitated the department's procurement of two unmanned aerial vehicles for the purposes of forest monitoring. Government resources should be allocated to support the vigorous protection of Zanzibar's forest reserves and singular national park, and patches of community forest should be carefully managed to preserve habitat for wildlife and to keep hunting to sustainable levels.

The mammalian fauna of Unguja includes endemic taxa that may have been shaped by the founder effect, genetic drift, and adaptation to the local environment as a result of climatic change and isolation from the mainland following the end of the last ice age.

Palaeozoological research has demonstrated the extinction of several species of mammals on the island (Prendergast et al. 2016). Though many Zanzibaris believe that the island's former apex predator, the Zanzibar Leopard *Panthera pardus adersi*, may still be present (Goldman & Walsh 2002; Walsh & Goldman 2012, 2017), there is no recent physical evidence for its persistence. To our knowledge there are no verified still or moving images of the Zanzibar Leopard in the wild, and we concur with the international authorities (e.g., Hunter et al. 2013) who consider it to have been extirpated. Unique island animals are particularly vulnerable to extinction and every effort should be made to ensure the survival in the wild of mammal populations in Zanzibar.

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Swahili abstract: Mfumo bioanuwai wa Kisiwa cha Unguja, kilichopo katika funguvisiwa vya Zanzibar, Tanzania, una idadi kubwa ya watu na baadhi ya aina za wanyama ambao hawapatikani mahali pengine popote. Kamera zilizotegwa mwezi wa tisa 2017 katika Hifadhi ya Taifa Jozani-Chwaka Bay na Msitu wa Hifadhi Kiwengwa-Pongwe zimemnasa ushundwi (aina ya kanu) *Genetta servalina archeri* kwa mara ya kwanza katika video. Ushundwi ni spishi ndogo anayepatikana Unguja pekee; alitangazwa kisayansi kwa mara ya kwanza mwaka wa 1998. Wanyama mbua wengine wadogo waliorekodiwa pia kwa mara ya kwanza katika uchunguzi wa 2017 walikuwa ni fungo-miti *Nandinia binotata*, mnyama ambaye upatikanaji wake Unguja umeelezwa kwa mara ya kwanza 2004, kicheche aina ya *Herpestes sanguineus rufescens* na kitu (kwa jina la kisiwani) *Bdeogale crassicauda tenuis*. Video nyingine za ushundwi na fungo-miti zimechukuliwa ndani ya Hifadhi ya Jozani mwezi wa nane 2018. Picha za ngawa (kwa jina la kisiwani) *Civettictis civetta*, na spishi mbili za kigeni – nguchiro *Mungos mungo* na fungo (kwa jina la kisiwani) *Viverricula indica* – hazikupatikana katika unasaji wa video wa mwaka 2017 na pia 2018. Kwa kuwa misitu ya asili ya Zanzibar inazidi kupungua na kubaki visehemu sehemu chache, ni muhimu zaidi kutafiti na kuandika habari za wanyama mbua na wanyama wengine visiwani, ili hatua madhubuti za uhifadhi wanyama hao kutoweka kabisa ziweze kuchukuliwa.

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COMMUNICATION

The identification of pika and hare through tricho-taxonomy (Mammalia: Lagomorpha)

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Abstract: The macroscopic and microscopic characters of dorsal guard hairs of Indian lagomorphs (four species of pikas and three species of hare) are described; the cuticular and medullary characters are similar between the species studied. The cuticular and medullary characters, however, are dissimilar between the family Ochotonidae and Leporidae. The cross-section of hair of the species had shown two identical shapes between the family Ochotonidae and Leporidae. The cross-section was observed as an oval shape in all the four ochotonid species, whereas there was a dumb-bell shape in all three leporid species. The hair of the Indian lagomorphs can easily be differentiated up to the family level on the basis of their unique cuticula, medulla and cross-section of the dorsal guard hair. The high-resolution microphotographs and key characteristics of hair that are presented here can be used as an appropriate reference for family-level identification of Indian lagomorphs.

Keywords: Cuticular, dorsal guard hairs, lagomorphs, medullary character, microphotographs.

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Author contribution: MK conducted the laboratory examinations, designed the study and prepared the manuscript. KC directed and encouraged the study and provided the necessary facilities to accomplish the work. JKD and CV supervised the study.

INTRODUCTION

Mammalian hair characters are one of the important features that can be used to identify the species when the external morphology is unable to help with identification in case only of a small part of the skin of the mammal is available (Teerink 1991; Chakraborty & De 2010). Tricho-taxonomy (the study of hair) is relatively significant in the study of the food habit of carnivores and is supportive of controlling the illegal trade of wildlife and its derivatives (Chakraborty & De 2010; Sahajibal et al. 2010). There are many researchers, viz., Mayer (1952), Stains (1958), Brunner & Comman (1974), Moore et al. (1974), Koppiker & Sabins (1976), Teerink (1991), Wallis (1993), Chakraborty & De (2010), and Dharaiya & Soni (2012), who have documented the different hair characters of mammals well. Least importance has been given to the species belonging to the order Lagomorpha, except for a few studies by Moore et al. (1974) and Teerink (1991).

The order Lagomorpha comprises of two living families: Ochotonidae and Leporidae. The family Ochotonidae comprises the pikas, under the single genus *Ochotona*; out of a total of 30 species worldwide, India has seven species. The family Leporidae includes hares and rabbits consisting of 61 species under 11 genera, of which India has four species under two genera (Wilson & Reeder 2005).

Ochotonids are distinguished by a small-sized body (head-body length: average 15cm) and weighing 70–300 g, having greyish-brown silky fur. Unlike leporids, the pikas lack a visible tail and have short rounded ears, short limbs, with the hind limbs being barely longer than the forelimbs (Vaughn et al. 2000; Smith 2008; Sokolov et al. 2009).

The leporids are distinguished by a medium-sized body (head and body length: 40–70 cm), long hindlimbs and feet, a small visible tail, and relatively long ears (up to 20cm in length). Most leporids are counter-coloured, with dark-coloured dorsal pelage and light-coloured ventral pelage. Pelage texture can be thick and soft or coarse and woolly (e.g., Hispid Hare) and may become increasingly sparse along the length of the ears. Rabbits and hares have short bushy tales, which are sometimes conspicuously marked, and the soles of their hind limbs are covered with hair (Nowak 1999; Vaughn et al. 2000; MacDonald 2001; Sokolov et al. 2009).

The above-mentioned morpho-taxonomic characters have differentiated the families Ochotonidae and Leporidae. The present tricho-taxonomy study, however, helps to differentiate the two families only with the help of hairs when morpho-taxonomy is unable to offer the fruitful result (Teerink 1991; Chakraborty & De 2010).

METHODS

A bunch of dorsal guard hairs was collected from five, dry, preserved skins of four pika species, namely Ladakh Pika *Ochotona ladacensis* (Günther, 1875), Large-eared Pika *Ochotona macrotis* (Günther, 1875), Royle's Pika *Ochotona roylei* (Ogilby, 1839), and Moupin's Pika *Ochotona thibetana* (Milne-Edwards, 1871) of the family Ochotonidae, and three species of hare, namely, Hispid Hare *Caprolagus hispidus* (Pearson, 1839), Indian Hare *Lepus nigricollis* F. Cuvier (1823), and Woolly Hare *Lepus oiostolus* Hodgson (1840) of the family Leporidae, housed at the National Zoological Collections of Zoological Survey of India, Kolkata, India.

The morphological characters of hairs (n=20) such as colour, number of bands and profile of hairs were recorded, and the length and diameter of hairs were measured using a dial calliper (Mitutoyo). To study the cuticular characters, the acetone washed hair samples were placed over the varnish coated-microscopic glass slide and the dried hairs were dragged gently over it to leave the imprint of scales over the microscopic glass slide. To study the medulla characters, the hair samples were mounted over the microscopic glass slide using D.P.X. To study the shape of the cross section, the hair samples were hand sliced and mounted over the microscopic glass slide using D.P.X. The cuticular characters of hair such as scale position, scale patterns, structure of scale margins and distance between scale margins, the medullary characters such as width composition, the structure and form of margins of the medulla and the shape of cross-section of hairs were examined and photographed (400x magnifications) using a digital camera set onto an optical microscope (Olympus BX41).

To obtain the three-dimensional structure and a more detailed examination of cuticular scales of the hair, the scanning electron microscope (ZEISS Evo18 - special edition) was used. The cuticular structures of hairs were observed under the high magnifications 1630x and 2600x, and the observed cuticular structures of hairs were photographed.

The measurement data such as the maximum, minimum, mean and standard deviation of cuticular scales and medulla were obtained through the digital scale fitted on an optical microscope. The methodology was followed according to the descriptions provided by Brunner & Comman (1974) and Teerink (1991). The description of different terms of patterns used in the

results and discussion that have been given herewith were followed from Teerink (1991) and the nomenclature of colour was followed as per Ridgway (1886).

RESULTS

Family Ochotonidae

The pelage colour of four species of the family Ochotonidae show different shades of brownish-grey; however, the colour of single guard hairs that was observed was grey-buff. The hair of all four species were observed as bicoloured with two bands. The profile of the hair of all species had shown no variations and was observed as a wavy form (Table 1).

The mean length of hair significantly varied among the four species (range: 8.5–22.6 mm): the maximum length was recorded in *Ochotona roylei* (16.6±3.4 mm) and the minimum in *O. ladacensis* (11.7±1 mm), the mean length of hair of *O. macrotis* and *O. thibetana* were recorded as 15.6±4.7 and 16.3±3.1 mm, respectively (Table 1). The mean diameter of hair also significantly varied among the four species (range: 11.4–56.3 µm): The maximum diameter was recorded in *O. macrotis* (44.7±14.4 µm) and the minimum in *O. thibetana* (32.2±10 µm), the mean diameter of hair of *O. ladacensis* and *O. roylei* was recorded as 38.6±11.4 and 33.4±8.2 µm, respectively (Table 1).

The hair of four species had shown almost similar cuticular characters (Images 1 & 7) between the species: the scale position, scale patterns, the structure of scale margins and distance between scale margins were observed in all the four species as 'transversal', 'streaked' ('regular wave' in *O. thibetana*), 'smooth' and 'near', respectively (Table 2).

The measurement values had shown significant variations among the four species, the mean scale count per millimetre length of hair (range: 69–201 µm) was highest in *O. ladacensis* (158±34.8 µm) and lowest in *O. roylei* (82.8±11.7 µm). The mean length of cuticular scales (range: 20–37.9 µm) was observed; as a maximum (35.9±1.2 µm) in *O. thibetana* and as a minimum (21.8±1.7 µm) in *O. ladacensis*. The mean width of cuticular scales (range: 4.3–13.6 µm) was highest in *O. ladacensis* (10.3±2.1 µm) and lowest in *O. thibetana* (6.3±1.7 µm) (Table 1).

The medullary characteristics of hair (Image 2) showed no variations between four species: the composition of medulla, the structure of medulla and medulla margins were observed as 'multicellular', 'isolated' and 'scalloped', respectively (Table 3).

The mean width of medulla (range: 27.1–47.8 µm) showed slight variations among the species. *Ochotona ladacensis* had the highest (45.1±1.1 µm) mean medullary width while the lowest (34.3±2.8 µm) was in *O. thibetana*. The mean medullary width of *O. macrotis* and *O. roylei* were recorded as 39.3±3 and 34.6±1.1 µm, respectively (Table 3).

The cross-section of hair (Image 3) of the species showed similar shapes in the family Ochotonidae and was observed as an oval shape in all the four ochotonid species (Table 3).

Family Leporidae

The pelage colour of the three species of the family Leporidae had shown different shades of blackish-grey and the colour of a single guard hair had also shown various shades of black yellow. The hair of all three

Table 1. Macroscopic characteristics of dorsal guard hairs of the species of the order Lagomorpha.

Species	Coat colour	Colour of hair	Base	Tip	No. of Bands	Profile	Length (mm)	Width (µm)
Family Ochotonidae								
O. ladacensis	Orangeish, sandy brown or grey	Bicoloured	Slate gray	Buff	2	Wavy	10.3–13.5 (11.7±1)	17.4–49.1 (38.6±11.4)
O. macrotis	Pale brownish-grey with an ochre tinge	Bicoloured	Gray	Buff	2	Wavy	8.5–21.6 (15.6±4.7)	18.1–56.3 (44.7±14.4)
O. roylei	Rufous grey	Bicoloured	Gray	Earth yellow	2	Wavy	11.6–22.6 (16.6±3.4)	18.1–41.2 (33.4±8.2)
O. thibetana	Rich russet brown	Bicoloured	Slate gray	Earth yellow	2	Wavy	13.1–22.6 (16.3±3.1)	11.4–40.1 (32.2±10)
Family Leporidae								
C. hispidus	Brown with black grizzled hair	Bicoloured	Black	Yellow	4	Slightly wavy	14.9–34 (27.5±6.6)	71.5–166.5 (113.2±39.6)
L. nigricollis	Reddish-brown with black hair	Bicoloured	Cream	Black	3	Wavy	12–23.2 (18.5±3.4)	64.1–109.2 (78.6±13.4)
L. oiostolus	Black grizzled with brownish-grey	Bicoloured	Pale yellow	Black	4	Wavy	10.3–33.2 (21.8±7.5)	36.1–76.1 (65.8±14.8)

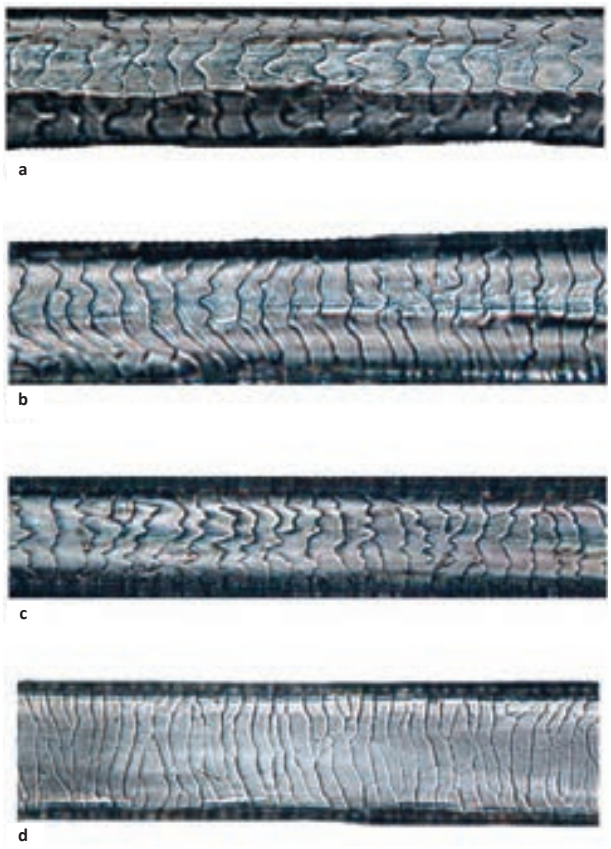

Image 1. Micro-photographs of cuticula (400 X) of dorsal guard hair: a—*O. ladacensis* | b—*O. macrotis* | c—*O. roylei* | d—*O. thibetana*

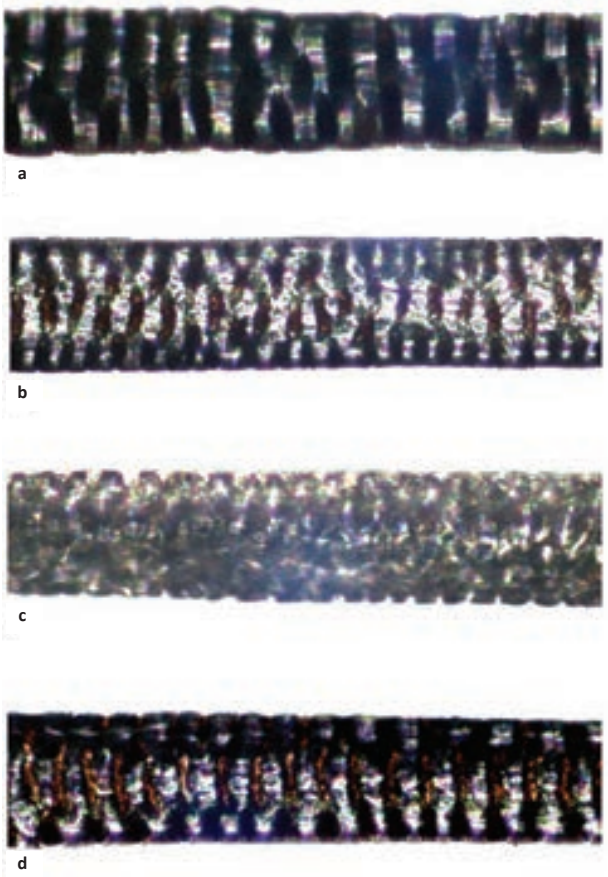

Image 2. Micro-photographs of medulla (400 X) of dorsal guard hair: a—*O. ladacensis* | b—*O. macrotis* | c—*O. roylei* | d—*O. thibetana.*

Table 2. Cuticular characteristics of dorsal guard hairs of the species of the order Lagomorpha.

Species	Scale position	Scale patterns	Structure of scale margins	Distance between scale margins	Scale count/mm length of hair	Length of scale (µm)	Width of scale (µm)
Family Ochotonidae							
O. ladacensis	Transversal	Streaked	Smooth	Near	104–201 (158±34.8)	20–26.3 (21.8±1.7)	6.7–13.6 (10.3±2.1)
O. macrotis	Transversal	Streaked	Smooth	Near	104–160 (139.6±18.5)	23.8–29.6 (27.4±1.6)	6.7–13.6 (9.4±2)
O. roylei	Transversal	Streaked	Smooth	Near	69–102 (82.8±11.7)	28.1–32.1 (30.6±1.4)	6.9–10.2 (8.1±1.4)
O. thibetana	Transversal	Regular wave	Smooth	Near	103–163 (125.8±18.3)	34.1–37.9 (35.9±1.2)	4.3–9.2 (6.3±1.7)
Family Leporidae							
C. hispidus	Transversal	Regular wave	Smooth	Near	176–226 (200.6±15.7)	88.7–116.2 (99.9±7.8)	7.4–11.4 (9.3±2.2)
L. nigricollis	Transversal	Regular wave	Smooth	Near	118–168 (137.9±14.2)	47.1–51.3 (49.3±1.3)	9.6–13.2 (12.2±1.3)
L. oiostolus	Transversal	Regular wave	Smooth	Near	135–160 (148.6±8.5)	34.6–40.8 (37.1±2.1)	14.2–15.1 (14.3±0.8)

species were observed as bicoloured with 3–4 bands. The profile of the hair had shown slight variations and was observed as slightly wavy in *C. hispidus*, and wavy in both *L. nigricollis* and *L. oiostolus* (Table 1).

The mean length of hair significantly varied among the three species (range: 10.3–34 mm): the maximum length was observed in *C. hispidus* (27.5±6.6 mm) and minimum in *L. nigricollis* (18.5±3.4 mm), whereas the mean length of hair of *L. oiostolus* was recorded as 21.8±7.5 mm (Table 1). The mean diameter of hair also significantly varied among the three species (range: 36.1–166.5 µm): the maximum diameter was observed in *C. hispidus* (113.2±39.6 µm) and minimum in *L. oiostolus* (65.8±14.8 µm), whereas the mean diameter of hair of *L. nigricollis* was recorded as

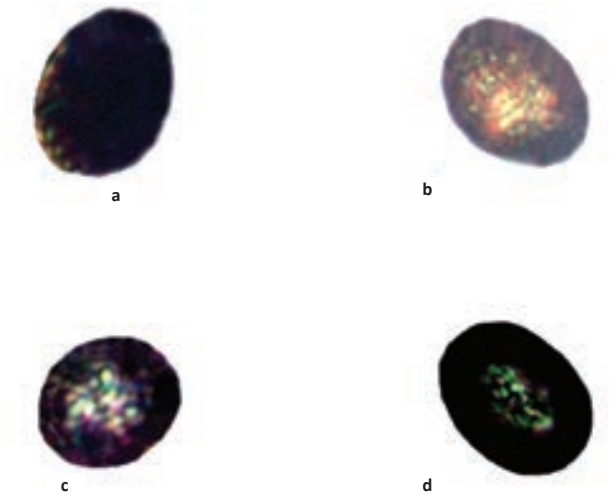

Image 3. Micro-photographs of cross-section (400 X) of dorsal guard hair: a—*O. ladacensis* | b—*O. macrotis* | c—*O. roylei* | d—*O. thibetana.*

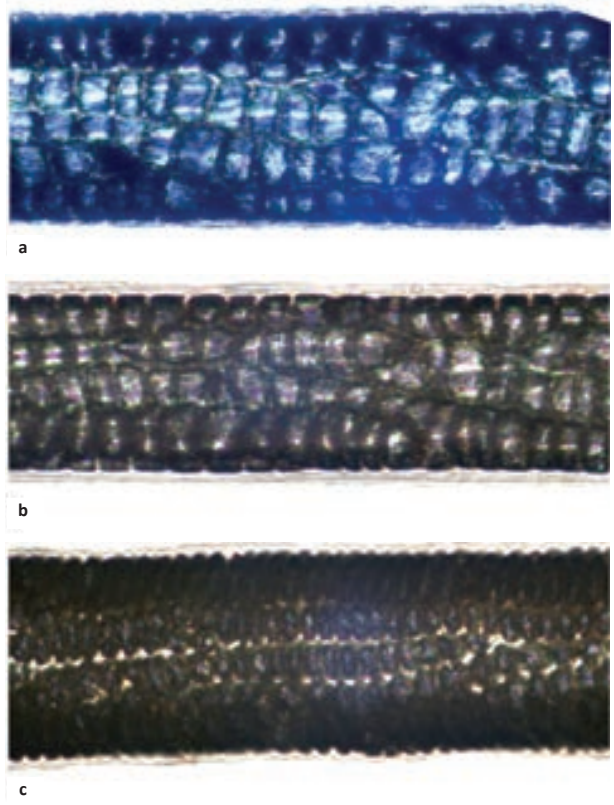

Image 5. Micro-photographs of medulla (400 X) of dorsal guard hair: a—*C. hispidus* | b—*L. nigricollis* | c—*L. oiostolus.*

78.6±13.4 µm (Table 1).

The cuticular characteristics of hairs of all the three leporid species (Images 4 & 8) had shown no variations between the species and were observed with

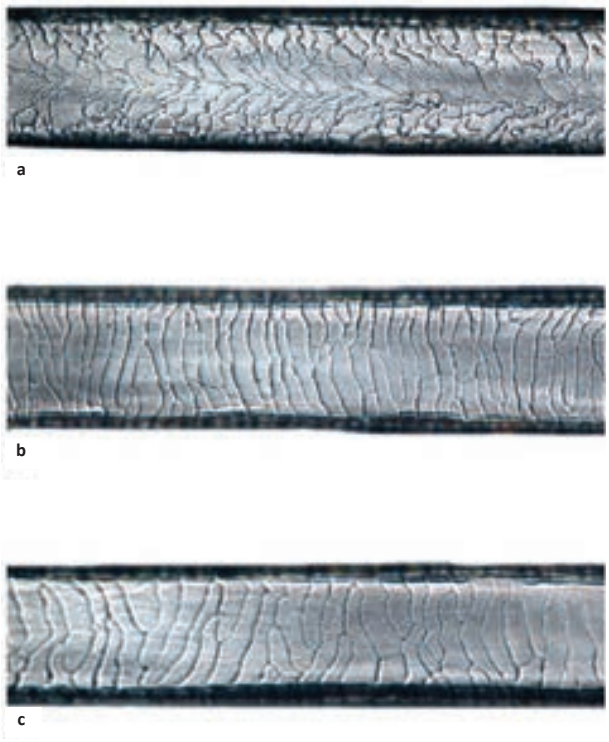

Image 4. Micro-photographs of cuticula (400 X) of dorsal guard hair: a—*C. hispidus* | b—*L. nigricollis* | c—*L. oiostolus.*

Image 6. Micro-photographs of cross-section (400 X) of dorsal guard hair: a—*C. hispidus* | b—*L. nigricollis* | c—*L. oiostolus.*

scale position- 'transversal', scale patterns- 'regular wave', the structure of scale margins- 'smooth' and distance between scale margins- 'near'. The measurement values had shown slight variations among the species, the mean scale count per millimetre length of hairs (range: 118-226 µm) were observed as maximum in *C. hispidus* (200.6±15.7 µm) and minimum in *L. nigricollis* (137.9±14.2 µm), whereas *L. oiostolus* was 148.6±8.5 µm. The mean length of scale (range: 34.6–116.2 µm) was observed to be the highest in *C. hispidus* (99.9±7.8 µm) and the lowest in *L. oiostolus* (37.1±2.1 µm), whereas *L. nigricollis* was 49.3±1.3 µm. The maximum and minimum of mean

Table 3. Medullary characteristics and shape of cross-section of dorsal guard hairs of the species of the order Lagomorpha.

Species	Composition of medulla	Structure of medulla	Margins of medulla	Width of medulla (µm)	Shape of cross-section
Family Ochotonidae					
O. ladacensis	Multicellular	Isolated	Scalloped	44.1–47.8 (45.1±1.1)	Oval
O. macrotis	Multicellular	Isolated	Scalloped	34.6–45.6 (39.3±3)	Oval
O. roylei	Multicellular	Isolated	Scalloped	33.1–36.1 (34.6±1.1)	Oval
O. thibetana	Multicellular	Isolated	Scalloped	27.1–38.1 (34.3±2.8)	Oval
Family Leporidae					
C. hispidus	Multicellular in rows	Multiserial ladder	Scalloped	7.4–11.4 (9.3±2.2)	Dumb-bell
L. nigricollis	Multicellular in rows	Multiserial ladder	Scalloped	64.1–68.1 (65.9±1.2)	Dumb-bell
L. oiostolus	Multicellular in rows	Multiserial ladder	Scalloped	64.1–69.8 (66.9±2)	Dumb-bell

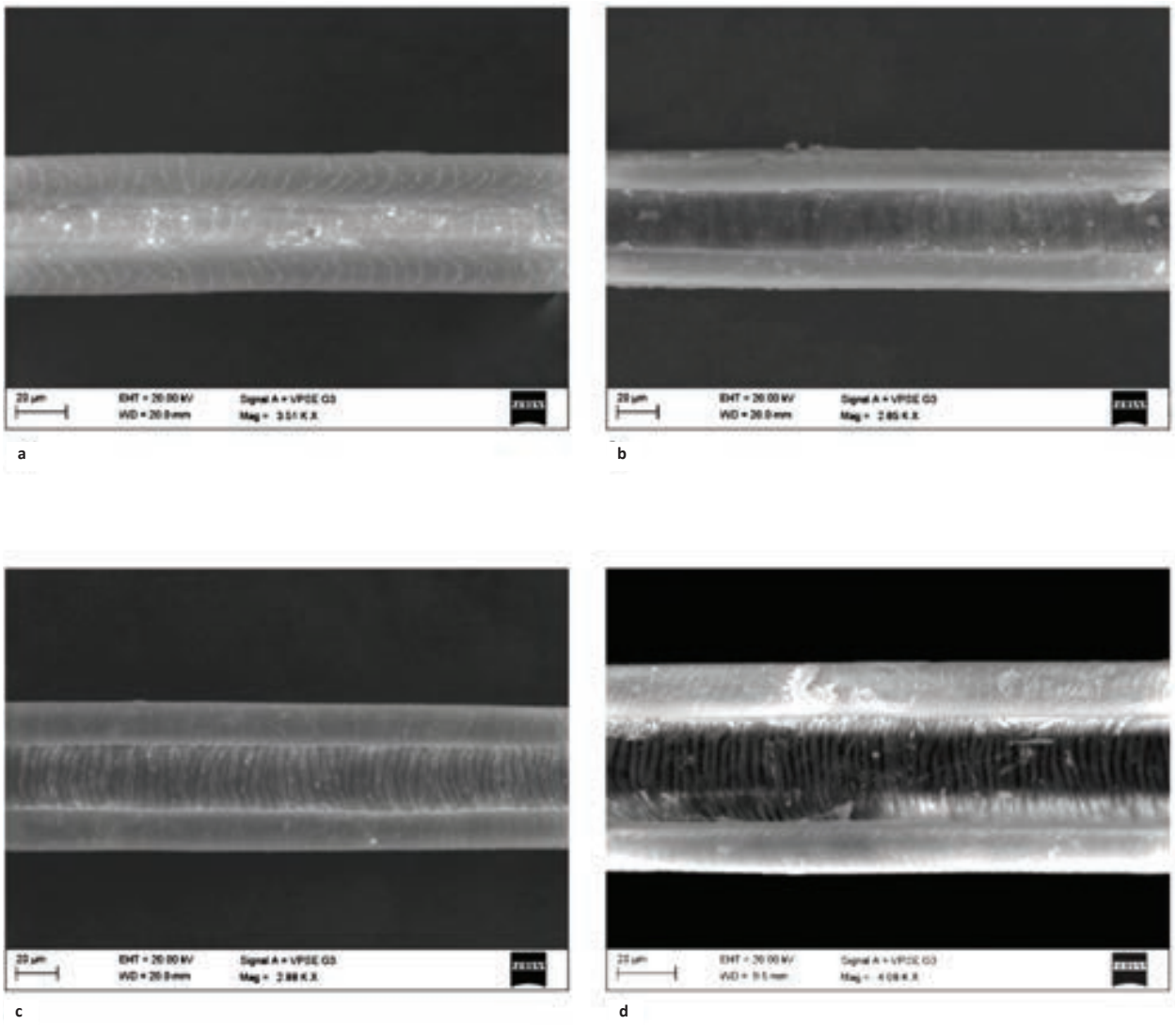

Image 7. Scanning electron micrographs of cuticula (400 X) of dorsal guard hair: a—*O. ladacensis* | b—*O. macrotis* | c—*O. roylei* | d—*O. thibetana*.

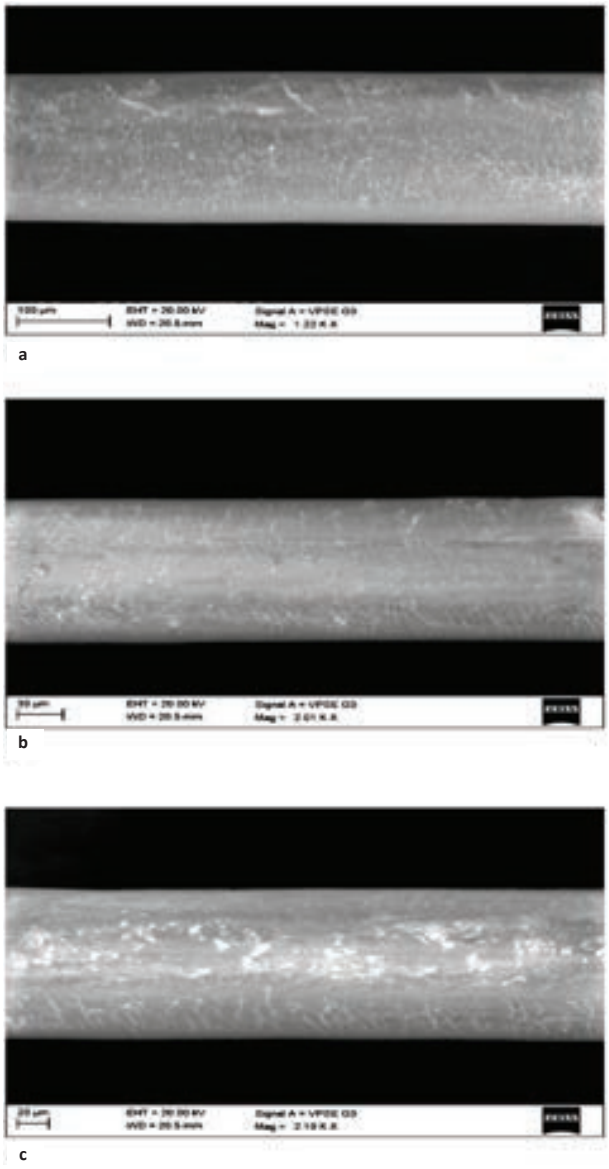

Image 8. Scanning electron micrographs of cuticula (400 X) of dorsal guard hair: a—*C. hispidus* | b—*L. nigricollis* | c—*L. oiostolus.*

scale width of hair (range: 7.4–15.1 µm) was recorded in *L. oiostolus* (14.3±0.8 µm) and *C. hispidus* (9.3±2.2 µm), respectively, where *L. nigricollis* was 12.2±1.3 µm (Table 2).

The medullary characteristics of the hair of three species (Image 5) had shown similar characters between the species and were observed as the composition of medulla- 'multicellular in rows', the structure of medulla- 'multiserial ladder' and 'medulla margins-scalloped'. The mean width of medulla was observed to be the highest as 77.1±1.6 µm in *C. hispidus* and lowest as 65.9±1.2 µm in *L. nigricollis*, whereas *L. oiostolus* was 65.9±1.2, µm (Table 3).

The cross-section of hair of the species (Image 6) showed similar shapes in the family Leporidae and was observed as a dumb-bell shape in all the three leporid species (Table 3).

DISCUSSION

Family Ochotonidae

The pikas can be distinguished as the family of the order Lagomorpha by their specific cuticular scale pattern and unique medullary structure such as the different cuticular patterns. The multicellular composition of medulla and isolated structure of medulla of hair differentiates it from the other groups which is confirmed by comparing the previous study of Koppiker & Sabins (1976), Teerink (1991), Chakraborty & De (2010), Dharaiya & Soni (2012), Kamalakannan (2018, 2019). The hair characters, however, are similar between the four species studied. The hair characteristics of pikas of Wyoming, United States by Moore et al. (1974) reviewed that the identification hairs of pika up to the species level is difficult, as the microscopic characters of hairs are similar and the present study also supports the same.

Family Leporidae

The hare of the family Leporidae is one of the easiest to distinguish because of its specific cuticular scale position and pattern, and unique medulla structure and the dumb-bell shape of the cross-section. The transverse cuticular and multiserial ladder medulla patterns of hair differentiates it from the other groups of mammals (Chakraborty & De 2010; Sarkar 2011; Kamalakannan 2018, 2019). The above-mentioned characters are similar in all the three species. The present study shows that the result is consistent with the findings of hares that occur in Wyoming, Unites States by Moore et al. (1974) and western Europe by Teerink (1991).

According to Hoffmann & Smith (2005), the difference between the order Lagomorpha and Rodentia had been discussed first by Simpson (1945). Later, many morphological and molecular phylogeny studies supported the differences between the order Lagomorpha and Rodentia (Huchton et al. 1999). As mentioned earlier, the hares are often differentiated by external morphology from the pikas by the medium-sized body, and length of their tails and ears. The hares have a highly arched skull, pikas have a less arched skull; the hares have an upright posture of the head, strong hindlimbs and pelvic girdle, which the pikas lack (Vaughn et al. 2000; Sokolov et al. 2009). The dental formula (incisors, canines,

premolars and molars of the upper and lower jaw) also varies between these two groups as 2.0.3.3/1.0.2.3x2 = 28 and 2.0.3.2/1.0.2.3x2 = 26 in the hares and pikas, respectively (Sokolov et al. 2009). The present tricho-taxonomic study also shows the difference between the families Ochotonidae (pikas) and Leporidae (hares) under the order Lagomorpha by highlighting the unique characters of cuticula, medulla and cross-section.

Identification up to species level of the order Lagomorpha was difficult through tricho-taxonomic study, as all the four ochotonid species and three leporid species have similar microscopic characters between the species (Moore et al. 1974; Teerink 1991). The macroscopic characters of hair of mammals may also differ due to age, sex, season, climate, geographical variations, etc., especially since the pikas change pelage colour seasonally (Grange 1932; Nowak 1999; Vaughn et al. 2000; Grzimek 2003; Smith 2008). The macroscopic and microscopic characters (Table 1–3) and the microscopic photographs (Images 1–8) of dorsal guard hairs of lagomorphs would be helpful in the identification of species under the families Ochotonidae and Leporidae of the order Lagomorpha by considering the combination of all the characters of hairs.

CONCLUSION

It should be noted that very meagre information is available in the literature on tricho-taxonomic studies of species under the order Lagomorpha particularly as there is no tricho-taxonomic study in India. Thus, this study may be regarded as the first attempt from India.

Hare species are highly trafficked due to the local bush-meat consumption (Menon & Kumar 1999). They are the chief prey of small and large carnivores, similarly, pikas are also chief prey of small carnivores. Hence, the identification keys (provided here) would be useful in animal forensic science as well as in food habit analysis of carnivores.

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Palynological analysis of faecal matter in African Forest Elephants *Loxodonta cyclotis* (Mammalia: Proboscidea: Elephantidae) at Omo Forest Reserve, Nigeria

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Abstract: The factors affecting African Forest Elephants include food availability, demand for ivory and changes in land-use. In order to survive, they tend to traverse considerable distances in search of food; on such occasions they are trapped and killed for their ivory. This present study is aimed at assessing the faecal matter of elephants, and at providing information on the season of ingestion and foraging preferences of these elephants. Faecal matter was collected at nine different locations for one year before being processed and subjected to standard palynological laboratory procedures. The analyses showed that the samples had moderately abundant and diversified palynomorphs. A total of 27 palynomorphs belonging to 22 families with a total count of 2,895 accounting for 94.34% were found to be eaten, while other plant fragments (epidermal cells, xylem vessel elements, and seeds) accounted for 5.66%. The wet and dry seasons accounted for 73.26% and 26.74% respectively. Epidermal cells and xylem vessel elements recorded (70.76%) and (29.2%) during the dry and wet seasons, respectively. In the palynological analysis, pollen of *Balanites wilsoniana, Desplatsia subericarpa, Chrysophyllum albidum,* among others were recovered in the faecal matter. Pollen analysis of faecal matters provided no information about the quantitative composition of the natural vegetation of elephants, but rather valuable information about their diet. It is recommended that these preferentially foraged parent plants should be cultivated on a large scale. This would potentially reduce competition for food and movement of these animals to other greener areas, consequently leading to poaching.

Keywords: Diet, ivory, palynomorph types, pollen, sampling, southwestern Nigeria, vegetation

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Author contribution: OJW designed and conducted the present study. CO assisted in the collection of samples, while OHA supervised the research work with technical inputs as research adviser.

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INTRODUCTION

The studies of faecal matter allows one to determine a wide range of biological information about a creature, including its diet, environment, health, and infections such as tapeworm. In combination with the analysis of pollen, an abundance of information about diet, disease, and general health can be acquired from such archaeological materials (Reinhard 1994). Not all faecal matter have the same potential information due to taphonomic conditions. Seasonal changes in the diets of African Forest Elephants *Loxodonta cyclotis* are difficult to quantify because of the difficulty of observing the same animal regularly on a long-term basis. Using their trunks, elephants are skilled at manipulating food and show strong preference for specific plant parts (i.e., bark, roots, leaves, and fruits; McKay 1973). This selection is driven by factors like palatability, nutrient composition, secondary and toxic plant compounds, physical defenses, and handling time (Sukumar 1989). Understanding the diet of elephants requires detailed information on the specific plants they consume, but this information is rarely reported. This ideology instigated the study on how pollen grains and other macro elements of plants could be used to reveal the foraging preferences and period of ingestion of plants by African Forest Elephants. These will provide significant insights into ecological requirements relevant for the management of wild elephant populations and their habitats and for the mitigation of human-elephant conflicts, since their existence has been threatened as a result of increased human population and anthropogenic activities. They are sometimes the only disperser of some tree species, such as *Desplatsia subericarpa* and *Balanites wilsoniana*. The rate of seed germination of many forest plant species increases significantly after passage through an elephant's gut (Barnes et al. 1991). It is worth stressing that the pollen in elephant coprolites gives a regional perspective of the palaeo-environment since these animals travel long distances in search of food. Elephants' coprolites reflect more regional pollen sources than sediment analysis. Also, elephants play a significant role in seed dispersal and maintaining plant diversity (Campos-Arceiz & Blake 2011). In spite of their uniqueness and key role in forest ecosystems, African forest elephant populations have depleted over the years owing to a number of factors including ivory poaching and trade across the globe, habitat loss through the conversion of land to agriculture and increasing competition for resources with growing human populations (Maisels et al. 2013). In southwestern Nigeria, *Loxodonta cyclotis* have become in danger of extinction in many ecological zones while the remnant fragile population remains at risk of been endangered. As the human population increases more rapidly, the elephant kingdom is currently being broken down into smaller units traversed by roads, human settlement and infrastructures, thereby bringing elephants into conflict with humans. This is with a view to assisting people in management to make strategic decisions for the effective conservation of our forest reserves and animals. A better understanding and knowledge of grazing behaviour and foraging preferences of some plants by elephants will make it possible to develop a coherent strategy for the conservation and management of the forest reserve.

MATERIALS AND METHODS

Description of the Study Area

Omo Biosphere Reserve is located between 6'35'09.90 –7'05'04.94 ^{0}N and 4'19'21.28–4'40'21.16 ^{0}E (Fig. 1) in the south-west of Nigeria, about 135km north-east of Lagos, about 120km east of Abeokuta and about 80km east of Ijebu Ode (Ola-Adams 1999). The reserve shares a common boundary in its northern part with Ago Owu and Shasha forest reserves in Osun State. It also has a common boundary with Oluwa Forest Reserve in Ondo State (Karimu 1999); and covers 130,500ha of land (Ojo 2004).

Vegetation

The study locations are currently open vegetation that comprise tree species such as *Celtis zenkeri, Diospyros dendo, Cleistopholis patens, Anthonathia macrophylla, Ficus exaserata, Canarium scheveinfurthii, Brachystegia eurycoma, Albizzia ferruginea, Cola negrica, Aistonia boonei, Ricinodendron heudelotti, Cordia millenii, Diospyros nigerica, Desplatsia subericarpa, Terminalia superba, Humeria umbellate, Musanga cecropioides, Entandrophragma angolense, Diospyros monbuttensis, Celtis brownie, Khaya ivorensis, Ficus mucuso, Macaranga barteri, Celtis mildbraedii, Pycanthus angolense, Paspalum viginatum,* among others. The study area is also composed of herbs, climbers, epiphytes, stranglers, saprophytes and parasites (Adamson 1996). The reserve is in the mixed moist semi-evergreen rainforest zone. The northern parts of the reserve are relatively dry with typical species such as *Sterculiar hinopetala. Nauclea diderrichii* and *Balanites wilsoniana* are common in the wetter central parts (Ola-Adams 1999). As a result of continuous human activities, mainly logging and

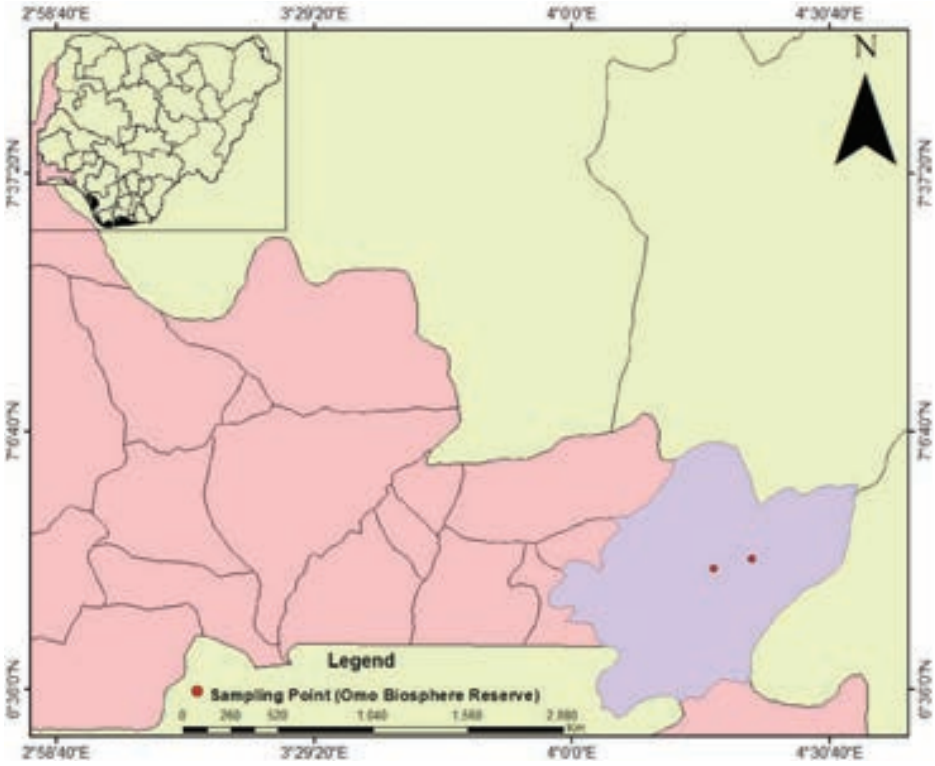

Fig. 1. Omo Forest Reserve in southwestern Nigeria.

farming for almost a century, the vegetation pattern in Omo has changed remarkably. The reserve now carries monocultures of *Gmelina arborea, Tectona grandis, Theobroma cacao,* and arable farmlands. Natural forests of varying degrees of disturbance and a 460-ha strict nature reserve (SNR) which was established in 1946 as an inviolate plot but later designated an SNR also exist. The SNR is in Area J1 by Omo River, just a few kilometers south of the confluence of Omo and Owena rivers in the north-central part of the reserve.

Sample collection

One-hundred-and-eight faecal matters were collected monthly, from nine locations for a period of 12 months. The faecal matter was collected by removing the upper surface as well as the lower surfaces to form a thin section, thereby reducing the number of contaminants. The fresh faecal matter was then placed into sterilized plastic bags and then weighed and stored in tightly closed sterilized containers with a small amount of alcohol (70%) to avoid microbial growth and then frozen in the laboratory. This sampling period was divided into the wet and dry seasons. The strongest and the first wet period lasts between April and July while the second and weaker wet period between September and November. In between these wet periods is a relatively dry period in August to September commonly referred to as the 'August Break'. The main dry season lasts from December to March and is usually characterized by harmattan winds from the north-east trade winds during November.

Laboratory analysis

Samples were placed into 10ml test tubes and washed using distilled water by centrifugation and decantation to remove alcohol. Potassium hydroxide (KOH) treatment was conducted for 10g of each faecal sample to remove humic materials and soften the other organic material. About 10ml of 5% KOH was added to each sample in the beaker and heated for several minutes. Samples were then sieved with a 1mm mesh to remove large organic particles that were then discarded. The remaining sample was placed in 15ml plastic screw-topped centrifuge tubes and centrifuged. The sample was then rinsed with distilled water and centrifuged multiple times. The residue was subjected to acetolysis method (Erdtman 1969). The acetolysis mixture of nine parts of acetic anhydride and one part of sulphuric acid (H_2SO_4) was prepared. This mixture was then poured into the tubes containing the residue and, boiled in a beaker at 100 °C for five minutes and was stirred occasionally with a glass rod. After cooling, the mixture was centrifuged at 2000rpm for five minutes. The liquid supernatant was then decanted leaving only the

palynomorphs in the tube. Samples were then stored in 100% glycerin to prevent the palynomorphs from drying out. From stock mixture, samples were collected and mounted on slides and studied under 40x objective lens magnification using an Olympus BX43 light microscope. A micropipette was used to pipette two drops of the prepared residue into a well-labeled slide and was stirred with the tip of the micropipette for even distribution. The coverslip was placed gently on the residue in a way to prevent the formation of air bubbles. The slide was sealed using a commercial nail lacquer and to make a semi-permanent slide. The prepared semi-permanent duplicated slides were then studied qualitatively and quantitatively using an Olympus BX43 light microscope under (400x magnification).

Taxonomic Identification

The identification of palynomorphs was made by comparing with some pollen albums, relevant journals (Sowunmi 1995; Gosling et al. 2013), and pollen reference slide collection in the Palynology and Palaeobotany Laboratory, Department of Botany, University of Lagos. Photomicrography of some of the identified palynomorphs was taken with the aid of a Motic 2300 digital camera. Pollen was identified up to the family level and where possible up to the species level. Those that were unidentifiable due to their broken nature were referred as indeterminate.

RESULTS AND DISCUSSION

Analyses showed that the samples have moderately abundant and diversified palynomorphs. The elephants consumed different plant species with varying degrees of preferences. Twenty-seven palynomorphs belonging to 22 families accounting for 94.34% were found to be eaten (Table 1). These Families include Zygophyllaceae which accounts for 882 (32.2%), Poaceae 410 (14.93%), Tiliaceae 295 (10.8%), Fabaceae 162 (5.91%), Irvingiaceae 135 (4.94%), Amaranthaceae 108 (3.95%), Lamiaceae 99 (3.62%), Asteraceae 85 (3.11%), and Calophyllaceae 69 (2.48%) while the least families are Sapindaceae 5 (0.18%) and Mimosaceae 4 (0.14%). Epidermal cells and xylem vessel elements recorded (70.76%) and (29.2%) during the dry and wet seasons, respectively. This has provided information on the season during which this large terrestrial mammal debarks trees more. Seeds were recovered in the faecal matter during sample preparation. The seeds recorded all-time high during the dry season (November–March), but few were also recorded during the end of the wet season (August–October). The occurrences of these palynomorphs are displayed on a Tilia™ graph (Fig. 2).

Elephants browse and graze on a variety of plants but the time spent foraging and the proportions of the plants consumed vary depending on the season and availability (Fig. 2). The ratio of recovery of pollen grains in the faecal matter between Poaceae (grass), herbs (*Tridax procumbens*), and higher plants suggest that *Loxodonta cyclotis* spent more time browsing than grazing despite the availability of grass in both the wet and dry seasons (Fig. 2). Also, the occurrences of *Mangifera indica, Desplatsia subericarpa, Balanites wilsoniana* among others in their faecal matter conforms to the assertion made by Amusa et al. (2017) in which he reported that the African Forest Elephant is mostly a browser and frugivore rather than the grazing and browsing habit exhibited by the Savanna Elephant. The drastic increase observed in Poaceae, Asteraceae, *Zea mays*, and *Tridax procumbens*, however, indicate an obvious change in feeding preference with grazing becoming more important during the wet season. Browsing materials such as *Zea mays*, *Parkia biglobosa, Mangifera indica, Chrysophyllum albidum,* among others were therefore abundant in the dry season compared to the wet season (November–March).

The pollen analysis revealed that fruit was an important component of the diet, while *Balanites wilsoniana* is the most preferred plant for forage by forest elephants especially in the dry season, despite its unpleasant smell. Its recovery in these studies may suggest that at this time of the year a maximum number of plant species are flowering, while some are fruiting. Fruits such as *Irvingia gabonensis, Chrysophullum albidum, Parinari excelsa*, among others are characterized by firm, dry, dense flesh, and are therefore rich in lipids and proteins (Mckey 1975). Furthermore, the analyses revealed that during the second half of the main dry season, the lean season for most animals, there was a peak in fruiting of animal-dispersed tree species. Throughout this period forest elephants move from their preferred secondary vegetation, as well as the logging sites in which the pollen of *Zea mays* (March–May) and *Treculia africana* (July–December), *ELaeis guineensis* (Febuary-May) were used as a pointer, to denote the period at which the African Forest Elephants encroaches on farmlands where fruiting trees and crops of favoured species are to be found. This assertion is also supported by Merz (1986), Barnes et al. (1991), and White (1994). According to Chapman et al. (1992) the tree species, *Balanites wilsoniana* substantiated this hypothesis with

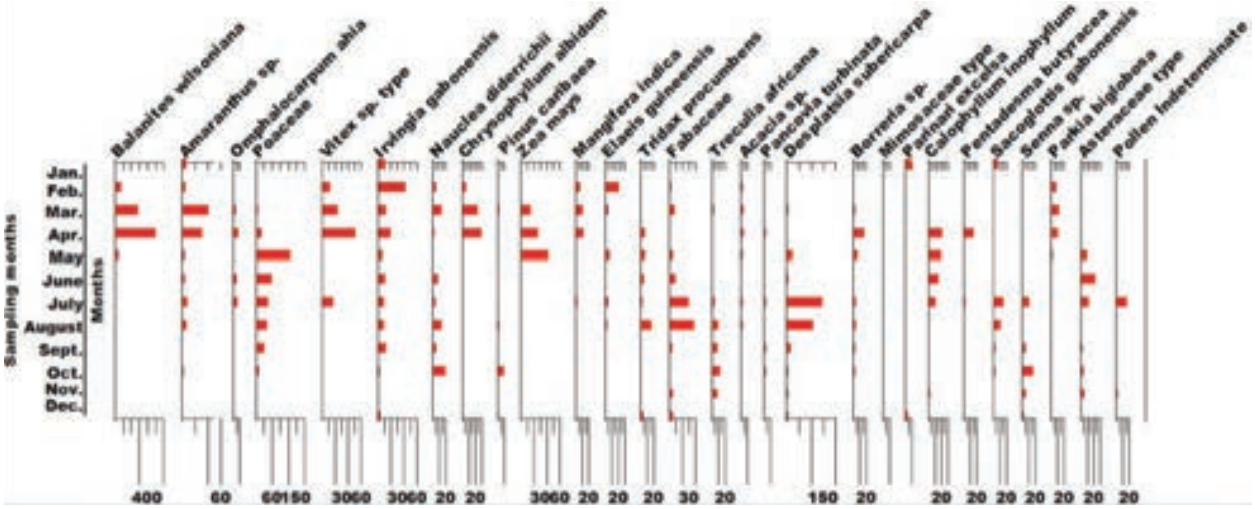

Figure 2. Pollen calendar of palynomorphs recovered from African Forest Elephant faecal matter at Omo Forest reserve.

germination trials on fresh and ingested seeds of eight trees and one species eaten by forest elephants. Such research has led to the understanding that several tree species could become extinct in the absence of forest elephants.

The family Poaceae were the second largest group that were found to be eaten. Poaceae abundances can be attributed to its ubiquitousness and their ability to produce in large quantities. The clear preference for grass over browses exhibited by the elephant in the wet season (April–October) is probably related to the protein content of the food available, as a result of high nutrient content, low toxins, and fibre contents (Lindsay 1994), it also provides a return per unit time feeding that is higher than browse. It lacks certain essential nutrients, however, and at maturity its nutrient content becomes very low. Their low recovery in the dry season could be linked to the reduction in moisture content which becomes more fibrous and abrasive, hence causing increased wear on teeth and a decline in digestive efficiency. This supports the view of (McCullagh 1969) that there is a decrease in the digestibility of protein when the protein content of a food item is low and the fibre content high. These support the claim made by Sinclair (1975) that this is apparently a limiting factor in any herbivore/resource relationship. This may account to some extent for the large amounts taken, as the elephant at the start of the wet season, may have been choosing the component with the highest protein level. The elephants graze throughout the year but grazing activity becomes unimportant when grass becomes dry and coarse. It could also be argued that elephants are primarily grazers because large quantities of grass are eaten even when large quantities of browse are available. It does not seem that elephants have been forced to adopt a primarily grazing habit, as asserted by Sikes (1971), but have in fact always been grazers, and will always graze when large enough quantities of grass are available; yet factors such as digestibility, quality of food and ease of gathering also have to be taken into consideration. Laws (1970) stated that elephants when feeding on large quantities of young grass take bark as a form of roughage. The increasing number of epidermal cells and xylem vessel elements recovered in the month of May and (November–February) supports the assertion made by Laws (1970). The elephants debarked trees both in wet and dry seasons, but more particularly during the dry season, possibly because of the increased translocation of food substances from the roots to the new flushing leaves.

Desplatsia subericarpa Bocq. was the third most foraged species and was found to be abundant during the end of the wet season and the beginning of the dry season. It bears large fruits with a hard seed coat. The pollen analysis revealed that the African Forest Elephants are attracted to large fruits, as a result of their body size. Furthermore, there was a positive correlation between herbivore body size, the size of food intake and dietary breadth, but still dependent on the diversity and composition of the plants available. These highly frugivorous diets make them particularly formidable dispersers of seeds which could be referred to as 'megafauna-syndrome', i.e., plants with large fruits and seeds that may have evolved to attract large herbivores to consume and disperse them.

Crops which include *Amaranthus* sp., *Zea mays,*

Table 1. The frequency and percentage composition of palynomorphs recovered from faecal matter of *Loxondata cyclotis*.

	Palynomorph types	Family	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	%
1.	*Amaranthus* sp.	Amaranthaceae	6	5	41	31	3	4	8	6	1	2	1	0	108	3.95
2.	*Mangifera indica* L.	*Anacardiaceae*	0	6	10	12	0	0	1	0	0	0	0	0	29	1.06
3.	*Elaeis guineensis* Jacq	Arecaceae	0	21	4	0	7	0	3	2	1	0	0	0	38	1.39
4.	*Tridax procumbens* L.	Asteraceae	0	0	0	6	5	4	1	16	0	0	0	3	35	1.28
5.	Asteraceae type	Asteraceae	0	0	0	0	9	22	11	0	1	3	4	0	50	1.83
6.	*Calophyllum inophyllum* L.	Calophyllaceae	0	0	0	21	19	15	11	0	0	0	2	0	68	2.48
7.	*Parinari excelsa* Sabine	Chrysobalanaceae	8	0	0	0	0	0	0	0	0	0	0	2	10	0.36
8.	*Pentadesma butyracea* Sabine	Clusiaceae	0	0	0	14	0	0	2	0	0	0	0	0	16	0.58
9.	*Parkia biglobosa*(Jacq) R. ex Don-H.C	Fabaceae	0	6	11	9	1	0	0	0	0	0	0	0	27	0.98
10.	*Acacia* sp.	Fabaceae	0	1	2	2	1	0	1	1	0	0	0	0	8	0.29
11.	*Senna hirsuta* L.	Fabaceae	0	0	0	0	0	0	10	0	4	15	4	1	34	1.24
12.	Fabaceae	Fabaceae	0	1	7	0	4	8	28	36	2	0	3	4	93	3.40
13.	*Sacoglottis gabonensis* (Baill.) Urb.	Humiriaceae	6	0	0	0	0	0	15	11	2	2	0	0	36	1.31
14.	*Irvingia gabonensis* (Aubry Lecomte)	Irvingiaceae	10	42	12	19	6	10	9	9	12	2	1	3	135	4.94
15.	*Vitex* sp. type	Lamiaceae	0	11	23	50	0	0	15	0	0	0	0	0	99	3.62
16.	Mimosaceae type	Mimosaceae	0	0	0	0	0	0	0	1	1	1	0	1	4	0.14
17.	*Treculia africana* Decne.	Moraceae	0	0	2	0	0	0	3	8	7	12	7	0	39	1.42
18.	*Pinus caribaea* Mor.	Pinaceae	0	0	1	0	0	0	0	1	0	8	0	0	10	0.36
19.	Poaceae	Poaceae	0	2	5	18	125	55	42	38	30	9	3	0	327	11.9
20.	*Zea mays* L.	Poaceae	0	0	15	26	42	0	0	0	0	0	0	0	83	3.03
21.	*Borreria* sp.	Rubiaceae	0	0	1	15	5	0	2	3	1	1	0	0	28	1.02
22.	*Nauclea diderrichii* (De Wild. & Th. Dur.)	Rubiaceae	0	4	12	1	0	7	2	12	4	18	0	0	60	2.1
23.	*Pancovia turbinata* Radlk.	Sapindaceae	0	0	0	1	0	0	1	0	2	1	0	0	5	0.18
24.	*Chrysophyllum albidum* G.Don.	Sapotaceae	0	5	24	29	0	1	0	1	0	0	0	0	60	2.19
25.	*Omphalocarpum ahia* A.Chev.	Sapotaceae	0	0	3	7	0	4	5	0	0	0	0	0	19	0.69
26.	*Desplatsia subericarpa* (Bocq)	Tiliaceae	0	0	1	0	21	1	145	104	15	4	3	1	295	10.8
27.	*Balanites wilsoniana* Dawe & Sprague	Zygophyllaceae	1	65	271	494	32	0	0	2	6	4	5	2	882	32.2
28.	Pollen Indeterminate	Pollen Indeter.	0	0	0	0	0	0	15	0	0	0	1	0	16	0.58
		Total pollen count	31	169	445	755	280	131	330	251	89	164	34	52	2731	94.3
29.	Xylem fibers	Plant Fragment	13	16	0	0	20	0	0	0	0	0	17	11	78	2.84
30.	Seeds	Plant Fragment	1	7	4	0	0	0	0	9	3	13	11	19	53	2.82
Total plants fragments			14	23	4	0	20	0	0	9	3	13	38	30	154	5.66

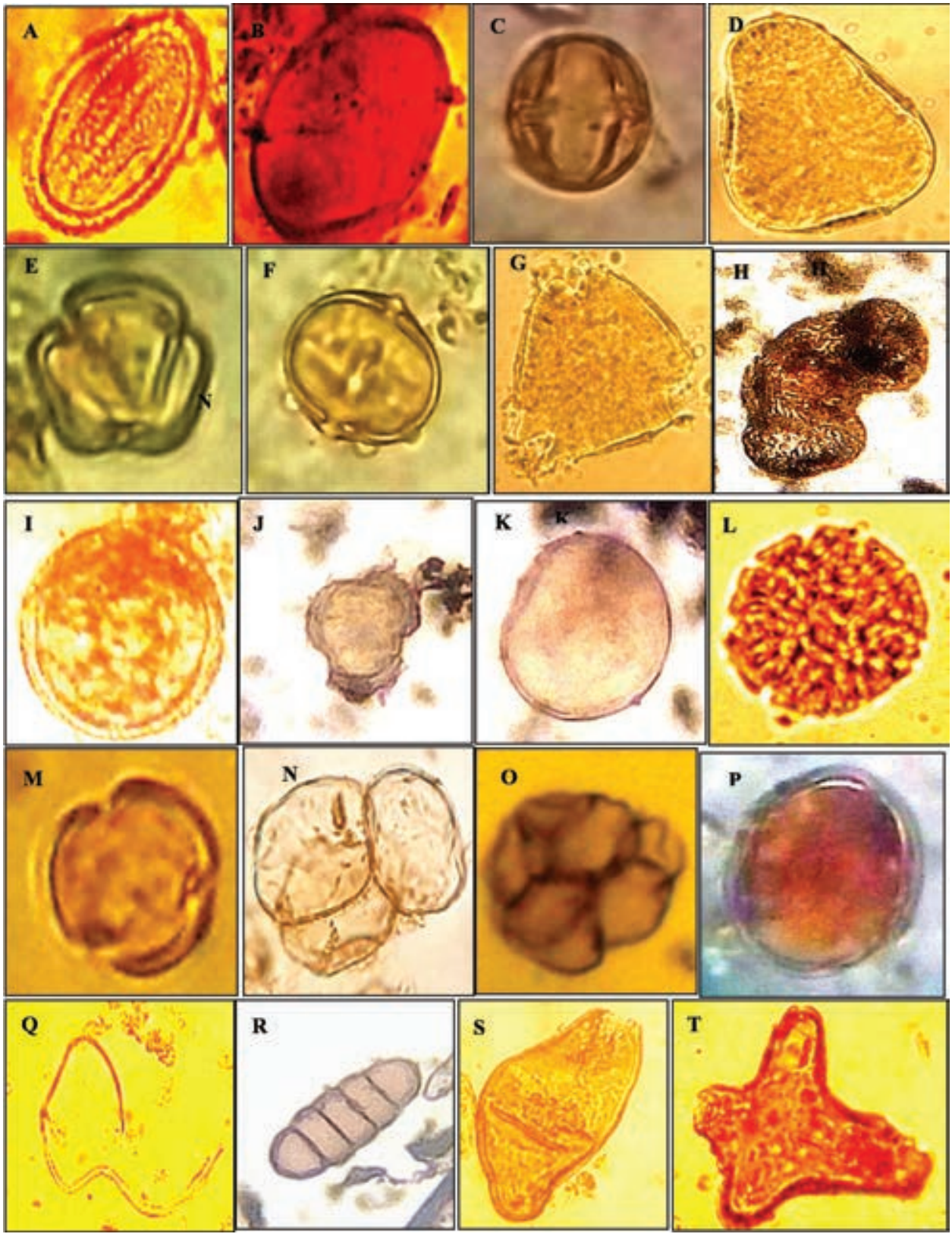

Image 1. Recovered palynomorphs: A—*Balanites wilsoniana* Dawe & Sprague | B—*Calophyllum inophyllum* L. | C—*Chrysophyllum albidum* G.Don. | D—*Elaeis guineensis* Jacq. | E—*Nauclea diderrichii* (De Wild. & Th. Dur.) | F—*Omphalocarpum ahia* A. Chev. | G—*Parinari excelsa* Sabine | H—*Pinus caribaea* Mor. | I—*Senna hirsuta* L. J—*Tridax procumbens* L. | K—*Zea mays* L. | L—*Borreria* sp. | M—*Vitex* sp. | N—Poaceae | O—Mimosaceae type | P—Fabaceae Q—Ascaris worm | R—Fungi spores | S–T—plant fragment (scale=10µm).

Mangifera indica, Elaeis guineensis, and Fabaceae were also found to be eaten and intensively used by the rural population. Their abundances in the faecal matter indicate farmland incursion by the African Forest Elephants during the months of February–May. Despite the large array of plants available for forage in the reserves, forest elephants still consume and destroy farm produce. This attests to the fact that the African Forest Elephants are species specific when it comes to their foraging preferences. Therefore, it should come as no surprise that elephants have an attraction for crops which are found to be nutritious and palatable, thus resulting in human-elephant interactions and sometimes death for both parties. Habitat fragmentation, however, increases the contact between elephants and agriculture, and the intensity of crop-raiding is usually higher in more fragmented habitats.

Pollen grains of *Callophyllum inophyllum,* were also recovered, this plant has been reported by several authors as toxic. Their presence in the faecal matter signifies that the African Forest Elephants take in toxic plants to balance their nutritional requirements. Therefore, detailed studies should be carried out on the nutritional value vs toxicity, and the mechanisms behind these choices. Some plants appeared to be fed on only incidentally, perhaps when the species was being browsed. The plants—*Acacia* sp., *Pancovia turbinata,* Mimosaceae, *Parinari exelsa, Pinus caribaea, Pentadesma butyracea,* and *Omphalocarpum ahia*—were less than one percent in representation. These were mostly the smaller sized fruits which were commonly eaten by other animals, thus they may form a valuable supplement to the diet, and also mainly for their water content. This usually happens when they traverse a considerable distance in search of food in areas where there is little or no presence of water.

The presence of xylem fibers in the samples supports the claim made by Sukumar (1989) that the consumption of bark helps to cover the calcium needs of elephants, and may consequently serve more than just for satisfying hunger. Furthermore, there was an abundance of fungal spores recovered. This denotes that the Feacal matter may have retained some moisture during defecation by the African forest Elephants which favours fungal growth. The high relative humidity in the study location may have allowed for greater moisture retention, making it ideal for fungal invasion.

The information obtained from the faecal matter using the palynological method helped to describe the diet of *Loxodonta cyclotis* and to understand the paleo-environment of the study location. Therefore, these selected plants should be cultivated on a large scale in our forest reserves to restrict the movement of African Forest Elephants in search of food, which can lead to poaching as well as human-elephant interactions. Our forest reserves without the African Forest Elephants would be less in species richness and less structurally diverse. Likewise, the African Forest Elephants affect the complexity of the forest by spreading ingested seeds during defecation and help maintain open areas for the reflection of high light intensity near the forest floor, leading to the proliferation of grasses, climbers, shrubs, and young trees to spring up. Nevertheless, conservation concepts based on strictly intellectual or aesthetic values understandably may have little meaning to local villagers who have to struggle for their existence (Nepal & Weber 1995). In order to end the negative interactions between African Forest Elephants and the human populace in rural areas, multidisciplinary approaches must take into account the requirements needed for both elephants and humans so as to achieve sustainable forest management goals.

CONCLUSION

Feeding and nutritional ecology is key to elephant conservation. There is a need for the conservation and management of certain species of trees and grasses for the continued existence of forest elephants in the concerned forest reserves. It is recommended that these preferentially foraged parent plants should be cultivated on a large scale. This would potentially reduce competition for food and movement of these animals to other greener areas, consequently leading to poaching. Also, for a qualitative and quantitative assessment the habitat characteristics, techniques and data from many different disciplines must be combined; however, there is a need for continuous sensitization, support and empowerment of members of the host communities through community social responsibility initiatives to make sure they take part in the conservation and afforestation. Furthermore, nature conservation issues must be dealt with by considering also the needs of humans, since the existence of a native human population in any place involves complex interactions of ethnic, social, economic, political, historical, and biological aspects that exceed a strictly ecological approach. These will pose a positive outcome for the African Forest Elephants in the days ahead.

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Avitourism opportunities as a contribution to conservation and rural livelihoods in the Hindu Kush Himalaya - a field perspective

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Abstract: The Hindu Kush Himalaya is a biodiversity hotspot subject to multiple anthropogenic stressors, including hydropower plants, pollution, deforestation and wildlife poaching, in addition to changing climate. Bird photography tourism, as a locally important element of avitourism, has the potential to integrate sustainable development and wildlife conservation. We conducted field surveys around the reaches of four Indian Himalayan rivers—the Kosi, western Ramganga, Khoh, and Song—outside of protected national parks (the Corbett and Rajaji tiger reserves) to ascertain the distribution of bird species along river corridors that could be sites of avitourism. Species richness along the surveyed reaches were: Kosi (79), western Ramganga (91), Khoh (52), and Song (79). This study contributes critical data to the existing baseline information on the avifaunal species of Uttarakhand. It further discusses the possibility of developing avitourism for knowledge generation on species distribution and innovative livelihood options for local communities in Uttarakhand, reinforcing local vested interest in bird conservation. The findings have generic applicability worldwide.

Keywords: Birds, community-led conservation, eco-tourism, India, Khoh, Kosi, Song, Uttarakhand, western Ramganga.

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Author contribution: NG designed the work, conducted the fieldwork, analysed the data, and wrote the paper. ME assisted with the writing of the paper. IK assisted with the images in the paper. VKB assisted with the data collection.

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INTRODUCTION

Species conservation in the Hindu Kush Himalaya (HKH henceforth) has often focused on megafauna. The Bengal Tiger *Panthera tigris tigris*, Snow Leopard *Panthera uncia*, Indian Elephant *Elephas maximus indicus*, the Greater One-horned Rhinoceros *Rhinoceros unicornis*, and Red Panda *Ailurus fulgens* are afforded the highest judicial protection, and are the prime recipients of conservation grants. Very little current information is available regarding the distribution in the HKH of previously reported species of birds (based on observations in the wild, visual signs, discussion with communities, unconfirmed reports). It is, however, reasonable to infer that pressures arising from increasing anthropogenic stressors (e.g., hydropower plants, pollution, deforestation, poaching) and changing climatic variables continue to have potentially significant impacts on multiple avian species (INCCA 2010; Shrestha et al. 2015; Alfthan et al. 2018). It is, therefore, critical that information regarding the distribution of birds is made a priority as they play important and diverse roles in the structure, functions and ecosystem services of food webs (Sekercioglu et al. 2004).

Environmental indicators serve important roles in conservation responses and land-use management by constituting simplified summaries synthesising multiple datasets or specific pieces of information within complex systems (Jackson et al. 2000). Birds are perceived as useful environmental quality indicators owing to their conspicuousness and mobility, the scale at which they utilise landscapes, as well as their diversity, roles in food webs, integrated responses to multiple pressures, association with specific habitat types and public appeal (Gregory et al. 2004, 2005). Bird indicators, therefore, provide valuable tools for assessing ecosystem health including in wetland and freshwater systems. One such indicator has been developed for this purpose in Britain (Everard & Noble 2010).

Avitourism, where birdwatching is the primary motivation of a trip, has gained momentum as a niche of nature-based tourism products for birders, conservationists and photographers alike (Connell 2009; Cordell & Herbert 2002). This industry is experiencing a paradigm shift from historically localised birdwatching into a global market, in part due to the increasing affordability of travel (Steven et al. 2014). The avitourists are usually well-off and passionate people willing to travel greater distance just to see endemic and/or endangered species, a significant aspect of societal valuation of species diversity (Sekercioglu 2002).

Avitourism is consequently a rapidly expanding activity, especially in developing countries with high biodiversity. The passion and enthusiasm associated with this recreational pastime have ensured that birders travel to remote locations, bringing along with them livelihood opportunities for local people. There have been previous assessments on the potential development of avitourism globally (Steven et al. 2014). The potential impacts of birdwatching (Biggs et al. 2011; Puhakka et al. 2011), birdwatching destinations, birdwatching festivals, migration events, and their impacts on local people have been examined (Lawton 2009). The social perspective surrounding the activity (Cordell & Herbert 2002; Eubanks et al. 2004; Connell 2009), along with bird species fed artificially for tourism attraction (Jones 2011), have also been studied. As avitourism has huge potential to achieve win-win outcomes for local communities and the objectives of protected area managers, there is a need to establish locally specific interlinkages between birdwatching ecotourism, environmental conservation and economic co-benefits (Vas 2013).

The HKH is the world's most densely populated mountain range (Alfthan et al. 2018), but one that is subject to numerous anthropogenic threats. By the 2050s, temperatures across the region are projected to increase by about 1–2 °C, the monsoon is expected to become longer/more erratic, precipitation is projected to change by 5% on average, and the intensity of extreme rainfall events is likely to increase (Shrestha et al. 2015; Alfthan et al. 2018). These climatic factors are likely to have an adverse impact on the bird habitats across the region (Alfthan et al. 2018).

The HKH region is home to a rich assortment of avifaunal species, and many of these have established an important position in the psyche of local communities through cultural, traditional and religious associations (Singh et al. 2017). It is, therefore, important to involve the public, the private sector, and the government around common interests, which may enable co-creation of solutions to counteract the decline of bird populations, particularly for lesser known avian species (Hausmann et al. 2017; Watts 2018). Nonetheless, it is important to note that unsustainable development, unregulated tourism, and unnecessary feeding may have negative impacts on native bird species.

This study focuses on the current distribution of birds along four river corridors—the Kosi, western Ramganga (henceforth Ramganga River), Khoh, and Song—in Uttarakhand State of the Indian Himalayan region, focusing on river reaches outside protected

areas (i.e., the core areas of Corbett and Rajaji Tiger Reserves). It proceeds to discuss possible management responses to promote immediate protection and long-term conservation of birds in the region, including promotion of bird photography tourism as a potential livelihood option for local communities. Focus group discussions (FGDs) were undertaken to understand any ongoing avitourism efforts and livelihood benefits that occur here.

METHODS

Study area

The field survey of river corridor birds focused on the state of Uttarakhand (30.0668° N, 79.0193° E), lying within the western region of the Indian Himalayan biodiversity hotspot (Gupta et al. 2015). Key characteristics of the four surveyed rivers, described in greater detail by Gupta et al. (2015), are outlined in Table 1 and illustrated in Fig. 1.

Members of communities in this region that engage in aspects of ecotourism provide multiple services such as tour guides, accommodation and food, transportation, and other necessary infrastructure for incoming tourists (Nishikant Gupta, pers. obs. 2010–2019).

Avifaunal survey

Field surveys were conducted by teams of three surveyors, travelling on foot along the banks of each of the four rivers to collect direct and indirect evidence of the presence of birds. Fieldwork was conducted pre- and post-monsoon, and in the winter months of 2018 and 2019. GPS locations of indirect and direct signs were recorded. Avian species were recorded at 20 independent sites using the line transect method (Chettri et al. 2005). Transect locations were selected based on the presence of bird signs (e.g., nesting sites, droppings). Surveyors walked in a transect parallel to the river, recording evidence of birds (seen by naked eye or with 10x50 binoculars or heard) in 500m sections. Each observation session lasted 60–90 minutes, each transect was surveyed three separate times, and the points travelled (and therefore sampled) were in a specific order, i.e., along the downstream of a particular river stretch. Where possible, birds were photographed. Standard published literature was used to identify bird species. Avifaunal surveys were limited by the dynamic and potentially hazardous nature of some study sites, and occurrence and detection of some bird species were constrained by season and time of the day due to variation in activity levels and behaviour among species (Bashir et al. 2012).

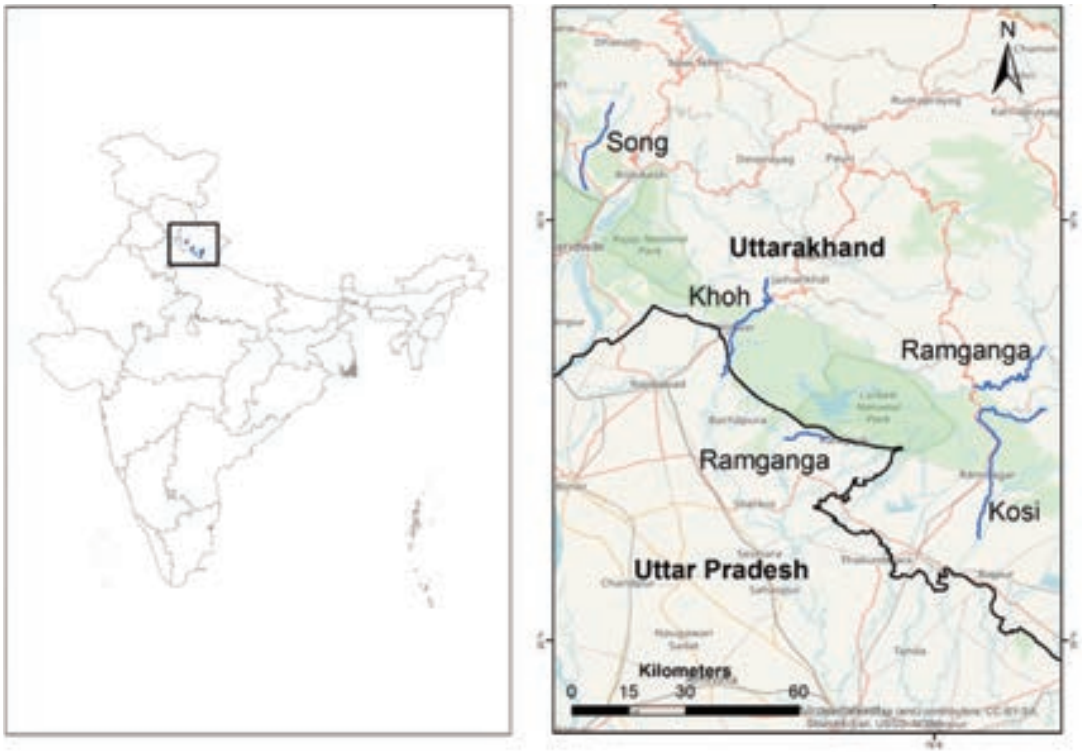

Figure 1. The study area and sampling stations. Each river stretch is labelled in blue, with each transect location spread across at every 500m.

It is important to note that the bird counts may be slightly different during this study, compared to the times that local avitourism operators would take birdwatchers out to look for birds. This could result in the authors missing some of the abundance and diversity of birds at peak dawn and evening hours as we avoided these hours for safety reasons.

RESULTS

The overall avian species richness from the four rivers was 136 (Table 2). Across the individual rivers, the species richness were as follows: Kosi = 79 species, western Ramganga = 91 species, Khoh = 52 species, and Song = 79 species. The data of avian species recorded (overall and from individual rivers) were visualised as a heat map, where the x-axis represented bird population trend, and the y-axis the IUCN Red List Status of Threatened Species. The bars represent the count of IUCN Red List Status and corresponding population trend (Figures 2 and 3). Of the overall avian species richness (N=136), 89% were seen (detected visually from river banks) within navigable distances from the villages and tourist-access points, characteristics that could make them the most suitable for avitourism and more general ecotourism in the area. In addition, 75% of the species could be photographed by surveyors in this study, adding extra potential avitourism value.

DISCUSSION

Avitourism research is significantly skewed towards the northern hemisphere, and North America in particular, as bird-related activities have constituted significant leisure activities among North Americans over the past century (Connell 2009). Mexico and Colombia, which collectively play host to over 1,900 bird species, are the topmost destinations for US birdwatchers,

Table 1. Key descriptors of the four surveyed rivers in Uttarakhand.

River	Source and additional notes	Number of transect	Avian species richness (N)
Kosi	Budha Peenath Village in the Kausani area of Almora district, Uttarakhand. The Kosi is an important tributary of the Ramganga River	20	79
Western Ramganga	Shivalik Himalaya at Dudhatoli in Chamoli district, Uttarakhand. The Ramganga is an important tributary of the Ganges River	20	91
Khoh	Langur in Dwarikhal, Uttarakhand. The Khoh is a tributary of the Ramganga	20	52
Song	Spring-fed stream in the southern slopes of the Mussoorie ridge of the Himalayan range. The Song is a tributary of the Suswa River, which in turn is a tributary of the Ganges	20	79

Figure 2. Avian species recorded from all the study sites (the x-axis represents the population trend, the y-axis the IUCN Red List Status, and the bars provide the IUCN Red List Status and their corresponding population trend).

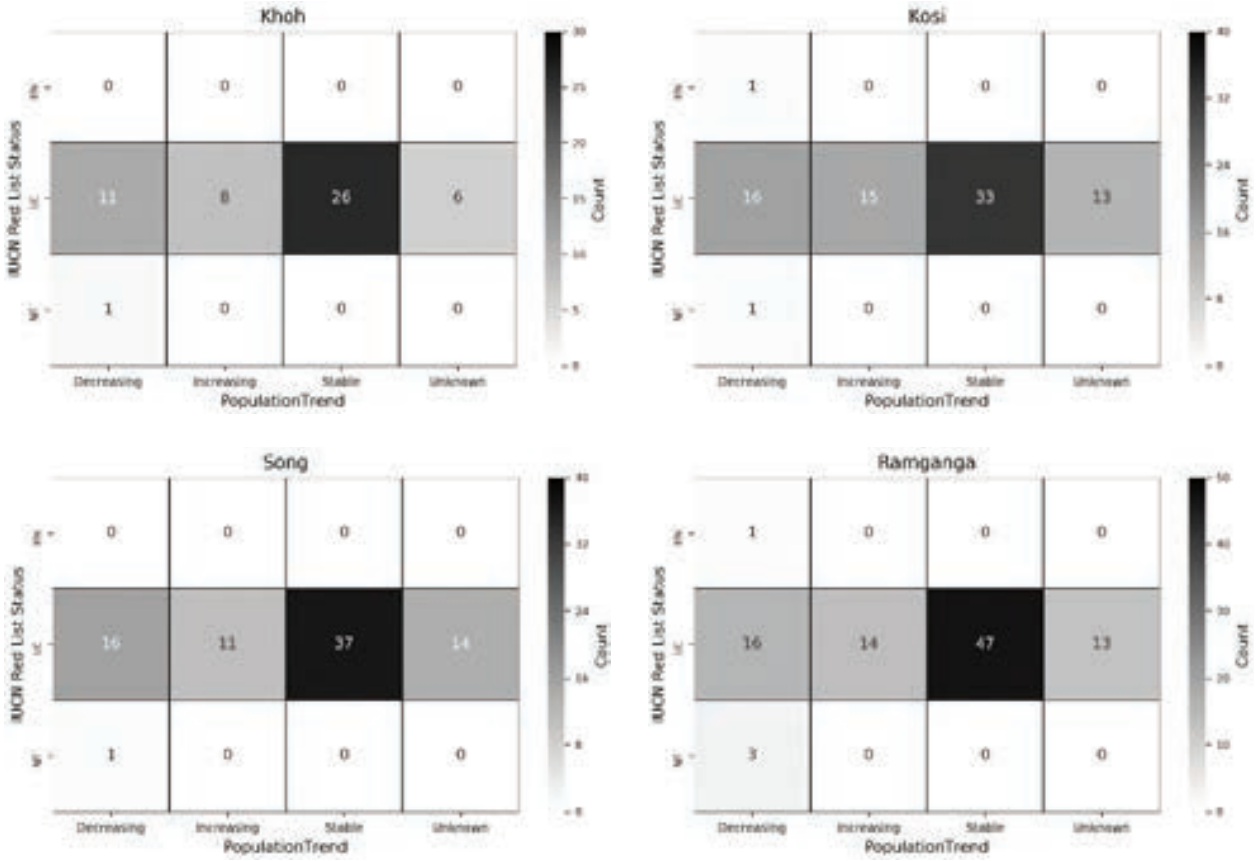

Figure 3. Avian species recorded from the individual rivers (the x-axis represents the population trend, the y-axis the IUCN Red List Status, and the bars provide the IUCN Red List Status and their corresponding population trend). The unit here is the number of species rather than count of individuals.

followed by Venezuela, Costa Rica and Panama (Maldonado et al. 2018). Many countries have thriving bird watching societies, which promote and sponsor trips to destinations where there is an abundance of bird life (Serkercioglu 2003). The socio-economic, ecological, gender and governance dimensions of the birdwatching tourism have been recorded previously (Callaghan et al. 2017). The values that people ascribe to rare or infrequently encountered species, however, have been studied to a lesser extent (Booth et al. 2011).

Avitourism is an important tool with the potential to influence the psyche of local, rural communities and individuals towards a bird species. And it is important that these local communities continue to sustainably work towards increasing the experience of tourists visiting the area. This is because what attracts the birders' 'gaze' and explains the rationale behind their long-distance travel decisions are abundant bird species and good ecological conditions. In addition, reasonable cost, good hospitality of local villagers, and easy approval procedures for entry into birdwatching areas are also important determinants.

Focus group discussions (FGDs) undertaken with village members (N=126), ornithologists (N=5), conservationists (N=10) and bird guides (N=15) in the surveyed areas of Uttarakhand (Nishikant Gupta, per. obs. 2019) revealed that a total of 76% of local households (N=156; 15–65 years; 125 males, 31 females) showed interest in participation in one or more forms of avitourism services if they strengthened livelihood opportunities (when asked regarding the potential applicability of avitourism in their area). Respondents were informed that it is essential to: (a) understand the ecological impacts of feeding to attract birds for tourists, (b) promote organic farming in order to minimise the use of pesticides and fertilisers, (c) regulate the tourist conduct, (d) enhance local environments, and (e) improve the services provided by homestay entrepreneurs (accommodation providers). Ninety-six percent of the respondents revealed that, if sustainably managed, the tourism revenue generated through this activity could protect critical species, economically help the local communities, and potentially lessen the outmigration of men from rural to urban areas seeking

Table 2. Avian species recorded from all the study sites in alphabetical order.

	Family	Order	Common name	Scientific name	IUCN Red List Status#	Population trend#
1	Cisticolidae	Passeriformes	Ashy Prinia	*Prinia socialis*	LC	Stable
2	Meropidae	Coraciiformes	Asian Green Bee-eater	*Merops orientalis*		Increasing
3	Ploceidae	Passeriformes	Baya Weaver	*Ploceus philippinus*		Stable
4	Pycnonotidae		Black Bulbul	*Hypsipetes leucocephalus*		
5	Timaliidae		Black-chinned Babbler	*Cyanoderma pyrrhops*		
6	Dicruridae		Black Drongo	*Dicrurus macrocercus*		Unknown
7	Accipitridae	Accipitriformes	Black Kite	*Milvus migrans*		
8	Paridae	Passeriformes	Black-lored Tit	*Machlolophus xanthogenys*		Stable
9	Muscicapidae		Black Redstart	*Phoenicurus ochruros*		Increasing
10	Accipitridae	Accipitriformes	Black-shouldered Kite	*Elanus caeruleus*		Stable
11	Recurvirostridae	Charadriiformes	Black-winged Stilt	*Himantopus himantopus*		Increasing
12	Muscicapidae	Passeriformes	Blue Rock-thrush	*Monticola solitarius*		Stable
13	Megalaimidae	Piciformes	Blue-throated Barbet	*Psilopogon asiaticus*		
14	Muscicapidae	Passeriformes	Blue-throated Blue-flycatcher	*Cyornis rubeculoides*		
15			Blue Whistling-thrush	*Myophonus caeruleus*		Unknown
16	Sturnidae		Brahminy Starling	*Sturnia pagodarum*		
17	Cinclidae		Brown Dipper	*Cinclus pallasii*		Stable
18	Strigidae	Strigiformes	Brown Fish-owl	*Ketupa zeylonensis*		Decreasing
19	Muscicapidae	Passeriformes	Brown Rockchat	*Oenanthe fusca*		Stable
20	Ardeidae	Pelecaniformes	Cattle Egret	*Bubulcus ibis*		Increasing
21	Accipitridae	Accipitriformes	Changeable Hawk-eagle	*Nisaetus cirrhatus*		Decreasing
22	Sittidae	Passeriformes	Chestnut-bellied Nuthatch	*Sitta cinnamoventris*		Unknown
23	Meropidae	Coraciiformes	Chestnut-headed Bee-eater	*Merops leschenaulti*		Increasing
24	Passeridae	Passeriformes	Chestnut-shouldered Bush-sparrow	*Gymnoris xanthocollis*		Stable
25	Sturnidae		Chestnut-tailed Starling	*Sturnia malabarica*		Unknown
26	Hirundinidae		Collared Sand Martin	*Riparia riparia*		Decreasing
27	Leiotrichidae		Common Babbler	*Argya caudata*		Stable
28	Upupidae	Bucerotiformes	Common Hoopoe	*Upupa epops*		Decreasing
29	Aegithinidae	Passeriformes	Common Iora	*Aegithina tiphia*		Unknown
30	Alcedinidae	Coraciiformes	Common Kingfisher	*Alcedo atthis*		
31	Sturnidae	Passeriformes	Common Myna	*Acridotheres tristis*		Increasing
32	Scolopacidae	Charadriiformes	Common Sandpiper	*Actitis hypoleucos*		Decreasing
33	Muscicapidae	Passeriformes	Common Stonechat	*Saxicola torquatus*		Stable
34	Cisticolidae		Common Tailorbird	*Orthotomus sutorius*		
35	Megalaimidae	Piciformes	Coppersmith Barbet	*Psilopogon haemacephalus*		Increasing
36	Emberizidae	Passeriformes	Crested Bunting	*Emberiza lathami*		Stable
37	Alcedinidae	Coraciiformes	Crested Kingfisher	*Megaceryle lugubris*		Decreasing
38	Accipitridae	Accipitriformes	Crested Serpent-eagle	*Spilornis cheela*		Stable
39	Hemiprocnidae	Caprimulgiformes	Crested Treeswift	*Hemiprocne coronata*		
40	Nectariniidae	Passeriformes	Crimson Sunbird	*Aethopyga siparaja*		
41	Columbidae	Columbiformes	Eastern Spotted Dove	*Spilopelia chinensis*		Increasing
42	Columbidae		Eurasian Collared-dove	*Streptopelia decaocto*		
43	Picidae	Piciformes	Fulvous-breasted Woodpecker	*Dendrocopos macei*		Stable

	Family	Order	Common name	Scientific name	IUCN Red List Status#	Population trend#
44	Megalaimidae		Great Barbet	*Psilopogon virens*		
45	Phalacrocoracidae	Suliformes	Great Cormorant	*Phalacrocorax carbo*		Increasing
46	Ardeidae	Pelecaniformes	Great Egret	*Ardea alba*		Unknown
47	Paridae	Passeriformes	Great Tit	*Parus major*		
48	Cuculidae	Cuculiformes	Greater Coucal	*Centropus sinensis*		Stable
49	Picidae	Piciformes	Greater Yellownape	*Chrysophlegma flavinucha*		
50	Nectariniidae	Passeriformes	Green-tailed Sunbird	*Aethopyga nipalensis*		
51	Cisticolidae		Grey-breasted Prinia	*Prinia hodgsonii*		
52	Columbidae	Columbiformes	Grey-capped Emerald Dove	*Chalcophaps indica*		Decreasing
53	Picidae	Piciformes	Grey-capped Woodpecker	*Picoides canicapillus*		Stable
54			Grey-faced Woodpecker	*Picus canus*		Increasing
55	Stenostiridae	Passeriformes	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis*		Stable
56	Timaliidae		Grey-hooded Babbler	*Cyanoderma bicolor*		Decreasing
57	Phylloscopidae		Grey-hooded Warbler	*Phylloscopus xanthoschistos*		Stable
58	Corvidae		Grey Treepie	*Dendrocitta formosae*		Decreasing
59	Motacillidae		Grey Wagtail	*Motacilla cinerea*		Stable
60	Pycnonotidae		Himalayan Bulbul	*Pycnonotus leucogenys*		Increasing
61	Corvidae		House Crow	*Corvus splendens*		Stable
62	Passeridae		House Sparrow	*Passer domesticus*		Decreasing
63	Phalacrocoracidae	Suliformes	Indian Cormorant	*Phalacrocorax fuscicollis*		Unknown
64	Muscicapidae	Passeriformes	Indian Robin	*Saxicoloides fulicatus*		Stable
65	Bucerotidae	Bucerotiformes	Indian Grey Hornbill	*Ocyceros birostris*		
66	Monarchidae	Passeriformes	Indian Paradise-flycatcher	*Terpsiphone paradisi*		
67	Phasianidae	Galliformes	Indian Peafowl	*Pavo cristatus*		
68	Picidae	Piciformes	Indian Pygmy Woodpecker	*Picoides nanus*		Increasing
69	Ardeidae	Pelecaniformes	Indian Pond-heron	*Ardeola grayii*		Unknown
70	Coraciidae	Coraciiformes	Indian Roller	*Coracias benghalensis*		Increasing
71	Ardeidae	Pelecaniformes	Intermediate Egret	*Ardea intermedia*		Decreasing
72	Leiotrichidae	Passeriformes	Jungle Babbler	*Turdoides striata*		Stable
73	Sturnidae		Jungle Myna	*Acridotheres fuscus*		Decreasing
74	Strigidae	Strigiformes	Jungle Owlet	*Glaucidium radiatum*		Stable
75	Phasianidae	Galliformes	Kalij Pheasant	*Lophura leucomelanos*		Decreasing
76	Corvidae	Passeriformes	Large-billed Crow	*Corvus macrorhynchos*		Stable
77	Accipitridae	Accipitriformes	Lesser Fish-eagle	*Icthyophaga humilis*	NT	Decreasing
78	Picidae	Piciformes	Lesser Yellownape	*Picus chlorolophus*	LC	Stable
79	Megalaimidae		Lineated Barbet	*Psilopogon lineatus*		
80	Phalacrocoracidae	Suliformes	Little Cormorant	*Microcarbo niger*		Unknown
81	Ardeidae	Pelecaniformes	Little Egret	*Egretta garzetta*		Increasing
82	Campephagidae	Passeriformes	Long-tailed Minivet	*Pericrocotus ethologus*		Stable
83	Laniidae		Long-tailed Shrike	*Lanius schach*		Unknown
84	Accipitridae	Accipitriformes	Mountain Hawk-eagle	*Nisaetus nipalensis*		Decreasing
85	Hirundinidae	Passeriformes	Nepal House Martin	*Delichon nipalense*		Stable
86	Turdidae		Orange-headed Thrush	*Geokichla citrina*		Decreasing
87	Accipitridae	Accipitriformes	Oriental Honey-buzzard	*Pernis ptilorhynchus*		Stable
88	Muscicapidae	Passeriformes	Oriental Magpie-robin	*Copsychus saularis*		

	Family	Order	Common name	Scientific name	IUCN Red List Status#	Population trend#
89	Columbidae	Columbiformes	Oriental Turtle-dove	*Streptopelia orientalis*		
90	Zosteropidae	Passeriformes	Oriental White-eye	*Zosterops palpebrosus*		Decreasing
91	Accipitridae	Accipitriformes	Pallas's Fish-eagle	*Haliaeetus leucoryphus*	EN	
92	Muscicapidae	Passeriformes	Pied Bushchat	*Saxicola caprata*	LC	Stable
93	Alcedinidae	Coraciiformes	Pied Kingfisher	*Ceryle rudis*		Unknown
94	Muscicapidae	Passeriformes	Plumbeous Water-redstart	*Phoenicurus fuliginosus*		Stable
95	Psittacidae	Psittaciformes	Plum-headed Parakeet	*Psittacula cyanocephala*		Decreasing
96	Nectariniidae	Passeriformes	Purple Sunbird	*Cinnyris asiaticus*		Stable
97	Corvidae		Red-billed Blue Magpie	*Urocissa erythroryncha*		Increasing
98	Leiotrichidae	Passeriformes	Red-billed Leiothrix	*Leiothrix lutea*		Decreasing
99	Psittacidae	Psittaciformes	Red-breasted Parakeet	*Psittacula alexandri*	NT	
100	Phasianidae	Galliformes	Red Junglefowl	*Gallus gallus*	LC	
101	Hirundinidae	Passeriformes	Red-rumped Swallow	*Cecropis daurica*		Stable
102	Pycnonotidae		Red-vented Bulbul	*Pycnonotus cafer*		Increasing
103	Charadriidae	Charadriiformes	Red-wattled Lapwing	*Vanellus indicus*		Unknown
104	Pycnonotidae	Passeriformes	Red-whiskered Bulbul	*Pycnonotus jocosus*		Decreasing
105	Charadriidae	Charadriiformes	River Lapwing	*Vanellus duvaucelii*	NT	
106	Columbidae	Columbiformes	Rock Dove	*Columba livia*	LC	
107	Sturnidae	Passeriformes	Rosy Starling	*Pastor roseus*		Unknown
108	Muscicapidae		Rufous-bellied Niltava	*Niltava sundara*		Stable
109	Leiotrichidae		Rufous Sibia	*Heterophasia capistrata*		Unknown
110	Anatidae	Anseriformes	Ruddy Shelduck	*Tadorna ferruginea*		
111	Corvidae	Passeriformes	Rufous Treepie	*Dendrocitta vagabunda*		Stable
112	Passeridae		Russet Sparrow	*Passer cinnamomeus*		
113	Timaliidae		Rusty-cheeked Scimitar-babbler	*Erythrogenys erythrogenys*		
114	Caprimulgidae	Caprimulgiformes	Savanna Nightjar	*Caprimulgus affinis*		
115	Accipitridae	Accipitriformes	Shikra	*Accipiter badius*		
116	Muscicapidae	Passeriformes	Slaty-blue Flycatcher	*Ficedula tricolor*		
117	Psittacidae	Psittaciformes	Slaty-headed Parakeet	*Psittacula himalayana*		
118	Dicruridae	Passeriformes	Spangled Drongo	*Dicrurus bracteatus*		
119	Muscicapidae		Spotted Forktail	*Enicurus maculatus*		
120	Accipitridae	Accipitriformes	Steppe Eagle	*Aquila nipalensis*	EN	Decreasing
121	Ardeidae	Pelecaniformes	Striated Heron	*Butorides striata*	LC	
122	Leiotrichidae	Passeriformes	Striated Laughingthrush	*Grammatoptila striata*		
123	Accipitridae	Accipitriformes	Tawny Eagle	*Aquila rapax*		
124	Strigidae	Strigiformes	Tawny Fish-owl	*Ketupa flavipes*		Stable
125	Sittidae	Passeriformes	Velvet-fronted Nuthatch	*Sitta frontalis*		
126	Columbidae	Columbiformes	Western Spotted Dove	*Spilopelia suratensis*		Increasing
127	Alcedinidae	Coraciiformes	White-breasted Kingfisher	*Halcyon smyrnensis*		
128	Rallidae	Gruiformes	White-breasted Waterhen	*Amaurornis phoenicurus*		Unknown
129	Motacillidae	Passeriformes	White-browed Wagtail	*Motacilla maderaspatensis*		Stable
130	Muscicapidae		White-capped Water-redstart	*Phoenicurus leucocephalus*		
131	Leiotrichidae		White-crested Laughingthrush	*Garrulax leucolophus*		Decreasing
132	Rhipiduridae		White-throated Fantail	*Rhipidura albicollis*		Stable

	Family	Order	Common name	Scientific name	IUCN Red List Status#	Population trend#
133	Tyrannidae		White-throated Flycatcher	*Empidonax albigularis*		
134	Alcedinidae	Coraciiformes	White-throated Kingfisher	*Halcyon smyrnensis*		Increasing
135	Sylviidae	Passeriformes	Yellow-eyed Babbler	*Chrysomma sinense*		Stable
136	Columbidae	Columbiformes	Yellow-footed Green-pigeon	*Treron phoenicopterus*		Increasing

The IUCN Red List of Threatened Species 2019 | LC—Least Concern | NT—Near Threatened | EN—Endangered.

better employment opportunities (see Everard et al. 2019 for discussion of outmigration pressures in the Indian Himalaya).

Avitourism can be a cost-effective way to simultaneously create jobs whilst delivering conservation and human development benefits (Biggs et al. 2011), as birdwatchers are willing to travel to remote and less-developed locations, providing livelihood opportunities to areas that hold unique or locally characteristic bird resources. Increasing the number of tourists and the socio-economic and ecological benefits they create also raise associated ecological challenges that will require sensitive management. It is also important to ensure that benefits accrue to local communities in addition to tour operators, if incentives for local conservation action are to be guaranteed (Everard & Kataria 2011). A comprehensive management plan (CMP) including avitourism, with support from local government for developing more scientific and sustainable approaches will become essential in the coming years.

CONCLUSION

One of the key highlights of this work was that it was undertaken outside of the two critical protected areas of the region: Corbett and Rajaji tiger reserves (Figure 1). Avitourism performed outside of protected areas has the potential to assist in protecting bird habitats that are not subject to such a high level of statutory protection, and spreading societal benefits and tourism pressures including reducing disturbance to threatened species within the protected areas (Basnet et al. 2019). Such supportive benefits have also been previously reported from southern Poland, where riverine habitats constitute biodiversity hotspots for migratory birds (Figarski & Kajtoch 2015). It is important to note that birdwatching tourism is dependent upon the diversity and visibility of species in the target destination, with sightings of migratory birds, songbirds and birds of prey also in popular demand from avitourists (Maldonado et al. 2018). This fundamental requirement is compatible with conservation goals. Birdwatching activities at the study sites can not only boost the economic potential of the local community, but also help in the gathering of information on little known/Data Deficient species. Avitourism can, thus, make a significant contribution to the growing need for knowledge-gathering to support the conservation of species other than those with specific conservation designations or in formally protected areas (Whitelaw et al. 2014).

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Pollination in an endemic and threatened monoecious herb *Begonia satrapis* C.B. Clarke (Begoniaceae) in the eastern Himalaya, India

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Abstract: *Begonia satrapis* was studied for its pollination aspects at Sumbuk, Sikkim, India. The floral details and the foraging behaviour of insects visiting the flowers were examined to define the pollination syndrome and its functionality for the success of sexual reproduction in this species. The flowers do not produce nectar and offer only pollen as floral reward to foraging insects. Therefore, male flowers were foraged more for its pollen than the female flowers. There was a significant difference in the visit to male and female flowers by both *Apis florea* and *Bombus breviceps*, respectively. The bees spent more time on male flowers than on female flowers. The bees appear to rely on visual stimuli to visit male and female flowers. The plant produces abundant fruit and seed set in both hand and open-pollinations indicating that it is facultatively xenogamous. The female flowers lacking any reward resemble male flowers and in effect are pollinated by deceit.

Keywords: *Apis florea*, *Bombus breviceps*, deceit, northeastern India, Sumbuk.

***Nepali* सार:** भारतको उत्तर-पूर्वीय राज्य सिक्किमको सुम्बुकमा पाइने मंगरकाँजे (*Begonia satrapis*)को परागण प्रक्रिया माथीको विशेष अध्ययन हो। यहाँ पाइने यस प्रजातिको प्रजनन प्रक्रिया तथा स्त्री फूल अनि नर फूलको पराग मिलन प्रक्रियालाई बुझ्न, फूलको मुख्य भागको जाँच साथै फूलको पराग खान आउने किटपतङ्गको क्रिया कलापमाथी विशेष जाँच गरिएको छ।फूलमा रस नहुनाले गर्दा किटपतङ्गले परागको धुलोलाई नै टिप्ने गर्दछ। विशेष गरि नर फूलमा परागको धुलो पाइनाले गर्दा मौरी (*Apis florea*) अनि भमरा (*Bombus breviceps*)ले नर फूलमा मात्र अधिक समय बिताएको पायौं।आफ्नै हातले गरिएको परागण प्रक्रिया साथै प्राकृतिक स्वभावले हुने परागण (Open pollination)द्वारा अधिक मात्रामा फल र बिज लागेको हुनाले मँगरकाँजेको यस प्रजातिलाई *फ्याकलटेटिभ जिनोग्यामस्* भन्न सकिन्छ। मौरी अनि भमराले आफ्नो नजरमाथी भर परेर नै नर फूल र स्त्री फूलमाथी बसेको अवलोकन गर्यौं। स्त्री फूलमा किटपतङ्गको निम्ति कुनै रस अथवा आहार नभए पनि नर फूल झैं दुरुस्त देखिने हुनाले किटपतङ्ग झुक्किएर स्त्री फूलमा बस्दा नर फूलबाट टिपेको परागको धुलो छरिन्छ, यसो हुँदा फूलमा परागण प्रक्रिया सम्भव भएको पाइन्छ।

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Author contribution: Study designed by SG; Data collected by SG, AP; analysis of data done by AC, and SG wrote the manuscript.

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INTRODUCTION

Male and female flowers provide different levels of rewards to the pollinators. In fact, some female flowers do not produce a pollinator reward and are actually pollinated by deceit (Willson & Ågren 1989; Ågren & Schemske 1991). Deceit pollination can be considered as an extreme case of unreliable signalling in plants since flowers do not offer any reward while they benefit from pollinator visitation (Renner 2006). Intersexual mimicry drives the pollinators to visit the female flowers that do not provide any reward (Little 1983; Ågren & Schemske 1991). Mimicry hypothesis suggests that plants that exhibit intersexual mimicry experience selective advantage when pollinators pay more visits to reward-less female flowers which resemble reward-providing male flowers (Ågren & Schemske 1991). Female flowers in many monoecious species of the genus *Begonia* may attract pollinators by mimicking conspecific male flowers in which bees mistakenly visit unrewarding female flowers (Vogel 1998; Wiens 1978; Ågren & Schemske 1991; Schemske & Ågren 1995; Corff et al. 1998). This hypothesis is based on the remarkable similarity between unrewarding female flowers and the pollen-rich male flowers (Ågren & Schemske 1991). Although, mimicry hypothesis and the behaviour of pollinators have been studied in some species of *Begonia* (Ågren & Schemske 1991; Castillo et al. 2002; Wyatt & Sazima 2011), no detailed study of such kind has been done in *Begonia satrapis* C.B. Clarke (Begoniaceae), an IUCN Red Listed Endangered herb of eastern Himalaya (Adhikari et al. 2018).

Little (1983) suggested that in floral mimicry hypothesis the mimic and the model floral displays are similar, and the pollinators mostly visit the model more often than the mimic. Accordingly, we tested this hypothesis by studying the floral display of male and female phase inflorescences and the pollinator behaviour in *B. satrapis*. The study addressed the following questions: (i) are there any differences between the size and morphology of male and female flowers? (ii) do pollinators discriminate between male and female flowers? (iii) what is the success rate of intersexual mimicry to deceive the pollinators to effect pollination?

MATERIALS AND METHODS

Study site

This study was conducted in a private forest in Sumbuk which falls in the Rangit Valley, South District, Sikkim, eastern Himalaya (27^{0}06'18.90"N & 88^{0}22'07.32"E, altitude 555m). The area experiences a maximum and minimum temperature of 26.9^{0}C and 17.3^{0}C, respectively, with an annual precipitation of 2,766mm. The study site comprises a sub-tropical type of forest where *B. satrapis* flourished in abundance along the margins of this forest which is close to human habitation. The forest surroundings comprised species of *Shorea robusta* C.F. Gaertn and *Schima wallichii* Choisy.

Statistical data analysis

Mann-Whitney U Test was performed to evaluate the difference in seed set rate in hand and open pollination of female flowers. Non-parametric t-test was used to evaluate the variation in morphological characters of male and female flowers. Data collected from different patches were pooled and subjected to a t-test to know whether the resulting variation levels are statistically significant or not. A t-test was performed between the open flowers and closed buds of both male and female flowers, respectively, to check if there is any chronological difference in the opening of male and female flowers.

Inflorescence sex ratio and floral morphology

A sample of 50 flowers, each for male and female sex, was used to record floral morphometrics. A sample of 50 plants was used to record the average number of male and female flowers produced in individual inflorescences. Anthesis schedule and flower lifespan were observed in the field itself.

Foraging activity and pollination

Pollinators were observed in three 3×1 m randomly chosen patches of *B. satrapis* which were reselected on 31 August, 1, 2 and 14 September 2017 (as per Ågren & Schemske 1991). The observation period for the day continued until the pollinators ceased to visit the flowers. Before making observations, number of open male and female flowers were counted within the monitored patch. A total of 1,013 open flowers were counted in each of the inflorescences of the monitored patch out of which 895 were male flowers and 118 were open female flowers. The foraging behaviour of pollinators that entered the patch was observed until they moved out

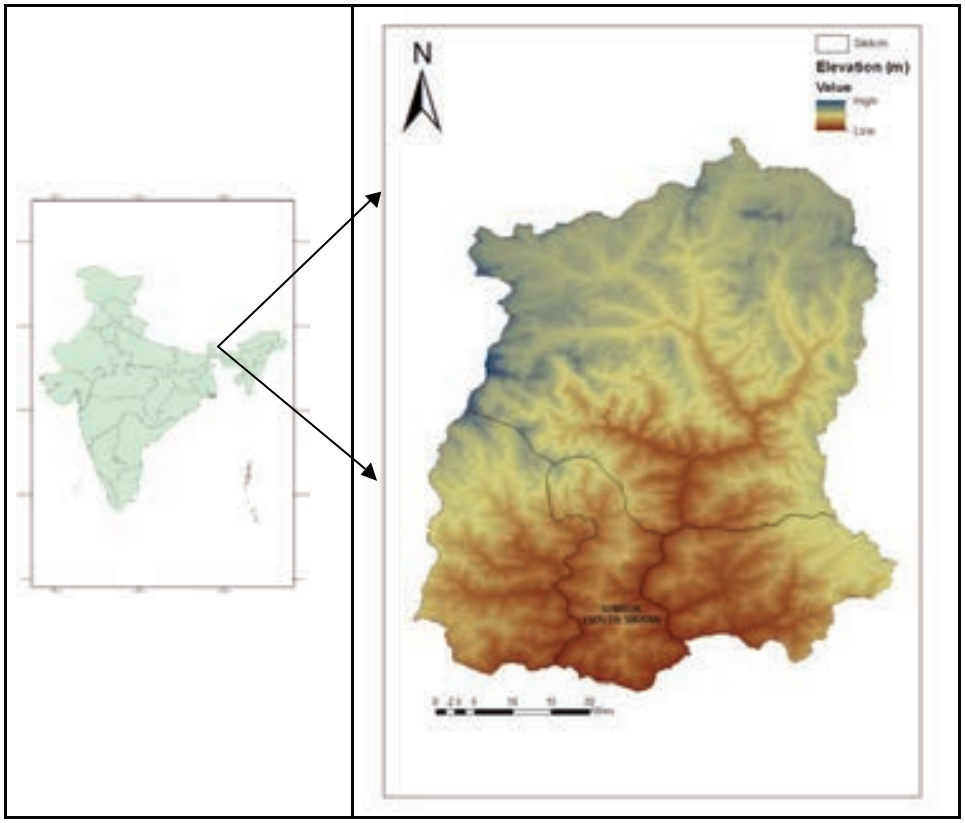

Figure 1. Study site in South Sikkim, the eastern Himalaya.

of it. The number of visits to both the male and female flower were recorded. The time spent on each flower was recorded with a stopwatch in each monitored patch (Male: N=50; Female: N=14). A minimum count of 50 visits to the flowers were kept mandatory in each monitored patch. To test if pollination occurs by wind, several of the buds (N=25) were bagged with mosquito nets which were made into small bags to exclude visitors in order to record the fruit and seed set rate. Similarly, another set of buds (N=25) were bagged and tagged with ribbons to test apomixis.

Apis florea and *Bombus breviceps* were the most frequent pollinators throughout this study. A few rare visits by two other unidentified bee species were noted. The observations were made only on *A. florea* and *B. breviceps* as other foragers visited the flowers rarely.

Hand pollination

Female buds (N=50) were bagged and tagged with a coloured ribbon a day before their anthesis and were hand pollinated on the following day. Hand pollination was performed by brushing the fresh dehisced anther against the stigma of a different plant. Similarly, female buds (N=50) were tagged with a different coloured ribbon and were left for open pollination. The matured fruits were collected to record the number of seeds produced against the number of ovules produced per flower. The pollen limitation was estimated as the ratio of hand cross pollination to open pollination (Larson & Barrett 2000). The scale ranged from 0–100 where 0 indicated no pollen limitation to 100 indicating pollen limitation. All the tagged flowers could not be retrieved at the time of their collection due to anthropogenic activities at the study site.

RESULTS

Floral morphological details

The flowers of *B. satrapis* bloom during July–October. The flowers are open from 05.00–06.00 h. A female flower lasts for 7–9 days while a male flower lasts for almost 15 days. The inflorescence is a cymose with male and female flowers with pink tepals (Image 1). Male flowers comprise four tepals (2+2) while female flowers comprise five tepals (2+3). The outer tepals of male flowers were significantly longer (1.5 ± 0.24 vs. 1.2 ± 0.17 cm; t=1.55e-09, p<0.05) and wider

Image 1. *Begonia satrapis*: a—habitat | b—male flower | c—female flower | d—*Apis florea* | e—*Bombus breviceps*. © Subhankar Gurung.

(1.2 ± 0.16 vs. 1.0 ± 0.16 cm; t=4.05e-04, p<0.05) than those of the female flowers. In addition to the two large tepals, the inner tepals were significantly longer (1.2 ± 0.17 vs. 1.0 ± 0.18 cm; t=1.46e-06, p<0.05) than the female flowers while the inner tepal width showed no significant difference (0.6 ± 0.17 vs. 0.7 ± 0.19; t=0.13, p<0.05, NS) in both male and female flowers. The male flowers produced 34.9 ± 4.1 stamens which are 4.3 ± 0.8 mm in length. The anthers are rimose and each one produced 3,761.3 ± 1,409.4 pollen grains. The anther and stigma of a male and female flower are yellow in colour and are located in the centre of the flower respectively. *B. satrap*is is protandrous and exhibits temporal separation in the production of male and female flowers. The inflorescence was considered as a male phase inflorescence when a larger number of male flowers were open compared to the number of female flowers. The number of open male flowers produced per inflorescence was 3.36 ± 1.84, N=50 and that of female flowers was 0.34 ± 1.17, N=50. The number of open male flowers and closed male flower buds per inflorescence did not differ (t=0.39, p>0.05, NS) whereas difference was observed between open female flowers and closed female flower buds per inflorescence in a population (t=0.0001, p<0.05).

Foraging activity and pollination

During nine hours of observation on pollinators' behaviour on *B. satrapis* a total of 458 male and 14 female flowers were visited by *A. florea* and 100 male and seven female flowers were visited by *B. breviceps* inside the monitored patches (Image 1). The flowers were foraged by bees as and when they were open and continued foraging activity until 12.00h. *Apis florea* and *B. breviceps* showed strong preference to male flowers than female flowers (Table 1). The number of flower visits in the monitored patches by *A. florea* varied between male (91.6 ± 49.8) and female flowers (2.8 ± 2.2; *t*=0.007, *p*<0.05). Similarly, 107 flowers visited by *B. breviceps* varied between male (20 ± 8.3) and female flowers (1.4 ± 1.3; *t*= 0.005, *p*<0.05). *A. florea* and *B. breviceps* spent more time on male flowers than on female flowers due to pollen collection activity (Table 2). *Apis florea* used their legs to remove the pollen while *B. breviceps* performed vibration to collect pollen. Both bee species discriminated female flowers after making first visit to them. The foraging activity of *A. florea* was slower than *B. breviceps* while there was no significant difference in time spent on male flowers (t=0.31, p>0.05, NS) and female flowers(t=0.13, p>0.05, NS) by both bee species.

Table 1. Number of *A. florea* and *B. breviceps* visits to male and female flowers of *B. satrapis*.

	Number of flowers in a patch		Number of flowers visited			
			A. florea		*A. breviceps*	
Patch	Male	Female	Male	Female	Male	Female
1	177	7	60	2	22	2
1	177	7	175	6	32	0
2	173	26	48	2	15	2
3	197	16	83	4	10	3
2	173	63	92	0	21	0

Table 2. Time (in seconds) spent on male and female flowers of *B. satrapis* by *A. florea* and *B. breviceps*.

	A. florea		*B. breviceps*	
	Male	**Female**	**Male**	**Female**
Patch	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1	4.9 ± 3.4	0.7 ± 0.3	1.1 ± 0.6	1.4 ± 0.1
1	4.6 ± 2.9	0.4 ± 0.1	1.2 ± 0.7	-
2	3.1 ± 2.4	0.6 ± 0.3	1.9 ± 1.2	1.0 ± 0.2
3	5.4 ± 3.2	0.7 ± 0.6	2.0 ± 1.6	1.0 ± 0.1
2	2.5 ± 1.4	-	1.4 ± 0.7	-
	4.1 ± 2.7	0.6 ± 0.3	1.5 ± 0.9	1.2 ± 0.1

Note: The visits to flowers outside the patch were also considered for better results.

Hand pollination

Although fruit set was observed in both hand pollinated and open pollinated flowers, hand pollination between male and female flowers of different plants resulted in an increase in seed set (95.4 ± 8.1, N=17) than open pollination (81.1 ± 17.2, N=17) and showed a significant difference between the two (U=0.001, $p<0.05$). Fruit and seed set was absent in both wind pollination and apomixis. The estimated pollen limitation (1.17) indicated that the pollinators deposit adequate pollen in its natural environment.

DISCUSSION

B. satrapis is a monoecious species with both male and female flowers borne in the same inflorescence whose morphological characters varied significantly between male and female flowers in a population. The larger tepals of male flowers appear to be an adaptation to provide visual stimuli to pollinator bees to locate the flowers that provide the reward (Ågren & Schemske 1991). The anthesis of male flowers prior to female flowers enable the pollinators to habituate themselves to the forage source and visit rewardless female flowers by deceit when available on the same or different inflorescences of the same or different conspecific plants. Similar observations were reported in *Jacaratia dolichaula* (Bawa 1980) where pollinators first encountered the rewarding male flowers and therefore, reduced the chances of discrimination of early flowering rewardless female flowers (Corff et al. 1998). The stigmas of female flowers are yellow and strongly resemble male flowers. The female flowers attract pollinators by mimicking male flowers (Wiens 1978; Ågren & Schemske 1991). The rimose anthers are grouped in large number which facilitate pollen collection by vibration (Wyatt & Sazima 2011). The two important foragers *A. florea* and *B. breviceps* showed more preference to the male flowers than the female flowers. This possibly could be because of the pollinators ability to recognize unrewarding flowers (Wyatt & Sazima 2011). It was observed that *A. florea* seemed diffident to collect pollen from a male flower immediately after its visit to a male flower. The lower rate of visitation and the hesitation shown in collecting pollen could be because of the lack of fragrance which has been experimentally proven to be an important aspect to encourage landing on a female flower (Lunau 1991; Schemske & Ågren 1995). Despite the negligible visits to a female flower a high seed set was observed in flowers left for open pollination which could be because of pollination by vibration (Wyatt & Sazima 2011). When a pollinator performs vibration while it visits a female flower by deception it transfers a large load of small and powdery pollen to the stigma (Wyatt & Sazima 2011). A single visit is adequate to deposit a large amount of pollen load to the stigma (Wyatt & Sazima 2011). Seed set in hand pollination was significantly higher than that of open pollination. The lack of pollen limitation, however, indicates that the pollinators are efficient in depositing pollen for successful seed set. Since wind pollination and apomixis are absent in *B. satrapis,* it becomes evident that it depends largely on pollinators for its successful sexual reproduction.

CONCLUSION

It is apparent from our study that the pollinators prefer to visit the polleniferous male flowers more than the rewardless female flowers. The imperfect discrimination by the pollinators by the number of

"mistaken" visits to female flowers, however, guarantees pollination by deceit. Further, abundant fruit and seed set indicate that pollinators are efficient in contributing to the production of fruit and seed in *B. satrapis*. The study indicates that *A. florea* and *B. breviceps* are the principal pollinators of *B. satrapis* and hence, this plant is melittophilous.

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PLATINUM
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Multivariate analysis of elements from the microhabitats of selected plateaus in the Western Ghats, Maharashtra, India

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Abstract: The Western Ghats represents a small part of the Deccan Traps continental flood basalt province that erupted about 65 million years ago. It is an area of outstanding scenic beauty and has attracted the attention of geologists, naturalists and geomorphologists for over a century. One of the unique habitats in the Western Ghats are the rocky plateaus. Previous studies have covered plant species composition, geological and geomorphological status of the rocky plateaus. An analytical study of microhabitats and associated therophytes of four rocky plateau sites was conducted. The study sites were Durgawadi Plateau, Naneghat Plateau which are basalt outcrops and Zenda plateau and Amba Plateau, which are laterite outcrops on the escarpment of the northern Western Ghats. The results revealed a correlation between basalt and lateritic rock outcrops as well as ephemeral plant elements. All four outcrops are similar in their nutrient status but the microhabitats of these plateaus are extremely different from each other.

Keywords: Basalt, ephemeral, geology, laterite, Rock outcrop, therophytes.

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Author details: Ms. Priti Vinayak Aphale—associated with Department of Environmental Science, Fergusson College, Pune. Interested in habitat ecology studies and conservation related research. Baseline data collected for sacred groves of Maval Tahsil, Pune since 2012 with special reference to community participation in conservation. Current studies include impact assessment of developmental activities on plateaus and geomrphological and geochemical characterization of plateaus in Western Ghats. Dr. Dhananjay Chintaman Meshram—Professor in Geology, associated with Department of Geology, SPPU, Pune. Interested in Geochemistry, characterization of river sediments, characterization of Basalt. Dr. Dnyaneshwar Maruti Mahajan—Associate Professor with over 24 years of teaching experience and 27 years of research experience. Interested in plant diversity, wetland Ecology, phytoremediation ,ecological restoration, habitat modification and its impact, urban ecology, biomass carbon sequestration and exotic and invasive species. Dr. Prasad Anil Kulkarni—associated with Post Graduate Research Center in Environmental Sciences Department of Applied Sciences, College of Engineering, Pune. Interested in change detection mapping of Mangrove Ecosystem of Raigad Coast, Maharashtra and in ecosystem monitoring and its conservation related research. Dr. Shraddha Prasad Kulkarni—associated with Department of Environmental Science, Fergusson College, Pune. Interested in ecosystem monitoring and its conservation related research. Baseline data collected for Ujjani Wetland, Maharashtra, India since 2010 with special reference to preferential habitat utilization of wetland by bird communities. Habitat monitoring and association of communities were analysed by applying various statistical models.

Author contribution: PVA—contributed in research idea development and experiment design as well as implementation on field, sample collection and analysis; DCM—suggested and contributed in geochemical and geomrphological characterization of plateaus and interpretation of the data; DMM—contributed in identification of species and microhabitats from the plateau ecosystem; PAK—supported in plateau Ecosystem monitoring, field data collection and technical aspects; SPK—supported in statistical analysis for various tests applied to the data and result interepretaion.

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INTRODUCTION

The Sahyadri Range is one of the spectacular geographic features of the Indian subcontinent. Documenting the plant species was necessary to understand the nature of vegetation (Sambhaji 2015). A compilation with commentary of landmark papers by the Geological Society of India's (Gunnell & Radhakrishna 2001) findings till date gives us an idea about its uniqueness. One of the distinctive aspects of the geomorphology of the Sahyadri Range is the presence and preservation of two "paleosurfaces" indicated by laterite (Fox 1923; Widdowson & Cox 1996; Widdowson 1997). Cliffs, isolated hills, and platforms of rocks formed due to landscape level activities of weathering are the types of outcrops seen commonly in India, whereas "rock outcrops" is the term recognized by IUCN as a category of habitats wherein some portions of freely exposed bedrock project above the soil level due to natural reasons (Porembski & Watve 2005). According to Porembski (2007) well-known rocky outcrops in the world are inselbergs, barrens, cedar glades, cliffs, serpentine, ultramafic, limestone, and gypsum outcrops. He also suggested that each of these are known to harbor highly specialized vegetation rich in microhabitat-specific and endemic plants. Rock outcrop habitats are generally of small extent within a region and present particular habitat limitations, e.g., greater exposure to sun and scarcity of soil. The microenvironment at the rock surface ranges from very hot and arid in dry season to water logged in the wet season. Hence edaphically controlled herbaceous plant communities are characteristic of rock outcrops. Rock outcrops are very well known throughout the world for their uniqueness, but are less studied habitats. Most studies are from African, American and Australian outcrops (Porembski et al. 1994, 2000; Burke 2005a,b; Jacobi et al. 2007) describing the habitat types and associated vegetation composition. In India, relatively very few reports exist about vegetation on these special habitats (Porembski & Watve 2005; Watve 2008, 2013; Lekhak & Yadav 2012; Bhattarai et al. 2012).

The rock outcrops in the Western Ghats of Maharashtra are of two types based on the rock formation and soil type developed from it: (i) Lateritic—lateritic rock cover is well preserved over the parent basalt rock and soil rich in iron, and (ii) Basaltic—having black hard rock and soil. Durgawadi and Naneghat plateaus from the northwestern corner of Pune District are entirely basaltic but have some lateritic soil due to weathering. They have a diversity of micro-habitats and are rich in flora and fauna. Trees or shrubs are less in number, but herbaceous angiosperms, algae, mosses, ferns and lichens are generally abundant in these habitats. Many of the endemic ephemerals, herbaceous angiosperms, pteridophytes and lichens, however, are restricted to these special habitats (Watve 2008). Species composition patterns and outcrop communities are influenced by multiple environmental factors like soil type, elevation, aspect of that rock outcrop and micro-environments (Watve 2013). Moreover, transect studies of plateaus in northern Western Ghats region conducted by Watve (2008 & 2013) discuss the vegetation composition and pattern of some microhabitats on the plateaus. A comprehensive botanical study of two rock outcrops, Durgawadi Plateau (DP) and Naneghat Plateau (NP), on the escarpment of northern Western Ghats revealed a very high plant diversity within the sites and between the sites (Rahangdale & Rahangdale 2014). Herbaceous vegetation of high-level lateritic plateaus of southwestern Maharashtra have been studied by Lekhak & Yadav (2012). These studies have revealed the importance of microhabitats as this plateau vegetation has unique microhabitats that support distinct plant communities depending primarily on soil, depth of the soil and moisture availability. None of these studies describe the interrelationship between nutrient status and plant communities. Hence, the present study was carried out to find out the correlation between nutrient status of selected microhabitats and associated plant communities with the following objectives.

1. Identification and RS & GIS based mapping of microhabitats at plateau ecosystem
2. Sampling and analysis of trace and major elements of rock as well as soil from microhabitats
3. Identification and selection of ephemerals in plateau ecosystem
4. Sampling and analysis of trace and major elements of selected plant communities
5. Understanding correlation among elements, microhabitats and plant communities as well as plateaus using statistical methods

STUDY AREA

Durgawadi Plateau (Image 1): It is located 60km from Junnar Town at 1,200m altitude. The plateau top can be reached after a steep climb from Inglun Village at 19.193^{0}N, 73.695^{0}E & 19.217^{0}N, 73.642^{0}E. The road passes through the villages of Ambe, Hatwij, and Kathewadi and ends at the sacred grove of Durgawadi, which overlooks the Konkan area. Adjacent to it is the

Image 1. Durgawadi Plateau.

Image 2. Naneghat Plateau.

plateau of Warsubai Temple. The Durgawadi Plateau is floristically very important because a number of new taxa are described from this region or adjacent region. According to Rahangdale (2009), Yadav (2010), Aitawade & Yadav (2012), and Rahangdale & Rahangdale (2012) all new taxa described from the location are endemic to Durgawadi.

Naneghat Plateau (Image 2): It is located 26km away from Junnar Town at 19.271^{0}N,73.720^{0}E & 19.298^{0}N,73.672^{0}E, 700m. The rocky hills of this region are well known forts. There is a tar road from Junnar to Naneghat (Ghatghar Village). The basalt is exposed as a broad expanse at a low altitude and bounded by sacred groves, reserve forest patches, rice fields and vertical slopes. The outcrop and its surroundings are affected by biotic pressures. Hemadri (1980) and Rahangdale (2009) denoted that Naneghat Plateau area is rich in plant diversity.

Amba Plateau (Image 3): Amba plateau is located at 16.985^{0}N, 73.784^{0}E & 16.987^{0}N, 73.797^{0}E, 740m, and overlooks the Amba Ghat which is a famous monsoon tourist destination. The plateau top can be reached from a forested path through Amba village.

Zenda plateau (Image 4): Zenda-Dhangarwada Plateau is a least disturbed outcrop located at 16°55'5.50"N, 16.918^{0}N, 73.797^{0}E & 16.904^{0}N, 73.849^{0}E, 1025m. The plateau is known as Zenda Hill and is located between Manoli-Gajapur-Dhangarwada villages near Amba Ghat. The plateau top on Manoli side can be approached from a forested footpath branching from Amba to Vishalgad road (Images 5 & 6).

Image 3. Amba Plateau.

Image 4. Zenda Plateau.

Image 5. Zenda Plateau during the monsoon season.

Image 6. During the eight months plateaus are dry, but possess therophytic communities of endemic plants which are less studied. (Zenda Plateau, Kolhapur) during dry conditions.

METHODS

Maharashtra possesses characteristic habitats called high level plateaus (Watve 2007). Many of them represent lateritic, basaltic as well as sandy characteristics. Of the four plateaus which were found least disturbed, the ones representing basalt and laterite were selected for the said research. All of these are located in the Western Ghats at Pune and Kolhapur regions. These were specifically selected after referencing existing literature and after conducting several field surveys.

GIS mapping – tools and techniques

The research area was surveyed extensively to mark the boundaries of the plateaus. Exact latitudes and longitudes were recorded and marked by using Garmin 5 handheld GPS. These lat-longs were then calibrated with Google Earth version 6.2 (http://www.Google.com/earth/index.html) to get .kmz images as a reference database. For freshly captured images, satellite data was procured from NRSC, Hyderabad. The data was further used to mark each microhabitat at each plateau (Table 1) on ArcGIS … and ERDAS 9.1 platform. Each plateau as well as each microhabitat was GPS marked.

In all, three field study visits were carried out during different seasons: pre-monsoon (March–May), monsoon (June–October), and winter (November–February) to understand the seasonal variations from 2013 to 2017.

Sampling and analysis of soil and rock

Rock and soil sampling was done from the microhabitats marked using GIS; wherever soil was accumulated in microhabitats soil samples were collected from 100cm depth. For habitats like boulders and exposed rock surfaces, the intact rocks were broken and samples were collected. These samples were analyzed using x-ray fluorescence spectrophotometry (XRF). It is a non-destructive analytical technique used to determine the elemental composition of materials. XRF analyzers determine the chemistry of a sample by measuring the fluorescent (or secondary) x-ray emitted from a sample when it is excited by a primary x-ray source. The method is used extensively to analyze trace and major elements of rock as well as soil in a powdered form. Nutrients, Nitrogen by Kjeldahl's method and organic Carbon by Walkley & Black method. The data of XRF analysis is heterogenously distributed over 50 elements around two rock types from four locations distributed over 10–11 microhabitats. Dimensions of which are 2*4*11*50 and types of measurements are percentage and part-per-million.

The statistical analysis was carried out using R $v_{3.3.3}$ and ggplot2 $v_{2.2.0}$ package

Identification of micro habitats at plateau ecosystem

Plants on the plateaus are adapted to various microhabitats and each of these is unique in its edaphic properties, water availability and species composition (Porembski & Barthlott 2000). According to Jacobi et al. (2007) and Watve & Thakur (2006) the most common habitat types observed on plateaus have been identified by following an established categorization for rock outcrops.

Identification and selection of ephemerals at plateau ecosystem

A comprehensive list of plants has been prepared for each microhabitat classified as per Raunkiaer (1934). Phenology was recorded and all the specimens collected were therophytes. An analysis reveals that nearly 70% of the species associated with plateau ecosystem are therophytes (Porembski 2000). The species found in abundance were collected by direct uprooting method along with all parts including roots to flowers. Care was taken to avoid disturbing species nearby. Identification of species was done using regional flora of Kolhapur and Pune and the literature available. Collected plant specimens were processed at the herbarium using standard techniques. All herbarium specimens were deposited in Agharkar Research Institute, Pune for authentication. This was recorded as a first set of samples. The second set of samples were carefully dried in shade. Soil particles from the roots were carefully removed from the plants, and the sample plants were powdered with mortar and pestle. Further, these set of samples were analyzed by XRF to understand trace

Table 1. Samples collected from microhabitats across the plateaus.

Microhabitat	Durgawadi	Naneghat	Amba	Zenda
Cliffs	Rock	Rock	Rock	Rock
Exposed rock surfaces	Rock	Rock	Rock	Rock
Ephemeral pools	Soil	Soil	Soil	Soil
Sacred groves	Soil	Soil	NA	NA
Soil covered areas	Soil	Soil	Soil	Soil
Seasonal ponds	Soil	Soil	Soil	Soil
Rock crevices	Rock	Rock	Rock	Rock
Boulders	Rock	NA	Rock	Rock
Soil richareas	Soil	Soil	Soil	Soil
Soil filled depressions	Soil	Soil	Soil	Soil
Plateau tree cover	Soil	Soil	Soil	Soil

and major elements (Table 2). Kjeldahl's and Walkley & Black methods were used for nutrients like Nitrogen and organic Carbon, respectively. Multivariate statistical analysis was done using software like PAST and R. This was done to understand correlation among elements, microhabitats and plant communities as well as plateaus (Shtangeeva & Alber 2009). Interrelationship among elements was also identified. Table 1 shows the details of the samples collected and processed.

RESULTS AND DISCUSSION

The multivariate analysis of variance (MANOVA) was carried out between the selected elements of plants and rocks across four regions (Durgawadi, Naneghat, Amba, and Zenda) for 10 nutrient elements. The p-values were estimated using multivariate Pillai–Bartlett test statistic.

The overall MANOVA, carried out across all the regions, indicated a significant difference in the content of all the nutrient elements between rocks and plants (p-value = 2.2e-16; <0.001) (Fig. 1).

In the case of Durgawadi region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 1.795e-12; <0.001). Further investigations revealed that except Zinc, all other elements were significantly contributing towards the differences in nutrients of rocks and plants in the Durgawadi (Fig. 2) plateau.

Similar to Durgawadi, the Naneghat region also showed a significant difference in the content of nutrient elements between rocks and plants (p-value = 4.761e-09; < 0.001). Copper, however, did not contribute significantly towards the differences between rocks and plants in the Naneghat (Fig. 3) region.

When Amba region was analysed using MANOVA it revealed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 5.667e-10; <0.001). Further investigation revealed that except Zinc, all other elements significantly contributed towards the differences in nutrients of rocks and plants in the Amba region, which is similar to Durgawadi (Fig. 4)

In case of Zenda region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 1.31e-06; <0.001). Closer inspection showed that the elements Calcium, Manganese, Zinc and Copper did not contribute towards the significant differences in plants and rocks of Zenda region (Fig. 5). It shows that the nutrient profiles of plant and rocks in Zenda region is characteristically different from other regions.

MANOVA between Plants and Rocks

The Multivariate Analysis of Variance (MANOVA) was carried out between plants and rocks across four regions (Durgawadi, Naneghat, Amba and Zenda) for ten nutrient elements. The p-values were estimated using multivariate Pillai–Bartlett test statistic.

In case of the Durgawadi region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (*p*-value = 1.795e-12; <0.001). Further investigation revealed that except Zinc, all other elements were significantly contributing towards the differences in nutrients of rocks and plants in the Durgawadi (Fig. 1: Durgwadi_manova_boxplot.png) region.

Similar to Durgawadi, the Naneghat region also showed significant difference in the content of nutrient elements between rocks and plants (p-value = 4.761e-09; <0.001). However, Copper did not contribute significantly towards the differences between rocks and plants in the Naneghat (Fig. 2: Naneghat_manova_boxplot.png) region.

When Amba region was analyzed using MANOVA it revealed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 5.667e-10; <0.001). Further investigation revealed that except Zinc, all other elements were significantly contributing towards the differences in nutrients of rocks and plants in the Amba region, which

Table 2. Selection of elements for XRF and nutrient analysis of ephemeral plants.

Type of element	Name of the element	Reason for selection	Method of estimation
Nutrients	Organic Carbon, Nitrogen, Phosphorous, Potassium	Essential nutrients	OC (Walkley & Black), Nitrogen (Kjeldahl's), Phosphorous & Potassium (XRF)
Major elements	Calcium, Magnesium, Iron, Manganese	Selected as per t-test results across the regions	XRF method
Trace elements	Zinc, Copper	Selected as per t-test results across the regions	XRF method

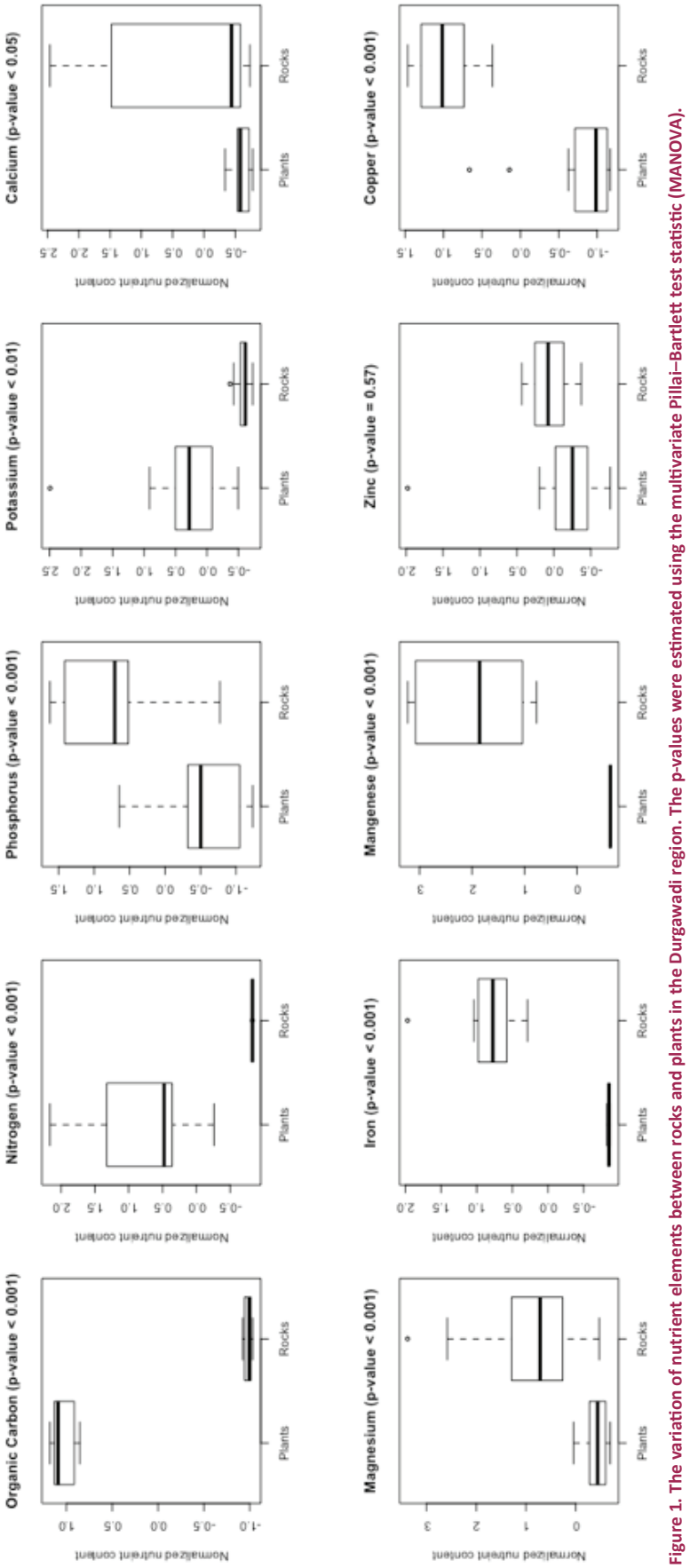

Figure 1. The variation of nutrient elements between rocks and plants in the Durgawadi region. The p-values were estimated using the multivariate Pillai–Bartlett test statistic (MANOVA).

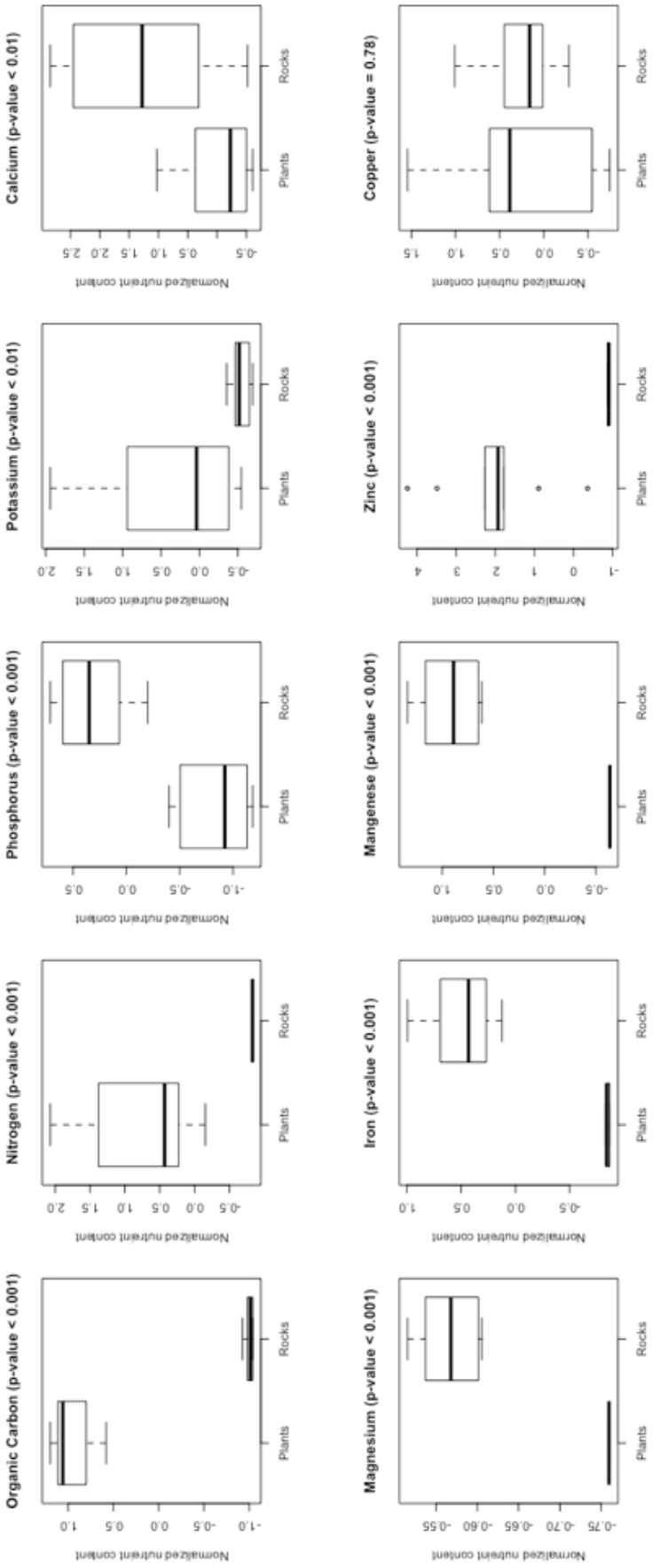

Figure 2. The variation of nutrient elements between rocks and plants in the Naneghat region. The p-values were estimated using the multivariate Pillai–Bartlett test statistic (MANOVA).

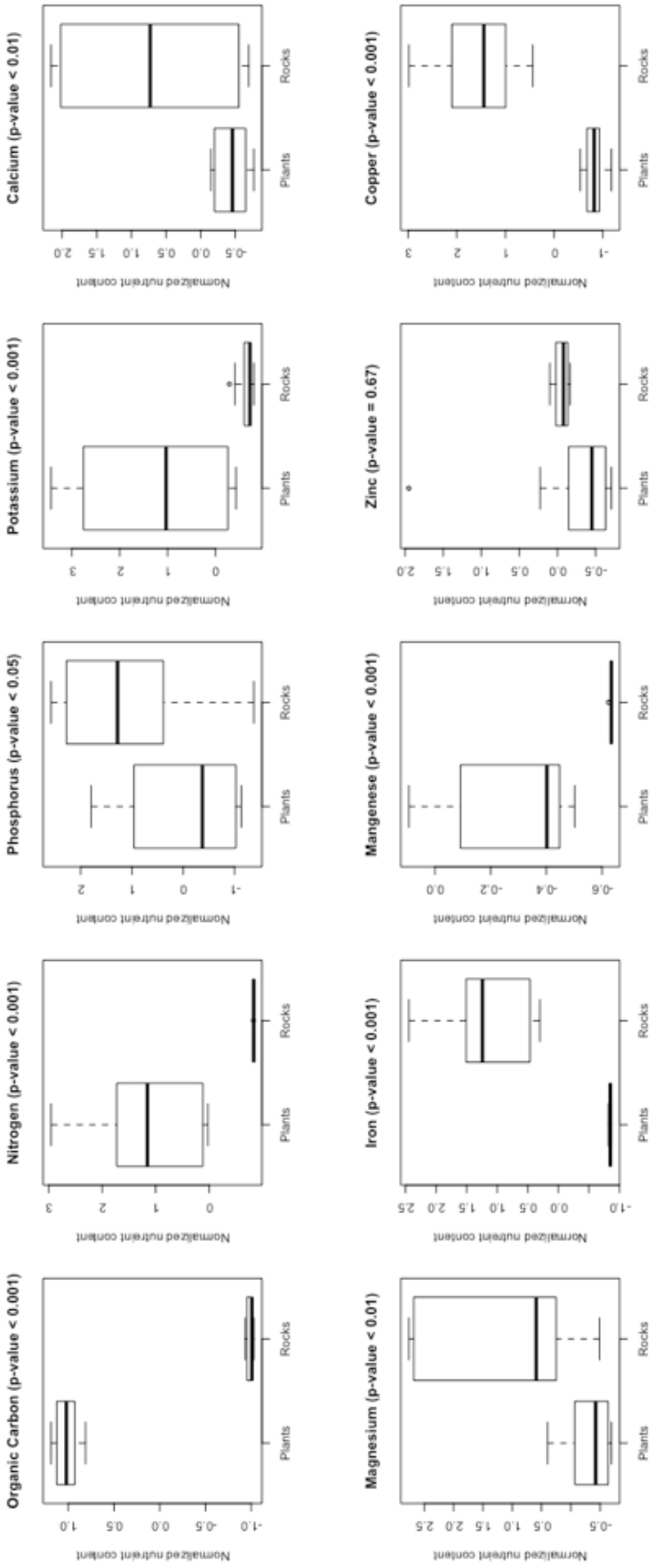

Figure 3. The variation of nutrient elements between rocks and plants in Amba region. The p-values were estimated using the multivariate Pillai–Bartlett test statistic (MANOVA).

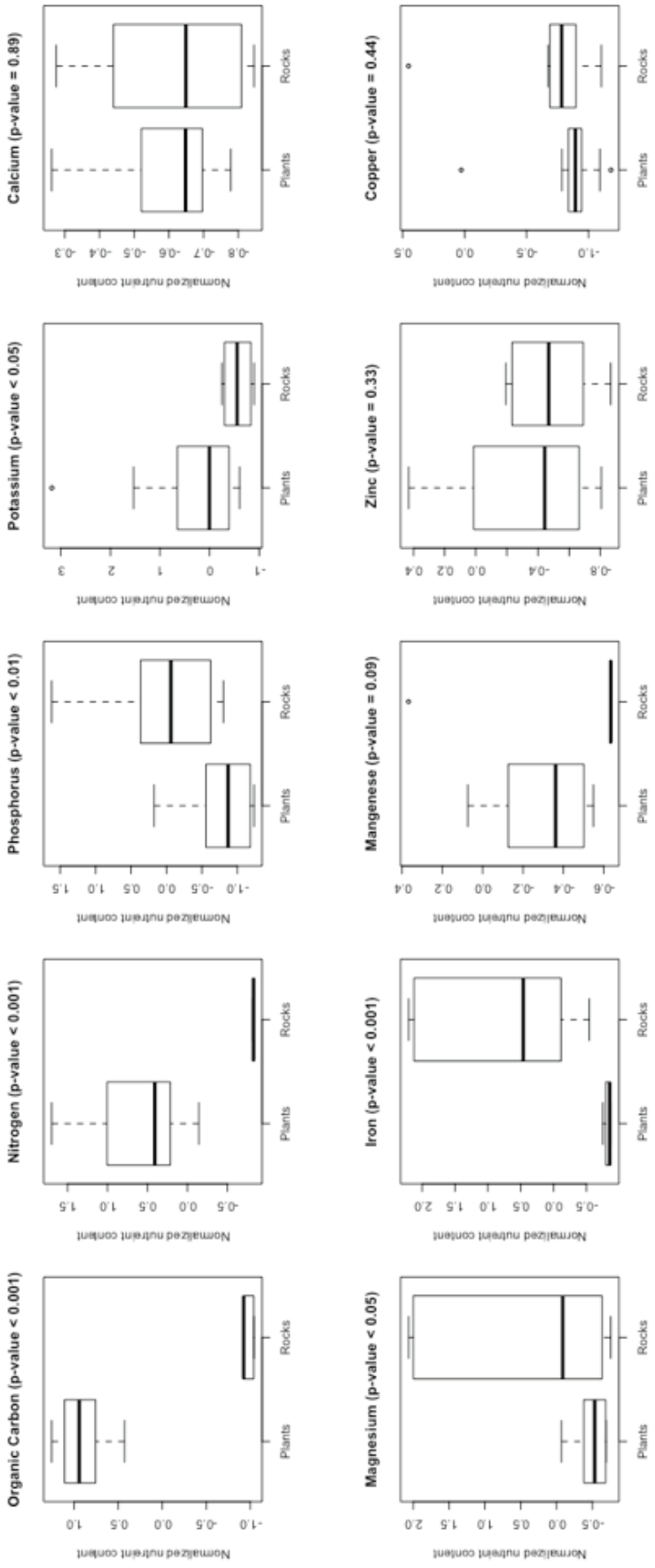

Figure 4. The variation of nutrient elements between rocks and plants in Zenda region. The p-values were estimated using multivariate Pillai–Bartlett test statistic (MANOVA).

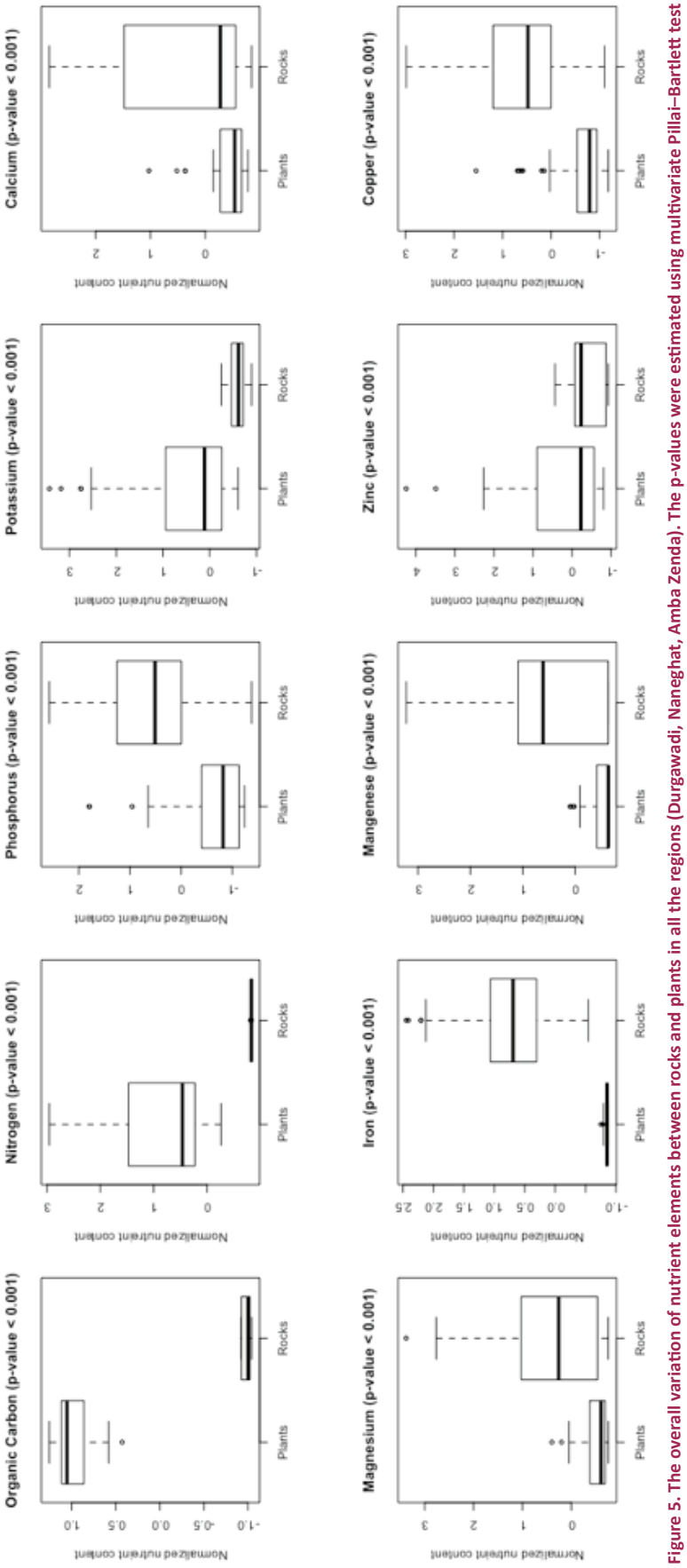

Figure 5. The overall variation of nutrient elements between rocks and plants in all the regions (Durgawadi, Naneghat, Amba Zenda). The p-values were estimated using multivariate Pillai–Bartlett test statistic (MANOVA).

is similar to Durgawadi (Fig. 3: Amba_manova_boxplot.png).

In case of Zenda region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (*p*-value = 1.31e-06; <0.001). Closer inspection shows that the elements Calcium, Manganese, Zinc and Copper do not contribute towards the significant differences in plants and rocks of Zenda region (Fig. 4: Zenda_manova_boxplot.png). It shows that the nutrient profiles of plant and rocks in Zenda region is characteristically different from the other regions.

The overall MANOVA, carried out across all the regions, also indicated the significant difference in the content of all the nutrient elements between rocks and plants (*p*-value = 2.2e-16; < 0.001) (Fig. 5: Combined_manova_boxplot.png).

CONCLUSION

The overall results show that nutrients, trace and major elements under study in all four selected plateaus are significantly different. The Zenda Plateau, the least disturbed plateau in all four plateaus, shows characteristically different nutrient and element content. As Calcium, Manganese, Zinc, and Copper do not contribute towards significant differences in plants and rocks of Zenda region. Each of these areas is different and needs to be studied in detail to understand the dynamics of the ecosystem. Except Zinc, similarity was observed in all elements when samples were analyzed from rocks as well as plants at Durgawadi- Basalt and Amba-Lateritic plateaus. For understanding the causes of such similarities more such studies are needed. The environmental exceptionality, high diversity, lack of studies and speedy destruction of these ecosystems pose an abrupt challenge for their conservation. These should not be considered as wastelands as they are ecologically significant and a hold scientifically unknown facts.

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Appendix 1. Species recorded from four plateaus.

	Species	Family	Durgawadi microhabitat	Naneghat microhabitat	Amba microhabitat	Zenda microhabitat
1	*Acanthospermum hispidum* DC.	Asteraceae	-	CE	-	-
2	*Acmella paniculata* (Wall. ex DC.) R.K. Jansen	Asteraceae	-	-	SCA	-
3	*Adenocaryum coelestium* (Lindl.) Brand	Commelinaceae	+	SCA	-	SCA
4	*Adenoon indicum* Dalzell	Asteraceae	-	-	-	SFD
5	*Adiantum* sp.	Adiantaceae	-	-	-	B
6	*Alysicarpus belgaumensis* Wight	Fabaceae	-	-	-	SFD
7	*Antraxon jubatus* Hack	Poaceae	CE, SCA, PTC	CE, SCA, PTC	-	CE, SCA, PTC
8	*Antraxon lanceolatus* var *meeboldi (stapf) welzen*	Poaceae	-	-	-	SFD
9	*Argemone mexicana* L.	Papaveraceae	SFD	-	-	-
10	*Argyreia cuneata* Ker Gawl.	Convolvulaceae	SG	-	PTC	-
11	*Argyreia sericea* Dalzell	Convolvulaceae	SG	SG	-	PTC
12	*Arisaema murrayi* (Graham) Hook.	Araceae	SRA,B	SRA,B	SRA,B	SRA,B
13	*Arundinella ciliata*	Poaceae	-	SFD	-	
14	*Arundinella pumila* (Hochst. ex A. Rich.) Steud	Poaceae	-	-	SRA	-
15	*Asystasia dalzelliana* Sant.	Acanthaceae	CE, RC, SG	CE, RC, SG	CE, RC	CE, RC
16	*Begonia crenata* Dryand.	Begoniaceae	CE, B	CE	CE, B	CE, B
17	*Bidens biternata* (Lour.) Merr. & Sherff.	Asteraceae	-	ERS	-	-
18	*Biophytum sensitivum* (L.) DC.	Oxalidaceae	SRA	-	-	-
19	*Blepharis maderaspatensis* B. Heyne ex Roth	Acanthaceae	-	ERS, RC	-	-
20	*Blumea malcolmii* Hook.f.	Asteraceae	CE, RC	CE, RC		CE, RC
21	*Buchnera hispida* Buch.-Ham.	Scrophulariaceae	SCA	-	-	-
22	*Burmannia coelestis*	Burmanniaceae	-	-	SRA	-
23	*Canscora diffusa* (Vahl) R. Br. ex Roem. & Schult.	Gentianaceae	CE, RC	CE, RC	CE, RC	CE, RC
24	*Carvia callosa* (Nees) Bremek.	Acanthaceae	-	B, SG, SCA	-	-
25	*Catharanthus pusillus* (Murr.) G.Don	Apocynaceae	-	ERS,SRA	-	-
26	*Celosia argentea* L	Amaranthaceae	B, CE	CE	B, CE	-
27	*Ceropegia rollae* Hemadri	Asclepiadaceae	RC, SFD	-	-	RC, SFD
28	*Chlorophytum glaucoides* Blatt.	Anthericaceae	SRA	-	-	SRA
29	*Chlorophytum laxum* R.Br.	Anthericaceae	-	SCA	-	-
30	*Chrysopogon polyphyllus* Blatt. & McC.	poaceae	SCA	SCA	-	-
31	*Commelina benghalensis* L.	Commelinaceae	SCA, RC, SFD	SCA, RC, SFD	-	SCA, RC, SFD
32	*Commelina maculata* Edgew.	Commelinaceae	-	-	SCA	-
33	*Commelina paludosa* Blume	Commelinaceae	-	-	SCA	-
34	*Commelina suffruticosa* Blume	Commelinaceae	-	SCA	-	-
35	*Conyza stricta* Willd.	Asteraceae	-	-	SRA	-
36	*Cosmos bipinnatus* Cav.	Asteraceae	ERS	-	-	-
37	*Crinum latifolium L.* var. *latifolium*	Amaryllidaceae	SRA	-	SFD	SFD
38	*Crinum pratense* Herb.	Amaryllidaceae	-	-	SCA, SFD, RC	-
39	*Crotolaria filipes* Benth.	Fabaceae	-	SFD	-	-
40	*Curcuma pseudomontana* Grah.	Zingiberaceae	SG,SRA	SG,SRA	,SRA	SRA
41	*Cyanotis fasciculata* (Heyne ex Roth) Schult.f.	Commelinaceae	RC, SCA	RC, SCA	RC, SCA	-
42	*Cyanotis tuberosa* (Roxb.) Schult.f. var. *tuberosa*	Commelinaceae	SRA	SRA	-	SRA
43	*Cyathocline lutea* Law ex Wight	Asteraceae	SEP, SCA	-	-	-
44	*Cynodon dactylon* (L.) Pers.	poaceae	SRA	-	-	-
45	*Cyperus difformis* L.	Cyperaceae	SEP, SP	-	-	-
46	*Cyperus rotundus* L.	Cyperaceae	SRA	-	SRA	SRA
47	*Cyperus tenuispica* Steud.	Cyperaceae	SEP, SP	-	-	SEP, SP

	Species	Family	Durgawadi microhabitat	Naneghat microhabitat	Amba microhabitat	Zenda microhabitat
48	*Delphinium malabaricum* (Huth) Munz.	Ranunculaceae	CE,SG	CE,SG	-	CE
49	*Desmodium triflorum* (L.) DC.	Fabaceae	-	-	SCA	-
50	*Digitaria stricta*	poaceae	-	-	SFD	-
51	*Drimia indica* (Roxb.) Jessop	Hyacinthaceae	ERS	ERS	-	-
52	*Drosera indica* L.	Droseraceae	SCA, SEP	-	SCA, SEP	SCA, SEP
53	*Elephantopus scaber* L.	Asteraceae	-	PTC	PTC	PTC
54	*Emilia sonchifolia* (L.) DC.	Asteraceae	-	SFD	-	-
55	*Eragrostis unioloides* (Retz.) Steud.	Poaceae	SCA	SCA	SCA	SCA
56	*Eriocaulon achiton* Korn	Eriocaulaceae	ERS	-	-	ERS
57	*Eriocaulon eurypeplon* Körn	Eriocaulaceae	-	-	-	-
58	*Eriocaulon sedgwikii* Fyson	Eriocaulaceae	SEP, SP	SEP, SP	-	SEP, SP
59	*Euphorbia thymifolia* L.	Euphorbiaceae	-	ERS	-	-
60	*Evolvulous alsinoides* L.	Poaceae	-	ERS, SCA	-	SRA
61	*Exacum lawii* C.B. Clarke	Gentianaceae	SCA, SFD		SCA, SFD	SCA, SFD
62	*Fimbristylis lawiana* (Boeckeler) J.Kern	Cyperaceae	SRA	SRA	SRA	SRA
63	*Fimbristylis tenera* Schult	Cyperaceae	-	-	-	CR,SFD
64	*Gloriosa superba* L.	Colchicaceae	SCA,SG	-	-	-
65	*Glyphochloa forticulata* (C.E.C.Fischer) W.D.Clayton	Poaceae	SFD	SFD	-	SFD
66	*Gynura bicolor* (Roxb. ex Willd.) DC.	Asteraceae	-	SFD, CE	SFD, CE	-
67	*Habenaria foliosa* A. Rich var. *foliosa*	Orchidaceae	SRA	SRA	-	SRA
68	*Habenaria grandifloriformis* Blatt. & McC.	Orchidaceae	SCA	SCA	-	SCA
69	*Habenaria heyneana* Lindl.	Orchidaceae	SCA	SCA	SCA	SCA
70	*Habenaria longicorniculata* J.Graham	Orchidaceae	-	-	SRA	-
71	*Habenaria panchganensis* Santapau & Kapadia	Orchidaceae	-	-	-	RC
72	*Habenaria rariflora* A.Rich	Orchidaceae	SCA	SCA	SCA	SCA
73	*Hedyotis aspera* Heyne ex Roth	Rubiaceae	SCA	-	-	-
74	*Hedyotis stocksii* (Hook.f. & Thomson) R.S.Rao & Hemadri	Rubiaceae	-	Naneghat	-	ERS,B
75	*Heliotropium indicum* L.	Boraginaceae	-	SRA	-	-
76	*Hypoxis aurea* Lour	Hypoxidaceae	SRA	SRA	SRA	SRA
77	*Impatiens acaulis* Arn.	Balsaminaceae			CE	
78	*Impatiens balsamina* L.	Balsaminaceae	SRA, SFD	SRA, SFD	SRA, SFD	SRA, SFD
79	*Impatiens lawii* Hook. f. & Thomson	Balsaminaceae	SFD, RC	-	SFD, RC	SFD, RC
80	*Impatiens minor* (DC.) Bennet	Balsaminaceae	RC,SG	-	RC	RC
81	*Impatiens oppositifolia* L.	Balsaminaceae	SFD	SFD	SFD	SFD
82	*Indigofera dalzelli* T. Cooke	Fabaceae	-	-	SFD,CR	SFD,CR
83	*Iphigenia indica* (L.) A.Gray ex Kunth	Colchicaceae	SCA	-	-	-
84	*Iphigenia stellata* Blatt.	Colchicaceae	SCA	SCA	SCA	-
85	*Isachne elegans* Dalz. ex Hook.f.	Poaceae	SCA	-	-	SCA
86	*Jansenella grafithiana* (M.Il.Hal) Bor	Poaceae	-	-	SFD	SFD
87	*Jansenella neglecta* Yadav, Chivalkar & Gosavi	Poaceae	SCA	-	-	SCA
88	*Justicia betonica* L.	Acanthaceae	SRA, SG	SRA, SG	-	SRA
89	*Justicia glaucea* Rottl.	Acanthaceae	SRA, SG	SRA, SG	-	SRA
90	*Lavandula bipinnata* Kuntze	Lamiaceae	ERS	ERS	-	ERS
91	*Linum mysurense* B. Heyne ex Benth.	Linaceae	SCA	-	SFD	SFD
92	*Momordica dioica* Wall.	Cucurbitaceae	RC, SFD	RC, SFD	-	RC, SFD
93	*Murdannia lanuginosa* G. Brückn	Commelinaceae	-	-	-	RC
94	*Murdannia semiteres* (Dalzell) Santapau	Commelinaceae	ERS	ERS	ERS	ERS

	Species	Family	Durgawadi microhabitat	Naneghat microhabitat	Amba microhabitat	Zenda microhabitat
95	*Murdannia simplex* (Vahl) Brenan	Commelinaceae	-	-	SFD	-
96	*Murdannia spirata* L.	Commelinaceae	-	ERS	-	ERS
97	*Murdannia versicolor* G. Brückn.	Commelinaceae	-	-	SEP, SCA	RC
98	*Neanotis calycina* (Wall. ex Hook.f.) W.H. Lewis	Rubiaceae	SRA, RC, SFD	SRA, RC, SFD	SRA, RC, SFD	SRA, RC, SFD
99	*Neonatis foeitida* (Dalzell) W.H. Lewis	Fabaceae	SCA	SCA	SCA	SCA,SRA
100	*Nervilia aragoana* Gaudich.	Orchidaceae	-	-	Amba	-
101	*Nicandra physalodes* (L.) Gaertn.	Solanaceae	SRA	SRA	-	SRA
102	*Nilgirianthus reticulatus* (Stapf) Bremek.	Acanthaceae	CE, SRA	CE, SRA	-	CE, SRA
103	*Nilgirianthus reticulatus* (Stapf) Bremek.	Acanthaceae				
104	*Nymphoides indica* (L.) Kuntze	Menyanthaceae	SP	-	-	SP
105	*Panicum antidotale* Retz.	poaceae	SRA	SRA	SRA	SRA
106	*Paspalum canarae* (Steud.) Veldk. var. *canarae*	Poaceae	ERS,SFD	ERS	ERS	SFD
107	*Pimpinella adscendens* Dalzell	Apiaceae	RC, CE	RC, CE	RC, CE	RC, CE
108	*Pinda concanensis* (Dalzell) P.K.Mukh. & Constance	Apiaceae	SFD, SCA	SFD, SCA	-	SFD, SCA
109	*Pogostemon deccanensis* (Panigrahi)	Lamiaceae	SP	SP	SP	SP
110	*Remusatia vivipara* (Roxb) Schott	Araceae	SFD, SG	-	SFD	SFD
111	*Rhamphicarpa longiflora* Benth.	Scrophulariaceae	SP, SEP	SP, SEP	SP, SEP	-
112	*Rostellularia diffusa* (Nees.) Nees	Acanthaceae	-	CE	-	-
113	*Rotala densiflora* Koehne	Lythraceae	SP, SEP	SP, SEP	SP, SEP	SP, SEP
114	*Senecio bombayensis* N.P. Balakr.	Asteraceae	CE, RC, SFD	CE, RC, SFD	CE, RC, SFD	CE, RC, SFD
115	*Senecio dalzellii* C.B. Cl.	Fabaceae		SFD,SEP		
116	*Smithia bigemina* Dalzell	Fabaceae	SCA, SFD, RC	SCA, SFD, RC	SCA, SFD, RC	SCA, SFD, RC
117	*Smithia hirsuta* Dalzell	Fabaceae	SCA	SCA	SCA	SCA
118	*Smithia purpurea* Hook	Fabaceae	SRA, SEP, RC,	SRA, SEP, RC,	-	-
119	*Smithia racemosa* B. Heyne	Fabaceae	SRA	SRA	SRA	SRA
120	*Smithia sensitiva* Aiton	Fabaceae	SRA	SRA	-	SRA
121	*Solanum anguivi* Lam.	Solanaceae	SCA	-	SCA	SCA
122	*Sonerila scapigera* Dalzell	Melastomataceae	B,RC	B,RC	B,RC	B,RC
123	*Sopubia delphinifolia* G. Don	Scrophulariaceae	SP, SEP, SCA	SP, SEP, SCA	SP, SEP, SCA	SP, SEP, SCA
124	*Sphaeranthus indicus* L	Asteraceae	-	SCA	-	-
125	*Striga gesnerioides* (Willd.) Vatke	Scrophulariaceae	SCA	-	-	SCA
126	*Swertia densifolia* (Griseb.) Kashyapa	Gentianaceae			SRA, SFD	
127	*Swertia minor* Knobl.	Gentianaceae	SCA, SEP	SCA, SEP	SCA, SEP	SCA, SEP
128	*Thunbergia laevis* Wall. & Nees	Acanthaceae	SRA, SG	SRA, SG	-	SRA, SG
129	*Torenia indica* C.J. Saldanha	Scrophulariaceae	PTC	-	-	PTC
130	*Utricularia graminifolia* Vahl	Lentibulariaceae	SP, SEP	-	SEP	-
131	*Utricularia praeteria* P. Taylor	Lentibulariaceae	-	-	-	SP, SEP
132	*Utricularia purpurescens* Grah.	Lentibulariaceae	SP, SEP, B,	SP, SEP, B,	SP, SEP, B,	SP, SEP, B,
133	*Utricularia striatula* J.E. Sm.	Lentibulariaceae	SP,SEP	SP,SEP	SP,SEP	SP,SEP
134	*Vigna vexillata* (L.) A.Rich	Fabaceae	SFD, RC, SCA	SFD, RC, SCA	SFD, RC, SCA	SFD, RC, SCA

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SHORT COMMUNICATION

Diversity of butterflies of the Shettihalli Wildlife Sanctuary, Shivamogga District, Karnataka, India

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Abstract: A study was conducted on the diversity of butterflies by using the pollard walk method in the tropical dry deciduous habitats of Shettihalli Wildlife Sanctuary, Shivamogga District, Karnataka, from February 2010 to January 2011. A total of 151 species of butterflies belonging to 99 genera and five families was recorded. The family Nymphalidae was the most dominant with the highest number of species (52 species; 35%), followed by Lycaenidae (33 species; 22%), Hesperiidae (25 species; 17%), Pieridae (24 species; 16%), and Papilionidae (15 species: 10%). The study also revealed 24 species of butterflies which are protected under various schedules of Indian Wildlife Protection Act, 1972, and 13 species as being endemic to the Western Ghats, peninsular India and Sri Lanka.

Keywords: Diversity, endemicity, southern Western Ghats.

The Western Ghats is a prominent globally recognized biodiversity hotspot (Myers et al. 2000; Gunawardene et al. 2007), which covers about 60% of the forest area of Karnataka and one among the 36 biodiversity hotspots of the World.

There are a few reports available until date on the butterflies of the Western Ghats (e.g., Gaonkar 1996; Kunte 2000, 2008; Kehimkar 2008; Padhye et al. 2012; Kasambe 2018). Some examples of earlier documentation on butterflies from the Western Ghats protected areas include: 100 species from Silent Valley National Park (Mathew & Rahamathulla 1993), 124 species from Parambikulam Wildlife Sanctuary (Sudheendrakumar et al. 2000), 139 species from Kudremukh National Park (Radhakrishnan 2007), 74 species from Peechi-Vazhani Wildlife Sanctuary (Mathew et al. 2005), 53 species from Neyyar Wildlife Sanctuary (Mathew et al. 2007), 115 species from Gudavi Bird Sanctuary (Dayanand 2014), and 85 species from the montane forests of Eravikulam National Park (Sreekumar et al. 2018); and non-protected areas: 75 species from Siruvani Reserve Forests (Arun 2003), 282 species from the Kerala part of Nilgiri Biosphere Reserve (Mathew 2016), and 172 species from Dakshina Kannada District (Naik & Mustak 2016). The present study was conducted to examine the status, endemicity, and abundance of butterflies from Shettihalli Wildlife Sanctuary, Shivamogga, Karnataka.

Material and Methods

Study area

The Shettihalli Wildlife Sanctuary (SWS) located between 13.8873^{0}N and 75.3879^{0}E occupies an area about 395.6km^2 (Fig. 1). It is spread over parts of three taluks of Shivamogga District: Shivamogga, Hosanagara, and Thirthahalli. The terrain in the sanctuary is plain

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Competing interests: The authors declare no competing interests.

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to undulating with a few pockets consisting of very steep terrains and hillocks. The temperature within the sanctuary varies from 15˚C to 39˚C and the average rainfall varies around 2000mm dominated by the southwest monsoon during July to September. It covers dry deciduous, moist deciduous and semi evergreen forests of the Western Ghats. The sanctuary is rich in both floral and faunal diversity.

Sampling method

Butterfly survey was carried out from February 2010 to January 2011 to record their status and abundance. The line transect method developed by the Institution of Terrestrial Ecology (Pollard 1979) was followed to monitor the diversity. Butterflies were recorded by direct visual observation along the three fixed transect routs, each of 2km long and 10m wide, passing through the different landscape elements like dry deciduous, semi evergreen and scrub forest and walked at a constant pace for approximately one to one and half an hour. The data collection carried out in a bi-weekly random survey in the whole study period. Observations were made between 07.30hr to 11.00hr, when butterflies are most active. Butterflies were identified by using various field guides (Kunte 2000; Sharma & Radhakrishna 2005; Kasambe 2018) and the nomenclature followed is as per Kasambe (2018). Butterflies observed in this study were categorized into five categories on the basis of their abundance under different score classes such as: very common (VC) 80–100%, common (C) 60–80%, occasional (O) 40–60%, rare (R) 20–40% and very rare (VR) below 20% (Aneesh et al. 2013).

Results and Discussion

The study revealed the presence of 151 species of butterflies, belonging to five families. The checklists of all the species observed with their status are given in Table 1. Family-wise distribution of butterflies species showed that, Nymphalidae was the most dominant with 52 species (35% of total species), followed by Lycaenidae with 33 species (22%), Hesperiidae with 25 species (17%), Pieridae with 24 species (16%), and Papilionidae with 15 species (10%). On the basis of the frequency of occurrence of each butterfly species' abundance, we calculated that 68 (46%) species were common followed by 35 (23%) rare, 30 (20%) very common, 13 (9%) occasional, and 3 (2%) very rare species (Fig. 2).

Thirteen taxa listed in SWS were found to be endemic species of which six species are endemic to the Western Ghats, viz.: *Pachliopta pandiyana*, *Papilio dravidarum*, *Troides minos*, *Kallima horsfieldi*, *Idea malabarica*, and *Caltoris canaraica* (Kunte 2008); five species, viz.: *Discophora lepida*, *Cirrochroa thais*, *Mycalesis patina*, *Cethosia mahratta*, and *Pareronia ceylanica* endemic to the Western Ghats and Sri Lanka (Kasambe 2018); and two species, viz.: *Prioneris sita* and *Papilio polymnestor* endemic to peninsular India and Sri Lanka (Kunte 2008; Kasambe 2018).

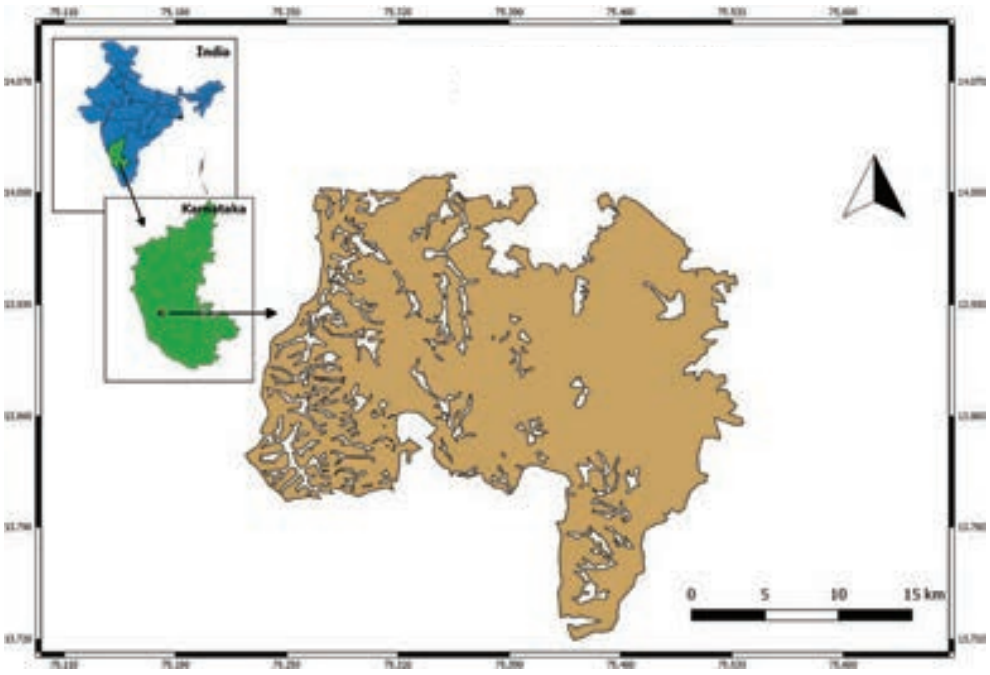

Figure 1. Shettihalli Wildlife Sanctuary.

Table1. Checklist of butterflies along with their conservation status in Shettihalli Wildlife Sanctuary, Shivamogga, Karnataka.

	Common name	Scientific name	Status	WPA 1927
Family: Papilionidae				
1	Crimson Rose	*Pachliopta hector* Linnaeus, 1758	VC	Sch. I
2	Common Rose	*Pachliopta aristolochiae* Fabricius, 1775	R	
3	Malabar Rose*	*Pachliopta pandiyana* Moore, 1881	R	
4	Common Jay	*Graphium doson* C. & R. Felder, 1864	C	
5	Tailed Jay	*Graphium agamemnon* Linnaeus, 1758	C	
6	Spot Swordtail	*Graphium nomius* Esper, 1799	C	
7	Southern Bluebottle	*Graphium teredon* C. & R. Felder, 1865	R	
8	Common Mime	*Papilio clytia* Linnaeus, 1758	VC	Sch. I
9	Lime Butterfly	*Papilio demoleus* Linnaeus, 1758	C	
10	Common Mormon	*Papilio polytes* Linnaeus, 1758	VC	
11	Blue Mormon***	*Papilio polymnestor* Cramer, 1775	VC	
12	Common Banded Peacock	*Papilio crino* Fabricius, 1792	R	
13	Red Helen	*Papilio helenus* Linnaeus, 1758	O	
14	Malabar Raven*	*Papilio dravidarum* Wood-Mason, 1880	C	
15	Southern Birdwing*	*Troides minos* Cramer, 1779	C	
Family: Lycaenidae				
16	Common Silverline	*Spindasis vulcanus* Fabricius, 1775	C	
17	Common Pierrot	*Castalius rosimon* Fabricius, 1775	VC	Sch. I
18	Banded Blue Pierrot	*Discolampa ethion* Westwood, 1851	VC	
19	Dark Pierrot	*Tarucus ananda* de Niceville, 1883	C	Sch. IV
20	Striped Pierrot	*Tarucus nara* Kollar, 1848	R	
21	Red Pierrot	*Talicada nyseus* Guerin-Meneville, 1843	C	
22	Common Cerulean	*Jamides celeno* Cramer, 1775	C	
23	Dark Cerulean	*Jamides bochus* Stoll, 1782	VR	
24	Lime Blue	*Chilades lajus* Stoll, 1780	C	
25	Gram Blue	*Euchrysops cnejus* Fabricius, 1798	C	Sch. II
26	Zebra Blue	*Leptotes plinius* Fabricius, 1793	C	
27	Pea Blue	*Lampides boeticus* Linnaeus, 1767	C	Sch. II
28	Tiny Grass Blue	*Zizula hylax* Fabricius, 1775	R	
29	Dark Grass Blue	*Zizeeria karsandra* Moore, 1865	R	
30	Common Hedge Blue	*Acytolepis puspa* Horsfield, 1828	C	Sch. I
31	Lesser Grass Blue	*Zizina otis* Fabricius, 1787	VC	
32	Plain Hedge Blue	*Celastrina lavendularis* Moore, 1877	C	
33	Large Oakblue	*Arhopala amantes* Hewitson, 1862	R	
34	Indian Oakblue	*Arhopala atrax* Hewitson, 1862	R	
35	Common Ciliate Blue	*Anthene emolus* Godart, 1824	C	
36	Pointed Ciliate Blue	*Anthene lycaenina* C. Felder, 1868	C	Sch. II
37	Indian Red Flash	*Rapala iarbus* Fabricius, 1787	C	
38	Indigo Flash	*Rapala varuna* Horsfield, 1829	C	Sch. II
39	Slate Flash	*Rapala manea* Hewitson, 1863	C	
40	Yamfly	*Loxura atymnus* Stoll, 1780	C	
41	Plum Judy	*Abisara echerius* Stoll, 1790	VC	
42	Monkey Puzzle	*Rathinda amor* Fabricius, 1775	C	

	Common name	Scientific name	Status	WPA 1927
43	Plains Cupid	*Chilades pandava* Horsfield, 1829	VC	
44	Grass Jewel	*Freyeria trochylus* Freyer, 1845	C	
45	Forget-Me-Not	*Catochrysops strabo* Fabricius, 1793	C	
46	Common Apefly	*Spalgis epius* Westwood, 1852	C	
47	Common Lineblue	*Prosotas nora* Felder, 1860	VC	
48	Indian Sunbeam	*Curetis thetis* Drury, 1773	R	
Family: Nymphalidae				
49	Club Beak	*Libythea myrrha* Godart, 1819	R	
50	Common Castor	*Ariadne merione* Cramer, 1777	C	
51	Angled Castor	*Ariadne ariadne* Linnaeus, 1763	R	
52	Tawny Coster	*Acraea violae* Fabricius, 1793	VC	
53	Blue Tiger	*Tirumala limniace* Cramer, 1775	VC	
54	Dark Blue Tiger	*Tirumala septentrionis* Butler, 1874	C	
55	Plain Tiger	*Danaus chrysippus* Linnaeus, 1758	R	
56	Striped Tiger	*Danaus genutia* Cramer, 1779	C	
57	Glassy Tiger	*Parantica aglea* Stoll, 1782	R	
58	Grey Count	*Cynitia lepidea* Butler, 1868	R	Sch. II
59	Common Crow	*Euploea core* Cramer, 1780	VC	Sch. IV
60	Danaid Eggfly	*Hypolimnas misippus* Linnaeus, 1764	C	Sch. I
61	Great Eggfly	*Hypolimnas bolina* Linnaeus, 1758	C	
62	Southern Blue Oakleaf*	*Kallima horsfieldi* Kollar, 1844	O	
63	Autumn Leaf	*Doleschallia bisaltide* Cramer, 1777	R	Sch. I
64	Lemon Pansy	*Junonia lemonias* Linnaeus, 1758	VC	
65	Peacock Pansy	*Junonia almana* Linnaeus, 1758	C	
66	Yellow Pansy	*Junonia hierta* Fabricius, 1798	C	
67	Chocolate Pansy	*Junonia iphita* Cramer, 1779	C	
68	Gray Pansy	*Junonia atlites* Linnaeus, 1763	R	
69	Blue Pansy	*Junonia orithya* Linnaeus, 1758	VC	
70	Rustic	*Cupha erymanthis* Drury, 1773	C	
71	Baronet	*Symphaedra nais* Forster, 1771	R	
72	Nigger	*Orsotriaena medus* Fabricius, 1775	C	
73	Commander	*Moduza procris* Cramer, 1777	R	
74	Common Sailer	*Neptis hylas* Linnaeus, 1758	VC	
75	Common Leopard	*Phalanta phalantha* Drury, 1773	VC	
76	Common Five-ring	*Ypthima baldus* Fabricius, 1775	C	
77	Common Three-ring	*Ypthima asterope* Klug, 1832	C	
78	Common Four-ring	*Ypthima huebneri* Kirby, 1871	VC	
79	Common Baron	*Euthalia aconthea* Cramer, 1777	C	
80	Common Lascar	*Pantoporia hordonia* Stoll, 1790	R	
81	Common Nawab	*Polyura athamas* Drury, 1773	R	
82	Cruiser	*Vindula erota* Fabricius, 1793	O	
83	Clipper	*Parthenos sylvia* Cramer, 1775	VC	Sch. II
84	Southern Duffer**	*Discophora lepida* Moore, 1857	O	Sch. II
85	Tamil Yeoman**	*Cirrochroa thais* Fabricius, 1787	R	
86	Indian Red Admiral	*Vanessa indica* Herbst, 1794	R	

	Common name	Scientific name	Status	WPA 1927
87	Painted Lady	*Vanessa cardui* Linnaeus, 1758	O	
88	Blue Admiral	*Kaniska canace* Linnaeus, 1763	O	
89	Common Evening Brown	*Melanitis leda* Linnaeus, 1758	VC	
90	Dark Evening Brown	*Melanitis phedima* Cramer, 1780	C	
91	Common Bushbrown	*Mycalesis perseus* Fabricius, 1775	C	
92	Glad-eye Boshbrown**	*Mycalesis patnia* Moore, 1857	R	
93	Dark-branded Bushbrown	*Mycalesis mineus* Linnaeus 1758	C	Sch. II
94	Tamil Treebrown	*Lethe drypetis* Hewitson, 1863	O	
95	Bamboo Treebrown	*Lethe europa* Fabricius, 1775	O	Sch. I
96	Tailed Palmfly	*Elymnias caudata* Butler, 1871	C	
97	Common Palmfly	*Elymnias hypermnestra* Linnaeus, 1763	C	
98	Common Map	*Cyrestis thyodamas* Boisduval, 1846	VR	
99	Tamil Lacewing**	*Cethosia mahratta* Moore, 1872	O	
100	Malabar Tree Nymph*	*Idea malabarica* Moore, 1877	VR	
Family: Pieridae				
101	Indian Cabbage White	*Pieris canidia* Linnaeus, 1768	C	
102	Common Albatross	*Appias albina* Boisduval, 1836	R	Sch. II
103	Pioneer	*Anaphaeis aurota* Fabricius, 1793	VC	
104	Common Emigrant	*Catopsilia pomona* Fabricius, 1775	C	
105	Mottled Emigrant	*Catopsilia pyranthe* Linnaeus, 1758	C	
106	Common Jezebel	*Delias eucharis* Drury, 1773	C	
107	Painted Sawtooth***	*Prioneris sita* C. & R. Felder, 1865	R	Sch. IV
108	Common Grass Yellow	*Eurema hecabe* Linnaeus, 1758	VC	
109	Small Grass Yellow	*Eurema brigitta* Stoll, 1780	C	
110	One-Spot Grass Yellow	*Eurema andersoni* Moore, 1886	C	
111	Three-spot Grass Yellow	*Eurema blanda* Boisduval, 1836	C	
112	Great Orange Tip	*Hebomoia glaucippe* Linnaeus, 1758	R	
113	White Orange Tip	*Ixias marianne* Cramer, 1779	R	
114	Yellow Orange Tip	*Ixias pyrene* Linnaeus, 1764	R	
115	Crimson Tip	*Colotis danae* Fabricius, 1775	C	
116	Plain Orange Tip	*Colotis aurora* Cramer, 1780	C	
117	Small Orange Tip	*Colotis etrida* Boisduval, 1836	C	
118	Large Salmon Arab	*Colotis fausta* Olivier, 1804	R	
119	Small Salmon Arab	*Colotis amata* Cramer, 1775	R	
120	Common Wanderer	*Pareronia hippia* Cramer, 1776	C	Sch. II
121	Dark Wanderer**	*Pareronia ceylanica* C. & R. Felder, 1865	O	
122	Common Gull	*Cepora nerissa* Fabricius, 1775	C	Sch. II
123	Lesser Gull	*Cepora nadina* Lucas, 1852	C	Sch. II
124	Psyche	*Leptosia nina* Fabricius, 1793	R	
Family: Hesperiidae				
125	Chestnut Bob	*Iambrix salsala* Moore, 1865	VC	
126	Indian Palm Bob	*Suastus gremius* Fabricius, 1798	C	
127	Indian Skipper	*Spialia galba* Fabricius, 1793	R	
128	Common Grass Dart	*Taractrocera maevius* Fabricius, 1793	R	
129	Tamil Grass Dart	*Taractrocera ceramas* Hewitson, 1868	VC	

	Common name	Scientific name	Status	WPA 1927
130	Common Palm Dart	*Telicota colon* Fabricius, 1775	VC	
131	Dark Palm Dart	*Telicota bambusae* Moore, 1878	VC	
132	Indian Dartlet	*Oriens goloides* Moore, 1881	C	
133	Tamil Dartlet	*Oriens concinna* Elwes & Edwards, 1897	R	Sch. IV
134	White Banded Awl	*Hasora badra* Hubner, 1818	C	
135	Common Banded Awl	*Hasora chromus* Cramer, 1780	VC	
136	Brown Awl	*Badamia exclamationis* Fabricius, 1775	O	
137	Common Snow Flat	*Tagiades japetus* Stoll, 1781	C	
138	Water Snow Flat	*Tagiades litigiosa* Moeschler, 1878	VC	
139	Common Yellow-breasted Flat	*Gerosis bhagava* Moore, 1866	C	
140	Tricoloured Pied Flat	*Coladenia indrani* Moore, 1866	C	
141	Fulvous Pied Flat	*Pseudocoladenia dan* Fabricius, 1787	C	
142	Common Redeye	*Matapa aria* Moore, 1866	O	
143	Variable Swift	*Pelopidas mathias* Fabricius, 1798	VC	
144	Rice Swift	*Borbo cinnara* Wallace, 1866	VC	
145	Kanara Swift*	*Caltoris canaraica* Moore, 1884	C	
146	Dingy Scrub Hopper	*Aeromachus dubius* Elwes & Edwards, 1897	R	
147	Bush Hopper	*Ampittia dioscorides* Fabricius 1793	C	
148	Common Banded Demon	*Notocrypta paralysos* Wood-Mason & de Niceville, 1881	C	
149	Grass Demon	*Udaspes folus* Cramer, 1775	O	
150	Indian Ace	*Halpe hindu* Evans, 1937	C	Sch. II
151	Southern Spotted Ace	*Thoressa astigmata* Swinhoe, 1890	VR	

Endemism: *—Endemic to Western Ghats | **—Endemic to Western Ghats and Sri Lanka | ***—Endemic to Peninsular India and Sri Lanka. Legal Status: IWPA, 1972, Schedules I to IV. Status: VC—Very common | C—Common | O—Occasional | R—Rare | VR—Very Rare.

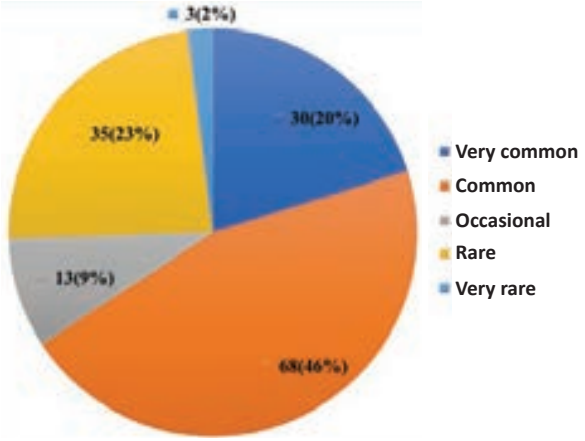

Figure 2. Species frequency of occurrence of butterflies in Shettihalli Wildife Sanctuary, Shivamogga District.

Butterflies are sensitive to changes in the habitat and climate, which influence their distribution and abundance (Wynter-Blyth 1957). The study area hosts 24 scheduled butterfly species: seven species under Schedule I Part IV, 13 species under Schedule II, and four species under Schedule IV of the Indian Wildlife (Protection) Act 1972 (Arora 2003; Gupta & Mondal 2005) (Table 1).

The present study reports for the first time preliminary information on the butterfly species diversity of Shettihalli Wildlife Sanctuary, which can be used in monitoring ecosystem health, stability and functioning of the study area (Mandal 2016). Occurrence of the schedule and endemic species in the study area indicates that SWS is home to a rich diversity of butterflies.

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Image 1. Great Eggfly *Hypolimnas bolina* © M.N. Harisha.

Image 2. Grey Count *Cynitia lepidea* © Harish Prakash.

Image 3. Palm Judy *Abisara echerius* © Harish Prakash.

Image 4. Lime Butterfly *Papilio demoleus* © Harish Prakash.

Image 5. Lemon Pansy *Junonia lemonias* © Harish Prakash.

Image 6. Glassy Tiger *Parantica aglea* © Harish Prakash.

Image 7. Psyche *Leptosia nina* © Harish Prakash.

Image 8. Rustic *Cupha erymanthis* © Harish Prakash.

Image 9. Southern Birdwing *Troides minos* © M.N. Harisha.

Image 10. Clipper *Parthenos sylvia* © Harish Prakash.

Image 11. Common Mormon *Papilio polytes* © Harish Prakash.

Image 12. Common Leopard *Phalanta phalantha* © Harish Prakash.

Image 13. Common Snow Flat *Tagiades japetus* © Harish Prakash.

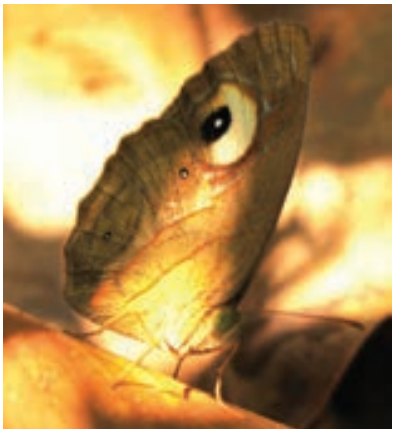

Image 14. Glad-eye Boshbrown *Mycalesis patnia* © Harish Prakash.

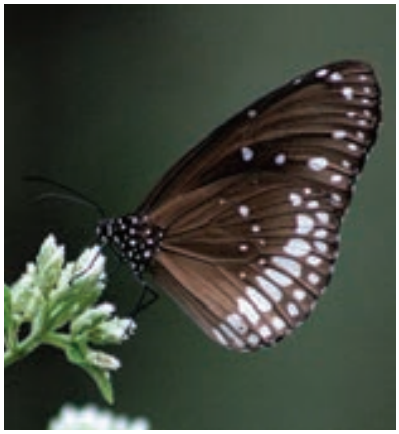

Image 15. Common Crow *Euploea core* © M.N. Harisha.

Image 16. Tamil Yeoman *Cirrochroa thais* © Harish Prakash.

Image 17. Common Sailer *Neptis hylas* © Harish Prakash.

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First record of two rare brachyuran crabs: *Drachiella morum* Alcock, 1896 and *Quadrella maculosa* Alcock, 1898 along the Tamil Nadu coast, India

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Abstract: The present report describes the first record of two brachyuran crabs, *Drachiella morum* Alcock, 1896 and *Quadrella maculosa* Alcock, 1898 along the coast of Tamil Nadu, India. The morphological characters of the specimens are described and discussed. Among the two crabs, *Q. maculosa* was previously recorded only in the Andaman & Nicobar Islands.

Keywords: Crab, *Drachiella morum*, morphological characters, *Quadrella maculosa*.

In recent years, biodiversity research has gained significant momentum owing to the decline of flora and fauna worldwide. Reporting the occurrence of a rare species is, thus, very important in order to update the country's biodiversity database. The brachyuran crabs of the family Aethridae Dana, 1851 is a small group with 37 species under seven genera worldwide (Davie & Fransen 2015). Some members of the Aethridae (*Actaeomorpha* and *Drachiella*) have long been associated with the family Leucosiidae (Ng et al. 2008). The family Trapeziidae Miers, 1886 are known as obligate commensals of corals throughout the Indo-Pacific and eastern Pacific regions (Castro et al. 2004). Trapeziidae has 43 species belonging to three subfamilies and seven genera (Davie & Türkay 2009). Both Aethridae and Trapeziidae are least studied from Indian waters since only three species of aethrids and nine species of trapezids are known from India. Previously, aethrids were reported in 1896 and 1934 (Alcock, 1896; Chopra, 1934); thereafter, no additional observation from the Indian coast has been made in the scientific reports, whereas a few trapezids were reported from Rameshwaram and Andaman Islands (Alcock 1898; Sankarankutty 1961, 1962, 1966; ZSI 2012).

In the present study, we report an Aethridae crab, *Drachiella morum* and a Trapeziidae crab *Quadrella maculosa* for the first time from Tamil Nadu, southeastern coast of India. The former was previously recorded in

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Odisha (Alcock 1896) and West Bengal (Chopra 1934) and the latter was reported only in the Andaman Islands (Alcock 1898; ZSI 2012).

Materials and Methods

During the field survey, one crab belonging to the species, *D. morum* (female) from Kasimedu fishing harbour and two crab individuals belonging to the species, *Q. maculosa* (male, female) from Kottivakkam fish landing centre of Tamil Nadu, southeastern coast of India, were collected. The former was collected from a trawl bycatch while the latter was collected from a gill net. Species identification of the collected specimens was made by following the descriptions of Alcock (1896, 1898) and Galil (1986). The collected specimens were deposited in the Marine Biological Regional Centre (MBRC), Zoological Survey of India (ZSI), Chennai.

Order Decapoda Latreille, 1802
Family Aethridae Dana, 1851
Genus *Drachiella* Guinot, in Serène & Soh, 1976

***Drachiella morum* Alcock, 1896 (Image 1)**

Synonyms: Holotype. *Actaeomorpha morum* Alcock 1896: 172–173. pl. VIII, fig. 3; Ihle, 1918: 308.

Actaeomorpha morum Chopra 1934: 480–481; Edmonson 1935: 20; Sakai 1937: 116, text-fig. 13, 1965: 35, pl. 15, fig. 3; Serene 1954: 458, pl. 7 and text-fig. 1,2; Zarenkov 1969: 16, fig. 1(1); Takeda & Miyake 1970: 218.

"Aff. *Oreophorus*" *morum*, Guinot 1966: 757.

Image 1. Dorsal view of *Drachiella morum*.

Oreophorus rugosus Yokoya 1933, not *O. rugosus* Stimpson 1858; *vide* Takeda & Miyake (1970).

Type locality: Ganjam coast, India (Alcock 1896).

Materials examined: MBRC/Reg No: D1-511, 07 September 2015, 1 female, from trawl net hauled at a depth of 20–30 m, and landed at Chennai Kasimedu fishing harbor, Bay of Bengal, Tamil Nadu, India, coll. Goutham Sampath.

Measurements: Carapace width 10.7mm; carapace length 8.6mm (details in Table 1).

Description: Carapace broader than long, quite oval. The entire surface of the body and appendages are closely covered with vesiculous granules. The carapace as a whole is segmented and isolated into regions from a broad marginal ring by sculptured groves; a narrow bridge alone connecting the front to the gastric regions. The segmented regions are elegantly isolated from each other by a) two obliquely-longitudinal channels that cut off the acutely triangular gastro-cardiac region from the reniform branchial regions, and b) a transverse channel that cuts off the semi-oval intestinal region – the channels being all connected to the marginal ring. The orbits are spherical and are entirely closed out from the antennulary fossettes, the infra-orbital lobe being in close contact with the frontal lobes. The basal antennal segment is fused with the infra-orbital lobe, but the antennal flagellum is distinct. The chelipeds and legs are closely crowded with large granules. The carpus and propodus are covered with spiniform granules. Merus in the last pair of legs is also spiniform on the posterior region.

Colour: Orange brown colour in fresh specimen.

Distribution: India: Odisha and West Bengal (Alcock 1896), Tamil Nadu, India (present study); Japan (Yokoya 1933): Misaki (Sakai 1937), Sagami Bay (Sakai 1965), Kii Nagashima and Tosa Bay (Sakai 1976); East China Sea (Takeda & Miyake 1970a); South China Sea (Dai & Yang 1991); Vietnam, Thailand and Philippines (Serène & Vadon 1981; Chen 1989).

Remarks: *Drachiella morum* was first reported as *Actaeomorpha morum* by Alcock (1896). Later, Guinot (1966) removed the species from *Actaeomorpha* and classified it under *Oreophorus*. Serene & Sow (1976) however, included the species under *Drachiella* with clear illustrations. *Drachiella* was long associated with the family Leucosiidae (Ng et al. 2008).

Order Decapoda Latreille, 1802
Family Trapeziidae Miers, 1886
Genus *Quadrella* Dana, 1851

***Quadrella maculosa* Alcock, 1898 (Image 2)**

Synonyms: Holotype. *Quadrella coronata* var. *maculosa* Alcock, 1898: 226

Quadrella coronata var. *maculosa* Alcock & Anderson, 1899, figures 2, plate 38.

Quadrella maculosa Rathbun, 1911: 235; Guinot 1967: 285; Serene 1968: 89; Garth 1969: 188; Serene 1973a: 204, figures 4, 9, 20–22, plate 3; 1975: 513; Serene et al. 1974: 24; Serene 1984: 288, figure 194, plate 41, figure E; Galil 1986c: 285, figures 5 C–F; Galil and Clark 1990: 372; Allen & Steene 1994: 162; Colin & Arneson 1995: 214, figure 1007.

Quadrella cyrenae Ward 1942: 45, figures 5,6, plate 3; Michel 1964: 30; Guinot 1967: 275.

Type locality: The Andaman Islands, India (Alcock 1898).

Materials examined: MBRC/Reg No: D1-512, 04 January 2016, 1 male, and 1 female gill net, Kottivakkam fish landing centre, Bay of Bengal, Tamil Nadu, India, coll. Goutham Sampath.

Measurements: Carapace width 4.8mm (male), 4.5mm (female); carapace length 3.8mm (male), 3.9mm (female) (details in Table 1).

Description: Carapace hexagonal, slightly wider than long; anterior margin with conspicuous triangular, teeth-like lobes. Polygonal markings in carapace and propodus of chelipeds. Epibranchial spine prominent, projecting outward. Chelipeds are massive. Merus little shorter than the carapace, and strongly granulate on anterior margin; with eight lateral spines on each cheliped. Carpus short, rounded, prominent anterior spine on interior margin. Chelipeds 1.5x longer than carapace length, distended, tuberculate, tubercles increasing in size posteriorly, giving the posterior margin a serrate appearance. First ambulatory leg more than twice carapace's length. Fourth ambulatory dactyl with 16 triangular teeth on posterior margin, proximally diminishing in size. Propodus and dactylus are hairy on each walking leg.

Colour: Light brown in fresh specimen.

Distribution: Red Sea; Gulf of Aden; Kenya; Madagaskar-Tuléar and south coast; Nosy Bé and Tuléar; Seychelles; Amirante Islands; Réunion; Mauritius; Cargados Carajos Islands; Maldives; Sri Lanka - Gulf of Mannar; Andaman Islands; Japan - Kuroshima, Yaeyama-retto; Taiwan; Philippines - Golo Island; Palau; Indonesia - Kepulauan Aru and Kai, Kepulauan Kai, Kepulauan Aru and Geelvinck Bay, New, Makassar Strait and Auri Island, Irian Jaya; Papua New Guinea - Madang; New Caledonia; Vanuatu; Marquesas Islands - Fatu Hiva (MSIP 2016).

Remarks: *Quadrella maculosa* can be differentiated from other species of *Quadrella* by a) having slender and long walking legs b) having a clear epibranchial spine that projects from each side of the carapace and c) merus of a cheliped that is armed with acute tubercles (Castro 1997).

Table 1. Morphometric characters of the identified crabs (mm).

Characters	*Drachiella morum* (n = 1)	*Quadrella maculosa* (n = 2)
Carapace length	8.6	3.8, 3.9
Carapace width	10.7	4.8, 4.5
Frontal width	1	2.1, 2.2
Posterior width of carapace	2.5	2.7, 2.9
Merus length	2.3	2.9, 2.8
Merus width	1.2	1.1, 1.3
Carpus length	1.1	0.8, 0.8
Carpus width	0.9	0.5, 0.5
Propodus length	2.8	5.4, 5.3
Propodus width	1.3	1.4, 1.5
Dactylus length	1.2	1.3, 1.3

Image 2. Dorsal view of *Quadrella maculosa*.

Discussion

The brachyuran crab, *Drachiella morum,* was first reported as *Actaeomorpha morum* by Alcock (1896). He recorded two females (10mm CW, 12mm CL) at 28 to 30 fathoms off the Ganjam coast, Bay of Bengal, India during the "Investigator" expedition. Later, a single

female (12.5mm CW, 10mm CL) specimen was recorded in the mouth of the Hoogly River, West Bengal, India at >20 fathoms (Chopra 1934). Thereafter, no additional observations from the Indian coast were made in any scientific reports. Like *D. morum*, *Q. maculosa* was also first reported by Alcock (1896) from the Andaman Islands. Later, in the 1980s, scientists from the Zoological Survey of India reported its presence from the same region (ZSI 2012). Until now, there are no records from the coasts of mainland India. The specimens collected in the present study agree well with the original descriptions and illustrations of both *D. morum* and *Q. maculosa*.

The present study reports *D. morum* for the first time on the Tamil Nadu coast, and its presence revealed that it has been reported after eight decades from the Indian coast. The crabs belonging to the genus *Quadrella* Dana, 1851 are commensal with anthozoans and were collected at a depth range between 20–150 m. They are mostly obtained by bottom trawling or dredging (Shih & Mok 1996). The present specimen, *Q. maculosa,* was taken from the trash of gill net hauled at 30m depth, and the specimens (a male and a female) were collected attached to gorgonians. The report of *Q. maculosa* from Tamil Nadu coast reveals that its distribution range extends from the Andaman Islands to the mainland coast of India.

Though these species do not contribute towards commercial fishery, they might serve as food for other organisms and their larvae might also be consumed in the food web (Viswanathan et al. 2013). Moreover, *Quadrella* species have a commensal relation with soft corals where they feed on the lipid-rich coral mucus, and the crab reciprocates by cleaning and protecting the coral polyp from predators. Rediscoveries and extension of species distribution help in the biodiversity documentation for future monitoring and management practices.

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SHORT COMMUNICATION

Records of the Marbled Cat *Pardofelis marmorata* and the Asiatic Golden Cat *Catopuma temminckii* (Mammalia: Carnivora: Felidae) from the community forests surrounding the Dzükou Valley in Nagaland, India

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Abstract: Northeastern India, situated within the Indo-Burma and eastern Himalaya biodiversity hotspot complex, is known for its high diversity of wild felid species. For most of these species, however, data on distribution and population trends are limited. Here, we present photographic records of the Marbled Cat *Pardofelis marmorata* and Asiatic Golden Cat *Catopuma temminckii* from outside protected areas in the state of Nagaland. These records are from community forests around the Dzükou Valley in Nagaland and are some of the few records of the species from the state. The confirmed presence of the two species highlights the pivotal role of community-managed forests in the conservation of endangered species in the region.

Keywords: Community-based conservation, distribution, felids, northeastern India.

The region of northeastern India has historically been known to harbour a rich community of wild felids numbering up to 11 species (Menon 2014). There is a paucity of information on the current distribution of most of these species within the region. Two species for which information on distribution and population parameters is unavailable are the Marbled Cat *Pardofelis marmorata* and the Asiatic Golden Cat *Catopuma temminckii* (McCarthy et al. 2015; Ross et al. 2016). Both species are elusive and are known to inhabit remote forest areas (Sunquist & Sunquist 2017). They are listed as Near Threatened under criteria A and C of the IUCN Red List (McCarthy et al. 2015; Ross et al. 2016) and are

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also CITES Appendix I species, fully protected over their range by national legislation. Within India, both species are protected under Schedule I of the Wildlife Protection Act, 1972 (Anonymous 1972).

Confirmed records of the Marbled Cat within northeastern India have been from the states of Assam (Kakati 2009), Arunachal Pradesh (Datta et al. 2008; Lyngdoh et al. 2011a; Selvan et al. 2013), Mizoram (Sethy et al. 2017; Singh & Macdonald 2017), and Nagaland (Grewal et al. 2011; Longchar 2013) (Table 1). In addition, the Marbled Cat has been reported from the adjoining state of West Bengal (Biswas et al. 1999). The Asiatic Golden Cat has been recorded in Assam (Kakati 2009), Arunachal Pradesh (Datta et al. 2008; Lyngdoh et al. 2011a,b), Mizoram (Gouda et al. 2016; Singh & Macdonald 2017), Sikkim (Bashir et al. 2011), and recently, for the first time, in Nagaland (Longchar et al. 2017). The species has been recorded in the neighbouring region of Neora Valley and in other locations in West Bengal as well (Chatterjee et al. 2018). A majority of these records are from within or near government-managed protected areas (PAs; Table 1).

In the hill states of northeastern India, community-owned lands hold a sizeable proportion of the region's forests and likely play a significant role in the persistence of endangered species. For instance, FSI (2017) reports 78% geographical cover of forests in the state of Nagaland, while government-owned PAs constitute less than 2% of the state. Similarly, nearly 80% of Meghalaya is covered by forests (FSI 2017), while less than 2% of the state falls under PAs (ENVIS 2018). Data on the status of endangered wildlife from community-owned forests, however, are critically limited. The northeastern Indian state of Nagaland, with large tracts of community-owned forests, has also faced problems of data paucity. Here, we report live records of the Marbled Cat and the Asiatic Golden Cat from community forests in Nagaland.

Methods

We undertook camera trap surveys in five villages surrounding Dzükou Valley (Fig. 1); these surveys were part of a larger ongoing effort aimed at understanding the distribution of different mammal species in community forests across Nagaland. Dzükou Valley is an ecologically important high-elevation grassland ecosystem surrounded by semi-evergreen and evergreen forests (Grewal et al. 2011). The forests of Dzükou Valley are contiguous with the Puliebadze Wildlife Sanctuary,

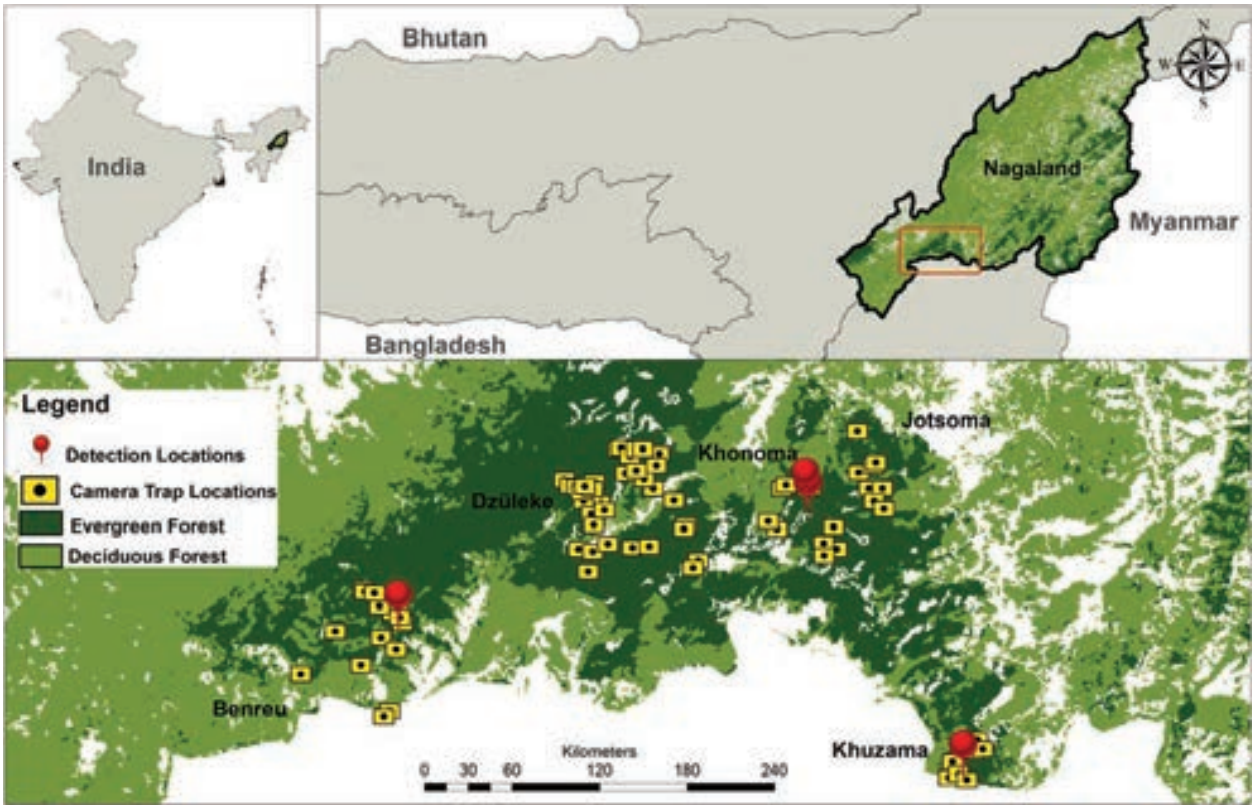

Figure 1. Villages in Nagaland State in India where the Marbled Cat and the Asiatic Golden Cat were recorded.

Khonoma Nature Conservation and Tragopan Sanctuary, and several other community-managed forests. Preliminary research indicated high biodiversity in the landscape (Grewal et al. 2011).

From January to May 2018, we conducted surveys in the villages of Jotsoma, Khonoma, Dzüleke, Benreu, and Khuzama. We set up camera traps—20 each in Khonoma and Dzüleke, 15 in Jotsoma and Benreu, and eight in Khuzama Village, for 10 days, totalling an effort of 78 trap days. The traps were placed at locations where initial reconnaissance surveys provided evidence of wildlife use through animal signs such as pug marks, hoof prints, scat, and droppings. We separated traps by at least 300m to maximize spatial coverage of the community forests.

Results

Our surveys yielded four detections of the two species at four different camera trap locations, all at an average elevation of approximately 2,000m (Table 1; Fig. 1). The Marbled Cat was photographed at two locations, on 01 and 21 April 2018, in the forests of Benreu and Khuzama villages, respectively (Images 1, 2). The Asiatic Golden Cat was photographed at two locations, on 29 January and 01 February 2018, both in the forests of Jotsoma Village (Images 3, 4). These images of the Asiatic Golden Cat were obtained along the same ridge in two neighbouring camera trap locations. All four detections were obtained between 07.00h and 08.30h.

In addition to the sighting of these two species, our camera traps detected the presence of other mammal species such as Dhole *Cuon alpinus*, Clouded Leopard *Neofelis nebulosa*, Leopard Cat *Prionailurus bengalensis*, Asian Black Bear *Ursus thibetanus*, Red Serow *Capricornis rubidus*, and Indian Muntjac *Muntiacus muntjak*.

Discussion

Previous live records of the Marbled Cat in Nagaland have only been from a PA—Intanki National Park (Longchar 2013). In addition, a Marbled Cat skin has been documented from Khonoma Village (Grewal et al. 2011), one of the villages covered in our survey. The Asiatic Golden Cat was recently documented in eastern Nagaland for the first time at the Indo-Myanmar border (Longchar et al. 2017). Our findings, to the best of our knowledge, are the first confirmed live records of the Marbled Cat and the Asiatic Golden Cat from the predominantly community-managed forested landscape within which Dzükou Valley is situated and provides valuable information to a data-sparse map of

Table 1. Records of the Marbled Cat and the Asiatic Golden Cat in northeastern India from previously published reports.

Species	Type of evidence	Location	State	Type of forest	Source
Marbled Cat	Skin	Khonoma Village	Nagaland	Community-owned forests	Grewal et al. 2011
	Camera trap	Intanki National Park	Nagaland	Protected area	Longchar 2013
	Camera trap	Namdapha National Park	Arunachal Pradesh	Protected area	Datta et al. 2008
	Camera trap	Pakke Tiger Reserve	Arunachal Pradesh	Protected area	Lyngdoh et al. 2011a
	Skin	Ziro	Arunachal Pradesh	Community-owned forests	Selvan et al. 2013
	Camera trap	Dampha Tiger Reserve	Mizoram	Protected area	Sethy et al. 2017; Singh & Macdonald 2017
	Camera trap	Jeypore-Dehing Landscape	Assam	Protected area	Kakati 2009
	Camera trap	Dzükou Valley	Nagaland	Community-owned forests	Our study
Asiatic Golden Cat	Camera trap	Namdapha National Park	Arunachal Pradesh	Protected area	Datta et al. 2008
	Direct sighting	Pakke Tiger Reserve	Arunachal Pradesh	Protected area	Lyngdoh et al. 2011a,b
	Camera trap	Prek Chu Catchment, Khangchendzonga Biosphere Reserve	Sikkim	Protected area	Bashir et al. 2011
	Camera trap	Dampha Tiger Reserve	Mizoram	Protected area	Gouda et al. 2016; Singh & Macdonald 2017
	Camera trap	Jeypore-Dehing Landscape	Assam	Protected area	Kakati, 2009
	Camera trap	Choklangan Village	Nagaland	Community-owned forests	Longchar et al. 2017
	Camera trap	Dzükou Valley	Nagaland	Community-owned forests	Our study

Image 1. Camera trap image of the Marbled Cat *Pardofelis marmorata* from Benreu Village in Nagaland, India.

Image 2. Camera trap image of the Marbled Cat *Pardofelis marmorata* from Khuzama Village from Nagaland, India.

Image 3. Camera trap image of the Asiatic Golden Cat *Catopuma temminckii* from Jotsoma Village in Nagaland, India.

Image 4. Camera trap image of the Asiatic Golden Cat *Catopuma temminckii* from Jotsoma Village in Nagaland, India.

felid presence in northeastern India, particularly in the community-owned forests of the region.

Habitat loss, degradation, and hunting pose major threats to these species throughout their range (McCarthy et al. 2015; Ross et al. 2016). In Nagaland, these threats are prevalent in most parts of the state. Thus, safeguarding areas with known potential for conservation of these species is of utmost importance. Our findings emphasize that the community forests surrounding Dzükou Valley can become a nodal point for conservation in Nagaland. The forests, together with Dzükou Valley, represent one of the largest landscapes in the state with contiguous habitat for wildlife.

Multiple villages in the landscape have realized the importance of protecting their forests and have initiated their own efforts to conserve them. These efforts vary among villages. In some villages, the village council, an apex governing body for the village, has issued complete or seasonal bans on hunting. In some cases, resource extraction from the forests for commercial purposes is regulated by the council. Sections of the village-owned forest in Khonoma, Dzüleke, Benreu, and other villages in the region are identified as village forest reserves to be preserved in the long term. Village councils in these villages have additionally created committees to manage and monitor community reserves and promote eco-tourism as an alternative livelihood source. These efforts are critical to ensure long-term ecosystem health and have the potential to protect the forests from land diversion, degradation due to unsustainable resource extraction, and extinction of species due to hunting. Notwithstanding these efforts, threats of habitat loss, degradation, and hunting are still present. Monitoring is still based on traditional and cultural knowledge and decision-making on regulations is uninformed by scientific information on the conservation status of forests or its inhabitant species. Strengthening existing conservation efforts with data and knowledge accrued from scientific surveys can further aid in ensuring the persistence of the Marbled Cat and the Asiatic Golden Cat and in sustaining the community forests in this region.

Thus, more concerted efforts from various agencies, including community leaders, scientists,

non-governmental organizations, and government departments, are required for effective long-term conservation in these forests. This is especially true as these forests lack the financial support of PAs. This, however, can be mitigated by wildlife-friendly alternative livelihoods and support from the government in ways that recognize and respect traditional community rights and decision-making authority vis-à-vis these forests and the resources therein. Further, scientific monitoring of the distribution and abundance of threatened species such as the Marbled Cat and the Asiatic Golden Cat in this landscape and others can greatly add to the ongoing conservation efforts that help ensure the survival of these species in the region.

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Rediscovery of *Calanthe davidii* (Orchidaceae) after 11 decades in the western Himalaya, India

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Abstract: *Calanthe davidii*, a rare orchid species was rediscovered after a gap of 119 years in the western Himalaya and it is also a new distribution record for the flora of Himachal Pradesh State. Detailed morphological description, distribution, ecology and conservation status along with colour photographs of the species are provided.

Keywords: Conservation status, distribution, ecology, Kullu, morphological description, orchid.

The western Himalaya, is the western stretch of the Himalayan biodiversity hotspot that starts from the western boundary of Nepal along Kali Ganga River and runs towards the northwest covering three states of India (Uttarakhand, Himachal Pradesh and Jammu & Kashmir), parts of northern Pakistan and small parts of northern Afghanistan (CEPF 2015). The area has been of botanical interest since 1796, when Thomas Hardwicke collected plants from the region for the first time, followed by J.F. Royle in 1839 and many other botanists including William Griffith, Richard Strachey, Sir George King, C.B. Clarke, Henry Collett etc. (Burkill 1965). Vij et al. (1982) documented 54 species of orchids from Shimla and the adjoining hills, whereas Chowdhery & Wadhwa (1984) listed 53 species from the whole of Himachal Pradesh, followed by 16 species from Kullu by Dhaliwal & Sharma (1999). Based on all the previously known collections and their additional collections, Deva & Naithani (1986) compiled a list of 239 orchid species belonging to 74 genera from the entire northwestern Himalaya. Jalal et al. (2008) reported 237 orchid species from the state of Uttarakhand and Vij et al. (2013) reported 85 species belonging to 44 genera from Himachal Pradesh. Based on a comprehensive survey for over 10 years, Jalal & Jayanthi (2015) reported 239 taxa of orchids belonging to 72 genera from the Indian side of western Himalaya. They reported eight species of *Calanthe*, namely, *C. alismifolia* Lindl., *C. alpina* Hook. f. ex Lindl., *C. brevicornu* Lindl., *C. davidii* Franch., *C. mannii* Hook. f., *C. plantaginea* Lindl., *C. puberula* Lindl. and *C. tricarinata* Lindl., of which *C. davidii* was added to the list based on Mackinnon's old collection (Mackinnon 21742 from DD), and there is one more collection by Falconer (1054 (K000810907)) from an unknown locality (but most likely in the western Himalaya).

During a recent survey in August 2018 in the state

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of Himachal Pradesh, the first author came across a small population of an unknown orchid. After detailed morphological studies, consultation of herbaria, and going through a monographic study on the genus *Calanthe* by Clayton & Cribb (2013), along with other regional treatises (Duthie 1906, 1903–1929; Seidenfaden & Arora 1982; Chowdhery & Wadhwa 1984; Deva & Naithani 1986; Jalal 2005, 2011; Jalal et al. 2008; Jalal & Jayanthi 2015), this species was identified as *Calanthe davidii* Franch. This proved to be the first record from the state of Himachal Pradesh, as well as a rediscovery after 119 years from the western Himalaya, because this species was first collected from western Himalaya, near Mussoorie (Uttarakhand) in July 1899, and for unknown reasons, this species was not reported during all these years. The current authors also assumed that, due to leaves resembling grasses and due to green-coloured flowers, this species would have been easily overlooked. Hence, it has been enumerated in detail with description, updated global distribution and photographic illustration. A detailed list of specimens examined are listed, which may aid future researchers who might be interested in studying this species or group.

Taxonomic Enumeration

***Calanthe davidii* Franch.**

Nouv. Arch. Mus. Hist. Nat., sér. 2, 10: 85 (1887 publ. 1888).

Type: China, Sichuan, Moupin (Baoxing), July 1869, *A.* David s.n. (P00378879) (P!-holotype).

Calanthe pachystalix Rchb. f. ex Hook. f., Fl. Brit. India 5: 850 (1890). *Alismorkis pachystalyx* (Rchb. f. ex Hook. f.) Kuntze, Revis. Gen. Pl. 2: 650 (1891). *Calanthe ensifolia* Rolfe, Bull. Misc. Inform. Kew 1896: 197 (1896). *Calanthe matsudae* Hayata, Icon. Pl. Formosan. 9: 112 (1920). *Calanthe bungoana* Ohwi, Acta Phytotax. Geobot. 5: 56 (1936). *Calanthe furcata f. matsudae* (Hayata) M. Hiroe, Orchid Flowers 2: 88 (1971). *Calanthe davidii* var. *bungoana* (Ohwi) T. Hashim., Proc. World Orchid Conf. 12: 124 (1987).

Terrestrial herbs, generally growing in clusters, 35–90 cm tall in vegetative phase, corms covered with leaf sheaths. Leaves 3–6, ensiform, 20–75 cm long, up to 5cm wide, acute, glabrous, plicate, 3-nerved. Inflorescence erect, scape up to 140 cm long, arising from the side or base of the corm, minutely pubescent, rachis 10–35 cm long, about 30 to 55 flowered, floral bracts minutely pubescent, 1.0–1.5 cm long. Flowers pale yellow to green, 1.4–1.8 × 1.0–1.3 cm, spurred. Sepals similar, sub–elliptic, reflexed, 0.6–0.8 cm long and 0.4–0.5 cm wide, acute, nearly glabrous, 5–veined. Petals oblanceolate, reflexed, 0.6–0.8 cm long and 2.0–2.5 mm wide, obtuse, 3–veined glabrous, with clawed base. Labellum adnate to entire length of column wings, broadly triangular, 0.7–1.0 cm long and 0.6–0.9 cm wide, 3-lobed. Lateral lobes oblong to ovate–triangular, 0.4–0.5 cm long and ca. 2.5mm wide, obtuse, mid lobe divided into 2 lobules by a deep sinus, lobules divergent, sub–oblong and narrower than lateral lobes; ca. 5.0mm long and ca. 1.5mm wide, disc with three clusters of wart–like calli, extending a little lower to sinus of mid lobe; spur cylindrical, puberulent, curved, 8–14 mm long. Column ca. 4.0mm long and ca. 4.5mm wide, glabrous, thick and dilated towards apex; rostellum bilobed; pollinia pear–shaped to obovoid, ca. 1mm with short caudicle; viscidium small. Capsule ovoid, 1.3–1.8 cm long and 0.6–0.9 cm wide (Image 1).

Phenology: Flowers from early July to August, fruiting from September to October.

Habitat: *Calanthe davidii* is a terrestrial herb growing in evergreen coniferous forests from 1,600–1,800 m in the state of Himachal Pradesh. It is generally found growing in clusters along rocks in shady conditions under *Cedrus deodara* canopy. Associated species include *Crepidium acuminatum*, *Onychium japonicum*, *Pteris cretica*, *Valeriana jatamansi*, *Sarcococca saligna, Drepanostachyum falcatum* etc.

Conservation status: *Calanthe davidii* was first collected from western Himalaya, near Mussoorie (Uttarakhand) in July 1899, since then, after various attempts by Deva & Naithani (1986) and Jalal (2011), it has never been collected from this region. Third author and Jalal have surveyed the area for over eight years in vain till 2011. The mention of this species by Jalal et al. (2008) was also based on the same specimen (Mackinnon 21742 at DD), but later Jalal (2011) didn't include this species in his enumeration of orchids of western Himalaya. We were unable to find this specimen at DD after many efforts and visits, however, we found two sheets of the same collection, P.W. Mackinnon 22714 at E (E0069089) and P (P00379000). It seems that the number mentioned earlier (21742) on the references were wrong. Teoh (2016) considered this species to be endangered or extinct in the Himalaya. It has now been rediscovered by the present authors from Kullu District of Himachal Pradesh in western Himalaya after a gap of 119 years.

Due to a very small population this species may be rare in western Himalaya but at a global scale, it is distributed across the Himalaya to China, Indochina, Taiwan, and Japan (Govaerts et al. 2019). As such, no known threat has been recorded across its distribution range except

Image 1. ***Calanthe davidii*** **Franch: A—plant in habitat | B—close up of inflorescence | C—top view of flower | D—side view of flower | E—dorsal sepal | F—lateral sepal | G—petal | H—labellum (spirit sample) | I—operculum with pollinarium | J—pollinarium | K—fruit (All photographs by Ashutosh Sharma except H which is by Nidhan Singh).**

for habitat loss. Until a thorough assessment is done throughout its geographic range, this species can be assessed as Data Deficient based on IUCN criteria (2019). At a regional level, however, this species is known from two authentic collections from Mussoorie (Uttarakhand) and Kullu (Himachal Pradesh) with no recent report from the former location, and less than 50 mature individuals from the latter population. It can be assumed that the population has been extirpated from Mussoorie due to unknown threats or due the developmental activity of this area of tourist interest. Kullu, where the new population was discovered also falls in a tourist area. This population is known to set fruits, hence the pollinator is present and there is a chance of new recruitment and so there is also a chance of finding more populations in adjacent areas. The closest population is supposedly in central Nepal which is over 600km away from the current location in Himachal Pradesh, hence there is no possibility of gene flow. Based on these facts, *Calanthe davidii* can be assessed at regional level as Endangered (C2a(i, ii); D)

Global distribution: China, India, Japan, Nepal, Taiwan and Vietnam.

Specimens examined

India: s.n. (DD172697) (DD), 07.vi.2018, Kasol, 32.001^{0}N & 77.190^{0}E, 1,800m, Kullu, Himachal Pradesh, India, coll. Ashutosh Sharma; s.n. (DD172698) (DD), 07.vi.2018, Kasol, 32.001^{0}N & 77.190^{0}E, 1,800m, Kullu, Himachal Pradesh, India, coll. Ashutosh Sharma; 1054 (K), western Himalaya, coll. Falconer; 22714 (E00694089) (E), Mussoorie, Uttarakhand, 5000–6000 ft., July 1899, coll. P.W. Mackinnon; 22714 (P00379000) (P), Mussoorie, Uttarakhand, 5000–6000 ft., July 1899, coll. P.W. Mackinnon.

China: s.n. (P00378880) (P), Thibet oriental, province de Moupin, coll. A. David; (P00378885) (P), Province du Kouy-Tcheou, environs de Kouei Yangfan, montagne de K'ien ling Chan, coll. J. Beauvais s.n.; 2322 (P00378886) (P), Province du Kouy-Tcheou, environs de Gan-pin, montagneprès de la ville, Coll. Bodinier & Martin; 2369 (P00378887) (P), Province du Kouy-Tcheou, Pin-fa et Na-jo, Coll. J. Cavalerie; 2369 (P00378888) (P), Province du Kouy-Tcheou, Pin-fa et Na-jo, Coll. J. Cavalerie; 2362 (P00378889) (P), Province du Kouy-Tcheou, Pin-fa, Coll. J. Cavalerie; 396 (P00378890) (P), Yunnan, Coll. F. Ducloux; 396 (P00378891) (P), Yunnan, Coll. F. Ducloux; 2557 (P00378892) (P), Yunnan: environs de Yunnan-sen, ravines boisées, Coll. F. Ducloux; 3825 (P00378893) (P), Yunnan, Tchong-chan, Coll. F. Ducloux; 3825 (P00378894) (P), Yunnan, Tchong-chan, Coll. F. Ducloux; 3825 (P00378895) (P), Yunnan, Tchong-chan, Coll. F. Ducloux; 315(P00378896) (P), Su-tchuen oriental, Tchen-Keou-Tin, Coll. P.G. Farges; 315 (P00378897) (P), Su-tchuen oriental, Tchen-Keou-Tin, Coll. P.G. Farges; 856 (P00378898) (P), Su-tchuen oriental, Tchen-Keou-Tin, Moungmoung Ky, prèsTchen-Kéou, Coll. P.G. Farges; 856 (P00378899) (P), Su-tchuen oriental, Tchen-Keou-Tin, Moungmoung Ky, prèsTchen-Kéou, Coll. P.G. Farges; 856 (P00378900) (P), Su-tchuen oriental, Tchen-Keou-Tin, Moungmoung Ky, prèsTchen-Kéou, Coll. P.G. Farges; 856 (P00378901) (P), Su-tchuen oriental, Tchen-Keou-Tin, Moungmoung Ky, prèsTchen-Kéou, Coll. P.G. Farges; 856 (P00378902) (P), Su-tchuen oriental, district de Tchen-Keou-Tin, Coll. P.G. Farges; s.n. (P00378905) (P), Yunnan, Coll. E.E. Maire; 2322 (P00378906) (P), Kouy-Tcheou, Coll. L. Martin; 2322 (P00378907) (P), Kouy-Tcheou, Coll. L. Martin; 1259 (P00378909) (P),West Hupeh, Coll. E.H. Wilson; 4597 (P00378910) (P), Western China, Coll. E.H. Wilson; 46 (P00378903) (P-syntype), 08.xix.1908, Su-tchuen (Sichuan), Massif des Oua Pao Shan, Coll. A.F. Legendre; 090602026 (326560) (TAIF), 06.ii.2009, Hubei, Enshi Tujia and Miao Autonomous Prefecture, Enshi Tujia and Miao Autonomous Prefecture, 517 m, Bing Zhang, Coll.Zhi-Rong Gu & Xin Xiang; s.n. (382914) (TAIF), 06.xviii.2009,Hubei, Lichuan City, Maoba Township, 770 m; s.n. (382957) (TAIF), 06.xxii.2009,Hubei, Xianfeng County, Huolongping Township, 1100 m; s.n. (382958) (TAIF), 06.xxii.2009, Hubei, Xianfeng County, Huolongping Township, 1100 m; 1969 (443700) (TAIF), 04.xx.2012, Hunan, Longshan County, Daan Township, 1135 m, Coll. Zhi-Jiang Zhang & Wen-Qi Liu; 2528 (450241) (TAIF), 05.xvii.2012, Hubei, Enshi City, Enshi City, 700 m, Coll. Zhi-Jiang Zhang & Wen-Qi Liu; 3488 (457990) (TAIF), 07.xxv. 2012, Sichuan, Hongya County, Fanjiaoping, 1300 m, Coll. Xiao-Jie Li; 5762 (391423) (TAIF), 05.xxiv.2012, Taiwan, Hsinchu County, Ssumakussu Ancient Trail, 1500–1700 m, Coll. Tian-Chuan Hsu; 3995 (392497) (TAIF), 05.xi.2011, Taiwan, Hualien County, Tienchang Cliff, 1300–1500 m, Coll. Tian-Chuan Hsu.

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PLATINUM OPEN ACCESS

Range extension of the Gooty Tarantula *Poecilotheria metallica* (Araneae: Theraphosidae) in the Eastern Ghats of Tamil Nadu, India

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The family Theraphosidae Thorell, 1869 is represented by 999 species in 147 genera (World Spider Catalogue 2019). The greatest diversity of this family is found in the tropical regions of the world and some species exist in the subtropical and temperate regions but notably absent in the polar region (Nanayakkara et al. 2012). In India, it is represented by six subfamilies: Eumenophorinae, Ischnocolinae, Poecilotheriinae, Selenocosmiinae, Selenogyrinae and Thrigmopoeinae (Pocock 1900; Mirza et al. 2011; Siliwal et al. 2012). Members of the family Theraphosidae are predominantly terrestrial in habit, dwelling in burrows, beneath the rocks, and fallen logs (Nanayakkara et al. 2012). The old world genus *Poecilotheria* Simon, 1885 of the subfamily Poecilotheriinae is the only genus specifically arboreal in habit, occurring largely in the dry deciduous and evergreen forests or wooded areas in peninsular India and Sri Lanka (Siliwal et al. 2013). Spiders of the genus *Poecilotheria* are widely known for their large size, colourful marking within a flattish carapace (Pocock 1900; Smith & Kirk 2002), their potent venom (Nanayakkara et al. 2012) and familiarity in the pet trade (Siliwal et al. 2013).

About 14 species have been recognized hitherto from the genus *Poecilotheria*, wherein seven species are endemic to India (*formosa, metallica, miranda, regalis, rufilata, striata,* and *tigrinawesseli*) and five to Sri Lanka (*fasciata, ornata, rajaei, smithi,* and *subfusca*) while two species (*hanumavilasumica* and *vittata*) are found in both (World Spider Catalogue 2019). *Poecilotheria metallica* Pocock, 1899 is commonly known as the Peacock Parachute Spider or Gooty Tarantula. This species is endemic to India, and according to the current IUCN Red List of Threatened Species, the species is categorized as Critically Endangered, as it is restricted to a 100km^2 highly degraded forest between Nandyal and Giddalur in the Eastern Ghats of Andhra Pradesh (Molur et al. 2008). Reginald Innes Pocock (1899) had reported its type locality as Gooty on the basis of a single female specimen. About 102 years later, Molur et al. (2003) found two immature individuals in an extremely degraded forest between Nandyal and Giddalur in the Eastern Ghats of Andhra Pradesh. Subsequently, Molur

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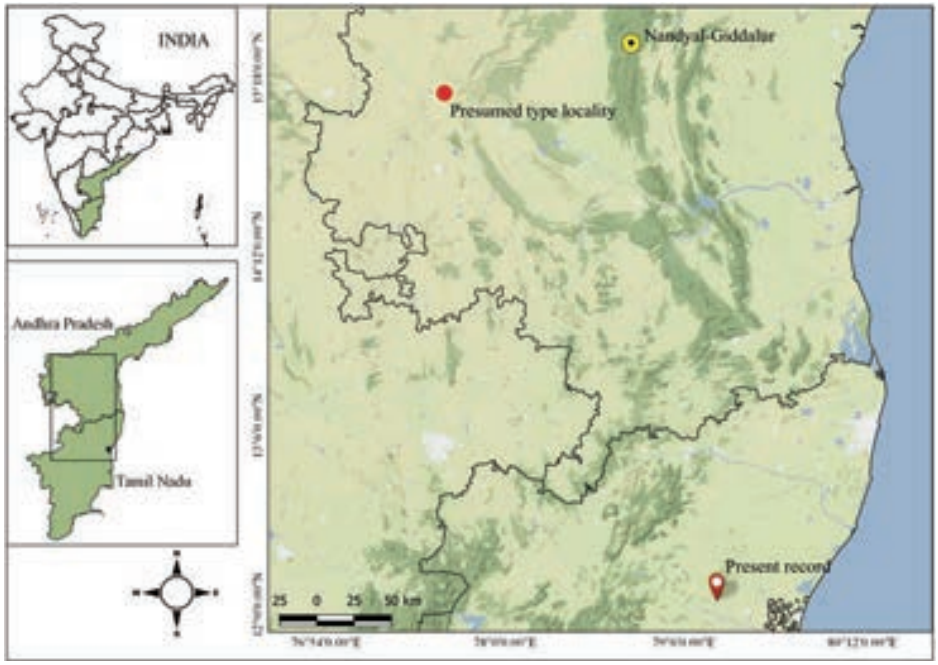

Figure 1. Map of southern India illustrating the previous record (yellow dot) of *Poecilotheria metallica*, present sighting (place holder) and presumed type locality as reported by Pocock (1899) (red circle).

Image 1. Habitat of *Poecilotheria metallica* at Pakkam Malai Reserve Forest, Villupuram District, Tamil Nadu. The photograph was taken during the monsoon when vegetation is lush.

et al. (2003) provided the first detailed description of its habitat. Previous to their record Gooty was considered as the existence locality of *P. metallica.* Pocock (1899) recorded that a single female specimen was collected from the railway timber yard in Gooty, however, it could inadvertently have been transported with timber from the Eastern Ghats (Molur et al. 2008). Presently, this species is found only within 100km^2 Reserve Forest between Nandayal and Giddalur (Molur et al. 2008). An additional location in Andhra Pradesh is not considered here as it was published in a predatory journal (see Beall's List 2019). Hitherto, *P. metallica* has not been found in any other parts of India or Sri Lanka. This paper is based on the observations from Tamil Nadu. The presence of this threatened theraphosid recorded for the first time outside of its known distribution expands its range further south from its confirmed record.

Gingee is a heritage town in the district of Villupuram, located in the northeast of Tamil Nadu (Muralidharan & Narasimhan 2012; Vimalraj et al. 2018). Pakkam Malai Reserve Forest has been protected as a sacred groove (Vimalraj et al. 2018). The average elevation of this

Image 2. Dorsal aspect of *Poecilotheria metallica* in life: A—Adult female showing peculiar metallic luster and orange yellow patches on tibiae | B—Adult female from the cave | C—Adult male from the bat cave.

rocky terrain is about 400m and the vegetation type ranges from dry thorn scrub to tropical dry deciduous and tropical dry evergreen forest (Kalaimani 2011; Balachandran et al. 2015). The annual rainfall is about 700mm, and the temperature fluctuates between 30^{0}C and 36^{0}C during the non-monsoon period of the year; during monsoon season it drops down to 24^{0}C (Karthik et al. 2018).

While undertaking a floral survey at Pakkam Malai (Image 1) on 09 December 2018, we sighted a huge blue coloured spider resting in a cave. We approached the specimen closely and photographed it with a Nikon D3200 (Image 2). The spider was later identified as *Poecilotheria metallica* described by Pocock (1899)

Table 1. Details on observation of *Poecilotheria metallica* on different occasions during the field visit at Pakkam Malai Reserve Forest, Villupuram District.

	Pakkam Malai Reserve Forest	Date of sighting	Microhabitat
1	Tharbasuanai (Spring)	09.xii.2018	Inside the cave (water was oozing out from the rock crevices inside the cave)
2	Sanipparai	22.i.2019	On the dry rill
3	Sanipparai	23.i.2019	On the dry rill
4	Bat cave	24.ii.2019	Inside the cave (bats also were roosting)
5	Tharbasuanai (Spring)	01.iii.2019	At the entrance of the cave

and corroborated using the photographic identification poster (Indian Parachutes) published by the Zoo Outreach Organization and Wildlife Information Liaison Development Society (ZOO/WILD 2010). Subsequently, we sighted *P. metallica* on four different occasions at Pakkam Malai Reserve Forest during fieldwork, details of which are given in Table 1.

The present sighting extends its distribution range along the Eastern Ghats by approximately 370km south from its previous record (Molur et al. 2008) (Figure 1). Further exploration could reveal the presence of *P. metallica* in the adjacent hills too. Documentation of biodiversity has become a very significant part of the conservation of that particular ecosystem (Nanayakkara et al. 2015). A few years ago, the Grizzled Giant Squirrel *Ratufa macroura* was reported from Pakkamalai RF (Vimalraj et al. 2018), and the addition of *P. metallica* from the same locality emphasizes the significance of these forests from the biodiversity and conservation perspectives.

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Some recent evidence of the presence of the Critically Endangered *Gyps* vulture populations in northern Shan State, Myanmar

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Four species of vultures are found in Myanmar, namely, *Sarcogyps calvus* Red-headed Vulture, *Gyps bengalensis* White-rumped Vulture, *G. tenuirostris* Slender-billed Vulture, and *G. himalayensis* Himalayan Vulture (Htin Hla et al. 2011). Of these, the latter three are present in Kachin, Shan State and Sagaing Region (Tordoff et al. 2007; Htin Hla et al. 2011; Shwe & Aung 2016), and *G. himalayensis* is additionally observed in Chin State (Htin Hla et al. 2011).

Gyps *bengalensis* was abundant in Myanmar and considered as the most common vulture in Myanmar throughout the plains in the early 20th Century (Smythies 2001; Naing et al. 2012). The population of vultures decrease in many parts of their former distribution ranges has been generally attributed to food shortage, chemical poisoning (i.e., diclofenac), and other human impact. Consequently, the population size decreased (Robson et al. 1998; BANCA 2007; Tordoff et al. 2007; Htin Hla et al. 2011; Shwe & Aung 2016), and the more recent status remains uncertain for all four species for most of the country (Pain et al. 2003, 2008).

On 27 November 2018, we observed a flock of *G. bengalensis* (Critically Endangered; BirdLife International 2017), *G. tenuirostris* (Critically Endangered; Birdlife International 2016b), and *G. himalayanensis* (Near Threatened; BirdLife International 2016a), in Man Sant Village, Mong Yai Township, Northern Shan State, Myanmar (22.43°N, 97.92°E; see map). The flock was feeding on the carcass of cattle (likely accidental death). The most notable feature of our observation was the presence of *G. bengalensis* and *G. tenuirostris*: we could observe as many as 38 vultures of three species (*G. bengalensis*: 31, including six juveniles; *G. tenuirostris*: 5; *G. himalayensis*: 2).

The vulture flock departed westwards three days after they completely consumed the carcass. The local people were apparently familiar with vultures, informed us that they also occur in Nar Ma Lan Village, Nam Lan Village and Ho Ti Village, all of which are located within a 15-km radius from Man Sant Village.

Unfortunately, we failed to observe any nests or nesting sites of the flock. The local people confirmed frequent observations of the three species from April to May (the local breeding season according to the information we obtained from the locals; October to March after Robson 2011) in the area of interest, particularly before monsoon, indicating possible breeding attempts in the area.

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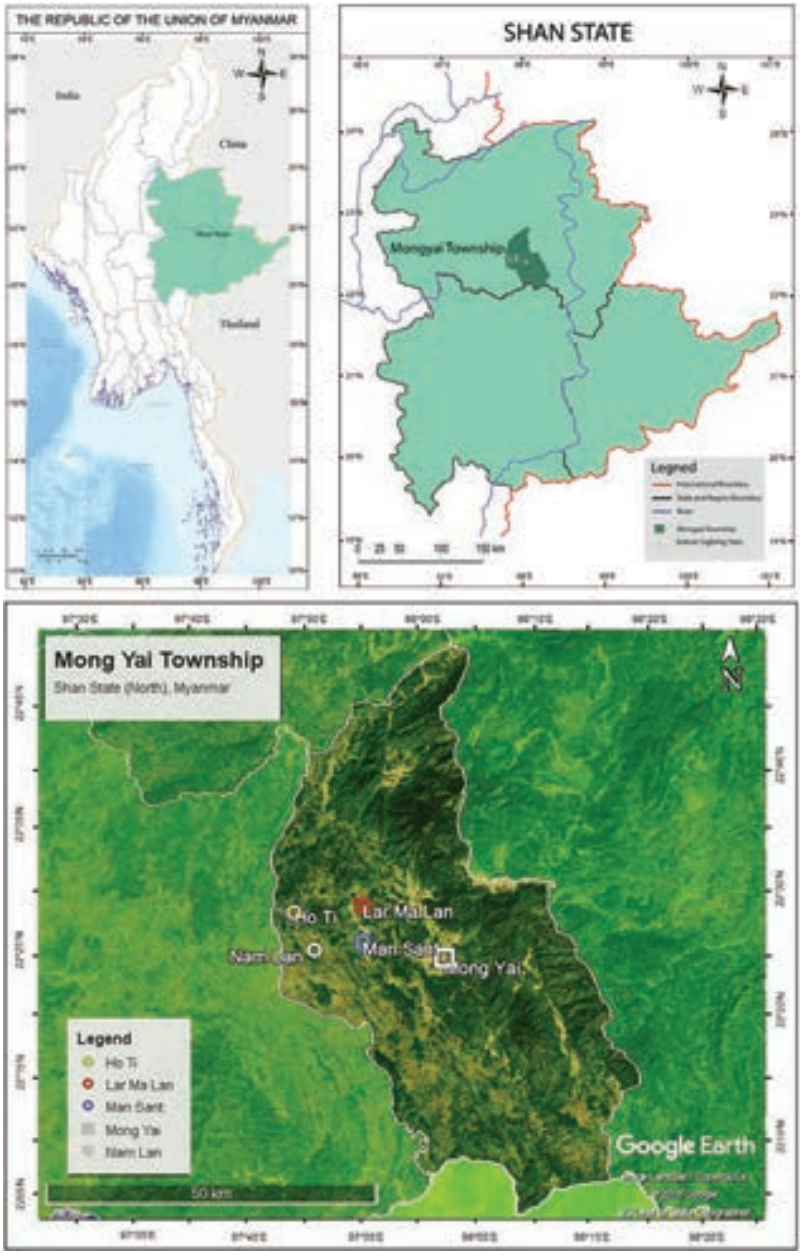

Figure 1. Vulture sighting locality in Shan States (dots in inset) and Shan States within Myanmar.

Htin Hla et al. (2011) reported *G. bengalensis* as more abundant than *G. tenuirostris* during their survey in Chin State, Kachin State, and Shan State. Additionally, they also stated that *G. bengalensis* were recorded regularly associating with other vulture species in Myanmar (1997 to 2006). In Shan and Chin states, *G. bengalensis* was regarded as the most common vulture species in the early 20th Century (Rippon 1901), but was hardly reported in recent decades (Sayer & Han 1983; Htin Hla 2003; Bezuijen et al. 2010). Although the current population status of *G. bengalensis* in these states is not known, Htin Hla et al. (2011) estimated a minimum of 62 individuals during surveys in 2006 and 2007. They also estimated that the overall population of vultures in Myanmar was at least 136 individuals. Congruent with these observations, Tordoff et al. (2007) reported *G. bengalensis* with a daily maximum of 62, along with 12 *G. tenuirostris* in the Kamaing area, Kachin State.

Using open interviews questions, we also recorded information on the beliefs of some local villagers; the locals use body parts (especially bones) of vultures for belief-based use. Shwe & Aung (2016) found the vulture bone trade in southern Shan State as a significant challenge for vulture conservation. Similarly, feathers, bones, meat, beak, claws, faeces and internal organs of vultures have been used as traditional 'medicine' since

Image 1. Himalayan Vulture *Gyps himalayensis* and Slender-billed Vulture *G. tenuirostris*, roost on the Banyan tree nearby the carcass (27 November 2018).

Image 2. A flock of White-rumped Vulture *Gyps bengalensis*, on the Banyan Tree (*Ficus elastica*) near the carcass.

Image 3. Slender-billed Vulture *Gyps tenuirostris.*

Image 4. A juvenile White-rumped Vulture *Gyps bengalensis*, in flight around Man Sant Village, Mong Yai Township, Northern Shan State, Myanmar (27 November 2018).

ancient times in China (Leung 2006). Many Myanmar do not have a positive attitude towards vultures, but the local people informed us that they avoided consumption of vultures or their parts, because they are considered disgusting (in taste) and have a putrid odour. Additionally, as in Nepalese communities, many people assume that vultures are a bad omen and bring ruin or bad luck, because vultures are associated with death (Baral & Gautam 2007).

Threats to vulture populations in Myanmar are manifold; but the major threats are nest destruction (tree), poisoning (poison baits targeting other species such as mammals) and low food supply (Htin Hla et al. 2011). Contrasting with many sites in India, diclofenac has not been documented so far for Maing Yaw Village, Lashio, Naung Pho Mae Village, Shan State, Naung Kwin, Indawgyi Lake, or Kachin State (Htin Hla et al. 2011; Shwe & Aung 2016). Congruent with this observation, the township medical officer of the Livestock Breeding and Veterinary Department in Shan State informed us that the practice of using veterinary diclofenac is absent for cattle treatment in the township (Dr. Soe Naing Win, pers. comm. 2018), while diclofenac is used by many veterinarians widely in Myanmar (Bowden 2019). Although *G. bengalensis* and *G. tenuirostris* were distributed in most of the Indian subcontinent and southeastern Asia, its population declined rapidly in the 1990s and 2000s (Bildstein 2017). Bildstein (2017) indicated a decline of over 95% of the entire population in a rough estimation. Our recording of several juveniles suggests breeding may well occur in Myanmar although the dispersal range of vultures is huge.

We recommend further surveys of the vultures in the region, paying particular attention to locating any breeding attempts for all three species. Finally, food is likely the limiting factor for vulture populations in Myanmar (Bowden 2019), hence maintaining uncontaminated food resources to support the local population should be beneficial.

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Two new locations for the Vulnerable Black-necked Crane *Grus nigricollis* (Przhevalsky, 1876) (Aves: Gruiformes: Gruidae) in Arunachal Pradesh, India

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Black-necked Cranes *Grus nigricollis* are a globally Vulnerable species which breed across the Qinghai-Tibetan Plateau to the Ladakh region of northern India and winter south in Bhutan and parts of western Arunachal Pradesh, India (Birdlife International 2017). It is estimated that there are around 10,000 individuals globally with a decreasing trend in populations (Birdlife International 2017). In India, this large bird has been previously sighted on numerous occasions in the Ladakh region in the western Himalaya and from three main valleys in the eastern Himalaya—the Zemithang Valley, Sangti Valley, and the Chug Valley, Arunachal Pradesh (Mazumdar & Samal 2012; Chandan et al. 2014; Mize et al. 2018). Historically, the Black-necked Crane was sighted in the Apatani Valley, in the Subansiri region of central Arunachal Pradesh in 1979 (Chandan et al. 2014). It is thought that the population wintering in Subansiri was hunted out by the local communities. The species has also been reported from the high-altitude region of Sikkim, India, which is also part of the eastern Himalaya belt (Acharya & Vijayan 2010; Chandan et al. 2014) and from two sites in the Namdapha Tiger Reserve, the easternmost sightings for India (Srinivasan et al. 2010). Here we describe two new locations in Arunachal Pradesh for the Vulnerable Black-necked Crane: one being a potential wintering site and the other a stopover site on a possible flyway (Fig. 1).

Mechuka (1,829m; 28.58°N, 94.12°E) is located in the Shi Yomi District of Arunachal Pradesh and is nestled in between snow-capped mountains on three sides. Mechuka is about 28km (aerial distance) from the Chinese border and is located to the south of the Tibetan Plateau. The Yargyap Chu River flows through the town and there are large open spaces consisting of grassland, high altitude marshland and cultivated land which are well-suited for Black-necked Cranes. On 23 December 2017, an injured juvenile Black-necked

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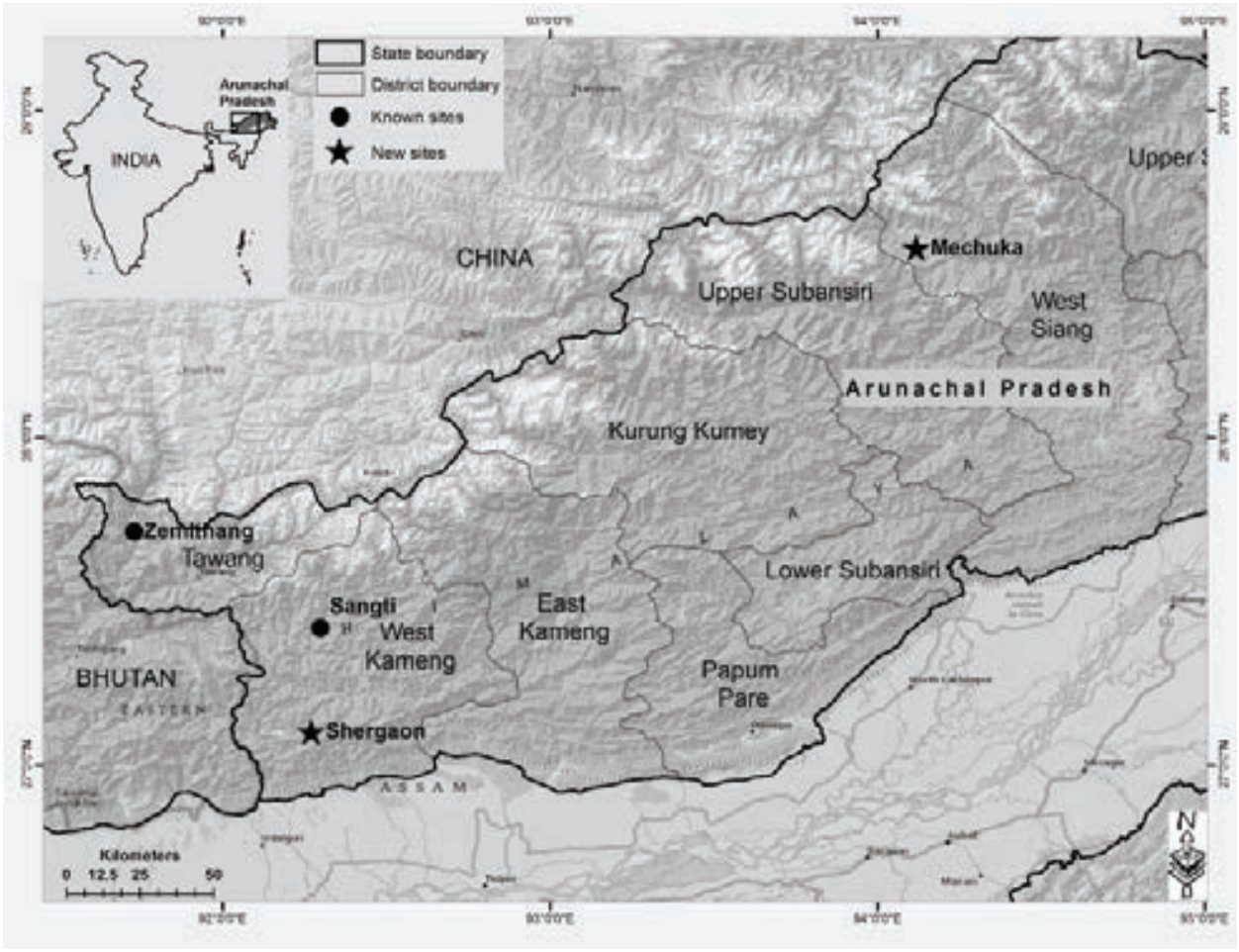

Figure 1. Key locations for Black-necked Cranes in Arunachal Pradesh, India. The black circles represent previous known records from the Zemithang and Sangti valleys. The black stars denote the new locations of Shergaon and Mechuka.

Crane landed on the property of a resident in Mechuka Town. The bird had suffered a bullet wound to its left leg as a result of a hunting attempt in or around the town. Presumably, the young bird's injury rendered it too weak since it needed to walk and feed (Image 1). The town lacks veterinary facilities, and although the family tried to keep the bird alive until help arrived from the closest city, it proved to be too late. The young crane succumbed to its injuries on the morning of 27 December 2017. Aware of the status of the Black-necked Crane, the forest department authorities in the district headquarters of Along, who were alerted by the locals of Mechuka, proceeded to conduct a reconnaissance survey of the Yargyap Chu River for the crane and other migratory birds. This survey resulted in locating nine potential stops for migratory birds along the river based on habitat suitability.

The town of Shergaon (2,000m; 27.10°N, 92.27°E) is situated in the West Kameng District of Arunachal Pradesh which shares a border with Bhutan. One of the two well-known stopovers in Arunachal Pradesh, the Sangti Valley, is also located in this region, about 30km (aerial distance) away from Shergaon. Similar to Mechuka, this high-altitude site possesses several rivers and streams along with open habitat mixed with farmland. The residents of Shergaon are fascinated with birds and have, unique to Arunachal Pradesh, imposed a ban on bird hunting for the past 20 years. Shergaon predominantly consists of Buddhist Sherdukpen tribe, who look forward to the landing of the Black-necked Cranes once a year; however, in the last five years, the birds have only landed twice (Garung Thuk, pers. comm.). The birds reportedly stay for about a week usually at the end of December or the beginning of January (Image 2). Although the birds don't visit every year, they are welcomed and upon arrival, the village council informs the residents of Shergaon not to harm the Black-necked Cranes and reminds them that they

Image 1. A juvenile Black-necked Crane with a bullet wound on its right leg in Mechuka.

Image 2. An adult Black-necked Crane in Shergaon, photographed by a local resident on his phone on 4 January 2017 at 16.00h.

will be punished if they do so. The cranes that stopover at Shergaon are usually lone birds or sometimes in pairs. It is possible that the Black-necked Cranes traveling south from China stopover at the Zemithang Valley, the Sangti Valley (only 30km away), and finally Shergaon before entering Bhutan. Due to the short duration of their stopover, it is less likely that the birds wintering in Bhutan from the Shenzha region in China (Liu et al. 2012) are spilling over to eastern Arunachal Pradesh.

While both Mechuka and Shergaon appear to have similar habitats, well-suited for the Black-necked Crane, there are differing threats that might affect this threatened species in each location. In Mechuka, there has been an increase in tourism and subsequent development to accommodate tourists. The government aims to develop Mechuka as a hub for adventure tourism, which comes with its own share of problems. Commercial aviation services will soon commence in Mechuka and this could potentially result in an increased disturbance to the birds. Black-necked Cranes are sensitive to habitat alterations and it can cause behavioural changes in the birds (De-Jun et al. 2011). Based on the incident from Mechuka described here, hunting is likely to be a significant threat to the wintering birds visiting here. Although, most of the local community members are Buddhists belonging to the Memba tribe who revere the Black-necked Crane, there are some residents from other tribes who still hunt the species. This cultural reverence of the Black-necked Crane also applies to the locals of Shergaon where the birds have the additional protection of the hunting ban. Although the brief stopover at Shergaon is made by only a few birds, the high levels of grazing and pesticide use could pose a major threat at a local scale (Birdlife International 2017). The proposed dams upstream of the rivers in both locations, however, could drastically alter the landscape downstream and hence influence the presence of the Black-necked Crane. The Monpa Tribe of Tawang District has long opposed the construction of dams on the Nyamjang Chhu River which would displace a 3-km stretch of the Black-necked Cranes wintering site (Lenin 2015). Due to the geographic position and the presence of suitable habitat in Arunachal Pradesh for the Black-necked Crane to winter, the state of Arunachal Pradesh can play a key role in the conservation of this species. Rigorous surveys and monitoring at both locations, along with educating the local communities about the importance of the species, would be extremely useful for the rare Black-necked Cranes in India and also to help understand the species from a global standpoint.

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Aquilaria malaccensis (Malvales: Thymelaeaceae): a new host plant record for *Deudorix epijarbas cinnabarus* (Lepidoptera: Lycaenidae) in Malaysia

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Aquilaria malaccensis Lam. (Thymelaeaceae), one of the most sought-after agarwood producing species, was recently lifted to Critically Endangered (Harvey-Brown 2018) from Vulnerable (Asian Regional Workshop 1998) under the global International Union for Conservation of Nature (IUCN) Red List. This catastrophe clearly indicates that this species is in dire need of urgent attention from plant conservationists, policy makers, and enforcers. This tree can be found as an under-story species in tropical forests. The species' natural range includes India, Myanmar, Sumatra, Peninsular Malaysia, Singapore, Borneo, and the Philippines (Tawan 2004). In 2017, close to 350,000kg of *A. malaccensis* derivatives and products were exported (and re-exported) from many countries including the non-range states (CITES Trade Database 2019). Essential oils derived from this tree species have been in high demand and are widely used in traditional medicines (Ding 1960; Nor Azah et al. 2008; Jayachandran et al. 2014), in the production of incense and perfumery in the Middle East (Barden et al. 2000; Chang et al. 2001). The lucrative international trade for many years had ultimately driven the genus into the list of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II in 2005. Species listed under Appendix II require an export permit and a re-export certificate before any international trade can take place. Consequently, a 'non-detriment findings' is needed to show that an export will not be detrimental to the survival of that species in the wild.

Phenological studies on wild *A. malaccensis* trees in Penang Island and Perak (Peninsular Malaysia) started since 2011 and collection of aborted flowers, fruit capsules and seeds were done using 10–20 square-framed nettings measuring 1m × 1m placed at four selected mature trees. Aborted fruits on the forest ground were randomly picked for inspection. Towards the end of the fruiting season on 23 May 2018 in Penang Island, several freshly aborted fruits were collected from the ground and upon dissection, one was seen infested with a living larva. The moth larva of *Pitama hermesalis* Walker was previously reported to infest *A. malaccensis* fruit (Ong & Lau 2016). Closer observation of the physical appearance of the larva, however, resulted in ambiguity of the identity and therefore, the larva was reared in a plastic container [outer dimensions; 13.4 (length) × 5.8 (width) × 22.0 (height) cm] in the laboratory at 26–28°C and 60–80% humidity.

The sluggish, late-instar larva (Image 1) pupated eight days later inside the fruit (Image 2) and pupation was completed in eight days. The adult was identified as

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Image 1. *Deudorix epijarbas cinnabarus* larva feeding inside the fruit of *A. malaccensis*.

Image 2. Pupal skin of *Deudorix epijarbas cinnabarus* inside the rotted fruit.

Image 3. Adult female of *Deudorix epijarbas cinnabarus* (wingspan = 2.7cm).

Image 4. The underside of *Deudorix epijarbas cinnabarus* female.

a female *Deudorix epijarbas cinnabarus* Fruhstorfer with a wingspan of 2.7cm (Image 3). This female specimen has a dull colour on the upper side – dark brown to black while the underside is grey brown with white markings. The black lobes and tails protruding from the hindwings are used to deceive predators as they resemble the head and antennae when its wings are folded (Image 4) (Kirton 2014). Subspecies *cinnabarus* occurs from Singapore to southern Thailand (Kirton 2014).

Deudorix epijarbas Moore is a seed and fruit feeder. In India, Thailand and China, it has attained pest status due to its damaging habits on fruit crops such as *Punica granatum* (pomegranate) (Dubey et al. 1993), *Litchi chinensis* (lychee) (Balakrishnan et al. 2019), *Dimocarpus longan* (longan) (DAFF 2004) and *Nephelium* sp. (rambutan) (CABI 2019). In Malaysia, the host plants of *D. epijarbas* were *Scorodocarpus borneensis* (garlic nut), *Aesculus indica* (Indian Horse Chestnut), *Panicum* sp. (panicgrass) and *Pinus kesiya* (Khasya Pine) in addition to pomegranate and rambutan (Robinson et al. 2010). Interestingly, the larva was feeding on the leaves of *P. kesiya* in the records by Robinson et al. (2010). This indicated that the larva could consume other parts of the plant when the seeds or fruits are depleted or unavailable, however, more information on the life history and host plants of this cryptic butterfly are needed. The *A. malaccensis* fruit had aborted prematurely as a result of *D. e. cinnabarus* attack; however, its presence is unlikely to have any significant impact on the reproduction of *A. malaccensis* trees.

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Rediscovery of Nilgiri Mallow *Abutilon neelgerrense* var. *fischeri* T.K. Paul & M.P. Nayar (Malvaceae) after a century from southern India

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The genus *Abutilon* Mill. is one of the larger genera of Malvaceae with about 120 species distributed in tropical and warm temperate regions (Mabberley 2017). It is represented by 12 species and 12 infraspecific taxa (Paul 1993) in India, whereas Sivarajan & Pradeep (1996) have reported seven species from southern peninsular India.

As a part of the revisionary study of the genus *Abutilon* in India specimens of *A. neelgerrense* were collected from Suruli Falls, Theni District, Tamil Nadu, with flowers and fruits. The specimens with flowers were collected in the month of March and with fruit in the month of May. After scrutiny of relevant literature and study of the specimens, it was identified as *A. neelgerrense* var. *fischeri* T.K. Paul & M.P. Nayar and confirmed by consulting protologue and Type.

Paul & Nayar (1985) described the variety based on a specimen collected by C.E.C. Fischer on January 1910 (Fischer 1581, CAL), from Coonoor River bank, Nilgiri District, Tamil Nadu. Now this variety was collected from the Meghamalai Mountain range, near Suruli Falls, Theni District, Tamil Nadu (population of 30–40 mature individuals) after 109 years and is the first re-collection after type.

Comparative morphology with its allied variety *A. neelgerrense* var. *neelgerrense* is presented in Image 1.

Abutilon neelgerrense var. ***fischeri*** T.K. Paul & M.P. Nayar

in Bull. Bot. Surv. India 25: 183. 1985 & Fasc. Fl. India 19: 90. 1988. Type: India, Tamil Nadu: Nilgiri District (then part of Coimbatore District), Coonoor River bank 1,200 ft, 10 January 1910, C.E.C. Fischer 1581 (Holotype: CAL!, Isotype: FRC!).

Shrub, ca. 1m high; stem and branches densely stellate pubescent mixed with short simple hairs. Petiole 8–10 cm long, stellate pubescent; stipules 6–15 mm long, linear, pubescent; lamina 8–10 × 4–5 cm, ovate, cordate at base, acute to acuminate at apex, crenate or dentate at margin, rarely obscurely entire, 7–8-nerved, pubescent on both surfaces, more so beneath. Flowers 2–5 in axillary cymes, rarely solitary; peduncles 8–12 cm long; pedicels 1–1.5 cm long, articulated near the apex. Calyx 6–8 mm across, campanulate, 5-lobed, divided to below the middle; lobes 5–10 × 4–7 mm,

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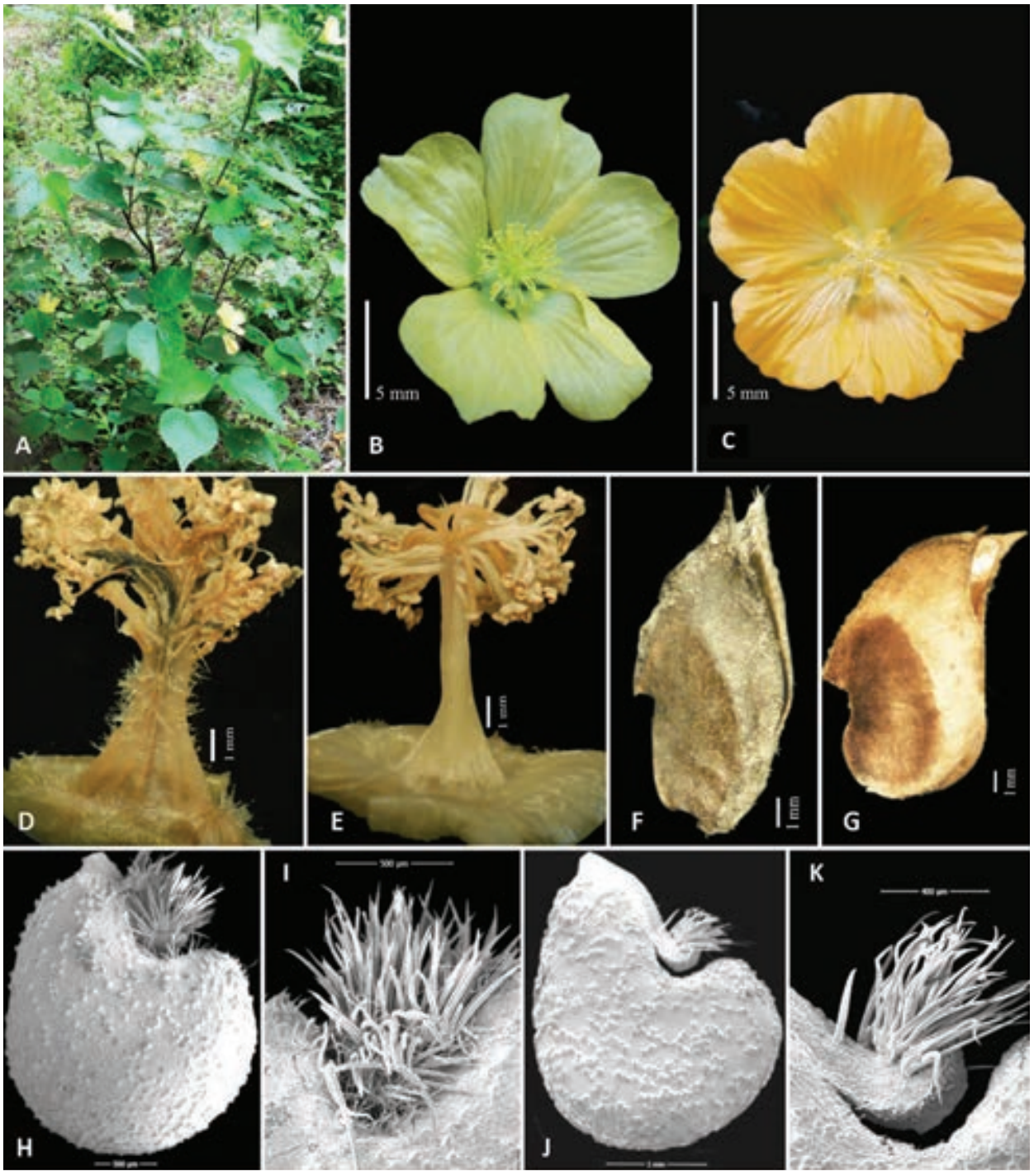

Image 1. Comparative photographs of varieties of *Abutilon neelgerrense*. var. *fischeri* T.K. Paul & M.P. Nayar: A—Habit | B—Flower | D—Staminal tube | F—Mericarp | H—SEM photograph of seed | I—SEM photograph of seed showing hairs on hilar region. var. *neelgerrense*: C—Flower | E—Staminal tube | G—mericarp | J—SEM photograph of seed | K—SEM photograph of seed showing hairs on hilar region.

ovate-lanceolate, acute to acuminate, 3-nerved with prominent midvein, pubescent on both surfaces. Corolla ca. 1.5cm across, pale yellow; petals 5, 12–15 × 6–10 mm, obovate, truncate at apex, sometimes pointed and slightly reflexed, glabrous, ciliate on margins at the base. Staminal column 5–6 mm long, densely pubescent, antheriferous at apex, free filaments, 2–3 mm long, yellow, glabrous. Ovary ca. 3.5 × 3 mm, ovoid, densely pubescent, 8–10-loculed, 2–3-ovules in each locule; style 8–10-branched, branches 7–8 mm long; stigmas

Key to the varieties

1a. Corolla dark yellow; staminal tube 7–8 mm long, glabrous, filaments forming clusters; mericarp curved at apex ..... var. *neelgerrense*

1b. Corolla pale yellow; staminal tube up to 5mm long, stellate hairy, filaments free; mericarp not curved at apex ..... var. *fischeri*

capitate. Schizocarps ca 1.5cm in diameter, subcylindric, erect at apex; mericarps 8–10, ca. 15 × 5 mm, laterally compressed-reniform with ca. 3mm mucro, ventral side of base compressed forming notch, densely pubescent with simple and stellate hairs. Seeds 2–3 in each mericarp, reniform, hilum pubescent.

Flowering: November–March; fruiting: January–May.

Distribution: India (Tamil Nadu: Nilgiri and Theni districts), endemic.

Habitat: It occurs from 300–1500 m altitude in moist semi-shady situations along forested hill slopes.

Specimen examined: MMS1643 (BSI, CAL, MH, SPPU), 19.v.2018, 9.659^{0}N, 77.305^{0}E, 400m, Suruli Falls, Tamil Nadu, India, coll. Arun Prasanth R.

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