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continued on the back inside cover

Cover: Whale Shark *Rhincodon typus* and Reef - made with poster colours. © P. Kritika.

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COMMUNICATION

Asiatic Black Bear *Ursus thibetanus* attacks in Kashmir Valley, India

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Abstract: Asiatic Black Bear attacks are reported rarely throughout the majority of their global range; however, this has not been the case in the Kashmir Valley where over the past 20–30 years attacks have been relatively common. There are several causes for the high number of attacks, though the foremost reason likely stems from the conversion of natural habitat to orchards and agricultural fields. Asiatic Black Bears actively crop raid orchards and agricultural areas putting them into close proximity to humans. The Jammu & Kashmir Wildlife Protection Department has collected data on 2,357 Asiatic Black Bear attacks in the Kashmir Valley between 2000 and 2020. A total of 2,243 (95.2%) resulted in injury and 114 (4.8%) resulted in death. The majority of injuries were reported as minor (57.4%, n=1126), 42.4% (n=832) as grievous, and 1.2% (n=21) caused permanent disability. The highest proportion of attacks occurred from July through November, coinciding with the harvesting season, and the least occurred from December through March, coinciding with when most Asiatic Black Bears are hibernating. Victims of bear attacks were most often working in farms or orchards, and were mostly between the ages of 31–40 years old. Most attacks occurred in the morning hours when people first entered the orchards or agricultural fields to work. The frequency of attacks has declined since 2016, which could be attributed to retaliation killings, better management by the wildlife department, and the engagement of NGO's with local people to create bear awareness and teach safety measures.

Keywords: Bear attacks, bear awareness, crop-raiding, hibernation, Jammu & Kashmir, retaliation-killing, victims, wildlife-conflict, Wildlife Protection Department.

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Author contributions: Aaliya Mir—1) project leader, 2) project coordination, 3) writing and analysis. Shanmugavelu Swaminathan—1) writing and analysis. 2) insights to bear activity Raashid Y. Naqash—1) data collection, 2) analysis and insights, Thomas Robert Sharp—1) writing and analysis, 2) background research on Asiatic Black Bear attacks 3) arrangement of manuscript to JoTT. Attur Shanmugam Arun—1) writing and analysis.

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INTRODUCTION

Asiatic Black Bears *Ursus thibetanus* though generally cryptic and shy, are involved in crop raiding and to a lesser extent attacks on humans (Chauhan 2003; Ali et al. 2018; Jamtsho & Wangchuck 2018; Image 1). Attacks are rare throughout much of their global range which encompasses 18 different countries (Garshelis & Steinmetz 2020), however, this is not the case in India's Kashmir Valley where they are relatively common (Chauhan 2003; Choudhury et al. 2008; Tak et al. 2009; Rasool et al. 2010). Bear attacks in the Kashmir Valley have increased in the last 20–30 years, possibly due to (1) expansion of agricultural practices such as fruit and nut orchards (that are particularly attractive to bears), (2) the lack of fire-arms among farmers, (3) the India-Pakistan border fencing blocking predator movement, continued human encroachment into wild habitat, and (4) a new generation of people not familiar with coexisting with large predators (Choudhury et al. 2008). Installations by security forces may also fragment the habitat and divert the bears into human dominated areas causing human-bear conflicts.

The Asiatic Black Bear is listed as 'Vulnerable' on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species due to habitat loss and the commercial trade for live bears and bear parts (Garshelis & Steinmetz 2020). They are also listed as an Appendix I species under CITES and a Schedule I species in India under the Wildlife Protection Act, 1972. There are few published accounts, or long-term data collections, of Asiatic Black Bear attacks. The majority of scientific literature on the topic are from locations with a relatively healthy number of black bears, namely India, Bhutan, and Japan. Often these accounts are listed alongside crop raiding and livestock depredation (Chauhan 2003; Charoo et al. 2011; Sanwal & Lone 2012; Ali et al. 2018; Zahoor et al. 2020). There is still a great deal that is not understood about Asiatic Black Bear attacks. However, most reported attacks are due to surprise encounters that occur in either the woods or in agricultural areas (Tak et al. 2009; Rasool et al. 2010; Akiyama et al. 2017; Penjor & Dorji 2020). As would be expected, the vast majority of attacks appear to be defensive, however, there have been a few accounts that appear to be more predatory (Yamazaki 2017).

Over the past 20 years, the Kashmir Valley has become a hotspot of Human-Asiatic Black Bear conflicts. This paper chronicles the number of Asiatic Black Bear attacks that occurred in the Kashmir Valley between the years of 2000 and 2020. It also looks at the trends and attempts to discern the causes.

Image 1. Wild Asiatic Black Bear *Ursus thibetanus* in the Kashmir Valley © Mradul Pathak.

Study Area

The Kashmir Valley is roughly 15,500 km^2 in size (about 140 km by 32 km) and is located between 32° & 34°N and 74° & 75°E (Figure 1). The average elevation is roughly 1,850 m. The valley is partially surrounded to the north by the Himalayan and Pir Panjal ranges, which have an average elevation of roughly 3,050 m. The climate is mild with precipitation occurring throughout the year, though spring is the wettest season. Summer is usually mild and fairly dry, but the relative humidity is generally high and the nights are cool. July is the warmest month with temperatures averaging around 24.4°C, and January is the coldest with average temperatures around 2.7°C. The biggest river in the valley is the Jhelum. Oak-Rhododendron forests (Image 2), cover the valleys and Blue Pine *Pinus excelsa* covers the slopes.

METHODS

Asiatic Black Bear attack data was collected by the Jammu & Kashmir Wildlife Protection Department, Kashmir Region, which was established in 1978 and is equivalent to the wildlife wing of the state forest departments in other states. There are five divisions, namely the Central, South, North, Wetland and Shopian, which maintain data on human-bear conflicts for the purpose of paying compensation for bear attacks. These efforts were intensified and payment augmented after

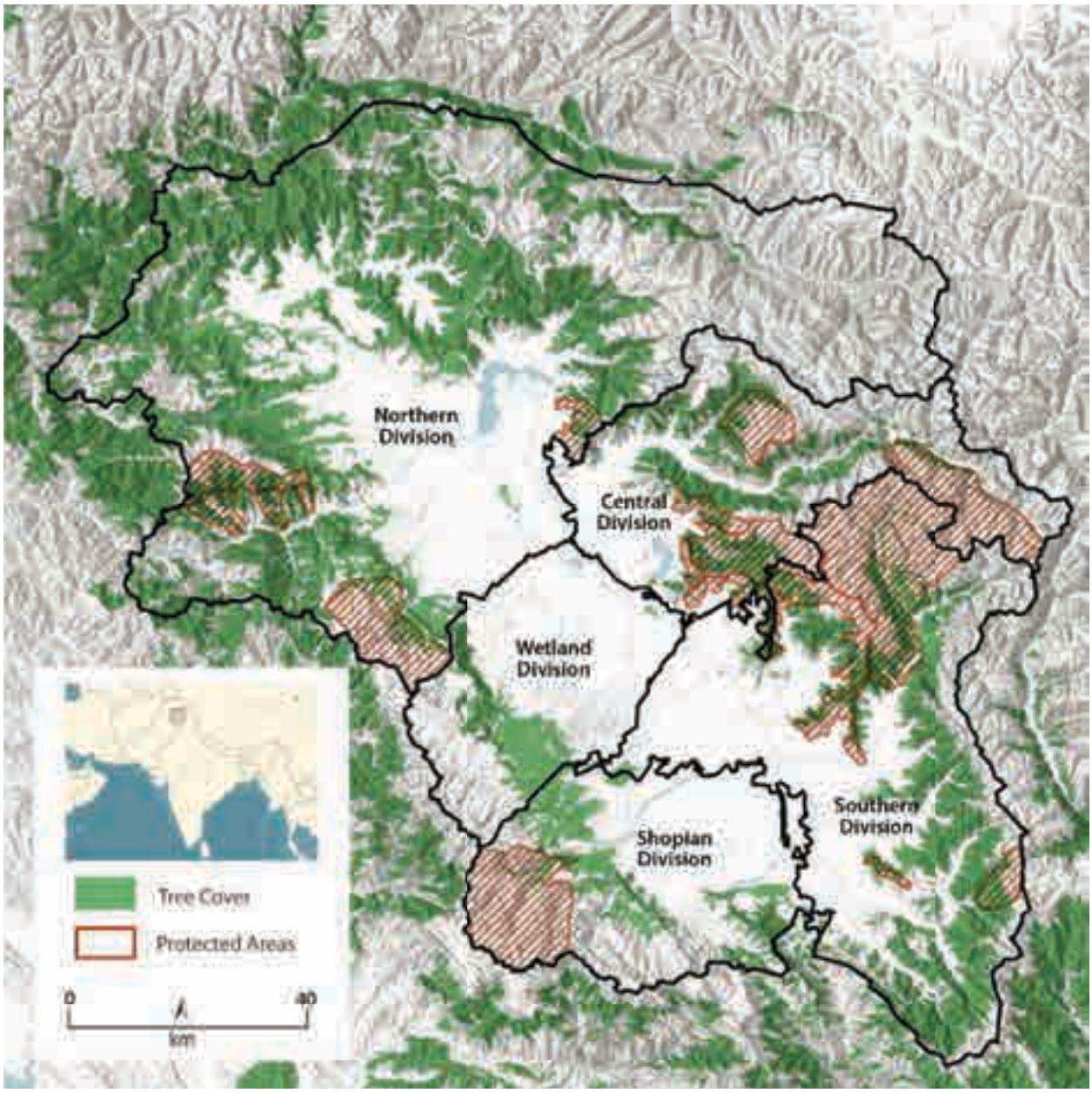

Figure 1. Wildlife divisions in the Kashmir region responsible for handling human-wildlife conflicts including Asiatic Black Bear attacks.

2013. We used this data to assess bear attack patterns over time. Ex gratia rates prior to and after 2014 are given in Table 1. The processing of a case starts with the filing of a police and medical report which is produced to the block level officer of the wildlife department who subsequently forwards it to the higher offices which includes the range officer, wildlife warden, regional wildlife warden, and finally to the chief wildlife warden. The ex gratia application goes through a lot of scrutiny during processing.

RESULTS

Attacks and Deaths by Year

A total of 2,357 bear attacks were reported in the Kashmir Valley between 2000 and 2020, of which 2,243 (95.2%) resulted in injury and 114 (4.8%) in death (Table 2). The Wildlife Protection Department did not have the resources prior to 2006 to collect detailed bear attack data, and therefore bear attacks prior to 2006 are likely underrepresented in the data set. The maximum number of reported attacks in a single year was 282 in 2010 and included 10 deaths. The number of reported

Table 1. Ex gratia paid (in INR) to victims of Asiatic Black Bear attacks prior and post 2014.

Years	Minor injuries	Grievous injuries	Permanent incapacitation	Death
Prior to 2014	5000	Up to 33,000	50,000	100,000
2014-2020	15000	Up to 100,000	Up to 300,000	300,000
* Department of Forest, Ecology and Environment 2014				

Table 2. Asiatic Black Bear attacks resulting in injury or death between 2006 and 2020 in Kashmir Valley, India.

Year	Number of recorded attacks	% of recorded attacks from the total number of attacks recorded from 2006–2020	Number of recorded deaths	% of recorded attacks that resulted in death the same year
2006	87	3.7	7	8.0
2007	93	4.0	8	8.6
2008	155	6.6	7	4.5
2009	182	7.8	8	4.4
2010	282	12.1	10	3.5
2011	275	11.8	13	4.7
2012	226	9.7	7	3.1
2013	256	10.9	12	4.7
2014	185	7.9	5	2.7
2015	205	8.8.	5	2.4
2016	135	5.8	6	4.4
2017	71	3.0	5	7.0
2018	63	2.7	5	7.9
2019	66	2.8	7	10.6
2020	49	2.1	4	8.2

attacks and deaths started diminishing in 2016, and by 2020 the number of attacks was down to 49 with four deaths (Figure 2).

Differences Between Districts

The majority of attacks occurred in the South and North divisions. These two divisions are the largest and have the most forest coverage. Additionally, these divisions are undergoing rapid deforestation and urbanization. The Wetland and Shopian divisions used to be part of the North and South divisions, respectively. The Wetland Division does not consist of much prime bear habitat and this results in fewer attacks. The Central Division, which includes Dachigam National Park, has excellent bear habitat. However, the wildlife department in this division is well funded and equipped to deal with human-wildlife interactions and therefore are able to keep bear attacks in check despite the large bear population.

Injuries

The exact type of injuries sustained by the victims were not readily available, however, we were able to classify the injuries in three categories based on reports and the amount of ex gratia paid. The three categories are minor, grievous, and permanent disability. Injuries were considered minor if the victim was treated at a local hospital and did not need to stay in the hospital for more than a day for the treatment (Image 3). Injuries were considered grievous if the victim needed to be referred for special treatment, usually to a specialty hospital, where they can undergo specialized procedures and stay for an extended period (Image 4). Finally, permanent disability when the victims were permanently incapacitated. Overall, the majority of injuries were reported as minor (57.4%, n=1126), 42.4% (n=832) as Grievous, and 1.2% (n=21) resulted in permanent disability.

Attacks by Month

A total of 1,449 attacks were documented by month (Figure 3). August (n=309, 21.3% of the total attacks)

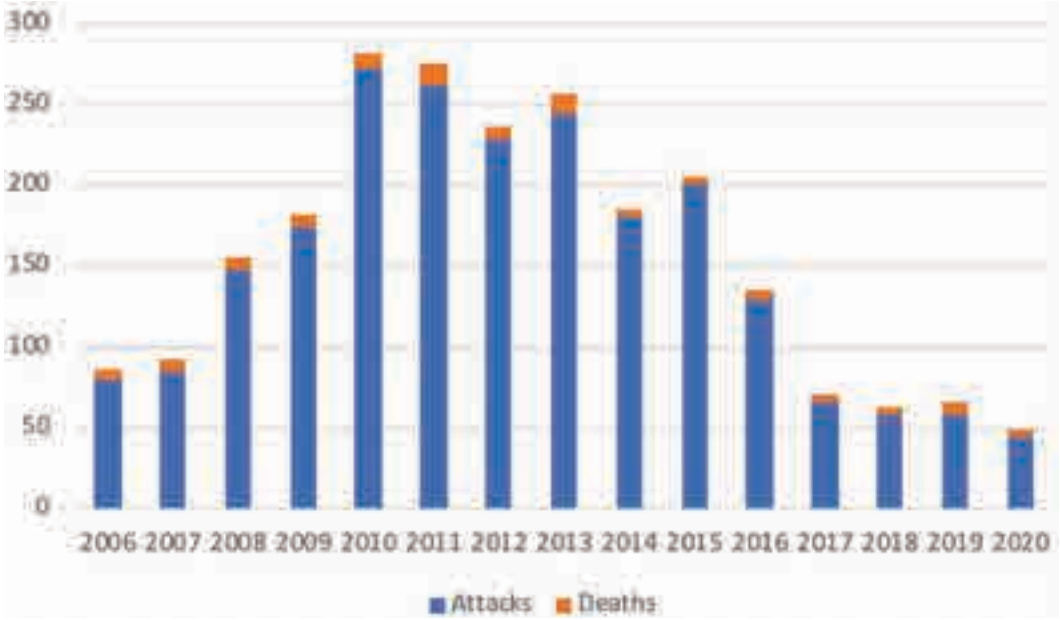

Figure 2. Asiatic Black Bear attacks resulting in injury or death between 2006 and 2020 in and around the Kashmir Valley, India.

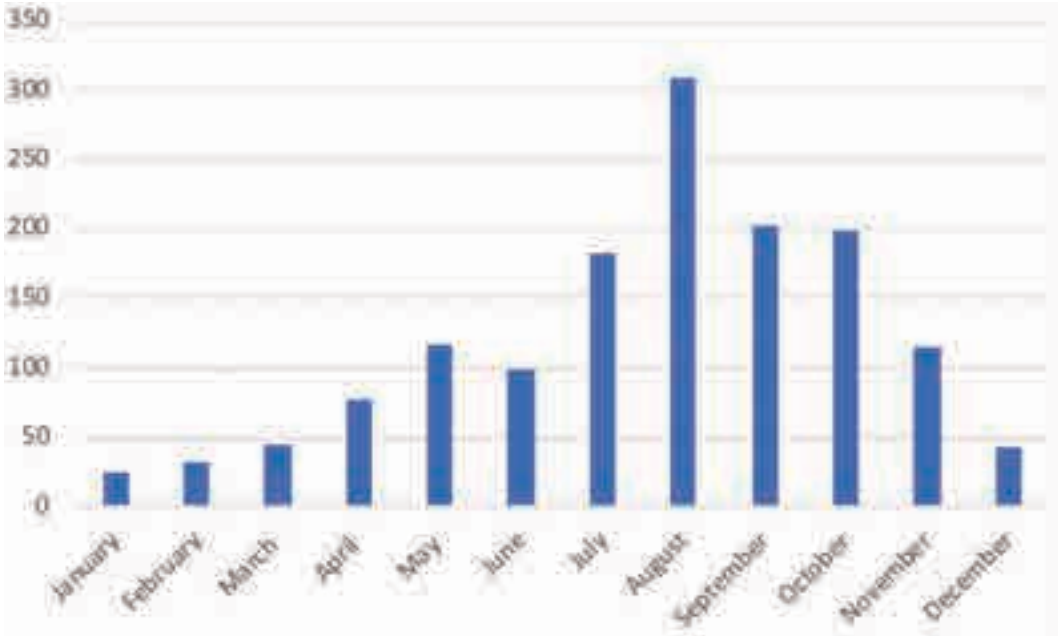

Figure 3. Asiatic Black Bear attacks by month from 2000-2020 in Kashmir, India.

had the most attacks, followed by September (n=203, 14%), October (n=198, 13.7%), and July (n=182, 12.6%). The least number of attacks took place in the month of January (n=26, 1.8%), February (n=32, 2.2%), December (n=44, 3.0%), and March (n=45, 3.1%).

Attacks by Time of Day

A total of 410 attacks were documented by the time of day in which they occurred (Figure 4). The highest number of attacks occurred between the hours of 0901–1000 h (n=75, 18%), and 218 attacks (53%) took place between 0801–1200 h.

Age of People Attacked

A total of 482 attacks were documented by the age of the victims (Figure 5); 226 of the victims (47%) were

Image 2. Asiatic Black Bear habitat in Kashmir Valley © Mradul Pathak

Image 3. Minor injury due to Asiatic Black Bear. © Wildlife SOS

Image 4. Grievous injury due to Asiatic Black Bear. © Wildlife SOS

between 31 and 50 years of age.

Activity of People Attacked

The activity of 277 people attacked in the Shopian Division between 2010 and 2019 was documented. People working in, or walking to, fields or orchards made up 176 (63.5%) of the attacks. The second largest group of people attacked were made up of shepherds & herders, and accounted for 33 (11.9%) attacks. People walking to areas not necessarily related to fields or orchards (n=23, 8.3%) and people near & around their homes (n=22, 7.9%) also made up relatively high percentages, though

Table 3. Asiatic Black Bear attacks by month from 2000–2020 in Kashmir, India.

January	February	March	April	May	June	July	August	September	October	November	December
26 (1.8%)	32 (2.2%)	45 (3.1%)	78 (5.4%)	118 (8.1%)	99 (6.8%)	182 (12.6%)	309 (21.3%)	203 (14.0%)	198 (13.7%)	115 (7.9%)	44 (3.0%)

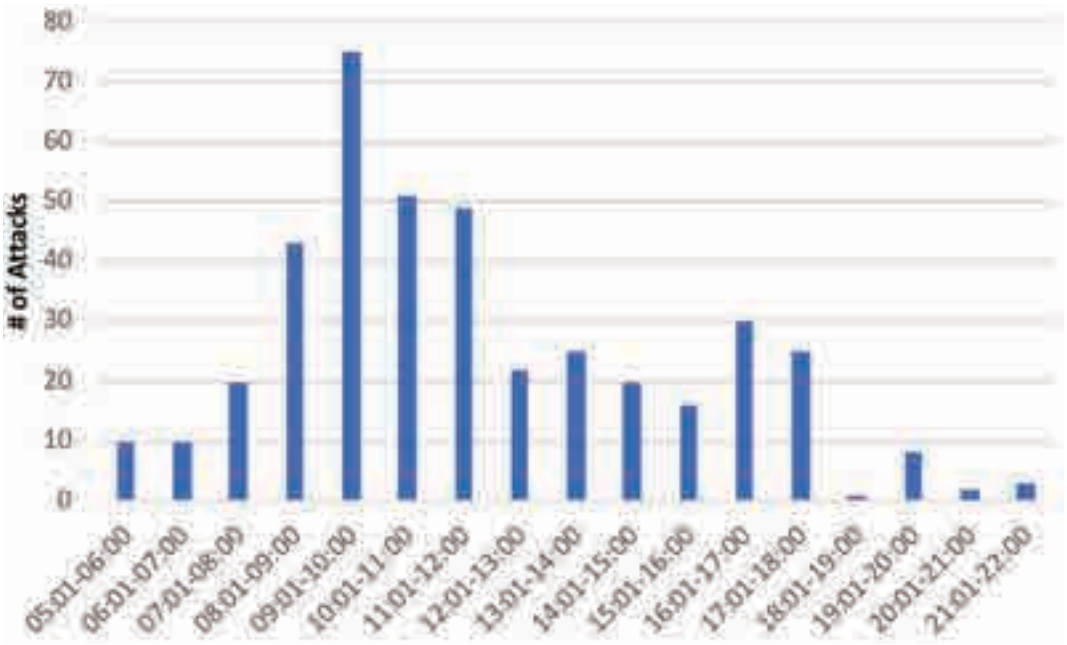

Figure 4. Asiatic Black Bear attacks by time of day from 2000–2020 in Kashmir, India.

many of these people were working in their vegetable gardens. Other activities made up the remainder of the attacks (n=23, 8.3%).

DISCUSSION

General Patterns in Kashmir Valley

There is no data to suggest that the Asiatic Black Bear subspecies, *U. t. laniger* that occurs in northern India, is any more aggressive than other subspecies (Matt Hunt, co-chair IUCN Asiatic Black Bear Expert Team, pers. comm. August 8 2021). It is therefore more likely that the increased number of attacks are related to: 1) bears being in close proximity to humans, 2) a relatively high density of bears in the area, and finally, 3) how humans react to the presence of bears. Along these lines, it is important to note that in orchards, the bears not only eat the fruit and nuts but also potentially do extensive damage to the trees, such as breaking off productive branches. Because of this the bears are often actively chased and shooed away from the orchards. This aggressive interactions between humans and bears could be a contributing factor for the high rate of attacks in the region.

Reasons for the Decreases in Bear Attacks

The decrease in bear attacks since 2016 is likely due to 3 main reasons: 1) a number of bears have been killed in retaliation, 2) proactive work by the wildlife department, and 3) bear awareness programmes conducted by non-governmental organisations (NGOs). The total number of bears killed remains unknown, however, some of these killings have been documented, including incidents when bears have been tied and the tree set on fire. Other bear killings go unnoticed, such as, when bears are secretly poisoned or shot. To date there have been no prosecutions for killing bears.

The wildlife department was able to be much more proactive starting in 2016. The political scenario in Kashmir has been very fragile in recent times, particularly from 2010–2016. Once the wildlife department was up and running, it was still poorly equipped and dealing with frequent closures in the valley. Even communication was hampered as mobile phone connectivity was not steady. These issues paralyzed normal life and resulted in fewer

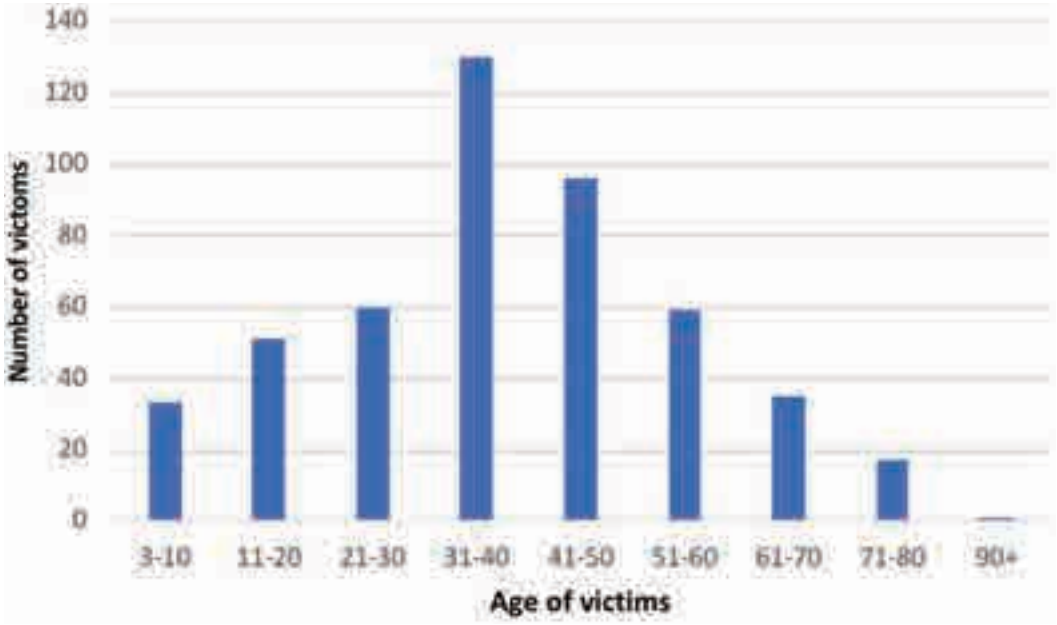

Figure 5. Asiatic Black Bear attacks by age of the victim from 2000–2020 in Kashmir, India.

reports of wildlife-human conflicts. Because of this, people often took affairs into their own hands. Since 2016, the wildlife department has had greater man power & the necessary equipment including cages, tranquilizing guns, and vehicles as well as mobile connectivity, to deal with wildlife issues. Presently 42 control rooms work 24 hours a day, seven days a week, to attend to the wildlife distress calls. The number of rescue calls to the wildlife department as well as to other NGOs, including Wildlife SOS, has increased, which has led to a more professional handling of human-wildlife conflicts and has reduced the number of bear encounters and injuries to people.

Bear awareness & safety programs are also believed to have played an important role in reducing human-bear conflicts by educating people. These programs are largely being coordinated by NGOs in the region and stress awareness, especially when entering or conducting activities around orchards.

Asiatic Black Bear Attack Overview

The causes and mitigation strategies for Asiatic Black Bear attacks are not well understood, especially in comparison to attacks by other bear species, namely, Grizzly Bears *Ursus arctos*, American Black Bears *Ursus americanus*, Sloth Bears *Melursus ursinus*, and even Polar Bears *Ursus maritimus*. This may be partly due to Asiatic Black Bear attacks being relatively rare. Existing studies tend to agree that the vast majority of Asiatic Black Bear attacks are defensive, most often occurring due to a surprise encounter (Thakur et al. 2007; Tak et al. 2009; Rasool et al. 2010; Akiyama et al. 2017). This certainly appears to be the case in Kashmir, India, however, predatory attacks on humans by Asiatic Black Bears have been reported in Japan (Yamazaki 2017; Oshima et al. 2018). This is perhaps not surprising as Asiatic Black Bears are omnivorous and have been reported throughout parts of their range to actively hunt, kill, and eat primates, ungulates, and wild boar (Neas & Hoffman 1987; Hwang 2003; Gursky-Doyen & Nekaris 2007). Predatory attacks on humans appear to be exceptionally rare.

Behavioral approaches to safety in Asiatic Black Bear country should primarily focus on avoiding bear encounters and secondarily surviving defensive attacks with the fewest number of injuries. Making noise while moving into an area that bears may occur, giving the bear a chance to leave the area before the human and bear find themselves at close quarters, is a proven method to avoid attacks by Grizzly & Sloth Bears (Ordiz et al. 2013; Ratnayeke 2014; Sahlén et al. 2015; Sharp et al. 2020). This method would likely be effective in avoiding surprise encounters with Asiatic Black Bears as well.

There are advisories on what to do in case of a defensive attack by a bear. Herrero (2002) advocated falling to the ground and balling up while covering the head and face with your arms for surviving a defensive grizzly bear attack. Asiatic Black Bears, like Grizzly & Sloth Bears, focus on the head and face during an attack (Thakur et al 2007; Rasool et al. 2010). Falling to the ground and covering up allows attack victims to protect

themselves from injury while allowing the Asiatic Black Bear to run off which they almost always do after overpowering a person.

CONCLUSION

The number of Asiatic Black Bear attacks in Kashmir have decreased notably since 2016, probably due to bears being removed from the area as well as government and non-government agencies working to lessen the number of negative encounters. The number of annual attacks should be monitored and tracked to detect future changes. Further studies are required to more fully and accurately understand the best methods to avoid and survive Asiatic Black Bear attacks. It is likely that certain behavioral strategies that work for avoiding or minimizing attacks from other bear species, namely Brown Bears & American Black Bears, will also work for the Asiatic Black Bear. However, this cannot be known with certainty without further research.

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COMMUNICATION

Food habits of the Red Fox *Vulpes vulpes* (Mammalia: Carnivora: Canidae) in Dachigam National Park of the Kashmir Himalaya, India

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Abstract: Food habits of the Red Fox *Vulpes vulpes* were studied in Dachigam National Park of the Kashmir Himalaya from December 2017 to November 2018 by scat analysis. A total of 246 scats were collected across seasons from different habitat types of the park. The diet of the Red Fox was characterized by a wider prey spectrum with small rodents, plants, and Himalayan Grey Langur *Semnopithecus ajax* as the major food items. The dietary behaviour showed slight seasonal variation with more invertebrates and plant material (fruits, berries, & grasses) during spring and summer. The food niche of the canid was wider in the warm season than in the cold season. Diet analysis revealed substantial use of anthropogenic food sources (human refuse and livestock carrion) by the Red Fox. The frequency of occurrence of human refuse and livestock carrion in the scats of the canid species varied seasonally. The results show that the Red Fox is an opportunistic feeder, and capable of adapting to a variety of dietary items.

Keywords: Anthropogenic items, dietary behaviour, livestock carrion, scats, seasonal diet, wild prey.

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Author details: Kulsum Ahmad Bhat, Aamir Majeed, Naziya Khurshid and Muniza Manzoor are pursuing PhD in Zoology at the University of Kashmir. Dr. Bilal Ahmad Bhat is currently working as Assistant Professor in the Department of Zoology, University of Kashmir Srinagar, UT of Jammu & Kashmir, India and is actively involved in guiding PhD research scholars and teaching conservation biology, wildlife ecology and management. He is presently running two major research projects on Himalayan Goral and Markhor *Capra falconeri* as Principal Investigator with funding from DST-SERB and Ministry of Education under RUSA. Bashir A. Ganai is a Professor in the Centre of Research for Development (CORD) at the University of Kashmir and is actively engaged in guiding research scholars working in the fields of molecular biology, phytochemistry and biochemistry.

Author contributions: Kulsum Ahmad Bhat, Aamir Majeed, Naziya Khurshid and Muniza Manzoor conducted field surveys and collected scat samples from hilly terrain of Dachigam National Park. Bilal A. Bhat and Bashir A. Ganai are mentors and helped the first author in analysis and writing of the manuscript.

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INTRODUCTION

The Red Fox is cosmopolitan in distribution (Hegglin et al. 2001; Mcdonald & Reynolds 2008) with opportunistic feeding behaviour (Vlachos et al. 2010; Lanszki et al. 2018; Alexandre et al. 2020; Jahren et al. 2020). The species is the most widespread wild canid in India and is distributed across the Himalayan and Trans-Himalayan ranges in the north and the desert region in the north-west (Ghoshal et al. 2015; Reshamwala et al. 2018). The species has managed to survive over almost all of its former range irrespective of habitat destruction and anthropogenic pressure (Jahren et al. 2020). The enormous range of the Red Fox is evidence of its adaptability and opportunistic behavior (Delibes-Mateos et al. 2008). The diet of Red Fox is highly diverse, both in space and time, which allows the species to survive in diverse habitats (Cavallini & Volpi 1995; Cagnacci et al. 2003).

The elusive and nocturnal habits of the animal make direct observations difficult in the field. Therefore, the use of scats is common and extensive method to investigate its food habits (Descalzo et al. 2020). This investigation is based upon examining a collection of scat samples for a thorough dietary analysis of the canid species in the Dachigam National Park (DNP) of Kashmir Himalaya. Being a key meso-carnivore in most parts of the world with its known ecological role (Sánchez 2018), it may be of crucial importance to the ecology of Kashmir Himalaya as well. Meso-carnivores like Red Fox occupy a central position in the food web and any change in their ecology may affect higher and lower trophic levels (Sánchez 2018). A thorough investigation of its seasonal food habits is, therefore, necessary for understanding the pattern of distribution of this canid species in and around DNP. The available information on the diet and prey preferences of Red Foxes in the northwestern Himalayan region is scanty (Reshamwala et al. 2018). With this background, the present study was undertaken in the DNP to augment the existing literature in this region. The study will help further in understanding the role of human subsidies in driving this canid species outside the National Park.

MATERIALS AND METHODS

Study area

The intensive study area, Dachigam National Park (DNP), a key protected area of Kashmir Himalaya lies in the northwestern Himalayan landscape (Image 1). The mountain ranges surrounding Dachigam are a part of the great Zanskar Range, which forms the north-west branch of the central Himalayan axis. The geographical location is roughly between 34.083–34.183 ^{0}N and 74.883–75.150 ^{0}E (Rodgers et al. 2000). The landscape is dominated by high mountains, rugged cliffs, and high-altitude pastures with an elevation of 1,676–4,267 m. The climate of the area is sub-Mediterranean to temperate with varying degrees of precipitation and dryness. The maximum average temperature recorded in summer is 27ºC and in winter a minimum of 2ºC. The annual average rainfall recorded is about 660 mm with snow as the main source of precipitation. The vegetation structure of Dachigam is typically Himalayan moist temperate with sub-alpine and alpine forest types (Champion & Seth 1968). The faunal elements of the national park include Hangul Deer *Cervus hanglu hanglu*, Himalayan Grey Langur *Semnopithecus ajax*, Golden Jackal *Canis aureus*, Common Leopard *Panthera pardus*, & Asiatic Black Bear *Ursus thibetanus* are major mammals whereas Black Bulbul *Hypsipetes leucocephalus*, Yellow-billed Magpie *Urocissa flavirostris,* & Blue Whistling Thrush *Myophonus caeruleus* are the birds usually found in DNP.

Collection of samples

A total of 246 scats of Red Fox were collected along systematic transects and opportunistically whenever found in and around the fringe areas of the study site and analysed. The scat samples were collected monthly from December 2017 to November 2018 along 12 transects, covering different habitat types and altitudinal zones. The total transect effort was 319 km for all seasons (Figure 1). The scats of Red Fox were identified on the basis of certain features such as shape, size, odour, and quantity typical to that of the relative species, following a standard protocol (Vanak & Mukherjee 2008). The sites were also searched for fox dens, rock crevices, and burrows in order to increase scat samples. The location, date, associated marking signs, and GPS location were recorded for each scat using a handheld global positioning system. The scats were collected in paper bags with a unique identification number, transported to the laboratory for further analysis and stored at -20ºC until processing (Ciucci et al. 1996).

Laboratory analysis

The scats were decontaminated in an oven at 80ºC to eradicate any parasitic infection frequently found in canid scats (Eddine et al. 2017) and then rinsed with tap water through a sieve of BSS 120 having a pore size of 125 µm so that the digested material could

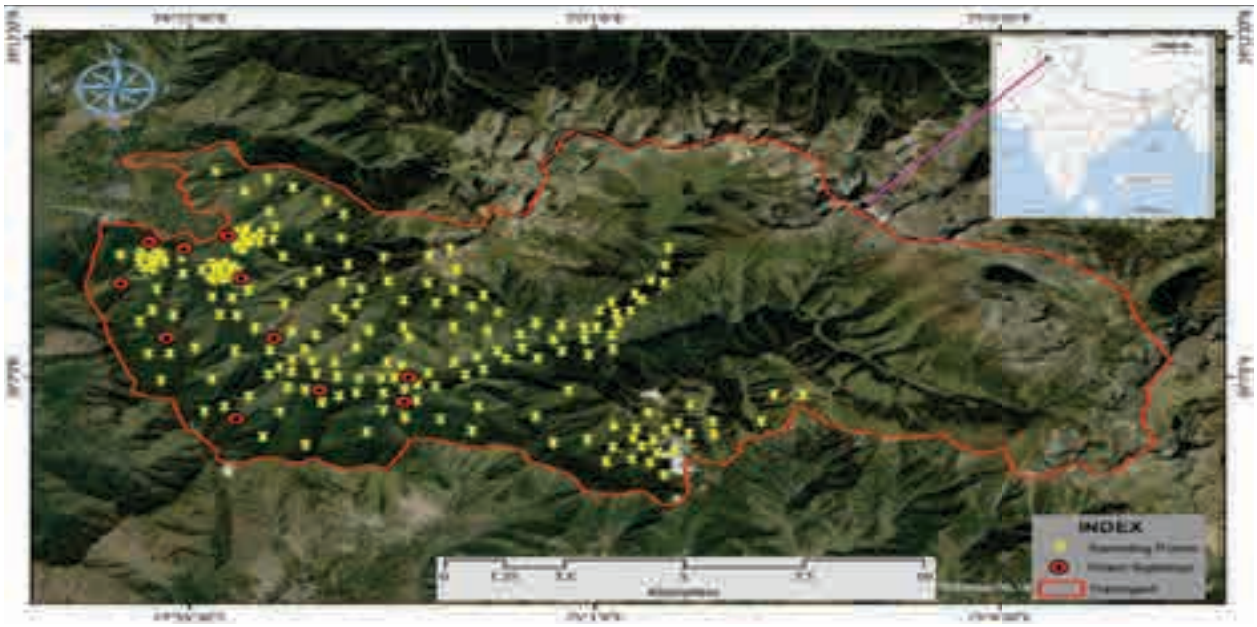

Image 1. Locations of scat samples and direct sightings of Red Fox in Dachigam National Park.

pass through the sieve. The remains were separated macroscopically for identification of prey items such as the claws, teeth, bones, seeds, insects, hairs, feathers, grasses & other plant materials, and human subsidies like pieces of cloth, paper, and plastic. The hairs were then dried in an oven at 47ºC for 48 hours and then soaked overnight in absolute alcohol to remove any wax depositions and moisture. Sampled hairs were mounted on slides and observed under a microscope. Hairs were microscopically examined to the lowest taxonomic level possible by comparison with reference hair collections. The medullary pattern of the hair was compared with the reference slides as well as the reference guide (Mukherjee et al. 1994; Bahuguna et al. 2010). Flight feathers of some birds recovered from the scats were identified on the basis of their color, shape and structure (Fraigneau 2017). Moreover, feathers from some scats in the fringe areas of DNP were compared with the remains of domestic fowl left over by Red Fox near scats.

Statistical analysis

Diet was expressed in terms of frequency of occurrence (scats with food item (i) / number of scats) multiplied by 100 (Mahmood & Nadeem 2011) and relative frequency of each food item (number of times a specific item was found) as a percentage of all items identified (Ackerman et al. 1984; Amroun et al. 2006). Seasonal differences in the prey species in the diet were verified using chi-square ($\chi 2$) test where differences at $p < 0.05$ reflected significance.

RESULTS

The overall diet composition of the Red Fox included 18 items across all seasons. The food items were broadly classified into rodents, wild carrion, livestock carrion, birds, plants, invertebrates (insects), and human subsidies. Rodents were the major food item with a relative percent occurrence of 26.81 followed by vegetation (25.64), wild carrion (17.01), insects (13.84), birds (7.43), livestock carrion (5.72), and human subsidies (3.45). Hair analysis revealed that among Wild Carrion, Himalayan Grey Langur contributed most to the diet (15.57%), followed by Hangul Deer with 1.44%. Among the livestock species, sheep *Ovis aries* contributed most to the diet (2.88%), followed by Domestic Fowl *Gallus gallus domesticus* & Goat *Capra aegagrus hircus* with a relative percent occurrence of 1.14 & 0.85, respectively. Cow *Bos taurus* & Horse (*Equus ferus*) were represented least with a relative percent occurrence of 0.57 & 0.28, respectively. Of the total hair samples, 2.9% remained unidentified. Invertebrates (insects) contributed significantly (13.84%) to the diet. Vegetation was represented by grasses (12.39%) and wild seeds (10.67%). The birds constituted 7.43% of the diet. Human subsidies constituted the lowest proportion in the diet with a relative occurrence of 3.45% (Table 1, Figure 2). The fox occurrence showed a positive association with the availability of human subsidies along the adjoining areas, with increased sightings around human settlements and orchards. Thus, human

Table 1. Diet composition of the Red Fox in Dachigam National Park (Fi = frequency of occurrence, n = number of appearances of food items, and N = number of scats).

Food items	Winter N = 74		Spring N = 62		Summer N = 51		Autumn N = 59		Total N = 246		χ^2 Value	P Value
	n	Fi	n	Fi	n	Fi	n	Fi	n	Fi		
Rodents	21	28.3	32	51.61	22	43.13	18	30.50	93	37.80	4.763	›0.05
Wild carrion	13	17.56	19	30.64	16	31.37	11	18.64	59	23.98	2.491	›0.05
Livestock carrion	11	14.86	3	4.83	3	5.88	3	5.08	20	8.13	9.600	‹0.05
Birds	5	6.75	9	14.51	6	11.76	6	10.16	26	10.56	3.261	›0.05
Plants	27	36.48	29	46.77	17	33.33	16	27.11	89	36.17	6.056	›0.05
Invertebrates (Insects)	9	12.16	20	32.25	12	23. 52	7	11.86	48	19.51	8.167	‹0.05
Human subsidies	8	10.81	0	0	2	3.92	2	3.89	12	4.87	6.000	‹0.05

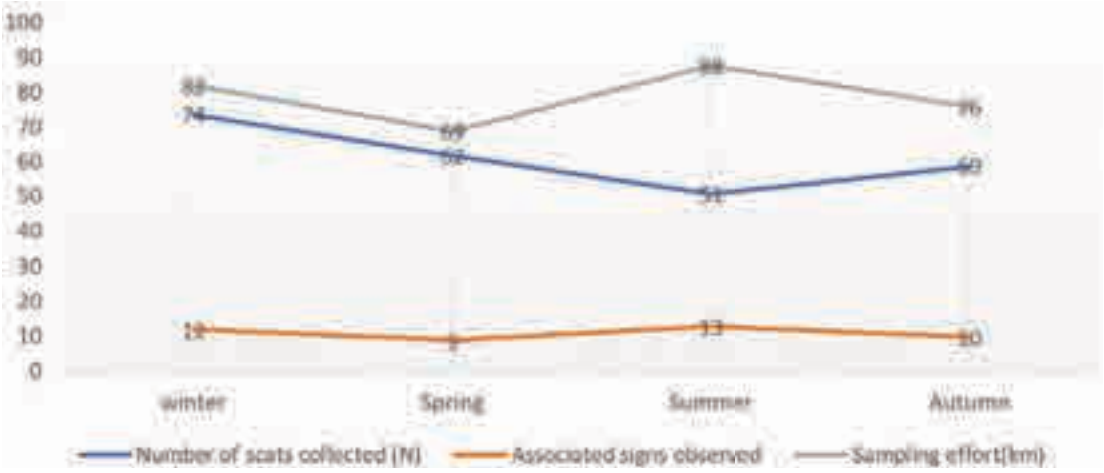

Figure 1. Details of sampling efforts (December 2017–November 2018).

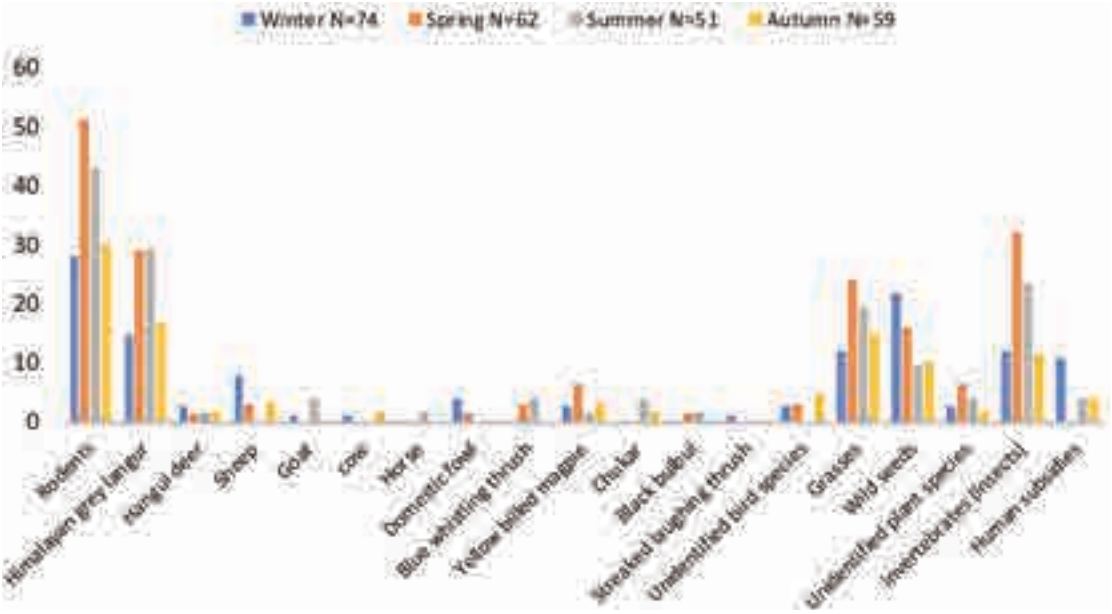

Figure 2. Percent occurrence of food items in the diet of Red Fox in Dachigam National Park.

Image 2. Red Fox in different habitat types of Dachigam National Park.

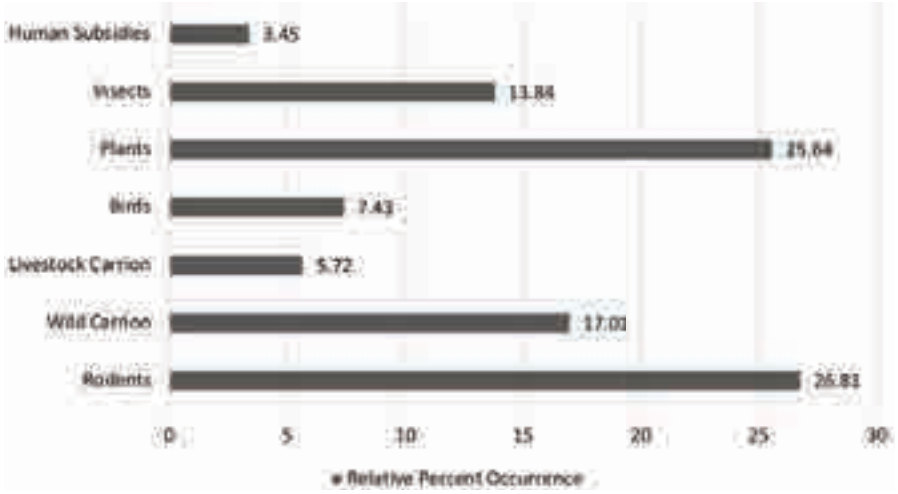

Figure 3. Relative percent occurrence of food items in the diet of Red Fox.

subsidies attracted Red Foxes and constituted an important part of their diet, especially during harsh winter. Chi square analysis has revealed that there is a significant difference ($p < 0.05$) in the consumption of livestock carrion, invertebrates and human subsidies. The rest of the prey types (rodents, wild carrion, birds, and plants) did not differ significantly across seasons ($p > 0.05$).

DISCUSSION

The diet of the Red Fox in the Dachigam National Park was dominated by rodents, wild carrion, plants and invertebrates (Figure 3). The rodents were a major source in the diet without following any habitat or temporal pattern. This is in conformity with Reshamwala et al. (2018). A variety of food items in the diet of Red Fox in the DNP showed that its feeding behavior is of generalist and opportunistic type, which is consistent with several previous workers (Macdonald 1980; Cavallini & Lovari 1991; Dell'Arte et al. 2007; Hartová-Nentvichova et al. 2010). During the warm season a broader trophic niche was witnessed owing to diverse food availability compared to a narrower niche during colder months when the food resources were scarce. This seasonal variation in the diet was obtained and this may be due to seasonal habitat utilization patterns as confirmed by Jędrzejewski & Jędrzejewska (1992), Baltrūnaitė (2006), Sidorovich et al. (2006), and Díaz-Ruiz et al. (2013). It has been noted that among wild carrion, Himalayan Grey Langur always formed a substantial percentage of the Red Fox's diet. The reason being that the langur is preyed upon consistently by leopards across all habitats

Image 3. Steps of scat analysis, separation of prey items and preparation of slides.

and seasons owing to their abundance in the park (Shah et al. 2009). The Hangul Deer represented a small percentage in the diet of Red Fox indicating that the deer is infrequent in distribution (Khurshid et al. 2021). The low occurrence of Hangul in the diet of Red Fox may be due to scavenging. The Red Fox utilized insects (mostly beetles) and was often reported in spring and summer owing to their availability. This is in concurrence with Ricci et al. (1998), Ciampalini & Lovari (1985), and Calisti et al. (1990).

Significant consumption of vegetation in different seasons was revealed with grasses, wild seeds, and fruits (mostly *Malus domestica, Prunus avium, Pyrus* spp.) forming an important component of the Red Fox diet. Fruits such as apple, plum, cherry, berries, and pear are reported worldwide as part of the Red Fox diet (Basuony et al. 2005; Hartová-Nentvichova et al. 2010; Matías et al. 2010). Red Foxes play an important role in the dispersal and germination of seeds (Juan et al. 2006), it might be aiding in the dispersal and germination of seeds in our study site as well. Birds were preyed uniformly across seasons and habitats probably due to low hunting energy costs. The consumption of avian prey decreased during autumn and winter. This may be due to the reason that during spring and summer juveniles are learning to fly and thus are more vulnerable to predation risk (Cavallini & Volpi 1995).

The winter diet of Red Fox revealed that human subsidies formed an essential part and its utilization increased along the fringe areas in the form of garbage and improper disposal of livestock carcasses. Our study revealed that 6.71% of the diet of Red Fox consisted of livestock carrion which included sheep, goat, horse, and domestic fowl. This finding is similar to previous studies (Doncaster et al. 1990; Saunders et al. 1993; Contesse et al. 2004; Mateos et al. 2007; Killengreen et al. 2011). Most of these studies suggest that the reason behind this might be the easier availability of human subsidies than natural prey items.

Red Foxes generally eat and hunt in a wide range of habitats and also show a seasonal shift in their food preferences. They sustain themselves on available food but become scavengers when food is limited (Basuony et al. 2005). This was attributed to the seasonal availability of different dietary items. Our findings suggest that foraging of the Red Fox with reference to human subsidies needs further investigation in the north western landscape for strengthening the understanding of the critical facets of this carnivore.

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COMMUNICATION

Status distribution and factors affecting the habitat selection by Sambar Deer *Rusa unicolor* in Pench Tiger Reserve, Madhya Pradesh, India

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Abstract: Sambar *Rusa unicolor* is one of the deer species distributed throughout the Indian subcontinent. The species has been listed as 'Vulnerable' on the IUCN Red List since 2008, and Schedule I Part A of the Indian Wildlife Protection Act, 1972. Populations have declined throughout its distribution range. This study aims to investigate the status, distribution, and habitat selection of Sambar in Pench Tiger Reserve, Madhya Pradesh, India. Fifteen line transects of 2-km length were laid in five different habitats. Data were collected during the winter and summer seasons during 2013 and 2015. Transects were traversed morning and evening and eight replicates were made on each transect, for a total of 1,232 km survey effort. The overall density of Sambar was 3.7 individuals per km^2, and the group density 1.4 groups per km^2. During the summer 113 individual Sambar were observed, and in winter only 80 individuals were observed. Male:female sex ratio was calculated as 100:59 in winter, and 100:56 in summer. Indirect evidence was also collected to supplement the direct sightings for analysis of habitat use. Ten-meter circular plots were laid on all 15 transects at an interval of 200 m between two plots. Principal component analysis and logistic regression were performed to understand the habitat use of this species during summer, post-monsoon, and winter seasons using pellet groups. The logistic regression model showed an efficiency of 97% correct classification during post-monsoon, 67% in winter, and 66% in summer.

Keywords: Habitat utilisation, population density, principal component analysis, logistic regression.

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INTRODUCTION

Sambar *Rusa unicolor* is native to India, Pakistan, Sri Lanka, Philippines, southern China, Taiwan, Malaysia, Borneo, Sumatra, and Java (Wilson & Mittermeier 2011). In India the distribution range extends east along the southern Himalaya and south throughout the Deccan peninsula. Sambar are abundant in the southern states of Karnataka, Tamil Nadu, and Kerala (Sridhar et al. 2008; Timmins 2015). In other central and east Indian states, Sambar is considered very rare, and the distribution is patchy and declining due to severe hunting pressure, insurgency, and habitat destruction (Timmins 2015). Sambar have disappeared from Sikkim and Tripura (Khan & Johnsingh 2015).

Ungulates play an important role in maintaining the ecosystem by influencing vegetation structure (Augustine & McNaughton 1998; Bagchi & Ritchie 2010). They also play a major role in maintaining prey-predator relations. Sambar is known to be a preferred prey of tiger, throughout its range (Karanth & Sunquist 1992; Karanth & Nichols 2000; Ramesh et al. 2009). Tiger Estimation Report (2019) reported 2,967 tigers in India among which a maximum of 526 tigers are present in Madhya Pradesh (Jhala et al. 2018). Such population of tigers needs a good prey base and population estimation is key for managing the population of prey species. The Sambar and Chital *Axis axis* together form the bulk of the prey base for all large carnivores of the Indian subcontinent such as the Tiger, the Asiatic Lion, the Leopard, and the Dhole (Devidar 1974; Johnsingh 1983; Bhatnagar 1991; Venkataraman 1995). Sambar contributes the most to the prey biomass and is considered a keystone species in Pench Tiger Reserve (Venkataraman 1995).

Information on specific habitat requirements is important for conservation, and governing species habitat use including aspect, slope, food availability, vegetation cover, food availability, vegetation cover, terrain, and cover against extremes of weather and other biotic pressures. Conservation of species requires a good understanding of the habitat requirements and careful monitoring of populations (Yocozetal 2001; Acharya 2007). Understanding population trends and habitat use is crucial for implementation of conservation actions.

The study aims to evaluate the density and population structure of Sambar and the factors affecting its distribution in different seasons within Pench Tiger Reserve (PTR), Madhya Pradesh, India. This study will update knowledge on the abundance and habitat use of Sambar in PTR. The present study will be useful for the managers and policymakers for conservation of the species and its habiatat throughout its distribution range.

MATERIAL AND METHODS

Study Area

The Pench Tiger Reserve, Madhya Pradesh, India is one of the important protected areas of the Satpura-Maikal ranges of the central Indian Landscape. The area was declared as the 19th tiger reserve of India in 1992. PTR comprises a sanctuary and national park, covering an area of 757.85 km^2 (21.6200^0 latitude and 79.2125^0 longitude) at an altitude of 425–600 m (Figure 1). The terrain is gently undulating comprising seasonally flowing streams and nullahs. The Pench River, from which this tiger reserve is named, runs through the reserve over a length of 24 km bisecting it into two halves.

The tiger reserve has four seasons: Summer (March–June), Monsoon (July–August), Post-monsoon (September–November), and Winter (December–February). The temperature ranges from 4^0 C in peak winter to 45^0 C in the peak summer. The PTR receives an average annual rainfall of 1,300 mm. The PTR is a dry deciduous forest dominated by *Tectona grandis*, *Boswellia serrata*, *Anogeissus latifolia*, *Sterculia urens*, and *Gardenia latifolia*. Tiger *Panthera tigris*, Leopard *Panthera pardus*, Dhole *Cuon alpinus*, Jungle Cat *Felis chaus*, Small Indian Civet *Viverricula indica*, Striped Hyena *Hyaena hyaena*, Sloth Bear *Melursus ursinus*, Golden Jackal *Canis aureus*, and Common Palm Civet *Paradoxurus hermaphroditus* are the carnivore species of the reserve. Herbivores, apart from Sambar, include Chital, Gaur *Bos gaurus*, Nilgai *Boselaphus tragocamelus*, Barking Deer *Muntiacus muntjac*, and Chowsingha *Tetraceros quadricornis*.

Methods

Distance sampling was used to study the population density of Sambar in PTR. A total of 15 line transects of 2-km length were traversed morning and evening. The study area was divided into five different habitats on the basis of vegetation composition, and the transects were set to cover all the five habitats and three transects were laid in each one, i.e., Bamboo forest, Grassland, Mixed forest, Teak forest, and Teak mixed forest.

Two seasons were selected to reduce the bias in data collection: Summer and Winter. Eight monitorings were made on each transect in summer and winter, 0600–0900 h and 1600–1800 h. The direct sightings of

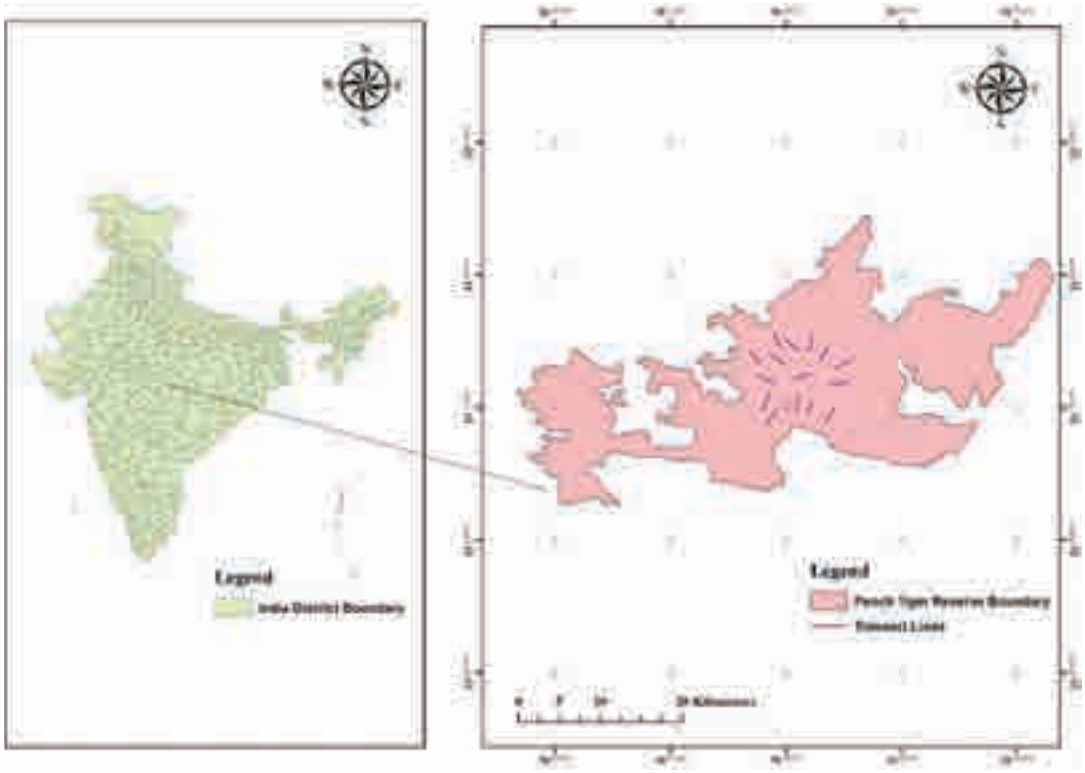

Figure 1. Map of the study area with location of transects.

Sambar were recorded. During the field survey a total of 1,232km efforts were given while traversing the transects.

To assess the habitat utilization pattern, indirect data were also collected. Ten-meter radius circular plots were laid on all of the 15 transects at an interval of 200 m from one another. The tree species present were counted within each plot. Five-meter circultar plots were laid to assess shrub cover and 1-m quadrats for grasses and herbs. Pellet groups are another indicator of the presence of a species in a given habitat. For assessing the habitat utilization pattern of Sambar, along with the vegetation data, data on Sambar pellet groups were also collected.

On each sampling plot, canopy cover was measured at four different points, using a mirror of 25 x 25 cm divided into 100 equal grid squares. The mirror was held horizontally at 1.25 m above ground level, and grid squares covered by more than 50% tree foliage were counted. Percentage canopy cover for each sampling plot was calculated from these counts. Shrub cover, grass cover and herb cover was also measured for each plot in different seasons through ocular estimation.

Data analysis

Line transect data collected were analyzed using DISTANCE 7.0. The distribution of the data was firstly examined by assigning very small cut-off points to the distance intervals during the curve fitting. After choosing convenient cut-off points for the distance intervals, the best key function (with the appropriate adjustment term, where necessary) was selected using the criterion of lowest AIC (Akaike information criteria).

Age classification of Sambar followed Schaller (1967), Sankar (1994), and Sankar et al. (2001). Data on group size and composition were analyzed following Schaller (1967) and Johnsingh (1983). Mean group size was estimated by taking the average of different group sightings, and group size was classified into different class intervals for better explanation between different seasons.

Analysis of indirect evidence such as pellet groups was organized in a simple habitat matrix in order to investigate the habitat selection at macro level. The pallet group density was calculated using following formula:

Density / ha = (Number of pallet groups / Area) × 10000.

Species diversity and richness were calculated by using modified version of "SPECDIVER BAS" (Ludwing & Reynolds 1988), a module of software STASTICAL

ECOLOGY written in BASIC.

One-way ANOVA was used to test significant differences in mean pellet group density in different habitats in different seasons using the computer program SPSS 6.1 (Norusis 1994).

To understand the habitat selection at micro level, principal component analysis (PCA) was performed to avoid confounding highly correlated variables. All the quantitative data in the matrix were transformed using log and arcsine transformation and transformed data were standardized by calculating the mean and standard deviation of each column of data matrix.

Factor analysis was used to reduce the dimensionality of different habitat variables. The first two factors were used for interpretation as these explained maximum variations in the data set. Before using PCA most of the auto-correlated variables were dropped. As habitat selection analysis concentrated on 30 variables around different sampling plots in different season, were recorded out of which different variables in different seasons were used for PCA, and factor scores were saved. Utilized and available plots were plotted in two dimension space defined by PCI, and PCII. All the extracted factors with eigen values of more than one were saved and used for logistic regression analysis. In logistic regression, the principal component was then used as candidate variables in logistic regression model with forward step-wise entry.

RESULTS

Population density and abundance of Sambar

During the winter season, a total of 80 sightings were observed, while in summer 113 sightings were observed (sightings for both years were pooled). The long distance sightings were trancuated to reduce the bias. A total number of detection of Sambar was 80 in winter, and 113 in summer were used to estimate density. Half-normal cosine model was selected for both winter and summer season as best fit estimator. The effective strip width for winter season was (23.7 ± 3.45) m whereas for summer season it was (18.7 ± 2.34) m. The estimated density of Sambar was 6.93 (± 1.69) km^{-2} in winter 2014, 4.27 (± 1.05) km^{-2} in winter 2015 and 3.36 (± 0.71) km^{-2} for overall winter season. Summer density was 10.2 (± 2.58) km^{-2} in 2013, 15.7 (± 4.88) km^{-2} in 2014, 8.53 (± 2.48) km^{-2} in 2015 and 4.06 (± 0.74) km^{-2} for summer overall (Table 1). Group density of Sambar in different seasons are also shown in Table 1.

Mean pellet group density of Sambar during post monsoon, summer and winter season were maximum (100.8±101, 89.8±88, 98.2±94), respectively, in Teak forest, teak mixed forest, & bamboo forest and minimum (30.78±37.85, 50.24±62.78, 53.07±65.20) in teak mixed, grassland, & teak mixed forest, respectively. Analysis of two way ANOVA shows significance differences in mean pellet group density in different habitat in different seasons [F8 1043 = 3.706, η2 (166748.3), P <0.05]. Post hoc test shows that mean pellet group density of Sambar in grassland and teak forest were found significantly different with each other. It also shows that mean pellet group density of Sambar shows significant differences between post monsoon season and winter season. The group density ± SE was highest in Teak forest (1.22 ± 0.24) followed by Mixed forest, (0.54 ± 0.14), Grassland (0.50 ± 0.12), Teak mixed (0.33 ± 0.07), and Bamboo forest (0.27 ± 0.06) (Table 5).

Age and sex structure of Sambar

Adult males (AM) and adult females (AF) were observed more (31% and 53%, respectively) in winter than in summer (27% and 48%, respectively). Observations of yearlings (Y) were (15%) in summer and (10%) in winter. The sex ratio wasfound biased towards females. In winter, out of 165 individuals, the AF:AM sex ratio was 100:59, and AF:Y 100:18. In summer out of 341 individuals, the AF:AM ratio was 100:56 and AF:Y 100:32. The mean group size ± SE of Sambar, during winter was 2.08 (±0.11) and in summer 3.15 (±0.18).

Factors affecting the selection of habitats by Sambar in different seasons

For Sambar during post monsoon season, there were 15 variables that had correlation coefficient above 0.80 therefore, these variables were removed from the analysis for avoiding multicollinearity (Table 2). The first two principal components accounted for 26.52% of the variation on data set. The first principle component (PC 1) was highly positively correlated with herb diversity (r = 0.84), herb density (r = 0.79), and tree diversity (r = 0.70). The second PC 2 was highly positively correlated with grass diversity (r = 0.88) and grass density (r = 0.86). Figure 2 indicates a relationship between the use of PC 1 and PC 2 in the selection of habitat by Sambar during the post-monsoon. Our analyses showed a clear shift in habitat use in response to the increased use of low to medium grass diversity and grass density and medium to high herb diversity, herb density, and tree diversity. Overall, the logistic regression model had an efficiency of 97.40% correct classification of cases that identified tree density, as a key predictor of Sambar habitat use

Table 1. Sambar Densities (Individuals/km2) in Pench Tiger Reserve, Madhya Pradesh, during winter and summer seasons (2013 to 2015).

Years/Seasons	Winter				Summer			
	2013	2014	2015	Pooled	2013	2014	2015	Pooled
Total effort (km)	NA	272	240	512	240	240	240	720
TotalObservations	NA	48	32	80	27	41	45	113
Truncated at (m)	50				45			
Observation after Truncation	NA	48	32	78	27	41	40	104
Density±SE/km²	NA	6.93 ± 1.69	4.27 ± 1.05	3.36 ± 0.71	10.21 ± 2.58	15.73 ± 4.88	8.53 ± 2.48	4.06 ± 0.74
Group Density ± SE/ km²	NA	2.46 ± 0.57	2.17 ± 0.51	1.60 ± 0.32	2.17 ± 0.48	3.43 ± 0.97	2.99 ± 0.82	1.28 ± 0.22
Mean Group Size ± SE	2.08 ± 0.11				3.15 ± 0.18			
Effective Strip Width± SE (m)	23.66 ± 3.45				18.67 ± 2.34			
A value	201.68				213.34			
Model+ Adjustment term	Half-normal Cosine				Half-normal Cosine			

Table 2. Principal component analysis of Sambar pellet group during post-monsoon season.

Variables	PC I	PC II	PC III
Bear Ground	0.0331	0.107829	0.105539
Grass Density	0.027686	0.868578	-0.136
Grass Diversity	0.136071	0.883648	-0.06249
Herb Cover	-0.03474	0.262041	0.084252
Herb Density	0.799433	-0.12273	0.133806
Herb Diversity	0.840358	0.278337	0.011688
Sapling Density	0.248571	0.018811	0.109222
Sapling Diversity	0.005983	0.06579	-0.0031
Shrub Cover	-0.36659	-0.01112	0.660385
Seedling Density	0.095794	-0.0226	0.079414
Seedling Diversity	0.101087	0.134554	0.063229
Shrub Diversity	0.12455	-0.04253	0.77041
Shrub Density	0.186455	-0.15938	0.777779
Tree Density	-0.02252	0.295619	0.346735
Tree Diversity	0.701757	0.086988	-0.04878
% of Variance by each component	14.17153	12.35785	12.25404
Cumulative Variance	14.17153	26.52938	38.78343

Table 3. Principal component analysis of Sambar pellet group during the summer season.

Variables	PC I	PC II	PC III
Grass Density	0.83167	0.275057	0.010902
Herb Cover	0.207257	0.698108	0.041515
Herb %	0.317452	0.768572	0.048339
Herb Density	0.747446	0.401299	0.053116
Herb Diversity	0.25406	0.449724	0.400123
Litter	-0.82924	-0.04759	0.018185
Rock	0.25652	-0.61443	0.028021
Seedling Density	-0.00611	-0.04101	0.892497
Seedling Diversity	-0.0352	0.089607	0.872159
Tree Cover	-0.0003	-0.05004	-0.09414
Weathered Stone	0.542355	-0.35789	-0.03183
% of Variance by each component	22.79538	18.51902	15.77547
Cumulative Variance	22.79538	41.31441	57.08987

in the post-monsoon season. During summer, 11 out of 30 variables were selected from data collected from 519 sampling plots (Table 3). The first two principal components accounted for 41.31% of the variation. The first principle component (PC 1) was highly positively correlated with grass density (r = 0.83), herb density (r = 0.74), weathered stone (r = 0.54) and negatively correlated with litter (r = -0.82). The second principle component (PC 2) was highly positively correlated with herb cover (%) (r = 0.76) and and negatively correlated with rocks (r = -0.61). During summer the distribution of available and utilized plots in relation to first and second component is shown in Figure 3. The graph shows that during summer Sambar preferred the area with low to high herb cover % and and medium to high grass density, herb density and weathered stone and on the other hand avoiding rock and litter. The logistic regression model had an efficiency of 66.28% correct classification of available and used plots by Sambar during summer. According to this model, herb diversity was the most important predictor for Sambar's habitat selection.

During winter, 12 variables from 350 sampling plots of 30 variables were selected (Table 4). The first two principal components accounted for 33.32% of

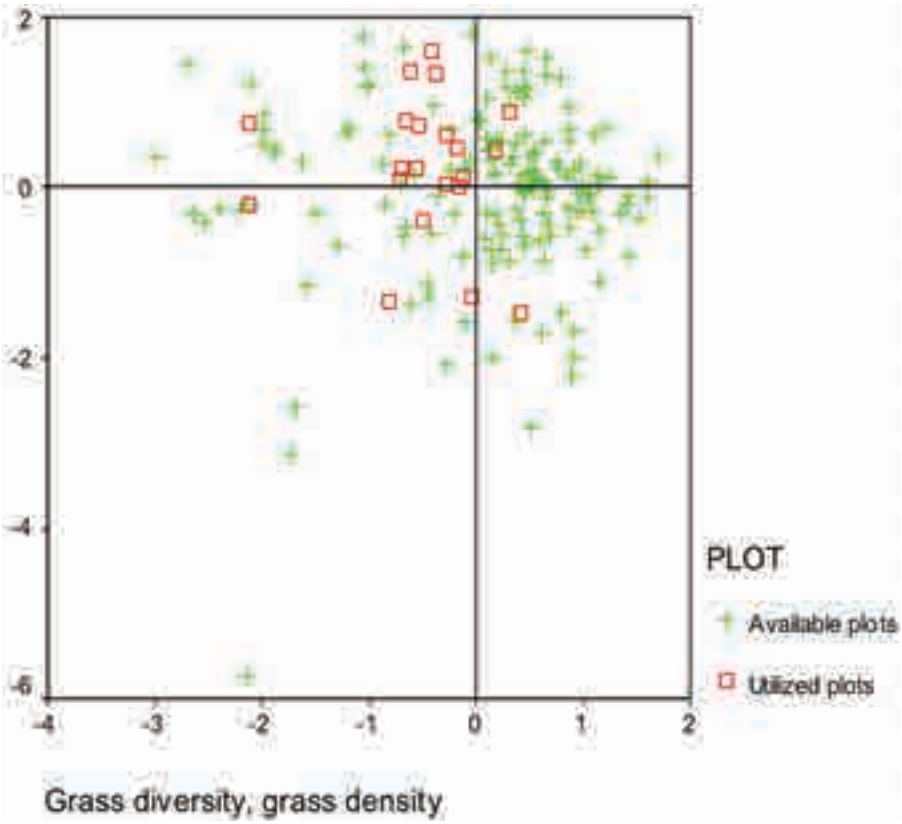

Figure 2. Ordination of available and utilized plots for Sambar during post-monsoon season in Pench Tiger Reserve.

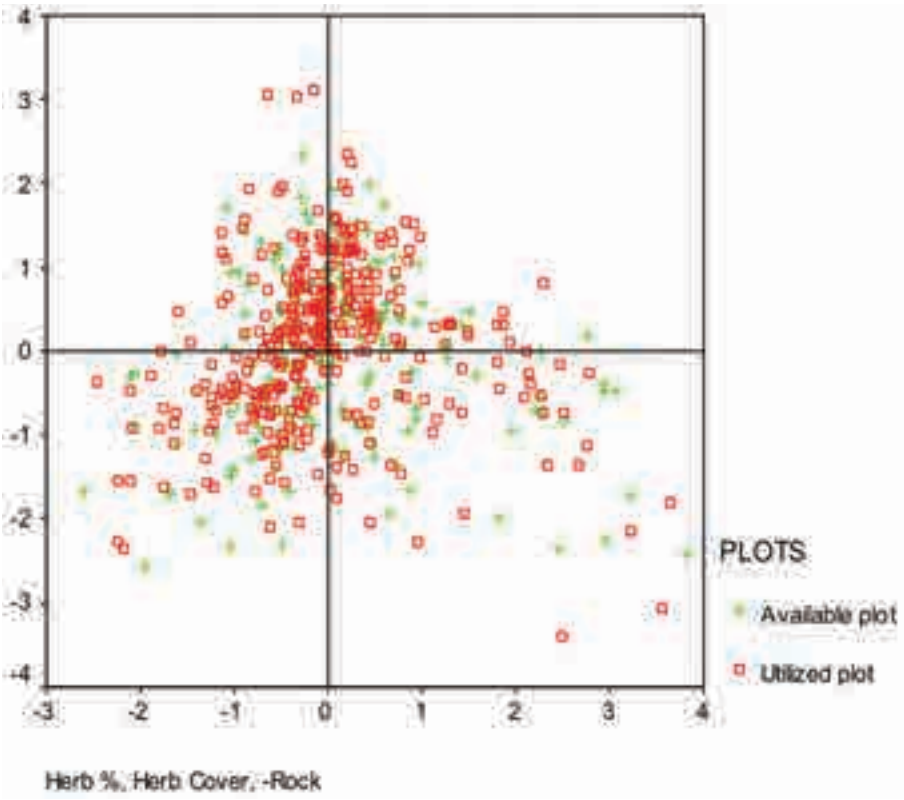

Figure 3. Ordination of available and utilized plots for Sambar during the summer season in Pench Tiger Reserve.

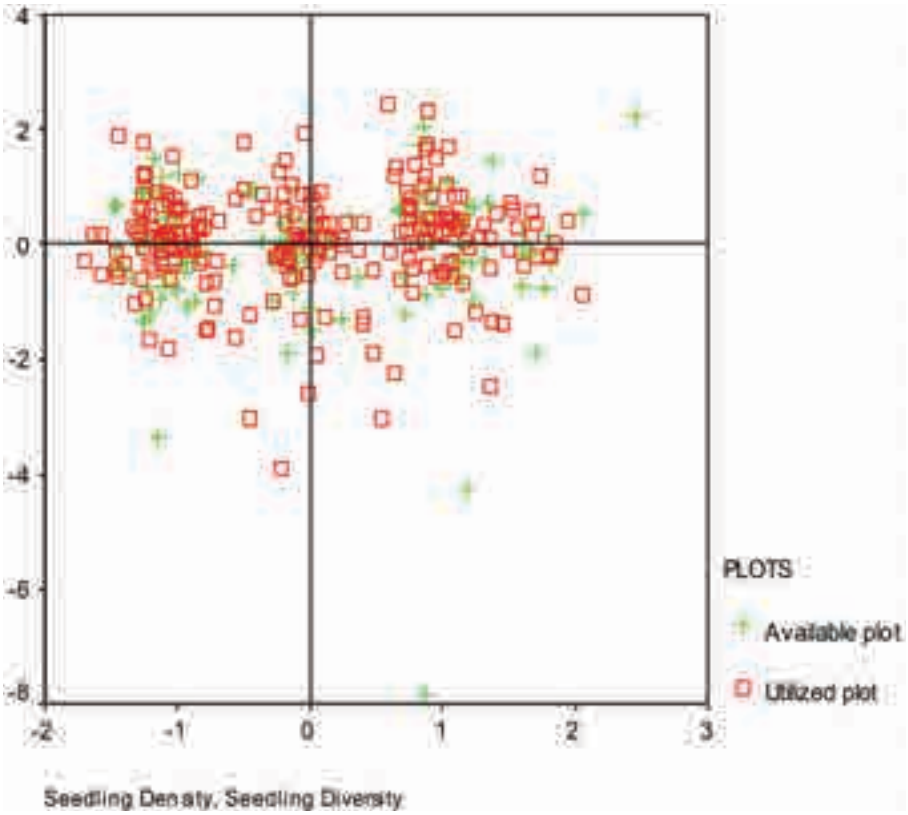

Figure 4. Ordination of available and utilized plots for Sambar during the winter season in Pench Tiger Reserve.

Table 4. Principal component analysis of Sambar pellet group during the winter season.

Variables	PC I	PC II	PC III
Grass Density	0.617863	-0.04698	-0.27626
Grass Diversity	0.525874	0.300114	-0.19871
Herb Cover	0.651132	-0.01108	0.147166
Herb Density	0.674319	0.013231	0.116658
Herb Diversity	0.62023	0.166813	0.171585
Rock	-0.53704	0.072539	0.282335
Sapling Density	0.090378	0.061656	-0.08938
Seedling Density	-0.01843	0.890214	0.110038
Seedling Diversity	0.090306	0.878828	0.016763
Shrub Diversity	0.054001	-0.10344	0.854835
Shrub Density	0.005772	0.232585	0.779192
Tree Cover	-0.08705	-0.05413	0.171437
% of Variance by each component	18.64389	14.68341	13.73232
Cumulative Variance	18.64389	33.3273	47.05962

Table 5. Seasonal variation in density of Sambar in different habitats of Pench Tiger reserve, Madhya Pradesh (2013 to 2015).

Habitat	Sambar (Density±SD)		
	Post monsoon	Summer	Winter
Bamboo Forest (n= 180)	45.64±51.34	69.70± 83.63	98.19 ±94.59
Grassland	41.40 ±45.15	50.24 ±62.78	61.04± 78.29
Mixed (n=180 in PNP & n=144 in PMS)	64.85 ±66.56	65.89 ±69.94	82.51 ±82.67
Teak Forest (n=180)	100.84± 101.77	72.54± 65.28	80.67 ±78.55
Teak-mixed (n=180)	30.78 ±37.85	89.87 ±88.36	53.07 ±65.20

PNP—Pench national Park | PMS—Pench Mowgli Sanctuary.

the variation. The first principle component (PC 1) was positively correlated with herb density (r = 0.67), herb cover (r = 0.65), herb diversity (r = 0.62), & grass density (r = 0.61) and negatively correlated with rocks (r = -0.53). The second principle component (PC 2) was highly positively correlated with seedling density (r = 0.89), seedling diversity (r = 0.87). For Sambar during winter season the distribution of available and utilized plots in relation to first and second component is shown in Figure 4. The graph shows that during winter season Sambar preferred the area with low to medium seedling density and seedling diversity and medium herb density, herb cover, herb diversity, grass density and avoiding rocks. The logistic regression model had an efficiency

of 66.57% correct classification of available and used plots by Sambar during winter season. According to this model, sapling density was the most important predictor for Sambar's habitat selection.

DISCUSSION

Sambar density is showing a declining trend inthe last two decades in PTR. During 1995–2000 Sambar density was reported to be 9.6 animals/km^2 (Karanth & Nichols 2000). Sambar favours dense forest patches as well as hilly terrain (Biswas & Sankar 2002; Kushwaha et al. 2004) and a similar trend was observed in the present study. Our results show that Sambar prefers the teak dominated habitat with hilly terrain and dense forest during winter and summer, and feeding results also confirm the same as Sambar utilizes *Tectona grandis* less than the availability in both seasons (Ilyas 2015). Most of the sightings were around water holes. Studies conducted in different parts of India suggest the Sambar tend to concentrate their activity around these waterholes (Ilyas 2001; Biswas & Sankar 2002; Kushwaha et al. 2004). Being a deer that prefers relatively dense forest, distribution pattern of Sambar was found to be clumped type with highest pellet group recorded in Teak forest. Studies on a variety of other ungulates have also shown clumped type distribution patterns due to the availability of food resources (Adhikari & Khadka 2009). The Chital density in PTR was reported to be 31.48 (± 3.47) in winter and 39.99 (± 2.73 during summer), 8–9 times higher than Sambar density (Ilyas 2015). The increased population of chital may also be one of the reasons for the clumped distribution of Sambar, to avoid competition. The overabundant population of Spotted Deer in PTR is a major concern for the management point of view, and translocation of chital to unoccupied areas outside PTR could resolve the issue to some extent for Sambar (Ilyas 2015).

Schaller (1967) and Eisenberg & Lockhart (1972) reported that Sambar does not remain in permanent social groups. In PTR, the observed Sambar male:female ratio was 0.59:1 in winter and 0.56:1 in summer. The observed low male ratio might be due to selective predation by tiger on male Sambar as reported in other studies (Schaller 1967; Johnsingh 1983; Karanth & Sunquist 1992). Sambar male:female sex ratio of the present study can be compared with Gir—0.5:1 (Khan et al 1996), Wilpattu—1.2:1 (Eisenbrg & Lockhart 1972), Ranthambore—0.83:1 (Bagchi et al. 2003), and Florida—0.73:1 (Flynn et al. 1990). In Sambar, group size is generally small, numbering fewer than six individuals (Schaller 1967). The characteristic social unit in Sambar is one hind and one fawn or one hind, one yearling, and one fawn (Schaller 1967; Downes 1982). In the present study group size of 1–5 individuals was recorded throughout the year, as was also reported in Mudumalai (Ramesh 2010).

Habitat studies provide crucial information about the ecological requirements of a species or community. Habitats of animals have been studied for long. From the days of Aristotle (344 BCE) where man learnt about habitat use by animals due to innate curiosity to today's times when understanding ecological relationships (Morisson et al. 1992), conservation of natural resources (e.g. Soule 1986), and management of areas with specific requirements (e.g. Fox et al. 1988; Rahmani 1989) have made it mandatory to understand habitat requirements of different species. Increasing habitat loss causes a significant increase in extinction risk among many species, especially habitat specialists (Rahmani 1989; Birdlife International 2001; Mallon 2003; Norris & Harper 2003). While it is important to assess the habitat usage, it is equally important to conduct studies addressing the pattern of usage. It is assumed that high quality resources will be selected more than low quality ones and use may change with availability when the latter is not uniform (Manly et al. 1993).

Unoccupied habitat with little selection cannot be assumed to provide low fitness potential. Although effects of habitat cover, landscape structure and spatial variables on abundance of birds has been reported (Heikkinen et. al. 2004), fitness potential of habitat cannot be assumed to vary with habitat selection and a gradient in observed density does not necessarily indicate a gradient in habitat quality (Hobbs & Hanley 1990). The approaches used in the present study for collecting data on habitat use reduced chances of collecting insufficient or biased data. Ungulates defecate at a particular rate, which varies between species, but is usually constant within species (Marques et al. 2001; Laing et al. 2003). Using pellets as indirect evidence of presence have their understandable strengths, but also have some challenges. Although the issue of detectability is reduced to a great extent when areas were combed thoroughly for faecal matter, disintegration rate and site selection pose concerns (Marques et al. 2001; Laing et al. 2003).

In the present study most of the pellet groups of Sambar were recorded from hilly terrain with Teak dominated forest type. The study shows that Sambar avoid dense forest which is also supported by Imam (2014). This, however, is contrary to the studies

conducted by Ramesh et al. (2012) and Khushwaha et al. (2014). Findings of factorial analysis state that density and diversity of trees and herbs were the most important factors for their habitat preference which is significantly supported by logistic regression analysis. These findings are similar to the study conducted by Khushwaha et al. (2004). Water is an important resource, particularly in hot temperatures. Sambar, being an animal of hilly terrain, reduce energy expenditure by restricting their home ranges around the water resources in summer. In certain occasions they rush into a water body to avoid predation (Yahya 2014), often unsuccessfully. Our study also shows a similar trend. It is also supported by studies conducted by Johnsingh (1983), Eisenberg & Lockhart (1972), and Imam (2014). The study area consists tropical dry and tropical moist deciduous forests, so that covering of the ground with leaf litter is common during summer. Sambar avoids habitats covered with high amount of litter as they contain very few plant materials to be utilized as food. In the present study similar results were recorded, where Sambar avoids litters in summer. The rocks do not provide any protection from predators, high temperature and forage. This has resulted in a decrease of suitable habitat for this habitat specialist species. The woodland contains climax stage species with interspersion of shrubs was the most preferred habitat type and favourable for its grazing and browsing requirement throughout the year.

Ungulates in general and Sambar in specific are a good indicator of the health of the forest. Their population structure should be assessed at temporal and spatial levels at different landscapes. The Pench Tiger Reserve is one of the best managed tiger reserve and contains a very good prey base for the thriving tiger population. For effective Sambar conservation a large undulating tract of undisturbed habitat is required. Such tracts should have protection from poaching as poachers prefer Sambar as it provides more meat. At the global level Sambar population has declined and in peninsular Malaysia Sambar has lost more than 50% of its historical range. (Kawanishi et al. 2014). In India also Sambar has disappeared from Sikkim, Tripura and many other places, which is an alarming condition for the managers (Khan & Johnsingh 2015). The government as well as NGOs involved in conservation should pay special attention to Sambar conservation. Sambar is not only ecologically important for the ecosystem but is also a main prey for tigers. We also recommend IUCN Red List authorities to review the Red List category of Sambar, presently listed as 'Vulnerable' (Timmins et al. 2015). If Sambar continue to disappear from other areas, then soon it may be included in the Endangered category.

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COMMUNICATION

Assessing illegal trade networks of two species of pangolins through a questionnaire survey in Nepal

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Abstract: Pangolins are among the most extensively traded taxa in southeastern Asia mainly due to the perceived medicinal value of their scales and other body parts, putting them at risk of extinction, however, little is known about their trade status in Nepal. The purpose of the study was to assess the status of pangolin trade in Makwanpur district of Nepal. Semi-structured interview with household (n = 90), key informant survey (n = 15), Four focus group discussion at each study site was conducted. Seizure data (2015–2019) were gathered from the law enforcement agencies to identify and analyze the major trade routes. The majority of the respondents (63%) were well aware of the protection status of pangolins. Further, our study found that historically local peoples used pangolin body parts in making rings, bags, jackets, and musical instruments but at present they stopped it. Pangolin traders were typically middle-aged men and unemployed youth. Majority of the hunting was found to be opportunistic but when pangolins were caught, they were generally sold for additional income. Currently, the seizure data has shown the declining trend of pangolin trade within the Makwanpur district. Community forest user groups and community based anti-poaching units are working actively for the conservation and promulgation of threatened pangolins in the Makwanpur district which had long served as a major trade route to China. Thus, we advocate strengthening border security and the formation of community-based anti-poaching units, followed by mobilization, anti-poaching trainings, security assurance, and incentives for worthy conservation results in pangolin-rich communities. Further, we recommend sustained conservation awareness programs, in addition to alternative livelihood opportunities, for the long-term conservation of pangolins and their habitat.

Keywords: capacity strengthening, ethno-medicinal importance, middle-aged man, opportunistic hunting, semi-structured interviews.

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Authors contributions: NF—conceptualization, research design, data collection, data analysis and interpretation, drafting of manuscript, critical review, and revisions at different stages. BMS—drafting of manuscript, critical review, and revisions at different stages. RK—drafting of manuscript, critical review, and revisions at different stages. RB—drafting of manuscript, critical review, and revisions at different stages. SB—drafting of manuscript, critical review, and revisions at different stages. NR—drafting of manuscript, critical review, critical review, and revisions at different revisions at different stages. BD—conceptualization, methodology design, manuscript drafting lead, GIS mapping lead, review draft and edit.

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INTRODUCTION

Nepal has two of the eight extant species of pangolin found in the world: the Indian Pangolin *Manis crassicaudata* & Chinese Pangolin *Manis pentadactyla* (Suwal et al. 2020; Dhami et al. 2023). The Indian Pangolin is cryptic and has complex biology (Mohapatra et al. 2021), i.e., a single one is born in the breeding season and is a diet specialist, which makes it vulnerable. The Indian Pangolin has a wide range of distribution with major holds in India, Nepal, Pakistan, Sri Lanka, and Bangladesh (Mahmood et al. 2019) whereas the Chinese Pangolin is found to be distributed in Nepal, Bhutan, India, Bangladesh, Vietnam, Thailand, Myanmar, China, and Lao (Challender et al. 2019; Sharma et al. 2020a). Globally, both the species are listed as Endangered and Critically Endangered species, respectively, under the IUCN Red List of Threatened Species (Challender et al. 2019; Mahmood et al. 2019) and are appended in Appendix I of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2020). Despite the ban on the international commercial trade of specimens by CITES, pangolins are one of the most widely trafficked mammal species (Boakye et al. 2015; Challender et al. 2014, 2020). Indian Pangolins are relatively larger than Chinese Pangolins; the former weigh 8–21 kg and are 100–120 cm in length (DNPWC 2019).

Wildlife trade, a major contributor to decline and extinction of species (Paudel et al. 2020), is now globally considered to be the fourth largest illegal trade, after drugs, people, and arms valued at $7 billion to $23 billion each year (Lehmacher 2016). Along with increased threats to biodiversity conservation, illegal wildlife trade also impacts the security of the community and their livelihood, living together with wildlife (Riskas et al. 2018). Furthermore, it has had far-reaching consequences for the nation's governance and economy (Felbab-Brown 2017). For instance, corruptions associated with the illegal wildlife trade undermines the rule of law thereby affecting the country's governance (Vines & Lawson 2014). Moreover, to regulate and control the illegal trade, manpower is required in the enforcement agencies which ultimately affects national economy in a way (Vines & Lawson 2014). Poverty, unemployment, illiteracy, and lack of alternative livelihood opportunities motivate individuals to partake in illegal wildlife trade (Rao 2002). While Nepal's effort in protecting species like tigers and rhinos is getting global recognition (Bhattarai et al. 2017), the rampant poaching and illegal trade of threatened pangolin species has not been given sufficient attention.

Income generated from illegal wildlife trade is essential to sustain the livelihood of wildlife poachers and traders in many developing nations like Nepal (Milliken 2014). It is impossible to reduce poaching without providing alternative livelihood options (Biggs et al. 2015). Therefore, mitigating the impacts of wildlife trade at the grassroots level ought to consider satisfying the short-term goals (ensuring livelihood) of nearby communities (Mulder & Coppolillo 2005). Until and unless the short-term goals of local communities living in proximity to wildlife is not fulfilled incidence of wildlife poaching is practically impossible to reduce. Despite the fact that Nepal is home to two species of pangolins and shares an international border with China, one of the world's largest pangolin traders, there is little information on the extent of pangolin trade in Nepal (Katuwal et al. 2015, 2016; Sharma et al. 2019; Ghimire et al. 2020; Paudel et al. 2020). On top of that, only few robust studies regarding illegal trafficking of pangolins have been conducted in central Nepal (Dangol 2015; Sharma et al. 2020b). Hence, this research aimed to identify the trade routes and understand the social attributes of the people involved in illegal trade in Makwanpur district of central Nepal.

METHODS AND MATERIALS

Study area

The study was carried out in the Hetauda sub-metropolitan city and Makwanpurgadi rural municipality (Figure 1) of Makwanpur (2,426 km^2) district, Nepal. The district is located with the coordinates (27.3333–27.6666 ^{0}N & 84.6833–85.6833 ^{0}E). The climate of the district varies from near-tropical to upper-temperate forest type with mean annual precipitation between 16.6°C to 30.3°C and mean annual rainfall (2,288 mm). About 75% of the land of the district is mountainous and the rest 25% is plain areas (Shrestha & Nepal 2016). The main ethnic groups residing in the districts are Tamang, Newar, Majhi, Magar, and Praja (CBS 2012). Vegetation like Sal *Shorea robusta*, Chilaune *Schima wallichii*, and Saj *Terminalia bellerica* are commonly found in this region. Different indicators such as the presence of pangolin in the study site, several anecdotal evidence such as seizure and arrest records on local and national newspapers as well as major markets were considered for selecting these municipalities as study areas. Katuwal et al. (2015) also used major market areas as indicators for site selection.

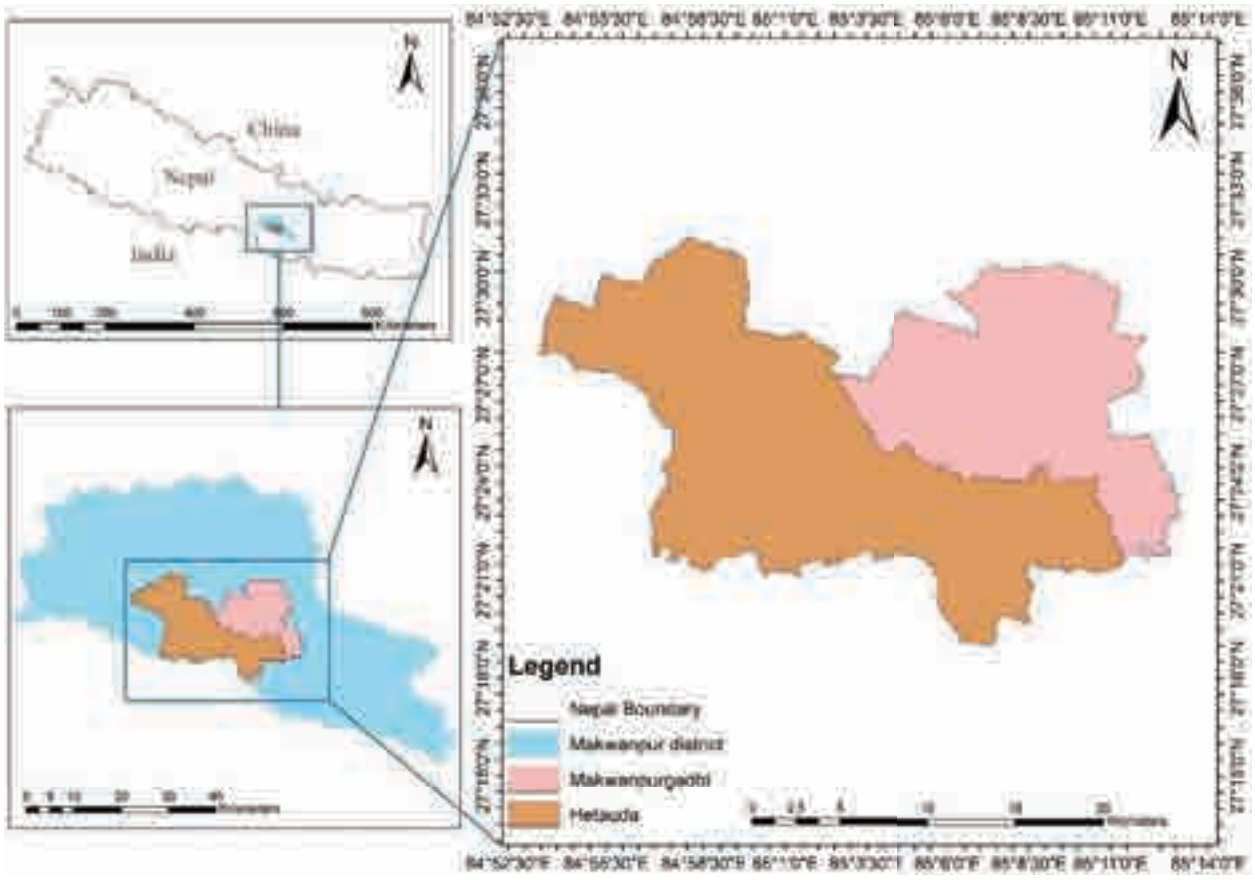

Figure 1. Map of study area showing Hetauda & Makwanpurgadhi.

Data collection and analysis

The study was conducted between February and March 2020. Data were collected through both primary sources (household survey, key informant survey, focus group discussion, and seizure data) and secondary sources (published and unpublished reports). Snowball technique of purposive sampling method was used to identify the potential respondent (Newing 2011) from different ethnic groups and about 90 households were selected (60 households from Hetauda and 30 households from Makwanpurgadhi). Although the study area was dominated with Brahmin and Rai community, we also ensured the representation of other communities in our purposive survey (see Table 1 for detail). We interviewed the head of each household, but if he or she was unavailable, we interviewed the available (>18 years old) adult. A semi-structured questionnaire was used to interview the selected respondents (Newton et al. 2008) (Appendix A). Interviews were conducted in the local language and were then translated into English. We tried to pose open-ended questions wherever possible in order to access the respondent's true feelings on an issue. Surveyor provided well-illustrated pictures of both Chinese and Indian Pangolins and also played videos showing the behavior of both species to facilitate the respondent for species identification. In addition, we asked respondents to rank five pre-determined threats from 1 to 5 according to the degree of severity posed, 5 being the greatest and 1 being the least. We used the non-parametric Friedman test to identify people's opinions regarding pre-determined threats at a 1% level of significance similar to Ghimire et al. (2020). Further, 15 key informant interview was conducted involving division forest office (DFO) staff (n = 5), FECOFUN head (n = 1), police officers (n = 5), and district court staff (n = 4). There were altogether 32 questions that were directed towards assessing information on trade and its triggering factors (Appendix B). Also, four focus group discussions were carried out in each study site (three with the local respondent and one with community-based anti-poaching Unit) to identify major trade routes and market hub for pangolin trade. During the focus group discussion, the team tried to pose close-ended questions to compare and validate the answers

of different respondents. In addition, we obtained trade information from DFO and district police station including details on quantity and part of pangolin seizure, date, time and place of seizure, name, and address of the culprit from 2015–2019. The information gathered was entered into excel for analyses and presentation. Information accessed from household surveys, key informants, focus group discussion and seizure records was used to prepare a map highlighting the possible trade route with the help of the ArcGIS 10.8 version.

RESULTS

Socio-economic characteristics of respondents

Most of the respondents interviewed were male (70%) belonging to the age group of 35–55 years (74.44%). Similarly, most of the respondents (48.89%) surveyed were illiterate. And the majority of the respondents (74.44%) were involved in agriculture as shown in Table 1.

Table 1. Socio-economic characteristics of respondents.

Characteristics	Number	% of respondents
Gender		
Male	63	70
Female	27	30
Community		
Brahmin	35	39
Chhetri	11	12
Tamang	13	14
Chepang	13	14
Rai	18	20
Age group		
Young (<35 year)	15	17
Adult (35–55 year)	67	74
Old (>55 year)	8	9
Education		
Illiterate	44	49
School-level	35	39
College level	11	12
Occupation		
Agriculture	67	74
Forest guard	3	3
Teacher	2	2
Shopkeeper	8	9
Housewife	6	7
Government job	4	4

People's perception of protection of pangolin

The majority of the respondents supported pangolin conservation (63%), few were against it (4%), and 32% were ignorant of the issue.

Ethno-medicinal importance of pangolin

People belonging to Tamang (40%), Chepang (24%), and Rai (16%) communities are more aware of the ethno-medicinal importance of pangolin in the study area (Figure 2). They do have good knowledge regarding the use of pangolin claws and scales.

In the local context, the use of pangolin and its body parts (like its scales) are believed to have healing power to cure wounds. More importantly, pangolin meat is used for treating gastrointestinal problems, pain killers during pregnancy, cardiac problems, back pain relief, and bone problems. The scale is used as a symbol of good luck to avoid danger and to make finger rings. Scales are rubbed together and applied to cure skin diseases, burn wounds, teeth problems, and to cure pneumonia. Likewise, scales are kept near the baby basket (kokro) to protect children from different diseases. They used the scales in preparing bags, boots, and musical instruments. Similarly, pangolin claws are used to make a ring, necklace, and bracelet that help to protect individuals against bad omen as well as protect from any other bad consequences.

Manner of pangolin hunting

Out of the total respondents surveyed, the majority (42%) reported the hunting to be opportunistic, followed by rare (19%), intentional (17%) hunting, and no idea (22%), respectively.

Type of people involved in hunting

Mostly unemployed adults (45.55%) and young men (40%) were involved in the trade. The rest had no knowledge about the trade (Figure 3).

Purpose of pangolin hunting

About the purpose of hunting, 53% reported hunting for money, 23% for traditional medicine, 17% for meat and 7% for cultural value (ornaments such as rings and bracelets made from pangolin scales are considered as an emblem for good luck).

Threat to pangolin

Out of five threats, respondents ranked human hunting (4.43) as a severe threat to the pangolins followed by habitat fragmentation (3.39) and least for

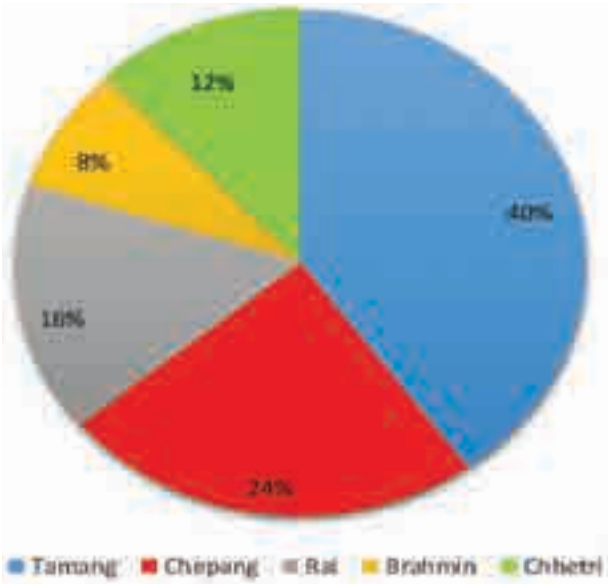

Figure 2. Different community people's knowledge on ethno-medicinal use of pangolin.

complex biology (1.93). On applying the Friedman test the results were statistically significant (χ^2 = 135.997, p <0.01) as shown in Table 2.

People's perception on status of Pangolin and major reasons for trade

Out of the total respondents, the majority (44.44%) had noticed the increase in the pangolin population, some (32.22%) had no idea about the pangolin population and the remaining (23.34%) had noticed the decrease in pangolin population.

Regarding the reasons behind the trade, the majority (34.44%) of the respondent identified high profit to be the major reason for trade followed by poor security, poverty, and lack of awareness as 26.68%, 23.33%, and 15.55%, respectively.

Fluctuation in pangolin trade

The fluctuation in pangolin trade was assessed,

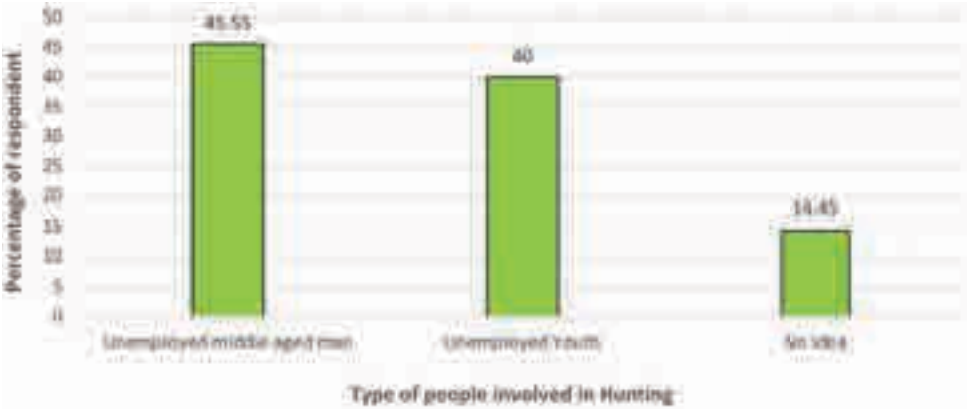

Figure 3. Type of people involved in hunting of pangolin.

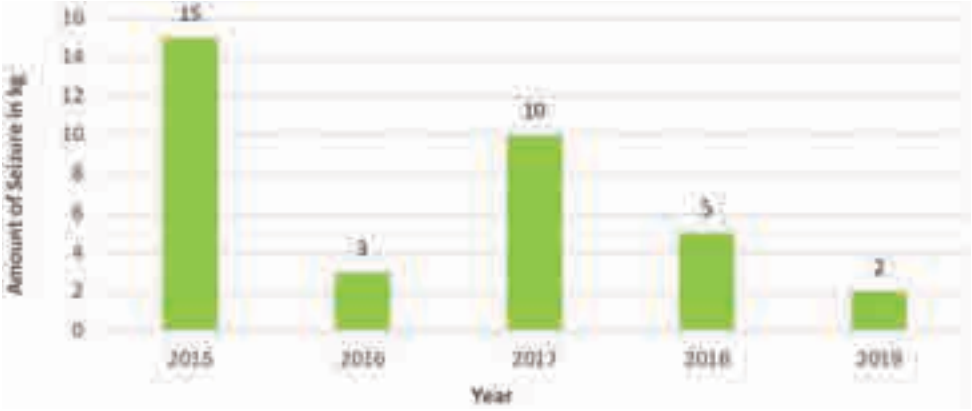

Figure 4. Analyzing pangolin trade condition from seizure data.

Table 2. Pre-determined threat ranking based on people's opinion using non-parametric Friedman test.

	Major threat	MR	χ^2	P-value
1.	Human hunting	4.43	135.997	0.0000*
2.	Habitat fragmentation	3.79		
3.	Hunting by wild animal	2.57		
4.	Low food availability	2.27		
5.	Complex biology	1.93		

MR—Mean Rank | X^2—Chi-square value | P—significant value.

taking into account both the respondent's opinion and the seizure data obtained from DFO, District Police Office (DPO) for the last five years. The seizure data were tallied with the respondent's opinion which showed a decreasing trend in trade. When questioned about the pattern or trend of pangolin trade in the district, 43.33% admitted about declining status of trade, 24.45% feel the trade is still increasing, and the remaining 32.22% had no idea about the pangolin trade as shown in Figure 4.

Identification of major trade routes through Makwanpur district

As per the information provided by concerned authorities (DFO, Police office), major markets for pangolin trade are either China or India. The majority of the pangolin parts from different parts of the district or from outside the district reach the district headquarters, Hetauda – a sub-metropolitan city and are transported to China and India via various routes.

The highlighted pink line indicates the trade route via road (Figure 5). The route is identified through information obtained from group discussion, key informant interviews and mainly by analysis of seizure data and follows following route:

1) Hetauda—Birgung—Kalaiya—Gaur—Malangawa—Rajbiraj—India
2) Hetauda—Kathmandu—Dhadingbesi—Bidur—Dhunche—China
3) Hetauda—Kathmandu—Dhulikhel—Chautara—Charikot—China

DISCUSSION

Our results show that the majority of respondents supported pangolin conservation which could be attributed to the efforts of the personnel of the community forests and community-based anti-poaching units in the study site. Media such as television, radio, and newspapers might also have played a positive role in creating awareness among the people (Sharma et al. 2019). Especially people living around Rani and Chhucekhola community forests were highly positive towards the protection of threatened pangolins despite knowing the fact that pangolin meat, scales, and skin are of high value in an international market Katuwal et al. (2015), they were against the trade of pangolins. Our result contradicts with the findings made by Katuwal et al. (2015) where most people were unaware of the protection status of pangolin. Sharma et al. (2020b) mentioned that people from the diverse background were knowledgeable about Chinese Pangolin and concerned about the conservation of this species as pangolin plays a vital ecological role in controlling the pest such as termites, ants (Swart et al. 1999) and also in improving the soil structure and composition similar to other burrowing mammals (Laundré & Reynolds 1993).

Previous studies (Nash et al. 2016; D'Cruze et al. 2018; Ghimire et al. 2020) recorded that the pangolin parts are used for traditional medicines. Similar to our finding on ethno medicinal use of pangolin parts for curing wounds, gastrointestinal problems, pain killer during pregnancy, cardiac problems, back pain, and bone problems, cure wounds, cure arthritis, and anti-poisonous reagents. Pangolin scales were used for ornaments such as rings and bracelets and as an emblem for good luck while others showed that they bring bad luck (Nash et al. 2016; D'Cruze et al. 2018; Ghimire et al. 2020).

In our study, the majority of the respondents reported hunting to be opportunistic followed by rare and intentional, thus providing insights into the intensity of hunting. Results from the study by Ghimire et al. (2020) and D'Cruze et al. (2018) also suggest that opportunistic hunting is one of the major causes of pangolin population decline.

Our study showed that unemployed middle-aged men followed by unemployed youths were majorly involved in pangolin hunting. Our results are similar to the studies made by Ghimire et al. (2020) and Katuwal et al. (2015) where they reported that youth, especially those unemployed, were involved in pangolin hunting for monetary reasons. We suggest two key strategies of the many used to combat illegal wildlife poaching; first the development of reward and sanction mechanism through legally agreed rules and regulations and second, the introduction of strong and sustained awareness programs, prioritizing and implementing income generating activities or skill development trainings to facilitate alternative livelihood options (Khatiwada et al. 2020). The effective conduction of skill development training and income-generating activities like mobile repair, house wiring, and plumbing is likely to make

Figure 5. Map showing trade route of pangolin within Makwanpur district.

the marginalized populations self-reliant and less likely to engage in poaching and illicit activities (Bhatta et al. 2018).

Likewise, our study showed that money and traditional medicinal values were the driving factors for hunting. Different parts of the pangolins are consumed traditionally in a local context as the parts of pangolins are believed to have curative properties as mentioned earlier Ghimire et al. (2020). However, these social and cultural values are suppressed by monetary value at present which coincides with the study made by Corlett (2007) where he stated that pangolins are hunted for trade rather than for local consumption. Further, Katuwal et al. (2015) revealed that the minimum price of live pangolin and scales of pangolin in the Nepali market range between $ 7–12.5 /kg for local hunters, however the price doubles at every subsequent level of trader which supports our results. Despite the fact, people believe that the pangolin population is increasing in the study site, however, this hypothesis need to be proved by detailed field study. The reason could be the decrease in pangolin trade with the active involvement of police and concerned authority in controlling the wildlife trade. Further, National Park and Wildlife Conservation (NPWC) Act has a provision of a penalty of NRs 100,000–500,000 or 1–10 years of imprisonment or both if any offense regarding them is committed (GoN 1973).

Heinrich et al. (2017) explored the impacts of hunting on tropical forests in southeastern Asia and highlighted the importance of opportunistic hunting as it does not require much skill. We also identified hunting as the major threat which is similar to the findings of Ghimire et al. (2020). Challender & Hywood (2011) and Patel & Chin (2009) also identified hunting and poaching as the primary threats to pangolin. Local people use different techniques to hunt pangolins. The most commonly used hunting practice is filling burrows with water and hitting on snout of pangolin when they attempt to escape from the burrow (Katuwal et al. 2016). Hunters catch pangolins to supply to the trader for money rather than personal consumptions (Corlett 2007) as a decrease in the global wild population and strong law enforcement have increased the price of pangolins in the market (Shepherd 2009; CITES 2016).

As compared to the record of previous years, the pattern of pangolin seizures seems to be decreasing in the study area after 2015. The result corresponds with the result of Ghimire et al. (2020) where they have clearly stated that the seizure of Pangolin in recent years is declining in Illam, Dhankuta, Taplejung, and Sankhuwasaba districts. However, the obtained result is in contrast with the findings of Katuwal et al. (2015) where they have reported the increasing pattern of pangolin trade in eastern Nepal. Currently, several attempts are made by the Nepal government for pangolin conservation. National pangolin workshop was organized by the government of Nepal to develop a road map for conserving the country's globally significant pangolin population. Similarly, a wide range of stakeholders from local pangolin experts including pangolin specialist group to government officials are working together to develop scientific information through performing intensive surveys on multiple arenas of threatened pangolins. In addition to this, the Pangolin Conservation Action Plan for Nepal (2018–2022) aimed to address the critical threats to pangolin conservation by developing appropriate conservation strategies and action (DNPWC 2018). The major objective of this plan is to curb poaching and illegal trade of pangolins. Currently people in Makwanpur district are also more aware of the protection status of pangolins. Similarly, CF (especially Rani and Chhuchekhola CF) are working actively for the conservation of pangolins. They keep conducting awareness classes in various schools and trade-prone areas to make community people aware of the legal and ecological consequences of trade. In addition to this, pangolin park is made in Chhuchekhola CF for the conservation and promulgation of threatened pangolins. Nevertheless, the community-based anti-poaching Unit (CBAPU) was established four years ago in Makwanpur district which discourages people against the illicit trade of pangolins. We obtained very few registered cases of pangolin seizures at the DFO, Makwanpur. Even though very few seizures and arrest records have been registered in DFO and DPO, police are claiming that trade is still happening but in a confidential way. Due to the clandestine nature of the trade and the strong network among the poachers, they are finding it very difficult and challenging to track and arrest culprits.

According to the information on trade routes provided by DPO, Makwanpur, poachers from each area use different trade routes nevertheless, the final destination in Nepal is typically the border to China. Similarly, most of the key informants admitted China to be the major market place for trade. In the study made by Katuwal et al. (2015) also trade flow was more across the Chinese border. The findings of our study is again supported by the study made by Sharma et al. (2020b) where they have clearly stated that most illegal Chinese pangolins trades from Nepal are motivated by the demand from China. Illegal wildlife trade generally occurs through a complicated network of locations and routes where poachers of one village supply pangolin to poachers of another village and so on until it reaches the international border. Heinrich et al. (2017) stated that wildlife trafficking occurs through a mobile trade network with constantly shifting trade routes. This may also be presumed in our study area that trade might still be rising by shifting the route rather than using old routes.

CONCLUSION

Our study shows that especially the unemployed adults were involved in pangolin hunting especially for a monetary cause. Further, our study reported the use of different parts of the pangolin as cultural values and curative reagent in the study area. Similarly, our results have shown the decreasing trend of seizure records of pangolin whereas trade flow was more skewed towards the Chinese border. On top of that, hunting and habitat fragmentation were ranked as most severe threat for pangolin conservation. However, community forests are working actively for the conservation and promulgation of threatened pangolins in the Makwanpur district. Finally, we suggest that to discourage the involvement of youth in illegal pangolin trade, strong and sustained awareness programs should be launched with development of alternative livelihood opportunities. In addition, forming community-based anti-poaching units in prospective pangolin habitat could be a significant intervention to stop the trade. This necessitates long-term motivation, anti-poaching training, security guarantees, and, most importantly, incentives for worthy conservation outcomes. Finally, we propose a national-level investigation into unlawful pangolin hunting and trading, as the species' survival is in jeopardy.

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Appendix A
Questionnaire survey

1. Socio-economic characteristics of respondents
a. Gender (circle one)
i. Male ii. Female
b. Age group:
i. Young(<35yr) ii. Adult(35-55yr) iii. Old(>55yr)
c. Education:
i. Illiterate ii. School-level iii. College level
d. Occupation: ……
e. Community:
i. Tamang ii. Chepang iii. Rai iv. Brahmin v. Chhetri

2. People belonging to which community are more aware with ethno-medicinal uses of pangolin?
a. Tamang b. Chepang c. Rai d. Brahmin e. Chhetri

3. Do you agree pangolin should be protected?
a. Agree b. Disagree c. No idea

4. Do you know the medicinal value of pangolin?
a. Cure of arthritis b. Cure wound c. Prevent body ache problem d. Others

5. Do you know the cultural value of pangolin?
If yes, Please specify……

6. Have you ever heard or seen pangolin killed in your locality?
a. Intentional b. Opportunistic c. Rare d. No idea

7. What type of people are mostly involved in hunting?
a. Unemployed middle aged man b. Unemployed youth c. No idea

8. Why are pangolins hunted?
a. Meat b. Cultural value c. Traditional medicine d. Money

9. Rank the following threats to pangolin according to the degree of the severity?
a. Habitat fragmentation b. Human hunting c. Hunting by wild animals d. Complex biology e. Low food availability

10. Have you perceived an increase or decrease pangolin habitat and its number in your area?
a. Increase b. Decrease c. Don't know

11. What driving factors is most responsible to encourage people to involve in trade?
a. Low awareness b. High profit c. Poor security d. Poverty

12. Can you tell me the trend of pangolin trade for last 5 years?
a. Increase b. Decrease c. Don't know

13. What are the major hub for pangolin trade?
a. China b. India c. China and India d. No idea

Appendix B
Checklist for Key- Informant Interview

Name of respondent: Date:
Address: Age:
Phone number: Sex:
Designation:

1. Have you seen Pangolin or their burrow? When and where?
.....
2. How familiar are you with Pangolin and its benefits?
.....
3. Are you aware regarding ethno-medicinal use of pangolin?
.....
4.Which part of pangolin is most valuable?
.....
5. What are the major threats for pangolin?
.....
6. Are pangolins being hunted in your area?
.....
7. What method they used to hunt them?
.....
8. For what purpose they hunt pangolins?
.....
9. How often does the hunting of pangolin occur in your area?
.....
10. Can you estimate the hunters number in your locality?
.....
11. In average how much pangolins are being killed in one year from your area? Can you estimate last year's number?
.....
12. People of which caste are mostly involved in trade?
.....
13. People of which occupation are mostly involved in trade?
.....
14. People of which age are mostly involved in trade?
.....
15. What are the major reason for increased trade of the pangolin?
.....
16. Do you have any estimate of pangolin population trend in last five years? Is it increasing or decreasing? If decreasing why?
.....
17. Do you know where live Pangolins and its body parts are sold?
.....
18. Are there any selling and buying station in the market?
.....
19. Who are mainly responsible for selling?
.....
20. Where do buyers come from?
.....
21. Where are Pangolin's scales sold, do you have any idea?
.....
22. What are the major hub for pangolin trade in this area? (key places)
.....
23. Does any buyer/middleman visit the place for buying? If yes then from where.....

24. How and where Pangolins are hidden during transport and trade?
.....
25. By what route the Pangolins are smuggled? Identify the key routes within the district?
.....
26. In your information, what is the average price per kg of pangolins scale at local level? Or how much a poacher earn selling a kg of pangolin scale in your area?
.....
27. Do you have any idea how much a middleman earn selling a kg of pangolin scale?
.....
28. In your opinion, why is the trade network so vast and difficult to control?
.....
29. Do you have any idea of fine and punishment in case of seizure? Is it enough to limit the alarming trade?
.....
30. Is there any conservation effort to mitigate illegal wildlife trade of Pangolin?
.....
31. What type of organization worked here/ working here to control the illegal trafficking and poaching of threatened pangolins?
.....
In case the key informant is the dignitaries of any organization.....
a. What kind of programs and actions are carried out to control illegal trafficking and poaching of threatened pangolins?
.....
32. Are community-based anti-poaching unit working effectively to control illegal trade of endangered pangolins?
.....

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COMMUNICATION

First occurrence record of Indian Roundleaf Bat *Hipposideros lankadiva* in Rajasthan, India

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Abstract: An erroneously cited text of Wason by subsequent authors has led to the assumption that *Hipposideros lankadiva* was first recorded in Rajasthan in the Bhim Bharak caves of Jodhpur. A careful review of Wason's note revealed that it in fact mentioned another species from the genus, *H. fulvus.* This erroneous citation has led to several research articles published on the ecological aspects of this species to be misinformed. The authors discovered a small population of *H. lankadiva* in eastern Rajasthan and have monitored this new population since 2010. Since the Bhim Bharak cave location is erroneous, Kased Cave (26.2209N, 77.1024E) is the only location of *H. lankadiva* for Rajasthan and is therefore the first record of the species from the state.

Keywords: Bhim Bharak caves, Chiroptera, Jodhpur, Kased Cave, occurrence, population.

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INTRODUCTION

The Indian Roundleaf Bat *Hipposideros lankadiva* is endemic to southern Asia, and has been recorded from many parts of India, as well as neighbouring nations like Sri Lanka, Bangladesh, and Myanmar (Bates et al. 2015; Saha et al. 2015). *Hipposideros lankadiva* Kelaart, 1850 was described from the city of Kandy in the central hills of Sri Lanka (Bates & Harrison 1997). Three subspecies have been reported for this species of bat. The subspecies described from Sri Lanka is *H. lankadiva lankadiva* (Kelaart, 1850) and the subspecies from India is referred to as *H. lankadiva indus* (Andersen, 1918). The latter is small in size relative to the former (Bates & Harrison 1997). Bates et al. (2015) described a new subspecies, *H. lankadiva gyi* from Myanmar with its distribution in northeastern India, which is morphometrically similar to the Sri Lankan subspecies.

Many taxonomic accounts have contributed to chiropteran studies in Rajasthan, such as Blanford (1891), Ryley (1914), Wroughton (1918), Ellerman & Morrison-Scott (1951), Prakash (1963a,b, 1973), Agrawal (1967), Biswas & Ghosh (1968), and Sinha (1973, 1975, 1976, 1977). The first detailed taxonomic exploration of bats in Rajasthan was conducted by the Zoological Survey of India (Sinha 1980) which documented detailed descriptions, illustrations, and zoogeography of 21 bat species in the state. Later on, various explorers described new occurrence records and ecology of bats in Rajasthan (Sinha 1981; Sharma 1986; Bhupathy 1987; Bohra 2011; Senacha & Dookia 2013).

On the occurrence of *H. lankadiva* in Rajasthan

Bates & Harrison (1997) quoted a published note by Wason (1978) on the occurrence of *H. lankadiva* in the Bhim Bharak caves of Jodhpur, Rajasthan. However, Sinha (1980, 1996) did not discuss this bat's presence in the state, and this led to doubts about the occurrence of *H. lankadiva* in the state. Bats have been studied in the Thar desert by various scientists, especially those based in Jodhpur such as Prakash (1963a,b, 1973), Agrawal (1967), Biswas & Ghosh (1968), Sinha (1973, 1975, 1976, 1977, 1981), Sharma (1986), and Senacha & Dookia (2013). Thus, no prior reports of this species lent credence to the idea that the observation by Bates & Harrison (1997) is incorrect.

A careful review of Wason's (1978) note revealed that it mentioned another species from the genus—*H. fulvus*—and the inclusion of *H. lankadiva* was due to an error by Bates & Harrison (1997).

Srinivasulu et al. (2013), examined published literature and compiled a list of 25 bat species from Rajasthan, including *H. lankadiva* from the Bhim Bharak caves of Jodhpur. Interestingly, without physically verifying the note by Wason (1978), Srinivasulu et al. (2013) quoted the same distribution area for *H. lankadiva* in Rajasthan. It seems that while they may have followed Bates & Harrison (1997), they cited Wason (1978) for the occurrence of *H. lankadiva* in Rajasthan. Afterwards, many documents have included *H. lankadiva* for the state of Rajasthan (Menon 2014; Bates et al. 2015).

This erroneous citation has led to various research articles published on the ecological aspects of this species to be misinformed. For example, Dookia et al. (2017) expressed concern that *H. lankadiva* was not reported from the Thar desert since 1979. This erroneous location has also been used in spatial studies to predict new possible areas for the species (Venugopal 2020).

However, we recorded a small population of *H. lankadiva* in eastern Rajasthan and have monitored this new population since 2010, which was opportunistically discovered during a wildlife survey of the region. Since the Bhim Bharak cave location is erroneous, Kased Cave (26.2209N, 77.1024E) is the only location of *H. lankadiva* for Rajasthan and it is thus the first record of the species from the state.

Study Area

The population of *H. lankadiva* occurs in a natural cave between the Kailadevi Wildlife Sanctuary and National Chambal Gharial Sanctuary in Karauli, Rajasthan, India. The precise location is a Hindu religious site, known as the Kased Cave (26.2209N & 77.1024E) near the town of Karanpur (Figure 1). The cave is situated on a low hill close to the contiguous Vindhyan hill range of Kailadevi WS. Due to its holy status, no tree felling has occurred in its immediate vicinity although the local community has completely denuded its surrounding areas.

The cave is formed of sand stone. The main chamber of the cave is 12 x 12 m in size. This chamber is used by a "sadhu" (hermit) and other pilgrims alike to shelter, cook food, and perform devotional music. The height of the chamber is around 4.5–5.5 m from the centre, and form a dome shape. The surface is dark black in colour, as a result of exposure to smoke. In the main cave chamber, three narrow tube like tunnels further extend from it, one of them has a slow flowing stream and two of them are dry. When the pilgrims cook food for ritual offerings and create a disturbance, the bats move inside the narrow water tunnels. The water tunnel is 55–60 m long and a small stream flows through it year round. The main tunnel is 1–1.5 m high and 1–3 m wide. The temperature

Figure 1. New distribution localities for Indian Roundleaf Bat *Hipposideros lankadiva* in Rajasthan, India

in this water tunnel stays the same year round, because it is underground and not affected by surface weather patterns. The temperature of the cave is usually close to the average annual temperature. During the study we found two other species of bats, *Lyroderma lyra* and *H. fulvus,* along with *H. lankadiva* at the same site.

The tree species found on the hill are *Anogeissus pendula, Mitragyna parvifolia, Crateva adansonii, Butea monosperma,* and exotic trees & herbaceous plants recently planted in the area by the guardians of the temple. A seasonal water stream forms a waterfall nearby. The surrounding area is high and the cave opening is in a depressed area, which makes it moist and cool. The nearby areas are comprised of a mosaic of agriculture fields and scrubland. The Chambal river 1.2km away from the cave site. An undulating landscape consisting of ravines exists between the Chambal river and Kased Cave.

MATERIAL AND METHOD

Basic data of habitat and the surroundings has been collected like measurements of the cave and vegetation species. Five individuals of the species were captured in hand nets at Kased Cave, Karanpur, and Karauli (Figure 1). Specimen and habitat photographs were taken with the help of Nikon D850 DSLR with 300 mm, 17–35 mm lens. Morphological data was taken by manual examination in which measurements were taken with a digital calliper and compared with earlier findings (Srinivasalu et al. 2010; Bates et al. 2015; Saha 2015). The captured bats have been released after taking morphometric measurements. All data was compared with available literature to conclude a final result. Lux meter was used to observe the intensity of light in the cave (Lacoeuilhe et al. 2014). To detect if light intensity influenced roost selection in bats, lux values were observed at places where the bats roost. MS6610 high accuracy 0~50,000 LUX digital luxmeters illuminometer was used to measure the value of light.

RESULTS

We captured 5 individuals of bats (three males and two females) for morphometric analysis. (Table 1). The morphometric data revealed that the bat matches with the subspecies *H. lankadiva indus*. The pelage of the bats varied from yellowish-brown to dark brown (Image 1). They were darker on the head & shoulders and paler on the underside. For species identification we compare morphometric analysis from Srinivasalu et al.(2010), Saha (2015), and Bates et al. (2015). The average value of FA (mm) in three male samples was found to be 85.99 ± 2.12 and in two females to be 83.70 ± 0.65, respectively. Similarly (Saha 2015) the mean value of FA (mm) was 87.64 ± 3.62.

In the study of Srinivasulu (2010) the HBL (mm) range was 87.0–106.0 in males and females as well. In this study we have also rendered the range and mean value of HBL (mm) reported in (78.11–98.57) 89.62 ± 10.47 males and (91.28–92.81) 92.05 ± 1.08 females.

On the comparison of tail length, our observation is supported by Srinivasulu et al. (2010) and Bates et al. (2015). According to Bates et al. (2015), the tail length was found to be 35.0–47.0 (mm) in males and 40.0–45.0 (mm) in females. According to Srinivasulu et al. (2010) the vast range length of the tail (mm) was 35.0–58.0. The mean TL (mm) recorded in this study is 33.36 ± 2.24 in males and 37.80 ± 0.48 in females.

Morphologically, there is no extraneous character variation from different species ranges in males and

Table 1. Morphological Characters of *Hipposideros lankadiva* (Kelaart, 1850).

Body characters	Srinivasulu et al. 2010	Saha 2015	Bates et al. 2015		Present study						
					Male				Female		
			Male	Female	Male 1	Male 2	Male 3	AVG	Female 1	Female 2	AVG
Forearm Length FA (mm)	75.0–99.0	87.64±3.62	80.1–87.0	75.0–89.0	86.76	83.59	87.62	85.99±2.12	83.24	84.16	83.70±0.65
Head Body Length HBL (mm)	87.0–106.0	98.1±4.24	NA	NA	78.11	98.57	92.17	89.62±10.47	92.81	91.28	92.05±1.08
Tail Length TL (mm)	35.0–58.0	51.45±2.34	35.0–47.0	40.0–45.0	30.84	35.12	34.12	33.36±2.24	38.14	37.46	37.80±0.48
Hind Foot Length HFL (mm)	12.0–20.0	19.35±1.0	12.0–16.0	13.0–16.0	15.77	19.29	17.53	17.53±1.76	14.52	13.88	14.20±0.45
Ear Length EAR (mm)	19.5–30.0	27.6±2.05	22.0–26.0	19.5–27.0	23.19	26.93	27.11	25.74±2.21	26.39	28.63	27.51±1.58
Length of Tibia TIB (mm)		35.55±2.48			35.02	33.89	34.46	34.46±0.57	33.15	34.09	33.62±0.66
No. of Supplementary Leaflets	4	NA	NA	NA	4	4	4	-	4	4	-
Narial Lappets	Well-developed	NA	NA	NA	Well-developed	Well-developed	Well-developed	-	Well-developed	Well-developed	-
Length of Third Metacarpal 3MT (mm)	NA	67.71±0.79	57.2–63.7	57.0–65.0	56.7	62.18	60.41	59.76±2.80	58.49	58.43	58.46±0.04
Length of Fourth Metacarpal 4MT (mm)	NA	NA	57.2–61.8	55.3–63.6	58.26	55.59	62.31	58.72±3.38	60.18	58.93	59.56±0.88
Length of Fifth Metacarpal 5MT (mm)	NA	NA	50.7–56.9	49.7–58.6	49.73	51.14	50.19	50.35±0.72	47.78	50.12	48.95±1.65
First Phalanx of the Third Digit 3D1P	NA	31.60±1.17	25.4–28.5	26.0–30.0	26.14	25.82	26.15	26.04±0.19	28.43	28.07	28.25±0.25
Second Phalanx of the Third Digit, 3D2P (mm)	NA	34.34±1.23	24.4–28.4	24.5–28.8	28.39	28.79	29.88	29.02±0.77	27.12	27.86	27.49±0.52
First Phalanx of the Fourth Digit 4D1P (mm)	NA	NA	19.0–21.8	19.4–21.1	20.11	21.23	20.44	20.59±0.58	21.16	20.78	20.97±0.27
Second Phalanx of the Fourth Digit 4D2P (mm)	NA	NA	11.2–14.0	12.5–14.1	9.96	11.49	12.23	11.23±1.16	11.56	11.93	11.75±0.26
Nose-leaf	NA	11.17±0.09	NA	NA	9.92	10.19	10.06	10.06±0.14	10.56	10.89	10.73±0.23

Image 1. Portrait of Indian Roundleaf Bat *Hipposideros lankadiva*.

Image 2. Close of an Indian Roundleaf Bat *Hipposideros lankadiva* face.

females between our five samples and the reference value (Bates et al. 2015). *H. lankadiva* (Kelaart 1850) is a Large Leaf-nosed Bat having four (additional) supplementary leaflets on the nose-leaf with the 4th leaflet reduced, which is a key character of the species are present in all specimens (Image 1). The length of the ear is also an important parameter by which we can see the account of the species. According to Bates et al. (2015) the range of ear length (mm) in females was found to be 19.5–27.0, but in our study, the maximum value of female ear (mm) was found to be 28.63 and the average value was recorded as 27.51 ± 1.58. In the same cave, we found 89 *L. lyra* and four *H. fulvus* bats along with *H. lankadiva.*

We also surveyed the Bhima Bharak cave site at Jodhpur. No specimens of *H. lankadiva* were found in the main part of the cave (Shiva Temple) and in the lower part of the cave. We found 39 individuals of *Taphozous perforatus* and four *Rhinopoma hardwickii* at the cave. During this study, we personally communicated with Anil Wason to investigate if the species had ever been reported by him in the past, but Wason categorically denied ever observing or reporting *H. lankadiva*.

There was a considerable difference between the internal climate and light intensity inside Kased Cave and outer area of the cave, where the value of light intensity was measured to be 62 lux on the opening of the cave. By comparison, the internal light intensity at the site in Karauli was measured at zero lux. The bats prefer zero lux intensity area of the cave. Humidity of the Kased Cave in Karauli was also recorded at more than 50% with water source availability.

DISCUSSION

The species *H. lankadiva* has been observed for the first time in 2010 by the authors in Rajasthan, but it has been first reported now in 2022. This delay in reporting is because of the species already being listed on the bat checklist of Rajasthan, which was the consequence of the erroneous inclusion. Bates & Harrison (1997) erroneously included the bat in Rajasthan and some other reports strengthened this erroneous record

like Srinivasalu et al. (2013) and Bates et al. (2015). Srinivasalu et al. (2013) and Bates et al. (2015), have not only erroneously included the bat, but also cited a wrong reference for Wason (1978), i.e., Srinivasalu et al. (2013) mentioned "44(5): 305–306"; whereas Bates et al. (2015) mentioned "46(5): 331–332", while the correct reference is 43(5): 305–306. It seems like they mixed Wason (1978) with another reference, Wason & Misra (1981) and it is important to note that neither mentioned *H. lankadiva*. The erroneous report perpetuated and impacted many other studies like Venugopal (2020).

Venugopal (2020) used a habitat modelling approach (MaxEnt) based on known locations, to predict new possible geographic presence of *H. lankadiva*. The study also included the erroneous Bhim Bharak location, which misinformed the study and, in all likelihood, must have had an adverse impact on the results, which may have expanded the predicted distribution area of the species. Since this erroneous location is far from the other known locations and lies in a new biogeographic zone, the magnitude of the error could be substantial. The majority of the predicted suitable areas were in and around known localities which are in the Western Ghats and central India (Venugopal 2020). The predicted areas around western Gujarat and Rajasthan, may be due to inclusion of sites where this species has been incorrectly identified. The Jodhpur lies in totally different biogeographic zone.

It is proved that the report of *H. lankadiva* from the Bhim Bharak caves, Jodhpur, Rajasthan is erroneous, and must be omitted from the list of bats occurring in that particular part of Rajasthan, so that it does not continue to perpetuate and impact any further studies.

The newly reported site has a very small population and shows a decline in numbers. The Kased Cave location is under observation by the authors since December 2010 and at that time the number of bats was 150–200 as per personal records. At present, the number shows that the bats are declining in the area and their numbers are five times lower. In the most recent survey (October 2021) we recorded only 32–35 bats. The anthropogenic disturbance level in the cave has also increased. The conservation status of *H. lankadiva* is listed by the IUCN Red List as 'Least Concern' (Molur et al. 2008). Rajasthan is geographically the most largest state in India and only Sinha (1980) conducted comprehensive chiropteran species exploration work throughout the state. Most other studies are sporadic and opportunistic. There is still an immense opportunity for greater chiropteran exploration in the state.

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COMMUNICATION

Food availability and food selectivity of Sri Lanka Grey Hornbill *Ocyceros gingalensis* Shaw, 1811 in Mihintale Sanctuary, Sri Lanka

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Abstract: This study was focused on explaining food selectivity in endemic Sri Lanka Grey Hornbill *Ocyceros gingalensis* to fill the gaps in the behavioral ecology of this endemic species. The study was conducted within Mihintale Sanctuary for five months from December 2015 to April 2016. Ringed hornbills were used to monitor the number of food items that were consumed from within the Food Abundance Index (FAI) and quantify the distribution and availability of resources to examine the potential of fruit selectivity. Thirteen fruiting plant families were recorded as preferred food. Food consumption and FAI values are not significantly correlated ($r = 0.60$, $p = 0.285$). The dietary composition increased in the breeding season due to a higher requirement for nutrients by the nestlings. Nutrient analysis results revealed that moisture ($H = 7.50$, $p = 0.006$), fiber ($H = 6.53$, $p = 0.011$), and ash ($H = 6.07$, $p = 0.013$) components were significant between eaten and non-eaten fruits. The amount of all the nutrients available in the fruits as well as FAI does not directly affect the fruit selectivity of the Sri Lanka Grey Hornbill in the Mihintale Sanctuary. This fruit selection and the seed dispersal ability of the Sri Lanka Grey Hornbill contributes to maintaining the ecosystem diversity and forest regeneration, especially in the Dry Zone in Sri Lanka.

Keywords: Dry zone, FAI, food abundance index, forest regeneration, nutrients, seed dispersal ability.

Abbreviations: A—Avoidable fruits | FAI—Food abundance index | P—Preferable fruits | SLGH—Sri Lanka Grey Hornbill.

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Author contributions: IW—Field data collection, lab works, data handling, data analysis, writing, PP— Field data collection, lab works, data handling, reviewing, SW—Conceptualization, study plan, reviewing, editing and supervision.

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INTRODUCTION

During the past 27 years, 8% of the net forest cover loss has been observed in the Dry Zone of Sri Lanka (Ranagalage et al. 2018). Conserving the forest cover under this kind of situation is especially important in understanding the seasonal patterns, abundance, and distribution within ecosystems, highlighting the importance of the forest systems for conservation purposes. Plant-animal interaction is one such important example for describing interspecific relationships. Seed dispersers play a vital role in maintaining the sustainability of ecosystems. The plants within these ecosystems also benefit from highly diverse seed vectors such as birds and mammals. The strategies of fruit production and nutritional rewards must evolve to attract the greatest possible variety of seed dispersers (Snow 1981) which prefer to consume fleshy parts of the fruit (Bascompte & Jordano 2007). Most of the frugivorous birds typically swallow the whole fruit, such as *Ficus* spp. (Zach 1979), and remove the seed with the fecal matter after completing their digestive process which contributes to the process of plant seed dispersal.

Various conditions of the fruit can affect selectivity, such as nutrition, secondary compounds, palatability, digestibility; and spatial aspects of fruit display should also be taken into account (Coelho et al. 1976; Janson et al. 1986; Sourd & Gautier-Hion 1986). More than any of the above requirements, a bird or vertebrate's food can also be influenced by the changes and the stages of their lifecycle. Avian diet selection is mostly sensitive to seasonal changes in their life cycle, such as in their breeding season when they may have different behaviors in selecting fruits because the fruits are relatively deficient in minerals, which are critical for reproduction (Lamperti et al. 2014).

Hornbills are large frugivores and play an important role in dispersing seeds of the fruiting species in the tropical forests of Asia and Africa (Kitamura 2011; Corlett 2017). There are only two hornbill species in Sri Lanka—*Ocyceros gingalensis* (Sri Lanka Grey Hornbill – SLGH here onwards) and the *Anthracoceros coronatus* (Malabar Pied Hornbill). The SLGH is endemic to Sri Lanka and common in the forested areas of the low country, in both the Dry Zone and the Wet Zone (Henry & Thilo 1998). According to the National Red List of Threatened Flora and Fauna (MOE 2012) conservation status of SLGH is mentioned as Least Concern (LC).

Due to endemic status and the reducing habitats for these species, the provisional status report on biological diversity in 1989 and the subsequent revision in 1999 (IUCN Sri Lanka 2000) mentioned this species as a threatened species. The SLGH is a shy bird that lives in pairs or small flocks numbering 5–6 individuals (Legge 1880) in tall forests. In terms of breeding biology, this species requires tree cavities, and the cavities are not common in the areas of human habitations due to the absence of mature old trees (Kotagama et al. 2011; Wijerathne & Wickramasinghe 2019). Though Wimalasekara & Wickramasinghe (2014) observed and mentioned SLGH as an arboreal frugivore in the Mihintale Sanctuary, there are no records of dietary requirements during the breeding season. Due to the lack of scientific and systematic breeding biological records of this bird (Kotagama et al. 2011; Wijerathne & Wickramasinghe 2018), this study was conducted to cover both the breeding and non-breeding periods of the lifecycle specifically to highlight the food availability and selectivity patterns in the Dry Zone of Sri Lanka. The main objective of the study is to understand the patterns of dietary requirements at different stages of the lifecycle and food selection factors as with the influence of available fruiting trees in the area specially to fill up the remaining gaps in the avian ecology of the Dry Zone forests.

MATERIALS AND METHODS

Study area

The study was conducted in the Dry Zone of Sri Lanka where the mean annual rainfall is 1,200–1,900 mm (Alahacoon et al. 2021). A study plot of more than 4.0 km^2 was selected in Mihintale Sanctuary (Image 1) Anuradhapura District Sri Lanka (8.351057N & 80.51812E). This area comprises both suburban and forested areas (Image 2) where the nesting cavities and fruit bearing trees being observed are present.

Field observations

March to June was recognized as the breeding season of SLGH (Wijerathne & Wickramasinghe 2018) in the Dry Zone. The study period was selected to represent both breeding and non-breeding (post fledging) stages of the life cycle from 2015 to 2016. Nine nest cavities were identified in the study site, mostly on the periphery of the forested areas (Wijerathne & Wickramasinghe 2018, 2019). The volume of fruits (fruiting species and the number of fruits consumed from each species per observation time slot) consumed by selected individuals (ringed male hornbills during 2011 by field ornithology group of Sri Lanka) within non-breeding and breeding

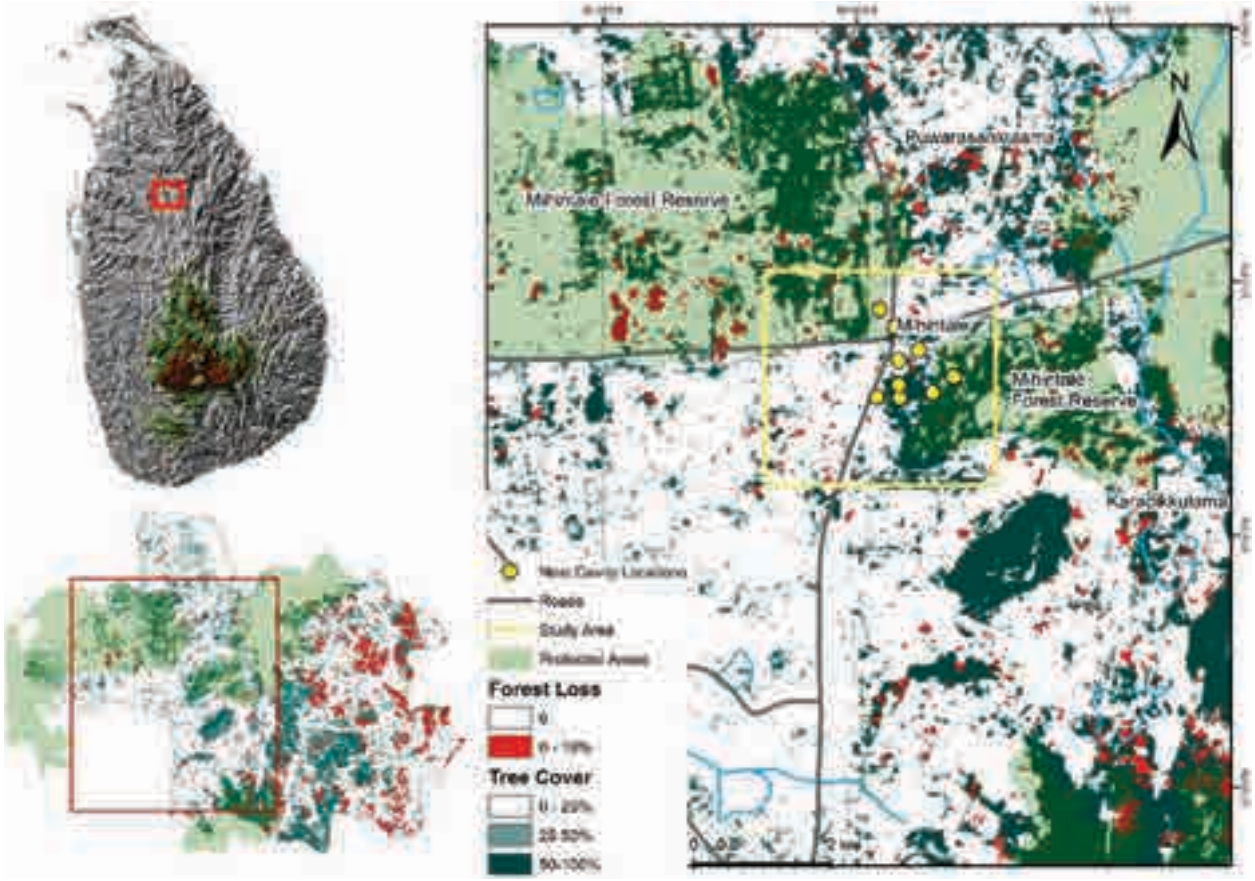

Image 1. Study area of Mihintale Sanctuary within Mihintale Divisional Secretariat (DSD).

Image 2. Mihintale Sanctuary, the study site with the Dry Zone forest habitat conditions for Hornbill species.

seasons were noted using the scan sampling method (Simpson & Simpson 1977) for generating fruit selectivity (Lamperti et al. 2014) index (Krebs 1973).

Fruit availability and abundance

Floral diversity of the study site was conducted using 10 x 10m random quadrats (16) along transects lines. All the trees with DBH ≥10 cm were identified to genus level and measured. Tree heights were measured using clinometers (SUNTO code PM 5/1520), DBH (Diameter at breast height) was measured by a standard DBH meter, and basal area/ha and density of trees were calculated.

Randomly selected 20 fruiting trees were monitored from the beginning of each week to record the phenological data to produce a quantitative measure of food abundance. This set of trees included both preferred and non-preferred fruiting trees for SLGH. Tree crowns were scanned using binoculars (Bushnell 8 × 10) to observe the availability of ripened fruits and fruit abundance was determined as four classes concerning

the canopy coverage 4 (100% ripened fruits present), 3 (75%), 2 (50%), 1 (25%) and 0 (0%). This criterion was based primarily on color changes indicating ripeness (Wijerathne & Wickramasinghe 2018) and was used for determining the monthly relative abundance of fruiting trees.

A food abundance index (FAI) (Anderson et al. 2005) was used to estimate the monthly food availability of each fruiting species from December 2015 to April 2016 with weekly collected phonological data.

FAI (per fruiting species) = $D_k \times B_k \times P_{km}$

D_k—Density of species k in home range (stems per ha)

B_k—Mean basal area of species k in each home range

P_{km}—Percentage of observed trees of species k that produce ripe fruits in each period.

Diet composition and quantity of food types.

Locations of nine nest cavities of SLGH were identified based on the previous studies conducted by Wijerathne & Wickramasinghe (2018, 2019). Three nests were selected from the above for frequent weekly nest feeding observations. All the observations were made between 0600–1700 h from 10 to 25 m distance from the cavities. Behavior patterns, food items, frequencies related to these, and visits of the parent birds to the cavities were recorded. Seed traps were laid under these nest cavities to collect fecal samples weekly. Dry weight of each sample was measured and seeds and other debris were separated and identified.

Food selection

Foraging ratios *(wi)* (Krebs 1973) or food selectivity index was calculated for each dietary species consumed by SLGH.

$$W_i = \frac{oi}{pi}$$

oi—percentage of species *i* in the diet

pi—percentage of species I available in the environment.

Forage ratios >1.0 indicate preference while values <1.0 indicate avoidance.

Chemical characters

Nutrient analysis of the two selected types of fruits which were observed as preferable and non-foraged by SLGH (Wijerathne & Wickramasinghe 2018) were used to test the selectivity influenced by the available nutrient capacity. Due to limitations of chemicals and equipment, all available fruits of the area could not be used for nutrient analysis. The moisture (Drying method), Ash (Dry method; Park 2016), Fat (Bligh & Dyer method; Smedes & Thomasen 2003), Protein (Kjeldahl method; Kirk 1950), and Fiber (Weende method; Williams & Olmsted 1935) content of the selected fruits were analyzed.

Analysis

R statistical package (R Team 2020) was used to analyze the data sets to compare the dietary requirements in the breeding and non-breeding seasons of the SLGH. The Kruskal-Wallis test (Kruskal & Wallis 1952) was used as a non-parametric method of analysis.

RESULTS

The number of individuals in the flocks observed within the study site varied 5–13 and they gathered mostly for foraging (Image 3a–c). The abundance of fruiting trees (Food availability index total) – there were 56 plant species belonging to 23 plant families recorded within a 4 km^2 area. Out of 23 plant families, 13 were recognized as the preferred food for the hornbills. Weekly FAI-Total varied particularly in the non-breeding season. Hence, the number of fruiting species did not influence the FAI-Total. Mean FAI-Total, including hornbill food (n = 10) and non-foraged food (n = 10) for all months, was 316192.00 ± 90613.5 (means: 269374.0 ± 59693.8 in breeding and 386418.3 ± 77045.4 in non-breeding seasons). The FAI-Total in the breeding season declined in February at the beginning and reached a peak in March, while in the non-breeding season within the observed two-month period it reached a peak in January (Figure 2a–b). Except for the month of April, all the others left skewed plots representing the lower rain conditions during the study period where the mean values were less than the median in Figure 3a, but, as per the Figure 3b, FAI for most of the same selected months show normal distribution and higher FAI in January compared to the other months. As per Figure 3c, hornbill abundance of the area varied from normal distribution in December to gradually fewer distribution in the other months. FAI was not altered significantly with rainfall (0.019, P 0.937 > 0.05, n = 20) and hornbill abundance according to the Spearman rank correlation (0.245, p 0.286 > 0.005, n = 20).

Considering the fecal sample gathered during the breeding season, the amount of averaged animal diet was 1.38%±0.59, the amount of *Ficus* spp. seeds was 31.52%±9.79 and fruit seeds and other remaining diet

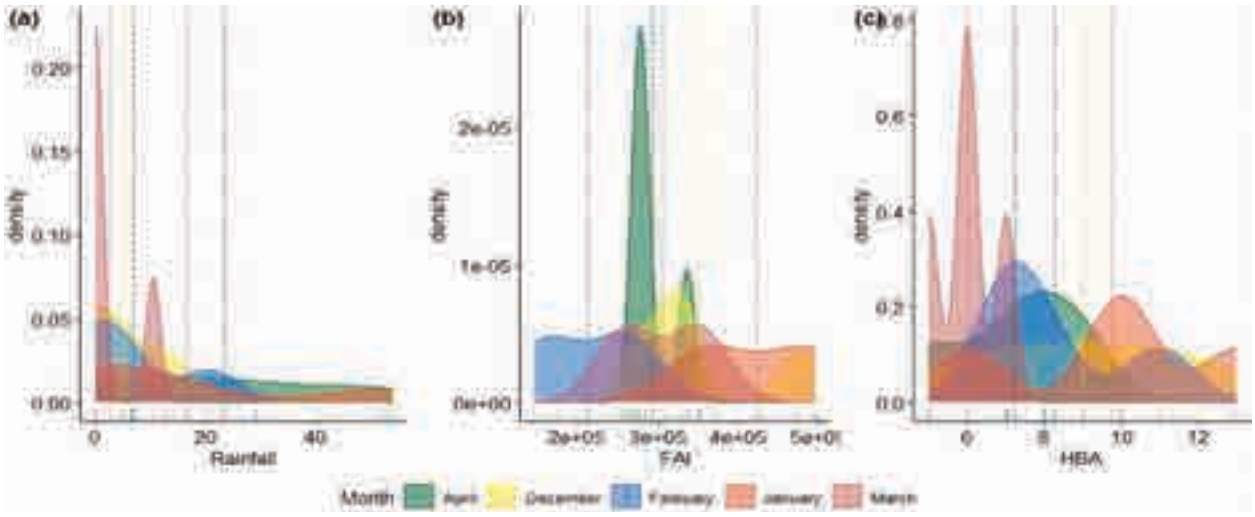

Figure 1. Dual axis plots for a—Hornbill abundance per km2 area vs the food availability index and averaged rainfall vs food availability index of the study area Mihintale sanctuary.

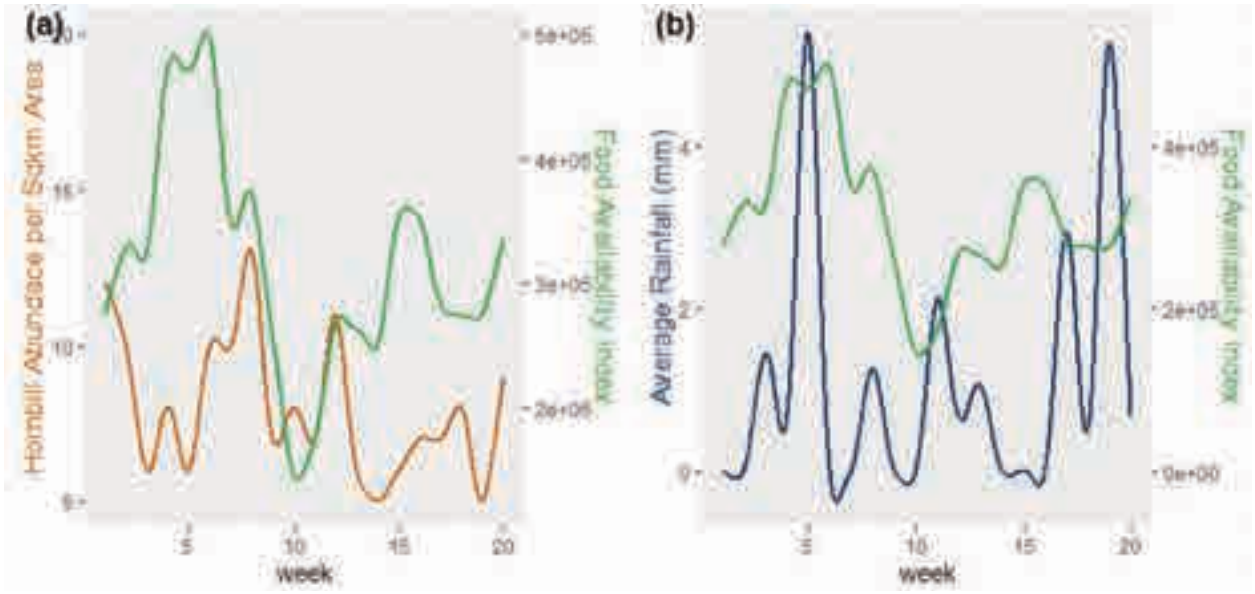

Figure 2. Density plots for: a—Rainfall | b—Food availability index | c—Hornbill abundance in Mihintale Sanctuary. Dashed lines show the mean value for each variable.

(lamp wicks and other unidentified) composition was 67.10%±10 (Figure 3).

The percentage of seeds present within the fecal matter, which was collected, and according to the visual observations during the non-breeding season showed several important plant species consumed by SLGH (Table 1). *Ficus benjamina*, *F. benghalensis*, *F. religiosa*, and *F. racemosa* were categorized into one group as *Ficus* spp. due to the difficulty of identification and separation of pulp and seed content. As high average consumption based on fecal sample analysis, *Ficus* sp. (55.85%), *Ptychosperma* sp. (6.6%), *Filicium decipiens* (12.45%), and *Manilkara hexandra* (4.5%) were recognized as the most important fruiting plant species in both seasons.

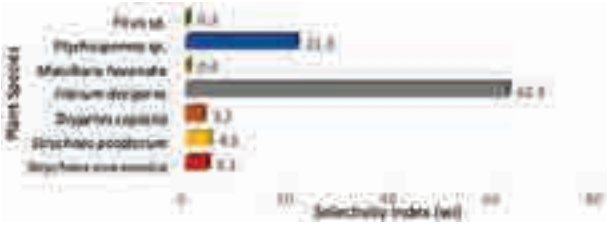

Figure 3. Selectivity index (Foraging ratio) values per seven selected fruiting plant species in the Mihintale Sanctuary.

Image 3a–c. Foraging behavior of the Sri Lankan Grey Hornbills as flocks mostly within the non-breeding season: a—Flocking behavior and foraging mostly as flocks (PC: Damindu Wijewardana) | b—Fruit sharing between coupled birds immediately before breeding starts, | c—Female bird feed on Ficus spp. © Gehan Rajeev.

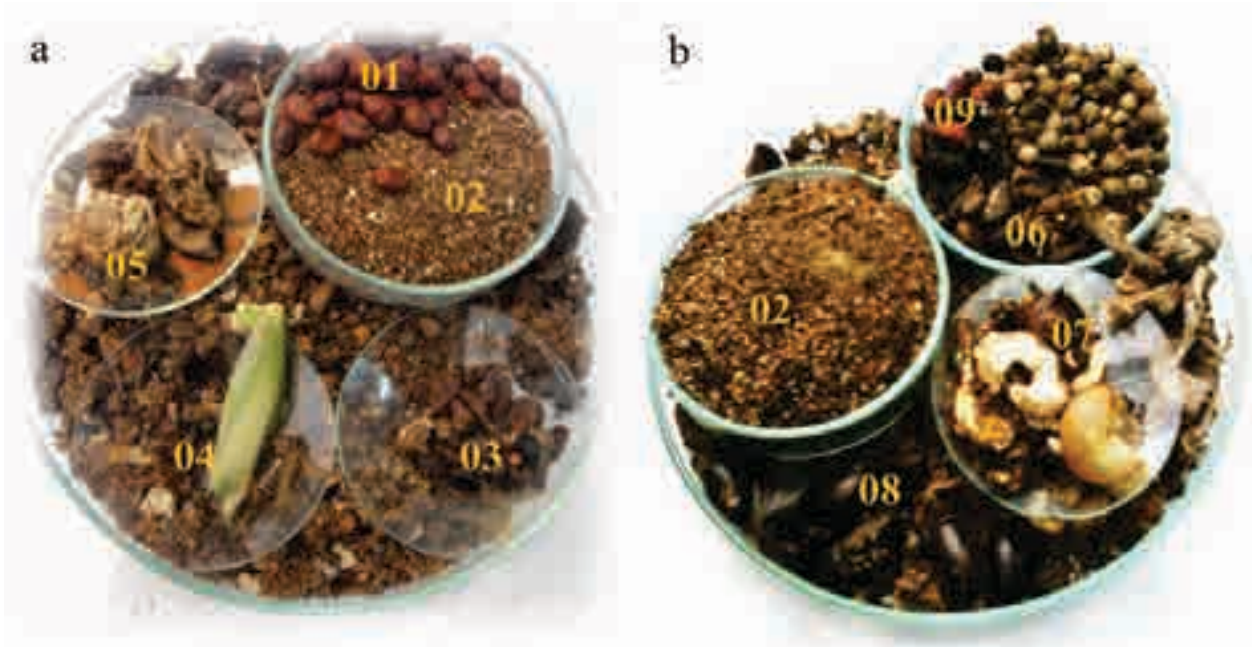

Image 4a–b. Separated fecal samples collected from seed traps during the breeding season: 1—*Ficus decipiens* | 2—*Ficus* spp. (including all types of *Ficus* spp.) | 3—*Manilkara hexandra* | 4—Wings of insects | 5—Wicks of oil lamps | 6—*Drypetes sepiaria* | 7—shells of insects and vertebrate bones | 8—*Stirculia foetida* | 9—*Ptychosperma* sp.

The food selectivity index was calculated for each consumed fruiting species following the FAI values which were calculated monthly based on selected species individually for seven selected important fruiting species (Figure 4). The highest food selectivity index shows *Filicium decipiens* (62.3) and the lowest index shows *Ficus* spp. (0.3). The *Filicium decipiens* and *Ptychosperma* sp. (21.2) were highly selected while *Ficus* spp. and *Manilkara hexandra* (4,112 m^2) were *the* least selected and represented in comparatively larger average basal areas.

There was no significant difference between

nutritional components of preferred fruits and non-foraged fruits (Table 2), except for the moisture, ash, and fiber under the 0.05 significance level. According to the Kruskal-Wallis test for the 10 species for moisture (H = 7.50, p = 0.006), ash (H = 6.07, p = 0.013), & fiber (H = 6.53, p = 0.011) with significant differences, while crude lipid (H = 0.53, p = 0.465), protein (H = 0.00, p = 1.000), and carbohydrate (H = 0.30, p = 0.584) showed no significant difference between values of preferable and non-preferable. Although the results indicate that there was a relatively higher moisture content in eaten fruits than in non-eaten fruits.

Table 1. List of important fruiting species identified as foraged species of Sri Lankan Grey Hornbills according to seed sampling during breeding season and observations from the non-breeding season.

Family	Species
Arecaceae	*Ptychosperma* sp.
Boraginaceae	*Cordia monoica*
Ebenaceae	*Diospyros* sp.
Loganiaceae	*Strychnos nux vomica*
Loganiaceae	*Strychnos potatorum*
Malvaceae	*Sterculia foetida*
Meliaceae	*Azadirachta indica*
Moraceae	*Artocarpus heterophyllus*
Moraceae	*Syzygium cumini*
Moraceae	*Ficus* spp.
Moringaceae	*Moringa oleifera*
Myrtaceae	*Psidium guajava*
Putranjivaceae	*Drypetes sepiaria*
Rhamnaceae	*Ziziphus oenopolia*
Sapindaceae	*Schleichera oleosa*
Sapindaceae	*Filicium decipiens*
Sapotaceae	*Manilkara hexandra*

DISCUSSION

Hornbills gather as groups mostly for foraging. They are usually frugivorous (Kitamura 2011), and seemingly depend on a fruiting diet throughout the year. They have an important ecological role, contributing to forest ecosystems as frugivorous and as seed dispersers by defecating most of the seeds of the plants away from the parental plants (Kitamura 2011). This frugivory is one of the essential processes for plant populations for the dispersal, especially when plant regeneration is strongly dependent on seed dissemination by zoochory (Armesto & Rozzi 1989; Aizen et al. 2002; Cousens et al. 2008; Moran et al. 2009). Three categories of frugivory are described in literature according to the habit of taking fruit: (1) legitimate seed dispersers: swallow the whole fruit, defecating or regurgitating the intact seed (endozoochory); (2) pulp consumers: peck fruits to obtain the pulp, dropping the seed; and (3) seed predators: feed on the seeds, eliminating fruit pulp or swallowing fruits, and digesting the whole content (Jordano 1987; Aizen et al. 2002; Bascompte & Jordano 2007). These species have all types of zoochronous

Table 2. Summary of nutritional values presence within the preferable food and non-eaten food of Sri Lanka Grey Hornbills.

	Moisture (g%)	Crude lipid (g%)	Protein (g%)	Ash (g%)	Fiber (g%)	Carbohydrate (g%)
Preferable (n = 6)						
N	6	6	6	6	6	6
Minimum	58.7	0.352	0.88	0.33	18.75	1.2
Maximum	64.5	7.09	4.03	2.9	34.37	5.2
Mean	61.1	2.8	2.7	1.4	30.5	2.2
SD	2.1	2.2	1.1	0.8	5.5	1.5
Non-preferable (n = 5)						
N	5	5	5	5	5	5
Minimum	2.1	2.2	1.1	0.8	5.0	1.5
Maximum	61.1	5.0	5.0	5.0	30.5	5.0
Mean	13.6	2.0	1.8	1.4	8.2	1.7
SD	27.2	1.2	1.6	1.9	11.9	1.5

*Preferable—*Manilkara hexandra*, *Strychnos nux-vomica*, *Strychnos potatorum*, *Filicium decipiens*, *Drypetes sepiaria*, *Ptychosperma* sp.
*Non-preferable—*Durantha repens*, *Phyllanthus emblica*, *Tamarindus indica*, *Ziziphus oenopyrs*, *Phyllanthus reticulatus*.

Image 5a–h. Foraging behavior of the Sri Lankan Grey Hornbill during the breeding period for nourishing the prisoned family members inside the cavity: a—Carrying a grasshopper | b—spying around the cavity before feeding with a long-horned insect | c—waiting to feed with a fruit to the nesters | d—carrying juvenile bird as a diet | e—carrying an insect | f—female starts feeding juveniles at the end of nesting period | g—carrying a fruit by male | h—carrying an insect diet by male. © Gehan Rajeev.

Image 6. Ripe fruit species used for the nutrient analysis: *P*—Preferable | *A*—(Avoidable) fruit species.

behaviors mentioned above throughout their life cycle but, dietary composition varies due to the stages of their life cycle.

The breeding cycle of SLGH normally includes pre-laying, laying, incubating, and nesting periods. They start nesting in the period March–April (Wickramasinghe et al. 2018; Wijerathne & Wickramasinghe 2018, 2019) where a high FAI index was observed during the study period. But also, these FAI could have been affected by the changes of the climate specially the rainfall.

The selectivity index was calculated directly from the foraged dietary composition, seasonal available fruiting species and the nutrient requirements. Other influential factors were neglected such as potential for competition for resources by other evolutionary closely related species like the Malabar pied hornbills (Gonzalez et al. 2013) which occupy similar ecological niches (MacArthur 1958) in mostly the same geographical distribution.

Considering the selectivity index *Ficus* spp. species didn't perform high in the selectivity index with the availability throughout the year. Due to their asynchronous fruiting, *Ficus* species were considered a keystone plant resource, defined as a reliable food that plays a prominent role in sustaining frugivores through periods of general food scarcity. But this prominent behavior of *Ficus* spp. can be depleted during general periods of food productivity when other species are fruiting abundantly (Lambert & Marshall 1991). The results provide evidence that figs in Mihintale Sanctuary are consumed by the hornbills during both breeding and non-breeding periods. Besides, throughout the breeding season, all the fig species (Image 5a–l) are shown to be the most important in the diet every month for SLGH.

Manilkara hexandra like species bearing high selectivity index but due to seasonal ripening reduce the availability. There are 13 fruiting plant families, out of a total of 23 species present within the area, which are preferred by hornbills. According to the analysis of the FAI, rainfall, and hornbill abundance within the area do not depend on each other. With the effect of climate change, rainfall patterns have changed. Lacking sufficient rainfall at the correct time directly impacts fruiting phenology (Dunham et al. 2018) and fruits ripened earlier than expected. But, the abundance of the flocks does not vary much and fluctuated around a constant range within the study period. Fruit nutrition characteristics of the plant during breeding and non-breeding season are similar, but the nutritional content of eaten and non-eaten food is not similar (Table 2) because hornbills tend to select those fruits with a greater moisture content over those lower moisture fruits. According to the results though the birds should consume less water content to reduce their body weight for flying (Carmi et al. 1992), due to the difficulties that they face with the consumption of water, they tend to consume highly moist fruits to fulfill the moisture requirements of the body. Also, they prefer to have fruits with high fiber and ash content. SLGH fulfills most of the protein requirements of an animal diet (Image 4a–h). Protein demand is very high during the breeding season (Poonswad et al. 2004). Due to the growing requirement of nestlings, SLGH's highest amount of protein provisioning was through the animal's diet and contained both vertebrates and invertebrates. The insect diet supplied particularly good percentages and is a good source of protein. The fecal materials collected from the nesting sites showed carapaces, parts of insects and appendages, mollusk shells, bird bones, feathers, and scales of lizards. *Calotes calotes*, *Schwarzerium* spp. (long-horned beetles) were the most preferred protein-rich diet and were found within the fecal materials (Average 1.38% ± 0.59 from fecal materials) most frequently.

The diversity of fruiting trees within the Mihintale Sanctuary is comparatively high where preferable fig items are present in both forested and adjacent forest boundaries (home gardens). Also, there is no correlation between food availability and selectivity as observed during the study period, which can be used to predict that there is minimum limitation for food selectivity in the Mihintale Sanctuary. The selection of food items by SLGH was directly influenced by the seasonal requirements of lifecycle and they are the largest omnivorous birds present in Sri Lanka. The influence of the morphological characteristics of the food items, changes in the dietary requirements of the lifecycle, and changes in the secretions of the endocrine system are likely factors for the selection of food by these birds and are recommended for further study to gain a better understanding of the physiological and ecological relationships of these birds for conservation across the entire ecological systems.

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Conservation significance of Changaram wetlands - a key wintering site for migratory shorebirds and other waterbirds in the western coast of Kerala, India

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Abstract: Changaram wetland is an important stopover ground for migratory shorebirds, gulls, terns, and other waterbirds in the western coast of Kerala and it encompasses major habitats like exposed mudflats, mangrove fringes, and an agroecosystem. A total of 77 species of waterbirds (shorebirds, large wading birds, gulls, and terns) including long distance migrants, local migrants, and resident species were encountered in our survey carried out during 2018 and 2019. Ten out of these 77 species fall under threatened category in the IUCN Red List and hence the Changaram wetlands demand immediate attention from the conservation perspective. Considering tremendous anthropogenic pressures faced by these wetlands, and the decline in the abundance of waterbirds, a regular system for monitoring the bird population and the wetlands must be deployed for the conservation of the ecosystem and of the birds.

Keywords: Anthropogenic activities, bird population, gulls, mangrove fringes, migrants, mudflats, terns, wading birds.

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INTRODUCTION

Wetlands make up 5–8% of the earth's surface. According to the national wetland inventory and assessment prepared by the Indian Space Research Organization (ISRO), wetlands cover 1,52,600 km^2 (4.63%) of the total land area of India and support one-fifth of the biodiversity (Bassi et al. 2014). Of the total area Inland, natural wetlands make up 43.4% whereas coastal natural wetlands make up 24.3% (SAC 2011; Panigrahy et al. 2012). In the last three centuries, global wetland loss is estimated to be 54–57%, but it might be as high as 87% (Davidson 2014). Scientific estimates show that 64% of the world's wetlands have disappeared since 1900 (Ramsar Fact Sheet 2014) due to human activity & urbanization, which has affected ecosystem health & quality (Ballut-Dajud et al. 2022). It is significant to mention the recent notification (in 2022) of the Government of India to designate more sites into Ramsar wetlands and the total number of Ramsar sites stands at 75, covering an area of about 13,26,677 ha (Government of India website 2022). Over the past 20 years, tidal wetlands have lost 4,000 km^2 of their land area, but ecosystem restoration and natural processes are helping to reverse the trend (Murray et al. 2022).

Kerala stands up among all the states of India in having a large proportion of land under wetlands (Nayar & Nayar 1997) with about 217 wetland areas (Kokkal et al. 2008) which forms one-fifth of the total land area of the state. Prominent coastal wetlands in Kerala are Vellayani Kayal, Aakkulam–Veli backwater stretch, Kayamkulam Pozhi, Kumarakom, Mangalavanam, Kole wetlands, Purathur estuary, Manoorkayal, Chervarpur Kayal, Kadalundi estuary, Dharmadam estuary, Kattampally, Ezhimala, Chemballi Kundu, and mangrove areas (Kurup 1996).

Wetlands provides an excellent habitat for migratory waterbirds and shorebirds, for feeding, nesting, rearing young ones, and as wintering grounds/stopover grounds. The degradation of wetland habitat may cause the water-table to drop, the food chain to get disrupted, eventually migratory bird populations to decline, and the nutrient cycle to slow down, all of which are detrimental to the environment, ecosystem, and human beings (Kumar & Kanaujia 2014). Wetlands in Kerala are under threat due to accelerated developmental activities and indiscriminate land & water use. However, no reports on the precise rate of wetlands destruction in Kerala is available, other than some reports on its qualitative degradation (Kokkal et al. 2008). The major issues leading to wetland degradation are pollution, eutrophication, encroachment, reclamation, mining, and biodiversity loss (Kokkal et al. 2008; Ballut-Dajud et al. 2022). The habitat destruction may lead to a decline in the abundance of shorebirds, as they are the top level predators, and hence they can be considered as bio-indicators of ecosystem health. Thus, understanding the structure of bird community in a habitat is essential to identify the local landscapes for the conservation of avifauna and their ecosystem (Kattan & Franco 2004).

Changaram wetland is an important stopover ground for migratory shorebirds, gulls, terns, and other waterbirds in the west coast of Kerala and it encompasses major habitats like exposed mudflats, mangrove fringes, and an agroecosystem. Hence it draws the attention of conservation biologists to formulate strategies for the protection of this significant ecosystem and its components. Being the ecological indicators, the present study of avifaunal observations from Changaram wetland will serve as baseline data for conservation measures to be taken up in this key wintering site of long-distance migratory shorebirds and other waterbirds in the near future.

MATERIALS AND METHODS

Study Site

Changaram (9.797438°N, 76.28876°E) (Image 1), spreads across 145 acres (57.87 ha) in the Kodamthuruth panchayats of Cherthala Taluk in Alappuzha District, western coast of Kerala. It is a waterlogged, palm fringed village with a narrow strip of land, on the coastal belt, with the Arabian Sea on the west, and Thazhappu Kayal (backwaters) on the east, Ezhupunna wetland on the north, and Pallithodu wetland on the south. Interconnected extensive paddy fields are seen in Changaram wetlands where Pokkali system of agriculture-a single crop of rice is cultivated on mounds during the low saline phase of the production cycle (June–mid October), followed by shrimp farming (*Penaeus monodon, Penaeus semisulcatus*) during the high saline phase (November–April) is practiced (Chandramohanan & Mohanan 2011). Changaram wetland has no direct connection to the estuary so it is barely affected by tidal activity. During shrimp farming, bunds are constructed, and water is pumped into it. After the shrimp culture, the water is drained out exposing the mudflats, which offer potential foraging ground for hundreds of wintering and resident waterbirds, particularly shorebirds. It also serves as an ideal breeding ground for several waterbird species. A short stretch of mangrove forests (major

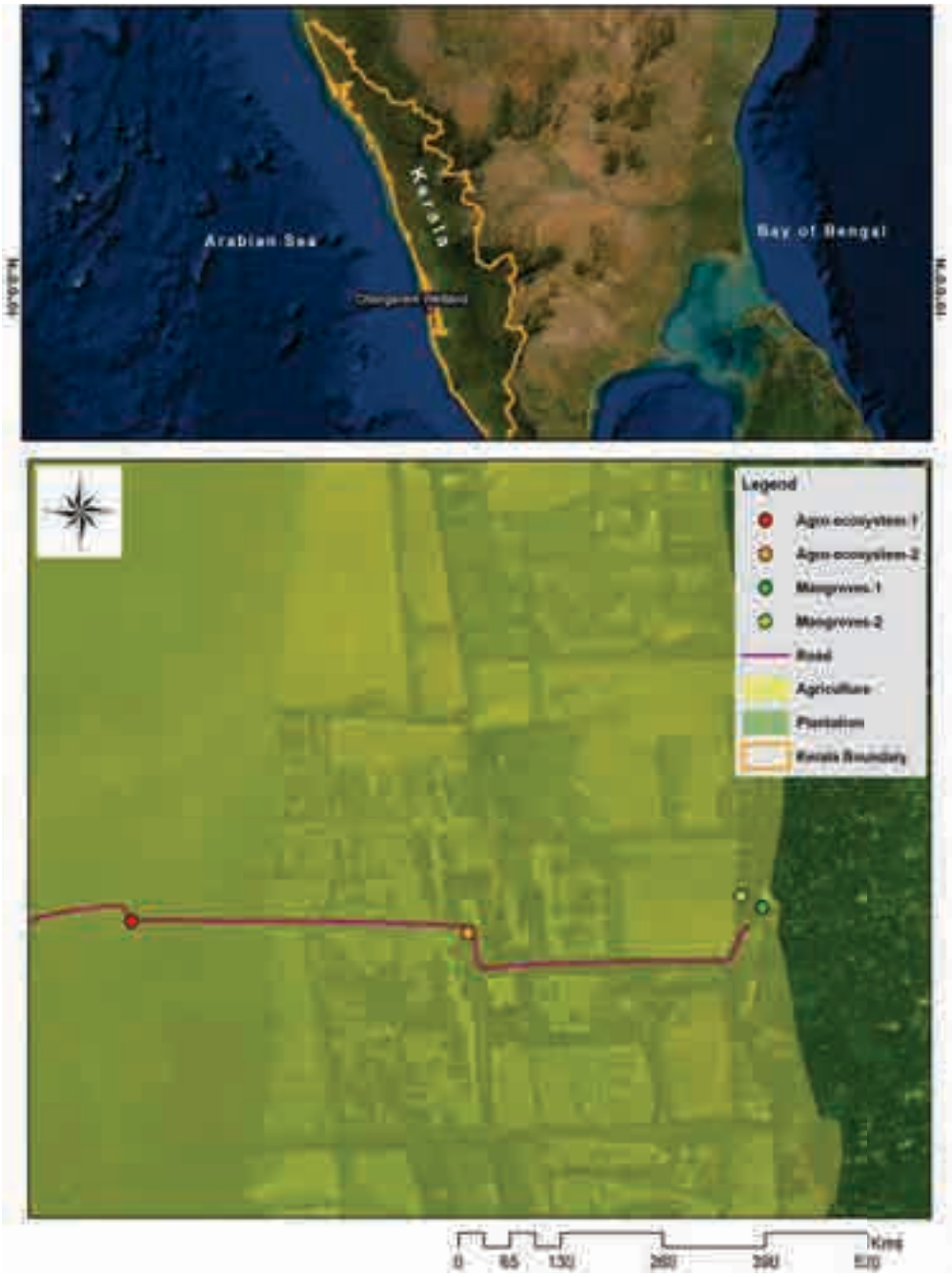

Image 1. Map showing the study area of Changaram wetlands. A total of four scanning points (two each at agroecosystem and mangroves) were selected to carried out the survey during the study period.

species—*Avicennia officinalis*, *Rhizophora mucronata*, *Excoecaria agallocha*, and *Bruguiera cylindrica*) of about 0.607 ha area extends on the edges of the Changaram wetland. The wetland is flanked by coconut trees and populated areas except from intermittent patches of these mangroves.

Methods

Waterbirds survey (including shorebirds, large wading birds, gulls, and terns) was carried out once a month (0700–1100 h) between 2018 and 2019. Observations were made using binoculars (10 x 50 Nikon) and a 4k series Nikon Coolpix p1000 camera. Data was collected following direct count (Howes & Bakewell 1989) and block count methods (Jadhav & Parasharya

2004; Urfi 2004). Shorebirds were encountered at four scanning points (Image 1) in both agro-ecosystem and mangroves which covered the whole area. The observations recorded while moving from one scanning point to another were entered as incidental records.

The status of waterbirds based on the frequency of sightings were categorized into Common (seen during most of the visits), Uncommon (seen less than five times), and Rare (seen once or twice). Migratory statuses of waterbirds were classified into Resident but not breeding (R/B—Resident but not breeding, which means, those birds are breeding at adjoining areas of the study site), Local Migrant (LM—Locally migrant, which means birds are breeding within the country), Breeding (Br—Breeding, means commonly or uncommonly breeding in the study site) and Winter Visitor (WV—Winter Visitor, birds visiting from another region or other countries) (Mc Kinnon & Philips 1993; Aarif et al. 2017a). The species-level identification was done with the help of a field guide (Grimmet et al. 1999) and based on our field experience.

RESULTS AND DISCUSSION

The total count of waterbirds during the year 2018 was 20,100_individuals and that of the year 2019 was 18,600 individuals. 77 species were identified from this fragile ecosystem. Among the 77 species recorded, 38 species of shorebirds, 23 species of other waterbirds (large wading birds), five species of gulls, and 11 species of terns were also recorded from the study area (Table 1–3). Among the shorebirds listed, 31 species were winter visitors, two species— Kentish Plover *Charadrius alexandrinus* and Great Thick-knee *Escacus recurvirostris* were local migrants, three species were resident but not breeding, and the two remaining species were breeding. Further, 16 species of shorebirds were common, three species were uncommon, and the remaining 19 species were classified as rare (Table 1). The most dominant species among the observed shorebirds was the Black-tailed Godwit *Limosa limosa* (Peak count at one time—2,534 in April) followed by Wood Sandpiper *Tringa glareola* (Peak count at one time—1,123 in May).

IUCN listed Near Threatened shorebird species recorded from the study area included, Bar-tailed Godwit *Limosa lapponica,* Black-tailed Godwit, Curlew Sandpiper *Calidris ferruginea*, Eurasian Curlew *Numenius arquata,* Asian Dowitcher *Limnodromus semipalmatus* (Image 2), Great Thick-knee, and one endangered species, Great Knot *Calidris tenuirostris*.

Among the 23 species of waterbirds listed, 18 species were most common, three species were uncommon, and two species were rare (Table 2). The most dominant waterbird species identified were, Median Egret *Ardea intermedia,* Little Egret *Egretta garzetta,* Great Egret *Ardea alba,* Little Cormorant *Microcarbo niger,* and Indian Pond Heron *Ardeola grayii.* Four other waterbirds species reported, having Near Threatened status are: Oriental Darter *Anhinga melanogaster*, Black-headed Ibis *Threskiornis melanocephalus*, Painted Stork *Mycteria leucocephala*, and Spot Billed Pelican *Pelecanus philippensis* (Table 2).

Apart from the shorebirds and waterbirds, five species of Gulls *viz.* Slender-billed Gull *Chroicocephalus genei*, Black-headed Gull *Chroicocephalus ridibundus*, Brown headed Gull *Chroicocephalus brunnicephalus*, Pallas's Gull *Ichthyaetus ichthyaetus,* and Lesser Black-backed Gull *Larus fuscus* were documented from this site. Of these, the most dominants ones were Black-headed Gulls and Brown-headed Gulls. Further, 11 species of terns, viz., Little Tern *Sternula albifrons*, Gull-billed Tern *Gelochelidon nilotica*, Caspian Tern *Hydroprogne caspia*, Whiskered Tern *Chlidonias hybrida*, Common Tern *Sterna hirundo*, Greater-crested Tern *Thalasseus bergii*, Lesser-crested Tern *Thalasseus bengalensis*, Sandwich Tern *Thalasseus sandvicensis*, Saunders Tern *Sternula saundersi*, White-winged Tern *Chlidonias leucopterus,* and River Tern *Sterna aurantia* were also encountered (Table 3). Whiskered Tern being the most dominant species of tern throughout the study period. Black-headed Gull, Brown-headed Gull, Little Tern, and Gull-billed Tern encompassed the other dominant species, coming under the Laridae family, reported from the study site. This observation goes in parallel with the report from KVCR (Aarif et al. 2015; Aarif et al. 2017c).

A total of two species of shorebirds; Black-winged Stilt *Himantopus himantopus* & Red-wattled Lapwing *Vanellus indicus* and 10 species of waterbirds, viz., Oriental Darter, Little Cormorant, Great Cormorant *Phalacrocorax carbo,* Indian Cormorant *Phalacrocorax fuscicollis,* Little Egret, Great Egret, Median Egret, Indian Pond Heron, Purple Heron *Ardea purpurea*, and Spot-billed Pelican were observed regularly to be breeding in Changaram wetlands. Further, due to the presence of mangrove fringes, this Changaram wetlands serves as a key foraging and roosting ground for these shorebirds and other waterbirds. A similar observation was documented from KVCR (Aarif et al. 2011, 2014).

Most of the shorebird species were documented during their northward return migratory season, i.e., March, April, and May, while some other shorebird

Table 1. List of shorebirds identified from Changaram wetland.

	Common name	Scientific name	Species status in Changaram wetland	Migratory status	IUCN Red List status	Peak count at one time observation
1	Black-tailed Godwit	*Limosa limosa* (Linnaeus, 1758)	Common	WV	NT	2534
2	Wood Sandpiper	*Tringa glareola* (Linnaeus, 1758)	Common	WV	LC	1123
3	Lesser Sand Plover	*Charadrius mongolus* (Pallas, 1776)	Common	WV	LC	508
4	Marsh Sandpiper	*Tringa stagnatilis* (Bechstein, 1803)	Common	WV	LC	85
5	Black -winged Stilt	*Himantopus himantopus* (Linnaeus, 1758)	Common	Br	LC	395
6	Pacific Golden Plover	*Pluvialis fulva* (Gmelin, 1789)	Common	WV	LC	240
7	Curlew Sandpiper	*Calidris ferruginea* (Pontoppidan, 1763)	Common	WV	NT	154
8	Greater Sand Plover	*Charadrius leschenaultii* (Lesson, 1826)	Common	WV	LC	112
9	Little Stint	*Calidris minuta* (Leisler, 1812)	Common	WV	LC	67
10	Little-ringed Plover	*Charadrius dubius* (Scopoli, 1786)	Common	WV	LC	61
11	Common Greenshank	*Tringa nebularia* (Gunnerus, 1767)	Common	WV	LC	60
12	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	Common	Br	LC	30
13	Pied Avocet	*Recuvirostra avosetta* (Linnaeus, 1758)	Rare	WV	LC	3
14	Kentish Plover	*Charadrius alexandrinus* ((Linnaeus, 1758)	Rare	LM	LC	5
15	Whimbrel	*Numenius phaeopus* (Linnaeus, 1758)	Uncommon	WV	LC	30
16	Common Redshank	*Tringa totanus* (Linnaeus, 1758)	Common	WV	LC	32
17	Broad-billed Sandpiper	*Limicola falcinellus* (Pontoppidan, 1763)	Rare	WV	LC	7
18	Common ringed Plover	*Charadrius hiaticula* (Linnaeus, 1758)	Rare	WV	LC	12
19	Ruff	*Calidris pugnax* (Linnaeus, 1758)	Rare	WV	LC	9
20	Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)	Common	WV	LC	26
21	Temminck's Stint	*Calidris temminckii* (Leisler, 1812)	Rare	WV	LC	25
22	Pin-tailed Snipe	*Gallinago stenura* (Bonaparte, 1831)	Common	WV	LC	3
23	Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	Common	WV	LC	7
24	Eurasian Curlew	*Numenius arquata* (Linnaeus, 1758)	Rare	WV	NT	56
25	Ruddy Turnstone	*Arenaria interpres* (Linnaeus, 1758)	Rare	WV	LC	3
26	Terek Sandpiper	*Xenus cinereus* (Güldenstädt, 1775)	Rare	WV	LC	5
27	Green Sandpiper	*Tringa ochropus* (Linnaeus, 1758)	Uncommon	WV	LC	7
28	Grey Plover	*Pluvialis squatarola* (Linnaeus, 1758)	Rare	WV	LC	2
29	Great Knot	*Calidris tenuirostris* (Horsfield, 1821)	Rare	WV	EN	1
30	Sanderling	*Calidris alba* (Pallas, 1764)	Rare	WV	LC	3
31	Bar-tailed Godwit	*Limosa lapponica* (Linnaeus, 1758)	Rare	WV	NT	1
32	Greater Painted Snipe	*Rostratula benghalensis* (Linnaeus, 1758)	Rare	R/B	LC	5
33	Long-toed Stint	*Calidris subminuta* (Middendorff, 1853)	Rare	WV	LC	10
34	Spotted Redshank	*Tringa erythropus* (Pallas, 1764)	Rare	WV	LC	5
35	Great Thick-knee	*Escacus recurvirostris* (Cuvier, 1829)	Rare	LM	NT	1
36	Asian Dowitcher	*Limnodromus semipalmatus* (Blyth, 1848)	Rare	WV	NT	1
37	Oriental Pratincole	*Glareola maldivaraum* (Forster, 1795)	Rare	WV	LC	1
38	Yellow-wattled Lapwing	*Vanellus malabaricus* (Boddaert, 1783)	Uncommon	LM	LC	1

WV—Winter visitor | LM—Locally migrant | R/B—Resident but not breeding in our study area | Br—Breeding.

Table 2. List of large wading birds recorded from Changaram wetland.

	Common name	Scientific name	Species status in Changaram wetland	IUCN Red List status	Migratory status
1	Oriental Darter	*Anhinga melanogaster* (Pennant, 1769)	Common	NT	Br
2	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	Common	LC	Br
3	Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	Rare	LC	LM
4	Indian Cormorant	*Phalacrocorax fuscicollis* (Stephens, 1826)	Common	LC	Br
5	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	Common	LC	Br
6	Great Egret	*Ardea alba* (Linnaeus, 1758)	Common	LC	Br
7	Median Egret	*Ardea intermedia* (Wagler, 1827)	Common	LC	Br
8	Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	Common	LC	Br
9	Grey Heron	*Ardea cinerea* (Linnaeus, 1758)	Common	LC	LM
10	Purple Heron	*Ardea purpurea* (Linnaeus, 1766)	Common	LC	Br
11	Little -green Heron	*Butorides virescens* (Linnaeus, 1758)	Common	LC	LM
12	Black- crowned Night Heron	*Nycticorax nycticorax* (Linnaeus, 1758)	Common	LC	R/B
13	Western- reef Heron	*Egretta gularis* (Bosc, 1792)	Common	LC	LM
14	Yellow Bittern	*Ixobrychus sinensis* (Gmelin, 1789)	Common	LC	R/B
15	Black-headed Ibis	*Threskiornis melanocephalus* (Latham, 1790)	Common	NT	LM
16	Glossy Ibis	*Plegadis falcinellus* (Gmelin, 1789)	Common	LC	LM
17	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	Common	LC	Br
18	Greater Flamingo	*Phoenicopterus roseus* (Pallas, 1811)	Uncommon	LC	LM
19	Lesser Flamingo	*Phoeniconaias minor* (Geoffroy Saint-Hilaire, 1798)	Rare	LC	LM
20	Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	Uncommon	NT	LM
21	Eurasian Spoonbill	*Platalea leucorodia* (Linnaeus, 1758)	Uncommon	LC	LM
22	Asian openbill Stork	*Anastomus oscitans* (Boddaert, 1783)	Common	LC	LM
23	Spot–billed Pelican	*Pelecanus philippensis* (Gmelin, 1789)	Common	NT	LM

Common (seen on most of the visits) | Uncommon (seen less than five times) | Rare (seen once or twice).

species were found over-summer in small numbers during June and July in the study area. The over-summering shorebirds were Black-tailed Godwit, Common Sandpiper *Actitis hypoleucos*, Wood Sandpiper, Marsh Sandpiper *Tringa stagnatilis*, and Pacific Golden Plover *Pluvialis fulva.* Similarly, several over-summering species have been reported from KVCR and it was pointed out that the over-summering birds were either juveniles or adults which were physically or sexually unfit (Aarif et al. 2017a, 2020). Hence it can be elucidated that the over-summering shorebirds are provided with food resources and shelter in the habitat, throughout the year.

CONSERVATION ISSUES

Many long-distance migrant shorebirds are well known to be highly reliant on a series of key stop-over sites between wintering and breeding grounds (Boere et al. 2006). As it is home to several important long-distance migrant species, the link between this coastal wetland and many other major shorebird habitats within India and other countries along the Central Asian Flyway must be unraveled through regular and systematic monitoring.

Thousands of migratory waterbirds use the western coast of India as a refuge during the winter, yet there are only a few systematic studies that are reported from KVCR in Kerala State (Aarif et al. 2014, 2020, 2021a; Athira et al. 2022; Rashiba et al. 2022) and Sindhudurg District of Maharashtra State (Rao et al. 2022), that provide data on continuous population monitoring. The ability of the migratory shorebirds to live in varied coastal environments makes them a global indicator species for any changes in habitat (Piersma & Lindstrom 2004).

For long-distance migrant shorebirds, the ecological quality of wintering grounds appears to be of key importance (Aarif et al. 2014, 2021a) and in the west coast, this quality is greatly affected by environmental

Table 3. List of gulls and terns recorded from Changaram wetland.

	Common name	Scientific name	Species status in Changaram wetland	IUCN Red List status	Migratory status
1	Slender-billed Gull	*Chroicocephalus genei* (Breme, 1839)	Uncommon	LC	WV
2	Black-headed Gull	*Chroicocephalus ridibundus* (Linnaeus, 1766)	Uncommon	LC	WV
3	Brown-headed Gull	*Chroicocephalus brunnicephalus* (Jerdon, 1840)	Uncommon	LC	WV
4	Palla's Gull	*Ichthyaetus ichthyaetus* (Pallas, 1773)	Uncommon	LC	WV
5	Lesser-black backed Gull	*Larus fuscus* (Linnaeus, 1758)	Uncommon	LC	WV
6	Little Tern	*Sternula albifrons* (Pallas, 1764)	Uncommon	LC	WV
7	Gull-billed Tern	*Gelochelidon nilotica* (Gmelin, 1789)	Uncommon	LC	WV
8	Caspian Tern	*Hydroprogne caspia* (Pallas, 1770)	Uncommon	LC	WV
9	Whiskered Tern	*Chlidonias hybrida* (Pallas, 1811)	Common	LC	WV
10	Common Tern	*Sterna hirundo* (Linnaeus, 1758)	Uncommon	LC	WV
11	Greater-crested Tern	*Thalasseus bergii* (Lichtenstein, MHC, 1823)	Uncommon	LC	WV
12	Lesser-crested Tern	*Thalasseus bengalensis* (Lesson, 1831)	Uncommon	LC	WV
13	Sandwich Tern	*Thalasseus sandvicensis* (Latham, 1787)	Uncommon	LC	WV
14	Saunders Tern	*Sternula saundersi* (Hume, 1877)	Uncommon	LC	WV
15	White-winged Tern	*Chlidonias leucopterus* (Temminck, 1815)	Uncommon	LC	WV
16	River Tern	*Sterna aurantia* (J.E. Gray, 1831)	Common	VU	LM

Common (seen on most of the visits) | Uncommon (seen less than five times) | Rare (seen once or twice).

Image 2. Mixed flocks (Lesser Sand Plover and Curlew Sandpiper) of shorebirds from Changaram wetland. © S. Abhijith

Image 3. Asian Dowitcher (rarely seen) from Changaram wetland. © S. Abhijith

threats due to tremendous anthropogenic pressures—e.g., habitat destruction and organic solid waste dumping (Aarif et al. 2014, 2020, 2021a). Therefore, it is imperative that continuous monitoring throughout the wintering season should be undertaken in this wetland too.

Changaram wetland is under tremendous anthropogenic pressures like plastic litter dumping, habitat incursion leading to alterations, also left-over nettings & plastic traps from shrimp farming, which may lead to bird injury (Aarif & Prasadan 2014; Aarif et al. 2021b) and thus the reduction of waterbirds. While the mudflats exposed after shrimp farming serve as ideal foraging grounds for wading birds, the left-over synthetic fiber threads pose a constant danger to waterfowls, as reported from KVCR (Aarif et al. 2011, 2014). Proactive steps, to alleviate these man-made impacts, like timely removal of discarded fishing accessories and spurious remains from wetlands may abate migratory bird injuries (Aarif et al. 2021b). Other threats include electrocution, feral predators like cats and stray dogs, as reported elsewhere (Blancher 2013).

CONCLUSION

To sum up, this study may be a trailblazer as there is no other systematic investigation reported from Changaram wetland and adjoining areas till date. This could serve as a baseline information in assessing population trends, dynamics, and habitat use of regular winter migrant shorebirds and other waterbirds from the area. Regular long-term monitoring and assessment should be conducted in future so as to establish the importance of this wetland in the world avian map. Further, the local community inhabiting the area may be given awareness of the importance and need for maintaining and conserving a healthy ecosystem. Nevertheless, this study provides the first comprehensive baseline data of selected shorebirds and other waterbirds from Changaram wetland and would be extremely helpful for future research in this site and for upholding the need of designating this as an area of conservation importance.

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COMMUNICATION

Long-term monitoring of pelicans in National Chambal Sanctuary, India

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Abstract: Monitoring of Gharial *Gavialis gangeticus* in National Chambal Sanctuary (NCS) since 1983 has resulted in collection of data on other ecological associates, located between 25.8474–26.4389 °N, 76.5645–79.2132 °E. One such beneficiary of this long term monitoring program are the pelicans, locally called 'Hawaseel'. Pelican species visiting Chambal from November to March include the Dalmatian *Pelecanus crispus*, Great White *Pelecanus onocrotalus*, and Spot-billed *Pelecanus philippensis*. Species-wise separation of pelicans at the sites of congregation is often difficult. The total number of pelicans counted during the annual census from 2003 to 2016 was 4,429. The study area extends over 435 km comprising 12 study zones, 99% counts were made in the study zones X, XI and XII. These zones stretch over 115 km that occur near the confluence of Chambal with river Yamuna. Here, the river is deep. Other large birds seen with the pelican squadrons are groups of Cormorant *Phalacrocorax carbo*, Painted Stork *Mycteria leucocephala*, Nakta or Comb Duck *Sarkidiornis melanotos*, and the Greylag Goose *Anser anser*. Other large birds seen on the riverbanks were the Common Crane *Grus grus*, Sarus Crane *Grus antigon*, Greater Flamingo *Phoenicopterus* species, and Demoiselle Crane *Grus virgo*. The study provides a baseline about the population of pelicans and the availability of large wetland birds in NCS. The biodiversity significance of NCS got highlighted because of the ongoing gharial conservation programme. The Chambal River Sanctuary is a composite unit of several un-notified 'core areas'. The sanctuary fulfills six of the nine criteria for possible consideration as an international Ramsar Wetland.

Keywords: Dalmatian Pelican, Great White Pelican, Spot-billed Pelican, river Chambal, river Yamuna.

सार: राष्ट्रीय चंबल अभयारण्य के आर्द्रभूमि आवास में घड़ियाल की निगरानी के दौरान पेलिकन समेत अन्य पारिस्थितिक सहयोगियों के डेटा संगृहीत हुए थे। इस अंचलमे सभी जातिके पेलिकन को 'हवासील' कहा जाता है । पक्षि मण्डली की साइट पर, क्योंकि प्रजातियों को अलग करना मुश्किल है, इस रिपोर्ट में 2003-2016 के दौरान संगृहीत सभी तीन पेलिकन प्रजातियों की कुल संख्या पर डेटा का उपयोग किया गया है। 2003-2016 के दौरान कुल पेलिकन संख्या 4429 थी, जो संख्या 1147 (26%) के साथ वर्ष 2008 में सबसे अधिक थी। 2013 से पेलिकन की संख्या में वृद्धि की प्रवृत्ति है। यमुना नदीसे मिलने पूर्व तीन अध्ययन क्षेत्रों अर्थात, जोन X, XI और XII में अधिकतम संख्या 4375 (99%) थी। हमारे वार्षिक सर्वेक्षण के दौरान हम, Nakta या कोम्ब बतख (*Sarkidiornis melanotos*), जलकाग के समूहों, (*Phalacrocorax carbo, Phalacrocorax fuscicollis*), चित्रित सारस (*Mycteria leucocephala*) और Grey-lag goose (*Anser anser*) फोटो दस्तावेज बनाया है । इसी दौरान नदी किनारे द्रश्यमान अन्य प्रजातिके बड़े पक्षियों में शामिल है Common Crane (*Grus grus*), Sarus Crane (*Grus antigon*), Greater Flamingo (*Phoenicopterus species*), and Demoiselle Crane (*Grus virgo*) । हम राजस्थान, मध्य प्रदेश और उत्तर प्रदेश को शामिल करते हुए भारत के एक त्रि-राज्य रामसर स्थल (Ramsar site) के रूप में चंबल नदी पर बेहतर ध्यान देने की आवश्यकता पर प्रकाश डालते हैं। अंतर्राष्ट्रीय मान्यता के साथ, यह उम्मीद की जाती है कि चंबल के आर्द्रभूमि जीवों पर अध्ययन जो हमने 1983 में भारत सरकार के आदेश पर शुरू किया था, नए सिरे से जारी रहेगा। वर्तमान अध्ययन का उद्देश्य दलील को मजबूत करना है।

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INTRODUCTION

The erstwhile Central Crocodile Breeding and Management Training Institute (CCBMTI) of the Government of India established a Field Research Camp in the campus for gharial project of Madhya Pradesh at village Deori in Morena district. The purpose was to conduct studies on the population of Gharial that was assisted through conservation measures in National Chambal Sanctuary (NCS) since 1978 (Singh 1985, 1999; Bustard 1999).

The camp operated in NCS during 1983–85, but the field work continued in the sanctuary till 2016 by the Madhya Pradesh Forest Department. These exercises helped in understanding the population status and trends of Gharial, Mugger Crocodile *Crocodylus palustris*, Gangetic Dolphin *Platanista gangetica*, river turtles, Indian Skimmer birds *Rynchops albicollis*, five species of storks and thirty species of raptors (Singh 1985; Rao & Singh 1987a,b,c; Sharma & Singh 1986, 2014, 2015, 2018; Singh & Sharma 2018; Singh et al. 2022).

Three species of Pelicans, discussed in the present article, were also sighted and counted during annual surveys for gharial in NCS from 2003 to 2016. The species are the Great White Pelican (GWP), Dalmatian Pelican (DP), and the Spot-billed Pelican (SBP). The IUCN Red List status of DP and SBP is NT (Near Threatened) and GWP is LC (Least Concern) (Birdlife International 2021). This article intends to record the biodiversity significance of NCS in terms of temporal and spatial occurrence of pelicans, locally known as 'Hawaseel'.

STUDY AREA

River Chambal included under wetland types 11 (rivers, streams – slow-flowing, lower perennial) & 12 (rivers, streams – fast-flowing, upper perennial) (Scott 1989). It is in the semi-arid zone of northwestern India. It is a clear, perennial, and fast flowing river which origins in the Vindhyan range of Madhya Pradesh. The gharial population in Chambal was highlighted in 1974 when the national crocodile survey was conducted (FAO 1974). Notification of the NCS along the river Chambal came in phases from 1978 onwards. A stretch of about 572 km of Chambal sanctuary flows through the states of Rajasthan, Madhya Pradesh (MP) and Uttar Pradesh (UP). Beyond Bhareh in Etawah District of Uttar Pradesh, Chambal forms the Pachhnada confluence with the rivers Yamuna, Kunwari, Sind, and Pahuj.

The updated status given for Important Bird Areas (IBA 1999) in Madhya Pradesh, covers our study area in river Chambal in the IBA site category A1 and A4iii (Rahmani et al. 2016). Some of the important birds of Chambal and their IUCN status are given here. The species include Red-headed Vulture *Sarcogyps calvus* (CR—Critically Endangered), Black-bellied Tern *Sterna acuticauda* (EN—Endangered), Indian Skimmer *Rynchops albicollis* (EN), River Tern *Sterna aurantia* (VU—Vulnerable), Painted Stork *Mycteria leucocephala* (NT), Black-necked Stork *Ephippiorhynchus asiaticus* (NT), Black-headed Ibis *Threskiornis melanocephalus* (NT), Oriental Darter *Anhinga melanogaster* (NT), Great Thick-knee *Esacus recurvirostris* (NT), River Lapwing *Vanellus duvaucelii* (NT), Laggar Falcon *Falco jugger* (NT), Eurasian Curlew *Numenius arquata* (NT), other rarely seen birds like Great Crested Grebe *Podiceps cristatus* (LC), and the Common Merganser *Mergus merganser* (LC).

MATERIALS AND METHODS

Survey years and data

Annual surveys of Chambal were made ever since 1983 (Supplementary Table A and Table 1). The surveys were conducted from mid-December to mid-February. In specific, the pelican counts were continuously recorded during the years 2003 to 2016, and have been used for understanding their spatial and temporal characteristics. Although three pelican species were visiting Chambal (Images 2–6), it was difficult to segregate them and make species wise separate counts. Therefore, the data was analysed for total pelican counts (Table 1).

Equipment

The survey facilities included an aluminium boat with outboard engines issued by the FAO component of the conservation scheme. These were available round the year with NCS, MP since 1983. One YAMAHA 20 HP engine was used for normal movement, and a 5 HP outboard remained standby. During the survey the motorboat speed was kept at the minimum, depending on the demands for observation and navigability of the river. The accelerator to the engine didn't have calibration expressing speed in terms of km/hour. Several stretches were also covered on foot by walking along the riverbank. To go beyond rapids or the Rahu water fall, the boat and other equipment were hand lifted from negotiable point. Pelicans were counted with the help of a pair of binoculars (Canon image stabilizer 10x30 IS). Occasionally, a spotting scope (Fujinon Japan super field scope 60-5) was used.

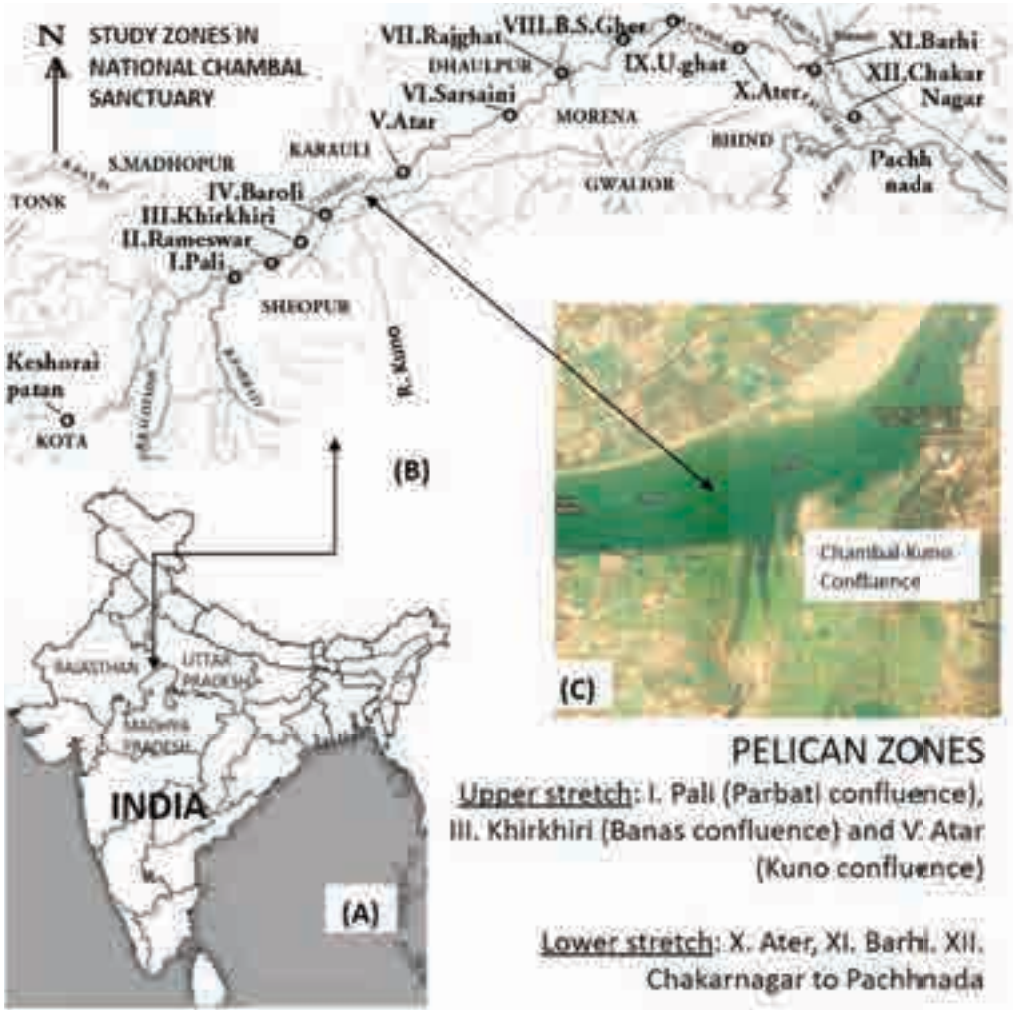

Image 1. A—Map of India | B—showing National Chambal Sanctuary with Pelican zones spread in 12 Study Zones, as observed during 2003–2016 | C—The confluence of rivers like Kuno provide good depth of water for pelican.

Survey team

The survey team comprised of five persons. Two of these were boatmen, one for the outboard engine and the other for manual rowing, with help from all when needed. Three research persons were in the team for identification and record of data. One of the researchers recorded all data exclusively related to birds.

Survey hours

The team moved and made observations during the day. The actual survey hours per day was variable and usually after 0900 h in the morning when fog cleared, and there was good visibility from a distance. A survey day lasted till about an hour before sunset when camping arrangements had to be made before it was dark. Night camps were made on the river bank, or a village overlooking the river. As per a tentative itinerary agreed from the beginning, the research Land Rover or a four-wheel jeep of the state government was usually available in some close by village in Madhya Pradesh. The vehicle could come to the riverside village only at a few locations.

Data sheets

The 435 km stretch of the river from Pali up to Pachhnada, was divided into twelve study zones (I through XII), starting from Palighat in Rajasthan up to Pachhnada in UP. The zones are name-based and easily identifiable (Image 1, Table 1) by the staff and local people. From 2003 onwards, Garmin GPS sets were introduced in the field. Instead of the coordinate values, the authors have retained the use of the names of locations. Most of these names were identifiable over topographic sheets issued by the Survey of India.

For daily use during the survey, observation sheets were prepared on A4 paper using map copies of 5-km

stretches from the toposheets. Data on pelican and other species were recorded directly on the observation sheets. It showed the exact locations where sightings were made. The protocol of the field survey was based on descriptions given in Singh (1985) for gharial, mugger, turtles, dolphin and all bird species. Birds were identified according to the procedure and description given in Ali (1979, 2002), Grimmett et al (2011), and Gill et al (2021).

RESULTS

Pelicans in different study years (Table 1, Figure 1)

The total number of pelicans counted during 2003–2016 was 4,429. The highest count was in the year 2008 with 1,147 or 26% of total counts. Although, there is no consistency in the year wise counts, from 2013 there is an increasing trend in the number of pelicans. The trend increased from 110 in 2013 to 788 in 2016.

Pelicans in different study zones (Table 1)

In the last three study zones, i.e., zone X, XI and XII the count was the maximum, totalling 4,375 (99%) out of 4,429. The counts were 71 in the study zone-X (Ater-Barhi), 784 in zone-XI (Barhi-Chakarnagar) and 3,520 in zone-XII (Chakarnagar-Pachhnada). Other than these, in study zone-I (Pali-Rameshwar) 19 pelicans were counted during the study period. But there were no pelicans observed here during the past five years (Table 1). Besides study zone I, the zones III (Khirkhiri-Baroli), and V (Atar-Sarsani) also featured with occasional counts.

Photo documentation of other wetland birds (Images 7–13)

In the course of our annual survey, we photo documented the pelican squadrons while they shared the habitat with groups of Great Cormorants, Painted Stork, Nakta or Comb Duck, Greylag Goose, Common Crane, Sarus Crane, and Greater Flamingos. The Demoiselle Crane were recorded in the beginning years of our observations (Sharma & Singh 1986). However, in the more recent years they were seen in Chambal only for a few days at the start of winter.

Table 1. Numbers of pelicans counted in 12 different study zones of National Chambal Sanctuary during 2003–2016. The data shows the total of all three species namely, Dalmatian Pelican (DP) and Great White Pelican (GWP), with occasional Spot-billed Pelican (SBP). The species-wise details from 1983–1997 is presented in Supplement Table A.

	I. Pali-Rameshwar (22)	II. Rameshwar-Khirkhiri (15)	III. Khirkhiri-Baroli (20)	IV. Baroli-Atar (48)	V. Atar-Sarsani (65)	VI. Sarsaini-Rajghat (35)	VII. Rajghat-BabusinghGher (35)	VIII. BabusinghGher-Usedghat (40)	IX. Usedghat-Ater (40)	X. Ater-Barhi (40)	XI. Barhi-Chakarnagar (38)	XII. Chakarnagar-Pachnada (37)	Total (435 km)
YEAR	Total number of pelicans in different Study Zones												
2003			13	-	-	-	-	-	3	12	80	-	108
2004	12	-	-	-	-	-	-	-	-	-	-	-	12
2005	-	-	-	2	6	-	-	-	-	6	14	-	28
2006	-	-	-	-	-	-	-	2	-	-	-	-	2
2007	-	-	-	-	-	-	-	-	-	-	-	407	407
2008	2	-	-	-	-	-	-	-	-	21	469	655	1147
2009	-	-	-	-	-	-	-	-	-	32	45	156	233
2010	1	-	-	-	6	-	-	-	-	-	50	214	271
2011	4	-	-	-	-	-	-	-	-	-	12	0	16
2012	-	-	-	-	2	-	-	-	-	-	-	0	2
2013	-	-	-	-	-	-	-	-	-	-	110	0	110
2014	-	-	-	-	-	-	-	1	-	-	4	529	534
2015	-	-	-	-	-	-	-	-	-	-		771	771
2016	-	-	-	-	-	-	-	-	-	-	-	788	788
Total	19	0	13	2	14	0	0	3	3	71	784	3520	4429

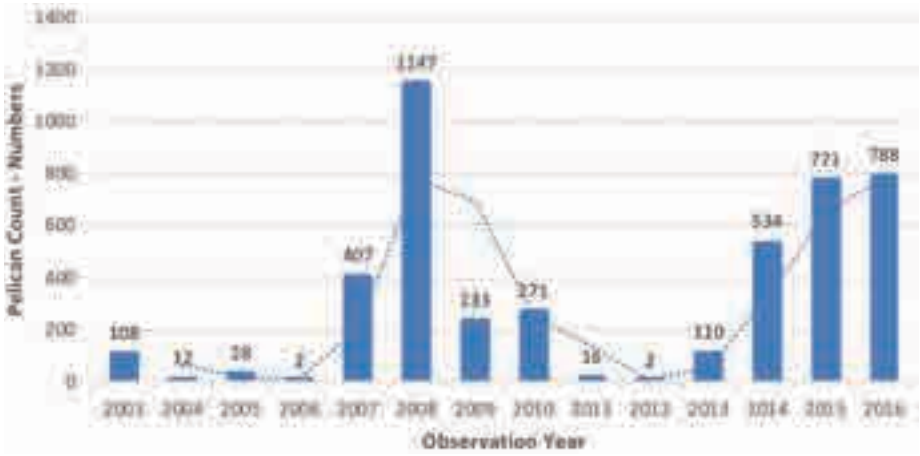

Figure 1. Total numbers of pelican counted in National Chambal Sanctuary during 2003–2016 with trendline showing moving average.

Image 2. A squadron of pelicans in National Chambal Sanctuary. © R.K. Sharma.

Image 3. Morphological variations among pelicans seen: A—darker legs and darker plumage on lower back to posterior end | B—dull underparts and legs. © R.K. Sharma.

DISCUSSION

Spatial occupation

Pelicans appear to have preferred the study zones X, XI, and XII which is a stretch of 115 km from Ater to Pachhnada. Majority of the counts, i.e., 99% were recorded here. In this stretch, the water course is deep. In the region around the confluence of Chambal with Yamuna, nylon set netting for fishing exists in deep water, but killing of pelicans is not confirmed. In upper stretches of Chambal, the appearance of pelicans in study zones I (Pali-Rameshwar), III (Khirkhiri-Baroli), and V (Atar-Sarsani) appear to be due to the conditions created at the confluences of rivers Parbati, Banas, Seep and Kuno. Here, the water depth and food availability are better. It is possible that the pelicans have avoided the stretches where adult breeding Gharials are present. These aspects need to be further studied.

Migration of pelicans to Chambal

Of the roughly 1,220 regularly occurring species of birds in India, 280 are long distance migrants, 116 are migrants within the subcontinent, and the remaining species are residents, either sedentary or showing local movements (State of Indian Birds 2020). Out of 310 species of wetland birds in India 107 species are winter migrants (Kumar et al. 2005). The sighting of pelicans in river Chambal may be due their local migration.

The Spot-billed Pelican (SBP) is a resident and local migrant species breeding in Brahmaputra valley and a few other locations in southern India. Some of the locations in Andhra Pradesh are the deltas of Krishna and Godavari. A famous location in Tamil Nadu is the Pulicat which borders Andhra Pradesh (Subramanya 1996; Talukdar 1999; Kannan & Manakadan 2005). Pandav

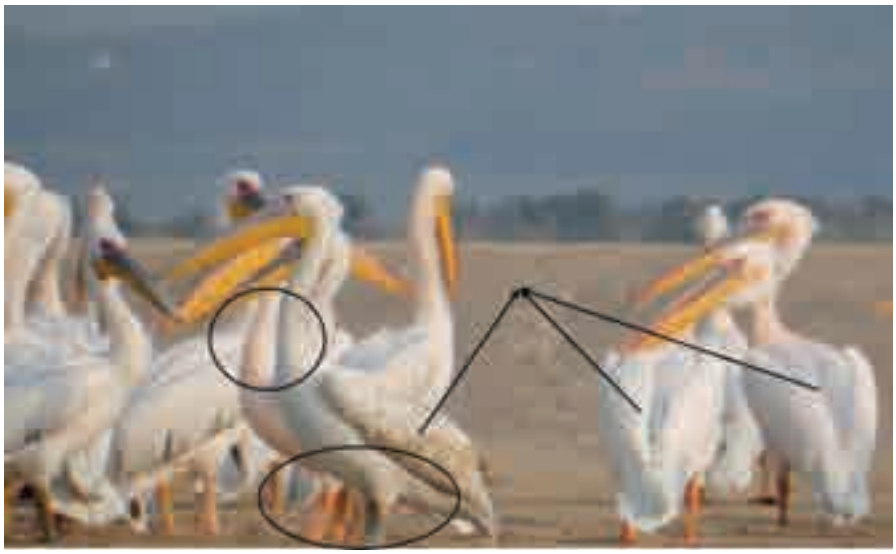

Image 4. Morphological variations among pelicans seen in the regions of neck, leg and back. Based on Salim Ali (2002), pelicans with pink legs are Great White Pelican (GWP), grey legs are Dalmatian Pelican (DP), and those with black spots on upper mandible are Spot-billed Pelican (SPB). GWP also have forehead ending in a point above bill. © R.K. Sharma.

Image 5. Distinguishing feature of Great White Pelican (GWP). © R.K. Sharma.

(1996) found a flock of 24 SBP roosting in the heronry during July–October 1993 in Bhitarkanika Wildlife Sanctuary of Odisha. SBP were seen in 1991 in Dihaila Jheel in Shivpuri, Madhya Pradesh (IBA 1999). Rahmani (1987, 1991) reported SBP in Karera Bustard Sanctuary, M.P. during 1986–87. Karera is in the direction closer to Pali (study zone-I).

GWP is a habitat specialist, largely depending on open water areas (Thirunaranan et al. 2017). The migration routes and stop over sites of GWP are poorly known (Izhaki et al. 2002). DP have been reported in Delhi by Ganguli (1975) and Urfi (2003). Rahmani et al (2021) in their work for the Madhya Pradesh Biodiversity Board, drew attention to the threatened birds of Madhya Pradesh. In this context they mentioned that the DP population in India is about 20,000–25,000 (Rahmani et al. 2021). A dedicated study on pelicans is expected to trace the status of migration and arrival

Image 6. Dalmatian Pelican swallowing fish. DP is distinguished from forehead feathers which end in a concave crescent (1,2,3 and inset). © R.K. Sharma.

Image 7. Pelicans with Greylag Geese Anser anser and cormorant. © R.K. Sharma.

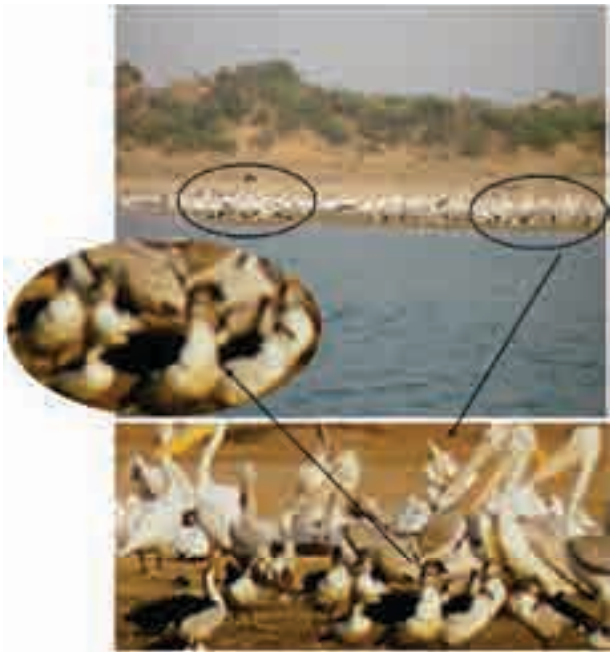

Image 8. Chambal pelicans with Nakta or Comb Duck *Sarkidiornis melanotos*. © R.K. Sharma.

patterns for all three species identified in NCS. Their movement in relation to adjoining wetlands also needs to be addressed.

Core zone of National Chambal Sanctuary

Visual assessments indicate that the transverse profile of NCS varies at different places along the length of the river. The differences are with respect to combinations relating to the hydrological characteristics, rocky surface, rapids, sand bar, small islands, roads communicating with villages, on-shore cultivation, and usage of the river for bathing and washings. There are sand-mining activities at places. Therefore, without attempting to have core and buffer zones along 572 km length of the river, the tri-state system of management has focused on the entire sanctuary. In this approach, it has been possible to sustain diversity of faunal indicators in NCS over the last 44 years.

Suggestion for 'Chambal River Ramsar site'

National Chambal Sanctuary is the longest national river sanctuary that offers vast scope for education,

Image 9. Chambal pelicans with Painted Stork *Mycteria leucocephala*. © R.K. Sharma.

Image 10. Pelicans with cormorant in National Chambal Sanctuary. © R.K. Sharma.

Image 11. Common cranes in National Chambal Sanctuary. Adult, chick, crops and riverside camp by local people are shown above. © R.K. Sharma.

Image 12. Sarus Cranes lack fear of people near crop and river ghats in National Chambal Sanctuary. Sarus are seen with smaller wetland birds Nakta (Comb Duck) and River Tern. © R.K. Sharma.

research and conservation. The proposal for recognition of NCS as a RAMSAR site was last processed in October 2008 by the principal chief conservator of forests (Wildlife), Madhya Pradesh. Coordination meetings were held by the state forest officers of Madhya Pradesh, Rajasthan and Uttar Pradesh, with WWF-India and experts from Wildlife Institute of India. In the light of findings from our studies, we present a discussion on the fulfilment of RAMSAR criteria by NCS, for possible reference in future.

Image 13. Greater Flamingos with smaller wetland birds Indian Skimmer, Brahminy Duck and geese in National Chambal Sanctuary. © R.K. Sharma.

Ramsar-criteria fulfilment by NCS

A Ramsar site has to fulfil one of the nine criteria (Anonymous 2022). Besides, the responsible stakeholders are expected to remain committed for maintenance & sustenance of the ecological, hydrological, and socioeconomic characteristics of the site. NCS meets six of the nine criteria for the international Ramsar-tag.

River Chambal in NCS is recognised under the wetland types 11 and 12 (Scott 1989), with ecological continuity in the semi-arid biogeographic zone (Rodgers & Panwar 1988), which is also termed in the Khathiar-Gir Ecoregion in India (WWF 2021). The studies on spatial and temporal trend of several indicator species from NCS for more than thirty years, testify the significance of the sanctuary as a 'site of international importance for conserving biological diversity (Ramsar Group-A Criterion 1).

Out of the Ramsar criteria under Group-B, NCS fulfils five criteria namely 2, 3, 4, 8 and 9, as it supports a number of internationally important faunal species and the associated ecological communities. Long term monitoring the conservation-assisted populations of Gharial, the Mugger, and the Gangetic Dolphin. Since 2010, the Gangetic Dolphin is recognised as the national aquatic animal of India. NCS holds populations of the unique freshwater turtles *Batagur kachuga* (CR), *Batagur dhongoka* (CR), *Chitra indica* (EN), *Nilssonia gangeticus* (EN), the Smooth Coated Otter *Lutra perspicillata* (VU), and at least 308 species of resident and migratory wetland birds (Nair & Krishna 2013) (Criterion 2). Continued support for Long-Term Ecological Monitoring (LTEM) is expected to strengthen the importance of these species for maintaining the biological diversity in the semi-arid biogeographic zone (Criterion 3).

NCS satisfies the Ramsar Criterion 4 as the river supports or provides refuge to several migrating bird species at a critical stage in their life cycles (Sharma & Singh 2018; Singh & Sharma 2018; Singh et al. 2022; and the present study). In fulfilling the Ramsar Criterion 9, the 572 km long river within NCS supports more than 1% of the individuals in population of wetland-dependent non-avian animal species namely the Gharial.

In the context of Ramsar Criterion-9, we refer here to the suggestion by Dubey & Mehra (1959) for more specific and long-term study on the fish fauna. The study continues to provide a general, yet landmark, ecological picture of the fish resource and fisheries in Chambal from the location of Gandhi Sagar dam up to River Yamuna. The fish fauna comprised sub-mountain and plain-land species. It is important because, of the 71 species they recorded, 46 are important for fisheries. The game-fish species include *Tor tor, Barilius bola* and *Puntius thagunio*. *Hilsa* is generally known as a long-range migratory species from estuaries of Bay of Bengal through Ganga and Yamuna. Such migration may not be entirely for breeding but also for feeding. During our work in 2000s, Tilapia and a Sting Ray was also reported by the fishermen. A series of dams and the Kota barrage have been constructed over Chambal but fish population do not seem to be severely affected as local consumption is extremely low. Big fishing enterprises were not existing and fishing practice was extremely low compared to that which existed in the Yamuna.

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Supplementary Table A. Pelican counts in National Chambal Sanctuary during 1983–1997. GWP—Great White Pelican | SBP—Spot-billed Pelican | DP—Dalmatian Pelican. There were no observations during 1998–2002.

Study Zone	River Zones and length in kms												
	I+II	III	IV+V	VI+VII+VIII+IX	X		XI		XII				
	Pali-Rameshwar-Khirkhiri (22+15))	Khirkhiri-Baroli (20)	Baroli-Atar-Sarsani (48+65)	Sarsaini-Rajghat-BabusinghGher-Usedghat-Ater (35+35+40+40)	Ater-Barhi (40)		Barhi-Chakarnagar (38)		Chakarnagar-Pachhnada (37)		Total		Grand Total all 3 species
YEAR	All 3 spp.	GWP+SBP	All 3 spp.	GWP+SBP	GWP+ SBP	DP	GWP+ SBP	DP	GWP+ SBP	DP	GWP+ SBP	DP	GWP+ SBP + DP
1983–85	0	1	0	0	-	-	-	-	-	-	1	-	**1**
1986	0	0	0	0	-	-	-	-	-	-	0	-	**0**
1987	0	0	0	0	-	-	-	-	10	-	10	-	**10**
1988	0	0	0	1	1	-	-	-	9	2	11	2	**13**
1990	0	0	0	0	5	2	3	-	14	5	22	7	**29**
1994	0	0	0	0	-	-		-	53	6	53	6	**59**
1996	0	0	0	0	-	-	43	6	65	9	108	15	**123**
1997	0	0	0	0	4	-	25	7	51	10	80	17	**97**
Total	0	1	0	1	10	2	71	13	202	32	285	47	332

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COMMUNICATION

A checklist of avifauna of Mangalore University, Karnataka, India

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Abstract: The study of the avifaunal diversity was carried out in the Mangalore University campus, located in Dakshina Kannada District, Karnataka from 2013 to 2021, in and around the campus. A total of 150 bird species belonging to 18 orders and 56 families were recorded during the study. Out of these, the study area supports five species which are endemic to the Western Ghats. The feeding guild analysis revealed that the insectivorous group had the highest number of species (53 species). The study provides baseline data for monitoring the avifauna in the campus and demonstrates the importance of the area in bird conservation.

Keywords- Birds, Dakshina Kannada, diversity, feeding guilds, Mangalagangotri campus, Mangaluru.

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Author contributions: KMR, KVK, VH, MCPK, and DN contribute and compiled the checklist. DN and KMR created the tables and figures. All authors contributed equally to the preparation of the manuscript.

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INTRODUCTION

Birds are one of the widely distributed vertebrates, showing maximum diversity. They play a key role in the ecosystem as environmental/biodiversity indicators. The diversity of birds, taxonomy and their distribution are well documented in India (Ali & Ripley 1987; Kazmierczak 2006; Grimmett et al. 2011). The global species accounts for a total of 10,721 species (Clements et al. 2019). India also has a rich avifaunal diversity with 1,340 species, which account for 12% of the world's total species (Praveen et al. 2021). Of these, 535 species of birds have been reported from Karnataka (Praveen et al. 2018).

Due to increased anthropogenic activities there is a continuous change in landscape (Jha et al. 2000; Purvis & Hector 2000), demanding the need for monitoring schemes to know the major flora and fauna at the global as well regional levels (Gadgil 1996). Bird studies help in understanding the importance of landscape in terms of their conservation. Continuous monitoring helps in understanding the habitat and distribution, which is crucial in planning effective conservation strategies (Paul & Cooper 2005).

There have been few ornithological studies carried out in Dakshina Kannada District, from coastal Karnataka (Shivashankar et al. 2011). Previously, (Ramitha & Vijayalaxmi 2001) reported 56 species of birds belonging to 31 families, however, in their study they covered University Campus along with some adjoining areas like Pavoor, Assaigoli, Someshwara and Netravathi bridge. Except for this earlier report, no detailed long-term studies have been made on the diversity of birds in the study area. In this context, the present study was undertaken to highlight the status, composition, feeding guilds and diversity of birds of Mangalore University Campus, Dakshina Kannada, Karnataka.

MATERIALS AND METHODS

Study site

The study was conducted in the Mangalore University campus located between 12.818°N & 74.917°E and is situated 20 km away from Mangalore City, Dakshina Kannada District, Karnataka (Figure 1). The campus is spread over 333 acres of land and it consists of different

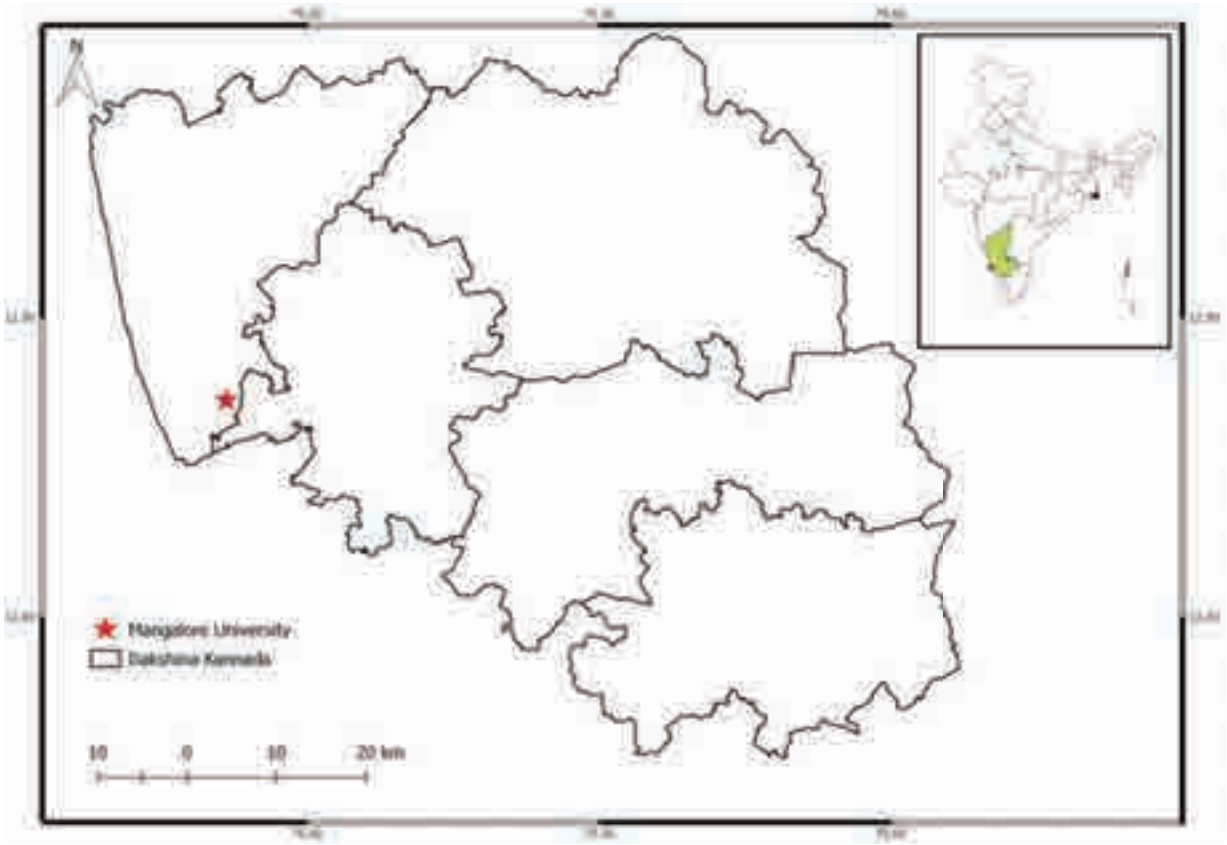

Figure 1. Location map of Mangalore University Campus.

habitat types such as laterite, shrubby patch and orchards. The overall habitat consists of open grassland and shrubs like *Aparosa* sp. (Phyllanthaceae), *Ixora* sp., *Mussaenda bellila* (Rubiaceae), *Premna serratifolia* (Lamiaceae) and trees like *Hopea ponga* (Dipterocarpaceae), *Mangifera indica*, *Holigarna ferruginea*, *Anacardia occidentale* (Anacardiaceae), *Peltophorum pterocarpum*, *Acacia auriculiformis, Accacia* spp, *Cassia fistula*, *Pongamia pinnata* (Fabaceae), *Terminalia* spp. (Combretaceae), *Artocarpus heterophyllus*, *Ficus* spp. (Moraceae), *Eucalyptus* sp. (Myrtaceae) and the orchard includes a few ornamental plant species. The study region receives an annual rainfall of 3479 mm and the average temperature ranges from 27°C to 32°C.

Bird survey method

The bird exploration was conducted for a period of nine years (2013–2021) to maintain the baseline data in the Mangalore University campus. The data was collected by opportunistic encounters during the regular field visits. Later, the bird survey was conducted using fixed 16 transects of 100 m length (each transect is 50 m away from the other) in different sites (Yashmita-Ulman & Singh 2021), during the month February 2016 to 2021 for four days between 0700 to 1000 h and 1600 to 1900 h. The species were recorded for 15 minutes by covering the transect length at a slow pace. The birds were recorded directly using a pair of field binoculars (Bushnell 8 x 42, Celestron outland 10 x 42) and a camera (Nikon D750, Nikkor 200-500mm f/5.6 lens). The identification of birds was done using the following field guides (Ali 2002; Grimmett et al. 2011). The common name, scientific name, IUCN Red List status, IWPA 1972, CITES and migratory status is followed using (SoIB 2020; Praveen et al. 2021) eBird database. To compile the list of birds we used secondary data cited in eBird data (accessed 20 February 2021). The feeding guild data for each species was collected from the existing literature (Ali & Ripley 1987; Vinayak & Mali 2018; Harisha et al. 2021; Norbu et al. 2021).

RESULT AND DISCUSSION

A total of 150 species of birds, belonging to 56 families under 18 orders were recorded from the study area (Table 1; Images 1–33). The order Passeriformes dominated the study area with a maximum number of species, i.e., 80 species (53%) and with the lowest Anseriformes, Bucerotiformes, Falconiformes, Suliformes, sharing one species (1%) each (Figure 2).

As per IUCN Red List (IUCN 2021), the campus supports, three Near Threatened (NT) species—*Ciconia episcopus*, *Threskiornis melanocephalus*, and *Brachypodius priocephalus*—and the remaining 146 species are under Least Concern (LC). The campus also supports five species namely, *Brachypodius priocephalus*, *Rubigula gularis*, *Argya subrufa*, *Sturnia blythii*, and *Dicaeum concolor* which are endemic to the Western Ghats (Table 1).

An analysis of the feeding guilds of these birds revealed that, 35% (53 species) were insectivorous, 28% (42 species) were omnivorous, 23% (34 species) were carnivorous, 6% (9 species) were granivorous, 4% (four species each) were frugivorous and nectivorous respectively (Figure 3).

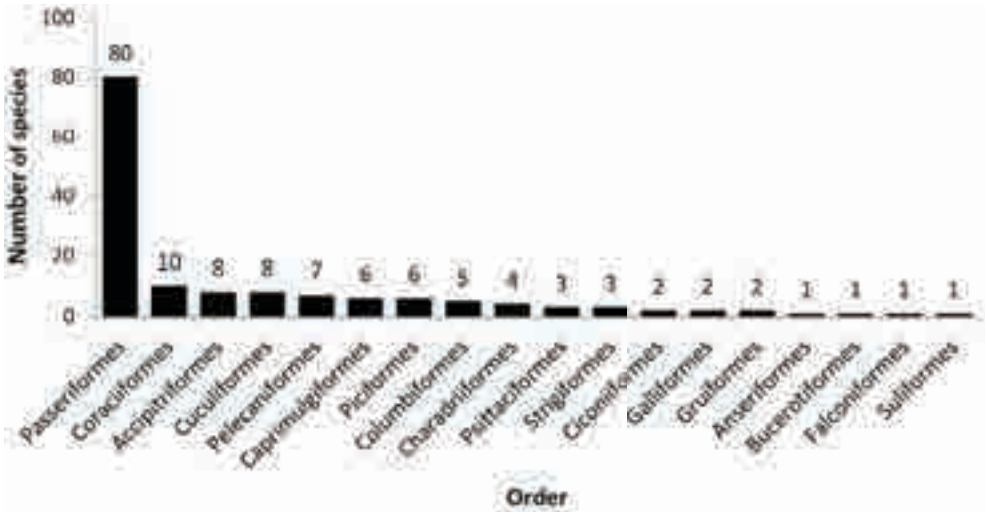

Figure 2. Order-wise species distribution and diversity of birds at Mangalore University campus.

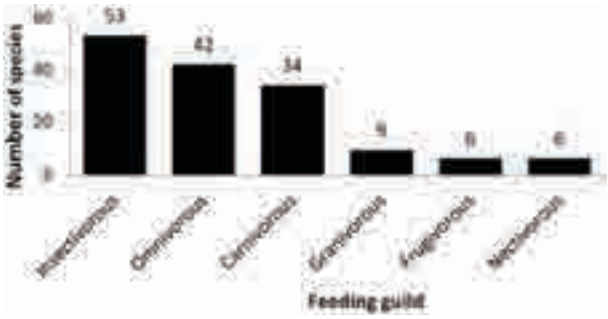

Figure 3. Feeding guilds of birds at Mangalore University campus.

During the study period 124 bird species were reported as residential (R), followed by 13 species long distance migratory (LD) and 13 species local migratory (LM).

Karnataka is home to 535 bird species (Praveen et al. 2018) and we recorded 150 (28%) species during the current study at Mangalore University Campus. Several other bird studies were conducted in different University campuses of Karnataka (Nazneen et al. 2001; Rajashekara & Venkatesh 2016, 2017; Harisha et al. 2021). Since there is a limitation in observation, the long-term monitoring of these species is essential (Schlegel & Rupf 2010). Our study provides important baseline information and the importance of species presence; this will help in the long term monitoring of birds in the campus besides acting as an essential document in planning conservation efforts in the campus.

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Table 1. Checklist of bird diversity of the Mangalore University campus along with legal status and migratory status.

	Species name	IUCN Red List 2021	IWPA 1972	CITES Appendix	Feeding guild	Migratory status
	Order Anseriformes, Family Anatidae					
1	*Dendrocygna javanica* (Horsfield, 1821); Lesser Whistling Duck	LC	IV		O	R
	Order Galliformes, Family Phasianidae					
2	*Pavo cristatus* Linnaeus, 1758; Indian Peafowl	LC	I		O	R
3	*Galloperdix spadicea* (J.F. Gmelin, 1789); Red Spurfowl	LC	IV		G	R
	Order Columbiformes, Family Columbidae					
4	*Columba livia* J.F. Gmelin, 1789; Rock Pigeon	LC	IV		G	R
5	*Streptopelia orientalis* (Latham, 1790); Oriental Turtle Dove	LC	IV		G	R
6	*Streptopelia chinensis* (Scopoli, 1786); Spotted Dove	LC	IV		G	R
7	*Chalcophaps indica* (Linnaeus, 1758); Asian Emerald Dove	LC	IV		G	R
8	*Treron phoenicopterus* (Latham, 1790); Yellow-footed Green Pigeon	LC	IV		G	R
	Order Cuculiformes, Family Cuculidae					
9	*Centropus sinensis* (Stephens, 1815); Greater Coucal	LC	IV		O	R
10	*Phaenicophaeus viridirostris* (Jerdon, 1840); Blue-faced Malkoha	LC	IV		O	R
11	*Clamator jacobinus* (Boddaert, 1783); Pied Cuckoo	LC	IV		I	R
12	*Eudynamys scolopaceus* (Linnaeus, 1758); Asian Koel	LC	IV		F	R
13	*Cacomantis sonneratii* (Latham, 1790); Banded Bay Cuckoo	LC	IV		I	R
14	*Cacomantis passerinus* (Vahl, 1797); Grey-bellied Cuckoo	LC	IV		I	R
15	*Surniculus dicruroides* (Hodgson, 1839); Fork-tailed Drongo Cuckoo	LC	IV		I	R
16	*Hierococcyx varius* (Vahl, 1797); Common Hawk Cuckoo	LC	IV		I	R
	Order Caprimulgiformes, Family Podargidae					
17	*Batrachostomus moniliger* Blyth, 1849; Sri Lanka Frogmouth	LC	I		C	R
	Order Caprimulgiformes, Family Caprimulgidae					
18	*Caprimulgus atripennis* Jerdon, 1845; Jerdon's Nightjar	LC	IV		I	R
19	*Caprimulgus asiaticus* Latham, 1790; Indian Nightjar	LC	IV		I	R
20	*Caprimulgus affinis* Horsfield, 1821; Savanna Nightjar	LC	IV		I	R
	Order Caprimulgiformes, Family Apodidae					
21	*Apus affinis* (J.E. Gray, 1830); Indian House Swift	LC	IV		I	R
22	*Cypsiurus balasiensis* (J.E. Gray, 1829); Asian Palm Swift	LC	IV		I	R

	Species name	IUCN Red List 2021	IWPA 1972	CITES Appendix	Feeding guild	Migratory status
	Order Gruiformes, Family Rallidae					
23	*Amaurornis phoenicurus* (Pennant, 1769); White-breasted Waterhen	LC	IV		O	R
24	*Zapornia fusca* (Linnaeus, 1766); Ruddy-breasted Crake	LC	IV		O	R
	Order Charadriiformes, Family Charadriidae					
25	*Vanellus malabaricus* (Boddaert, 1783); Yellow-wattled Lapwing	LC	IV		C	R
26	*Vanellus indicus* (Boddaert, 1783); Red-wattled Lapwing	LC	IV		C	R
	Order Charadriiformes, Family Scolopacidae					
27	*Tringa ochropus* Linnaeus, 1758; Green Sandpiper	LC	IV		C	LD
	Order Charadriiformes, Family Turnicidae					
28	*Turnix suscitator* (J.F. Gmelin, 1789); Barred Buttonquail	LC	IV		C	R
	Order Ciconiiformes, Family Ciconiidae					
29	*Anastomus oscitans* (Boddaert, 1783); Asian Openbill	LC	IV		C	R
30	*Ciconia episcopus* (Boddaert, 1783); Woolly-necked Stork	NT	IV		C	R
	Order Suliformes, Family Phalacrocoracidae					
31	*Microcarbo niger* (Vieillot, 1817); Little Cormorant	LC	IV		C	R
	Order Pelecaniformes, Family Ardeidae					
32	*Ardea purpurea* Linnaeus, 1766; Purple Heron	LC	IV		C	R
33	*Ardea alba* Linnaeus, 1758; Great Egret	LC	IV		C	R
34	*Ardea intermedia* Wagler, 1829; Intermediate Egret	LC	IV		C	R
35	*Egretta garzetta* (Linnaeus, 1766); Little Egret	LC	IV		C	R
36	*Bubulcus ibis* (Linnaeus, 1758); Cattle Egret	LC	IV		C	R
37	*Ardeola grayii* (Sykes, 1832); Indian Pond Heron	LC	IV		C	R
	Order Pelecaniformes, Family Threskiornithidae					
38	*Threskiornis melanocephalus* (Latham, 1790); Black-headed Ibis	NT	IV		C	R
	Order Accipitriformes, Family Accipitridae					
39	*Pernis ptilorhynchus* (Temminck, 1821); Oriental Honey Buzzard	LC	I	II	C	R
40	*Spilornis cheela* (Latham, 1790); Crested Serpent Eagle	LC	I	II	C	R
41	*Hieraaetus pennatus* (J.F. Gmelin, 1788); Booted Eagle	LC	I	II	C	LD
42	*Accipiter trivirgatus* (Temminck, 1824); Crested Goshawk	LC	I	II	C	R

	Species name	IUCN Red List 2021	IWPA 1972	CITES Appendix	Feeding guild	Migratory status
43	*Accipiter badius* (J.F. Gmelin, 1788); Shikra	LC	I	II	C	R
44	*Milvus migrans* (Boddaert, 1783); Black Kite	LC	I	II	C	R
45	*Haliastur indus* (Boddaert, 1783); Brahminy Kite	LC	I	II	C	R
46	*Haliaeetus leucogaster* (J.F. Gmelin, 1788); White-bellied Sea Eagle	LC	I	II	C	R
	Order Strigiformes, Family Tytonidae					
47	*Tyto alba* (Scopoli, 1769); Barn Owl	LC	IV	II	C	R
	Order Strigiformes, Family Strigidae					
48	*Athene brama* (Temminck, 1821); Spotted Owlet	LC	IV	II	C	R
49	*Strix leptogrammica* Temminck, 1832; Brown Wood Owl	LC	IV	II	C	R
	Order Bucerotiformes, Family Upupidae					
50	*Upupa epops* Linnaeus, 1758; Common Hoopoe	LC	IV		I	R
	Order Coraciiformes, Family Alcedinidae					
51	*Alcedo atthis* (Linnaeus, 1758); Common Kingfisher	LC	IV		C	R
52	*Alcedo meninting* Horsfield, 1821; Blue-eared Kingfisher	LC	IV		C	R
53	*Ceyx erithaca* (Linnaeus, 1758); Oriental Dwarf Kingfisher	LC	IV		C	R
54	*Pelargopsis capensis* (Linnaeus, 1766); Stork-billed Kingfisher	LC	IV		C	R
55	*Halcyon smyrnensis* (Linnaeus, 1758); White-throated Kingfisher	LC	IV		C	R
	Order Coraciiformes, Family Meropidae					
56	*Merops orientalis* Latham, 1801; Green Bee-eater	LC	IV		I	R
57	*Merops philippinus* Linnaeus, 1767; Blue-tailed Bee-eater	LC	IV		I	LM
58	*Merops leschenaulti* Vieillot, 1817; Chestnut-headed Bee-eater	LC	IV		I	R
	Order Coraciiformes, Family Coraciidae					
59	*Coracias garrulus* Linnaeus, 1758; European Roller	LC	IV		C	LD
60	*Coracias benghalensis* (Linnaeus, 1758); Indian Roller	LC	IV		C	R
	Order Piciformes, Family Megalaimidae					
61	*Psilopogon haemacephalus* (Statius Muller, 1776); Coppersmith Barbet	LC	IV		F	R
62	*Psilopogon viridis* (Boddaert, 1783); White-cheeked Barbet	LC	IV		F	R
	Order Piciformes, Family Picidae					
63	*Yungipicus nanus* (Vigors, 1832); Brown-capped Pygmy Woodpecker	LC	IV		O	R
64	*Micropternus brachyurus* (Vieillot, 1818); Rufous Woodpecker	LC	IV		O	R
65	*Dinopium benghalense* (Linnaeus, 1758); Black-rumped Flameback	LC	IV		I	R
66	*Picus chlorolophus* Vieillot, 1818; Lesser Yellownape	LC	IV		O	R
	Order Falconiformes, Family Falconidae					
67	*Falco tinnunculus* Linnaeus, 1758; Common Kestrel	LC	IV	II	C	LM
	Order Psittaciformes, Family Psittaculidae					
68	*Psittacula krameri* (Scopoli, 1769); Rose-ringed Parakeet	LC	IV		F	R
69	*Psittacula cyanocephala* (Linnaeus, 1766); Plum-headed Parakeet	LC	IV	II	F	R
70	*Loriculus vernalis* (Sparrman, 1787); Vernal Hanging Parrot	LC	IV	II	F	R
	Order Passeriformes, Family Pittidae					
71	*Pitta brachyura* (Linnaeus, 1766); Indian Pitta	LC	IV		I	LM
	Order Passeriformes, Family Campephagidae					
72	*Pericrocotus cinnamomeus* (Linnaeus, 1766); Small Minivet	LC	IV		I	R
73	*Pericrocotus flammeus* (J.R. Forster, 1781); Orange Minivet	LC	IV		I	R
74	*Coracina macei* (R. Lesson, 1831); Large Cuckooshrike	LC	IV		I	R
75	*Lalage melanoptera* (Rüppell, 1839); Black-headed Cuckooshrike	LC	IV		I	LM
	Order Passeriformes, Family Oriolidae					
76	*Oriolus kundoo* Sykes, 1832; Indian Golden Oriole	LC	IV		O	LM
77	*Oriolus chinensis* Linnaeus, 1766; Black-naped Oriole	LC	IV		O	LD
78	*Oriolus xanthornus* (Linnaeus, 1758); Black-hooded Oriole	LC	IV		O	R
	Order Passeriformes, Family Artamidae					
79	*Artamus fuscus* Vieillot, 1817; Ashy Woodswallow	LC	IV		I	R
	Order Passeriformes, Family Vangidae					
80	*Tephrodornis pondicerianus* (J.F. Gmelin, 1789); Common Woodshrike	LC	IV		I	R
	Order Passeriformes, Family Aegithinidae					
81	*Aegithina tiphia* (Linnaeus, 1758); Common Iora	LC	IV		I	R
	Order Passeriformes, Family Dicruridae					
82	*Dicrurus macrocercus* Vieillot, 1817; Black Drongo	LC	IV		O	R
83	*Dicrurus leucophaeus* Vieillot, 1817; Ashy Drongo	LC	IV		O	LM
84	*Dicrurus aeneus* Vieillot, 1817; Bronzed Drongo	LC	IV		O	R
85	*Dicrurus paradiseus* (Linnaeus, 1766); Greater Racket-tailed Drongo	LC	IV		O	R

	Species name	IUCN Red List 2021	IWPA 1972	CITES Appendix	Feeding guild	Migratory status
	Order Passeriformes, Family Monarchidae					
86	*Hypothymis azurea* (Boddaert, 1783); Black-naped Monarch	LC	IV		I	R
87	*Terpsiphone paradisi* (Linnaeus, 1758); Indian Paradise-flycatcher	LC	IV		I	LM
	Order Passeriformes, Family Laniidae					
88	*Lanius cristatus* Linnaeus, 1758; Brown Shrike	LC	IV		I	LD
89	*Lanius schach* Linnaeus, 1758; Long-tailed Shrike	LC	IV		I	R
	Order Passeriformes, Family Corvidae					
90	*Dendrocitta vagabunda* (Latham, 1790); Rufous Treepie	LC	IV		O	R
91	*Corvus splendens* Vieillot, 1817; House Crow	LC	V		O	R
92	*Corvus macrorhynchos* Wagler, 1827; Large-billed Crow	LC	IV		O	R
	Order Passeriformes, Family Alaudidae					
93	*Mirafra affinis* Blyth, 1845; Jerdon's Bushlark	LC	IV		O	R
	Order Passeriformes, Family Cisticolidae					
94	*Orthotomus sutorius* (Pennant, 1769); Common Tailorbird	LC	IV		I	R
95	*Prinia hodgsonii* Blyth, 1844; Grey-breasted Prinia	LC	IV		I	R
96	*Prinia socialis* Sykes, 1832; Ashy Prinia	LC	IV		I	R
97	*Prinia inornata* Sykes, 1832; Plain Prinia	LC	IV		I	R
	Order Passeriformes, Family Acrocephalidae					
98	*Iduna rama* (Sykes, 1832); Sykes's Warbler	LC	IV		I	LD
99	*Acrocephalus dumetorum* Blyth, 1849; Blyth's Reed Warbler	LC	IV		I	LD
	Order Passeriformes, Family Hirundinidae					
100	*Hirundo rustica* Linnaeus, 1758; Barn Swallow	LC	IV		I	LM
101	*Hirundo smithii* Leach, 1818; Wire-tailed Swallow	LC	IV		I	R
102	*Cecropis daurica* (Laxmann, 1769); Red-rumped Swallow	LC	IV		I	R
	Order Passeriformes, Family Pycnonotidae					
103	*Brachypodius priocephalus* (Jerdon, 1839); Grey-headed Bulbul*	NT	IV		O	R
104	*Rubigula gularis* (Gould, 1836); Flame-throated Bulbul*	LC	IV		O	R
105	*Pycnonotus cafer* (Linnaeus, 1766); Red-vented Bulbul	LC	IV		O	R
106	*Pycnonotus jocosus* (Linnaeus, 1758); Red-whiskered Bulbul	LC	IV		O	R
107	*Pycnonotus luteolus* (Lesson, 1841); White-browed Bulbul	LC	IV		O	R
108	*Acritillas indica* (Jerdon, 1839); Yellow-browed Bulbul	LC	IV		O	R
	Order Passeriformes, Family Phylloscopidae					
109	*Phylloscopus affinis* (Tickell, 1833); Tickell's Leaf Warbler	LC	IV		I	LM
110	*Phylloscopus nitidus* Blyth, 1843; Green Warbler	LC	IV		I	LD
	Order Passeriformes, Family Timaliidae					
111	*Pomatorhinus horsfieldii* Sykes, 1832; Indian Scimitar Babbler	LC	IV		I	R
	Order Passeriformes, Family Pellorneidae					
112	*Pellorneum ruficeps* Swainson, 1832; Puff-throated Babbler	LC	IV		I	R
	Order Passeriformes, Family Leiothrichidae					
113	*Argya striata* (Dumont, 1823); Jungle Babbler	LC	IV		O	R
114	*Argya affinis* (Jerdon, 1845); Yellow-billed Babbler	LC	IV		O	R
115	*Argya subrufa* (Jerdon, 1839); Rufous Babbler*	LC	IV		O	R
	Order Passeriformes, Family Sturnidae					
116	*Gracula indica* (Cuvier, 1829); Southern Hill Myna	LC	I		O	R
117	*Sturnia malabarica* (J.F. Gmelin, 1789); Chestnut-tailed Starling	LC	IV		O	LM
118	*Sturnia blythii* (Jerdon, 1845); Malabar Starling*	NE	IV		O	R
119	*Acridotheres tristis* (Linnaeus, 1766); Common Myna	LC	IV		O	R
120	*Acridotheres fuscus* (Wagler, 1827); Jungle Myna	LC	IV		O	R
	Order Passeriformes, Family Turdidae					
121	*Geokichla citrina* (Latham, 1790); Orange-headed Thrush	LC	IV		O	R
122	*Turdus simillimus* Jerdon, 1839; Indian Blackbird	LC	IV		O	LM
	Order Passeriformes, Family Muscicapidae					
123	*Muscicapa dauurica* Pallas, 1811; Asian Brown Flycatcher	LC	IV		I	LM
124	*Muscicapa muttui* (E.L. Layard, 1854); Brown-breasted Flycatcher	LC	IV		I	LD
125	*Copsychus fulicatus* (Linnaeus, 1766); Indian Robin	LC	IV		I	R
126	*Copsychus saularis* (Linnaeus, 1758); Oriental Magpie Robin	LC	IV		I	R
127	*Cyornis tickelliae* Blyth, 1843; Tickell's Blue Flycatcher	LC	IV		I	R
128	*Myophonus horsfieldii* Vigors, 1831; Malabar Whistling Thrush	LC	IV		O	R
129	*Saxicola caprata* (Linnaeus, 1766); Pied Bushchat	LC	IV		I	R

	Species name	IUCN Red List 2021	IWPA 1972	CITES Appendix	Feeding guild	Migratory status
	Order Passeriformes, Family Dicaeidae					
130	*Dicaeum agile* (Tickell, 1833); Thick-billed Flowerpecker	LC	IV		N	R
131	*Dicaeum erythrorhynchos* (Latham, 1790); Pale-billed Flowerpecker	LC	IV		N	R
132	*Dicaeum concolor* Jerdon, 1840; Nilgiri Flowerpecker*	LC	IV		N	R
	Order Passeriformes, Family Nectariniidae					
133	*Leptocoma zeylonica* (Linnaeus, 1766); Purple-rumped Sunbird	LC	IV		N	R
134	*Cinnyris asiaticus* (Latham, 1790); Purple Sunbird	LC	IV		N	R
135	*Cinnyris lotenius* (Linnaeus, 1766); Loten's Sunbird	LC	IV		N	R
136	*Arachnothera longirostra* (Latham, 1790); Little Spiderhunter	LC	IV		O	R
	Order Passeriformes, Family Irenidae					
137	*Irena puella* (Latham, 1790); Asian Fairy-bluebird	LC	IV		O	R
	Order Passeriformes, Family Chloropseidae					
138	*Chloropsis jerdoni* (Blyth, 1844); Jerdon's Leafbird	LC	IV		O	R
139	*Chloropsis aurifrons* (Temminck, 1829); Golden-fronted Leafbird	LC	IV		O	R

	Species name	IUCN Red List 2021	IWPA 1972	CITES Appendix	Feeding guild	Migratory status
	Order Passeriformes, Family Estrildidae					
140	*Lonchura striata* (Linnaeus, 1766); White-rumped Munia	LC	IV		G	R
141	*Lonchura kelaarti* (Jerdon, 1863); Black-throated Munia	LC	IV		G	R
142	*Lonchura punctulata* (Linnaeus, 1758); Scaly-breasted Munia	LC	IV		G	R
	Order Passeriformes, Family Passeridae					
143	*Passer domesticus* (Linnaeus, 1758); House Sparrow	LC	IV		O	R
	Order Passeriformes, Family Motacillidae					
144	*Motacilla cinerea* Tunstall, 1771; Grey Wagtail	LC	IV		I	LM
145	*Motacilla flava* Linnaeus, 1758; Western Yellow Wagtail	LC	IV		I	LD
146	*Motacilla maderaspatensis* J.F. Gmelin, 1789; White-browed Wagtail	LC	IV		I	R
147	*Motacilla alba* Linnaeus, 1758; White Wagtail	LC	IV		I	LD
148	*Anthus rufulus* Vieillot, 1818; Paddyfield Pipit	LC	IV		I	R
149	*Anthus godlewskii* (Taczanowski, 1876); Blyth's Pipit	LC	IV		I	LD
	Order Passeriformes, Family Emberizidae					
150	*Emberiza buchanani* Blyth, 1845; Grey-necked Bunting	LC	IV		I	LD

LC—Least Concern | NT—Near Threatened | NE—Not Evaluated | C—Carnivorous | F—Frugivorous | G—Granivorous | I—Insectivorous | N—Nectivorous | O—Omnivorous | *—Endemic to Western Ghats | R—Resident | LD—Migratory long distance | LM—Local migratory.

Image 1–15. 1—*Accipiter trivirgatus* | 2—*Milvus migrans* | 3—*Hieraaetus pennatus* | 4—*Pavo cristatus* | 5—*Haliaeetus leucogaster* | 6—*Batrachostomus moniliger* | 7—*Accipiter badius* | 8—*Haliastur indus* | 9—*Spilornis cheela* | 10—*Muscicapa muttui* | 11—*Phylloscopus affinis* | 12—*Hirundo rustica* | 13—*Lalage melanoptera* | 14—*Acrocephalus dumetorum* | 15—*Anthus godlewskii.* © Vineeth Kumar K and Prashantha Krishna MC.

Image 16–33. 16—*Iduna rama* | 17—*Phylloscopus nitidus* | 18—*Motacilla flava* | 19—*Ciconia episcopus* | 20—*Brachypodius priocephalus* | 21—*Argya subrufa* | 22—*Oriolus xanthornus* | 23—*Dicrurus macrocercus* | 24—*Turdus simillimus* | 25—*Dicrurus aeneus* | 26—*Aegithina tiphia* | 27—*Centropus sinensis* | 28—*Geokichla citrina* | 29—*Psittacula cyanocephala* | 30—*Lonchura punctulata* | 31—*Hierococcyx varius* | 32—*Surniculus dicruroides* | 33—*Strix leptogrammica*. © Vineeth Kumar K and Prashantha Krishna MC.

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COMMUNICATION

Biology of *Bhutanitis ludlowi* Gabriel, 1942 (Lepidoptera: Papilionidae) Bumdeling Wildlife Sanctuary, Bhutan

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Abstract: It was in 1933–34 that the first discovery of *Bhutanitis ludlowi* was made by plant explorer Frank Ludlow and George Sheriff at Tobrang, upper part of Trashiyangtse valley, Bhutan. It was rediscovered after a lapse of 76 years in 2009 by Bhutanese forester Karma Wangdi. *Bhutanitis ludlowi* is native to Trashiyangtse and occurs in few pockets of areas in northeastern part of Bumdeling Wildlife Sanctuary (BWS). There has been no report which described complete life cycle of *Bhutanitis ludlowi* till date. Listed in CITES appendix II, the endemic species is also the first butterfly species to be included under Schedule I of FNCRR of Bhutan, making it a totally protected species in Bhutan. For the first time a complete life cycle stages of *Bhutanitis ludlowi* was recorded at BWS on the host plant *Aristolochia griffithii* Hook.f. & Thomson ex Duch in ex situ environment. A greenhouse with dimensions of 12 X 5 X 3 m was constructed and a thriving habitat was created artificially through establishment of *Aristolochia griffithii* nursery inside the greenhouse. The eggs were brought down to the new environment at an elevation of 1,752 m from their natural habitat (elevation of 2,200 m). The eggs were incubated in the greenhouse with host plants in ex-situ conditions. Eggs incubated inside the greenhouse were examined at eight hour intervals daily (twice a day: 0900 h and 1700 h) to record physical changes in eggs such as colours. *Bhutanitis ludlowi* is univoltine brood where the life cycle completes in 365–367 days with egg hatching (Average = 16 days; SD = 2), larva (Avg. of 174 days SD 3), pupa (174 days, SD 1.53)) and adults emerged after 366 days. Predators of *Bhutanitis ludlowi* include spider, wasps, praying mantis, snails, and ants. *Bhutanitis ludlowi* protects themselves by avoiding predators through mechanisms like odour, camouflaged colorations, and excretion of poisons. Advocacy programs on its conservation importance and formation of community conservation support groups to protect its habitats is seen as one of the priority activities in the identified range of *Bhutanitis ludlowi.*

Keywords: Chrysalis, eggs, host plants, instars, life history, metamorphosis, molts.

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INTRODUCTION

Discovery of *Bhutanitis ludlowi* (Lepidoptera: Papilionidae) was first made in 1933–34 by Frank Ludlow (1885–1972) and George Sheriff (1898–1967) during their botanical expedition at Tobrang Makang, upper part of Trashiyangtse valley. *Bhutanitis ludlowi* was sporadically distributed between altitude ranges of 2,200–2,500 m (Harada et al. 2012). *Bhutanitis ludlowi* was named after the foreign botanist Frank Ludlow and it was only after eight years of discovery that it was described as new species in 1942 (Gabriel 1942). Except species description (Gabriel 1942), there has been no reports which described complete life cycle of *Bhutanitis ludlowi.* The only reference to life cycle of the concern species was made by a joint research team from Ministry of Agriculture and Forests (MoAF), Bhutan and a group of Japanese lepidopterists (Harada et al. 2012). In their paper they compared *Bhutanitis ludlowi* morphological characteristics with *Bhutanitis lidderdalii* Atkinson (Bhutan Glory) till second instar (Harada et al. 2012).

Bhutanitis ludlowi was accorded increased protection status in the provisions of Forest and Nature Conservation Act 1995 and Forest and Nature Conservation Rules and Regulation (FNCRR) 2017. Listed in CITES appendix II, it was also the first butterfly species to be included under Schedule I of FNCRR making it a totally protected species (Singh & Chib 2015). Endorsed during 123rd sitting of Cabinet, *Bhutanitis ludlowi* was officially declared as Bhutan's National Butterfly in 2012 (Singh & Chib 2015). The paper was written after nine years of rediscovery of the concern species, adding invaluable memorandum of complete life history report to other existing three congeneric species: *Bhutanitis lidderdalii* Atkinson 1873, *Bhutanitis thaidina* Blanchard 1871, and *Bhutanitis mansfieldi* Riley 1939. The present study, which is the first of such kind in Bhutan & the world, demystifies and elucidates the complete life cycle of *Bhutanitis ludlowi* on its only novel larval host plant *Aristolochia griffithii.*

MATERIALS AND METHODS

Study site

The study was carried out at Bumdeling Wildlife

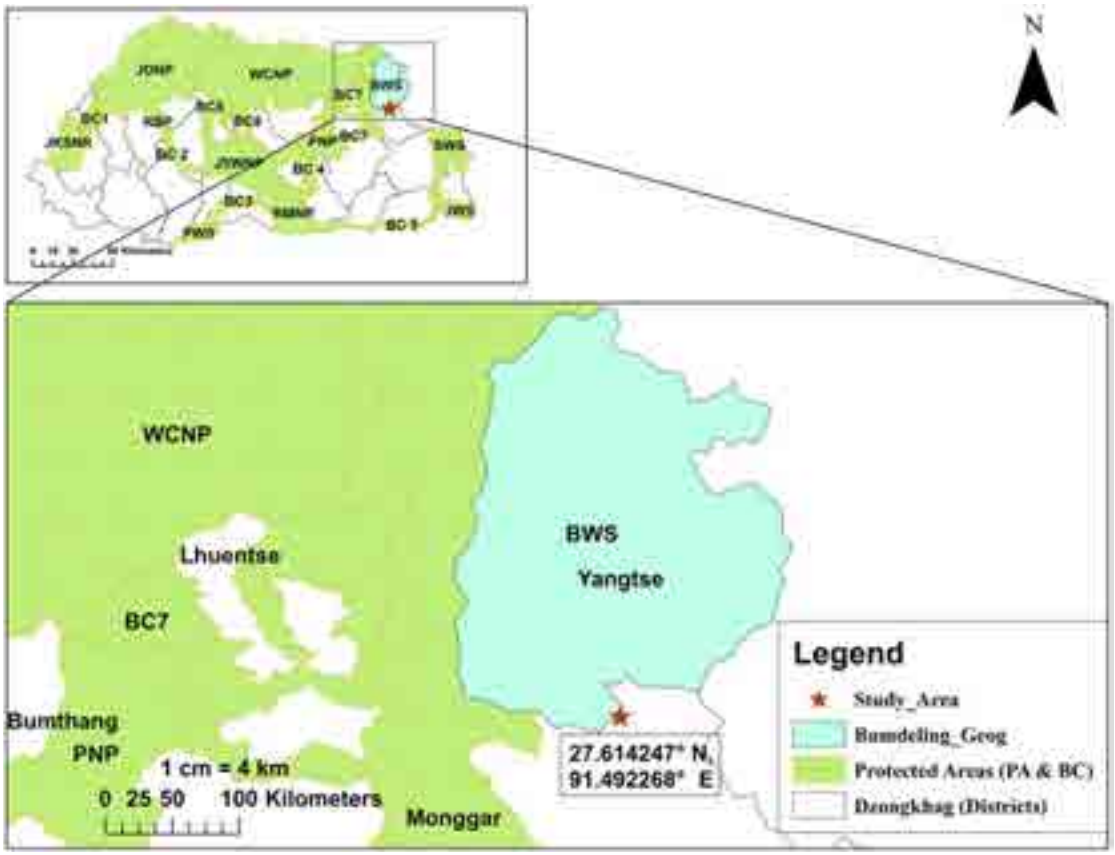

Figure 1. Study area of Bumdeling Wildlife Sanctuary, Yangtse.

Sanctuary (BWS) during 2017. The study site is located at an elevation of 1,752 m (27.614247° N 91.492268° E) in Trashiyangtse (Figure 1). The experimental site experiences a warm temperate climate with an average annual precipitation between 1,000–3,000 mm from June to September and the mean temperatures of 20°C in summer and 10°C in winter. Lighting condition was normal indirect sunlight through high density polyethylene (HDPE) green-agro shade net with mesh size 10 mm. An average hours of sun light received by greenhouse varied from short duration of about seven hours during winter months (November–March: 0800–1500 h) to long duration of about nine hours during summer months (April–October: 0800–1700 h).

Methods

Before eggs were introduced into an ex-situ environment, a green-agro shade net house with dimensions of 12 X 5 X 3 m was constructed (Image 1A,B). A single 2 X 2 m door was opened from one end of the green-agro shade house. Thriving habitat was created artificially through establishment of *Aristolochia griffithii* nursery inside the agro shade house (Image 2AC). The main purpose of agro net is to provide shade to growing host plants and to maintain thriving habitat for *Bhutanitis ludlowi*.

The first cluster of freshly laid *Bhutanitis ludlowi* eggs were collected in mid-August and introduced into ex situ environment of green-agro shade house at the study site with established host plants. Eggs were allowed to hatch in greenhouse in ex situ conditions. Rearing eggs were examined at every eight-hour intervals daily (twice a day: 0900 h and 1700 h) to record eggs physical changes such as colours. The eggs were enumerated as hatched when the larvae came out of them. Fresh young leaves of *Aristolochia griffithii* (Image 2C) were used as food by growing larvae. Molting stages were noted, thus the number of instars and their metamorphosis.

RESULT

Butterflies go through a life cycle known as complete metamorphosis. The stages of their life cycle include egg, larva, pupa, and adult. Female butterflies were very selective about their host plant and laying their eggs. Female *Bhutanitis ludlowi* laid its eggs in clusters on underside of mature host plant leaves in pyramidal

Table 1. Observation on life cycle stages of *Bhutanitis ludlowi*.

	Stages	Observation
1	Egg: The Beginning Stage	Golden yellow colour of the eggs turned darkish pale after 14–15 days and apical region of the eggs got darkened considerably before hatching (Image 3C). Freshly laid egg hatched after 14–18 days (Image 3CD) in an ex situ environment inside the greenhouse. Soon after emergence from the egg, larva consumed its eggshell before it spread to feed on young tender leaves. A complete life cycle of *Bhutanitis ludlowi* passed through eight larval instar stages including a pupal stage to emerge as an adult butterfly over an incredible period of 367 days.
2	Larval: The Feeding Stage	A young caterpillar that first hatches from its egg is referred to as instar caterpillar (Image 3CE) and the caterpillar's first molt is referred to as second instar. First cluster of eggs were hatched in early September and the young caterpillar or larva that emerged from eggs began their first feast by eating their eggshell along with tender parts of host plant. During the feeding stage all individuals generally fed on individual vine at the same time of the day. Larvae of all instars were generally inactive in nights. Instars caterpillars continued to eat and grow until it became too big for the exoskeleton to support. The caterpillar molts transform into next instar until they pupated to adults which is a dramatic change in ground colour occurred with the molt (sixth, seventh and eighth (final) instars). The dark yellow ground color of the body became ashy grey and processes into darker shades thus appearing more pronounced (Image 4A). The wart-like reddish orange processes on sub-dorsal part became more prominent making body segments more distinct and clearer. During these stages, instars intervals became longer with fewer activities. It could be in response to unfavorable and inhibiting conditions of cold winter months of November, December, January, and February. The remarkable differences in appearance of the instar stages were increased body size and length and more prominent setae on the body (Image 4A). The pattern of tubercle arrangement of the body remains same throughout the rest of larval life, however, change in coloration pattern of chalazae becomes more conspicuous. Ludlow's Bhutan Glory *Bhutanitis ludlowi* butterfly underwent eight larval instars to emerge as an adult.
3	Molting: The exuviating stage	Caterpillar stopped eating and stayed still in one place in group (during early instars) or single (later instars) for around seven–eight days as it prepared to molt. When molted, old head capsule slid forward and dropped off. Old exoskeleton then split just behind the head allowing the caterpillar to walk forward out of its former skin. The larva took one–two hours to inflate its body by drawing in surrounding air to sufficiently toughen to continue normal feeding without injuring itself. At this point, larva often ate its exuviae of ecdysis. *Bhutanitis ludlowi* caterpillar underwent seventh molt to pupate. During this stage, feeding potentiality was found to be very high in contrast to previous stages. At maturation, larva stopped feeding and vigorously moved in search of pupation site.
4	Adult (Imago): The reproductive stage	It is the fourth stage of a butterfly. An adult butterfly (Image 4D) is ready to emerge from a chrysalis after 188 days (six months and seven days). The adult emerged in morning hours after the sun had come up at around 10–12 pm. As the adult butterfly emerged from its chrysalis, its wings were weak, folded against its body and wet. It was not able to take flight instantly. Adult butterfly emerged from pupa in third week of August after 365–367 days from the eggs. The adult butterfly pumped fluids from its abdomen through the veins in its wings, which causes wings to expand to their full size. It dries its wings in the sun by keeping it flat (Image 4F), occasionally flaps to exercise flight muscles before it could fly. It took several hours depending on the weather before it is ready to flutter away. In this reproductive stage, adult butterfly mates to reproduce, searches for the proper host plant to lay her eggs and the cycle continues. Duration of life cycle ranged between 365–367 days (egg-18 days, larva- five months & eight days), pupa- six months & seven days).

Image 1. A—*Aristolochia griffithii* nursery inside greenhouse | B— *Aristolochia griffithii*, the host plant in greenhouse. © Tshering Dendup

Image 2. *Aristolochia griffithii*, novel host plant of *Bhutanitis ludlowi* in greenhouse: A—Flower | B—Fruit | C—Leaves. © Tshering Dendup

mound, covered with very thin and hardly seen shiny sticky substance, which attached them to the leaf surface (Image 3A). Each cluster composed of 60–160 number of eggs. The butterfly eggs underwent colour change (Image 3B) as young larvae developed inside them and the whole observation are recorded (Table 1).

DISCUSSION

Aristolochia species is used by most of the Swallowtail butterflies as host plants to lay their eggs to complete life cycle. *Bhutanitis ludlowi* Atkinson laid its eggs on *Aristolochia griffithii.* Similarly, Young (1973) found that food plants acceptance study of swallowtail butterfly *Paridesarcas mylotes* (Papilionidae) on *Aristolochia constricta* Grisebach and *Aristolochia labiata* was readily accepted. Concomitant to the number of eggs per cluster (65–180) of Harada et al. (2012), eggs of the *Bhutanitis ludlowi* were also laid in clusters or batch of 60–160 individuals in pyramidal dome mound, generally in dorsal side of the leaves of *Aristolochia griffithii*. Young (1973) wrote that eggs of *Paridesarcas mylotes* were found on ventral side (occasionally on the crotches of small stems and petioles) of the mature leaves of *Aristolochia constricta* as opposed to *Bhutanitis ludlowi* and *B. lidderdalii* that laid eggs on dorsal side of leaves.

As reported by Igarashi (1989), its closest kin *Bhutanitis lidderdalii* laid 20–40 eggs at a time in flat clusters (not mound) on *Aristolochia griffithii* (Bhutan), *Aristolochia kaempferi* Willdenow (Japan), *Aristolochia mandshuriensis* (Korea), and *Aristolochia shimadai* Hayata (Taiwan). *Bhutanitis Mansfield* Riley and *Bhutanitis thaidina* Blanchard were also found laying eggs in flat cluster of 7–42 eggs (Igarashi 1989; Harada et al. 2012). *Paridesarcas mylotes* lay single but usually in loose clusters of 2–5 eggs on a single mature leaf of *Aristolochia constricta* (Young 1973). The ovi-positioning habit of *Bhutanitis ludlowi* conformed to those of *Bhutanitis lidderdalii*, preferring underside of mature *Aristolochia griffithii* leaves (Suzuki 1987; Igarashi 1989). Ovi-positioning took place between August–September for *Bhutanitis ludlowi* and they do not prefer highly exposed and disturbed areas whereas, *Bhutanitis lidderdalii* took place between late September and early October (Igarashi 1989).

Larval Stage of *Bhutanitis ludlowi*

The eggs of *Parnassius* overwintered and spent approximately 10 months to hatch (Igarashi 1989). A Monarch was an egg for 3–8 days (Howard 2006) *Bhutanitis lidderdalii* took about 30 days in egg stage (Igarashi 1989) and hatched out between mid-October and mid-November while *Bhutanitis ludlowi* took 14–18 days to enter the first instar between first-second weeks of September. The larvae proved to be very hardy and passed through winter months of November, December, and January before they pupated in mid-February. Larvae were gregarious throughout their life. Similar to *Bhutanitis liddarlii* larvae (Igarashi 1989), *Bhutanitis ludlowi* larvae had tendency to disperse into smaller groups as they grow older to the extent that the last mature instar larva lived in solitary. As opposed to the feeding habit of *Bhutanitis liddarlii* that fed on leaves, mature larvae of *Bhutanitis ludlowi* fed on leafstalks and tender shoots agreeing to feeding habit of *Pachliopta* (Swallowtail butterflies) and *Atrophaneura* (Red-bodied Swallowtails) of Papilionidae family. *Bhutanitis ludlowi* underwent eight larval instars as opposed to other swallowtails like *Bhutanitis lidderdalii* (Igarashi 1989) and *Paridesarcas mylotes* (Young 1973) of five instars. It remained in caterpillar stage for 161 days while monarch butterfly caterpillar stage was for only 7–17 days (Howard 2006).

Pupa of *Bhutanitis ludlowi*

Bhutanitis ludlowi pre-pupated into "C" shape for seven–nine days and monarch butterfly 8–15 days (Howard 2006). Pupation took normal girdle position like most of the swallowtails. Unlike *Bhutanitis thaidina* that pupated among the leaves (Igarashi 1989); Bhutanitis ludlowi restlessly roamed around in search of healthy substrata. They pupated in mid-February on strong stems of the host plant and iron rod pillars of greenhouse. Young (1973) reported that Paridesarcas mylotes larva stopped feeding at maturation and moved vigorously in search of pupation sites. The monarch butterfly stayed in pupal stage for 8–15 days (Howard 2006) while *Bhutanitis ludlowi* remained in pupal stage for 188 days, one of the longest of such case for swallowtail butterflies.

Adult of *Bhutanitis ludlowi*

The basic life cycle of a butterfly from egg to adult varied from three weeks to two years (Opler & Krizek 1984). Young (1973) reported a developmental time for *Paridesarcas mylotes* on *Aristolochia species* of about 42 days under similar ex-situ condition. Developmental time of *Bhutanitis ludlowi* on *Aristolochia griffithii* in ex situ greenhouse was 365–367 days which is incredibly lengthier. This long developmental time could be attributed to the aestivating period during

Image 3. Development stages of eggs of *Bhutanitis ludlowi*: A—Freshly laid eggs | B—Maturing eggs | C—Apical region of the eggs get darkened as eggs mature | D—Hatching eggs | E—Newly emerged larvae. © Tshering Dendup

Image 4. A—Mature larva | B—Pre-pupating "C" shape larva | C—Pupating | D—Mature pupa | E &F—Adult *Bhutanitis ludlowi* butterfly. © Tshering Dendup

Image 5. Predators: A—Pupa being attacked by an ant | B—Pupa bleeds black fluid due to injury by ants | C—Pupa being attacked by an ant | D—Black fluid oozing out from injured pupa by ants. © Tshering Dendup

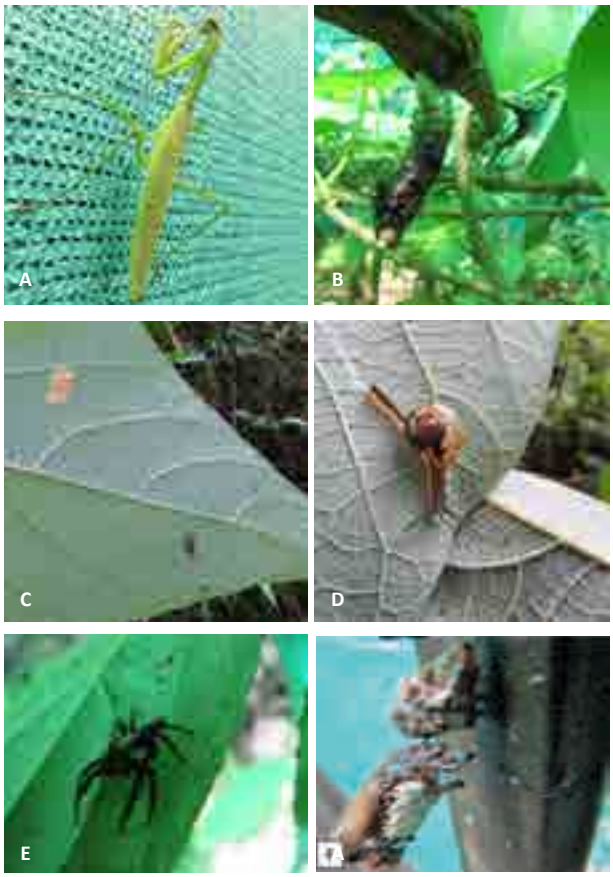

Image 6. Predators: A—Praying mantis | B—Larva attacked by Mantis | C&D—Snail | E—Spider | F—Pupa devoured by unidentified leech like insect. © Tshering Dendup

over-wintering of chrysalis in diapauses. Straatman (1970) found out that egg-adult time of *Ornithopteraa lexandrae* Rothschild to be 131 days on *Aristolochia schlechteri* Lauterb and 107 days on *Aristolochia tagala* Cham.

Enemies of *Bhutanitis ludlowi* and its conservation measures

Predators varied in each life stages of Bhutanitis ludlowi. Owing to the high mortality rate, very huge majority of them were not able to make it to become a butterfly out of few hundred eggs. There were many predators in all stages of lifecycle, but little information is available about the extent to which each of those predators influenced the population. Invertebrate predators such as snails (terrestrial gastropod mollusks), ants (Formicidae), spiders (Arachnids), wasps (Vespidae), and praying mantis (Mantidae) were among those that was found to prey on immature Bhutanitis ludlowi (eggs, larvae, pupae) on Aristolochia plants (Image 5A–D, 6A–E). This may be because of porous agro net used for captive breeding. Similar results were found by Zhang et al. (2019) while studying lifecycle of Bhutanitis lidderdalii in both natural and captive habitat, where the larva and egg were attacked by parasites and insects (Zhang et al. 2019). Bhutanitis ludlowi has mechanism to protect themselves and avoid from predations such as odour, camouflaged colorations and poisons which might have gain after feeding on host plant. A study carried out in Chile (2020) on larva and egg of pipevine Swallowtial found that larvae feed exclusively on highly toxic plants of the genus Aristolochia from which they sequester toxins and later used as defense mechanism to protect from predators (Palma-Onetto et al. 2020).

CONCLUSION

Ever since the discovery and rediscovery of *Bhutanitis ludlowi* by plant explorer Frank Ludlow and George Sheriff and Bhutanese researchers respectively, such comprehensive study on its life cycle was not carried out. For the first time, a complete life cycle stages of *Bhutanitis ludlowi* was recorded at Bumdeling Wildlife Sanctuary on the host plant *Aristolochia griffithii* in ex-situ environment. *Bhutanitis ludlowi* is univoltine brood where the life cycle completes in 365–367 days with egg hatching (14–18 days), larva (five months and eight days), pupa (six months and seven days), and adults emerged after eight instars. Predators of *Bhutanitis*

ludlowi include spider, wasps, praying mantis, snails, and ants.

There is need to carry out a comprehensive study of its life history in in-situ habitats. Though *Aristolochia griffithii* is not palatable to cattle disturbances due to presence of 'Tsethar' (lifelong freely released) bulls in *Bhutanitis ludlowi s*core habitats greatly contributed to reduction of natural regeneration of host plant through foot trampling of young shoots. In future it is important to carry out enrichment plantation of host plants in its prime habitats. The current study recommends in-depth studies like its distribution patterns, behaviors, population trends, and conservation threats in future. Advocacy programs on its conservation importance and formation of community conservation support groups to protect its habitats is seen as one of the priority activities in the identified range of *Bhutanitis ludlowi.*

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OPEN ACCESS

COMMUNICATION

Biodiversity of butterflies (Lepidoptera: Rhopalocera) in the protected landscape of Nandhour, Uttarakhand, India

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Abstract: An appraisal of butterfly species composition in terms of comparative diversity richness in various habitat types was conducted in and around the Nandhour Wildlife Sanctuary of Terai Arc landscape in Uttarakhand. During the two years of survey period (March 2018–February 2020), a total of 89 species of butterflies belonging to families Nymphalidae 43 species, Pieridae 15 species, Lycaenidae 13 species, Hesperiidae eight species, Papilionidae seven species, and Riodinidae three species were recorded, of which 46 species represented new records for the Nandhour Landscape. Butterfly diversity and richness were highest in dense moist & open dry riverine forests and lowest in human settlements & agricultural land. No significant differences in the number of species were found in moist mixed deciduous forest, subtropical Chir Pine forest, moist Bhabar Sal forest, moist Shiwalik Sal forest, and plantation forest. Eight species are endemic to the Indian Himalayan Region.

Keywords: Cultivation, forest ecosystems, host plants, Terai Arc Landscape

Abbreviations: CFD—Champawat Forest Division | HFD—Haldwani Forest Division | TAL—Terai Arc Landscape | TEFD—Terai East Forest Division.

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Author contributions: All the three authors participated in the field surveys. Data collection and analyses were done by HC and AV. Primary draft of the manuscript was written by AV, while editing and manuscript improvement were done by HC and MKA. All authors participated in preparing the final version of the manuscript.

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INTRODUCTION

Butterflies (Lepidoptera: Rhopalocera) are a vital component of our natural ecosystems due to their important pollination services, high specificity of habitat utilization and complex interactions in food webs (Rusman et al. 2016). The status of butterfly diversity and richness in a given area reveals information on the ecosystem health and its functioning (Andrew et al. 2011). Butterflies are useful model organisms in predicting the impact of climate change on biodiversity (Warren et al. 2001; Davies 2019), and are an excellent indicator taxon for monitoring changes in ecological parameters such as environmental health, land use, habitat quality, levels of biodiversity, and conservation status (Bonebrake et al. 2010; Sharma et al. 2020; An & Choi 2021). They respond quickly to changes in local vegetation, climatic conditions, land use types, and disturbances (Bergerot et al. 2011; Chettri et al. 2018; Sharma et al. 2020; Verma & Arya 2021). Several anthropogenic drivers of defaunation have resulted in a global decline of about 35% in butterfly abundance over the last 40 years (Dirzo et al. 2014), and due to unscientific management, many species are on the verge of extinction (Wallenius et al. 2010; Wagner 2020). The Indian subcontinent is represented by about 1,501 butterfly species (Kehimkar 2016), and the hilly state of Uttarakhand in the western Himalaya hosts around 508 species of butterflies (Sondhi & Kunte 2018).

The Nandhour landscape located in the eastern part of Uttarakhand, is a representative part of the vast conservation geographic division called Terai Arc Landscape (TAL). The TAL is an eco–fragile Terai–Bhabar region on the outer slopes of the Shiwalik Himalaya to the foothill areas and Gangetic flood plains (Semwal 2005; Chanchani et al. 2014). The entire region of the Nandhour due to its unique topography, geology, and climate is well known for pristine ecological conditions, spatial heterogeneity and rich biodiversity (WII 2019). The central part of the landscape was designated as a Nandhour Wildlife Sanctuary (covering a total geographical area of 269.95 km^2) in 2012, and recently an eco-sensitive zone (covering a total geographical area of 540.26 km^2) has been established around the periphery of the sanctuary for proper management and propagation of wildlife (Anonymous 2020). However, human activities such as habitat fragmentation, over–exploitation, and poaching have posed serious threats to the rich biodiversity of the region (Mehra 2015).

Published data on butterfly fauna is currently lacking from the protected landscape of Nandhour. The landscape has not been surveyed well since the British colonial era. The Nandhour Landscape provides a crucial corridor for wildlife movement across the eastern forests of TAL, such as Brahmadev & Sukhlaphata Wildlife Reserve of Nepal, and the western forests of Corbett & Terai Central Forest Division in India (Verma 2011; WII 2019). In the recent past, few empirical studies have been conducted in protected and unprotected forest ecosystems of Kumaon and Garhwal regions of Uttarakhand (Singh & Bhandari 2003, 2006; Joshi 2007; Joshi & Arya 2007; Singh 2009; Bhardwaj & Uniyal 2011; Smetacek 2012; Bhardwaj et al. 2012; Singh & Sondhi 2016; Arya et al. 2020a,b; Samraj & Agnihotri 2021; Verma & Arya 2021). However, the butterfly diversity and richness of Nandhour Landscape received less attention and was not comprehensively reported from the protected sanctuary. Earlier, Arya & Dayakrishna (2017) recorded 35 butterfly species from the Nandhour Wildlife Sanctuary. There are also few reports on recent rediscoveries and new records of butterfly species to Uttarakhand from the Nandhour Wildlife Sanctuary (Sondhi 2017; Kumar et al. 2020).

Studies on butterflies are important from the standpoint of their diversity, conservation, behavioral, and ecological functional roles as well as to assess the impact of land use changes on them (Bonebrake et al. 2010; Chettri et al. 2018). At present, there are no comprehensive studies that understand the systematic composition of butterflies in this region. Hence, this research primarily aims to record butterfly diversity and richness patterns across different habitats in and around the Nandhour Wildlife Sanctuary of biodiversity rich TAL. The study also intends to investigate the anthropogenic factors affecting butterfly diversity, and to provide guidelines for effective and proper butterfly conservation.

MATERIALS AND METHODS

Study area

Nandhour Wildlife Sanctuary stretched between 28°56'29.35"–29°16'39.79" N & 79°33'03.82"–80°10'00.03" E, is a sub landscape of the Shiwalik–Bhabar Tract in the central sector of the eastern part of TAL (Figure 1). This sub landscape of Nandhour (core zone) along with its adjoining buffer area (eco–sensitive zone) falls under three protected and managed territorial forest divisions of Uttarakhand i.e. Haldwani Forest Division (HFD in the north-west), Terai East Forest Division (TEFD in the south-east), and Champawat

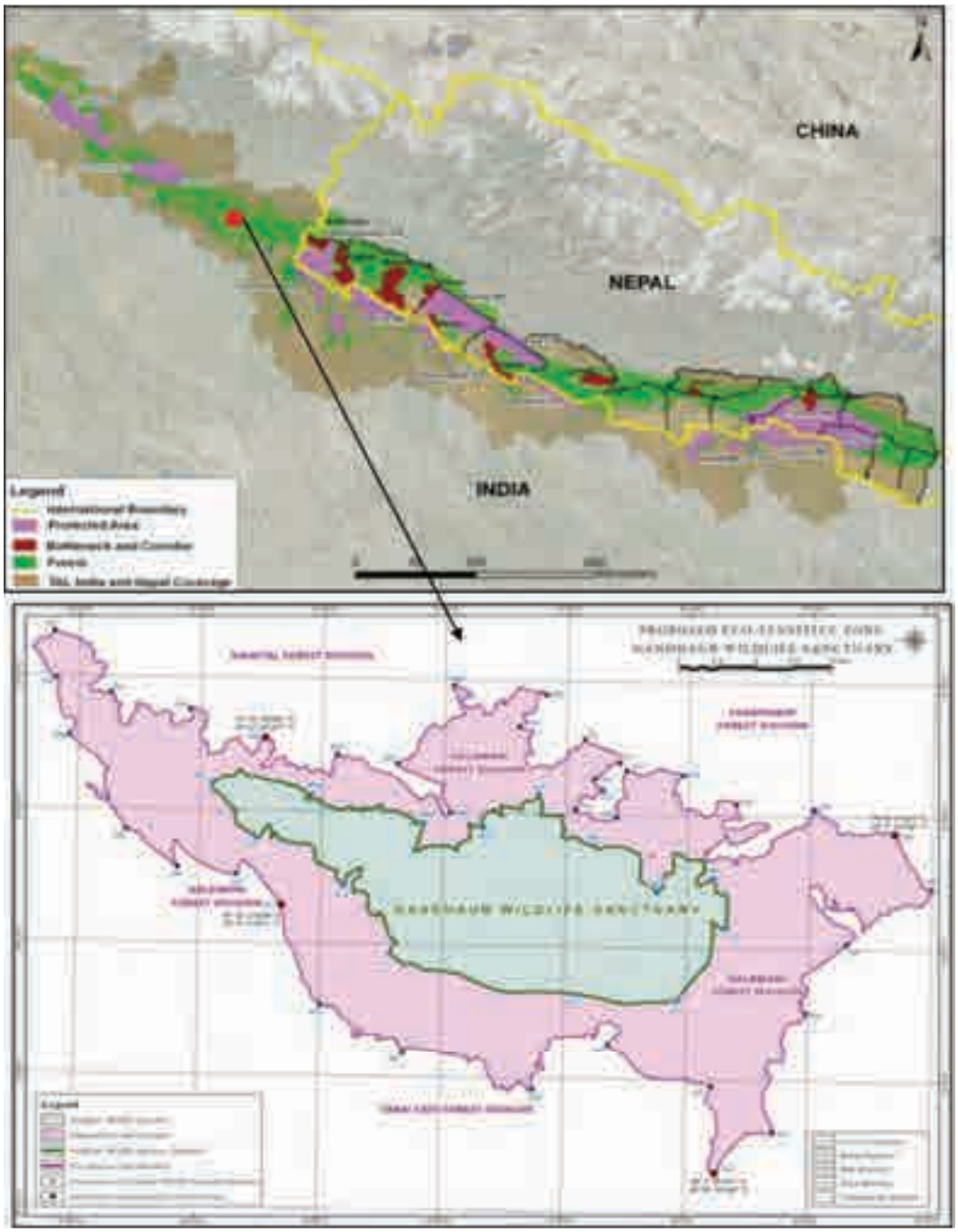

Figure 1. Geographical position of protected Nandhour Landscape in TAL (Terai Arc Landscape) of India (Map data Chanchani et al. 2014; Anonymous 2020).

Forest Division (CFD in the north-east). Majority of the landscape lies in the HFD of district Nainital (Mehra 2015). The Nandhour Landscape is intersected by the river Nandhour in the north, and bounded by river Gola and river Ladhiya in the west, and by the river Sharda in the east towards Nepal (Verma 2011). Geologically, the landscape consists mostly of alluvial plains (Bhabar), and loose conglomerates & hard sandstones of the Shiwalik Himalaya (Mehra 2015). The topography of Nandhour is represented by steep mountains, high denudational hills, broad & narrow valleys, flat & rugged slopes, and flood plains. Due to the close proximity to the Himalayan mountain range, the region experiences sub-tropical to temperate type of climate, and the maximum average temperature varies from 28°C in January–37°C in May (Mehra 2015). With an annual precipitation of over

1,400 mm, the region receives most rainfall from the southwest monsoon that breaks in mid June and lasts until the end of September–October (Mehra 2015).

The landscape harbors diverse and complex ecosystems of tropical moist forests and dry deciduous forests. The dominant vegetation includes *Shorea robusta, Tectona grandis*, *Dalbergia sisso*, *Syzygium cumini*, *Terminalia arjuna*, *Terminalia alata*, *Terminalia bellerica*, *Mallotus philippensis*, *Mallotus repandus*, *Anogeissus latifolia*, *Butea monosperma*, *Calotropis procera*, *Murraya koenigii*, *Clerodendrum infortunatum*, *Justicia adhatoda,* and *Woodfordia fruticosa* (Verma 2011). These natural forest and riverine habitats are home to about 32 mammalian species, including several endangered and flagship species such as the Royal Bengal Tiger *Panthera tigris* and Asian Elephant *Elephas maximus* (Mann et al. 2013), 250 species of resident and migratory birds, 15 reptilian species, and 20 fish species (Verma 2011). The landscape is also represented by plantation forests, wetlands, barren lands, human settlements, and cultivated lands.

Appraisal surveys on butterflies were conducted in different forest ranges by covering a variety of habitats in and around the sanctuary. Butterflies were sampled in eight habitat types (sites): human habitation & agricultural land (S1 in Nandhour Range of HFD), Butterfly Conservation Zone (S2 in Nandhour Range of HFD), dense moist riverine forest (S3 in Nandhour Range of HFD), moist Bhabar sal (*S. robusta*) forest (S4 in Chakata Range of HFD), open dry riverine forest (S5 in Jaulasal Range of HFD), subtropical Chir Pine *Pinus roxburgii* forest (S6 in Chakata Range of HFD), moist Shiwalik Sal forest (S7 in Dogadi Range of CFD) and moist mixed deciduous forest (S8 in Sharda Range of HFD). Of these S1, S2, S3, S5, S6, and S7 were located in the core zone, while S4 & S8 were located in the buffer area of the sanctuary. For the purpose of the present study, an area of one hectare was selected in each site (Image 1 & Table 1). The sites in the study area were selected on the basis of different land use and forest types to reflect the importance of a mosaic of habitats in sustaining butterfly diversity. Management practices and anthropogenic threats within each site were noted during the study period.

Sampling protocols and data collection

Every month, from March 2018–February 2020, butterflies were sampled for eight consecutive sampling days. Sampling was conducted along three permanent linear transects (each measuring 300 m), spaced about 300–500 m apart from each other, in each of the eight habitat types (sites) selected in the study area. Modified Pollard Walk Method was adopted for the presence–absence and abundance data of adult butterfly species in each site (Pollard 1977; Pollard & Yates 1993). Diurnal butterflies were counted mostly during optimal conditions of maximum activity, around an imaginary space of 5 m × 5 m × 5 m while walking slowly and uniformly covering each of the three transects of a site between 07.00–13.00 h of a day. A minimum of 1.5 h was spent on butterfly sampling in a permanent transect. The same survey method was employed in each site on consecutive sampling days. The preferred host plants of butterflies available in the sites were also noted through primary observations and secondary information (Wynter–Blyth 1957; Kunte 2000, 2006; Robinson et al. 2010; Sengupta et al. 2014; Nitin et al. 2018; Sondhi & Kunte 2018).

Most of the butterfly species were identified visually with the help of available field guides (Kumar 2008; Kehimkar 2016; Singh 2017; Sondhi & Kunte 2018), photographed by using lens of power 18–15 mm in DSLRs Nikon D3500 and Canon 750D. Species which were difficult to identify superficially were collected by a butterfly net, placed in a clear glass bottle, and identified using morphological keys outlined in the literature (Evans 1932; Wynter-Blyth 1957; Haribal 1992). Each collected individual was released immediately after identification at the site of its capture, and no specimen was harmed or killed during the field visits. Plant species were identified using published information (Verma 2011; Mehra 2015), and by the help of experts and taxonomists at G.B. Pant National Institute of Himalayan Environment and Sustainable Development.

Data analysis

Monsoon affects the diversity and distribution of butterfly community at a temporal scale across India (Wynter-Blyth 1957), and several species are strictly seasonal (Kunte 1997; Harisha & Hosetti 2021). Therefore, an annual survey period was categorized into three main seasons—summer (March–June), rainy (July–October), and winter (November–February) to determine the seasonality pattern of butterflies in the study area. The taxonomic classification of butterflies was adopted from Kehimkar (2016), Sondhi & Kunte (2018). The total number of counted individuals of each species across habitat types was pooled to obtain the relative abundance following Verma & Arya (2021) expressed as a percentage based on total individual counts of butterfly fauna in the study area. A rank abundance curve to depict the distribution pattern of different

Table 1. Descriptions of sites (habitat types) selected for butterfly samplings in the protected landscape of Nandhour.

Site code	Site name	Geographical coordinates		Elevation (m)	Habitat type	Major vegetation	Management practices and disturbances
		Latitudes (N)	Longitudes (E)				
S1	Nandhour village	29.122	79.701	315	Human habitation and agricultural land	*Mangifera indica*, *Syzygium cumini*, *Azadirachta indica*, *Tectona grandis*, *Cassia fistula*, *Citrus spp.*, *Carica papaya*, *Musa paradisiaca*, *Ageratum conyzoides*, *Urena lobata*, many cultivated crops and vegetables	Cultivation practices, use of pesticides and fertilizers, transportation
S2	Butterfly zone	29.132	79.704	332	Butterfly Conservation Zone	*Tectona grandis*, *Shorea robusta*, *Syzygium cumini*, *Ficus racemosa*, *Cassia fistula*, *Lagerstroemia speciosa*, *Asclepias curassavica*, *Ageratum conyzoides*, *Bidens pilosa*, *Solanum nigrum*, *Vallaris solanacea*, *Bauhinia vahlii*, *Tinospora cordifolia*, *Dendrocalamus strictus*, *Thysanolaena latifolia*	Plantation, ecotourism
S3	Machhli van	29.133	79.705	353	Dense moist riverine forest	*Syzygium cumini*, *Mallotus repandus*, *Ficus semicordata*, *Ficus virens*, *Dalbergia sissoo*, *Bischofia javanica*, *Pterospermum acerifolium*, *Kydia calycina*, *Bauhinia variegata*, *Albizia procera*, *Falconeria insignis*, *Lannea coromandelica*, *Leucaena leucocephala*, *Salix tetrasperma*, *Artemisia nilagirica*, *Rhus parviflora*, *Toddalia asiatica*, *Eclipta prostrata*, *Youngia japonica*, *Lantana camara*, *Argemone mexicana*,*Ageratina adenophora*	Forest patrolling, camping, trekking
S4	Suryadevi temple	29.231	79.638	419	Moist Bhabar sal forest	*Shorea robusta*, *Careya arborea*, *Terminalia alata*, *Aegle marmelos*, *Tectona grandis*, *Mallotus philippensis*, *Dalbergia sisso*, *Cassia fistula*, *Carissa spinarum*, *Calotropis procera*, *Murraya koenigii*, *Ziziphus xylopyrus*, *Clerodendrum infortunatum*, *Capparis zeylanica*	Sacred grove, religious activities, grazing, collection of fuelwood and fodder
S5	Jaulasal	29.069	79.821	245	Open dry riverine forest	*Holoptelea integrifolia*, *Dalbergia sissoo*, *Ficus racemosa*, *Accacia catechu*, *Cordia dichotma*, *Persea gamblei*, *Haldina cordifolia*, *Engelhardtia spicata*, *Kydia calycina*, *Ricinus communis*, *Ardisia solanacea*, *Datura stramonium*, *Lantana camara*, *Youngia japonica*, *Rungia pectinata*, *Ichnocarpus frutescens*, *Argemone mexicana*	Forest patrolling, illicit felling, grazing
S6	Patrani village	29.219	79.692	1044	Subtropical chir pine forest	*Pinus roxburghii*, *Quercus leucotrichophora*, *Ougeinia oojeinensis*, *Grewia optiva*, *Anogeissus latifolia*, *Myrica esculenta*, *Boehmeria rugulosa*, *Cinnamomum tamala*, *Berberis asiatica*, *Rubus ellipticus*, *Pyracantha crenulata*, *Urtica dioica*, *Achyranthes aspera*, *Bidens biternata*, *Cannabis sativa*, *Woodfordia fruticosa*, *Cirsium wallichii*, *Flemingia strobilifera*	Forest fires, grazing, collection of fuelwood, fodder and forest products
S7	Dogadi range	29.070	80.018	350	Moist Shiwalik sal forest	*Shorea robusta*, *Anogeissus latifolia*, *Adina cordifolia*, *Diploknema butyracea*, *Mallotus philippensis*, *Tectona grandis*, *Lagerstroemia parviflora*, *Terminalia alata*, *Ailanthus excelsa*, *Murraya koenigii*, *Clerodendrum infortunatum*, *Flemingia strobilifera*, *Smilax aspera*	Silvicultural activities
S8	Sharda range	29.080	80.092	280	Moist mixed deciduous forest	*Shorea robusta*, *Adina cordifolia*, *Tectona grandis*, *Toona ciliata*, *Dalbergia sisso*, *Mitragyna parviflora*, *Mallotus philippensis*, *Terminalia arjuna*, *Terminalia alata*, *Ehretia laevis*, *Aegle marmelos*, *Bahunia recemosa*, *Ficus benghalensis*, *Ficus religiosa*, *Phyllanthus emblica*, *Schleichera oleosa*, *Madhuca indica*, *Cassia fistula*, *Diospyros melanoxylon*, *Crateva religosa*, *Bombax ceiba*, *Murraya koenigii*, *Ziziphus xylopyrus*, *Clerodendrum infortunatum*, *Ageratina adenophora*, *Lantana camara*	Logging, transportation

species was created by log transforming the individual abundance data following Magurran (2004). Diversity measures were obtained using the Shannon–Weiner diversity index (Shannon & Weaver 1949), Margalef richness index (Margalef 1972), and Pielou evenness index (Pielou 1969). Individual based rarefaction curves were obtained for each habitat types following Gotelli & Colwell (2001). The analyses of diversity measures and rarefaction curves were done using the software PAST (Hammer et al. 2001). In order to compare the species

richness and abundance of butterflies across seasons and habitat types, one–way analysis of variance (ANOVA) tests at the 5% level of significance were performed using the software SPSS. The Sorensen's similarity index was calculated to determine the extent of assemblage similarity in different habitat types of the study area (Sorensen 1948).

RESULTS

Overall species composition of butterflies

A total of 10,713 individuals belonging to 89 species and six families were recorded during the study period (2018–20) from eight habitat types selected in the Nandhour Landscape (Appendix 1). The butterfly community was more or less evenly distributed in the study area as depicted by a relatively low steep inclination of the plot in the rank abundance curve (Figure 2). Detailed account of each family is given below:

Family Hesperiidae: This family comprised of eight species and 4.48% of the total recorded individuals (Images 1–8). Species namely, *Parnara guttatus* (Relative abundance = 1.82) and *Borbo bevani* (1.29) were the most abundant found across all habitats, while the least abundant species *Udaspes folus* (0.13) was found in agricultural land, dry riverine, and chir pine forests, & *Aeromachus stigmata* (0.13) in chir pine forest (Appendix 1).

Family Riodinidae: Riodinidae consisted of three species with 1.90% of the total individuals (Images 9–11). *Dodona durga* (1.39) recorded as the most abundant species in this family was found across all habitats except agricultural land and butterfly zone. *Abisara bifasciata* (0.07) recorded as the least abundant was found in moist riverine and Shiwalik Sal forests (Appendix 1).

Family Pieridae: With a total of 37.97% individuals, Pieridae was the most abundant family and comprised of 15 species (Images 12–26). Most of the species were euryoecious in nature. Species such as *Catopsilia pomona* (6.78), *Pieris brassicae* (5.84), *Eurema laeta* (5.05), *Eurema hecabe* (4.48), *Pieris canidia* (3.97), and *Catopsilia pyranthe* (3.85) were recorded as the most abundant and found across all habitats. The least abundant species under this family namely, *Colias erate* (0.35) was found in butterfly zone, moist & dry riverine forests, Chir Pine forest, and mixed deciduous forest, and *Eurema andersonii* (0.45) in moist Bhabar Sal forest, moist & dry riverine forests (Appendix 1).

Family Papilionidae: This family was comprised of

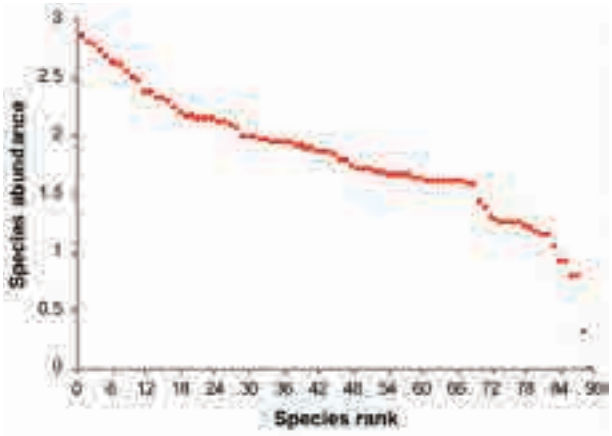

Figure 2. Rank abundance curve of butterfly species in the study area.

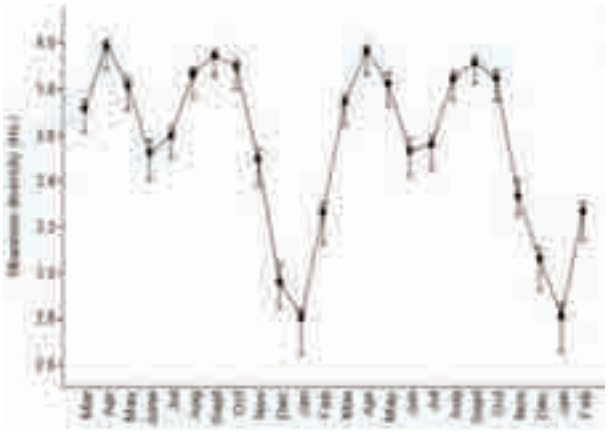

Figure 3. Month–wise Shannon diversity of butterflies recorded from March 2018–February 2020.

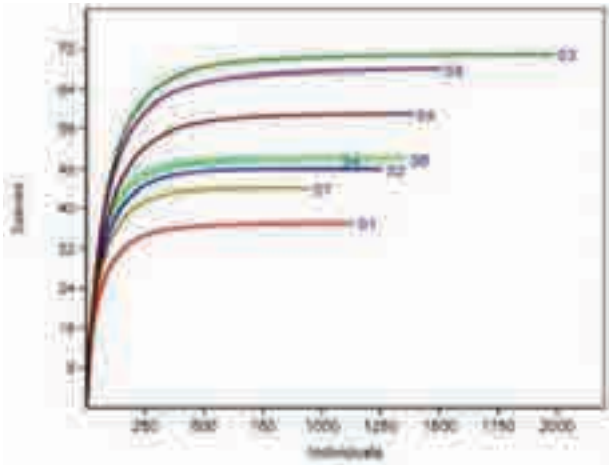

Figure 4. Individual rarefaction curves of butterfly assemblages across eight sites (habitat types) selected in the study area.

seven species and 9.24% of the total recorded individuals (Images 27–33). Swallowtails, namely, *Papilio polytes* (3.70), and *Papilio demoleus* (2.88) were the most abundant found across all habitats, while *Papilio clytia* (0.16) found in moist riverine and mixed deciduous forests, and *Graphium nomius* (0.42) in moist riverine, Bhabar Sal & mixed deciduous forests were the least abundant species under this family (Appendix 1).

Family Lycaenidae: This family was comprised of 13 butterfly species and 17.87% of the total recorded individuals (Images 34–46). Species such as *Pseudozizeeria maha* (5.69), *Heliophorus sena* (3.20), *Zizeeria karsandra* (2.81), and *Lampides boeticus* (1.91) were the most abundant and found in almost all habitats. *Flos asoka* (0.05) found in Shiwalik sal forest, *Tarucus nara* (0.05) in moist and dry riverine forest, and *Arhopala amantes* (0.10) in Shiwalik sal forest were recorded as the least abundant species under this family (Appendix 1).

Family Nymphalidae: Nymphalidae with a total of 43 species was the most species rich and with a total of 28.51% individuals was the second abundant family in the study area (Images 47–89). The most abundant species included *Euploea core* (2.14), *Danaus genutia* (1.91), *Danaus chrysippus* (1.66), *Junonia iphita* (1.48), *Ypthima kasmira* (1.28), and *Parantica aglea* (1.26) which were also found in all habitats. The least abundant species were *Athyma selenophora* (0.01) found in moist riverine forest, *Charaxes agrarius* (0.07), *Lethe confusa* (0.09), and *Ypthima asterope* (0.14) found in dry riverine forest (Appendix 1).

Seasonality of butterflies

Across the seasons, species richness, and abundance showed significant differences when analyzed through one–way ANOVA (Richness: F = 31.21, df = 2, 21, and P = 0.00; Abundance: F = 21.25, df = 2, 21, and P = 0.00). The highest number of species and individuals were recorded during rainy season (82 species and 50.46% of the total individuals), followed by summer (78 species and 37.56% of the total individuals) (Table 2). Winter season showed a significantly lower richness and abundance (48 species and 11.97% of the total individuals).

Seasonally, a bi-annual peak in butterfly diversity was observed in the study area (Figure 3). The Shannon diversity (Hs) was at its peak during the dry summers (Mar–May) and the monsoons (Aug–Oct). Diversity was at its minimum during Dec–Jan (winters). Forty-eight species were found across all seasons, 23 species were found during the summer and rainy seasons, 11 species were found during the rainy season, and seven species were found during the summer (Appendix 1).

Table 2. Number of species and individuals of butterflies recorded in different months and seasons in Nandhour landscape.

Seasons	Months	Month-wise		Season-wise	
		Species	Individuals	Species	Individuals
Summer	March	64	1,396	78	4,024
	April	76	1,328		
	May	66	811		
	June	48	489		
Rainy	July	54	929	82	5,406
	August	67	1,460		
	September	79	1,817		
	October	71	1,200		
Winter	November	44	500	48	1,283
	December	26	213		
	January	20	140		
	February	34	430		

Table 3. Values of diversity indices calculated for butterfly assemblages across sites and study area.

Diversity measures	Study sites								Study area
	S1	S2	S3	S4	S5	S6	S7	S8	
Shannon (Hs)	3.20	3.56	3.97	3.68	3.90	3.69	3.42	3.69	3.93
Margalef (Hm)	5.11	6.58	9.21	7.02	9.15	6.79	6.27	8.01	9.48
Evenness (J)	0.67	0.73	0.75	0.79	0.73	0.80	0.69	0.68	0.57

Diversity and richness patterns of butterflies across habitats

The steeper and asymptotic individual rarefaction curves showed adequate sampling efforts to differentiate assemblages in each site (Figure 4). The overall species richness pattern differed significantly across the selected habitat types (ANOVA: F 3.92, df 7, 184, and P 0.00), while the abundance showed insignificant differences (ANOVA: F 0.61, df 7, 184, and P 0.74). The highest number of species was recorded in S3 (71 species), followed by S5 (68 species), S8 (59 species), S4, S6 (50 species each), S2 (48 species), S7 (44 species), and S1 (37 species).

The calculated diversity measures show high richness patterns in eight habitat types of the study area (Table 3). The maximum species diversity and richness was recorded in the sites represented by riverine forests (S3, S5 with Hs 3.97 & 3.90; Hm 9.21 & 9.15, respectively), while the habitat characterized by human settlements and agricultural land showed the minimum

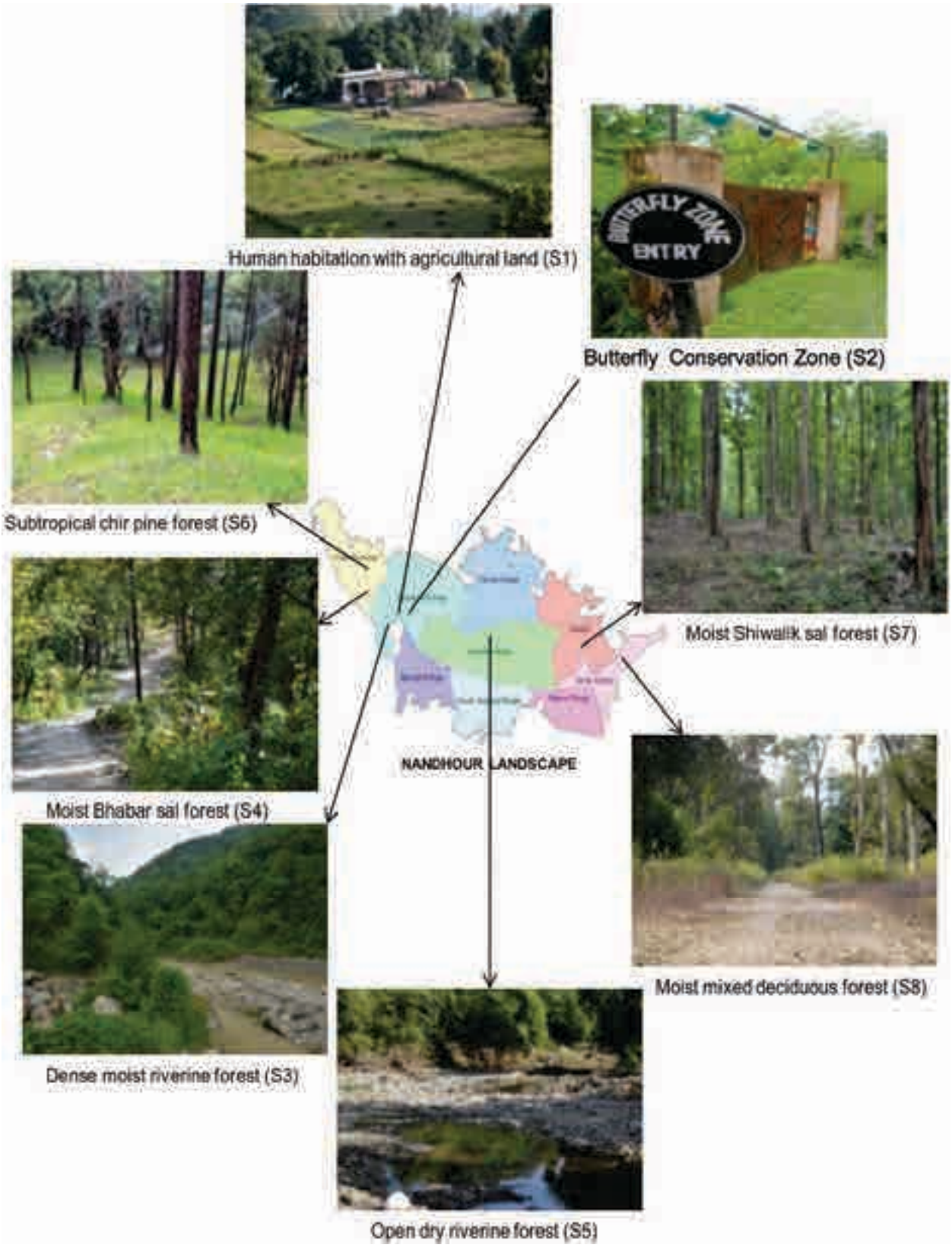

Image 1. Location and view of habitat types (sites) selected for butterfly samplings in the Nandhour Landscape (Map data Verma 2011).

Table 4. Values of Sorensen's similarity index calculated for butterfly assemblages across sites.

	S1	S2	S3	S4	S5	S6	S7	S8
S1	0							
S2	0.82	0						
S3	0.63	0.72	0					
S4	0.69	0.71	0.76	0				
S5	0.67	0.76	0.87	0.68	0			
S6	0.69	0.71	0.68	0.78	0.66	0		
S7	0.76	0.78	0.71	0.64	0.71	0.68	0	
S8	0.67	0.77	0.81	0.72	0.80	0.73	0.75	0

Value ranges between 0 to 1 and higher numbers indicate greater similarity.

diversity, richness, and evenness of the species (S1 with Hs 3.20, Hm 5.11, and J 0.66). Butterfly assemblage in the subtropical Chir Pine forest at S6 was very even in its distribution (J 0.80).

The pair-wise comparisons of Sorensen's similarity index for assemblages in different habitat types depicted that riverine forests (S3 & S5) had high similarity (0.87) and a unique species composition (Table 4). Similarly, man managed habitats (S1 & S2) had a high degree of similarity (0.82), and mixed deciduous forest (S8) had high similarity (0.81 & 0.80) with moist riverine forest (S3) and dry riverine forest (S5). 26 species were found across all the habitat types, while nine species were found as habitat specific in the study area (Appendix 1).

DISCUSSION

The present study revealed that the protected Nandhour landscape of TAL, with 89 species belonging to six families hosts good diversity (Hs 3.927) and richness (Hm 9.484) of butterflies (Appendix 1, Table 3). The recorded butterfly richness constituted about 17.50% of the total known species from Uttarakhand (Sondhi & Kunte 2018). Previous to this study, there are known records of 20 species in Nandhour Village (S1), 34 species in Butterfly Zone (S2), 32 species in Machhli Van (S3), 26 species in Suryadevi Temple (S4), and 28 species in Jaulasal (S5), which altogether constituted 53 species of butterflies from the protected area of Nandhour (Arya & Dayakrishna 2017). Of them, 42 species were also recorded in the present study, while the rest 47 species (out of 89 species) represent new records for the Nandhour Landscape (Appendix 1). The unreported butterfly species included *Spialia galba* (Hesperiidae), *Pachliopta aristolochiae*, *Graphium doson* (Papilionidae), *Ixias marianne*, *Colotis* sp., *Belenois aurota* (Pieridae), *Neopithecops zalmora*, *Freyeria trochylus* (Lycaenidae), *Hypolimnas misippus*, *Cupha erymanthis, Neptis sankara,* and *Ypthima huebneri* (Nymphalidae). Most of these species are either common or uncommon in Uttarakhand (Sondhi & Kunte 2018). Such results substantiate the importance of natural forest habitats in sustaining and maintaining the rich butterfly diversity. More intensive and consistent monitoring protocols could result in the addition of new butterfly species to the protected landscape of Nandhour.

In comparison to modern empirical studies conducted previously in different forest ecosystems of Uttarakhand, Samraj & Agnihotri (2021) reported 92 butterfly species in the nearby Terai region of Pantnagar, Verma & Arya (2021) reported 98 species in the Pancheshwar Multipurpose Project Site of district Champawat, Arya et al. (2020a) recorded 56 species in the Corbett Tiger Reserve, Arya et al. (2020b) reported 46 species in the Binsar Wildlife Sanctuary, Bhardwaj et al. (2012) recorded 79 species in the Tons Valley of Garhwal region, Smetacek (2012) reported 243 species from a dying watershed in the Kumaon region, Bhardwaj & Uniyal (2011) reported 34 species in the Gangotri National Park, Singh (2009) recorded 143 species in the Kedarnath Musk Deer Reserve, Joshi & Arya (2007) reported 54 species in the Pindari area of Nanda Devi Biosphere Reserve, Joshi (2007) reported 40 species in the Motichur Sanctuary of Rajaji National Park, Singh & Bhandari (2003, 2006) recorded 183 species in the Dehradun Valley of Garhwal region. Furthermore, annual rainfall patterns have a significant impact on tropical butterflies (Wolda 1988; Valtonen et al. 2013), and the occurrence of dry–wet seasonal cycles generate bi–annual rhythms in species diversity and similarity of butterfly communities by bringing changes in the host plant dynamics of the region (Grøtan et al. 2012, 2014). The reported high diversity and richness during dry summers (Mar–May) and wet monsoons (Aug–Oct) is in concordance with previous findings from the study area (Arya & Dayakrishna 2017), as well as from the regions experiencing tropical to sub–tropical type of climate in India (Gupta et al. 2019; Arya et al. 2020a).

Amongst the sampled habitats, butterfly richness was significantly low in the site (S1) characterized by human habitation and agricultural land (Figure 4). Local transportation, increased cultivation with use of chemical fertilizers & pesticides, and other human activities might have resulted in the least diversity and richness in S1 (Table 3). Generalist species like *P. brassicae*, *P. demoleus*, *P. polytes*, *C. pomona*, *E. hecabe*

and *P. guttatus* dominated this habitat (Appendix 1). It is known that declines in soil properties caused by pollution from anthropogenic toxins and habitat simplification through agriculture could result in reduced diversity and local extinctions of butterflies (Öckinger et al. 2006; Gilburn et al. 2015; Braak et al. 2018). On the other hand, the relatively less disturbed sites characterized by dense moist and open dry riverine habitats (S3 & S5), had the highest number of species and ample diversity (Figure 4, Table 3). Natural forests, especially associated with the riverine ecosystems usually have greater environmental heterogeneity, provide unique vegetation & large quantities of diverse resources, better mating & ovipositioning sites, safety from predation, and low disturbance, hence are highly preferred by several butterflies, including specialist species (Cabette et al. 2017; An & Choi, 2021).

Species namely, *A. selenophora* (in S3), *C. agrarius*, *L. confusa*, *Y. asterope* (in S5), *Pseudocoladenia fatih*, *T. nara*, *Charaxes bharata*, *Hestinalis nama*, *Kallima inachus,* and *Vagrans egista* (in both S3 & S5) were found as habitat specific butterflies in the riverine forests (Appendix 1). Similarly, *A. amantes*, *F. asoka* were unique to the moist Shiwalik Sal forest (S7), *A. stigmata*, *Ypthima nareda* to the subtropical Chir Pine forest (S6), and *Zizula hylax* to the butterfly zone (S2). These findings suggest that since the Nandhour landscape comprises of a variety of forest habitats types, it provides a congenial living environment and a diverse food supply for many species. Also, these results corroborate with a few earlier findings from nearby regions that revealed a high butterfly diversity and richness in natural habitats, but a low diversity and richness in habitats disturbed or managed by the human activities (Arya et al. 2020a; Samraj & Agnihotri 2021; Verma & Arya 2021).

As per the Indian Wildlife (Protection) Act 1972, five species identified in the present study are legally protected under different schedules (Appendix 1). Butterflies namely, *L. boeticus* (Lycaenidae), *Libythea lepita*, *Neptis soma* (Nymphalidae) are listed under Schedule II, and *E. core*, *Euploea mulciber* (Nymphalidae) are listed under Schedule IV (Anonymous 2006). Endemic butterflies of the Indian Himalayan Region included *Potanthus dara* (Hesperiidae), *D. durga* (Riodinidae), *H. sena* (Lycaenidae), *Acraea issoria*, *Aglais caschmirensis*, *Athyma cama*, *Neptis hylas,* and *Ypthima nikaea* (Nymphalidae) (Appendix 1). Such faunal records along with the reported rich diversity of butterflies signify a high conservation value of the study area. This means, the region must be conserved more intensely, especially by focusing on scientific management of riverine forest habitats located in and around the sanctuary. Butterflies are an excellent ecological indicator group for scaling and quantifying riverine characteristics because of their strong relationship with larval food plants, and riverine zones are thus conservation priority sites (Cabette et al. 2017; An & Choi 2021). Stream sides or muddy bogs in riverine forests are important microhabitats for those adult butterflies seeking rich puddling grounds to intake water and nutrients lacking in their larval diet (Nelson 2007; Verma & Arya 2021).

Human induced pressures in forest habitats from activities such as increased cultivation, forest fires, cattle grazing, illicit felling & logging, and collecting fuelwood, fodder & forest products could threaten the existence of several butterfly species in the protected landscape of Nandhour. These disturbances could have adverse impacts on their host plants in natural habitats, while the use of pesticides and fertilizers in cultivated areas adjacent to the sanctuary could be detrimental to rich biodiversity of the region (Braak et al. 2018; An & Choi 2021; Verma & Arya 2021). Being phytophagous, butterflies play vital role in the 'green' food webs of tropical ecosystems (Kitching et al. 2020), and form a critical food base for organisms at higher trophic levels (Bonebrake et al. 2010). Agricultural chemicals cause butterfly declines and may disrupt their complex ecological interactions, potentially harming insectivorous species such as birds and bats (Gilburn et al. 2015; Forister et al. 2016). Thus, it is extremely important that the soil properties in the cultivated lands of the protected Nandhour Landscape should not be deteriorated by the use of any sort of biocide, and the practice of organic farming must be encouraged by the concerned authorities for better socio-economic development of local inhabitants as well as for regional biodiversity conservation and natural balance.

CONCLUSION

The present study indicates the high conservation value of ecologically fragile natural habitats in sustaining rich diversity including several habitat specific, legally protected, and endemic butterflies of the Himalayas. However, overexploitation, illegal utilizations, excessive grazing, unauthorized access, and non-forestry related developments could cause declines in diversity by directly limiting important food choices and resources. Such activities should be regulated and strictly monitored in the protected Nandhour landscape. Special emphasis should be placed on the preservation and restoration of

Image 1. *Aeromachus stigmata* ©HC

Image 2. *Borbo bevani* ©HC

Image 3. *Parnara guttatus* ©HC

Image 4. *Potanthus dara* ©HC

Image 5. *Pseudocoladenia fatih* ©HC

Image 6. *Tagiades litigiosa* ©HC

Image 7. *Telicota colon* ©AV

Image 8. *Udaspes folus* ©HC

Image 9. *Abisara bifasciata* ©HC

Image 10. *Dodona durga* ©AV

Image 11. *Zemeros flegyas* ©AV

Image 12. *Catopsilia pomona* ©HC

Image 13. *Catopsilia pyranthe* ©HC

Image 14. *Cepora nerissa* ©HC

Image 15. *Colias erate* ©AV

Image 16. *Colias fieldii* ©HC

Image 17. *Delias eucharis* ©HC

Image 18. *Eurema hecabe* ©HC

Image 19. *Eurema andersonii* ©HC

Image 20. *Eurema blanda* ©AV

Image 21. *Eurema brigitta* ©HC

Image 22. *Eurema laeta* ©HC

Image 23. *Gonepteryx rhamni* ©HC

Image 24. *Pareronia valeria* ©HC

Image 25. *Pieris brassicae* ©HC

Image 26. *Pieris canidia* ©HC

Image 27. *Graphium nomius* ©HC

Image 28. *Graphium sarpedon* ©HC

Image 29. *Papilio blanor* ©HC

Image 30. *Papilio clytia* ©HC

Image 31. *Papilio demoleus* ©HC

Image 32. *Papilio polytes* ©HC

Image 33. *Papilio protenor* ©HC

Image 34. *Arhopala amantes* ©HC

Image 35. *Castalius rosimon* ©HC

Image 36. *Flos asoka* ©HC

Image 37. *Heliophorus sena* ©AV

Image 38. *Jamides celeno* ©AV

Image 39. *Lampides boeticus* ©AV

Image 40. *Loxura atymnus* ©HC

Image 41. *Pseudozizeeria maha* ©HC

Image 42. *Talicada nyseus* ©HC

Image 43. *Tarucus nara* ©HC

Image 44. *Zizeeria karsandra* ©HC

Image 45. *Zizina otis* ©HC

Image 46. *Zizula hylax* ©HC

Image 47. *Acraea issoria* ©HC

Image 48. *Aglais caschmirensis* ©AV

Image 49. *Ariadne merione* ©HC

Image 50. *Athyma cama* ©HC

Image 51. *Athyma perius* ©AV

Image 52. *Athyma selenophora* ©HC

Image 53. *Charaxes agrarius* ©HC

Image 54. *Charaxes bharata* ©HC

Image 55. *Cyrestis thyodamas* ©AV

Image 56. *Danaus chrysippus* ©HC

Image 57. *Danaus genutia* ©HC

Image 58. *Euploea core* ©HC

Image 59. *Euploea mulciber* ©AV

Image 60. *Euthalia aconthea* ©HC

Image 61. *Hestinalis nama* ©HC

Image 62. *Hypolimnas bolina* ©HC

Image 63. *Junonia almana* ©HC

Image 64. *Junonia atlites* ©HC

Image 65. *Junonia iphita* ©AV

Image 66. *Junonia lemonias* ©HC

Image 67. *Junonia orithya* ©HC

Image 68. *Kallima inachus* ©AV

Image 69. *Kaniska canace* ©AV

Image 70. *Lethe confusa* ©HC

Image 71. *Lethe rohria* ©HC

Image 72. *Libythea lepita* ©HC

Image 73. *Melanitis leda* ©HC

Image 74. *Mycalesis perseus* ©HC

Image 75. *Neptis hylas* ©HC

Image 76. *Neptis clinia* ©HC

Image 77. *Neptis soma* ©AV

Image 78. *Pantoporia hordonia* ©HC

Image 79. *Parantica aglea* ©HC

Image 80. *Phalanta phalantha* ©HC

Image 81. *Symbrenthia lilaea* ©HC

Image 82. *Tirumala limniace* ©HC

Image 83. *Vagrans egista* ©AV

Image 84. *Vanessa cardui* ©HC

Image 85. *Vanessa indica* ©HC

Image 86. *Ypthima asterope* ©HC

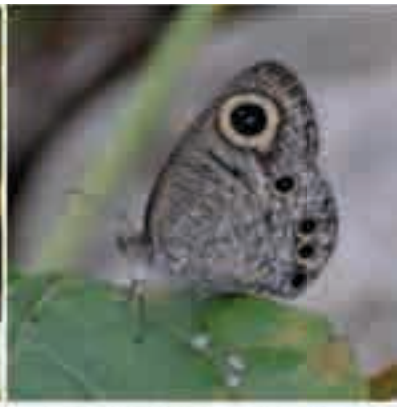

Image 87. *Ypthima kasmira* ©HC

Image 88. *Ypthima nareda* ©HC

Image 89. *Ypthima nikaea* ©AV

interconnected natural forests supporting rich diversity, as well as providing better gene flow between butterfly populations. The establishment of several biodiversity offsets in different habitats will aid in the proliferation of butterflies. Government authorities and local bodies associated with management of the sanctuary should focus on activities related to plantation of more host plants and continuous monitoring programs to ensure their effective long-term conservation in the landscape.

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Appendix 1. Checklist of butterflies recorded from the Nandhour Landscape, Uttarakhand, India (March 2018–February 2020).

	Common name	Scientific name	Presence (+) and absence (-) across sites								Seasonality	Relative abundance
			S1	S2	S3	S4	S5	S6	S7	S8		
	Family: Hesperiidae											
01	Veined Scrub Hopper	*Aeromachus stigmata* (Moore)*	-	-	-	-	-	+	-	-	R	0.13
02	Lesser Rice Swift	*Borbo bevani* (Moore)*	+	+	+	+	+	+	+	+	S, R, W	1.29
03	Straight Swift	*Parnara guttatus* (Moore)	+ (a)	+	+	+	+	+	+	+	S, R, W	1.82
04	West Himalayan Dart	*Potanthus dara* (Kollar)* [E]	-	-	+	+	+	-	-	-	R	0.38
05	West Himalayan Pied Flat	*Pseudocoladenia fatih* (Kollar)*	-	-	+	-	+	-	-	-	S, R	0.34
06	Water Snow Flat	*Tagiades litigiosa*Moschler*	-	-	+	+	-	+	-	+	R	0.22
07	Dark Palm Dart	*Telicota colon* (Fabricius)	-	-	+ (a)	+ (a)	+ (a)	-	-	+	S, R	0.14
08	Grass Demon	*Udaspes folus* (Cramer)*	+	-	-	-	+	+	-	-	R	0.13
	Family: Riodinidae											
09	Double–banded Judy	*Abisara bifasciata* Moore*	-	-	+	-	-	-	+	-	R	0.07
10	Common Punch	*Dodona durga* (Kollar)* [E]	-	-	+	+	+	+	+	+	S, R, W	1.39
11	Punchinello	*Zemeros flegyas* (Cramer)*	-	+	+	-	+	+	+	+	S, R, W	0.43
	Family: Pieridae											
12	Lemon Emigrant	*Catopsilia pomona* (Fabricius)	+ (a)	-	+	+	+	+	+	+	S, R, W	6.78
13	Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus)	+ (a)	-	+	+	+	+	+	+	S, R, W	3.85
14	Common Gull	*Cepora nerissa* (Fabricius)	-	-	+ (a)	-	+	-	-	+	S, R	0.78
15	Eastern Pale Clouded Yellow	*Colias erate* (Esper)*	-	+	+	-	+	+	-	+	S, R, W	0.35
16	Dark Clouded Yellow	*Colias fieldii* Menetries	+	+	+ (a)	+	+ (a)	+	+	+	S, R, W	0.92
17	Indian Jezebel	*Delias eucharis* (Drury)	+	-	-	-	-	-	-	+	S, R, W	0.73
18	Common Grass Yellow	*Eurama hecabe* (Linnaeus)	+ (a)	-	+	+	+	+	+	+	S, R, W	4.48
19	One-spot Grass Yellow	*Eurema andersonii* (Moore)	-	-	+	+	+	-	-	-	R	0.45
20	Three-spot Grass Yellow	*Eurema blanda* (Boisduval)	-	-	+	+	+	-	-	-	S, R	0.80
21	Small Grass Yellow	*Eurema brigitta* (Stoll)*	+	+	+	-	+	-	-	-	S, R, W	2.22
22	Spotless Grass Yellow	*Eurema laeta* (Boisduval)	+ (a)	+	+	+	+	+	+	+	S, R, W	5.05
23	Pale Brimstone	*Gonepteryx rhamni* (Linnaeus)*	+	+	+	+	+	+	+	+	S, R, W	1.20
24	Indian Wanderer	*Pareronia valeria* (Cramer)	-	-	+	-	+	-	+	+	S, R, W	0.48
25	Large Cabbage White	*Pieris brassicae* (Linnaeus)*	+	+	+	+	+	+	+	+	S, R, W	5.84
26	Asian Cabbage White	*Pieris canidia* (Linnaeus)	+ (a)	-	+	+	+	+	+	+	S, R, W	3.97
	Family: Papilionidae											
27	Spot Swordtail	*Graphium nomius* (Esper)	-	-	+ (a)	+ (a)	-	-	-	+	S	0.42
28	Common Bluebottle	*Graphium sarpedon* (Linnaeus)*	-	-	+	-	+	-	+	+	S, R	0.78
29	Common Peacock	*Papilio bianor* Cramer*	-	-	+	+	+	+	-	+	S, R, W	0.71
30	Common Mime	*Papilio clytia* (Linnaeus)*	-	-	+	-	-	-	-	+	S	0.16
31	Lime Swallowtail	*Papilio demoleus* (Linnaeus)	+ (a)	-	+	+	+	+	+	+	S, R, W	2.88
32	Common Mormon	*Papilio polytes* (Linnaeus)	+ (a)	-	+	+	+	+	+	+	S, R, W	3.70

	Common name	Scientific name	Presence (+) and absence (-) across sites								Seasonality	Relative abundance
			S1	S2	S3	S4	S5	S6	S7	S8		
33	Spangle	*Papilio protenor* Cramer*	-	-	+	+	-	+	-	+	S, R	0.55
	Family: Lycaenidae											
34	Large Oakblue	*Arhopala amantes* (Hewitson)*	-	-	-	-	-	-	+	-	R	0.10
35	Common Pierrot	*Castalius rosimon* (Fabricius)	-	-	+ (a)	-	+ (a)	-	-	+	S, R, W	0.42
36	Spangled Plushblue	*Flos asoka* (de Niceville)*	-	-	-	-	-	-	+	-	S	0.05
37	Sorrel Sapphire	*Heliophorus sena* (Kollar)[E]	+	+	+ (a)	-	+	+	+	+	S, R, W	3.20
38	Common Cerulean	*Jamides celeno* (Cramer)	+	-	+	-	+	+	+	-	S, R, W	1.06
39	Pea Blue	*Lampides boeticus* (Linnaeus)#	+	-	+	+	+	+	+	+	S, R, W	1.91
40	Yamfly	*Loxura atymnus* (Stoll)*	-	-	-	-	+	-	+	+	R	0.36
41	Pale Grass Blue	*Pseudozizeeria maha* (Kollar)*	+	+	+	+	+	+	+	+	S, R, W	5.69
42	Red Pierrot	*Talicada nyseus* (Guerin-Meneville)*	-	-	+	+	-	+	-	-	S, R	0.66
43	Striped Pierrot	*Tarucus nara* (Kollar)	-	-	+ (a)	-	+ (a)	-	-	-	R	0.05
44	Dark Grass Blue	*Zizeeria karsandra* (Moore)*	+	+	+	+	+	+	+	+	S, R, W	2.81
45	Lesser Grass Blue	*Zizina otis* (Fabricius)*	+	+	+	+	-	-	-	-	S, R, W	1.35
46	Tiny Grass Blue	*Zizula hylax* (Fabricius)*	-	+	-	-	-	-	-	-	S	0.16
	Family: Nymphalidae											
47	Yellow Coster	*Acraea issoria* (Hubner)* [E]	-	-	+	-	+	+	-	+	S, R	0.68
48	Indian Tortoiseshell	*Aglais caschmirensis* (Kollar)* [E]	+	+	+	+	+	+	+	+	S, R, W	1.26
49	Common Castor	*Ariadne merione* (Cramer)	+ (a)	+	+ (a)	+ (a)	+ (a)	+	+	+	S, R, W	0.88
50	Orange Staff Sergeant	*Athyma cama* Moore* [E]	-	-	+	-	+	-	-	+	S, R	0.15
51	Common Sergeant	*Athyma perius* (Linnaeus)*	-	-	+	-	-	-	+	+	S, R	0.40
52	Staff Sergeant	*Athyma selenophora* (Kollar)*	-	-	+	-	-	-	-	-	S	0.01
53	Anomalous Nawab	*Charaxes agrarius* Swinhoe*	-	-	-	-	+	-	-	-	R	0.07
54	Indian Nawab	*Charaxes bharata* Felder & Felder*	-	-	+	-	+	-	-	-	S, R	0.25
55	Common Map	*Cyrestis thyodamas* Boisduval	-	-	-	-	+	+	-	+	S, R	0.46
56	Plain Tiger	*Danaus chrysippus* (Linnaeus)	+ (a)	-	+ (a)	+ (a)	+ (a)	+	+	+	S, R, W	1.66
57	Striped Tiger	*Danaus genutia* (Cramer)	+ (a)	-	+ (a)	+ (a)	+ (a)	+	+	+	S, R, W	1.91
58	Common Crow	*Euploea core* (Cramer)#	+ (a)	-	+ (a)	+ (a)	+ (a)	+	+	+	S, R, W	2.14
59	Striped Blue Crow	*Euploea mulciber* (Cramer#	-	-	+	-	+	-	+	+	S, R, W	0.37
60	Baron	*Euthalia aconthea* (Cramer)	+ (a)	+	- (a)	-	+ (a)	-	-	+	S, R, W	0.36
61	Circe	*Hestinalis nama* (Doubleday)*	-	-	+	-	+	-	-	-	S, R	0.38
62	Great Eggfly	*Hypolimnas bolina* (Linnaeus)	- (a)	-	+	+	+ (a)	-	+	+	S, R, W	0.57
63	Peacock Pansy	*Junonia almana* (Linnaeus)	- (a)	+	+ (a)	+ (a)	+ (a)	-	-	+	S, R, W	0.87
64	Grey Pansy	*Junonia atlites* (Linnaeus)	-	+	+ (a)	- (a)	+ (a)	-	-	+	S, R, W	0.40
65	Chocolate Pansy	*Junonia iphita* (Cramer)	+	+	+	+ (a)	+ (a)	+	+	+	S, R, W	1.48
66	Lemon Pansy	*Junonia lemonias* (Linnaeus)	+ (a)	-	+ (a)	+ (a)	+ (a)	+	+	+	S, R, W	0.84
67	Blue Pansy	*Junonia orithya* (Linnaeus)	+ (a)	-	+ (a)	+ (a)	+ (a)	+	+	+	S, R, W	0.73

	Common name	Scientific name	Presence (+) and absence (-) across sites								Seasonality	Relative abundance
			S1	S2	S3	S4	S5	S6	S7	S8		
68	Orange Oakleaf	*Kallima inachus* (Doyere)*	-	-	+	-	+	-	-	-	R	0.16
69	Blue Admiral	*Kaniska canace* (Linnaeus)*	-	-	-	+	-	+	-	-	S	0.16
70	Bamboo Treebrown	*Lethe confuse* Aurivillius*	-	-	-	-	+	-	-	-	S	0.09
71	BandedTreebrown	*Lethe rohria* (Fabricius)*	-	-	-	+	-	+	-	-	S, R	0.42
72	Common Beak	*Libythea lepita* Moore*#	-	-	-	-	-	+	-	+	S, R	0.17
73	Common Evening Brown	*Melanitis leda* (Linnaeus)	+ (a)	-	+ (a)	-	+ (a)	+	+	+	S, R, W	0.65
74	Long-banded Bushbrown	*Mycalesis perseus* (Fabricius)	-	-	-	+	-	+	-	-	S, R	0.18
75	Common Sailer	*Neptis hylas* (Linnaeus)* [E]	-	+	+	+	+	+	+	+	S, R, W	1.16
76	Sullied Sailer	*Neptis clinia* Moore*	+	-	+	+	+	-	-	-	S, R, W	0.48
77	Creamy Sailer	*Neptis soma* Moore*#	-	-	+	+	-	+	-	+	S, R, W	0.88
78	Common Lascar	*Pantoporia hordonia* (Stoll)*	-	-	+	-	+	-	+	+	S, R, W	0.37
79	Glassy Tiger	*Parantica aglea* (Stoll)	+	-	+	+	+	+	+	+	S, R, W	1.26
80	Common Leopard	*Phalanta phalantha* (Drury)	+ (a)	-	+ (a)	+ (a)	+ (a)	-	+	+	S, R	0.38
81	Common Jester	*Symbrenthia lilaea* Moore	-	-	+ (a)	+ (a)	+	+	-	+	S, R	0.41
82	Blue Tiger	*Tirumala limniace* (Cramer)	+	-	+ (a)	+ (a)	+	-	+	+	S, R, W	0.82
83	Vagrant	*Vagrans egista* (Cramer)*	-	-	+	-	+	-	-	-	S, R	0.41
84	Painted Lady	*Vanessa cardui* (Linnaeus)	-	+	+ (a)	+ (a)	+ (a)	+	-	-	S, R, W	0.69
85	Indian Red Admiral	*Vanessa indica* (Herbst)*	+	+	+	+	+	+	+	+	S, R, W	1.22
86	Common Three-ring	*Ypthima asterope* (Klug)*	-	-	-	-	+	-	-	-	S, R	0.14
87	Common Four-ring	*Ypthima kasmira* Moore*	+	+	+	+	+	+	+	+	S, R	1.28
88	Large Three-ring	*Ypthima nareda* (Kollar)*	-	-	-	-	-	+	-	-	S, R	0.51
89	Kumaon Five-ring	*Ypthima nikaea* Moore* [E]	-	-	-	+	-	+	-	-	S, R	0.71

S—summer | R—rainy | W—winter | *—represents new records for the Nandhour Landscape | #—represents legally protected species under the Indian Wildlife (Protection) Act 1972 | E—represents endemic butterflies of the Indian Himalayan Region (Evans 1932; Wynter-Blyth 1957; Smetacek 2012; Kehimkar 2016) | a—represents species also reported by Arya & Dayakrishna (2017).

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COMMUNICATION

A comparison of four sampling techniques for assessing species richness of adult odonates at riverbanks

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Abstract: Members of the insect order Odonata are known as good ecological indicators. Many are sensitive to habitat modifications and are easily monitored for use in environmental assessment studies. Rapid assessments rely on efficient sampling techniques. However, there is limited information available on sampling techniques for adult odonates, and protocols require evaluation. To do this, we standardized counting methods during sampling of odonates from August to November 2016 at the Mula River, Pune, India. We used four counting techniques; full-width belt transect (FWBT), full-circle point count (FCPC), half-width belt transect (HWBT), and half-circle point count (HCPC). For HWBT and HCPC areas facing the river were sampled, and for each technique we took multiple temporal replicates. We compared species detected per unit time, species detected per unit area, new species detected per unit time, and new species detected per unit area. Additionally, we compared species estimates. With HCPC we detected the maximum number of species and new species per unit area, whereas FWBT returned maximum coverage of recorded species. We recommend our proposed techniques be considered in the future across various habitats to decide the most suitable sampling strategy for the different habitats or situations.

Keywords: Dragonfly, ecological assessment, point count, species estimates, transect, urban wetland.

सारांश: चतुर या कुळामधील कीटक हे चांगले पर्यावरण सूचक म्हणून ओळखले जातात. पर्यावरणातील बदलांचा अभ्यास करण्यासाठी चतुर हे खूप महत्वाचे मानले जातात. त्यांचा अभ्यास करण्यासाठी वापरल्या जाणाऱ्या पद्धती या खुप कमी असून त्यांची पुरेशी माहिती अजून उपलब्ध नाही. त्यासाठी प्रमाणबद्ध उपाय उपलब्ध नाहीत. यासाठी आम्ही चतुरांची गणती करण्यासाठी पद्धतशीर तंत्र शोधण्याचा प्रयत्न केला आहे. हा अभ्यास २०१६ च्या ऑगस्ट ते नोव्हेंबर या महिन्यात मुळा नदीकाठी करण्यात आला. यामध्ये आम्ही ४ पद्धती - Full width Belt transect, Full circle point count,half width belt transect and half circle point count यांचा वापर केला. यामध्ये HWBT and HCPC या पद्धती नदीकडे तोंड करुन odonates ओळखण्यात व मोजण्यात आले. अभ्यासातील चुटी टाळण्यासाठी प्रत्येक पद्धत ही अनेकदा वापरली गेली. आम्ही चतुरांच्या प्रजातींची (species) प्रत्येक मिनीट व क्षेत्रफळानुसार तुलना केली तसेच सापडलेल्या नवीन प्रजातींची प्रत्येक मिनीट व क्षेत्रफळानुसार तुलना केली. यातून आम्हाला HCPC ही पद्धत क्षेत्रफळानुसार सर्वात जास्तं संख्येने प्रजाती तसेच नवीन प्रजाती शोधत आहे हे लक्षात आले. FWBT ही पद्धत जास्तीत जास्तं नोंदवलेल्या प्रजातींचे coverage देत आहे. आमच्या अभ्यासानुसार, चतुरांचा अभ्यास करण्याची चांगली पद्धत ठरवण्यासाठी ह्या पद्धती वेगवेगळ्या अधिवासात तसेच परिस्थितीत वापरल्या जाव्यात.

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Author contributions: AD collected and analyzed data, and wrote the initial draft of the manuscript. PK conceptualized the study, analyzed data, and helped with writing and editing the manuscript. AP helped with logistics for the project, provided lab facilities, and edited the manuscript.

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INTRODUCTION

Odonata depend on freshwater ecosystems to complete their life cycle, as their larvae are aquatic (Corbet 1962). This dependency on freshwater ecosystems makes odonates good aquatic and terrestrial bio-indicators (Corbet 1962; Simaika & Samways 2011, 2012; Stoks & Cordoba-Aguilar 2012; Monteiro-Júnior et al. 2014; Chovanec et al. 2015). Assessment of odonates primarily deals with sampling adults and is highly recommended (Kutcher & Bried 2014; Valente-Neto et al. 2016), because in many cases collecting and identifying adults is easier than finding larvae or exuviae, especially in the case of bio-monitoring projects (Córdoba-Aguilar & Rocha-Ortega 2019) except for gomphids (da Silva-Méndez et al. 2022). Identification keys and field guides for adult odonates are mostly available, while larval identification is more problematic for many species, as the Indian Odonata literature lacks larval and exuvial identification keys (Kumar & Khanna 1983). Another aspect is the availability of comparable data over more extensive spatial coverage. Adult odonate data can be relatively easily obtained for comparison purposes, making adult sampling more popular than larval or exuvial or combined sampling.

Odonates play a crucial role as predators in freshwater ecosystems. They are very useful as ecosystem service providers, especially in urban wetlands which are the freshwater ecosystems available in human-modified landscapes (Bolund & Hunhammar 1999; Angold et al. 2006; Suhling et al. 2015, Córdoba-Aguilar & Rocha-Ortega 2019). Studying such freshwater ecosystems is vital, as they may provide information about understanding the pace of urbanization and species losses (McKinney 2008; Johnson et al. 2013, Córdoba-Aguilar & Rocha-Ortega 2019), aiding conservation management.

Various methods have been employed to study odonates, such as collecting individuals with sweep nets, and using lights and malaise traps, line transects, and point counts (Almeida et al. 2013; Bried & Ervin 2006; Bried et al. 2012; Patten et al. 2015). Currently, relatively little published literature is available on standardized methods for sampling adult odonates. Taking transect surveys on a fixed route is the most popular method (Córdoba-Aguilar & Rocha-Ortega 2019). Quadrangular or rectangular survey plots have been used by some ecologists. For ponds and wetlands, sweep-nets have been used (Oertli 2008). Point counts (PC) have been used especially across pond ecosystems. Distance sampling methods have been used in rainforest ecosystems with scattered water resources (Oppel 2006). Random visual scanning method and visual scanning following a transect have been suggested for counting adult odonates (Sutherland 2006). For sampling adult odonates at rivers and streams, transects along the riparian zone are suggested (Panzer et al. 2005; Smallshire & Beynon 2010). Aerial netting is more useful when specimen collection is the primary aim. For systematic sampling, to come up with diversity indices and species estimates, non-invasive methods such as transects are expected to be more useful (Oppel 2006). Presently available sampling protocols have seldom been critically evaluated to identify the most efficient protocol that captures a reliable estimate of the species richness in a habitat.

In the present study, we tried to standardize a method of counting adult odonates at the riverbanks of a tropical urban river. We compared four different sampling techniques to check the best method which provides a complete assessment of the species richness of the selected urbanized site. This short-term study provides a baseline for future research on counting adult odonates.

MATERIALS AND METHODS

Sampling Methods

The study area was the riparian zone of the Mula River, Aundh, Pune, Maharashtra, India (18.5687 N, 73.8198 E, 551 m). The study site is present in the city and is much disturbed by humans. They carry out activities like cattle grazing nearby, and polluting the river by washing their clothes, among other activities. The study duration was four months from August 2016 to November 2016. We used direct observations for the identification of adult odonates at the site with the aid of binoculars. We identified species using field guides (Subramanian 2005) and referred to previously published material from the Pune area (Kulkarni & Subramanian 2013; Koparde 2016). The habitat sampled consisted of the stream bed and marginal vegetation. We used a transect length of 300 m, as at the study site it was the length that we could walk continuously without any breaks in the transect due to water level, mud, garbage, and uneven terrain. We standardized point count timing to two mins after a pilot survey. During our pilot sampling, we observed, while walking the transects, odonates aggregated in high numbers in the area facing the river rather than inland. We observed a similar pattern while conducting point counts. Therefore, we decided

Table 1. Details of four sampling techniques evaluated during the study.

Technique	Dimensions & Details	Area Sampled
Full-width Belt Transect (FWBT)	300 m X 10 m (length X width) transect covered while walking at the speed of 25 m per two minutes.	3,000 m^2 in 24 minutes
Half-width Belt Transect (HWBT)	300 m X 5 m (length X width) transect covered while walking at the speed of 25 m per two minutes. The width of the transect was restricted to the area facing the riverside.	1,500 m^2 in 24 minutes
Full-circle Point Count (FCPC)	Point counts with a radius of 5 m (full circle) placed at an interval of 25 m (such as 0 m, 25 m, 50 m, and so on) across a 300 m straight line.	78.54 m^2 per point X 13 stations = 1,021.02 m^2 surveyed in 26 minutes
Half-circle Point Count (HCPC)	Point counts with a radius of 5 m (semi-circle) placed at an interval of 25 m (such as 0 m, 25 m, 50 m, and so on) across a 300 m straight line. The semi-circle was restricted to cover the area facing riverside.	39.27 m^2 per point X 13 stations = 510.51 m^2 surveyed in 26 minutes

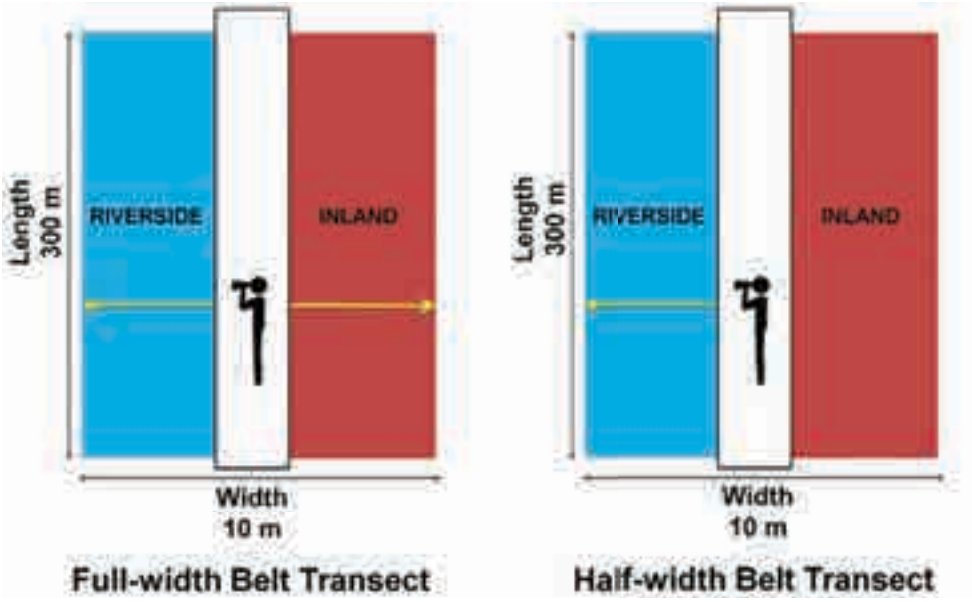

Figure 1. Graphic explaining Full-width Belt Transect (FWBT) and Half-width Belt Transect (HWBT) techniques. The details of the dimensions are provided in Table 1.

to add a variant in method, where we maximized the sampling effort at the riverside. Finally, we used two main sampling methods (belt transect and point count) with a variant in each (Table 1, Figure 1, Figure 2). We used two variants of the belt transect method: 1. Full-width belt transect, where we counted the adult individuals of the species present on the banks inland and at the riverside covering the 300 m belt transect (Table 1, Figure 1). 2. Half-width belt transect, where we counted the adult individuals of the species present only at the riverside covering the 300 m belt transect (Table 1, Figure 1). 3. Full-circle point count, where we counted the adult individuals of the species present in a circle of 5 m radius across a 300 m straight line at each 25 m interval (Table 1, Figure 2). 4. Half-circle point count, where we counted the adult individuals of the species present in a half circle facing the riverside across a 300 m straight line at each 25 m interval (Table 1, Figure 2).

Data Analysis

We performed the analysis in the statistical software PAST (v.3.) (Hammer et al. 2008) and R (R core team 2014). We compared the cumulative number of species detected per unit area, cumulative number of species detected per unit time, new species added per unit area, and new species added per unit time. We used nested analysis of variance (ANOVA) to compare the four techniques: FWBT, HWBT, FCPC and HCPC. Additionally, we used box-plots to visualize the differences in the capture of parameters across the techniques. We calculated species estimates CHAO1 (Chao 1984; Colwell & Coddington 1994), CHAO2 (Chao 1987; Colwell &

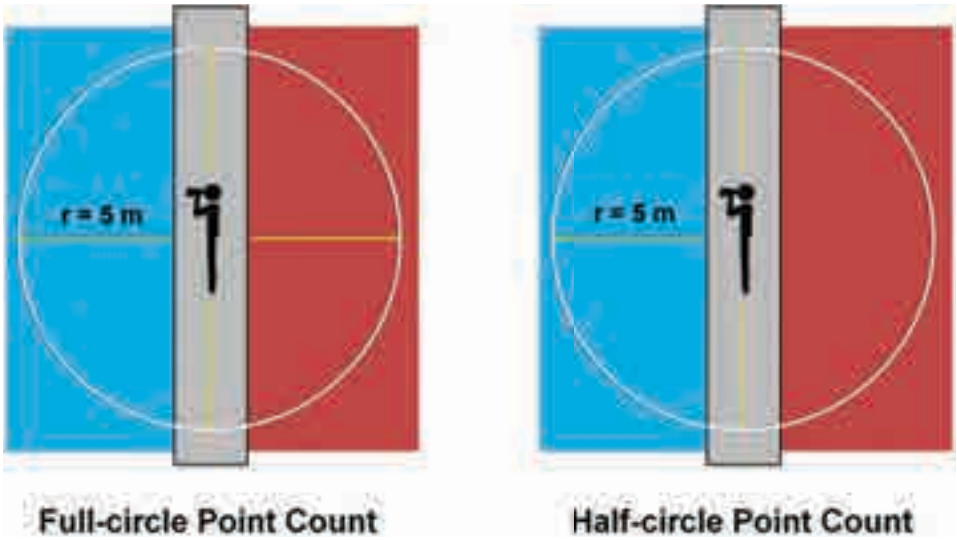

Figure 2. Graphic explaining Half-circle Point Count (HCPC) and Full-circle Point Count (FCPC). Both the methods were carried out along 300 m straight distance. The details of the dimensions are provided in Table 1.

Coddington 1994), Jack1 and Jack2 using Biodiversity Pro v2.0 (McAleece et al. 1997) for each technique and compared it with the cumulative number of species observed per technique. We kept a separate list of off-sampling observations to compare with our data and species estimates.

RESULTS

In total, we recorded 19 odonate species at the site; a complete list of species detected is given in Supplementary Table 1. We obtained statistically significant results for comparisons among techniques (Supplementary Table 2 & 3) for species detected per unit area ($F = 28.79$, $P << 0.0001$) (Figure 3A) and new species added per unit area ($F = 5.15$, $P = 0.0012$) (Figure 3B), through nested ANOVA (Supplementary Table 3).

The proportion of species detected and new species added per square meter were highest for HCPC (Figure 3A, 3B). There was no significant difference across techniques for species detected and new species added per minute ($P > 0.3$) (Figure 3C, 3D). We found through species estimate analysis all techniques except FWBT produced conservative estimates (Table 2).

DISCUSSION

Given equal effort in terms of replicates, HWBT, FCPC, and HCPC methods produced comparable ranges of species estimates, whereas the FWBT method had the maximal coverage (89.5% of 19) of the total number of species observed at the site (Table 2). Overall, belt transects had higher coverage of total species richness (80–90 %) than point counts (63–74 %), indicating that belt transects are highly time-efficient techniques, suggesting the reason for their popularity amongst ecologists. Our comparison of sampling techniques revealed that through the HCPC technique, we recorded significantly more species per unit area (Figure 3A & 3B, Supplementary Table 1 & 2). A reason for this is probably the more intensive search (two minutes) in a smaller area (39.25 m^2) per point count that can be achieved through HCPC compared with other techniques used. The HCPC method perhaps is the best method for intensive sampling but is not time-efficient.

This was a short-term study, but it provided some future research directions. We carried out standardization of adult odonate sampling technique only at one field site, however, taking multiple temporal replicates helped in eliminating sampling errors. Our analysis provided statistically significant results, but we think this procedure needs to be replicated at several sites for an extended time period to test if our results are consistent. In addition, these techniques need to be evaluated at other types of wetlands such as ponds, lakes, and streams, to come up with standard methods for assessing adult odonates at various habitats. For all the techniques used in the present study, double-counting seems to be a potential flaw. Individuals aggregating at a location may also introduce overestimation error,

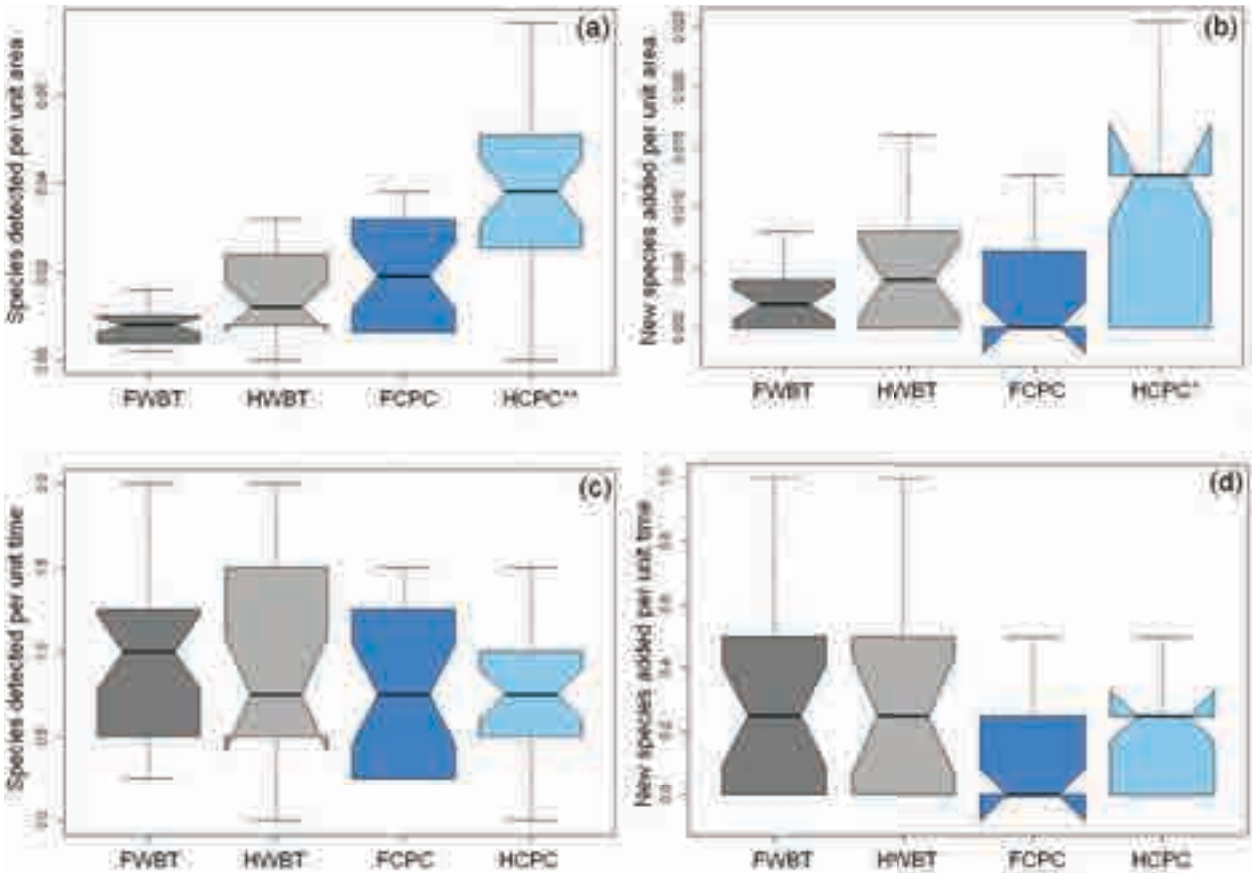

Figure 3. Comparison among sampling techniques. FWBT—Full-width Belt Transect | HWBT—Half-width Belt Transect | FCPC—Full-circle Point Count | HCPC—Half-circle Point Count | *—P <0.05 | **—P <<0.01.

Table 2. Species estimates across various adult odonate counting methods. The cumulative number of species observed across all techniques was 19.

Estimate	FWBT (n = 5)	HWBT (n = 4)	FCPC (n = 5)	HCPC (n = 5)
CHAO 1	18	15	12	15
CHAO 2	26.7	18.13	20	17.6
Jack 1	23.6	18.75	15.2	18.2
Jack 2	26.45	19.92	17.15	19.25
Observed	17	15	12	14
% coverage of all the species observed	89.5	80	63.2	73.7

n—number of temporal replicates | FWBT—Full-width Belt Transect | HWBT—Half-width Belt Transect | FCPC—Full-circle Point Count | HCPC—Half-circle Point Count.

especially if such sites fall on point count stations. These potential flaws can be fixed only with capturing and marking individuals or alternatively, by adding several sampling replicates to reduce the error. Since dragonflies and damselflies have different flight abilities and habits, it is necessary to adjust strategies and techniques to sample them (Koparde 2016). A one size fits all strategy is not suitable to sample both the suborders or habitats.

We draw attention to the desirability of standardized sampling protocols in species diversity sampling. Our preliminary analysis indicates that HCPC might be a suitable method to sample adult odonates at the riverbanks when time is not a limiting factor, and FWBT when it is.

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Supplementary Table 1. List of species recorded during the study.

	Species Name	FWBT (n = 17)	HWBT (n = 15)	FCPC (n = 12)	HCPC (n = 14)
ANISOPTERA (n = 12)					
Family:					
Aeshnidae (n = 1)	*Anax guttatus* (Burmeister, 1839)	X	X		
Gomphidae (n = 1)	*Ictinogomphus rapax* (Rambur, 1842)	X	X	X	X
Libellulidae (n = 10)	*Acisoma panorpoides* (Rambur, 1842)	X			
	Brachythemis contaminata (Fabricius, 1793)	X	X	X	X
	Crocothemis servilia (Drury, 1770)	X	X	X	X
	Orthetrum pruinosum (Burmeister, 1839)		X		X
	Orthetrum sabina (Drury, 1770)	X	X	X	X
	Pantala falvescence (Fabricius, 1798)	X		X	X
	Rhyothemis variegata (Linnaeus, 1763)		X		X
	Tramea basilaris (Palisot de Beauvois, 1805)	X	X	X	
	Trithemis aurora (Burmeister, 1839)	X	X	X	X
	Trithemis palidinervis (Kirby, 1889)	X	X	X	X
ZYGOPTERA (n = 7)					
Family					
Coenagrionidae (n = 6)	*Agriocnemis pygmaea* (Rambur, 1842)	X	X	X	X
	Ceriagrion coromandelianum (Fabricius, 1798)	X	X		X
	Ischnura aurora (Brauer, 1865)	X			
	Ischnura senegalensis (Rambur, 1842)	X	X	X	X
	Pseudagrion decorum (Rambur, 1842)	X	X	X	X
	Pseudagrion hypermelas (Selys, 1876)	X	X	X	X
Platycnemididae (n = 1)	*Disparoneura quadrimaculata* (Rambur, 1842)	X			

N—Number of species | FWBT—Full-width Belt Transect | HWBT—Half-width Belt Transect | FCPC—Full-circle Point Count | HCPC—Half-circle Point Count | X—Presence.

Supplementary Table 2. Point count standardization at six point count stations. Each PC column represents the cumulative number of species observed and numbers in brackets represent the cumulative number of individuals observed.

Minutes	PC 1	PC2	PC3	PC4	PC5	PC6
1st	1 (1)	3 (3)	1 (1)	1 (1)	1 (1)	1 (1)
2nd	3 (3)	4 (6)	1 (1)	1 (1)	1 (1)	1 (1)
3rd	3 (4)	5 (8)	1 (1)	1 (1)	2 (2)	1 (1)
4th	3 (5)	5 (9)	2 (2)	1 (1)	2 (2)	1 (1)
5th	4 (6)	5 (9)	2 (2)	1 (1)	2 (2)	1 (1)

Supplementary Table 3. Nested ANOVA across techniques reveal significant differences in species detected per unit area ($F = 28.79$, $P << 0.0001$) and new species added per unit area ($F = 5.15$, $P = 0.012$) across techniques.

	Sum of squares	Degrees of freedom	Mean square	Fs	*P*	Variance component (percentage)
Species detected per unit area						
among groups	0.0146	3	0.0048	28.79	0.0000	50.51
subgroups within groups	0.0025	15	0.0001	1.016	0.4457	0.14
within subgroups	0.0153	92	0.0001			49.35
total	0.0325	110				100
Species detected per unit time						
among groups	1.1142	3	0.3714	1.0956	0.3834	0.5010
subgroups within groups	5.0768	14.92	0.3389	1.6005	0.0887	9.2833
within subgroups	19.4552	92	0.2114			90.215
total	25.6464	110				100
New species added per unit area						
among groups	0.0010	3	0.0003	5.1571	0.0119	19.345
subgroups within groups	0.0011	15.93	0.0000	1.4270	0.1542	6.9312
within subgroups	0.0034	71	0.0000			73.723
total	0.0055	90				100
New species added per unit time						
among groups	0.3424	3	0.1141	1.1728	0.3530	0.9945
subgroups within groups	1.5558	15.93	0.0973	1.4417	0.1477	8.7746
within subgroups	4.7885	71	0.0674			90.23073
total	6.6868	90				100

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OPEN ACCESS

COMMUNICATION

Floristic diversity of native wild ornamental plants of Aravalli Hill Range: a case study from district Rewari, Haryana, India

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Abstract: Ornamental plants are important constituent of floristic diversity which beautify and glorify our surroundings. They add a positive attitude to life, intensify the feeling of happiness, and enhance the economic value of the estate. There has been a growing trend promoted by environmentalists, ecologists, and horticulturalists toward the inclusion of new wild ornamental plants (WOPs) for minimising their maintenance costs and enhancing their survival rate. The current study inventorised the floristic diversity of native WOPs of the Aravalli Hill Range of Haryana State. Researchers recorded 88 native WOPs species belonging to 40 plant families. Asteraceae and Poaceae are the most dominant families, contributing seven species each followed by Fabaceae and Malvaceae with six species each. The habit wise distribution of native WOPs from the Aravalli hill ranges depicted that herbaceous types of plants are dominant with 53.4 % followed by trees (18.2 %), climbers (14.8 %), and shrubs (11.4%). These native WOPs were found suitable for various ornamental purposes which ranges from the garden, potted, medicinal, lawn cover, avenue tree, hedge/fencing, edible, religious/ ceremonial, road dividers, cacti, succulent, and indoor foliage. The current study documented four plants, viz., *Argyreia cuneata* (Willd.) Ker Gawl., *Boswellia serrata* Roxb. ex Colebr., *Pulicaria wightiana* (DC.) C.B.Clarke, and *Rivea hypocrateriformis* (Desr.) Choisy. endemic to the Indian subcontinent. *Blumea lacera* (Burm.f.) DC., *Cleome viscosa* L., *Saccharum spontaneum* L., and *Triumfetta rhomboidea Jacq.* were reported to have somewhat invasive potential in this region. Further, it is also suggested to introduce some potential native WOPs into domestication by florists, horticulturists, nurserymen, and municipal authorities for the protection, conservation, and perpetuation of these plants to minimize the use of foreign floral species to control the further spread of alien plants.

Keywords: Asteraceae, Avenue trees, ceremonial plants, Fabaceae, florists, garden and indoor plants, horticulturists, Malvaceae, Poaceae.

Hindi: सजावटी पौधे जैव विविधता के महत्वपूर्ण घटक हैं। ऐसे पौधे हमारे परिवेश को सुशोभित और गौरवान्वित करते हैं। ये जीवन में सकारात्मक दृष्टिकोण का संचार करते हैं, प्रसन्नता को बढ़ाते हैं और रिहायशी संपत्ति के आर्थिक मूल्य में भी वृद्धि करते हैं। वैश्विक स्तर पर आजकल वनस्पति वैज्ञानिक पर्यावरणविद्, पारिस्थितिकीविद् और बागवानीविद् सजावटी पौधों के जीवित रहने की दर को बढ़ाने के लिए, उनके रखरखाव की लागत को कम करने और मौजूदा सजावटी पौधों की विविधता को बढ़ाने के लिए निरंतर शोध कार्य कर रहे हैं। वर्तमान अध्ययन में हरियाणा राज्य की अरावली की पहाड़ी श्रृंखलाओं के जंगल में पाए जाने वाले देशी सजावटी पौधों की विविधता का अन्वेषण किया है। शोधकर्ताओं ने 40 पौध परिवारों से संबंधित 88 देशी एवं जंगली सजावटी पौधों को सूचीबद्ध किया है। ऐस्टेरेसी और पोएसी प्रमुख पादप परिवारों के सात-सात और इसके बाद फैबेसी और मालवेसी परिवारों की छह-छह प्रजातियां इस इलाके में पाई जाती हैं। अरावली की पहाड़ी श्रृंखलाओं के जंगलों में 53.4 प्रतिशत जड़ीबूटियां, 18.2 प्रतिशत वृक्ष, 14.8 प्रतिशत बेल व लता और 11.4 प्रतिशत झाड़ियां रूपी देशी सजावटी पौधे पाए जाते हैं। इन जंगलों में पाए जाने वाले ये देशी सजावटी पेड़-पौधे बगीचे, पॉटेड प्लांट्स, औषधीय, लॉन कवर, एवेन्यू ट्री, हेज/बाड़, खाद्य, धार्मिक/सांस्कृतिक और इनडोर पौधों के रूप में प्रयोग किए जा सकते हैं। वर्तमान अध्ययन में अर्ग्रेइया क्यूनेटा, बोसवेलिया सेराटा, पुलिकेरिया वाइटियाना और रिविया हाइपोक्रेटेरिफॉर्मिस इत्यादि चार जंगली सजावटी पौधों को भारतीय उपमहाद्विप के स्थानिक पादपों के रूप में दस्तावेजीकरण किया गया है। इस क्षेत्र में ब्लुमिया लेसेरा, क्लियोम विस्कोसा, सैकेरम स्पोंटेनियम और ट्रायमफेटा रोहमबोइडिया को विदेशी आक्रमणकारी पौधों के रूप में सूचिबद्ध किया गया है। इस अध्ययन के आधार पर शोधकर्ताओं ने बागवानों, पौधा विक्रेताओं, अधिकारियों को जंगल में पाए जाने वाले देशी सजावटी पौधों के उगाने पर बल दिया। स्थानीय जैविक विविधता के संरक्षण एवं उचित प्रबंधन के लिए शोधकर्ताओं ने विदेशी सजावटी पौधे कम से कम उगाने पर जोर दिया।

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INTRODUCTION

Wild plants are natural gene banks containing exceptionally rich hereditary information, as well as humankind's important resources and the groundwork of present day garden plants (Dulloo & Maxted 2019; Cong & Han 2022). The constructive developments in the utilization of wild plant assets not just enhance the beauty of metropolitan greening and beautification yet additionally increase the urban biodiversity index and diminish the serious misfortunes brought about by the introduction of ornamental plants that are not appropriate for the local environment (Gong et al. 2019). Wild plants also constitute an integral part of urban green packages as part of nature based solutions for climate change adaptation mitigation strategies in rapidly growing cities (Nassary et al. 2022).

Plant species which are primarily utilized for aesthetic and decorative purposes are popularly known as ornamental plants (OPs). All plant species suitable for indoor or outdoor beautification and decorations are categorized as ornamental plants (Lecomte et al. 2016; Chowdhuri & Deka 2019). Shape & size of the plant, color, texture, line & form, lush foliage, and showy flowers are considered as important ornamental attributes of plant species (Vabrit 2002; Zucchi et al. 2020; Khaleghi & Khadivi 2022). Transportation durability, resistance to extreme of cold & hot conditions, quality & uniqueness, maintenance cost, trend in market, and other specific requirements such as medicinal, cultural, spiritual, or ritual are some of the other attributes of OPs. A large variety of herbs, shrubs, avenue plants, hedges, ground covers, cacti, succulents, bonsai, palms, bulbs, cones, hanging plants, epiphytes, decorative foliage, showy floral plants, sweet scented, and grasses fall under the category of OPs and are grown by individuals (Gajendrudu 2014).

OPs intensify and glorify our surroundings, they add positive attitude to life, intensify the feeling of happiness, and enhance economic importance of the estate (Harris 1992; Rocha et al. 2021). Owing to the beauty they bring, OPs spare an element of satisfaction, relaxation, and delight to human beings. OPs additionally play a significant role in metropolitan and rural environmental planning, fallow land improvement, afforestation, and finishing of open air & indoor spaces. Interior plants also improve worker productivity and reduce stress in a windowless environment (Lohr et al. 1996; Yeo 2021; Berger et al. 2022).

It is accepted worldwide that all plants used in ornamental and amenity horticulture and the diversity of cultivars derived through selection and breeding, originally came from wild plants or their relatives (Heywood 2001). The wild plants have owned a reviving knowledge on the link between wild nature and human wellbeing (Friedman et al. 2022). The majority of the decorative plants are obtained from wild resources. Missionaries, globetrotter, rambler, emissary, sea captains, and tourists have a significant contribution in introducing and naturalizing a large number of OPs from different continents. The transformation of these introductions of wild growing species into potential commercial cultivars was largely undertaken by highly skilled, observant, and entrepreneurial nurserymen, many of whom were very talented plant men who initiated plant improvement programmes themselves by selection and breeding. Wild ornamental plants (WOPs) are more resilient to water scarcity, extremes of temperature, and require less attention & care. WOPs are also well adapted to local soil conditions and their cultivation requires very less pesticides & fertilizers. Moreover, WOPs also provide shelter and food to native insects, birds, and other life forms. WOPs further influence the phenology of flowering plants by influencing health and number of pollinators (Stout & Dicks 2022).

There is a rich plethora of wild plants which are often used for ornamental and aesthetic purposes. WOPs are having striking feature and are easily distinguishable on the land surfaces. Some WOPs show high variability in different ornamental attributes as compared to cultivated plants. Rao et al. (2006) identified and documented 61 potential wild ornamental species of Convolvulaceae from Eastern Ghats of Andhra Pradesh, India. Babu et al. (2017) explored and documented the 153 wild ornamental flowering plants species belonging to 112 genera and 48 families from Palakonda hills of Eastern Ghats in Andhra Pradesh, India. Haridasan & Rao (1985) conducted floristic exploration in Meghalaya they identified a number of ornamentally useful important wild species. All these researchers documented great ornamental potentialities of WOPs due to their attractive foliage and good-looking flowers. According to their findings, there are lot of opportunities for exploring the meaning of both indoor and outdoor gardening and landscape techniques.

The diversity of WOPs found in the Aravalli Hill Ranges in India are facing high rate of depletion primarily due to increase in the illegal mining, urbanization rate, industrialization, pollution, over-exploitation, and heavy infestation by alien plant species like *Prosopis juliflora* (Sw.) DC., *Verbesina encelioides* (Cav.) Benth. & Hook.f.

ex A. Gray, *Parthenium hysterophorus* L. and many other plant species (Sharma et al. 2013). Though many floristic studies have been conducted in this region but no concerted efforts have been made to explore and document the diversity of ornamental plants of this region. Therefore, it seems to be an urgent requirement to carry out methodical floristic identification and studies of ornamental plants of wild genera from this region to formulate appropriate conservation and management strategies. Efforts have been made to explore the nativity of WOPs growing in different parts of the district. Hence, the present study was done to explore the types of ornamental plants from Aravalli Hill Ranges of Rewari district of Haryana.

MATERIALS AND METHODS

Study site description

The Rewari district is situated in the southern part of Haryana 80 km from New Delhi. It covers the geographical area of approximately 1,559 km^2, and lies between 27°86'–28°28' N & 76°15'–76°51' E. It is bounded by Jhajjar district in the north, Mahendergarh district in the west, Gurugram district in the east, Mewat district in north-east directions. Alwar district of Rajasthan touches Rewari in the south-east direction (Figure 1) (https://rewari.gov.in/about-district/location/). The temperature may be more than 45° C in summer months. The Rewari district is a part of the Indian arid zone having low rainfall of 569 mm annually. The region also receives low annual rainfall restricted to a few months of monsoon.

Collection and preservation of Plant Specimens

An intensive field survey was conducted from July 2016–September 2021 in different parts of the Rewari district. List of places visited for survey and documentation of ornamental plants are mentioned in Table 1. Coloured photographs were taken in their natural habitat before the collection of plant specimen for identification purposes. Every effort was made to collect specimens in their reproductive stages, i.e., flowering or fruiting stages. Small herbs were collected as whole plants while, reproductive twigs were collected for large plants. Voucher specimen number was given to collected specimen alongside field labels. The collected specimens were treated with 10% formaldehyde solution, kept in air-tight polythene bags, and were pressed in between the blotting/filter papers in the field press. The collected specimens were brought to the laboratory for long-term storage. In the laboratory the blotting papers of the specimens were replaced with new ones at a regular interval of 3–4 days until complete drying and were poisoned with 0.2% mercuric chloride.

Identification of plant specimens

The collected specimens were identified with the help of available standard floras published by various taxonomists (Hooker 1872–1897; Duthie 1903–1922; Maheshwari 1963). Photographs of the plants were taken in their natural habit and field notes were prepared for identification. Further, online literature and search engines were used for validating botanical names of the plants under study, viz., http://www.theplantlist.org/, https://powo.science.kew.org/, and http://www.flowersofindia.net/. The voucher specimens were deposited in the herbarium of Department of Botany, Maharshi Dayanand University, Rohtak (Haryana) India for future reference.

Determination of Nativity of Plants:

Knowing whether a plant species is native or introduced is less clear-cut than it might appear. For determination of nativity of plant species, methods of Webb (1985), Usher (2000), Pysek et al. (2004), Willis & Birks (2006), Bean (2007), Fertig (2011), Hughes & Convey (2012), & eflora of India (2022) have been consulted and for finalization of nativity the website https://powo.science.kew.org/ was taken as final distribution.

Data Analysis

Common names, habit, important ornamental attributes, and potential uses by the community of identified WOPs are mentioned in Table 2. The data were analysed though MS Excel package 2007.

RESULTS

In the present study, 88 plants belonging to 40 families have been documented from different parts of Rewari district, Haryana (Table 1). Out of 88 plant species, 78 dicot plant species belonging to 36 families and eight monocot plant species belonging to two families, fern & gymnosperm, viz., *Actiniopteris radiata* (Sw.) Link and *Ephedra foliata* Boiss. ex C.A. Mey. are represented by single family each. A comparison of monocots and dicots in terms of families and species is shown in Figure 2.

Dominant Families

Among the documented families, Asteraceae and Poaceae are the most dominating (Figure 3). The

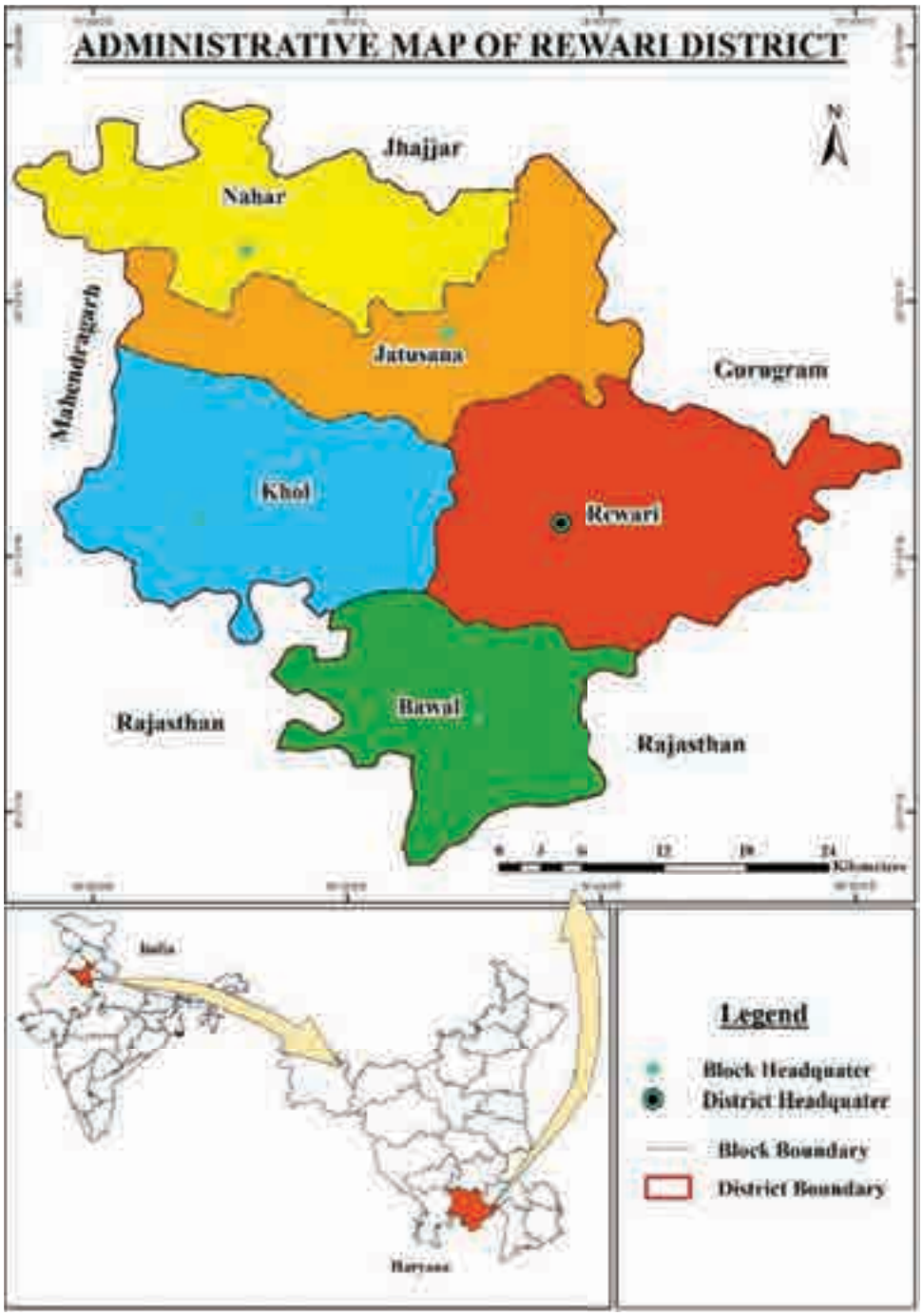

Figure 1. Map of study area.

remaining plants are fairly distributed in various families. In the present study, 22 families are represented by one species each. Out of these, 18 families are of dicots, one family from monocots, two families belonged to ferns, and one family belonged to gymnosperms. Some of the prominent WOPs plants from the region have been shown in Images 1,2(A–R). Families having single wild ornamental species in this region are Aizoaceae, Aristolochiaceae, Asclepiadaceae, Bignoniaceae, Boraginaceae, Celastraceae, Commelinaceae, Cucurbitaceae, Ephedraceae, Meliaceae, Menispermaceae, Moringaceae, Nyctaginaceae, Padaliaceae, Plumbaginaceae, Portulacaceae, Pteridaceae, Rubiaceae, Sapindaceae, Tamaricaceae, Verbenaceae, and Vitaceae.

Table 1. List of places visited for survey and documentation of ornamental plants.

Community block	Places visited	Place
Bawal	Amit Vatika Nursery, Jai Singh Pura, Khera Bawal	Nursery
	Baba Devnarayan mandir, Gujar Majri	Temple
	Bala Ji Mandir, Rajgarh	Temple
	CCS, HAU Regional Research center, Bawal	Research center
	Gujar majri	Village
	Harley Davidson motorcycles	Factory
	Kanuka	Village
	Minda Furukawa electric Pvt. Ltd.	Factory
	Mohanpur	Village
	Nechana	Village
	Ompal Garden Services, Bagthala, Banipur	Nursery
	Rajgarh	Village
	Tankri	Village
Rewari	Ahir college	College
	Baba Bhairav Temple, Dehlawas	Temple
	Baba Udhodas mandir, Saharanwas	Temple
	Bikaner	Village
	BMG Mall	Shopping mall
	Canal Valley Public School, Berli Kalan	School
	Chillar	Village
	District Court, Subash nagar	Judicial complex
	Hanuman Mandir lake , Jadra Village	Temple
	Hanuman Temple, Kundal	Temple
	Holy child public school, Madhu vihar	School
	I G University, Meerpur	University
	Jain Public School	School
	Kakoria	Village
	KLP college	College
	Lavishka Plants Nursery, Lisana	Nursery
	M2K Country Park, Dharuhera	Public park
	Madhu Sudan public school, Mahavir nagar	School
	Majra Sheoraj	Village
	Muradpuri	Village
	Nai Wali Bagachi and mandir	Temple
	Naichana	Village
	Nursery Berli, Berli Kalan	Nursery
	Nursery Hut Shri Ganga Ram Nursery, Zainabad	Nursery
	Old Saini Nursery, Kayasthwara Mohalla	Nursery
	Old Shiv Mandir, Bodia Kamalpur	Temple
	Plants Nursery, Dharuhera	Nursery

Community block	Places visited	Place
Rewari	Pushpanjali hospital	Hospital
	Ramgarh	Village
	Saini Nursery, Kayasthwara Mohalla	Nursery
	Sanatan park, Dharuhera	Public park
	Shanti devi college of law and Management, Saharanwas	College
	Shiv Temple, Asiaki Gorawas	Temple
	Shri Gangaram Nursery, Jainabad	Nursery
	Shri Shyam Nursery, Dahina	Nursery
	Tagore Public School, Jadra	School
	Thakur Ji Mandir, Lilodh	Temple
	Vedanta hospitals	Hospital
Nahar	Bhakli	Village
	DAV Girls College, Kosli	College
	Government College, Kosli	College
	Gudiani	Village
	Jhal	Village
	Jhal Nahar forest, Nahar	Wildlife century
	Lilodh	Village
	Lukhi	Village
	Lula Ahir	Village
	Mata Mandir, Nahar	Temple
	Shiv Mandir, Kosli	Temple
	Vandana Nursery, Bhakli, Kosli	Nursery
	We for nature Nursery, Palhawas	Nursery
Jatusana	Baldhan Khurd	Village
	Bodia Kamalpur	Village
	Jatusana	Village
	Mastapur	Village
	Musepur	Village
	Rajawas	Village
Khol	Baba Gopal Das mandir, Nandha	Temple
	Baba Nimriwala Temple, Pali	Temple
	Khori	Village
	Kund	Village
	Manethi	Village
	Nandha	Village
	Near Hanuman Mandir, Manethi	Temple
	Pali	Village
	Pali Herbal park, Pali	Public park
	Pithrawas	Village
	Sonam Nursery, Pithrawas	Nursery

Habit-wise distribution

Herbaceous WOPs dominated in this region with 47 species followed by 16 species of trees, 13 species of climbers, and 10 species of shrubs (Figure 4).

Potential use of wild ornamental plants

In the present study a total 88 native wild ornamental plants have been reported from different parts of Aravalli Hill Ranges. Out of 88 plants, majority of them are used as garden plants which tops the list with 60 plants followed by 36 medicinal, 34 potted plants, 16 avenue tree, lawn cover, and hedge/fencing with 14 species each. Nearly a dozen native WOPS are used for edible and religious/ ceremonial purposes. Eight plants are planted as road dividers, four cultivated as cacti & succulent, and two as wild ornamentals grown in indoor foliage (Figure 5). According to the present study, one plant species, i.e., *Ficus benghalensis* L. is being used for five different purposes—avenue plants, road side divider, hedge/fencing, religious/ceremonial, and medicinal. It was also reported that 16 plants are found to have four multiple uses, 25 plants have three multiple uses, 28 plants two uses, and 20 plants have single use (Figure 6).

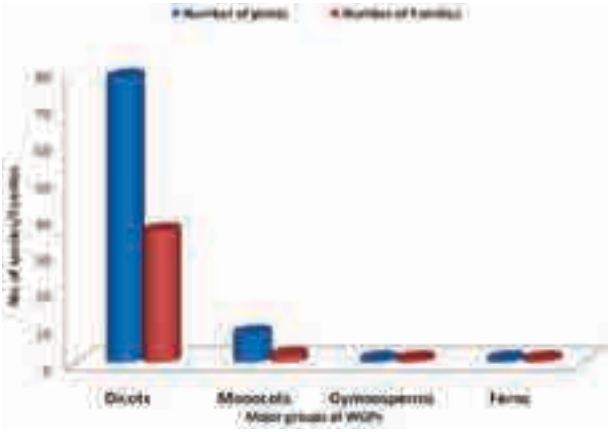

Figure 2. Composition of major groups of native wild ornamental plant in Aravalli Hill Range.

Ethnomedicinal Uses

Some native wild ornamental plants are also used for primary health care purposes and treating their routine maladies in this region. For example, dried fruit powder of *Acacia nilotica* (Roxb.) Willd is helpful in curing diabetes and arthritis. Root extract of *Boerhavia diffusa* L. helps in curing jaundice. *Capparis decidua* (Forssk.) edgew fruits powder is helpful in indigestion and diabetes while root boiled with mustered oil applied externally for curing skin diseases. Fresh and dried fruits of *Ficus racemosa* L. cures diabetes. *Salvadora persica* L. fruits decoction mixed with sugar taken orally cures typhoid. Paste of fresh leaves of *Withania somnifera* (L.) dunal kills head louse when applied with buttermilk on scalp. Fresh leaves of *Chrysopogon zizanioides* (L.) roberty are refreshing and remove tiredness.

DISCUSSION

Nature has bestowed us with abundance of WOPs and they exhibit high degree of variety & variability in contrast to cultivated ornamental plants. Wild plants are having striking features in terms of floral, foliage, fragrant, and form (Shape, Size, Colour, and Life form)

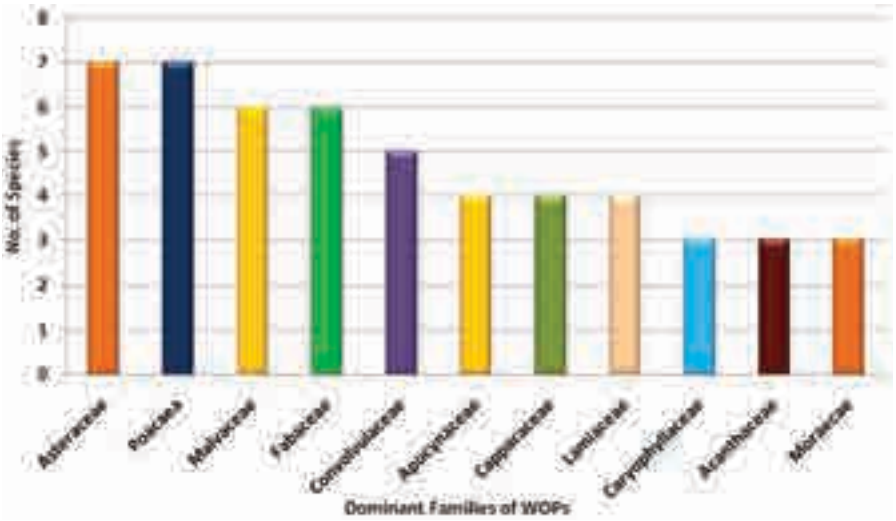

Figure 3. Dominant families having wild ornamental plant species in Rewari district.

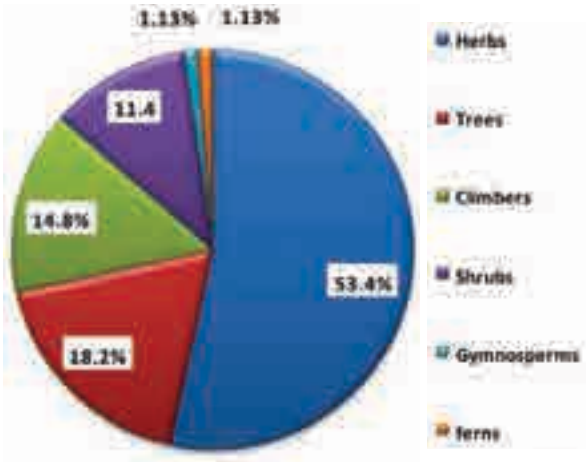

Figure 4. Habit-wise distribution of wild ornamental plants in Rewari District.

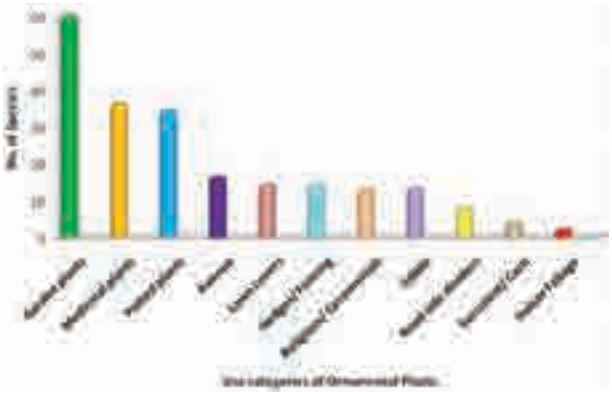

Figure 5. Potential use of ornamental plants.

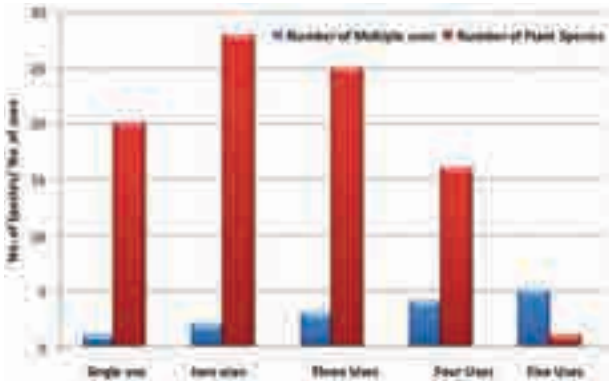

Figure 6. Wild ornamental plants with number of multiple uses in Rewari District.

attributes. They are vital considering their positive incentives for individuals and society. The majority of current day OPs can be traced to their wild relatives, many of which still exist in their natural habitats. OPs assume a significant role in preparation and modification of urban and rural landscapes, fallow land development, afforestation, and managing of open air & indoor spaces. Wild vegetation of Aravalli Hill Range of Rewari district of Haryana is blessed with huge number of inquisitive, taxonomically fascinating, economically significant, and endemic plants (Yadav et al. 2021).

The Aravalli Hill Range is among the most distinct and primeval mountain chain. These hill ranges are economically and ecologically very crucial as they check the desert extending along Indo-Gangetic plains and pose influence over regional climate (Thapar 2015). Extreme environment and exceptional ecological niches provide perfect habitat for plants which is a unique distinctiveness of the range for survival. It has a wide range of climatic and geographical diversity, including tropical evergreen, subtropical, desert, temperate (Khanna 2011). Many plant species have been imported beyond their natural ranges as a result of increased globalization, and some of them have established and sustained persistent populations without human intervention (Seebens et al. 2022). These hill ranges are rich reservoir of wild medicinal and ornamental plants (Yadav & Bhandoria 2012). These hill ranges are a unique amphitheatre of biological diversity. These WOPs species contribute to available extensive genetic resources available to for varietal improvement and genetic modification. Bansal et al. (2022a) explored the Rewari region of Aravalli hill ranges and documented 42 wild exotic plants of ornamental potential. They recommended the utilization of wild exotic ornamental plants as an important strategy for restoration of degraded ecosystems. They also opined that wild ornamental plants may also help in increasing genetic diversity.

Total 88 native WOPs species belonging to 41 families have been reported from different parts of Aravalli Hill Ranges. These native WOPs have a great potential of use for different purposes. *Azadirachta indica* A.Juss., *Capparis decidua* (Forssk.) Edgew, *Crateva religiosa* G.Forst., *Salvadora oleoides* Decne., and *Salvadora persica* L. have delicious, nutritive edible fruits. *Tecomella undulata* (Sm.) Seem is a valuable native timber yielding tree growing wild in different parts of southern Haryana. The wood of this plant is used for making high quality furniture. *B. serrata* Roxb. ex Colebr., *Commiphora wightii* (Arn.) Bhandari, *Tinospora sinensis* (Lour.) Merr. and *Wrightia tinctoria* R.Br. are important medicinal plant. *Ephedra foliata* is the only naturally occurring gymnosperm species which have good medicinal properties. Globally efforts are taken

Table 2. List of native wild ornamental plants of district Rewari, Haryana.

	Name of species	Vernacular name	Family	Habit	Nativity	Ornamental attribute	Ornamental purpose
1	*Abrus precatorius* L. VSN; Bansal:308	Rati	Fabaceae/ Leguminosae	Climber	India	S, Fr	Garden plant
2	*Abutilon indicum* (L.) Sweet VSN; Bansal:135	Kanghi	Malvaceae	Shrub	India	Fl, Fr	Potted, Garden plant
3	*Acacia nilotica* (Roxb.) Willd. VSN; Bansal:228	Kikar	Fabaceae/ Leguminosae	Tree	India subcontinent, Africa, Saudi Arabia Zimbabwe,	Infl, Fr, Fol	Avenue, Medicinal, Religious/ Ceremonial, Edible
4	*Acalypha indica* L. VSN; Bansal:234	Kupi	Euphorbiaceae	Shrub	India	Fol, P.f.	Potted, Garden plant
5	*Achyranthes aspera* L. VSN; Bansal:295	Ultakanta, Punch kanta	Amaranthaceae	Herb	India	Infl, P.f.	Hedge/Fencing, Potted, Medicinal
6	*Argyreia cuneata* (Willd.) Ker Gawl. VSN; Bansal:465	Purple convolvulus	Convolvulaceae	Climber	India	Fl, Fol	Garden plant
7	*Aristolochia indica* L. VSN; Bansal:333	Duck Flower	Aristolochiaceae	Climber	India	Fl,Fol	Garden plant
8	*Azadirachta indica* A.Juss. VSN; Bansal:168	Neem, Margosa	Meliaceae	Tree	Assam to Indo-China	Fol, Fr	Avenue, Road divider, Medicinal, religious/ Ceremonial
9	*Barleria prionitis* L. VSN; Bansal:163	Pila bansa	Acanthaceae	Shrub	India, Bangladesh, Philippines, Sri Lanka	Fl	Hedge/fencing, Road divider
10	*Blumea lacera* (Burm.f.) DC. VSN; Bansal:197	Gandhi	Asteraceae	Herb	Tropical and Subtropical Asia, Australia	Infl, Head	Garden plant
11	*Boerhavia diffusa* L. VSN; Bansal:107	Punarnava, Santi	Nyctaginaceae	Herb	Tropical and Subtropical world	Fol, Fl	Garden plant, Medicinal, Edible
12	*Boswellia serrata* Roxb. ex Colebr. VSN; Bansal:177	Salai Guggul	Burseraceae	Tree	India	Fl,Fr, P.f.	Avenue, Medicinal
13	*Caesalpinia bonduc* (L.) Roxb. VSN; Bansal:202	Fever Nut	Fabaceae / Leguminosae	Climber	Tropics & Subtropics	Fr	Garden plant
14	*Capparis decidua* (Forssk.) Edgew VSN; Bansal:238	Kair. Teent	Capparaceae	Shrub	Mauritania to Andaman & Nicobar Islands India	Fl, P.f.	Hedge/ fencing, Road divider, Edible, Medicinal
15	*Capparis sepiaria* L. VSN; Bansal:239	Wild Caper, Hins	Capparaceae	Shrub	India, China, N. Australia	Fl,fol	Hedge
16	*Cenchrus ciliaris* L. VSN; Bansal:219	Buffalo grass	Poaceae	Herb	India, Greece, Africa, Arabian Peninsula	Infl	Garden plant
17	*Chrysopogon zizanioides* (L.) Roberty VSN; Bansal:267	Vativeria	Poacaea	Herb	Indo-China, Malesia	Infl, P.f.	Garden Plant, Potted, Medicinal
18	*Cissus quadrangularis* L. VSN; Bansal:406	Hadjod	Vitaceae	Shrub	India, Sri Lanka, W. & C Malaysia	St	Potted, Hedge/ Fencing, Garden plant, Medicinal
19	*Cleome gynandra* L. VSN; Bansal:103	Kukar Bhangra	Cleomaceae	Herb	Tropical and Sub tropical Asia, Australia, Africa,	Fl, Fol	Potted, Garden plant
20	*Cleome viscosa* L. VSN; Bansal:106	Hulhul	Cleomaceae	Herb	Tropical and Subtropical old world	Fl, Fr	Potted, Medicinal
21	*Clerodendrum phlomidis* L.f. VSN; Bansal:356	Arno	Lamiaceae	Shrub	India, Java	Fol, Fl	Hedge/Fencing
22	*Coccinia grandis* (L.) Voigt VSN; Bansal:286	Kundru	Cucurbitaceae	Climber	Tropical Africa, Tropical and subtropical Asia	Fl, Fol, Fr	Garden plant, Edible
23	*Commelina benghalensis* L. VSN; Bansal:105	Widow's tear	Commelinaceae	Herb	India, South Africa, Myanmar	Fl	Lawn cover, Garden plant
24	*Commiphora wightii* (Arn.) Bhandari VSN; Bansal:437	Gugal	Burseraceae	Tree	India, Oman, Pakistan	P.f., Fr	Hedge/Fencing, Medicinal, Garden plant
25	*Crateva religiosa* G.Forst. VSN; Bansal:231	Sacred Burna	Capparaceae	Tree	India, China, Myanmar, Thailand	Fl	Avenue, Road divider
26	*Crotalaria burhia* Benth. VSN; Bansal: 331	Kharsana	Fabaceae	Herb	Iran, India	Fl, P.f.	Hedge/fencing
27	*Cyanthillium cinereum* (L.) H.Rob. *VSN; Bansal:288*	Sahadevi	Asteraceae	Herb	India, China, Japan, Zimbabwe, Myanmar, Medagascar	Fl	Potted, Garden plant
28	*Cynodon dactylon* (L.) Pers. VSN; Bansal:410	Doob grass	Poaceae	Herb	Asia, Africa, Australia	Lf	Lawn cover, Religious/Ceremonial

	Name of species	Vernacular name	Family	Habit	Nativity	Ornamental attribute	Ornamental purpose
29	*Desmostachya bipinnata* (L.) Stapf VSN; Bansal:265	Kusha	Poaceae	Herb	Sahara, Tanzania, Indo-China	Infl	Garden plant, Religious/Ceremonial
30	*Dodonaea viscosa* (L.) Jacq. VSN; Bansal:263	Hopbush	Sapindaceae	Shrub	Asia, Africa, S. and C. America, Australia	Fl,Fr,Fol,P.f.	Hedge/ fencing, Garden plant, Road divider, Potted
31	*Echinops echinatus* Roxb. VSN; Bansal:302	Oont kanteli	Asteraceae	Herb	India, Myanmar	Infl	Garden plant, Hedge/fencing, Medicinal
32	*Elytraria acaulis* (L.f.) Lindau VSN; Bansal:446	Indian Scaly stem	Acanthaceae	Herb	India, Sri Lanka, Tropical& S. Africa	Fl,Infl	Lawn cover, Potted
33	*Ephedra foliata* Boiss. ex C.A. Mey. VSN; Bansal:409	Joint fir	Ephedraceae	Gynmos-perm	India, Pakistan N. Africa	P.f., Fol	Potted, Medicinal
34	*Euphorbia granulata* Forssk. VSN; Bansal:316	Jangali Dudhi	Euphorbiaceae	Herb	India, Central Asia, N. & E. Africa,	Fol	Lawn cover, Succulent
35	*Evolvulus alsinoides* Kunyze VSN; Bansal:373	Dwarf morning Glory	Convolvulaceae	Herb	Tropics & Subtropics	Fl	Garden plant
36	*Ficus benghalensis* L. VSN; Bansal:198	Banyan Tree	Moraecae	Tree	India, South East Asia, Austrlia	P.f., Fol, Infl., Fr	Avenue, Medicinal, Potted, Religious/ Ceremonial, Edible
37	*Ficus racemosa* L. VSN; Bansal:125	Gular	Moraecae	Tree	India, Pakistan, N. Queensland	Fol, Fr	Avenue, Medicinal, Edible, Religious/ Ceremonial
38	*Ficus religiosa* L. VSN; Bansal:113	Peepal	Moraecae	Tree	India	Fol	Avenue, Potted Religious/Ceremonial
39	*Grewia tenax* (Forssk.) Fiori VSN; Bansal:269	Phalsa Cherry	Malvaceae	Shrub	India, S. Africa, Peninsula	Fl,Fr	Hedge/fencing
40	*Gymnosporia emarginata* (Willd.) Thwaites VSN; Bansal:250	Spike thorn	Celastraceae	Tree	India, Sri Lanka, Malaya	Fl, Fr, Fol	Avenue, Medicinal, Religious/Ceremonial
41	*Hemidesmus indicus* (L.)R.Br.ex Schult. VSN; Bansal:298	Annantmool	Apocynaceae	Climber	India, Indo-China and Peninsula Malaysia.	Fol, Fl	Lawn cover, Garden plant, Medicinal, Indoor foliage
42	*Indigofera linifolia* (L.f.) Retz. VSN; Bansal:277	Indigo	Fabaceae/ Leguminosae	Herb	India, Europe, Mediterranean Region, Tropical S. Africa	Fol, Color	Garden plant
43	*Ipomoea cairica* (L.) Sweet VSN; Bansal:110	Morming Glory	Convolvulaceae	Climber	India, Arabian Peninsula Africa,	Fl, Fol	Garden plant
44	*Ipomoea pes-tigridis* L. VSN; Bansal:170	Bili keladoo	Convolvulaceae	Climber	India, Srilanka, Tropical East Africa	Fol, Fl, Frs	Garden plant, Medicinal, Edible
45	*Justicia adhatoda* L. VSN; Bansal:156	Basaka	Acanthaceae	Herb	Afghanistan to Indo-China	Fl, Fol	Potted, Hedge, Medicinal
46	*Launaea nudicaulis* (L.) Hook.f. VSN; Bansal:208	Jungligobhi	Asteraceae	Herb	India, Canary Islands, Peninsula, Mediterranean.	Infl	Garden plant
47	*Leptadenia pyrotechnica* (Forssk.) Decne. VSN; Bansal:282	Kheep	Apocynaceae	Herb	India, Sahara, Iran	Fl, P.f.	Hedge/fencing
48	*Leucas aspera* (Willd.) Link VSN; Bansal:279	Drona Pushpi	Lamiaceae	Herb	India, Mauritius, Tropical and Subtropical Asia	Fl, Fol	Potted, Garden plant, Lawn cover
49	*Maerua oblongifolia* (Forssk.) A.Rich. VSN; Bansal:379	Desert caper	Capparaceae	Climber	India, Pakistan, Saudi Arabia and Africa	Fl, Fr	Avenue, Road divider, Hedge, Garden plant
50	*Mitragyna parvifolia* (Roxb.) Korth. VSN; Bansal:143	Desi Kadam, Kaim	Rubiaceae	Tree	India, Myanmar	Fl, Fr, Fol, P.f.	Avenue, Religious/ Ceremonial, Medicinal
51	*Moringa oleifera* Lam. VSN; Bansal:237	Sonjana, Drum Stick	Moringaceae	Tree	India, Pakistan, Maxico, Central America	Fol,Fl,Fr	Avenue, Medicinal, Edible
52	*Ocimum basilicum* L. *VSN; Bansal:116*	Maurava	Lamiaceae	Herb	India, Africa, Asia (South East)	Fol	Potted, Garden plant, Edible, Religious/ Ceremonial
53	*Oxystelma esculentum* (L. f.) Sm VSN; Bansal:249	Rosy milkweed vine	Apocynaceae	Climber	Egypt, Tanzania, Yemen, S. China, Australia	Fl,Fol	Garden plant
54	*Pedalium murex* L. VSN; Bansal:304	Bada Gokhru, Vilayatigokhru	Padaliaceae	Herb	India, Pakistan, Sri Lanka, Tropical Africa, Madagascar	Fol, Fl, Fr	Potted, Garden plant, Medicinal, Succulent

	Name of species	Vernacular name	Family	Habit	Nativity	Ornamental attribute	Ornamental purpose
55	*Pergularia daemia*(Forssk.) Chiov. VSN; Bansal:388	Pergularia	Asclepiadaceae	Herb	Africa, Peninsula, Iran, Indo-China.	Fl,Fr,Fol	Garden plant
56	*Phyla nodiflora* (L.) Greene VSN; Bansal:195	Jal Buti	Verbenaceae	Herb	Tropics & Subtropics	Fl	Lawn cover, Garden plant
57	*Plectranthus barbatus* Andrews VSN; Bansal:338	Patharchoor	Lamiaceae	Herb	Eritrea to Tanzania, Arabian Peninsula India, S. Central China	Fol, Infl	Potted, Garden plant, Medicinal, Indoor foliase
58	*Pluchea lanceolata* (DC.) C.B. Clarke VSN; Bansal:248	Khar jaal, Rasna	Asteraceae	Herb	Senegal, Chad, Tanzania, S. Iran to India	Infl	Potted, Garden plant, Edible
59	*Plumbago zeylanica* L. VSN; Bansal:447	Chitrak	Plumbaginaceae	Herb	Tropics & Subtropics	Fl, Fol	Garden plant, Medicinal
60	*Portulaca quadrifida* L. VSN; Bansal:274	Bichubuti, Wild Purslane	Portulacaceae	Herb	Tropical America, Asia, Africa, Pakistan	Fl, Fol	Potted, Garden plant, Succulent
61	*Pulicaria wightiana* (DC.) C.B.Clarke VSN; Bansal:377	Sonela	Asteraceae	Herb	India	Fl	Potted, Garden plant
62	*Rhynchosia viscosa* (Roth) DC. VSN; Bansal:398	Sticky Snoutbean	Fabaceae	Climber	India, China, Tropical Africa	Fl, Fr	Garden plant
63	*Rivea hypocrateriformis* Choisy VSN; Bansal:363	Gawal kakri	Convolvulaceae	Climber	India	Fl, Fol	Garden plant
64	*Saccharum bengalense* Retz. VSN; Bansal:115	Munja	Poaceae	Herb	India, Iran, Myanmar	Infl	Garden plant
65	*Saccharum spontaneum* L. VSN; Bansal:112	Kaans	Poaceae	Herb	India, Tropical West Asia	Infl	Garden plant, Medicinal
66	*Salvadora oleoides* Decne. VSN; Bansal:313	PeelaJaal	Salvadoraceae	Tree	India, China (Southern), Japan	Fol, Fr, P.f.	Avenue, Medicinal, Edible, Religious/Ceremonial
67	*Salvadora persica* L. VSN; Bansal:312	Peelu, Jaal	Salvadoraceae	Tree	India, China (Southern), Japan	Fol, Fr, P.f.	Avenue, Medicinal, Edible, Religious/Ceremonial
68	*Setaria viridis* (L.) P.Beauv. VSN; Bansal:213	Chepu	Poaceae	Herb	Old world and Central & SE. Australia.	Infl	Garden plant
69	*Sida acuta* Burm, f. VSN; Bansal:264	Wire weed	Malvaceae	Herb	Tropics and Sub tropics	Fl	Potted, Garden plant, Medicinal
70	*Sida cordifolia* L. VSN; Bansal:245	Heart leaf Sida	Malvaceae	Herb	Tropical & Subtropical Asia to N. Australia	Fol, Fl	Potted, Garden plant, Medicinal
71	*Sida rhombifolia* L. VSN; Bansal:268	Arrow leaf Sida	Malvaceae	Herb	Tropical and Subtropical Old World	Fol,Fl	Potted, Garden plant, Medicinal
72	*Silene conoidea L.* VSN; Bansal:305	Catchflies	Caryophyllaceae	Herb	India, America	Fl, Fr	Potted, Garden plant
73	*Solanum virginianum* L. VSN; Bansal:296	Satyanashan, Jharkeladoo	Solanaceae	Herb	Indo-China,Tropical Africa, China,	Fol,Fl	Potted, Garden plant, Medicinal
74	*Spergula arvensis* L. VSN; Bansal:326	Abrojito	Caryophyllaceae	Herb	India, C &S. America, Europe, Mediterranean region	Fol,Fl	Lawn cover, Potted, Garden plant
75	*Stellaria media* (L.) Vill VSN; Bansal:329	Chick weed	Caryophyllaceae	Herb	Eurasia, Africa	Fol,Fl	Lawn cover, Potted, Garden plant
76	*Suaeda vermiculata* Forssk.ex J.F. Gmel VSN; Bansal:320	Seep weed	Amaranthaceae	Herb	Macaronesia, S. Medit., Sahara and Arabian Peninsula, India, Sri Lanka.	Fol	Lawn cover, Potted, Garden plant, Succulent
77	*Tamarix aphylla* (L.) H. Karst. VSN; Bansal:301	Phras	Tamaricaceae	Tree	Sahara to India	Fol, P.f.	Avenue, Garden plant, Hedge/fancing
78	*Taraxacum javanicum* Soest VSN; Bansal:367	--	Asteraceae	Herb	India, Java	Fl	Potted, Garden plant
79	*Tecomella undulata* (Sm.) Seem. VSN; Bansal:408	Roheda	Bignoniaceae	Tree	Afghanistan, India, Iran, Oman, Pakistan	Fl	Avenue, Garden plant Religious/ Ceremonial, Road divider
80	*Tinospora sinensis* (Lour.) Merr. VSN; Bansal:104	Guduchi, Ghiloye	Menispermaceae	Climber	West Indies, India, China, Yunnan	Fol	Garden plant, Potted, Medicinal

	Name of species	Vernacular name	Family	Habit	Nativity	Ornamental attribute	Ornamental purpose
81	*Trianthema portulacastrum* L. VSN; Bansal:350	Saati	Aizoaceae	Herb	Tropical Africa, Asia, Tropical America	Fol	Lawn cover, Garden plant, Edible, Medicinal
82	*Tribulus terrestris* L. VSN; Bansal:300	Bhakri, Puncture Vine	Zygophyllaceae	Herb	Mediterranean region, Tropical America,	Fl, P.f.	Lawn cover, Garden plant, Medicinal
83	*Trichodesma indicum* (L.) Lehm. *VSN; Bansal:319*	Jnglikaronja, Chotakalpa	Boraginaceae	Herb	Philippines, Afghanistan, Thailand	Fl	Garden plant, Lawn cover
84	*Triumfetta rhomboidea* Jacq. VSN; Bansal:260	Buur Bush, China Bush	Malvaceae	Shrub	Tropical America, Asia, Africa	P.f., Fl, Fol	Lawn cover, edicinal
85	*Withania somnifera* (L.) Dunal VSN; Bansal:190	Ashvagandha, Aksand	Solanaceae	Herb	S. Europe, China, Africa, Myanmar	Fol, Fr	Potted, Garden plant, Medicinal
86	*Wrightia tinctoria* R.Br. VSN; Bansal:278	Indra jao	Apocynaceae	Tree	India, Myanmar	Fl,Fol	Avenue, Road divider, Medicinal, Ceremonial
87	*Zygophyllum indicum (Burm.f.) Christenh. & Byng* VSN; Bansal:240	Fagonia	Zygophyllaceae	Herb	India, Pakistan, Afghanistan and Africa	Fl,Fr	Garden plant, Potted
88	*Actiniopteris radiata* (SW.) Link VSN; Bansal:468	Fern	Pteridaceae	Fern	India, Africa, Peninsula, Iran, Myanmar.	Fol	Potted, Garden plant

Fl—Flower | Fol—Foliage | Fr—Fruit | Infl—Inflorescence | Lf—Leaf | P.f.— Plant form | S—Seed | St —Stem.

to explore and document the multipurpose ornamental plants. In Rewari region of Aravalli Hill Ranges, 42 wild exotic wild ornamental plants were reported by Bansal et al. (2022).

Many ornamental plants are also used for ethnomedicinal purposes by poor and marginal people living in rural and remote areas in different countries. Rao et al. (2021) explored the traditional medicinal uses of wild flora from Charkhi Dadri district of Haryana state. In this study, researchers mentioned that many ethnomedicinal ornamental plants, viz., *Boerhavia diffusa, Salvadora persica, Tribulus terrestris, Withania somnifera* and many other plants.. Some of these may be used as soil binder, fencing, and field protectors like *Caesalpinia bonduc*, *Capparis decidua, Clerodendrum phlomidis, Grewia tenax, Barleria prionitis,* and *Leptadenia pyrotechnica.* These wild plants are naturally growing on the walls of the buildings, in crop fields, foot hill areas, and their flowers and appearances easily attract the interested people. These plants can easily be domesticated and maintained at a very low cost.

The appealing characteristics of WOPs reflect their high ornamental and aesthetic potential. In recent years, many such WOPs have gained a lot of importance in the exploitation of many sorts and in the generation of revenue among the poor (Olsen 1998). Many plant species have been imported and domesticated beyond their natural ranges as a result of increased globalization, and some of them have established and sustained persistent populations without human intervention. The floriculture sector is always on the lookout for new goods, technology, and market gaps to fill. In comparison, the price of domestication and maintenance of WOPs species is likewise relatively low (Negrelle et al. 2012; Maroyi 2022).

WOPs may play a significant role in environmental planning for pollution abatement, wasteland development, afforestation, social & rural forestry, and open-air & interior landscaping (Ciftcioglu et al. 2019). The attractive WOPs can be grown in pots inside house, banks, hospitals, malls, institutions, and offices. These wild ornamental plants may play a valuable role in planning of environmental issues, landscaping of urban housing, waste land development, house designing, and afforestation (Bansal et al. 2022).

WOPs are intricately intertwined with our culture, literature, socioeconomic life, romance, and poetry (Rahnema et al. 2019). Incorporating such WOPs in daily use may be a fascinating but risky endeavor. OPs have become quite popular inside houses, workplaces, banks, hospitals, guesthouses, hotels, and other buildings. Cultivation of these plants could be useful commercially as well as for the conservation of rare, vulnerable, and endangered endemic plant species. Wild plants of the Aravalli hills have potential uses like the gum resin is collection performed since ever by the tribal populace utilizing conventional tapping method (Soni 2010). The significant position of ornamentals has been studied for 'habitat formation' and 'wildlife attraction' making it potentially useful (Ciftcioglu et al. 2019). Landscape gardening and bio-aesthetic planning have been popular in recent years as a way to create environmentally

Image 1. Prominent wild ornamentals: A—*Abrus precatorius* L. | B—*Caesalpinia bonduc* (L.) Roxb. | C—*Gymnosporia emarginata* (Wild.) Thwaites | D—*Maerua oblongifolia* (Forssk.) A.Rich. | E—*Grewia tenax* (Forssk.) Fiori | F—*Pergularia daemia* (Forssk.) Chiov. | G—*Rivea hypocrateriformis* Choisy | H—*Commiphora wight*ii (Am.) Bhandari | I—*Wrightia tinctoria* R.Br. © Authors.

friendly human habitats.

Botanic Gardens are the primary site of introduction and domestication of WOPs as they effectively manage the interchange of ornamental seeds and plant materials both within and outside the country (Niazian & Nalousi 2020). Organized expeditions by individual botanists, gardeners, and connoisseurs, should help in collection of these plants which are not commercially explored and only found in wild (van Kleunen et al. 2018). These plants can be collected in the wild, introduced, acclimatized to various altitudinal zones, multiplied, made accessible to nursery men for sale, and distribution to potential marketable places. These plants will benefit greatly from research into their phenology and numerous

Image 2. Prominent wild ornamentals: A—*Tecomella undulata* (Sm.) Seem. |K—*Crateva religiosa* G.Frost | L—*Barleria prionitis* L. | M—*Tribulus terrestris* L. | N—*Capparis decidua* (Forssk.) Edgew. | O—*Abutilon indicum* (L.) Sweet | P—*Pedalium murex* L. | Q—*Silene conoidea* L. | R—*Cleome gynandra* L. © Authors.

floricultural characteristics. The origin of potential uses of ornamentals has deep roots association to the animal empire. Several ornamental plants act as source of foodstuff, fiber, fuel, lumber, and medication. WOPs have an essential part in urban and rural environmental planning for pollution abatement, social & rural forestry, wasteland development, afforestation, and outdoor & indoor landscaping (Babu et al. 2017; Sangma & Chaurasiya 2021).

It is universally accepted that the remarkable

potential of novel ornamentals from wild sources exists throughout the globe (Janakiram et al. 2021; Bansal et al. 2022). In spite of having a rich and diverse plant wealth in many countries, especially in India majority of the exotic plants are given due weightage in floricultural trades as compared to the indigenous wild plant species. There is a need to take-up R&D work by interlacing the fraternity of botanists, floriculturists, and agriculturists. In our country, an enormous variety of wild plants from varied habitats can be grown in the botanical gardens and used in landscaping. Such wild plant species are awaiting the attention of garden lovers, specialists, nurserymen, town planners, florists, and experts from different industries for their popularization. Further, the introduction of such plant species in botanical gardens, regional stations and nurseries is highly recommended for their conservation, propagation, and dissemination (Cong & Han 2020). WOPs wealth will be also helpful in the improvement and evolution of new ornamental cultivars and will play pivotal role in the floriculture industry. Hence, domestication and concerted breeding efforts of WOPs of Aravalli hills may provide many useful ornamental plants for posterity.

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Author contributions: PB and SSY conceptualized and designed the study. PB and ASR surveyed the area, collected data and written the first draft of the manuscript. PB, MSB and SSD helped in identification of the plant material. SSY supervised the whole study. All authors were actively involved in manuscript preparation, reviewing and editing.

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COMMUNICATION

Flowering and fruiting of Tape Seagrass *Enhalus acoroides* (L.f.) Royle from the Andaman Islands: observations from inflorescence buds to dehiscent fruits

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Abstract: Seagrass phenophases are crucial in understanding their reproductive biology but are seldom documented. We studied flowering and fruiting phenophases of *Enhalus acoroides* from a mixed-species intertidal seagrass meadow in Ritchie's archipelago, Andaman Islands, India. The estimated mean densities of pistillate and staminate flowers were 16.0 ± 12.0/ m^2 and 12.7 ± 7.3/ m^2, respectively. We observed the bloom of free-floating male flowers (961.7 ± 360.4/ m^2) during the spring low tides (at mean sea surface temperature ~30°C). Seagrass cover, shoot density, and canopy height of *E. acoroides,* along with flowering densities, showed a zonal variation within the sampled meadow. We report the first-time observations of several phenophases of *E. acoroides,* such as female inflorescence buds, male inflorescence, a bloom of released male flowers, pollination, and fertilized flowers from the Indian waters. We also report the prevailing threats to seagrass meadows, such as meadow scarring done by boat anchorage in the Andaman Islands.

Keywords: Mass bloom, meadow scarring, mixed-seagrass meadow, Swaraj Dweep.

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Competing interests: The authors declare no competing interests.

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Author contributions: SG—Study design, field data curation, data processing and analysis, conceptualization, and drafting of the manuscript; SK—Funding acquisition, Study design, supervision, review, and editing of the manuscript; HD—Methodology design, supervision of work, validation of phenophases, review, and editing of the manuscript; JAJ—Funding acquisition, Supervision, review, and editing of the manuscript.

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INTRODUCTION

Characterizing the demography of local seagrass populations is essential to understanding the phenology and ecological processes of seagrass species (Inglis 1999). Such information is critical to improving the knowledge and management of high ecological value species like *Enhalus acoroides* (L.f.) Royle that regulates the food web, primary production, & sediment dynamics and supports a diversity of benthic organisms & fish communities (Estacion & Fortes 1988; Komatsu et al. 2004; Yu et al. 2018). *E. acoroides* has a wide distribution range in the Indo-Pacific region, extending from the eastern coast of Africa to northern Australia (Waycott et al. 2004; Short & Waycott 2010). The species is dioecious and reproduces asexually (through clonal growth) and sexually (pollination). Pollination in *E. acoroides* is epi-hydrophilous, and fruiting and flowering occur throughout the year (Hartog 1970; Brouns & Heijs 1986; Ackerman 2006; Rattanachot 2008). The positively buoyant seeds (Hartog 1970) and released fruits have a higher potential for long-distance dispersal, thus facilitating the wider species distribution and ensuring succession (Lacap et al. 2002; Kendrick et al. 2012).

In the Indian waters, *E. acoroides* is known to occur on the southeastern coast, Andaman & Nicobar Islands (ANI), and Lakshadweep Islands (Jagtap 1991, 1992; Das 1996). In ANI, *E. acoroides* distribution is reported from the North Andaman (Paschim Sagar and North Reef), South Andaman (Tarmugli, Chidiyatapu, Wandoor, Dugong Creek, and Vivekandapur), Ritchie's archipelago (Kalapatthar, Vijay Nagar, Inglis, and Henry Lawrence), and Nicobar archipelago (Pilomilow, Camorta, Trinket, Nancowry, Katchal, and Great Nicobar) (Jagtap 1992; Das 1996; Thangaradjou et al. 2010; D'Souza et al. 2015; Ragavan et al. 2016; Savurirajan et al. 2018; Figure 1). Although the seagrass distribution, status, and associated fauna of *E. acoroides* are well documented, the reproductive phenology of this species was rarely observed from the Indian coastal waters including from ANI (Patankar et al. 2019).

Seagrasses in the ANI are vulnerable to human-induced (coastal modification and pollution) and natural stressors (tsunami and recurrent cyclones). These threats may vary in intensity and subsequently have caused habitat alteration or in worst-case scenario, a complete wipe-out of the local populations. For example, the 2004 tsunami in the Indian Ocean critically impacted several seagrass meadows and changed the species composition, with the local extinction of a few species (Thangaradjou et al. 2010). For recovering from such major disturbances through recolonization, sexual reproduction (seeds) has proven to be more effective than clonal expansion (ramets) in the seagrass restoration initiatives (Darnell & Dunton 2016). Thus, for directing local efforts for seagrass conservation and effective management of large-scale loss, documenting the sexual phases of seagrass species is a prerequisite (Short & Wyllie-Echeverria 1996).

Despite sexual reproductive strategies of species like *E. acoroides* contribute to the resilience of seagrass populations and genetic diversity (Duarte et al. 1997; Yu et al. 2018), these observations are scarcely reported from the Indian waters (Patankar et al. 2019). In this context, the present study aims to fill the existing research gaps in seagrass phenology of *E. acoroides* from the Indian waters and reports rare phenological phases from a mixed-species intertidal seagrass meadow of the Andaman Islands. Our study presents a detailed natural history observation on 10 different flowering and fruiting phenophases of *E. acoroides*, which provide a baseline for future research. Although opportunistic in nature, we believe our findings establishes improved knowledge of seasonality in phenology of the species, especially in the wake of *E. acoroides* gaining attention as a target species in global seagrass restoration initiatives (Lawrence et al. 2007).

MATERIALS AND METHODS

As a part of pan-archipelago seagrass exploratory surveys, we sampled a mixed species intertidal seagrass meadow in Vijay Nagar, Swaraj Dweep Island of Ritchie's Archipelago (South Andaman; Figure 1), in January 2021 at the afternoon spring low tides. We mapped the seagrass meadow by walking around its fringes with a GPS and calculated the sampled area on Google Earth Pro version 7.3. Quadrats (0.5 X 0.5 m size; n = 18) were placed randomly in the selected seagrass meadow to document the species composition and seagrass cover (Duarte & Kirkman 2001). The shoot density (shoots/ m^2) of *E. acoroides* was calculated by counting all the shoots within the quadrat. Further, we randomly selected 20 shoots of *E. acoroides* from each sampling point and recorded canopy height using a measuring scale (cm). In addition, environmental variables such as sea surface temperature (SST), pH, and salinity were recorded at each sampling point using handheld multi-parameter testers (Eutech Oaklon- PCS Testr 35; refractometer- LABART).

We conducted field surveys for 12 consecutive days and studied different phenophases of flowering and fruiting of *E. acoroides*. We estimated the densities

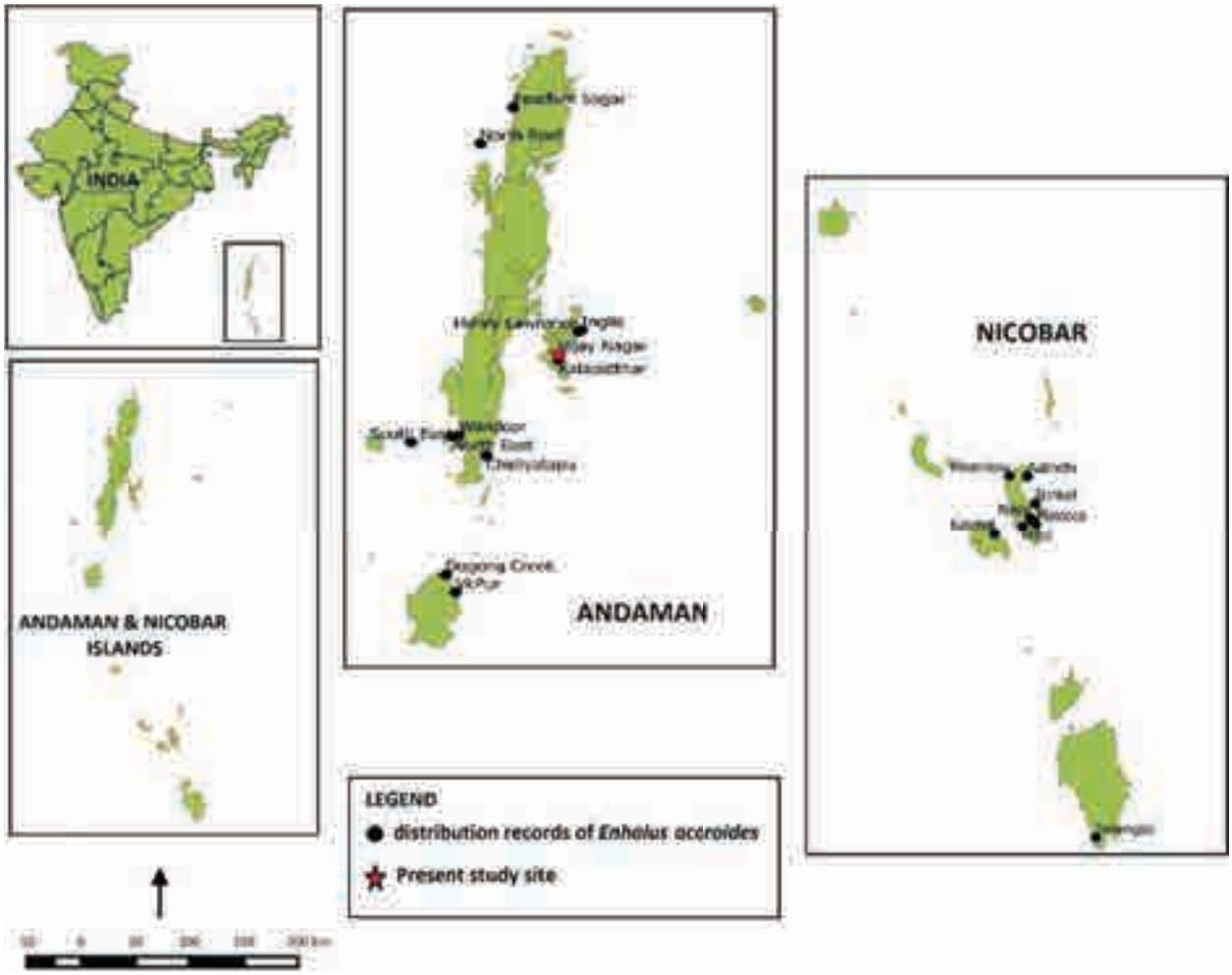

Figure 1. Study area map of *Enhalus acoroides* distribution and present sampling site at Vijay Nagar, Swaraj Dweep (Ritchie's archipelago), Andaman & Nicobar Islands, India.

of flowers and fruits within the quadrats across the sampling points. We measured peduncle length, sepal, and spathal leaf lengths of flowers using a measuring scale (cm). To study various stages of fruiting and seed development, we collected fruits of all phenophases (n = 5/ phase) except dehiscent fruits. Fruits were contained in seawater and immediately transported to the laboratory for further analysis. We dissected each fruit with a surgical blade and measured their diameter and length using a measuring scale (cm). Lastly, we recorded each fruit's seed development (immature/ mature seeds), the number of seeds, and morphometric measurements (seed length, seed base length).

We validated different flowering and fruiting stages by referring to published literature on the species (Bujang et al. 2006; Patankar et al. 2019) and through personal correspondences with seagrass experts.

RESULTS

Seagrass meadow characteristics

We observed six seagrass species from a continuous meadow spread across ~16.8 hectares in Vijay Nagar (Swaraj Dweep), viz: *Enhalus acoroides, Thalassia hemprichii* (Ehrenberg) Ascherson, 1871, *Halophila ovalis* (R. Brown) Hooker f., 1858, *Cymodocea rotundata* Asch. & Schweinf., *Halodule uninervis* (Forssk.) Asch, and *Syringodium isoetifolium* (Asch.) Dandy.

Enhalus acoroides was the dominant of all species with the highest mean cover, followed by *T. hemprichii* and *C. rotundata* (Table 1). Seagrass species exhibited spatial variation in distribution within the meadow. In the high tide zone, *S. isoetifolium* and *H. uninervis* occurred in a mixed substratum of very fine sand and silt (Table 1). The distribution of *C. rotundata* was patchy across the mid-tide edges, and the species preferred fine sand.

Table 1. Meadow characteristics, species' substratum preference, and spatial distribution of seagrasses at Vijay Nagar, Swaraj Dweep.

Seagrass species	Mean seagrass cover (%)	Shoot density (shoots/ m²)	Shoot length (cm; n=20)	Substratum	Species distribution within the meadow
Enhalus acoroides	36 ± 39.3	289.9 ± 103.9	35.3 ± 12.1	Fine sand mixed with silt and clay	high and mid-tide zones
Thalassia hemprichii	10.9 ± 4.8	70.3 ± 43.6	10.7 ± 4.8	Coarse sand and rubble	mid and low-tide zones
Cymodocea rotundata	6.5 ± 23.1	30.3 ± 18.5	6.0 ± 3.6	Fine sand	mid-tide zone
Halophila ovalis	5.9 ± 17.1	29.3 ± 17.9	0.4 ± 0.6	Sand and rubble	mid and low-tide zones
Halodule uninervis	1.9 ± 5.7	46.9 ± 41.6	8.5 ± 2.6	Very fine sand mixed with silt	high-tide zone
Syringodium isoetifolium	1.3 ± 4.6	53.3 ± 46.0	8.2 ± 3.0	Very fine sand mixed with silt	high-tide zone
SST (°C)- 30.1	pH- 7.7	Salinity (ppt)- 30.9			

Halophila ovalis and *T. hemprichii* occupied coarse sand and rubble in the meadow's mid and low-tide edges (Table 1). Distribution of *E. acoroides* was spread across high and mid-tide zones, where the species was found either as monospecific strands in fine sand mixed with silt and clay or co-occurred with *C. rotundata*, *H. uninervis*, *S. isoetifolium,* and *T. hemprichii*.

Seagrass cover, shoot density, and canopy height for *E. acoroides* varied considerably within the high and mid-tide zones of the sampled meadow. The total mean cover of *E. acoroides* was estimated as 36 ± 39.3 % (Table 1), but we observed a reduced species coverage from high (64.8 ± 33.5 %) to mid tide zone (19.3 ± 33 %). Similarly, overall shoot density for *E. acoroides* was 289.9 ± 103.9 shoots/ m² (Table 1); however, mean densities in the high and mid tide zones varied as 144.9 ± 130.8 shoots/ m² and 30.3 ± 55.2 shoots/ m², respectively. We observed longer shoots of *E. acoroides* in the high tide patches (33. 9 ± 10.1 cm). Shoots in the mid-tide zone were comparatively shorter (19. 4 ± 7.2 cm), with signs of herbivory.

Flowering phases and natural history

In the present study, we recorded different stages of both pistillate and staminate flowers of *E. acoroides*—female inflorescence bud, pistillate flower at anthesis, male inflorescence, the bloom of free-floating male flowers, empty male spathe (post-release of male florets), pollination (released male florets attached to female inflorescence), and fertilized flowers (Table 2). Like species characteristics, a significant zonal variation was observed in flowering densities of *E. acoroides* within the sampled meadow. Densities of pistillate flowers in high and mid tide zones were 22.8 ± 13.4/ m² and 4 ± 1.4/ m², respectively. Similarly, densities of staminate flowers were much higher (17.7 ± 10.4/ m²) towards the high tide shore than in the mid-tide region (4 ± 1.1/ m²).

We observed solitary female inflorescence buds on the terminal shoots. Peduncles of female buds were shorter than pistillate flowers at anthesis (Table 2; Image 1A). Female inflorescence appeared as solitary flowers on the terminal shoots, with visible sepals, petals, and pistils/ styles (Image 1B). Petals (3) were pink and had 2–3 longitudinal ridges with folded margins, enclosing 5–6 styles. Long peduncles aided the pistillate flowers to sway in the tidal waters, with petals wide open, floating at the surface. The male inflorescence had multiple white male flowers on the spadix enclosed at the base of widely open spathal leaves (Table 2; Image 1C). All male inflorescences we observed were submerged in the water column with shorter peduncles (5.2 ± 1.1 cm above the substratum) than the female inflorescence at anthesis (26.1 ± 8.0 cm; Table 2).

A noteworthy observation in the present study was the mass bloom of released male florets free-floating in the high tide zone. Male florets (white) were 0.2 ± 0.1 cm long, with 2–3 stamens and 5–6 tepals. We observed released male florets in masses (961.7 ± 360.4/ m²; n=3 quadrats) along the sandy coastline (~1.5 km), floating on the water surface and trapped in seagrass blades (Image 1D). After the release of male flowers, a male spathe with two valves and a barren spadix (light orange) was visible. Shorter peduncles supported empty spathes filled with sand in the seagrass meadow (Image 1E). Further, we observed released male florets attached to the pistil of a wide-open female inflorescence on the water surface (2–8 male flowers/ female inflorescence; Image 1F). Lastly, a fertilized inflorescence observed had shed its petals, and the ovary was swollen, indicating the beginning of fruit formation (Image 1G).

Fruiting phases, seed development, and natural history

Based on the stages of seed development, we categorized the fruits observed as immature, mature, and dehiscent fruits. Immature fruits were fleshy,

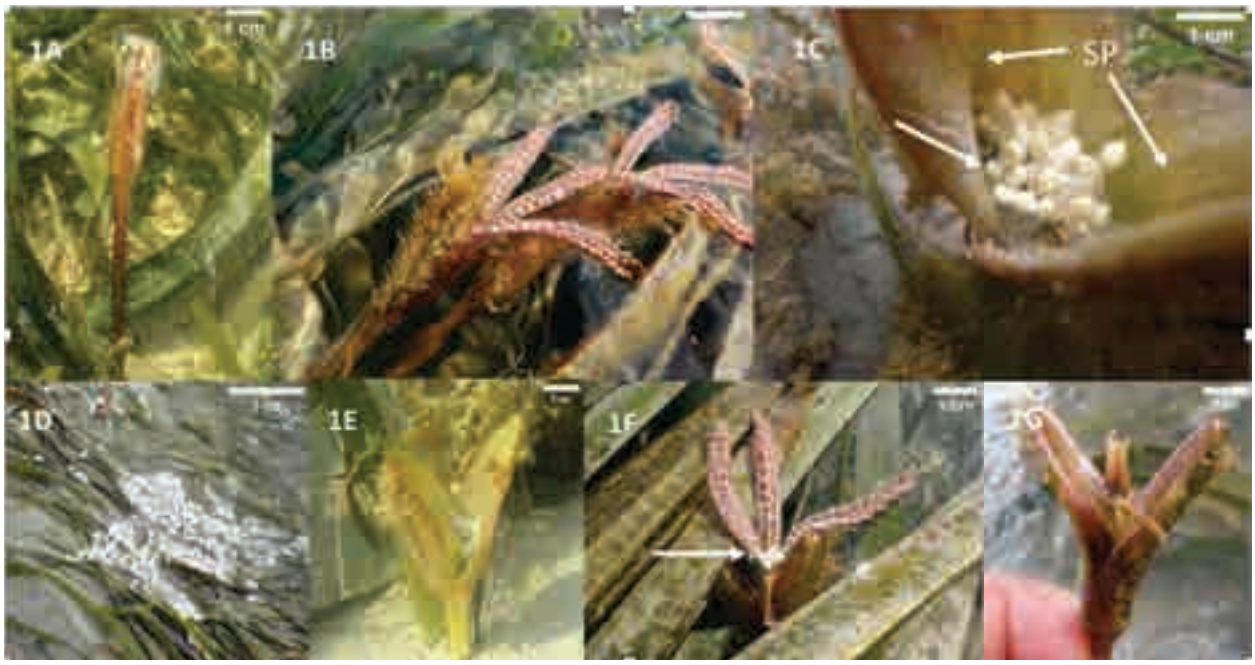

Image 1. Stages of flowering of *Enhalus acoroides*: 1A—Female Inflorescence bud (only sepals visible) | 1B—Pistillate flowers at an anthesis at the water surface (visible sepals, petals, pistils/ styles) | 1C—Male inflorescence with spathal leaves (SP) enclosing multiple white flowers (indicated by white arrow) | 1D—Released male flowers trapped in seagrass blades | 1E—Empty spathe filled with sand, post-release of male flowers | 1F—Pollination; male flowers attached to the pistil of female inflorescence at anthesis (indicated by white arrow) | 1G—Fertilized inflorescence. © Swapnali Gole and Ajay Kumar.

Table 2. Different phenophases of flowering and fruiting of *Enhalus acoroides* reported from the sampled seagrass meadow in Andaman Islands, India.

Stages of flowering	Density/ m^2	Peduncle length (cm)	Sepal/ Spathal leaf length (cm)
Female inflorescence bud	3.2 ± 1.8	23.2 ± 7.8	3.9 ± 0.7
Pistillate flower at anthesis	16.0 ± 12.0	26.1 ± 8.0	3.9 ± 0.8
Male inflorescence	12.7 ± 7.3	5.2 ± 1.1	4.2 ± 0.3
Male spathe (Post-release of male flowers)	3.3 ± 1.5	6.4 ± 1.6	4.1 ± 0.1
Pollination (Male flowers attached to female inflorescence)	10 ± 1.3	26.4 ± 8.0	3.9 ± 0.7
Fertilized flower	2.2 ± 1.0	20.3 ± 4.9	4.0 ± 0.6

Stages of fruiting	Density/ m^2	Diameter (cm; n = 20)	Fruit length (cm; n = 20)	No. of seeds/ Fruit (cm)	Seed length (cm)	Seed base (cm)
Immature fruits (Seeds still developing)	7.3 ± 2.0	4.6 ± 2.2	5.2 ± 0.8	11.3 ± 1.5	0.7 ± 0.1	0.8 ± 0.1
Mature fruits (Developed seeds)	8.0 ± 3.9	9.2 ± 2.8	6.7 ± 1.0	11.8 ± 3.3	0.9 ± 0.2	1.1 ± 0.1
Dehiscent fruits	2.2 ± 0.9	12.6 ± 0.7	-	-	-	-

Values expressed as mean ± standard deviation; (- not recorded).

greenish-brown in color, with an uncoiled peduncle. Solitary fruits were erect on terminal shoots of the peduncle and concealed 10–13 spherical white seeds still developing (Images 2A & 2B). Mature fruits were large, ovoid-shaped, and fleshy, with a pointed tip. The fruit cover was greenish, with longitudinal rows of brown spikes, and the coiled peduncle positioned above the substratum supported the fruits (Image 2C). We found 8–14 fully developed, germinating seeds per mature fruit (Image 2D). A membranous white seed coat concealed

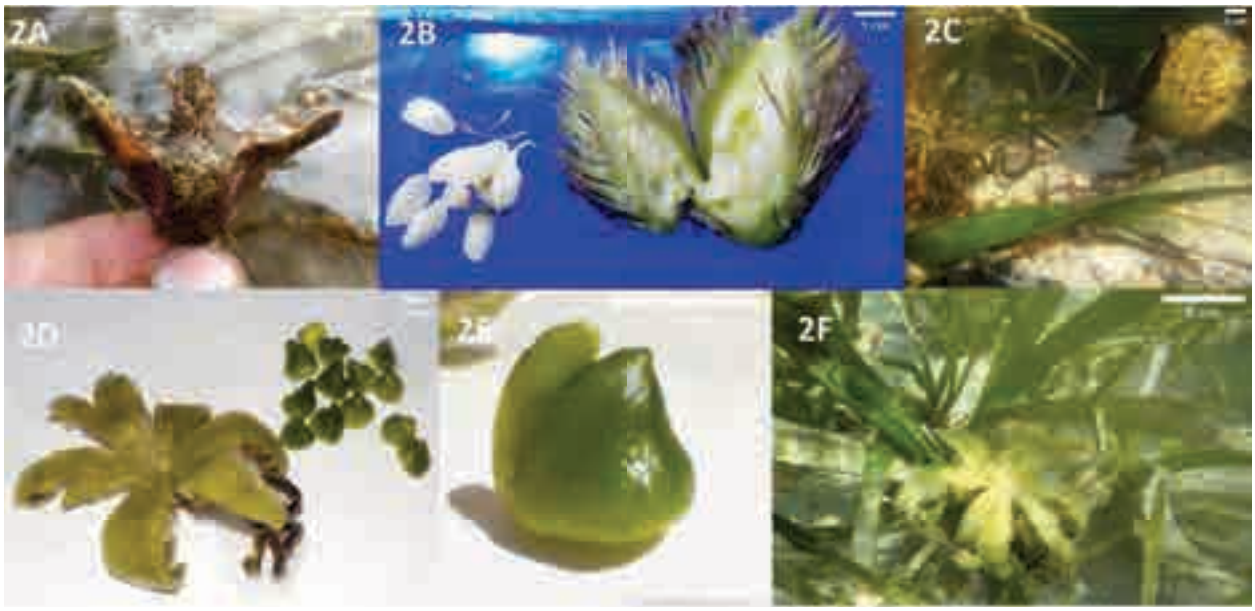

Image 2. Stages of fruiting of *Enhalus acoroides*: 2A—Young, immature fruit | 2B—Dissected immature fruit with developing seeds | 2C—Mature fruit with a coiled peduncle | 2D—Dissected mature fruits with developed seeds | 2E—Germinated seed with shoot bud visible | 2F—Dehiscent fruit. © Swapnali Gole and Ajay Kumar.

the seeds. Seeds were conical, yellow at the base and dark green at the apex. We observed visible shoot buds with a length of 1.2 ± 0.3 cm in each germinating seed (3 shoot buds/ seed; Image 2E). Dehiscent fruits were observed at the base of plant shoots, right above the ground (Image 2F). Fleshy fruit cover (mean diameter 12.6 ± 0.7 cm; Table 2) was broken into 6–7 halves post-release of seeds.

DISCUSSION

The lack of information on the phenology of *E. acoroides* from the Andaman Islands and Indian waters limits our understanding of the species' reproductive phases and seasonality. Densities of shoots, fruits, and flowers, in the present study (post-monsoon) were higher than previous reports in pre-monsoon (Patankar et al. 2019), possibly due to different sampling seasons. Additionally, no male flowers (inflorescence or released), pollination event, or fertilized flowers were recorded by Patankar et al. (2019). Since both the studies were opportunistic in nature, our findings supplement and strengthen the previous observations Patankar et al. (2019) made on *E. acoroides* phenology in the Andaman Islands.

In the present study, no correlation can be established between zonal variation in meadow characteristics and flowering densities of *E. acoroides*, given limited data. However, this aspect credits detailed investigation as studies have highlighted the role of meadow characteristics (seagrass cover, shoot density, and canopy height) and herbivory on the reproductive success of *E. acoroides* (Vermaat et al. 2004; Rattanachot 2008). Novel observations on the mass bloom of released male flowers (at SST ~30°C; mean) align with similar notes reported for the species (Hartog 1970; Rollon 1998).

In conclusion, based on higher densities of multiple phenophases observed in the present study (from buds to dehiscent fruits) as compared to previous reports (Patankar et al. 2019), we presume that January could be a critical period for *E. acoroides* phenology at a local scale, but this needs further validation through seasonal studies. Furthermore, the fruit ripening period for *E. acoroides* is long (2–3 months; Rollon 1998), after which the seeds are released. Thus, we assume that pollination is somewhere in October–November for the fruits observed in the present study. Thus, we recommend long-term seasonal monitoring studies to understand the peak flowering and fruiting season of *E. acoroides* and assess local drivers influencing the species' phenology in the Andaman Islands.

Lastly, our observations also report meadow scarring of the seagrass bed, as the study site is a fishing transit lane used for boat anchorage by local fishers (personal observations). Also, the entire inhabited coastline of Swaraj Dweep is known for gleaning activities and recreational and commercial fishing using 'khevla/ feka

jaal' (cast net) and 'taana jaal' (shore seine). Moreover, anecdotal reports (from local fishers) and our field observations (direct encounters) suggest that these seagrass beds are important to support threatened species like green sea turtles and dugongs. Hence, detailed baseline information on the seagrass meadow, including its biodiversity, needs to be established to emphasize its management and conservation and to understand the species' natural history. Therefore, although our observations have provided detailed documentation of the meadow and natural history notes on different phenophases for *E. acoroides*, this baseline needs to be supplemented with future research and long-term studies.

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SHORT COMMUNICATION

Status of Swamp Deer *Rucervus duvaucelii duvaucelii* (G. Cuvier, 1823) in grassland-wetland habitats in Dudhwa Tiger Reserve, India

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Abstract: Swamp Deer is an endemic species of the Indian subcontinent, mainly inhabiting tall grasslands in river floodplains. Populations of the northern subspecies (*Rucervus duvaucelii duvaucelii*), restricted to the Terai regions of northern India and western Nepal, have undergone dramatic declines over the past two–three decades. In this communication, we present results from systematic population counts conducted in Dudhwa Tiger Reserve between 2021–2022. These counts were conducted at 11 sites, each with two–three independent observers. The exercises covered summer, monsoon, post-monsoon, and winter seasons. We found the largest congregations of Swamp Deer in June during the summer and February in winter. In the monsoon months of July–September the Swamp Deer tend to use Sal woodlands along with farmlands adjoining the reserve edge. This is part of an ongoing research project on long-term monitoring and conservation of the threatened alluvial grasslands of the central Terai in Uttar Pradesh, India. Institutionalizing these monitoring practices for frontline forest staff is essential for understanding long-term population dynamics of the threatened Swamp Deer to develop conservation protocols for grasslands and their fauna.

Keywords: Alluvial grasslands, population ecology, long-term monitoring.

In the fertile low lying marshy interspersion of woodlands, grasslands, and wetland region of the Himalayan foothills popularly termed as 'Terai' (Dinerstein 1979), alluvial floodplain grasslands have largely been transformed to productive agricultural land where sugarcane, wheat, and rice are cultivated. This has in turn led to decline in populations of grassland obligate herbivores like One-horned Rhinoceros *Rhinoceros unicornis*, Hog Deer *Axis porcinus*, Hispid Hare *Caprolagus hispidus*, and Swamp Deer among others (Dinerstein 2003; Strahorn 2009).

Swamp deer are endemic to Indian subcontinent, with present distribution restricted to select regions of India and Nepal, while the species is reportedly extinct from Pakistan and Bangladesh (Duckworth et al. 2015). There are three distinct subspecies of Indian Swamp Deer: the northern *R. d. duvaucelii*, the central Indian *R. d. branderi*, and northeastern *R. d. ranjitsinhi* (Schaller 1967). Of these, the distribution of *R. d. duvaucelii* is relatively wide, spanning the states of Uttar Pradesh & Uttarakhand in India, and the western Terai in Nepal.

Although the distribution of the northern population is widely extended, their major populations are restricted primarily within protected area (PA) boundaries (Paul et al. 2020), with some movement between major blocks of habitats along riverine corridors and agriculture land (Warrier 2019). This was not always the case. In the late

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1960s, the largest known congregations of Swamp Deer in India were reported from the grassland-agriculture mosaics, south-west of Dudhwa (Schaller 1967). The disappearance of these large herds is, at least in part, the outcome of the progressive conversion of grassland habitats in the Terai into agriculture and other land-uses, which are now perhaps a mere 20% of their original extent (Dinerstein 2003; Strahorn 2009). In all likelihood, it may also be attributed to the species being hunted, especially beyond PA boundaries (Ahmed 2007).

The largest extant population of the northern subspecies has been reported from Shuklaphanta National Park in Nepal (2,300 individuals) in a grassland of 60 km^2 area (Ghimire et al. 2019; Yadav 2021). However, grassland habitats within Dudhwa Tiger Reserve (DTR), inclusive of Dudhwa National Park (DNP), Kishanpur Wildlife Sanctuary (KWS) (cumulatively spanning 141 km^2) have reportedly supported only around 1,300 Swamp Deer individuals in recent decades (Qureshi et al. 1995; Ahmed 2007). On the other hand, De (2001) reported around 2,100 individuals in the same areas.

Although DNP and KWS were declared PAs to conserve Swamp Deer and its natural habitat (Singh 1978), assessments of population status and fine-scale distribution have been scant. Chanchani et al. (2014) noted that the detection of the species was very sparse, even when transects in habitats with known aggregations were carried out on elephant back.

There have been no systematic population assessments for Swamp Deer since the late 2000s. The species status may be increasingly precarious in its former strongholds such as Sathiyana grasslands within DTR (Sankaran 1989). Therefore, a status assessment of the species was conducted in grassland habitats within Dudhwa Tiger Reserve in order to develop long-term monitoring protocols.

Methods

Population counts were conducted between March 2021–February 2022. We identified 11 monitoring sites after discussion with park managers and frontline staff, followed by reconnaissance surveys by the field team (Image 1). The counts were conducted by two–three observers independently using high vantage points like elevated machans or tall trees, across the four distinct climatic seasons in the study area namely, summer (March 2021–June 2021), monsoon (July–September), post-monsoon (October–November), and winter (December 2021–February 2022). Across these monitoring sites, we made 53 survey visits in summer, 26 in monsoon, 23 in post-monsoon, and 60 visits in winter season. The low number of visits in both monsoon and post-monsoon seasons is attributable to the water logging and flooding which made the study area inaccessible. The data was compiled & analyzed by estimating mean & standard errors of Swamp Deer individuals counted at each monitoring site and climatic season using R programming software ver 4.1.1 (R Development Core Team 2021).

Results

Across the sampling sites, the highest mean congregations of Swamp Deer were documented at the 'Jhadi taal' site in KWS [179 individuals (SE = 23.2)] in the summers, followed by the site 'Rhino Reintroduction Area-I' in DNP (Figure 1). The same sites visited in the monsoon months indicated low counts which is attributable to the movement of Swamp Deer herds to woodlands, uplands, and farmlands abutting the boundaries of two PAs. This is supported by the signs recorded during unintentional visits in agricultural fields near two of our monitoring sites namely, 'Madrahiya grasslands and Rhino Reintroduction Area-I'. We encountered signs such as hoof marks and pellets of Swamp Deer from 10 villages surrounding two of our sites along the southern peripheries of DNP. However, we did not conduct any systematic signs surveys in the farmlands and other areas adjoining the PA boundaries.

Discussion

Low counts of Swamp Deer across the study area in the winter months can be attributed to flooding caused by unseasonal rains in October 2021. This unusual event led to the rise in water levels at major wetlands/grasslands (specifically Jhadi taal in Kishanpur) of the monitoring sites, rendering these habitats unsuitable for Swamp Deer. In addition, low detectability in the grasslands due to the tall grasses (which may get as high as 3–4 m in the peak dry season) in winters may have resulted in lower counts of Swamp Deer at these sites. The low detections of Swamp Deer individuals in the tall grasslands have also been emphasized in previous research attempts which in turn have been limited to encounter rates and count methods (Qureshi 1995; De et al. 2013). However, there still exist pertinent gaps in robust methodologies to understand the trends in abundance and population dynamics of this grassland ungulate over spatial and temporal gradients (Chanchani et al. 2014).

Swamp Deer are indicator species of the alluvial floodplains (Ahmed 2007; Singh & Prasad 2013). Many wetlands/swamps in the study area are threatened due

Image 1. Spatial locations of the Swamp Deer monitoring sites in the study area.

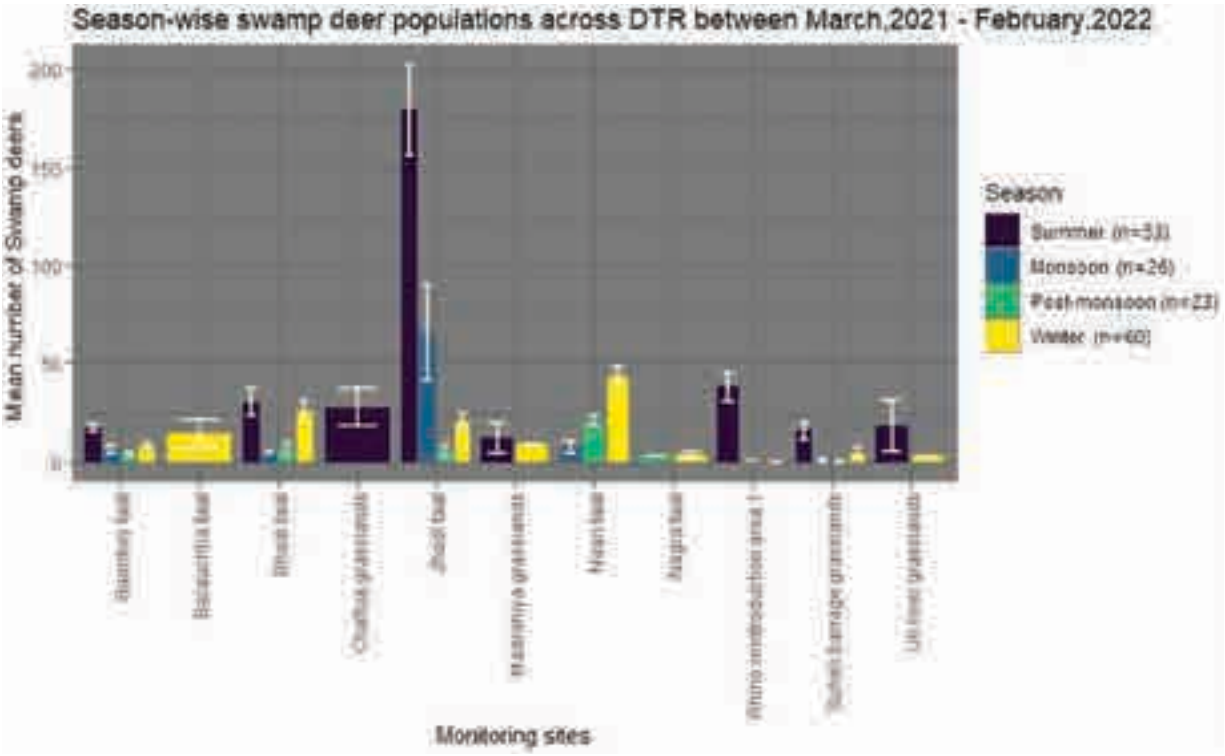

Figure 1. Swamp Deer counts across monitoring sites in Dudhwa Tiger Reserve (n: number of survey visits).

to the infestation of weeds such as Fox nuts *Euryale ferox* and Water Hyacinth *Pontederia crassipes* which need immediate interventions to secure these systems for dependent faunal species. In order to aid long-term research on the population dynamics of the Swamp Deer, the inclusion of monitoring exercises in the annual workplan of DTR administration is essential. Data collection can be facilitated by the use of simple electronic forms (both in English and native language), developed in discussion with experts, which can be preloaded on mobile devices of frontline staff. This valuable data generated through such efforts will help in designing necessary and robust conservation interventions for both the Swamp Deer and its threatened habitats in the Dudhwa landscape.

As part of our previous research work between 2019 & 2020, we assessed the probabilities of habitat use by Swamp Deer in grasslands within DTR (Rastogi et al. 2022). The results from the study revealed that about 30% of the overall grasslands were used by the species, with an occurrence probability of more than 40%. Therefore, gathering insights from previous work, we extended our survey jointly with the DTR administration, Uttar Pradesh Forest Department to monitor key grassland/wetland sites within the Dudhwa Tiger Reserve as part of this study in order to aid long-term conservation of the Swamp Deer.

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SHORT COMMUNICATION

First photographic evidence of Indian Pangolin *Manis crassicaudata* Geoffroy, 1803 (Mammalia: Pholidota: Manidae), in Colonel Sher Jung National Park, Himachal Pradesh, India

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Abstract: The Indian Pangolin *Manis crassicaudata* is 'Endangered' on the IUCN Red List. We report the first photographic evidence of its presence in Colonel Sher Jung National Park of Paonta Valley in Himachal Pradesh. Camera-traps (n = 64) were used to assess the diversity and abundance of terrestrial mammals. Over 1,912 trap nights, we documented 16 mammals, of which the Indian Pangolin was photo-captured at a single camera-trap station with two independent records. Although the presence of species has been indicated in a few studies conducted in the study area, no photographic evidence of the Indian Pangolin from the National Park has previously been reported. We strongly recommend additional fieldwork in and around the protected area to learn more about the Indian Pangolin's distribution, habitat use, and ecology.

Keywords: Activity pattern, camera-trapping, conservation, distribution, Manidae, *Shorea robusta*, Shivalik hills, small mammals.

The Indian Pangolin is categorised as Endangered (EN) in the IUCN Red List of Threatened Species (Mahmood et al. 2019). Due to the rapidly declining population of this species in India (Kumar et al. 2016; Aditya et al. 2021) and across its range (Mahmood et al. 2012; Baillie et al. 2014; Latafat & Sadhu 2016), the species is listed in CITES Appendix I (CITES 2017) as well as in Schedule I of the 2022 amendment of the Indian Wildlife (Protection) Act, 1972. The Indian Pangolin, a member of the Pholidota order and Manidae family, is one of the two pangolin species found in the Indian subcontinent (Kumar et al. 2016). The other is the Chinese Pangolin *Manis pentadactyla*, listed as 'Critically Endangered' on the IUCN Red List (Challender et al. 2019).

The Indian Pangolin, also known as the Thick-tailed Pangolin, is a medium-sized mammal with 11-13 rows of scales covering its dorsal surface (Mahmood et al. 2020). Because the species lacks teeth, it relies on the salivar-coated tongue to reach and lap up insects, ants, and termites present in deep crevices (Mahmood et al. 2020). When threatened, it quickly rolls into a ball, with the tail curled over the head, exposing only the protective scales (Mahmood et al. 2020). The Indian Pangolin is distributed across southern Asia, from parts of eastern Pakistan to much of the Indian subcontinent (except the Himalaya and the north-east, where the Chinese Pangolin is found), as well as south of the Himalaya, Bangladesh, southern Nepal, and Sri Lanka (ZSI 2002; Srinivasulu & Srinivasulu 2012; Aditya et al. 2021). The species inhabits various habitats, including tropical,

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sub-tropical, dry-mixed evergreen, sub-mountain, and riverine forests (Roberts 1977; Phillips 1981).

Pangolins are declining in numbers across their range despite being a protected species (Mahmood et al. 2012). The species faces major threats from hunting for meat, spiritual & ritualistic uses, and use in traditional medicines (scales) (Anon 1992; Brown et al. 1996). Globally, pangolins are the most trafficked animals (Baillie et al. 2014; Zhou et al. 2014; Challender 2015; Challender et al. 2015), and according to TRAFFIC India, almost 6,000 pangolins were poached in India between 2009 and 2017 (Ghosh 2020).

Materials and Methods

Study area

Colonel Sher Jung National Park, also known as Simbalbara National Park (SNP), is located in the Paonta Valley of Sirmour District, Himachal Pradesh, India, and covers an area of 27.88 km^2 (30.4058–30.4703 N & 77.4550–77.5239 E) (Figure 1). The elevation range of the study area lies at 580–700 m. The region's hilly terrain is representative of the lower Shivalik that further emerges into the middle and upper Shivalik. The western boundary of the National Park is shared with the Kalesar National Park of Haryana Forest Division. The sanctuary has a subtropical climate with hot summers and severe winters. The summer temperatures touch as high as 46°C and winter temperature drops to 6°C with a mean annual rainfall of 1,260 mm (Singh et al. 1990). The area, regarded as the westernmost limit of Sal distribution in India (Chand 2014), is covered by moist Sal-bearing forests and northern dry mixed deciduous forests (Champion & Seth 1968). The prominent mammal species are the Common Leopard *Panthera pardus*, Himalayan Brown Goral *Nemorhaedus goral*, Sambar *Rusa unicolor*, Barking Deer *Muntiacus muntjac*, Asiatic Wild Pig *Sus scrofa*, Golden Jackal *Canis aureus*, Indian Crested Porcupine *Hystrix indica*, Spotted Deer *Axis axis*, Himalayan Palm Civet *Paguma larvata*, and Yellow-throated Marten *Martes flavigula* (Chand 2014).

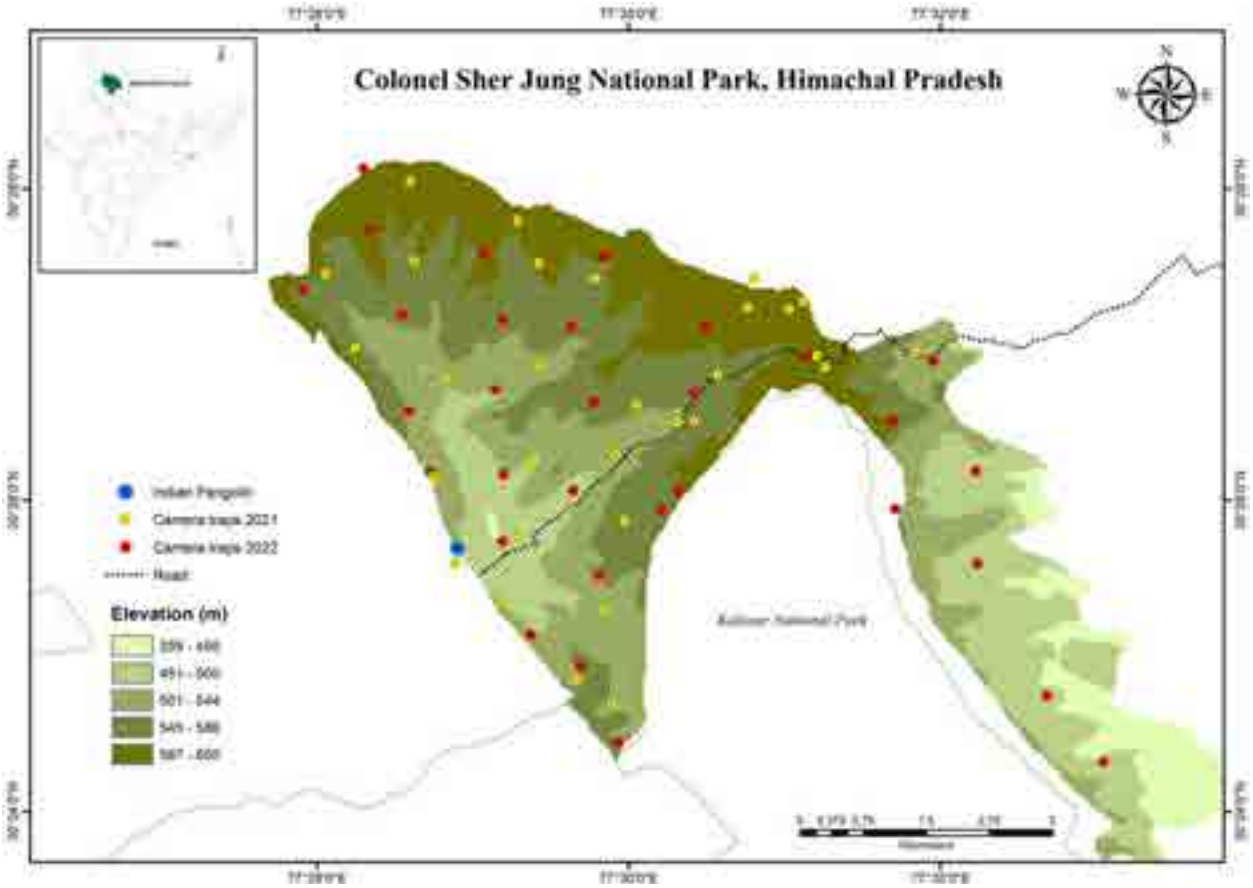

Figure 1. A map of the study area (Colonel Sher Jung National Park or SNP) shows camera-trap locations and location of the detected Indian Pangolin.

Camera-trap survey

Mammals were photographed using camera-traps in SNP. Camera-trap locations were unbaited and selected based on accessibility, terrain features, animal trails, and nallahs (seasonal drainages) with carnivore signs (Marinho et al. 2018). At each location, a single Cuddeback X-Change™ colour model (Cuddeback, Green Bay, WI, USA) with motion sensors was deployed, and a time lag of 1s was set between animal detections. Cameras were fastened to trees at 30–45 cm above the ground for an average of 30 days for both years. A total of 64 camera-trap locations were utilised in a grid-based approach (grid size: 1 km^2) during two sampling periods: March 2021–May 2021 (n = 31) and April 2022–May 2022 (n = 33). Camera-traps were monitored at regular intervals, and after the completion of each camera-trapping session, the photographs were examined for images of animals. Mammals were identified with the help of literature by Johnsingh & Manjrekar (2012) and Menon (2014). Photographic captures were taken at or more than 30 minutes apart from each other were considered independent events (Silver et al. 2004; Di Bitetti et al. 2006).

Table 1. Information on sampling and photo-captured Indian Pangolin in SNP, Himachal Pradesh, India.

Sampling information		
Sampling period	Mar 2021–May 2021	April 2022–May 2022
Mammals recorded through camera-trapping	15	16
Mammals recorded through direct sighting	5	0
Camera-traps	31	33
Trap-nights	887	1025
Information on Indian Pangolin		
Geographic coordinates (Latitude, Longitude)	-	30.4282^{0}N, 77.4817^{0}E
Total number of photos	-	2
No. of Independent photos	-	2
Duration of camera placement	-	09/04/2022 to 19/05/2022 (41 days)
Date & time of photo-captured events	-	09/05/2022, 0013 h & 0058 h
Elevation	-	501 m
Terrain	-	Rugged
Location	-	Animal Trail
Habitat type	-	Upper-temperate mixed-broadleaved forest
Habitat (Forest type)	-	Miscellaneous
Tree species around the camera trap	-	*Diospyros melanoxylon*, *Ougeinia oojeinensis*, *Anogeisis latifolia*, *Shorea robusta*, *Murraya paniculata*
Ground Cover	-	Dry leaves and grass
Distance to nearest human settlement	-	0.3 km

Results

We recorded 21 mammals (camera-trapping: 16, direct sightings: 5, carnivores: 8, non-carnivores or herbivores: 13) over 1,912 trap nights (Table1, Figure 1). We recorded the species from one station with two independent captures. Both captures occurred at night, i.e., 0013 h and 0058 h.

The species was recorded in a miscellaneous type of forest. The vegetation around the camera-trap station comprised *Diospyros melanoxylon*, *Ougeinia oojeinensis*, *Anogeisis latifolia*, *Shorea robusta*, *Murraya paniculata*, *Woodfordia fruticosa*, *Arthraxon lanceolatus*, along with climbers *of Bauhinia vahlii.* The species was recorded on an animal trail along a ridge that is also used by the local communities to extract forest resources, primarily fodder.

Discussion

The Indian Pangolin was detected during the sampling period of 2022. However, during the 2021 sample period, the camera-trap was deployed near the same location, on the same trail, for 40 trap nights, but no evidence of the species was recorded. Despite intensive sampling, failure to record the species over the 2021 sampling period may also indicate the rarity of species from the study region.

The presence of Indian Pangolin has been documented across the Shivalik hills in India (~300–1,000 m) (Joshi 2016; Bhandari et al. 2019; Kumar et al. 2022). Although this is the first photographic evidence regarding the presence of species in SNP, its presence has been reported in a few studies conducted in the National Park (Bhargav 2009; Chand 2014); however, no further information or evidence was provided. Furthermore, Sharma & Saikia (2009) did a study on the faunal diversity of the SNP, in which they reported the presence of species in the National Park based on scales of a dead animal collected in June 2005, with no sightings or proof given. The Indian Pangolin has also been reported from the Kalesar National Park (KNP) in Haryana (Sehgal et al. 2022), which borders our study area, i.e., SNP.

The Indian Pangolin is an understudied species (Mahmood et al. 2015); detailed studies on the species across its range and the Shivalik hills are still required to formulate conservation strategies. Due to increased

Image 1. Independent photographs (n = 2) of photo-captured Indian Pangolin in SNP, Himachal Pradesh, India.

demand in the trade market, the Indian Pangolin is under severe collection pressure (Mahmood et al. 2020). According to studies and available data, around 1,700 Indian Pangolin scales were trafficked internationally between 2011 and 2017; however, considering a lot of trade goes undetected, the actual number of animals involved is likely higher (Challender & Waterman 2017). Steps must be taken to prevent hunting and to halt the Indian Pangolin trade chain. The exact population of the species in concern is unidentified (Kumar et al. 2016). Thus, to ensure the long-term persistence of the Indian Pangolin, further research is needed to understand the distribution, population, and threats to the species. Setting up pangolin rescue and rehabilitation centres

and breeding centres (Hua et al. 2015) could also help the pangolin population recover in the future.

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SHORT COMMUNICATION

The Marine Otter *Lontra felina* (Molina, 1782) (Mammalia: Carnivora: Mustelidae) along the marine protected areas in Peru

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Abstract: *Lontra felina* (Molina, 1782) or Marine Otter is an endangered species according to the IUCN Red List and lives mainly on the rocky coast of Peru and Chile. In Peru it inhabits some marine protected areas, ports and some rivers. To determine the current state of conservation, monitoring data of National Reserves of Paracas, San Fernando & the Guano´s Islands, Islets & Capes National Reserve System were analysed as well as the management plans of each marine protected area. According to the results, the Marine Otter is only a target species in the Paracas Reserve. The Guano´s Islands, Islets & Capes National Reserve System is a network of mini-reserves that maintains the largest population of Marine Otters in Peru in at least 14 of its 33 protected sites. The effectiveness of management for *L. felina* is only verified in the case of the National Reserve of Paracas.

Keywords: Effective conservation, Guano´s Islands, Islets & Capes National Reserve System, Mustelids, Paracas, population.

The Marine Otter *Lontra felina* Molina, 1782 is an 'Endangered' species on the IUCN Red List (Mangel et al. 2022). This otter is distributed along the rocky shore from northern Perú to southern Chile as well as in some rivers in Peru (Jefferson et al. 2015). The habitat fragmentation, the entanglement in fishing gear of artisanal fisheries, the attack of dogs and pollution are considered the main menaces for *L. felina* (Medina-Vogel et al. 2008; Pizarro 2008; Valqui 2012). In Peru the National Service of Protected Areas (SERNANP in Spanish) manages some sites inhabited by Marine Otters (Ortiz et al. 2021). However, the current population size of Marine Otter along the Peruvian marine protected areas is unknown. The current population status and management effectiveness of the Marine Otter in the Peruvian marine protected areas is described in the present note.

Materials and Methods

The study sites: Three national reserves were studied using monitoring data of *L. felina* requested from SERNANP in December 2020. The location, coordinates and coastal length of the sites are shown in the Table 1. The coastal length was estimated using the multimedia tool 'Catastro Acuícola Nacional' (Ministerio de la Producción, 2022). The reserves are in fact marine protected areas as follows:

National Reserve of Paracas was the first marine protected area of Peru. Paracas was initially planned as a sanctuary for marine life with an area of 8 km^2 (ONERN 1974). Finally, it was established as an MPA (Marine protected area) with an area of 3,350 km^2 and a coast-line length of 140 km approximately. Paracas shoreline includes fishermen settlements, rocky and sandy beaches and two islets. Furthermore, currently Paracas is part of the hemispheric network of bird reserves and

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Figure 1. Study area.

is a RAMSAR site as well. Many threatened species as seabirds, and marine mammals, including the Marine Otter would be seeing within the reserve (SERNANP 2016a).

Guano´s Islands, Islets and Capes National Reserve System (RNSIIPG by its acronym in Spanish) was created in 2009 comprising 22 islands or islets and 11 capes, covering more of 1,400 km^2 (SERNANP 2016a). It is the first MPA founded in Peru designed as a network of several small protected sites. The RNSIIPG has as purpose conserve a representative sample of the biological diversity of coastal and marine ecosystems of the Humboldt cold sea current, ensuring continuity of the biological cycle of the species that inhabit there, as well as their use sustainable with fair participation and equitable benefits derived of the use of their resources (Ortiz et al. 2021). Almost all the RNSIIPG sites were in the past capes and islands managed for the exploitation of guano along the coast by the Peruvian government and therefore the establishment of a marine protected area inspired by a model of several mini reserves matches perfectly (Figure 1). The main threatened species to conserve in RNSIIPG are the Guano birds*: Phalacrocorax bougainvilli*, *Sula variegata* and *Pelecanus thagus*. Another endangered species protected within the RNSIIPG are the South American Fur Seal *Arctocephalus australis*, the South American Sea Lion *Otaria byronia*, the Green Turtle *Chelonia mydas* as well as the Humboldt Penguin *Spheniscus humboldti* (SERNANP 2016b).

National Reserve of San Fernando was founded in 2011, under the perspective of the conservation of a biological corridor between the highlands and the coast to permit migration of fauna such as Andean Condor *Vultur gryphus* and Guanaco *Lama guanicoe*. The main part of this reserve is terrestrial and includes fragile ecosystems as the "lomas", a plant formation endemic of the desert in Peru and northern Chile. The marine zone of the reserve comprises mainly cliffs and small-scale fishery villages as well. San Fernando is a refugee for guano birds, Humboldt Penguins, pinnipeds and associated fauna like the Marine Otter. There is very little information about Marine Otter population in this reserve.

To obtain data about population of *L. felina* in the reserves above mentioned, the author requested this information to the SERNANP in December 2020. In January 2021 SERNANP answered with the letter CARTA Nº 0001- 2021-SERNANP-AIP (see Annex 1), with the correspondent data of Marine Otter population. The information about Marine Otters was ordered by population in each site, coastal length and coordinates (Table 1). For the National Reserve of San Fernando the data were taken data from Apaza & Romero (2012).

To determine the effective conservation of the species, were analyzed management plans from each marine protected area looking for indicators of conservation and management of L. felina, following in part the recommendations of Hockings et al. (2015).

Results and Discussion

According to the data recorded, the population size of Marine Otters within the three protected areas studied during 2020 is 120 individuals. In addition, the RNSIIPG exhibits the largest population of *L. felina* among the marine protected areas of Peru with 71 individuals monitored (Table 1). SERNANP communicated that currently in the Reserve of San Fernando has no Marine Otters, therefore was consigned the population size mentioned by Apaza & Romero (2012) for this site.

On the other hand, the review of the reserve management plans shows that the Marine Otter is only a target species within the Paracas National Reserve. Following the management plan of the Paracas Reserve, at least 20 individuals of *L. felina* should live in this protected area to reach the goal of conservation of this species (SERNANP 2016a). According to the population reported for Paracas in the Table 1, the effective conservation of this species has been achieved. The RNSIIPG and the Reserve of San Fernando do not include the Marine Otter as an element of conservation (SERNANP 2016b, 2019).

The population of *L. felina* in Peru estimated by various authors is variable. Recent studies estimate a population between 789 and 2131 individuals for Peru and Chile (Valqui 2012), while Apaza & Romero (2012) suggest that 756 individuals inhabit Peru. However, the latter authors analyzed data from 130 different locations in Peru while Valqui (2012) only used a few sites to record the presence of Marine Otters in Peru. In any case, using the estimates of Apaza & Romero (2012), and according to the data presented here, the Marine Otters that inhabit marine protected areas in Peru represent about 15% of the total extant in the country and these MPA are located mainly in the central and northern coast of Peru (Figure 1). The Marine Otters outside marine protected areas are distributed mainly in the southern coast of Peru (Ortiz et al. 2021) and there is a population living in freshwater habitats at the Department of Arequipa, located at the south of the country (Duplaix & Savage 2018).

In relation with the management effectiveness of the Marine Otter within the reserves, the fact that the Marine

Table 1. Population of *Lontra felina* (Molina, 1782) in marine protected areas of Peru.

Marine protected area	Location	Marine Otter population (year)	Coastal length (km)***
National Reserve of Paracas	-14.116666667, -76.216666667	45 (2019) *	140
National Reserve San Fernando	-15.136111112, -75.367777778	1-4 (2012) **	88
RNSIIPG-Punta Coles Cape	-17.702777778, -71.379444445	5 (2020) *	5
RNSIIPG-Hornillos Cape	-16.875555556, -72.285	Without data	6.3
RNSIIPG-La Chira	-16.516388889, -72.933333334	1 (2020) *	2
RNSIIPG-Atico Cape	-16.231388889, -73.695555556	10 (2020) *	6.4
RNSIIPG-Lomas Cape	-15.571388889, -74.8525	5 (2020) *	2
RNSIIPG-San Juan Cape	-15.3655, -75.1921	1 (2018) *	4.7
RNSIIPG-Asia Islet	-12.788055556, -76.286944445	5 (2020) *	7.3
RNSIIPG-Pachacamac Islet	-12.30256, -76.90055	4 (2020)	2.6
RNSIIPG-Cavinzas Islet	-12.115833334, -77.205277778	9 (2020) *	1.7
RNSIIPG-Pescadores Islands	-11.786111112, -77.205833334	8 (2020) *	4
RNSIIPG-Salinas Cape	-11.291388889, -77.318888889	3 (2020) *	5.2
RNSIIPG-Don Martin islet	-11.020277778, -77.669722223	1 (2020) *	2.4
RNSIIPG Colorado Cape	-10.49138, -77.9641	2 (2020) *	1.4
RNSIIPG-Culebras Cape	-9.949722223, -78.233611112	6 (2020) *	4.7
RNSIIPG-Santa Island	-9.024166667, -78.668333334	12 (2020) *	9.2
RNSIIPG-Corcovado islet	-8.939444445, -78.701388889	2 (2020)*	0.8
RNSIIPG-Chao Islet	-8.759722223, -78.790833334	3 (2020)*	3

Source: Letter CARTA N^{0} 0001 - 2021-SERNANP-AIP*, Apaza & Romero (2012)** and Ministerio de la Producción (2022)***.

Otter appears as a conservation element only in the Reserve of Paracas would means that this species counts with previous studies which has been used to design the protected area and to perform a better management plan. Effectively, Grimwood (1969) mentioned that *L. felina* was abundant in Paracas before the elaboration of their first management plan. Later, several authors mentioned *L. felina* as a common species in Paracas (Brack-Egg 1978; Majluf & Reyes 1989; Pulido 1991; Sánchez 1992; Ormeño et al. 2008). Conversely, the vision of the management plan of the RNSIIPG explain that the outputs and outcomes of the management of the reserve are based in the protection of guano birds, pinnipeds as well as fishes and invertebrates of importance to the small-scale fisheries (SERNANP 2016b). It is a characteristic of MPA within the category VI of IUCN, where the main objective is to protect natural ecosystems and use natural resources sustainably, when conservation and sustainable use can be mutually beneficial (Dudley et al. 2012). In this context, the conservation of Marine Otter has been not prioritized. However, the fact that in the RNSIIPG the Marine Otter is part of a biodiversity monitoring programme could be seen as an attempt to achieve biological integrity of the reserve. And it opens the option to include the Marine Otter as target species in the RNSIIPG; there are sufficient data that evaluate the persistence of the species in some sites of this network of mini reserves. Moreover, since the Marine Otter is distributed in isolated patches along the coast and has a limited home range to 1-4 lineal km (Medina-Vogel et al. 2008; Jefferson et al. 2015), a network of sites would be a proper measure to conserve this species. In the case of the Reserve San Fernando the main problem to conserve the Marine Otter is the shore geomorphology with predominance of cliffs, wherein it is difficult to monitor the otters; the reason for few data from this site. Consequently, Sánchez (1992) as well as Apaza & Romero (2012) report only 1–4 otters there.

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SHORT COMMUNICATION

First record of the genus *Acropyga* Roger, 1862 (Hymenoptera: Formicidae: Formicinae) in Kerala, India

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Abstract: This is the first record of the ant genus *Acropyga* from Kerala, India. The ant was collected as a part of the research collections done in the Rosemala region of the Shendurney Wildlife Sanctuary, Kerala, India. The worker, male and queen ants have been described here. A detailed description, distribution, ecological notes, and images are also provided.

Keywords: *Acropyga acutiventris*, Shendurney Wildlife Sanctuary, new record, Rosemala

The genus *Acropyga* belong to the family Formicinae and was first reported worldwide by Roger (1862) from Sri Lanka. There are currently 41 species in this genera worldwide (AntWeb 2018). *Acropyga* ants are present worldwide. These ants are known for their mutualistic obligate symbiosis with mealybugs of the subfamily Rhizoecinae (Johnson et al. 2001; Kishimoto-Yamada et al. 2005). They take care of these mealybugs and feed on the exudates produced by them. They can be found in a range of habitats, from deserts to rainforests, and is largely thought to be subterranean (LaPolla 2004).

Major contributions to this genus were made by Forel (1878) by making the first description of the genus. Smith (1871) described the geographical distribution of these ants. Terayama et al. (2002) gave a species key to the East Asian species of genus *Acropyga*. Wang & Wu (1992) described a new species of *Acropyga* from China and made an identification key. Terayama (2009) gave a synopsis of the Family Formicidae of Taiwan in which a key to the *Acropyga* of Taiwan was given, along with a few species descriptions. Jaitrong & Nabhitabhata (2005) made a list of ant species from Thailand in which the presence of *Acropyga,* along with its distribution in the country was reported. *Acropyga acutiventris* was described in detail by LaPolla (2004).

Acropyga was first reported in India by Bingham (1903). Currently, only two species from this genus have been reported in India—*A. acutiventris* & *A. rubescens* (Bharti et al. 2016). *Acropyga acutiventris* has been reported from 13 states in India, mostly from the northeastern region (Bharti et al. 2016) and Andaman & Nicobar Islands (Mohanraj et al. 2010). This is the first record of this genus from Kerala and the first description from India on *Acropyga,* including the worker, male, and alate queen. The only other state in southern India *A. acutiventris* has been reported is Karnataka (Varghese 2004).

Material and Methods

The specimens were collected during the period of March 2021–August 2021 from the Rosemala region

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(8.9336N & 77.1922E) of the Shendurney Wildlife Sanctuary (Image 1). The 'Ants of Leaf Litter' (ALL) protocol (Agosti et al. 2000) was used for ant collections. These particular ant samples were collected using handpicking. The current specimens were found under a small rock in an evergreen forest region of the Rosemala region. A whole colony was found under the rock, & the workers, male & alate queen, were collected. The specimens were preserved in 70% ethanol. Identifications were done under a stereomicroscope (Labomed Luxeo 6z). The taxonomic key by Bolton (1994) was used for the identification of the genus. The species was identified using the key by LaPolla (2004). Leica S8AP0 microscope with Leica DFC 295 camera was used to capture images, and measurements were done using the Leica v4.2 software. Soil samples were collected from the site and analysed in the laboratory. The soil pH was analysed using a soil pH meter and soil organic carbon was measured using Walkley & Black method (Page et al. 1982). The soil moisture was measured using the gravimetric method (Kadam & Shinde 2005). The specimens were deposited in the zoological museum at the Department of Zoology, University of Kerala Campus, Kariavattom, Kerala, India.

Measurements

HL: Head Length. Length of the head in full-face view when measured as a straight line from the midpoint of the anterior clypeal margin and to the midpoint of the posterior margin. This excludes the clypeus.

HW: Head width. The maximum width of the head in full-face view.

EL: Eye length. The maximum length of the eye when in the same view as HL.

ML: Mesosomal length. Length of the mesosoma in side view from the posteroventral corner of mesosoma to the farthest point on the anterior face of pronotum, excluding the neck.

GL: Gaster Length. The length of the gaster in lateral view from the anterior point of the first gastral tergite to the posterior-most point of the last gastral tergite, excluding the sting.

SL: Scape Length. Length of the scape in a straight line excluding the basal constriction of the neck close to the condylar bulb.

PTL: Petiole length. Length of the petiole from dorsal view.

PTH: Petiole Height. Height of the petiole in lateral view.

PTW: Petiole Width. Width of the petiole in dorsal view.

TL: Total Length. HL+ML+PTL+GL

OI: Ocular Index. (EL/HW) x 100

CI: Cephalic Index. (HW/HL) x 100

SI: Scape Index. (SL/HW) x 100

DPI: Dorsal Petiole Index. (PTW/PTL) x 100

LPI: Lateral Petiole Index. (PTH/PTL) x 100

Results

***Acropyga acutiventris* Roger, 1862**

Acropyga acutiventris Roger, 1862 Sri Lanka, Indomalaya

Status as species: Mayr, 1862: 769

Material examined: Worker (n = 10): KUDZEN2021.X.12.a, Male (n = 1): KUDZEN2021.X.12.b, Queen (n = 1): KUDZEN2021.X.12.c Rosemala, Shendurney Wildlife Sanctuary, Kollam, Kerala, India. 27 July 2021 at 8.9336N & 77.1922E elevation 340 m, coll. Merin Elizabeth George, handpicking, under a stone in a leaf litter near a small stream in a primary evergreen forest. This is a typical specimen of the species (species typica). Specimen deposited at the reference section of the museum at the Department of Zoology, University of Kerala, Kariavattom, Thiruvananthapuram, Kerala, India.

Worker: Worker Morphometrics (in millimeters): HL: 0.83, HW: 0.987, SL: 0.81, ML: 1.024, GL: 1.50, EL: 0.125, PTL: 0.275, PTW: 0.27, PTH: 0.393, TL: 3.63, OI: 12.6, CI: 118.9, SI: 82, DPI: 98.1, LPI: 142.

Worker description: Head: Dull yellow colour, head slightly longer than broad and rectangular. Posterior margin of the head emarginated. Scape with dense pubescence. Teeth five, mandibles striate from base to the articulation point. Eyes small. Anterior margin of the mandible lined with long hairs. Head as long as wide. Antennae 11 segmented. Eyes placed at the lower half of the head (Image 1).

Mesosoma: Smooth and shiny, long erect setae present on alitrunk except propodeum. Propodeum with small recumbent hairs. Mesonotum raised and convex above pronotum when compared to pronotum when viewed in lateral angle (Image 2–3).

Petiole: Dull yellow, thick and erect with short erect hairs. Height about same as propodeum.

Gaster: Five gastral segments present, Smooth and shiny with both long erect hairs and short recumbent hairs.

Male

Male Morphometrics (in millimeters): HL: 0.599, HW: 0.635, EL: 0.423, SL: 0.866, ML: 1.428, PTL: 0.135, PTH: 0.38, PTW: 0.12, GL: 1.458, TL: 3.62, OI: 66.61, CI: 106, SI: 136, DPI: 88.8, LPI: 281

Images 1–3. *Acropyga acutiventris* worker: 1—Lateral view of the body | 2—Dorsal view of the body | 3—Full face view of head.

Images 4–6. 4–5—*Acropyga acutiventris* male | 6—Head (full face view).

Description

Head: Dull yellow. Eyes extremely large, covering most of the head, ocelli large, anterior margin of clypeus lined with long erect hairs. Head as long as wide. Dorsal surface of head smooth and shiny. Scape with dense pubescence. (Image 4)

Mesosoma: Dull yellow. Smooth and shiny. Alitrunk except propodeum with long erect hairs. Propodeum with short recumbent hairs.(Image 5–6)

Petiole: Erect and thick with a rectangular shape. Few short hairs are present on the dorsal surface.

Gaster: Smooth and shiny. Covered in long hairs.

Alate Queen: Queen Morphometrics (in millimeters): HL: 0.91, HW: 1.20, EL: 0.46, SL: 1.15, ML: 2.08, PTL: 0.182, PTW: 0.292, PTH: 0.65, GL: 2.98, TL: 6.152. OI: 38.3, CI: 131.8, SL: 95.8, DPI: 1.604, LPI: 357.1

Description

Head: Dull yellow. Mandibles with striation. Anterior clypeal margin lined with long erect hairs. Three distinct ocelli are present. Outer margin of head lined with hairs. Eyes large placed in the lower ¼ of the head. Head as long as wide. Antennae with 11 segments (including scape) (Image 7–9).

Mesosoma: Dull yellow, smooth, and shiny, covered in small erect hairs.

Petiole: Triangular, erect hairs, and with small erect hairs on the dorsal surface.

Gaster: Dull yellow & five gastral segments. Surface covered in with long recumbent hairs.

Leg: Entire leg covered in short erect hairs.

Differential diagnosis: This species is morphological very similar to *Acropyga rubescens,* but they are

Images 7—9. *Acropyga acutiventris* alate queen: 7—Body – lateral view | 8—dorsal view | 9—head – full face view.

Image 10–13. *Acropyga acutiventris*: 10—Queen forewing | 11—Queen hindwing | 12—Male forewing | 13—Male hindwing.

generally smaller in size and less hairy.

Diagnostic features: Mandibles with striations from base to the articulation point.

Ecology Notes: The ants were found in an evergreen forest, in between two stones in the leaf litter near a small stream with low light conditions and high humidity. There were 30 worker ants, one queen and four males in the colony. The ants were docile upon disturbance showing few movements. There was no nest formation of any type as the ants were found on top of a rock covered by another rock. The ants were handpicked. There were multiple *Anoplolepis gracilipes* ants a few kilometers away from the nest. Soil was collected from where the ants were found. The pH of the soil was measured to be 5.53. The organic matter in the soil was analysed to be 0.04%, and the soil moisture was 24.5%.

Discussion

A total of 10 workers, one male and one alate queen were taken from the site. These ants are relatively less common in collections because of their rarity. This study extends the range of this genus to Kerala. *A. acutiventris* was observed in the Shendurney Wildlife Sanctuary which is a part of the Western Ghats. The collections revealed that there were multiple *Anoplolepis gracilipes* ants near these *Acropyga* ants. The presence of invasive ants has been known to cause lowered species diversity of ants (Berman et al. 2013). *Anoplolepis* ants have also been known to cause a decrease in the diversity of ants (Mezger & Pfeiffer 2011). It can be said that the presence of *Anoplolepis* ants, which act as invaders, can be detrimental to native specialist ants like *A. acutiventris*. It is imperative that the forest be protected and its human interference be lowered so that such invasive ants can be controlled.

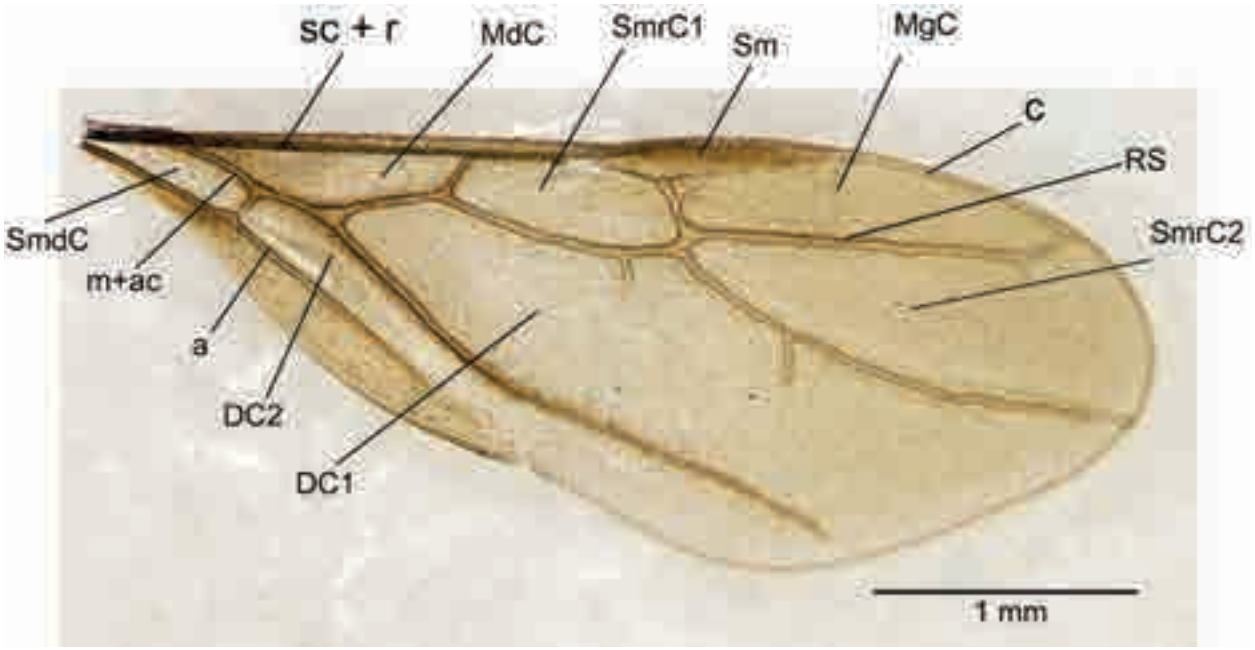

Image 14. Wing venation in *Acropyga acutiventris* Queen forewing. SmDc—Submedian cell | m—Median vein | ac—Anterior cubital vein | a—Anal vein | DC1—1st Discoidal Cell | DC2—2nd discoidal cell | sc—Subcostal vein | r—Radial vein | MdC—Median cell | SmrC1—1st Submarginal cell | Sm—Stigma | MgC—Marginal cell | c—Costal vein | RS—Radial sector | Smrc2—2nd submarginal cell.

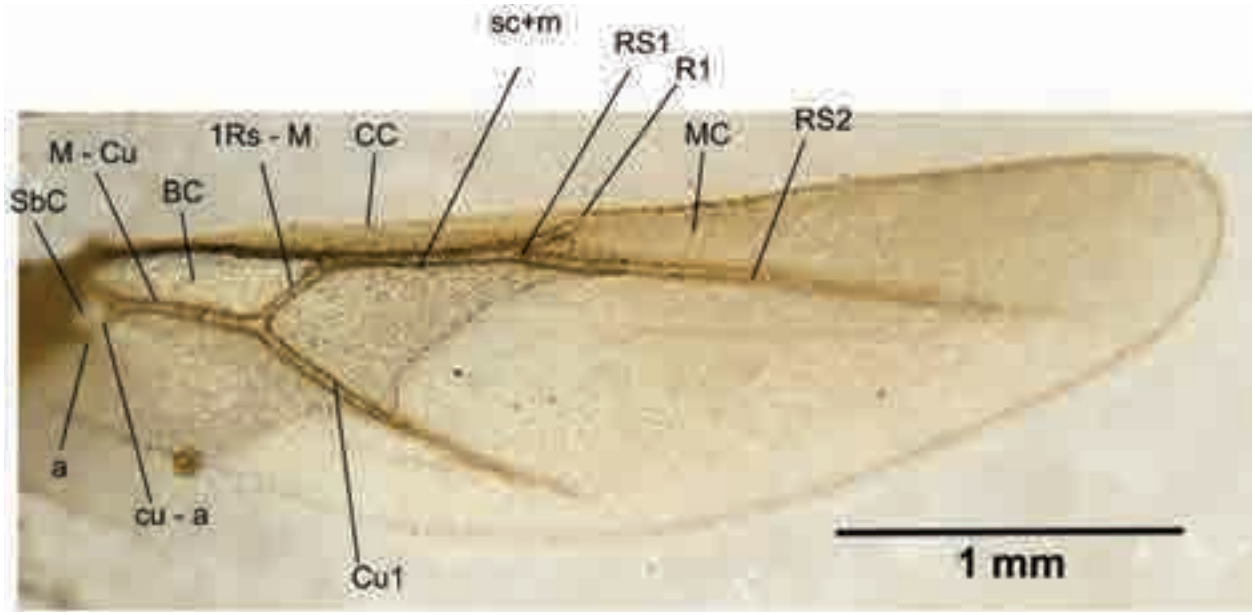

Image 15. Wing venation in *Acropyga acutiventris* Queen hindwing: SbC—Subbasal cell | A—Anal vein | M–C—Media-cubitus | cu-a—Cubitus + anal | BC—Basal cell | 1Rs-M—1 Radial sector-media | Cu1—Cubitus 1 | CC—Costal cell | sc+m—Subcosta + media | RS1—Radial sector 1 | R—Radial1 | MC—Marginal cell | RS2—Radial sector 2.

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Image 16. Previous records and the new record of *Acropyga acutiventris* in India.

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SHORT COMMUNICATION

First report of a coreid bug *Aurelianus yunnananus* Xiong, 1987 (Hemiptera: Heteroptera: Coreidae) from India

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Abstract: *Aurelianus yunnananus* Xiong, 1987 (Hemiptera: Heteroptera: Pentatomomorpha: Coreidae: Coreinae: Mictini) is reported for the first time from India. It was collected from Tripura, in the eastern part of our country. Brief redescription and several photos, including those of the male genitalia, are provided along with the images of the male holotype and female allotype. This report also adds the genus *Aurelianus* to the known Indian Coreidae genera.

Keywords: First record, leaf-footed bug, Mictini, Tripura, Yunnan.

Genus *Aurelianus* was erected by Distant with the only species *Aurelianus elongatus* Distant, 1902, originally described on the basis of two males collected from Bhamo, Myanmar (Distant 1902). The species then becomes the type species by monotype. For a long time, this genus had only this single species until Xiong (1987) described another species as *Aurelianus yunnananus* Xiong, 1987 from Yunnan, China.

One of us (Rahul Lodh) picked up this species while doing biodiversity survey in Agartala, Tripura (September, 2012). It was suspected to be another species of the genus *Aurelianus* but the lack of appropriate literature delayed its scientific report. When Xiong (1987) paper became available and when we could also obtain the images of the type from Kunming Institute of Zoology, Yunnan (courtesy Dr. Kaiqin Li), China, it was confirmed that the collected specimen is *A. yunnananus*. There is no previous record of either the genus *Aurelianus* or this species, namely, *A. yunnanaus,* from any part of India.

Xiong (1987) described both male and female of this species, provided habitus photos and drawings of some characters, including that of the pygophore (in posterior view) and female terminalia (in ventral view). We are providing several more photos of the only male we have, giving more details of the pygophore, the phallus and the parameres. Emphasis here is more on illustrations than the detailed redescription of the species, so the latter is kept to the minimum.

Material studied: One male. Collected by Rahul Lodh from Agartala, Tripura, in September 2012. Presently preserved in Modern College, Pune.

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***Aurelianus yunnananus* Xiong, 1987**

Redescription

Elongate coreid bug with an apically truncate body, incrassate hind femora and ampliated / dilated hind tibia.

Coloration: Overall reddish-brown or cinnamomeus (with a tinge of magenta at places). Head, part of pronotum and the first two pairs of legs ochraceous; labium ochraceous, only its tip black. General colour slightly darker on corium, metafemora and metatibiae dorsally and part of the thoracic sterna and abdomen ventrally; membrane, posterior part of connexivum, lateral marginal granules and apex of abdomen black. Pro- and meso-sternum medially of very light colour. Abdominal sternites medially lighter, with very small scattered black granules that are especially dense on posterior margin of fourth to seventh sternites medially; area around trichobothria of third to sixth segments pale; sixth and seventh abdominal sternites lighter than the rest and with bilaterally symmetrical pattern of dark black oblique lines. (Image 1A,B). All tarsal segments with a black band laterally on each side.

Structure

Head: Head almost quadrate, except for bulging eyes. Eyes large, globular. Ocelli situated closer to eyes than to each other. Anteocellar pit distinct; antenniferous tubercles prominent, situated in front of eyes at the anterior margin of head (Image 2A); antennomere I stout, much longer than head but shorter than head and pronotum together. First three antennomeres slightly darker and covered with grey adpressed setae and black, sharp, needle-like semierect setae. Antennomere IV paler, spindle shaped, with similar setae.

Ventrally head covered with greyish setae, especially laterally; area underneath labium smooth without setae. Labium moderately stout reaching well beyond middle of mesosternum. Labial segment I stout, longer than the visible ventral portion of head, II and IV joints subequal, III shortest. Bucculae short (Image 2B).

Thorax: Pronotum trapezoidal, much narrowed and steeply declivous towards head, its anterior margin straight behind head, anterior angles not prominent; lateral margins straight with posteriorly directed, prominent, blunt black tuberculous spines. Humeral angles of pronotum rounded, posterior margin sinuate laterally but nearly straight over scutellum. Whole surface covered with golden setae. Anterior lobe of pronotum not well demarcated except that it is less setose. Calli not distinct (Image 2C).

Seen ventrally, prosternum short, region between procoxae very narrow, not sulcate. Prosternum laterally coarsely punctured, punctures sparse and obscured by setae. Mesosternum with discal area smooth, lateral area setose and with punctures. Metasternum slightly elevated, shallowly sulcate medially, disc less setose, plural area densely setose (Image 2B). Metathoracic scent gland ostiole as wide, vertical slit-like opening; peritreme elevated from general plane with two disc like areas – anterior disc larger than posterior disc, evaporatorium rather small, mainly situated dorsal to ostiole, as shown in Image 2E.

Scutellum and hemelytra: Scutellum triangular, slightly convex at base, with transverse, fine rugae (Image 2C,D); punctures obscured by pubescence. Hemelytra well developed, just reaching tip of abdomen in single male specimen examined, leaving part of apical segment uncovered dorsally. Veins of corium elevated, prominent. Corium and clavus finely punctured and covered with dense, adpressed setae. Membrane with many parallel veins.

Legs: Procoxae closer to each other than meso- and meta-coxae, meta-coxae widest apart. Pro- and meso-femora slightly dilated distally while meta-femora swollen or incrassate considerably, slightly curved and with maximum width beyond middle, with a prominent preapical spine ventrally. Meso-femur also with sharp spine ventrally at apex while similar spine on pro-femur very small, indistinct. All tibiae compressed, all tarsi with the first segment longer, almost equal to segments II and III together; metatibia with lobe like expansion on dorsal as well as ventral margin, with a dorsal spine placed distally while the ventral margin finely granular, with narrow expansion and with an apical and preapical spine (Image 1B). Pulvilli prominent, claws black.

Abdomen: Abdomen more or less parallel-sided between second to fifth segment then considerably narrowed (Image 2F,G). Third segment with small, ventrolateral, blunt tubercle (Image 2I). Spiracles slightly closer to anterior margin than lateral margin of segment, transverse (Images 2G, 3A). All sternites with black, shining granules which are especially dense on the posterior margin of fifth segment (Image 2H). Extreme lateral margin (connexivum) of abdominal segments fourth to sixth covered with black granules. Of these granules, one at posterolateral corner of segment large and prominent (Image 3C). Connexivum of moderate size. Trichobothrial elevations prominent.

Male genitalia: Segment nine, or pygophore, almost completely covered dorsally by eighth tergum, with very narrow margin visible from above. The eighth tergite with wing like expansion on either side, seen in habitus images. Ventrally a large portion of pygophore is visible (Image 2G). Lateral view and posterior view of pygophore in situ

Image 1. Habitus of *Aurelianus yunnanaus*: A—Dorsal view | B—Ventral view. © Swapnil Boyane.

as in Images 3A,B. Detached pygophore appears almost squarish in dorsal and ventral view, respectively (Images 4A,B). Lateral view of the pygophore is shown in Image 4C, note that ventral surface is more setose.

Phallus just removed from pygophore (not everted) is shown here in dorsal, ventral and lateral views, respectively (Image 4D,E,F). Note large sclerotized area on ventral side of phallotheca, dorsal surface has no such sclerotization. A well sclerotized articulatory apparatus occupies almost half length of phallus. An everted phallus showing different lobes of conjunctiva and a coiled vesica are seen in dorsal, ventral and lateral views, respectively, in Images 4G,H,I. Paramere well sclerotized, strongly bent almost at right angle and with long setae on all surfaces (Image 4J).

We are also providing, for comparison, images of the male holotype and the female allotype. The dorsal and ventral views of both these types are presented (Image 5A–D).

Measurements in mm (single male): Total length 26.50

Head: length 1.50, width including eyes 2.75, width between eyes 1.50, distance between ocelli 0.90; antennae: antennomere I – 4.75, II – 1.75, III – 3.50, IV – 4.85; labium: segment I – 2.0, II – 2.25, III – 0.75, IV – 1.50; pronotum: width at anterior angles 2.50, at humeral angles 7.50, length as seen from above 4.25; scutellum: length 3.5, width 3; abdominal width at base 8.00, width at 7th sternum 4.5.

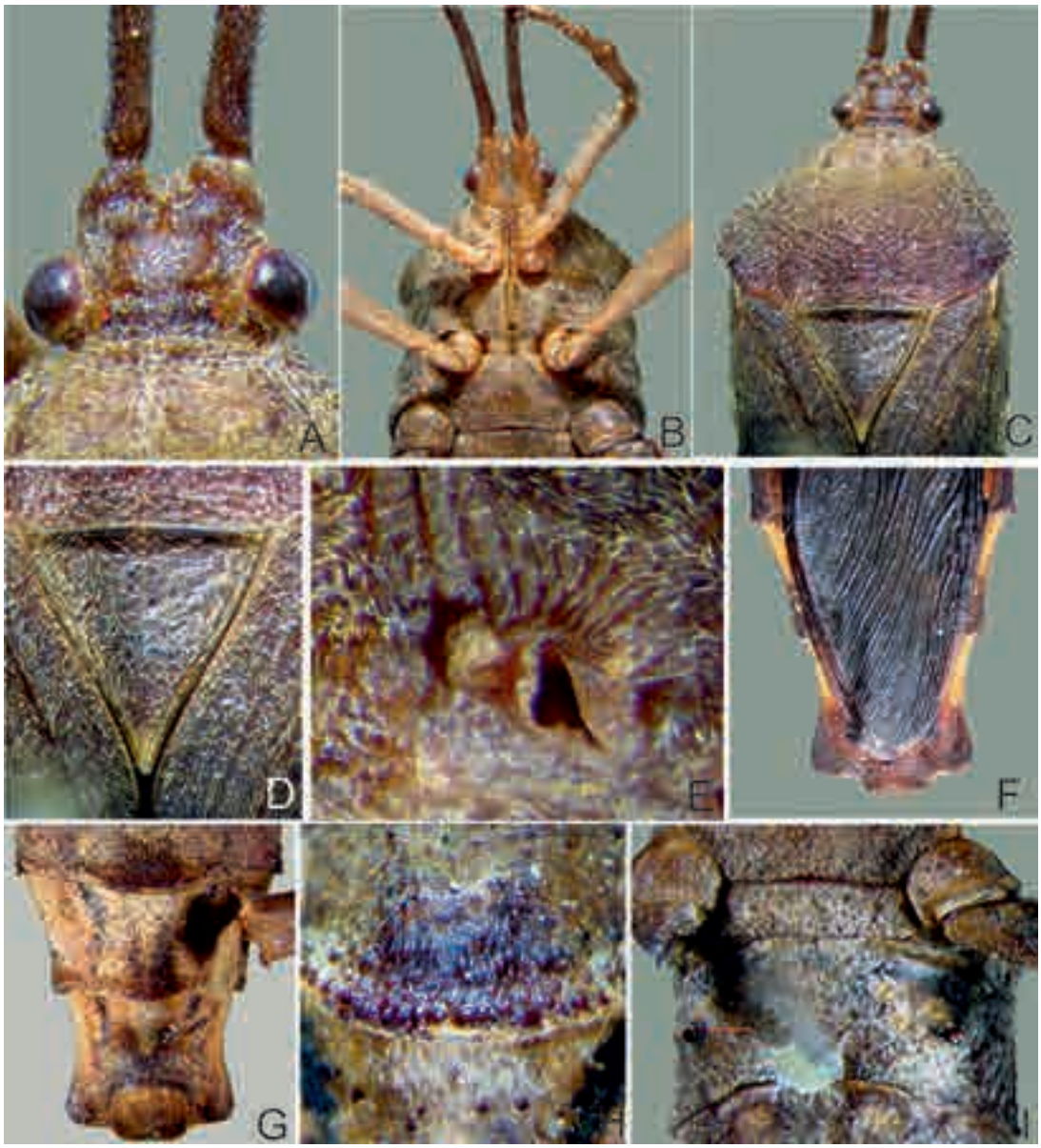

Image 2. Structure of *Aurelianus yunnanaus*: A—Head in dorsal view | B—Head and thorax in ventral view | C—Head, pronotum and scutellum | D—Scutellum | E—Metathoracic gland opening | F—Abdomen in dorsal view | G—Apical segments of abdomen in ventral view showing pygophore | H—tubercles on abdominal sternite | I—Small tubercles on third abdominal sternite (pointer red line). © Hemant Ghate.

Discussion

We obtained images of the male holotype of *A. yunnananus* and compared our specimen with these images as well as consulted the original description of the species. Both these things helped us to identify our specimen with certainty as *A. yunnananus* Xiong. The images of the type of *Aurelianus elongatus* Distant are also available on Coreoidea Species File website (2022) and it is possible to compare the general shape and a few other characters of the two species; it is also necessary to note here that neither *A. elongatus* nor A. *yunnanaus* have been reported again from any region.

O'Shea & Schaefer (1980), while revising the Australian and Oriental Mictini, dissected male of *A. elongatus* and provided outline sketch of a paramere and the phallus but it is difficult to compare our photographs and their small drawings, the structures of the phallus and the parameres are only broadly comparable; the gross structure of the phallus is like other Mictini we have studied (H. Ghate, unpublished). O'Shea & Schaefer (1980) also state that in general Mictini possess "conjunctiva with distodorsal and distoventral sacs with distolateral lobes sometimes sclerotized, vesica helical; parameres heavily sclerotized with curved tips" and this is observed in *A. yunnananus.*

Image 3. Structure of *Aurelianus yunnanaus*: A—Abdominal apex in lateral view showing spiracles and pygophore | B—Pygophore in posterior view | C—Lateral margin of abdomen showing tubercles. © Hemant Ghate.

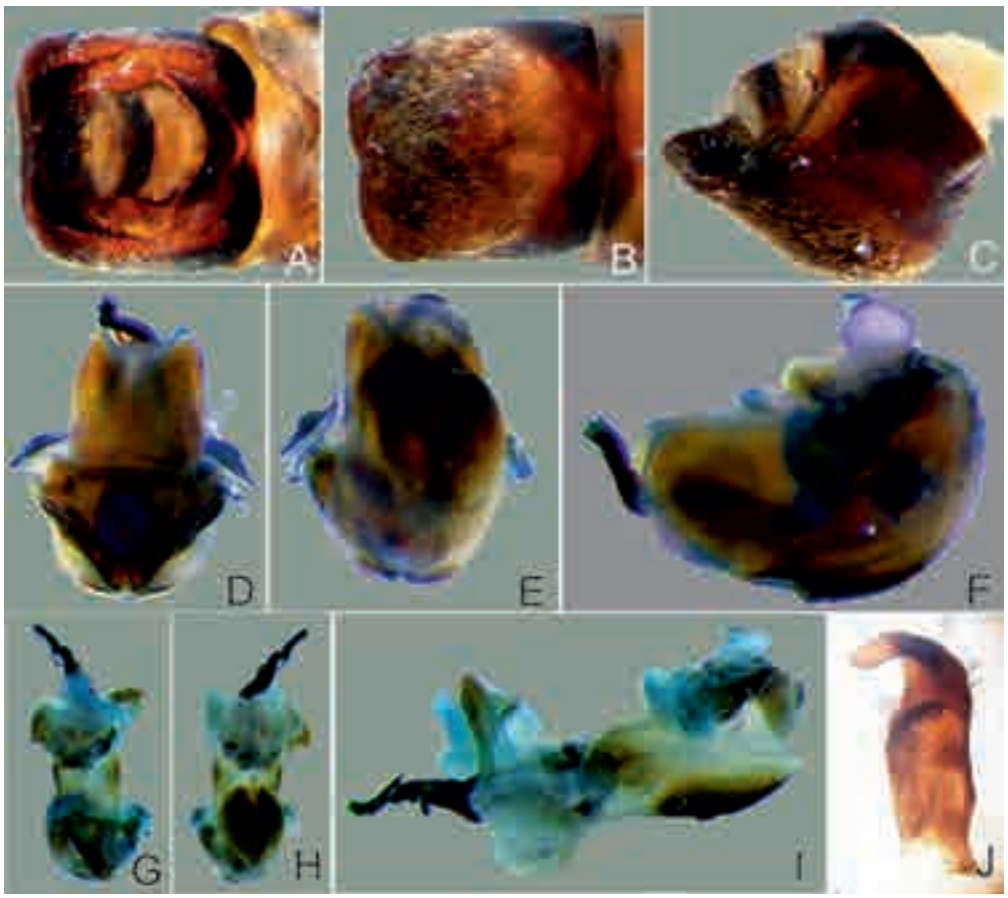

Image 4. Male genitalia of *Aurelianus yunnanaus*: A, B & C—Pygophore in dorsal, ventral and lateral views | D, E & F—Uneverted phallus in dorsal, ventral and lateral views | G, H & I—Everted phallus in dorsal, ventral, and lateral views | J—Paramere. © Hemant Ghate.

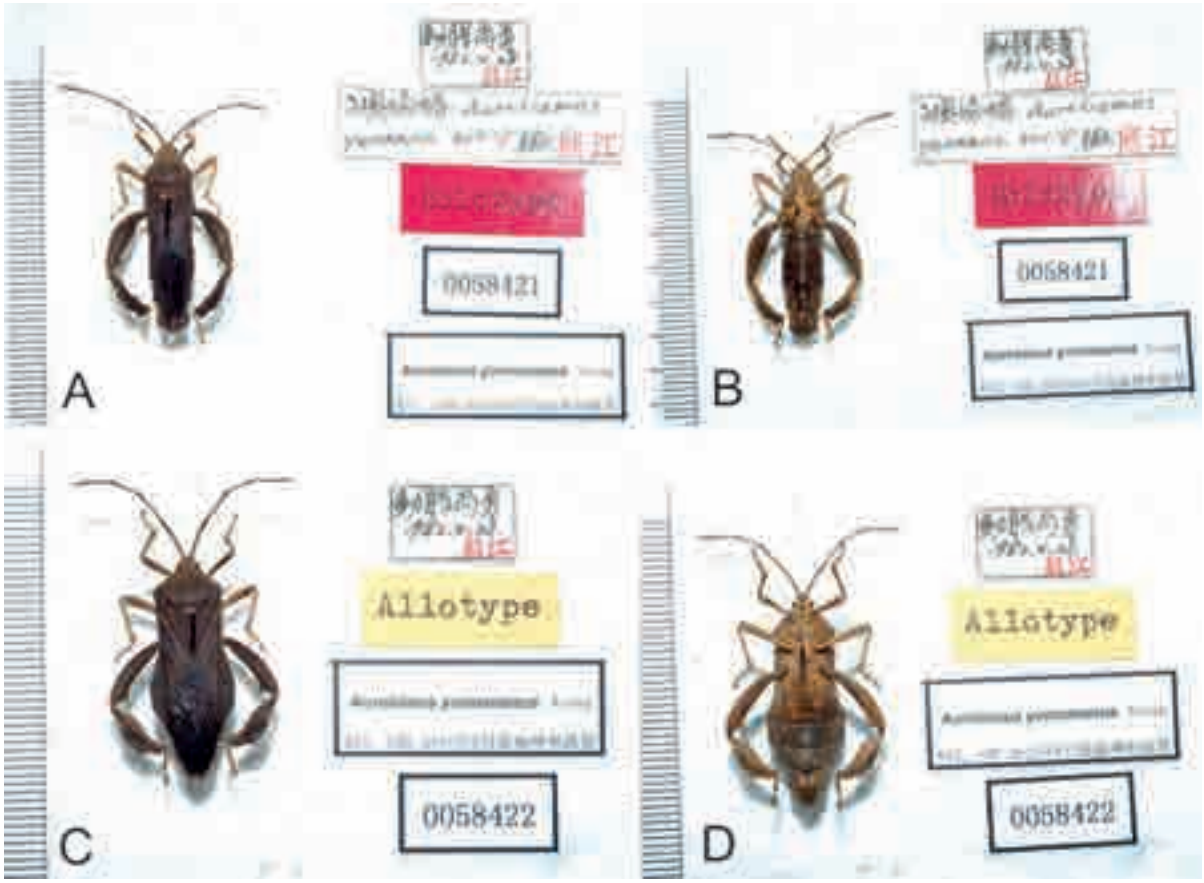

Image 5. *Aurelianus yunnananus* male holotype and female allotype: A—Male holotype, dorsal view | B—As in A, ventral view | C—Female allotype, dorsal view | D—As in C, ventral view. © Kunming Institute of Zoology, Yunnan, China. © Kaiqin Li.

Xiong (1987) did not dissect the male genitalia of *A. yunnananus* but the posterior view of the pygophore, given with the original description by Xiong, is identical with what we have presented here; same is the case with the line drawing of hind leg of the male.

Northeastern Indian states often harbor many insect species that are originally described from the nearby countries like Bangladesh, Myanmar, Bhutan, Nepal, and China, so the presence of *Aurelianus yunnananus* in northeastern India was always likely. What is interesting is that this species is as yet not recorded from the other northeastern states, like Mizoram, Manipur, and Nagaland, which are closer to Myanmar and Yunnan. Intensive surveys in northeastern India are necessary to document the present biodiversity. We recently reported *Epidaus wangi* Chen, Zhu, Wang & Cai, 2016, a Tibetan species, from Arunachal (Boyane & Ghate 2020). We also have some reduviid and coreid bugs collected from northeastern India but are originally described from the neighbouring countries (Ghate et al. 2017; H. Ghate, unpublished). Nevertheless, it is important to record the presence of the genus *Aurelianus* and the species *A. yunnananus* from India for the first time since the original description by Xiong (1987). Further, the details of the structure of the pygophore, phallus and parameres were not illustrated originally hence the illustrations we provide here are an addition to the knowledge about this species.

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SHORT COMMUNICATION

First record of the long-horned beetle *Niphona fuscatrix* (Fabricius, 1792) (Coleoptera: Cerambycidae: Lamiinae) from the Western Ghats, India

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Abstract: A long-horned beetle, collected when attracted to light, was identified as *Niphona fuscatrix* (Fabricius 1792). This species is reported for the first time from western India (Shivaji University, Kolhapur, Maharashtra).

Keywords: Kolhapur, male genitalia, Pteropliini.

The keys and descriptions of the various species of Indian Cerambycidae (without Lamiinae) is provided by Gahan (1906). Because there are no keys for Indian Lamiinae, there are many difficulties in identifying its members. The subfamily Lamiinae Latreille, 1825 is the most diverse subfamily of long-horned beetles (Švácha & Lawrence 2014) and Mulsant (1839) described the genus *Niphona* with the species *Niphona picticornis.* It is a widely distributed genus known from Paleotropical region, Afrotropical region, western Africa, central Africa, eastern Africa, southern Africa, northern Africa, western Palearctic region, northeastern Palearctic region, southeastern Palearctic region, southern Asia, northern Asia, southeastern Asia, Europe, and Australasian region as per the website of 'Lamiines of the World'. The genus *Niphona* consists of three subgenera, viz., *Hammatoniphona* Pic, 1936, *Niphona* Mulsant, 1839, and *Spinoniphona* Hua, 1989 of the subfamily Lamiinae (Danilevsky 2020) and the tribe Pteropliini. Breuning (1962) provided keys for the tribe Pteropliini Thomson, 1860 (metasternum short, mid-tibia without dorsal groove, mid-coxal cavities open), with key for 50 species of *Niphona* in German language. The species was identified as *Niphona* (*Niphona*) *fuscatrix* vide keys by Breuning (1962). Majumder et al. (2015) provided photographs, diagnosis, and distribution of *N. fuscatrix* which helped in identification of this beetle.

The species *N. fuscatrix* was first described by Fabricius in 1792 as *Lamia fuscator* from Nagapattinam, India. It is reported from Tamil Nadu, Uttarakhand, Himachal Pradesh, Kashmir, Punjab, Madhya Pradesh (Kariyanna et al. 2017), and Odisha (Majumder et al. 2015). The present communication is based on a male specimen collected from the Shivaji University Campus, Kolhapur, Maharashtra.

Materials and Methods

Material examined: SUKZ, Ceramb-191, 21.vi.2018, 1 male, Shivaji University, Kolhapur, Maharashtra, India, 16.678° N, 74.255° E, 595 m, coll. P.B. Patil, presently preserved in the Department of Zoology,

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Competing interests: The authors declare no competing interests.

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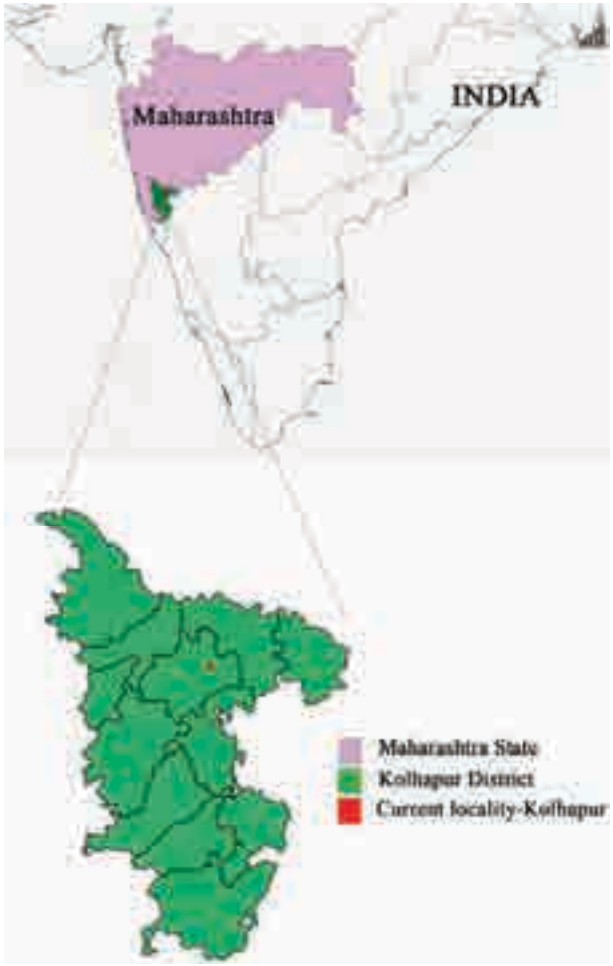

Figure 1. New locality Kolhapur for *Niphona fuscatrix* in India.

Shivaji University, Kolhapur. The specimen was studied under a Nikon stereozoom (SMZ 800) microscope and photographed by using Canon 550D camera with a 100 mm lens at various focal lengths and then stacked in Photoshop CC software for better illustration of diagnostic characters. Measurements were done with digital Vernier caliper. The male genitalia were dissected out from terminal abdominal segments with the help of fine forceps. The genitalia were kept in 10% KOH solution overnight (Majumder et al. 2014). Male genital parts were separated and photographed using Lynx LM-52-3621 stereozoom microscope. Terminology for genitalia follows Ehara (1954). The coordinates of the collection sites were taken from the website, LATITUDE (https://latitude.to/articles-by-country/in/india/21549/shivaji-university), which was further used in preparing maps of the sampling sites in DIVA-GIS software (Figure 1).

Results

Body—Medium size (16.9 mm long, 6 mm width at humerus), relatively brown, stout, with dense, golden pubescence dorsally & mixed whitish pubescence ventrally, including on legs (Image 1A,B,C). Head—Small (4.2 mm frontal height, 0.7 mm length), densely pubescent, slightly convex at clypeus and concave medially in frontal region, vertex broad; mandibles strong with black apices; palpi brown; eyes coarsely facetted, divided into upper small & lower large lobe joined with minute, narrow ommatidia-less connection at outer side of antennal socket; antenna 11 segmented, brown, with small yellow patches of pubescence, inner side densely pubescent, first segment swollen and robust, second segment short, as long as broad and smallest (Image 1A,a,c), inner side of each antennomere with long setae. Pronotum—(3.7 mm length, 4.7 mm width excluding anterior spine) coarsely punctured, with irregular ridges, densely pubescent with two lateral hornlike strong spines on each side with anterior spine slightly larger (Image 1F); scutellum tongue shaped, small, dark brown with yellowish margin, pubescent, broader than long (Image 1A,b). Elytra—(12.4 mm long, width 6.0 mm between humeral angles) pubescent, densely & deeply punctate basally, with three broad brown transverse bands basal dark, middle pale, apical is more paler (Image 1d); large globular tubercles at humeral region; two erect vertical tuft of brown pubescence basally one on either side of suture which look like small tooth when seen laterally (Image 1e), similar but small tufts are at 3/4th length of the elytra; posterior margin noticeably narrowed, curved, subrounded with brown fringed hairs (Image 1d). Thoracic Sternum—Strong prosternal & mesosternal processes on the anterior & posterior edge, processes covered with creamy white, dense pubescence; mesosternum large; legs fairly strong, but short with hind femora not reaching apex of abdomen; fore femur with strong carina on ventral side (Image1B), mid-coxal cavities open to epimera.

Male genitalia (Image 2A): Median lobe—Weakly projected through ringed part, longer than median struts, median foramen not elongated (Image 2B,C,D), median orifice is visible in ventral & lateral view (Image 2A,D), struts are wider & curved medially, in between which internal sac is seen (Image 2F,G,H). Lateral lobes (parameres)—Separated, broad, sub-rounded, densely covered with setae at the apex, ringed part constricted, broad medially and converging (Image 2F,G,H,I); VIIIth tergite—With numerous apical setae, somewhat pentagonal, marginate with pointed apex; apical corners and point with numerous setae (Image 2E).

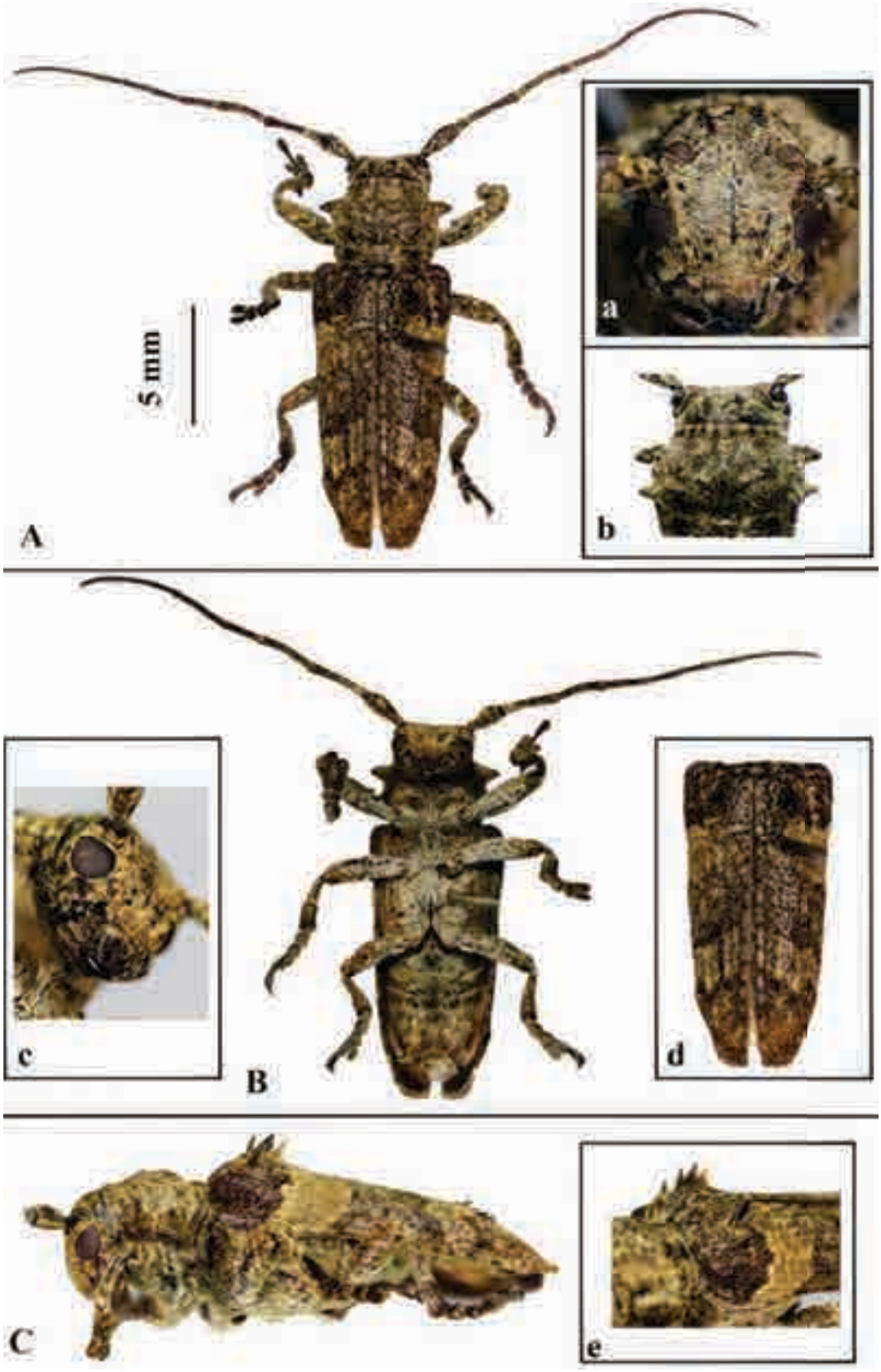

Image 1. Habitus of *Niphona fuscatrix* Fabricius, 1793: A—Dorsal view | B—Ventral view | C—Lateral view. Inset: a—Head in frontal view | b—Pronotum (magnified view) | c—Eye (magnified view) | d—Elytra (magnified view) | e—Elytral base (magnified lateral view showing vertical crest). © Yogesh Mane.

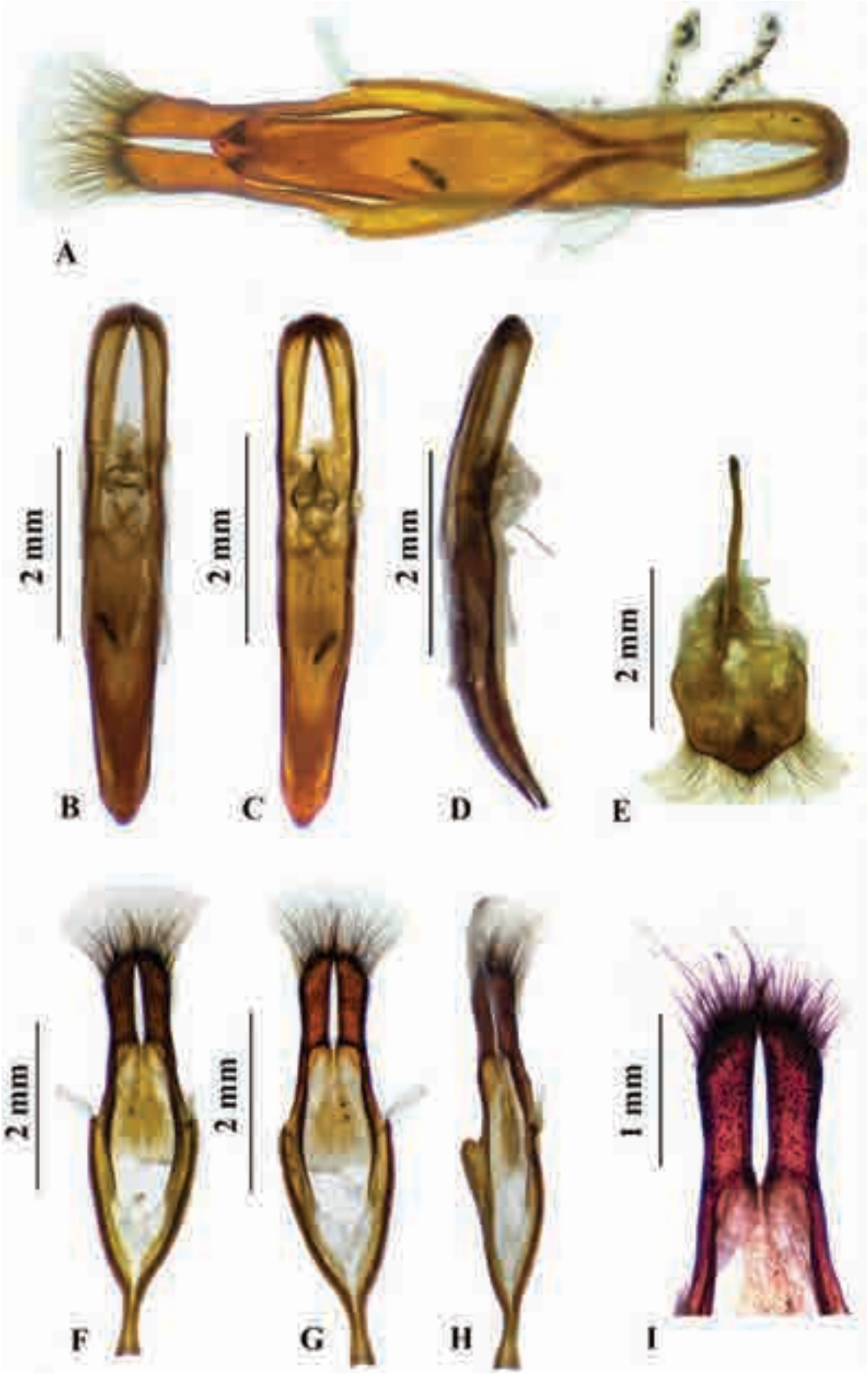

Image 2. ***Niphona fuscatrix*** **Fabricius, 1793 male genitalia: A—Aedeagus in ventral view | B–D—Median Lobe: B—Dorsal view | C—Ventral view | D—Lateral view | E—Tergite VIII | F–I Tegmen: F—Dorsal view | G—Ventral view | H—Lateral view | I—Magnified view of upper lobe. © Priyanka Patil.**

Discussion

The genus *Niphona* Mulsant, 1839 is mainly distributed in the Palearctic, Ethiopian, Oriental, and Australian regions (Lamiines of the World website).

The characters of *N. fuscatrix* given by Breuning (1962), Majumder et al. (2015) and the photos on the website 'Lamiines of the World' match with our specimen confirming that the species in question is *N. fuscatrix*. The fauna of Maharashtra is known to include 59 species of cerambycid beetles including 23 species of Lamiinae (Ghate 2012). However, the list does not include *N. fuscatrix.* The male genitalia of *N. fuscatrix* are described here for the first time with color photographs. Among the previously reported sites (from where this species was recorded), Salem and Nagapattinam in Tamil Nadu are the closest to the current locality, Kolhapur which is about 692 km and 980 km (aerial distance) away from these places, respectively. The present record extends its known geographical range notably westward and is an addition to the fauna of Maharashtra as well as the Western Ghats.

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SHORT COMMUNICATION

Incidence of *Clinostomum complanatum* (Trematoda: Clinostomidae) in *Trichogaster fasciata* (Actinopterygii: Osphronemidae), the first report from Deepor Beel, Assam, India

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Abstract: Fish constitute a major component of diet for the people of northeastern India and one of the main food items for most people in Assam. But fishes are facing serious risks due to parasitic infestations which deteriorate the food value and also leads to fish mortality. The present study aims to investigate the occurrence of helminth parasites in some selected fishes of the species *Mystus tengara*, *Channa punctata*, and *Trichogaster fasciata* collected from Deepor Beel, Guwahati, Assam. Trematode parasite species have been recorded from *Trichogaster fasciata*. The recovered trematode is *Clinostomum complanatum* belonging to the family Clinostomatidae. The present study incorporates the morphological, morphometric, and scanning electron microscopy studies of the prevailing parasite. This study is the first report on the occurrence of helminth parasites in the edible freshwater fishes collected from Deepor Beel.

Keywords: Food value, freshwater fish, Helminth, Infestation, parasite, Trematode.

India occupies its position among the 17 mega-diversity countries harboring around 55 families of freshwater fish (Koiri & Roy 2016). In northeastern India, Assam is the most water-resourceful state that has a rich variety of ichthyofauna and the beels (lakes) produce 50,000 tons of fish per year (Dutta & Lahon 1987; Lebanan & Mohilal 2021). Fish constitute a major component of diet of the people of northeastern India (Jyrwa et al. 2016) and one of the main food items for most people in Assam. Moreover, fish and fish cultivation provide a valuable source of food and employment opportunities. Also, fish constitutes the most beneficial and nutritional resource for human beings (Wali et al. 2016). But fishes are being threatened by various parasitic infestations throughout the world. Parasitic infestations cause deterioration of the food value of fish and may even lead to fish mortality (Keisham & Mohilal 2020; Moravec et al. 2017). Parasitic diseases of fish are prevalent and are of specific importance in the tropics. About 30,000 helminth species have been estimated as parasites of fishes, of which most are known to be of serious threat to their hosts. As estimated by the World Health Organisation (WHO), the number of people currently infected with fish-borne trematodes exceeds 18 million, and many more are at risk (Jyrwa et al. 2016). They pose serious problem causing huge economic losses in the fishing industry and in aquaculture (Amare et al. 2014). Helminth parasites constitute a significant group of pathogens and cause infection & diseases in

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fish in freshwater & marine environments (Jyrwa et al. 2016). Considerable work has been conducted on several aspects of fish faunal diversity, hydrobiology, and productivity of rivers and beels of Guwahati of Assam (Dey 1981; Das & Bordoloi 1997; Saha & Bordoloi 2009). Bhalerao (1942) has made a remarkable contribution to the taxonomy of digenetic trematode parasites.

In the context of Assam, a few works have been contributed to fish parasitology. Binky et al. (2011) studied the helminth parasites of Karbhala Wetland in Cachar District of Assam. Das et al. (2012) studied the intensity of cestode parasites in *Monopterus cuchia* of Cachar. Das & Goswami (2014) studied the organal distribution and seasonal occurrence of parasites from three wetlands of Goalpara District. Ngasepam & Kar (2014) worked on the helminth parasites of fishes of Sone beel in Karimganj. Singha et al. (2015) studied the parasites of *Notopterus notopterus, Channa punctata,* and *Heteropneustes fossilis* in Dolu Lake, Silchar. The present study was undertaken to study the presence of any helminth parasites in some selected edible freshwater fishes from Deepor beel, Guwahati, Assam that were not reported hitherto from this area.

Materials and Methods

During the present study, fishes of the species *Mystus tengara, Channa punctata*, and *Trichogaster fasciata* were collected from September 2020 to August 2021 from Deepor Beel with the help from local fishermen. During the study about 200 fishes were collected and examined. Fish samples were brought to the laboratory in live condition. Serial numbers were provided for each sample, the total length and weight measured of the specimens thoroughly examined for the parasitological study. In the present study, the body cavity, kidneys, liver, stomach, and intestines were examined for the presence of endoparasites. Trematodes were collected from the body cavity of *Trichogaster fasciata* by following Justine et al. (2012). The recovered parasites were flattened between two slides, fixed in 70% ethanol, and processed for wholemount preparation following standard procedure using Aceto alum carmine as a stain. *Clinostomum complanatum* were identified by light microscopy following Keys to Trematoda (Vol. 2) and the morphological description of *C. complanatum* by Caffara et al. (2011) and Ngamniyom et al. (2012). The morphometric measurements of the parasite were taken by using a stage and ocular micrometer.

Preparation of the specimen for Scanning Electron Microscopy (SEM)

For Scanning Electron Microscopy (SEM), the parasite specimens were fixed in 2.5% glutaraldehyde, washed in 0.1M Sodium Cacodylate Buffer for 4 hours at 4˚C before post-fixing them in 1% Osmium Tetroxide in the same buffer for 1 hour at 4˚C. The specimens were then dehydrated through a graded series of acetone, dried, and mounted on brass stubs. After mounting, the specimens were coated with gold and examined with a FESEM scanning electron microscope model Zeiss Sigma 300.

Results and Discussion

A total of eighty-five middle-size *Trichogaster fasciata* were examined during the study period, and 27 were found infested with the specimen of *Clinostomum complanatum* (Image 1a,b,c). All specimen were recovered from the peritoneal cavity of the examined fishes.

Description of trematode parasite, *Clinostomum complanatum*

Identifying characters: The fixed worms appear relatively stout; however, prior to fixation, the live

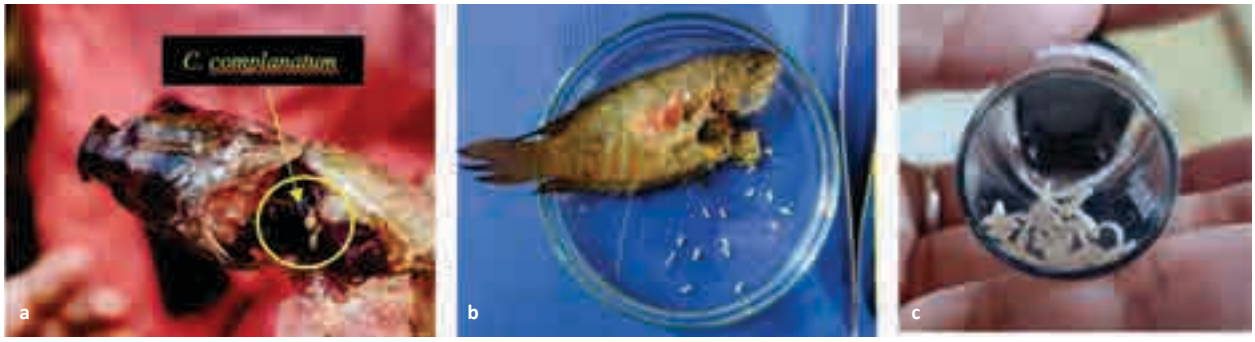

Image 1. *Clinostomum complanatum*: a—infected *T. fasciata* | b—collected in a petri dish | c—metacercariae stored in 70% ethanol. © Bobita Bordoloi.

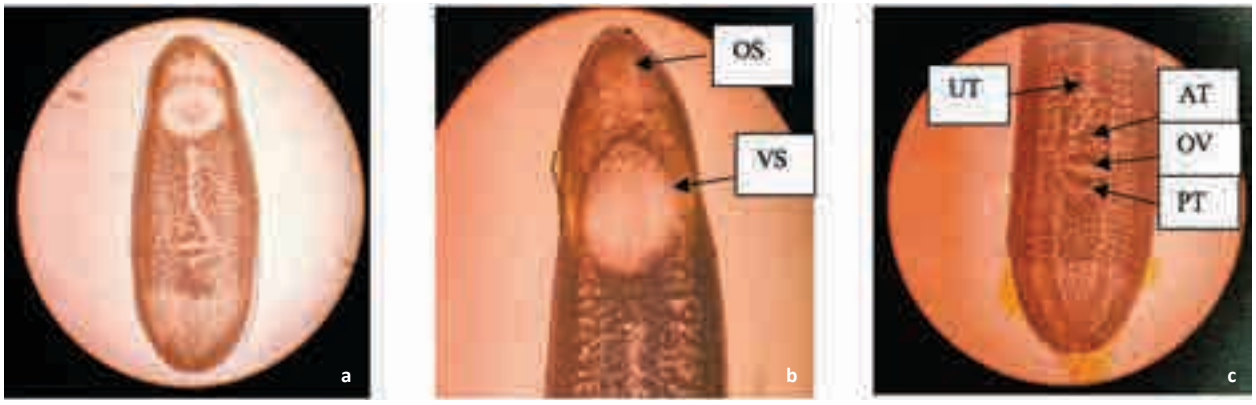

Image 2. Light microscopic structure of *Clinostomum complanatum*: a—Whole structure | b—Structure showing the position of anterior sucker (AS) and ventral sucker (VS) | c—Structure showing the position of the anterior testis (AT), posterior testis (PT), uterus (UT), and ovary (OV). © Bobita Bordoloi.

worms are very motile, exhibiting high contractility. The worm-like bodies are medium-sized to large, stout, linguiform, tongue-shaped, and bluntly rounded at the anterior and posterior ends. The body length varies between 5.7–7 mm, and the body width 1.9–2.5 mm. The body is convex dorsally and concave ventrally. Oral sucker oval, subterminal, and surrounded by collar-like folds and its surface is covered by ridges and pits. Oral sucker length ranges between 0.098–0.175 mm while the width varies between 0.200–0.395 mm. Ventral sucker muscular, well-developed, and larger than the oral positioned in the anterior half of the body. The length of the ventral sucker ranges between 0.700–0.900 mm, and the width ranges between 0.810–0.930 mm. Caeca long, simple, located in the anterior half of the body without long lateral branches and diverticula. Testes, located in posterior half of the body are smooth or irregular in shape. The anterior lobe of the testes lies in the middle, and the posterior lobe is positioned at the rear end of the parasite. The length of the anterior testis varies between 0.307–0.520 mm, and the width ranges between 0.290–0.480 mm. Posterior testis length varies between 0.292–0.500 mm, and the width varies between 0.450–520 mm. Ovary intertesticular, ovoid or rounded, median or submedian. The length of the ovary ranges between 0.149–0.164 mm, and the width ranges between 0.119–0.168 mm. Vitelline follicles are present between the posterior extremity and the level of the ventral sucker. The uterus is intercaecal, positioned between the caudal region of the ventral sucker and intertesticular space.

Scanning electron microscopy structure: Scanning electron microscopy of the trematode parasite revealed additional topographical features that confirmed the specimen as *Clinostomum complanatum*. The body surface is characterized by the presence of tegumental pits and furrows with a smooth, aspinous layer. The body has rounded extremities with two suckers (one oral sucker and one ventral sucker) (Image 3a,b). Oral sucker subterminal in position with a rounded opening characterized by two collar rings and covered by ridges, pits, and dome-like papillae (Image 3c). The rim of both the oral and the sucker were aspinous and non-papillated. The oval-shaped ventral sucker positioned in the anterior half of the body exhibited sponge-like characters, and wavy wrinkles with dome-shaped papillae around the ventral sucker (Image 3d,e). The tegumental infoldings, furrows, and ridges impart stretching and contractility to the metacercariae. The dorsal surface of the parasite body revealed regularly distributed spinous protrusions (Image 3f).

The family Clinostomidae was first erected by Lühe (1901) for *Clinostomum* Leidy, 1856. In the present study, the morphometric measurements of the parasite corroborate with the study of Caffara et al. (2011) and Ngamniyom et al. (2012). Scanning electron microscopic studies of the topography of the parasite revealed additional features which correlates with the study by Abidi et al. (1988), Caffara et al. (2011), Ngamniyom et al. (2012), & Kundu et al. (2021) and confirmed the recovered parasite specimen as *Clinostomum complanatum* belonging to the family Clinostomatidae. However, Ngamniyom et al. (2012) and Caffara et al. (2011) observed spines with cytoplasmic ridges in the dorsal and the ventral region showing cobblestone-like units, but such observations were not recorded in the trematode parasites in the present study.

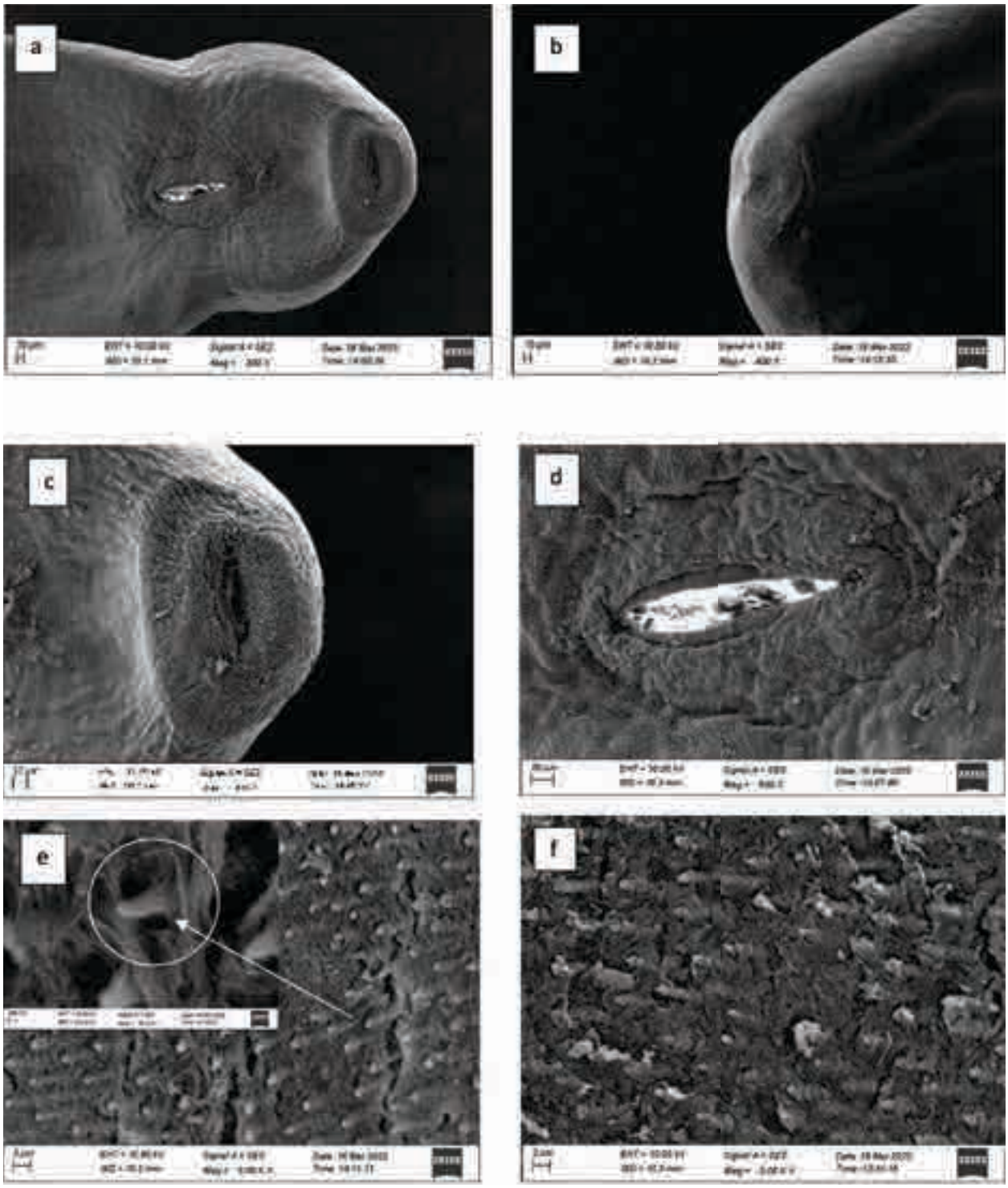

Image 3. Scanning electron microscopic structure of *Clinostomum complanatum*: a—Metacercariae showing the presence of anterior sucker (AS) and ventral sucker (VS) | b—Rounded posterior region of the metacercariae | c—Subterminal oral sucker surrounded by two collar rings and covered by ridges and pits | d—Ventral sucker surrounded by sponge-like characters, wavy wrinkles and spinous structures | e—Ventral surface of the metacercariae showing spinous characters | f—Dorsal surface of the metacercariae showing somewhat spinous structures.
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Conclusion

The present study is the first report on the occurrence of trematode parasite *Clinostomum complanatum* from edible freshwater fish species *Trichogaster fasciata* collected from Deepor Beel. The edible freshwater fish *Trichogaster fasciata* were infected with the metacercariae of the trematode parasite. Along with morphological data, SEM study provides specific characteristics of the topography that helped in the identification of the trematode parasite.

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SHORT COMMUNICATION

Sauromatum horsfieldii (Araceae): a new addition to the flora of Manipur, northeastern India

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Abstract: The present paper deals with the taxon *Sauromatum horsfieldii* Miq. reported for the first time from Manipur, India. The detailed morphological description and the photographs are provided along with the artificial key to the Indian species of *Sauromatum*.

Keywords: Morpho-Taxonomic Studies, Extended Distribution.

The genus *Sauromatum* Schott belongs to the family Araceae, tribe-Areae was recognized by Heinrich Wilhelm Schott (1832). The generic position of *Sauromatum* was unstable and differently placed under *Typhonium* or *Sauromatum* by earlier workers. However, Schott distinguished the genus *Sauromatum* from the genus *Typhonium* based on the characters of connate spathe tube, ovaries with two (rather than one) ovule, scattered staminodes, and short peduncle in *Sauromatum*. Later, Hetterscheid & Boyce (2000) reduced the generic status of *Sauromatum* and merged with *Typhonium* based on the phylogenetic analyses of character matrix of all *Typhonium* & *Sauromatum* species (62 species and 12 morphological characters). In contrast, Cusimano et al. (2010) recognized nine species of *Sauromatum*, segregating the genus from *Typhonium* based on the study of its chloroplast and nuclear DNA sequences; and considered *Sauromatum* and *Typhonium* were not sister groups but had a genetic distinctness among the genera.

The genus *Sauromatum* Schott is mainly distributed in southeastern Asia from China–Indonesia through Nepal, Bhutan, India, Bangladesh, Myanmar, Thailand, Vietnam, and Cambodia (Talukdar et al. 2014; Odyuo et al. 2015; Nangkar & Tag 2018; Sasikala et al. 2019). Nangkar & Tag (2018) described a new species of *Sauromatum nangkarense* from Arunachal Pradesh. But, later, (Roy, 2018) had reduced the specific status and become synonym of *S. meghalayense,* where the latter specific epithet had been accepted by Odyuo et al. (2015). A new species of *Sauromatum arunachalense* was recently described by Tiwari et al. (2021) from Arunachal Pradesh. In India, the genus *Sauromatum* is represented by six species, viz*., S. diversifolium* (Wall. ex Schott) Cusimano & Hett., *S. brevipes* (Hook.f.) N.E.Brown, *S. venosum* (Dryand. ex Aiton) Kunth, *S. meghalayense* D.K.Roy, A.D.Talukdar, B.K.Sinha & M.Dutta Choudhury, *S. arunachalense* U.L.Tiwari, R.Maity & S.S.Dash, and *S. horsfieldii* Miq. (Table 1).

During the field exploration in Mao area of Manipur, India, the authors came across an interesting aroid plant at Pudunamei Village, growing on the soil. On further

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Competing interests: The authors declare no competing interests.

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investigation and critical examination of the specimen and also from the available literature (Hetterscheid & Boyce 2000; Cusimano et al. 2010; Talukdar et al. 2014; Odyuo et al. 2015; Nangkar & Tag 2018; Tiwari et al. 2021) and further confirmed from N Odyuo 132792, Tiwari 41100, DK Roy 130216, A Nangkar & H Tag 055, and photograph images from https://powo.science.kew.org (Accessed on 19 September 2021), it has been identified as *S. horsfieldii*. This species was first reported in India from the Tuensang District of Nagaland by Odyuo et al. (2015). The occurrence of *S. horsfieldii* in Manipur is an extended distribution and a new addition to the flora of Manipur. A detailed description and taxonomic treatment, habitat photos and an image (Images 1 & 2) of the morpho-parts have been provided for easy identification of the species. A key to six species of *Sauromatum* reported from India has been given.

Materials and Methods

The collection, pressing, and preparation of herbarium specimens were done as per the conventional herbarium techniques (Jain & Rao 1976) and the herbarium specimen was deposited at Herbarium, Botany Department of D.M. College of Science, Imphal. The live plants photos were taken from Sony digital camera cyber-shot DSC-WX200. All the morphological descriptions and measurements were based on living plant specimen.

Taxonomic treatment

Sauromatum horsfieldii Miq. Fl. Ned. Ind. 3: 196, 1856 (Image 1–2)

Homotypic Synonyms: *Pedatyphonium horsfieldii* (Miq.) J. Murata & Ohi-Toma, Syst. Bot. 36: 254, 2011. *Typhonium horsfieldii* (Miq.) Steenis, Bull. Jard. Bot. Buitenzorg, sér. 3, 17: 403, 1948.

Heterotypic Synonyms: *Arisaema submonoicum* Gagnep., Notul. Syst. (Paris) 9: 128, 1941., *Heterostalis pedata* (Schott) Schott, Ann. Mus. Bot. Lugduno-Batavi 1: 278, 1864., *Pedatyphonium calcicola* (C.Y.Wu ex H.Li, Y.Shiao & S.L.Tseng) J.Murata & Ohi-Toma, Syst. Bot. 36: 254, 2011., *Pedatyphonium kunmingense* (H.Li) J.Murata & Ohi-Toma, Syst. Bot. 36: 254, 2011., *Pedatyphonium larsenii* (S.Y.Hu) J.Murata & Ohi-Toma, Syst. Bot. 36: 254, 2011., *Pedatyphonium omeiense* (H.Li) J.Murata & Ohi-Toma, Syst. Bot. 36: 254, 2011., *Typhonium calcicola* C.Y.Wu ex H.Li, Y.Shiao & S.L.Tseng, Acta Phytotax. Sin. 15(2): 104, 1977., *Typhonium fallax* N.E.Br., J. Linn. Soc., Bot. 18: 260, 1880., *Typhonium hongyanense* Z.Y.Zhu, Acta Bot. Yunnan. 5: 277, 1983., *Typhonium kerrii* Gagnep., Bull. Soc. Bot. France 89: 11, 1942. *Typhonium kunmingense* H.Li, Acta Phytotax. Sin. 15(2): 104, 1977., *Typhonium kunmingense* var. *alatum* H. Li ex H.Peng & S.Z.He, Acta Bot. Yunnan. 19: 40, 1997. *Typhonium kunmingense* var. *cerebriforme* H.Li ex H.Peng & S.Z.He, Acta Bot. Yunnan. 19: 40, 1997., *Typhonium larsenii* S.Y.Hu, Dansk Bot. Ark. 23: 448, 1968. *Typhonium omeiense* H.Li, Acta Phytotax. Sin. 15(2): 105, 1977., *Typhonium pedatum* Schott, Oesterr. Bot. Wochenbl. 7: 262, 1857.

Morphological description

Herbs, 35–40 cm tall, tuber depressed globose, 2–3 cm high and 3–3.5 cm in diameter; roots numerous, surrounding the tuber, creamy white in colour. Petiole glabrous, with a white stripe, dark brownish green to green, 25–30 cm long and *c.* 1 cm in diameter. Leaf blade 9-pedatified, green, lobes elliptic to lanceolate, margin entire, apex acuminate, central lobe 12 cm × 2.6 cm, lateral lobes gradually smaller, 4–9 × 1.3–2.5 cm. Inflorescence appears after the leaf formation, 1–2 per tuber, *c*. 17 cm long; peduncle subterranean, whitish-green, *c*. 5 × 0.3 cm. Spathe convolute at base, outside brown to dark green at basal part, light whitish-brown upper part with brown spot, upper mid-part light brown with brown spots, inside white at base, upper part light brown with brownish-purple spots, *c*. 12 cm long, c. 5.8 cm in diameter at base, apex pointed. Spadix shorter than spathe, c. 6.5 cm long; female zone cylindrical, 0.6 × 0.5 cm; ovary ovoid to oblong-ovoid, 1-loculate, creamy white, stigma sessile. Sterile zone 2.8 × 0.25 cm, sterile staminodes at base c. 0.4 cm long, bent upward, clavate to aristate, clavate part yellowish white, gradually reduced, become shorter, and finally become smooth. Male zone c. 0.6 × 0.3–0.4 cm wide, creamy white. Fruit zone at the spathe base, berries whitish green, 0.4–0.6 × 0.3–0.4 cm, crowded, obovoid to ellipsoid (Image 1,2).

Flowering & Fruiting: May–July.

Ecology: The plants grow in the open forests and in the kitchen garden along with many herbaceous plants like *Eupatorium* sp., *Fagopyrum* sp., *Persicaria* sp., and *Galinsoga parviflora* Cav. at an elevation of 1,800 m at Pudunamei, Mao, Manipur.

Specimen examined: India: Manipur: Senapati District, Pudunamei, 1,800 m, 25.317^{0}N & 94.936^{0}E, KE100021. N Odyuo 132792 (ASSAM), Tiwari 41100 (ASSAM), DK Roy 130216 (ASSAM), A Nangkar & H Tag 055 (ASSAM).

Distribution: India (Kashmir, Maharashtra, Uttarakhand, Uttar Pradesh, Mizoram, Meghalaya, Nagaland, Assam, and Manipur), Assam to southern China and Indo-China, Sumatra to Lesser Sunda Is. (Bali),

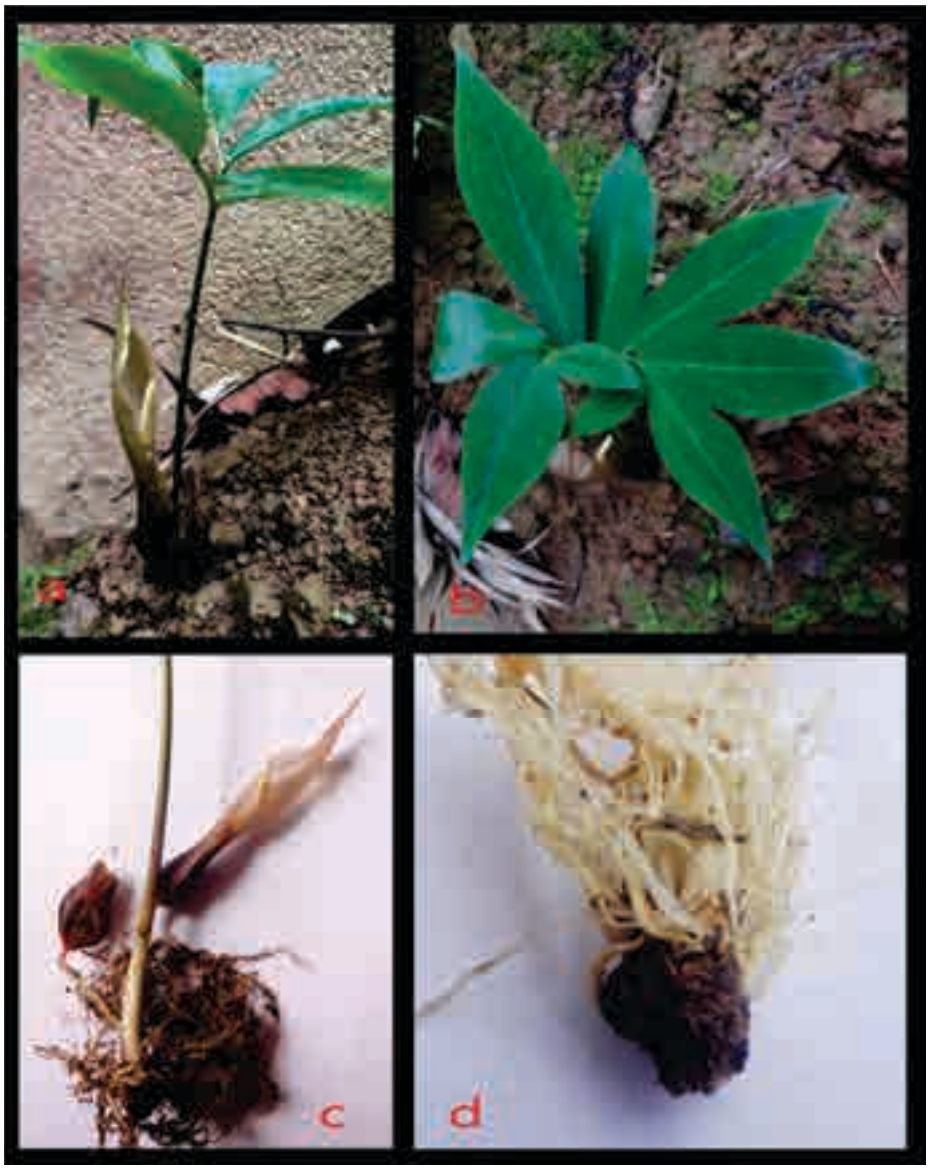

Image 1. *Sauromatum horsfieldii* Miq.: a—Plant with inflorescence in its natural habitat | b—Plant showing leaf arrangement | c—Lower half of plant | d—Tuber with many adventitious roots. © Kazhuhrii Eshuo.

Key to the Indian species of *Sauromatum*

(Six species of *Sauromatum* are reported from India)

1a. Plant pedatifid; leaflets (1) 3–7 2
1b. Plant pedatisect; leaflets 7–12 (–17) 3

2a. Leaf blade diversified (often in one plant) from simple to pedatisect ..... *S. diversifolium*
2b. Leaf blade oblanceolate, pedatisect, 5–7 leaflets ..... *S. arunachalense*

3a. Spathe tube connate; one type of staminode present 4
3b. Spathe tube convolute; two types of staminode present 5

4a. Inflorescence appears before leaves; spathe tube dark purple inside ..... *S. venosum*
4b. Inflorescence appears alongside first developing leaf; spathe tube greenish to white ..... *S. brevipes*

5a. Peduncle greenish white; spathe tube brownish-green outside, inside with white at the basal region; upper light brown with deep brown spots ..... *S. horsfieldii*
5b. Peduncle purplish brown; spathe tube purplish-brown to dark brown outside; inside purple but creamy to white on margin and toward the limp inside ..... *S. meghalayense*

Image 2. *Sauromatum horsfieldii* Miq.: a—Plant showing habit and habitat | b—Close up view of inflorescence | c—Inflorescence | d—L.S. of spathe tube in ventral view | e—L.S. of spathe in dorsal view | f—Longitudinally opened spathe | g—L.S. of lower region of spathe | h—Fruiting zone | i—Male flowering zone | j—Inflorescence in part showing fruiting zone and sterile zone of staminodes. © Kazhuhrii Eshuo.

Table 1. Distribution of *Sauromatum* species in India (Sasikala et al. 2019).

	Name of the species	Distribution
1	*S. diversifolium*	Himachal Pradesh, Maharashtra, Uttar Pradesh, Sikkim, Assam, and Arunachal Pradesh.
2	*S. brevipes*	Sikkim, Uttar Pradesh, and West Bengal
3	*S. venosum*	Bihar, Goa, Gujarat, Himachal Pradesh, Jammu & Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Punjab, Rajasthan, and Uttar Pradesh.
4	*S. meghalayense*	Meghalaya, Arunachal Pradesh
5	*S. arunachalense*	Arunachal Pradesh
6	*S. horsfieldii*	Kashmir, Maharashtra, Uttarakhand, Uttar Pradesh, Mizoram, Meghalaya, Nagaland, Assam, and Manipur

Myanmar, Thailand, Vietnam, Cambodia, Laos, and Indonesia (Table 1).

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SHORT COMMUNICATION

Rhynchostegiella menadensis (Sande Lac.) E.B. Bartram and *R. scabriseta* (Schwagr.) Broth.: two new records of mosses (Brachytheciaceae: Bryophyta) for peninsular India

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Abstract: *Rhynchostegiella menadensis* (Sande Lac) E.B. Bartram and *R. scabriseta* (Schwagr.) Broth. are the two species in the moss genus *Rhynchostegiella* from the family Brachytheciaceae, previously known only from northern India, is now recorded for the first time from peninsular India. They are described in detail along with a photoplate.

Keywords: Distribution, Idukki District, Kerala, Mathikettan Shola National Park.

The genus *Rhynchostegiella* (Schimp.) Limpr., of the family Brachytheciaceae is represented by 57 species in tropical and warm temperate regions of the world (Gangulee 1980; Vohra 1983). *Rhynchostegiella* is distributed in China, India, Indonesia, Nepal, Philippines, and Thailand. In India, the genus is represented by thirteen species (Gangulee 1980; Vohra 1983; Dandotiya et al. 2011). The Indian species are *R. assamica, R. divaricatifolia*, *R. fabroniadelphus*, *R. humillima*, *R. leiopoda*, *R. menadensis*, *R. percomplanata*, *R. plumosa*, *R. ramicola*, *R. sachensis*, *R. scabriseta*, *R. schwetschkeoides*, and *R. tenella*. *R. tenella* was recently reported from Kerala as a new record for India (Mufeed et al. 2021). *R. menadensis* (Sande Lac.) E.B. Bartram was earlier reported from Uttarakhand (Bargali et al. 2014) and *R. scabriseta* (Schwagr.) Broth. was reported from Assam (Robinson 1968), Himachal Pradesh (Alam 2013), Jammu & Kashmir (Alam 2013), Manipur (Govndapyari 2014), and Uttarakhand (Alam 2013; Bahuguna et al. 2016). Both species are new records for peninsular Indian moss flora, and now the genus *Rhynchostegiella* is represented by six species in peninsular India (Table 1).

Materials and Methods

The current study is the result of extensive field research conducted in Mathikettan Shola National Park between 2014 and 2018. The external features of the specimens were observed under the stereo dissection microscope (Labomed CZM4), the internal features were studied with the help of a compound microscope (Labomed Lx 500) and specimens were measured and photographed with the help of a Jenoptic ProgRes C5 USB connected camera.

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Table 1. Distribution of the genus *Rhynchostegiella* in peninsular India.

Species	Distribution in India	References
Rhynchostegiella humillima (Mitt.) Broth.	Tamil Nadu	Mitten 1856; Foreau 1931; Vohra 1983; Daniels 2010
Rhynchostegiella leiopoda Dixon & Cardot	Tamil Nadu	Brühl 1931; Foreau 1931; Daniels 2010
Rhynchostegiella menadensis (Sande Lac.) E.B. Bartram	Uttarakhand	Bargali et al. 2014
Rhynchostegiella scabriseta (Schwägr.) Broth.	Assam, Himachal Pradesh, Jammu & Kashmir, Manipur, Uttarakhand	Robinson 1968; Alam 2013; Govndapyari 2014; Bahuguna et al. 2016
Rhynchostegiella fabroniadelphus (Müll. Hal.) Broth.	Palni hills	Dandotiya et al. 2011
Rhynchostegiella tenella (Dicks.) Limpr.	Kerala	Mufeed et al. 2021

Result

Among the six species reported from India, *Rhynchostegiella menadensis* (Sande Lac.) E.B. Bartram was reported earlier from Uttarakhand, and *R. scabriseta* (Schwägr.) Broth. was reported from Assam, Himachal Pradesh, Jammu & Kashmir, Manipur, and Uttarakhand. Hence the present study reports these two species from peninsular India as new records.

Rhynchostegiella menadensis (Sande Lac.) E.B. Bartram, Philipp. J. Sci. 68: 302.1933.

Type locality: Mindanao Island, Philippines

Plant is yellowish-green, glossy, loose mat on log, bark; main stem creeping, 2–3 cm long, pinnately branched, branches short, feathery, loosely foliate; leaves erect-spreading, 0.8–0.9 × 0.37–0.4 mm, ovate-lanceolate, base wide, auriculate, acuminate tip, faintly denticulate at base; costa single, reached middle; basal cells rhomboid, 30–35 × 7–9 µm; elongated rhomboid, 62–80 × 3–5 µm at middle and tip; alar cells undifferentiated; branch leaves narrow, ovate-lanceolate, 1.5–1.6 × 0.36–0.38 mm, decurrent base, acuminate at apex; sporophyte not known.

Habitat: Seen on logs and bark along with *Meteoriopsis reclinata* (Müll. Hal.) M. Fleisch. in the shola forest (Image 1).

Distribution: China, India (Uttarakhand (Bargali et al. 2014)), Indonesia, Philippines (Shevock & Yorong 2018) and Thailand. The present report based on recent collection is a new record for peninsular India.

Specimens examined: India, Kerala, Idukki District, Mathikettan Shola National Park, Sivanpara (1,550 m), 28.xi.2012, Rajilesh V.K. 8236b; Chundel (1,450 m), 08.iv.2013, Rajilesh V.K. 9406; Vattapara (1,620 m), 28.xi.2014, Rajilesh V.K. 11640 (MBGH).

Rhynchostegiella scabriseta (Schwagr.) Broth., Nat. Pflanzenfam. I (3): 1161. 1909.

Type locality: Nepal

Plant is yellowish-green, glossy tufted on bark, on soil cutting; main stem prostrate, short, pinnately branched; branches erect, 2–2.5 cm long, densely foliate; leaves whorled, erect-spreading, imbricate, 1.6–1.7 × 0.6–0.66 mm, ovate-lanceolate, base wide, decurrent, apex narrow acuminate, shortly denticulate margin; costa single, reached above the middle; leaf cells narrow, elongated- rhomboid 28–43 × 4.2–5.5 µm from base to apex; alar rectangular, 16–23 × 9–11 µm; sporophytes on main branch; seta erect, 1.8–2 mm long, brownish, rough; capsule erect, ovate-cylindrical, brownish, 2.2–2.5 mm long, 0.5mm in diameter; peristome normal (Image 2)

Habitat: Epiphytic on bark and on land cuttings along with other mosses *Hookeriopsis secunda* (Griff.) Broth. And *Plagiomnium rostratum* (Schrad.) T.J. Kop. In the shola forest.

Distribution: **World**: India (Jammu & Kashmir (Alam 2013), Manipur (Govndapyari 2014), Himachal Pradesh (Alam 2013), Uttarakhand (Alam 2013; Bahuguna et al. 2016)) and Nepal. The present collection is a new record for peninsular India.

Specimens examined: India, Kerala, Idukki District., Mathikettan Shola National Park, Chundel (1,200 m), 09.iv.2013, Rajilesh V.K. 9450; Kurisukavala (1,550 m), 28.xi.2014, Rajilesh V.K. 11624; Karipara (1,650 m), 12.iii.2014, Rajilesh V.K. 10915; Aduvilanthankudi (1,600 m), 13.iii.2014, Rajilesh V.K. 10960 (MBGH).

Discussion

The current study reveals that two *Rhynchostegiella* species have been recorded as an extended distribution record for peninsular Indian moss flora, bringing the total number of *Rhynchostegiella* species to six.

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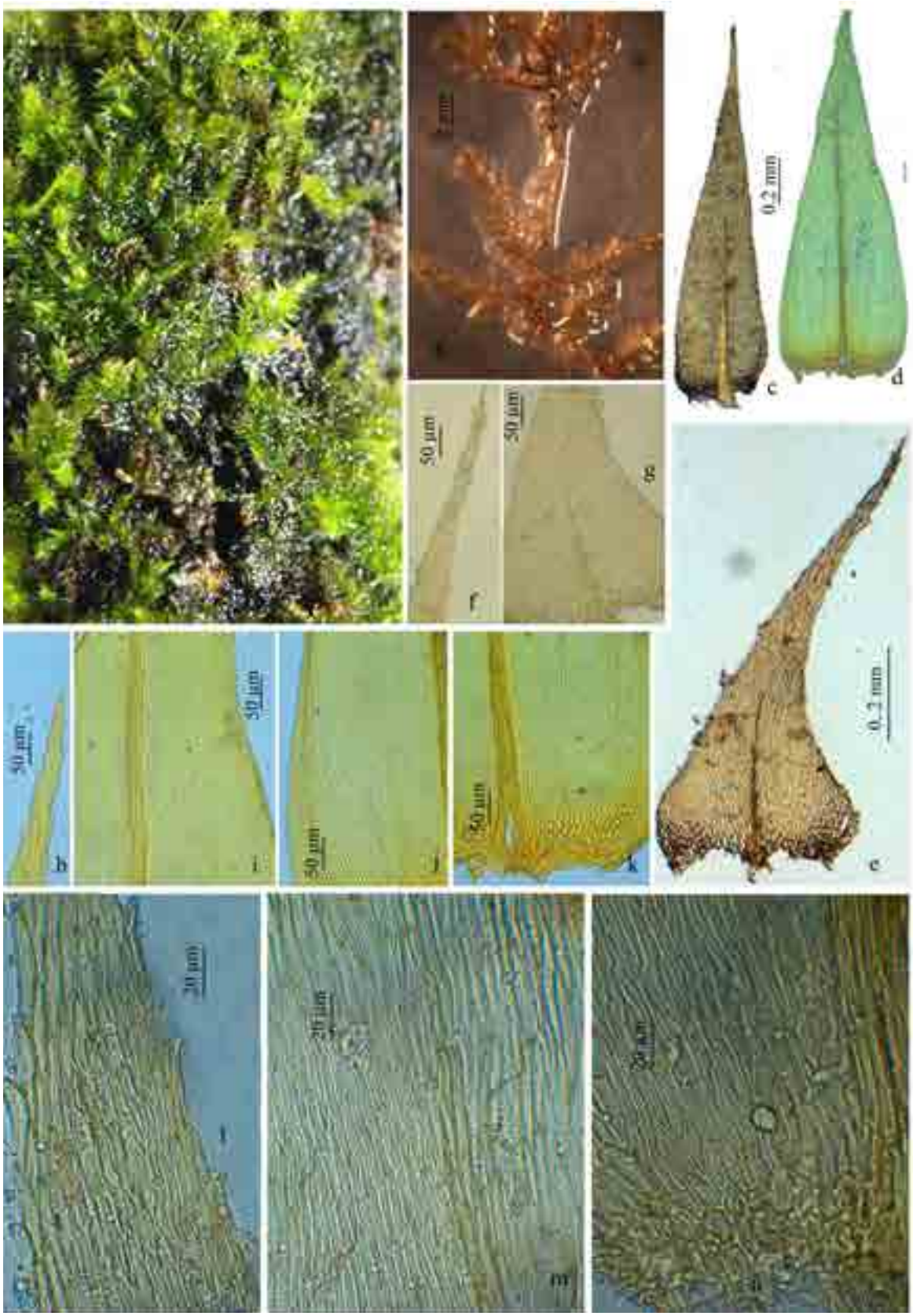

Image 1. ***Rhynchostegiella menadensis*** **(Sande Lac.) E.B. Bartram: a—habit | b—branch enlarged | c&d—branch leaves | e—stem leaf | f—stem leaf upper cells | g—stem leaf lower cells | h—branch leaf upper cells | i—middle cells | j—marginal cells | k—basal cells | l—leaf upper cells enlarged | m—middle cells | n—basal cells. © Rajilesh, V.K.**

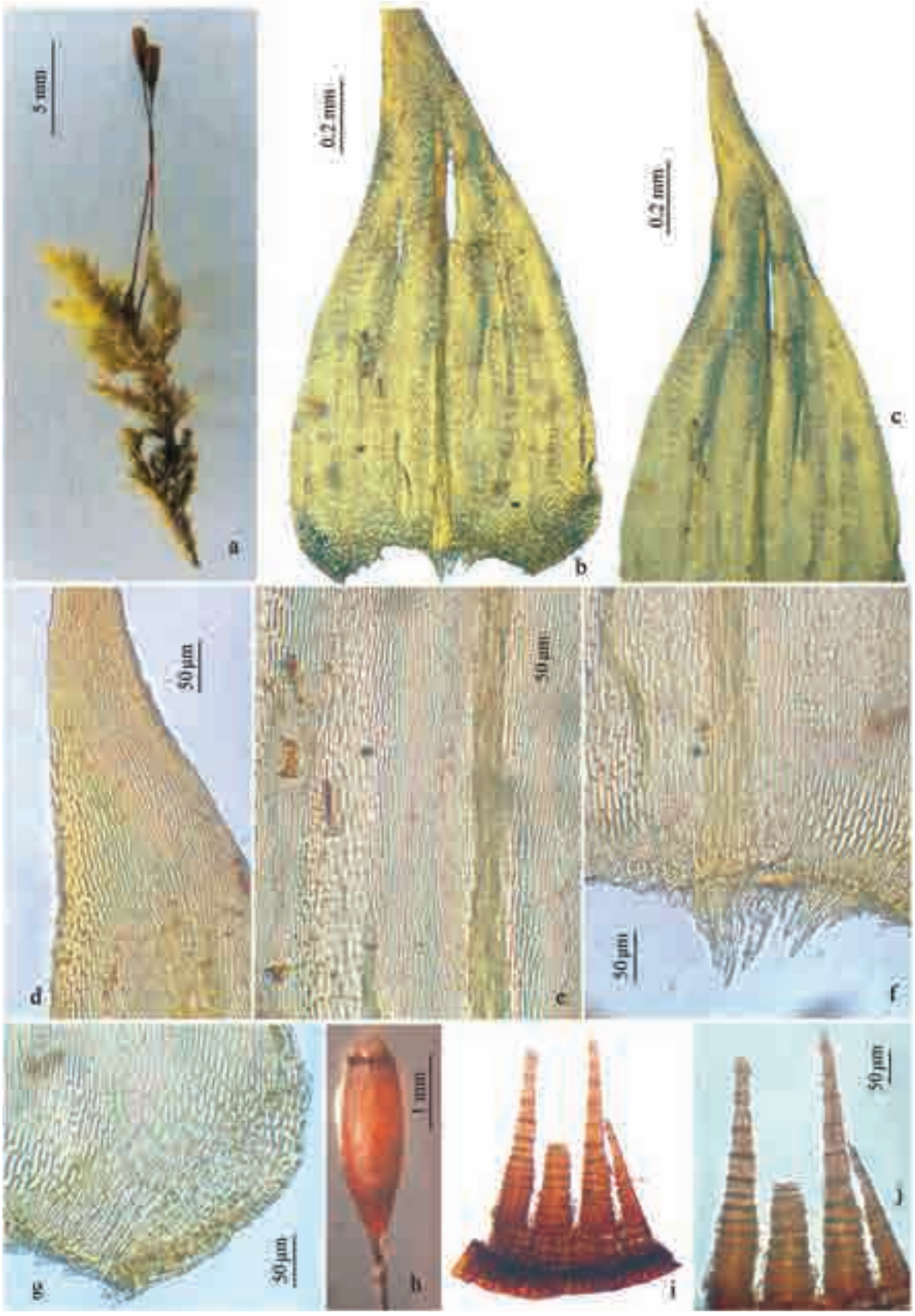

Image 2. ***Rhynchostegiella scabriseta*** **(Schwagr.) Broth.: a—habit | b&c—leaf | d—leaf upper cells | e—leaf middle cells | f—leaf basal cells | g—basal cells at margin | h—sporophyte | i&j—peristome teeth. © Rajilesh, V.K.**

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NOTE

Installation of hot boxes for conservation in the last nursery roost of Greater Horseshoe Bats *Rhinolophus ferrumequinum* in Austria

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Since the 1950s, populations of the Greater Horseshoe Bat *Rhinolophus ferrumequinum* Schreber, 1774, among several other European bat species, have plummeted, resulting in their local disappearance or even large-scale extinction (Ransome & Hutson 2000; Spitzenberger et al. 2010; Dietz & Kiefer 2014; Leitl 2021). Consequently, irrespective of its wide distribution from the western Palearctic to the east of the Asian continent and its concomitant IUCN Red List classification as Least Concern (LC), this large insectivorous bat species is nowadays considered as Endangered or even Critically Endangered in several central European countries (Piraccini 2016). Especially the loss of feeding grounds, related to agricultural intensification or change of land use, disturbances, loss of roosting sites and the loss of insects due to increased use of pesticides have been identified as factors driving population declines (Ransome & Hutson 2000; Dietz & Kiefer 2014; Matthäus et al. 2022). Nonetheless, recent studies have shown that some populations, e.g., in Great Britain are in fact stabilizing and/or recovering due to a combination of conservation efforts and perhaps also milder climate (van der Meij et al. 2015; Froidevaux et al. 2017). Similar trends were observed in Germany's last maternity roost as well where hot boxes have been installed to provide optimal temperature conditions for Greater Horseshoe Bats (Leitl 2021) as well as for Greater Mouse-eared Bats (Dietz & Dietz 2021). According to Leitl (2021), continuous population growth was observed in the years after installation due to increased survival and higher reproductive success. Since Berthinussen et al. (2014) reported a general lack of international literature about the effects of hot boxes, only very few international (Wright et al. 2022; Zingg et al. 2022) and national (Leitl 2021; Dietz &Dietz 2021) studies became available in the meantime.

In Austria, the former distribution of *R. ferrumequinum* covered large parts of southern and eastern Austria including findings from Tyrol (Spitzenberger 2001) and Upper Austria (Pysarczuk 2008) with 16 different nursery roosts reported until 1999 (Image 1; Spitzenberger 2001). However, *R. ferrumequinum* is considered Critically Endangered by the Red List of endangered mammals of Austria

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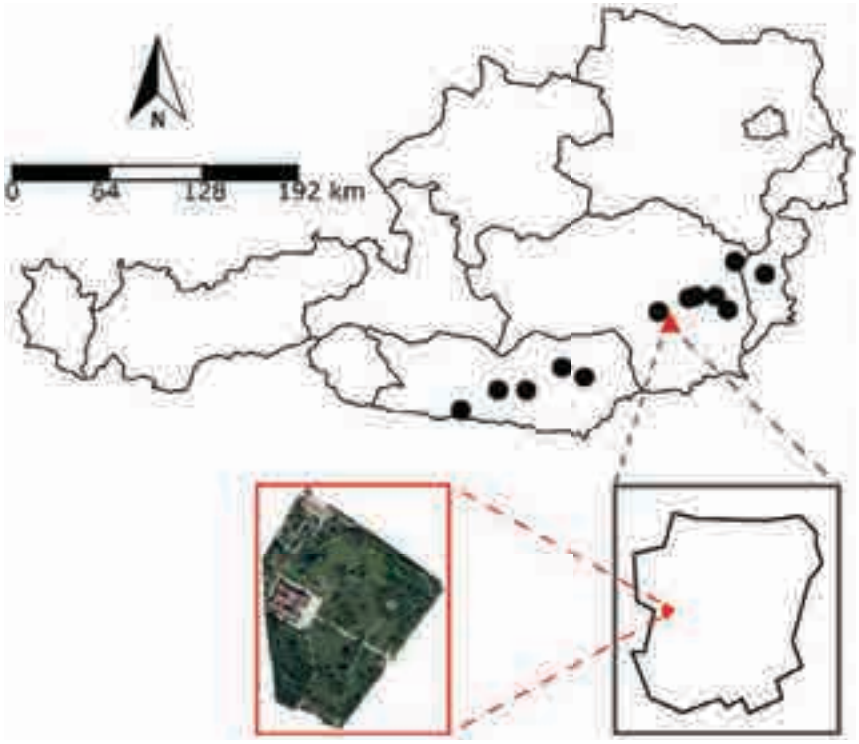

Image 1. Map of Austria (created using SimpleMappr) showing the previously known but inactive (black circles) and the last active (red triangle) maternity roosting sites of the Greater Horseshoe Bats. Inlays display the location of the SAC Schloss Eggenberg in Graz (grey frame) and a satellite image of the 17.9 ha area (red frame).

(Spitzenberger 2005) as all previously known maternity roosts have been abandoned, except the one in Schloss Eggenberg in Graz which between 2019 and 2021 harbored 48–56 female individuals (Spitzenberger et al. 2010, unpubl. data).

Consequently, following the Habitats Directive 92/43/EEC of the European Union, the castle and its surrounding gardens (Image 1 inlay) were declared as a Natura 2000 Special Area of Conservation (SAC) in 2015. Subsequently, and for the first time in Austria, in winter 2018/19, three hot boxes (one equipped with a finned tube heater (Friedrich Schultze Heizgeräte, Siegen, Germany) installed in 2021) were installed in the attic directly underneath the roof ridge of Schloss Eggenberg. The hot boxes consist of three-layered boards of wood wool with a rock wool core and measure 70 cm in height and 95 cm in diameter at the broadest section (Image 2 top left and right). The entire construction is non-flammable and equipped with wooden strips on the inside to provide proper hanging sites for the bats without damaging the covering wood wool layer. Additionally, underneath each hot box, a non-flammable box containing a webcam was installed to observe the bats' behavior and document their use of the different hot boxes. Warm spring temperatures are suggested to help the bats maintain higher body temperatures which in turn accelerates birth dates (Ransome & McOwat 1994) and, hence, development of the young (Ransome 1973; Ransome & Hutson 2000; Dietz & Dietz 2021). Therefore, following Leitl (2021) and Dietz & Dietz (2021) we hope to improve the maternity roosting site at Schloss Eggenberg through the hot boxes and initiate a positive trend of the Austrian breeding population. Initial use of hot boxes (Image 2 bottom left and right) may indicate tentative acceptance but the overall acceptance by and effects on the breeding population will have to be determined through a long-term monitoring.

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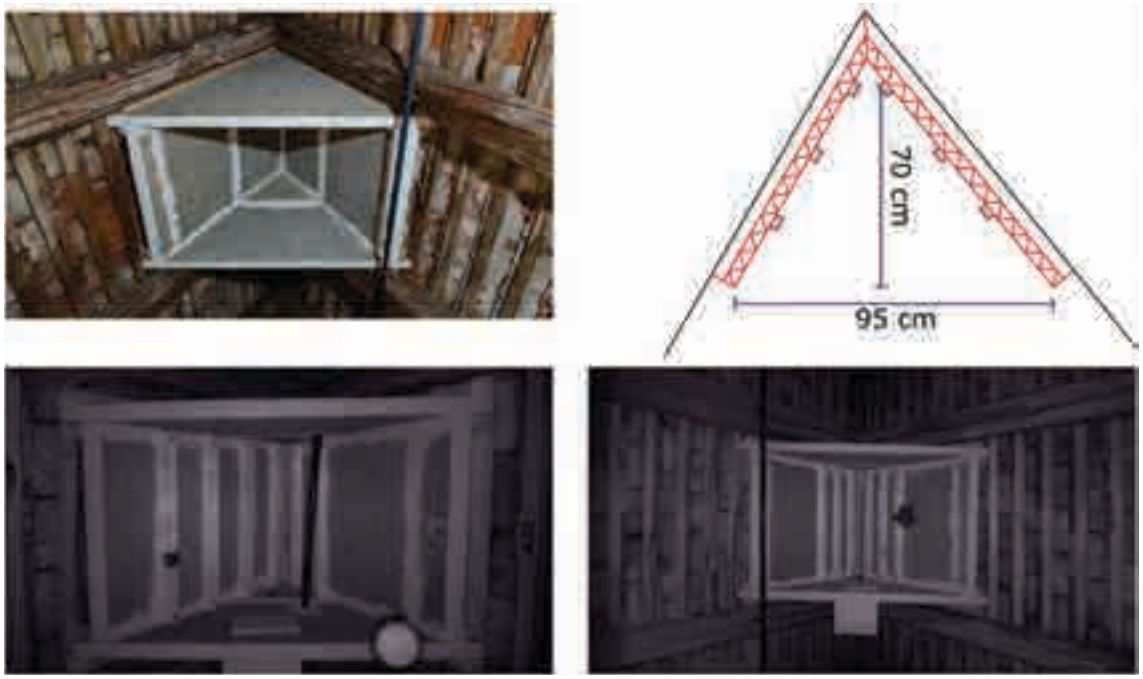

Image 2. Picture (top left) and schematics (top right) of the installed hot boxes in the attic of Schloss Eggenberg in Graz, Austria as well as webcam pictures of the first Greater Horseshoe Bats *Rhinolophus ferrumequinum* using the hot boxes (bottom left and right). Black lines in the schematics symbolize the roof, red lines indicate wood wool boards and attachments to the roof, brown squares represent wooden stripes offering hanging sites to the bats. © Picture Christian Schweiger, BT Bau-Tech GmbH.

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NOTE

New prey record of giant ladybird beetle *Anisolemnia dilatata* (Fabricius) (Coccinellidae: Coleoptera) feeding on Som Plant Aphid *Aiceona* sp.

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Ladybird beetles are also commonly called lady bugs and coccinellids. Around 6,000 species under 360 genera are classified in two subfamilies and 30 tribes worldwide (Slipinski 2007).

The giant ladybird beetle *Anisolemnia dilatata* (Fabricius) is a specialist predator of woolly aphids of bamboo plants and sugarcanes, and endemic to southern Asia and Asia-Pacific regions (Agarwala & Majumder 2016). Fabricius (1755) named this species as *Coccinella dilatata*, later Mulsant (1850) described this species as *Caria dilatata* but widely used name of this species is *Anisolemnia dilatata* which was given by Korschefsky (1932). Iablokoff-Khnzorian (1986) transferred the species into the genus *Megalocaria* but the name *Anisolemnia* was kept as its type species (Poorani 2002).

The genus *Aiceona* Takahashi (1921) belongs to the subfamily Aiceoninae of the family Aphididae. The genus occurs in eastern, southern, & southeastern Asia, including China, India, Nepal, Malaysia, Thailand, and Japan; associated mostly with Lauraceae (Takahashi 1960). Earlier, the subfamily Anoeciinae was composed of two tribes: Aiceonini and Anoeciini (Ghosh 1988), however, Remaudière & Remaudière (1997) elevated the tribe Aiceonini to the subfamily Aiceoninae that contains only one genus *Aiceona* Takahashi, 1921 in which 18 species are assigned under two subgenera, *Aiceona* Takahashi 1921 (17 species) and *Subaiceona* Remaudière & Remaudière, 1997 (1 species) (Remaudière & Remaudière 1997; Zhang & Qiao 1998; Qiao & Zhang 2002). In India, the subfamily Aiceoninae contains only one genus *Aiceona* of which eight species are recorded on about 10 species of plants belonging to five families: Araliaceae, Lauraceae, Malvaceae, Menispermaceae, Poaceae and Scrophulariaceae (Singh & Singh 2016).

During fortnightly visits (extending from April 2017 to March 2018) to the Som *Persea bombycina* Kost plantations at the farm of Uttar Banga Krishi Viswavidyalaya (North Bengal Agriculture University), Pundibari, Cooch Behar (89.3980^{0}E & 26.3405^{0}N, altitude 43 m), the aphid, *Aiceona* sp. was found to have significant presence and inflict serious damage to the Som plantations by feeding. The Cooch Behar District (West Bengal) adjoining Assam enjoys identical ecological conditions (Eastern Himalayan Zone) like northeastern India and very congenial for mugaculture. Muga Silkworm *Antheraea assamensis* Helfer is reared on two primary host plants, Som and Soalu *Litseae*

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Image 1. Giant lady predator on Som Plant Aphid.
a—Adult beetle in natural habitus in som aphid colony | b—Heavy population of aphid on leaves with black mould | c—Egg cluster of Giant Ladybird Beetle close to a high density colony of *Aiceona* sp. © Biwash Gurung.

monopetala Roxb under outdoor conditions.

The aphid is yellowish-green in colour, larger in size (Table 1) and colonizes the Som plants particularly during new flush. Both nymphs and adults infest the tender buds, apical shoots, and lower surface of leaves. Due to sucking of plant sap from the tender parts of the plant the growth is arrested and curling and reduction in size of the leaves takes place. In case of severe infestation black sooty mold develops on the honeydew secreted by the aphids (Image 1b). The aphid colony can be easily spotted out due to the association of different types of ants.

The population of aphid was counted from 10 cm apical twig /new flush selecting 10 plants at random and observing five twigs per plant at fortnightly interval during 2017–18. The aphid population throughout the

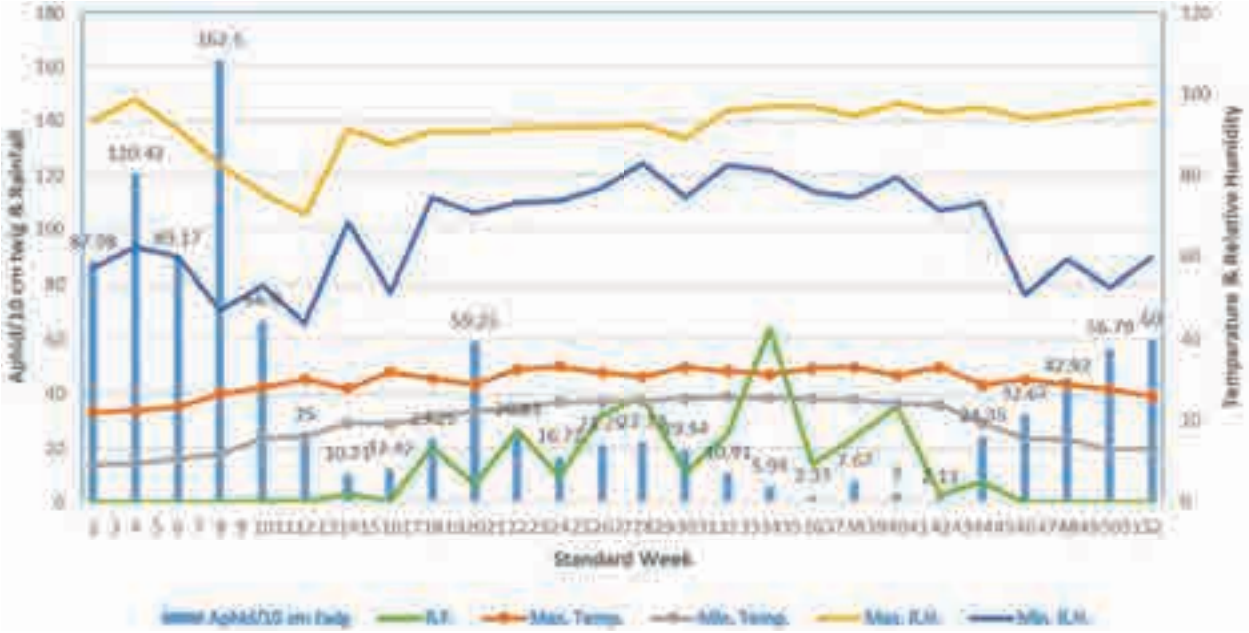

Figure 1. Field population fluctuation of som aphid, *Aiceona* sp. with respect to meteorological parameters.

Table 1. Body weight of different life-stages of *Aiceona* sp. feeding on *P. bombycina*.

Life stages of *Aiceona* sp.	Body weight* (mg)
First instar nymph	0.2167 ± 0.0747
Second instar nymph	0.5267 ± 0.1143
Third instar nymph	0.9500 ± 0.1167
Fourth instar nymph	1.2967 ± 0.0928
Adult female	1.6267 ± 0.1143

*Mean of 30 observations.

Table 2. Correlation of meteorological parameters with infestation of *Aiceona* sp.

Pest	Meteorological Parameters				
	Max. Temp.	Min. Temp.	Max. R.H.	Min. R.H.	R.F.
Aphid	-0.793**	-0.801**	-0.196	-0.576**	-0.479*

* Significant at 5% level (r = ± 0.388) | ** Significant at 1% level (r = ± 0.496)
Max. Temp.-Maximum Temperature; Min. Temp.- Minimum Temperature; Max. R.H.-Maximum Relative Humidity; Min. R.H.- Minimum Relative Humidity; R.F.- Rainfall.

study period was correlated with the meteorological parameters collected from the agro-meteorology unit, Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal. The population of the aphid persists throughout the year but there has been a noticeable upsurge in population with the advent of winter season and reached the peak level in the spring season, i.e., February end (Figure 1). But the population decreased with the rise of atmospheric temperature soon and maintained at a low to moderate level throughout the summer and rainy season. The population was again found increasing with lowering of temperature during winter season. Significant negative correlation coefficients were found to exist between the aphid population and the maximum and minimum temperature ('r' values -0.793 & -0.801, respectively) (Table 2). Significant negative associations were also established between aphid infestation and minimum relative humidity and rainfall ('r' values -0.576 & -0.479, respectively).

During the time of heavy infestation of aphid on Som, particularly during the spring season from February to April, a significant population of the giant ladybird beetle, *Anisolemnia dilatata* (F.) (Coccinellidae: Coleoptera) were observed associated with the aphid colony. All the life stages of the coccinellid including the egg clusters could be recorded on the high-density colony of the aphid *Aiceona* sp. (Image 1). The adult beetles were collected from the field and reared under laboratory conditions on the aphid for confirmation of its status as a predator on the Som plant aphid (Image 2).

As per the available literature the giant ladybird predator can prey on *Astegopteryx minuta* (Van der Goot), *A. bambusae* (Takahashi), *Ceratovacuna silvestrii* (Takahashi), *Pyrolachnus pyri* (Buckton), *Pseudoregma bucktoni* Ghosh, Pal & Raychaudhuri (Agarwala & Ghosh

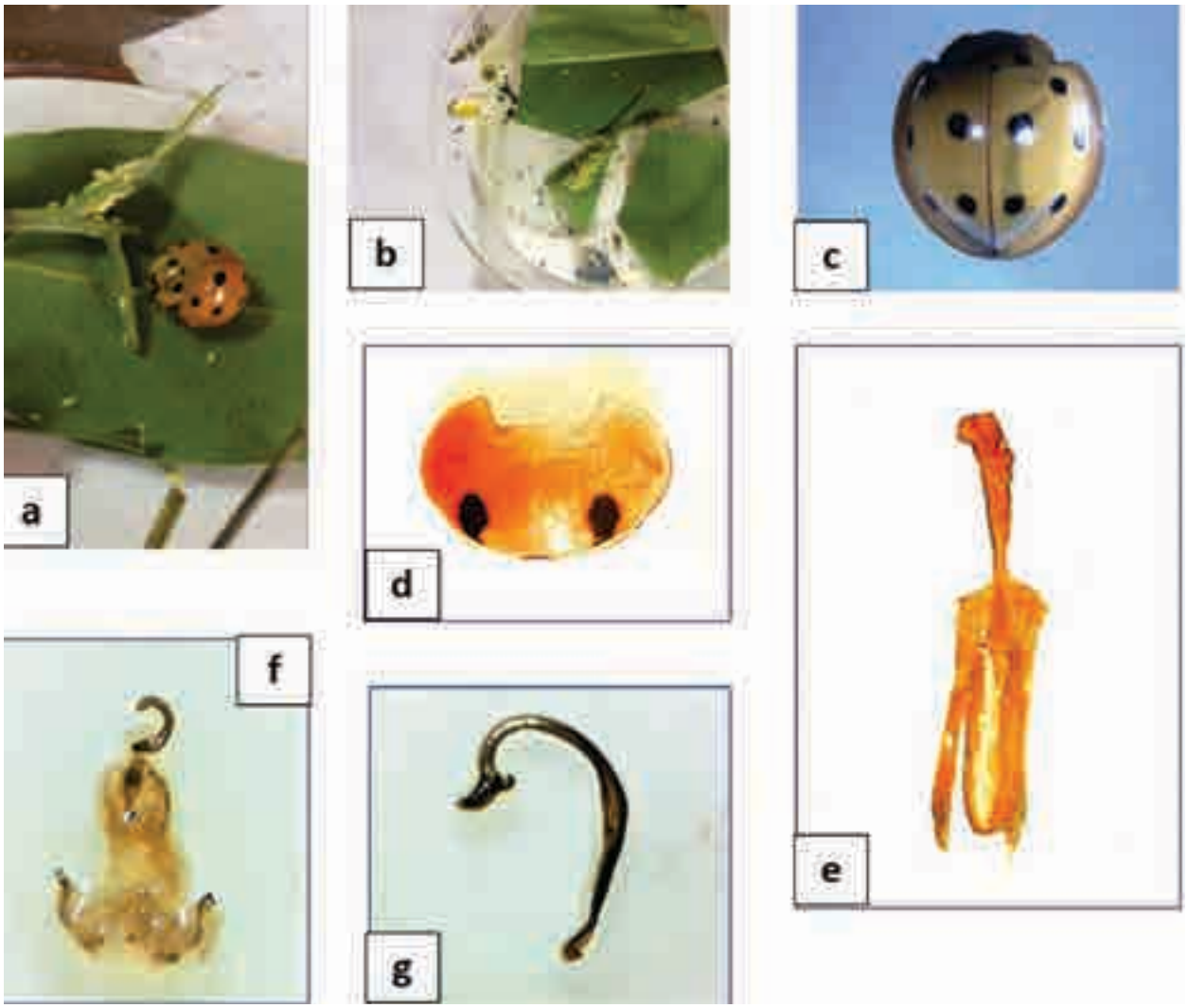

Image 2. Laboratory study of giant ladybird predator, *Anisolemnia dilatata* (F.).
a—Adult beetle reared on som aphid in laboratory | b—Grub & pupa of Giant Ladybird predator | c—Microscopic dorsal view of adult beetle | d—Pronotum of *Anisolemnia dilatata* | e—Male genetalia | f—Female genetalia g—Sipho. © Ponnusamy Natarajan.

1988). Giant ladybeetle *A. dilatata* feeds voraciously on woolly aphids infesting various bamboo species like *Ceratovacuna silvestrii* (Takahashi), *Ceratovacuna indica* (Ghosh, Pal & Raychaudhury) and *Pseudoregma bucktoni* (Takahashi) in northeastern India (Agarwala et al. 1984). Great predatory potential of *A. dilatata* against sugarcane woolly aphid *Ceratovacuna lanigera* Zehntner has been established under laboratory conditions (Kumar & Pal 2019). Giant ladybird beetles are unique among ladybird predators due to their large size and prey specialization. These beetles mostly appear under high prey density which can occur in case of woolly aphids infesting bamboos and sugarcanes. During the present investigation severe infestation of Som plant aphid with larger body size served as a good host (prey) for the Giant ladybird beetle and this is a new prey record for the coccinellid *Anisolemnia dilatata* (F.).

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BOOK REVIEW

Book Review - Under the Feet of Living Things
Editors — Aparajita Datta, Rohan Arthur & T.R. Shankar Raman

Review by Melito Prinson Pinto

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Nature Conservation Foundation (NCF) is an NGO that most of us are familiar with. A Mysore-based NGO, founded by a bunch of youngsters 25 years ago is now currently working in the different landscapes of India. The work they do in conservation is well known through different means, such as publications. But not everyone knows about the actual story, the thought process, the efforts, and the turn of events that led to a particular conservation work's success or failure. This is where 'At the Feet of Living Things', a collection of essays from the scientists and researchers at NCF gives us a narrative. As the book says, it's a commemoration of twenty-five years of wildlife research and conservation in India. The front page is designed with a beautiful illustration that contains landscapes from the Himalaya to the oceans, from the high-altitude flying cranes to the forest-dwelling Binturong, Lion-tailed Macaques and others, to the sea-dwelling Dugong, and Sea Turtle. And all of these are observed through the eyes of a naturalist.

Like Mahesh Rangarajan, in his foreword mentions, the uniqueness of this book is that there is not a single chapter that mentions or speaks about Tigers. Rather, there are chapters on other charismatic animals like Snow Leopard. Although there are four essays on Snow Leopards, they are written about their conservation in different aspects. Reading through the 16 different essays, an immersive reader experiences a wide range of emotions. There are moments where you feel sad looking at the situation of the landscape from the author's perspective, feel joy when a conservation program finally takes off, anguish when things go awry, and moments of shock when one didn't expect a particular thing to happen, and much more. But there is one common emotion among all this - hope.

This is how I journeyed through the book, First, I learnt what it means to think like a starfish, then joined Rucha Karkarey and Mayuresh Goyal at the

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Lakshadweep islands and saw how a survey for fishes led to identifying a beautiful grouper, which led up to the events of setting up an FSA (FIsh Spawn aggregation). And just when I had thought "you guys are lucky, things went really smooth for you", came a dark twist that I was not expecting. A similar thing was experienced in the next chapter by Aparajitha Dutta. I saw the beautiful landscapes around Namdapah, got to know about the Lisu tribes, and felt deep sympathy for them. Here too, I could see things taking a turn for the worst. I felt the fear and helplessness that the authors went through. Both the chapters had me saying one thing at the end "It's alright. You guys gave your best".

Reading through Charudutt Mishra's chapter, I found myself in the Spiti Valley, feeling that chill and thrill of wanting to conserve the Snow Leopards. The anger, and frustration the villagers felt towards the Snow Leopard became apparent to Mr. Mishra only when the two lives that meant a lot to him got preyed upon by the predator. This was one of the speechless moments. A moment where emotions would have all the capacity to destroy your work. But then how Mr. Mishra navigated through these emotions which eventually led to things slowly falling back into place was a relief. The chapter ends on a wholesome note.

In the chapter by Elrika D'souza, I could see her journey, an exploration in search of dugongs. The chapter answered the question of why it's called a 'Sea Cow' and not a 'Sea Pig'. Of the two marine species discussed in the book, I could see the Dugong functioning as a farmer, while the other species that would be mentioned later, a sheep. I was enjoying this journey until Elrika at a point mentioned 'a Grimm picture'. I immediately felt the fear that the Dugong population is doomed. But later, when the hunters turned to become protectors, the light of hope shined bright.

Moving on, with Aparajita Dutta again, this time I saw her explore the hornbills in the Pakke Wildlife Sanctuary along with her Nyishi acquaintances. A journey of ups and downs that ended with a big message to be resilient like the hornbills. The next chapter by Anindya Sinha was something different. Who would've expected that Bonnet Macaques were so cool? Conveying the narrative from the perspective of a protagonist bonnet macaque named 'small' made things enjoyable. Throughout this chapter, I was left saying "Oh Bonnet Macaques do that? How come I never thought of these"?

The next bunch of chapters was on 'living with the wildlife', where the essays contained conservation efforts made for coexistence between humans and wildlife. In 'conservation is an elephantine journey', I could see the situation in the landscape, the tension between the people and the departments, and the loss of crops and lives due to negative interaction with elephants. Ananda Kumar, Ganesh, Vinod, and Sreedhar Vijayakrishnan's essays give us the narrative of the critical situation in these landscapes. A particular mention where a farmer who had not just lost his crops to elephants, but also his hopes to repay his bank loan invites Vinod and his team for a lunch at his home. This was heart-wrenching and had me dumbfounded. Such things make anyone think about who's the actual sufferer.

The next two chapters on snow leopards by Kulbhushan Singh and Ajay Biroor, and Yash Veer Bhatnagar gave me an experience of efforts put into conserving snow leopards with the help of communities in the Himalayan landscapes. When Mr. Bhatnagar said 'landscape - level participatory conservation is here to stay", I felt the confidence that this conservation program is achieving what it was meant for. In the essay by Teresa Alcoverro and Rohan Arthur, what started as the banter between Teresa and Rohan continues to be a restoration of seagrasses for the green turtles. And yes, these are the sheep I referred to earlier, the same green turtles. Personalities like Al Badush really inspired me here with his enthusiasm. Here again, after multiple successes and failures, in the end, the ray of hope shines again. Every time Rohan Arthur writes something, there's always 'tea makes everything better'. Dear Rohan Arthur, I am really looking forward to the day we could have a great conversation on conservation over a cup of tea.

The next section of 'the fall and revival of nature' showed me a road filled with ups and downs. It began with hope, then came moments where the authors would question if it would work, the fear of failure and the efforts going to waste, and at the end of the road, meeting hope again. Shankar Raman and Divya Muddappa's essay on rainforest restoration takes place in a plantation landscape which I could connect myself more with. It's just crazy how a seed of hope of restoring the rainforest was found in the scat of a Palm Civet, categorized as a carnivore. Through all the ups and downs, visualizing the restored rainforest felt great. The essay ending where the civet scat is found again containing another seed is symbolic.

Rohan Arthur's search for resilience in a dying reef gave me a glimpse of the grim reality of coral bleaching. I could feel his worry, the fear of losing his favorite 'potato patch'. I too felt like saying to the reef patch "hang in there my friend, you're going to make it". And there is shown resilience of the reef and Rohan's skill of including subtle humor, which would make one smile

and relax after having a horrific experience. And.....tea makes everything better.

Part 5 is a bit different from the others. Although this too is about a journey, it's not directly about the conservation action for a species or in a particular landscape. Rather this is with bringing the citizens together for citizen science. Dr. Suhel Quader's 'birders in arms' gives us an account of how the e-bird came into play for the citizen science initiative and led to a bloom in birders in India. I wonder If I could find a similar sunflower field and reminisce about something sweet. The mentions of birding notes LBT - little brown thing and GOK - God only knows made me take a look back at my birding notes. Why hadn't I ever thought of these acronyms?

Pranav Trivedi's chapter on his nature education program was a delightful read. Getting students and teachers alike interested in nature, and getting feedback from someone like George Schaller is really a cool thing. Swathi Sidhu and Geetha Ramaswani's 'Citizens see the season's signs' gave me a glimpse of the beginning and the progress of seasonwatch. Ammu's Konna tree story was really lovely. It is absolutely true that it takes watching a tree to learn how to be patient, as the author mentioned. P. Jegannathan's confessions of crazy birder are indeed confessions that are crazy. If I was a person who was crazy about birding and had set multiple goals, then this would be something I would have really enjoyed. But this also gave me a glimpse into the level of craze one must possess for the passion he has.

With all these things being said, I wholeheartedly recommend this book to anyone interested in not just conservation, but wildlife in general. Every essay is worth the reading effort. The authors have tried to hold nothing back. Success is mentioned as success and failures as failures. Also, they have gone on to explain the reason for the failure and something that we can learn from. For anyone that is yet to begin reading the book, I have a fun activity: you see that the cover page illustration contains different animals. As you go on reading, try finding where these animals are mentioned. Don't cheat though.

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