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Cover: Himalayan Gray Langur *Semnopithecus ajax* (adult female) © Rupali Thakur.

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COMMUNICATION

SMALL WILD CATS SPECIAL SERIES

The killing of Fishing Cat *Prionailurus viverrinus* (Bennett, 1833) (Mammalia: Carnivora: Felidae) in Hakaluki Haor, Bangladesh

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Abstract: While considerable attention has been paid to the killing of carnivore species which cause significant damage, little attention has been paid to the killings of other carnivores causing less personal and economic damage. We therefore assessed the patterns and motives behind the killing of Fishing Cats *Prionailurus viverrinus* by local people in northeastern Bangladesh. We conducted interviews with local people and used qualitative content and narrative analyses to clarify the pattern and motives of killing. Most Fishing Cats were killed by gatherings of 10–15 people with any available tools. Dead bodies were not used after killing, suggesting that the intention was only to kill the individuals. The results of the survey indicated that fear was the strongest motive for killing, which differed from the motivation behind the killing of other sympatric carnivores. Therefore, we conclude that the killing of Fishing Cat cannot be prevented only by an economic based solution but, rather a change in attitude towards the species among local communities.

Keywords: Conservation, fear, human-wildlife interactions, human-carnivore interaction, motives, small wild cat.

Bengali: ক্ষতিসাধনকারি মাংসাশী প্রাণিনিধনের দিকে উল্লেখযোগ্য দৃষ্টিনিক্ষেপ করা হলেও যেসব মাংসাশী প্রাণী তুলনামূলকভাবে কম ব্যক্তিগত ও আর্থিক ক্ষতির কারণ সেগুলো হত্যার দিকে বিশেষ মনোযোগ দেওয়া হয়নি। এজন্য আমরা বাংলাদেশের উত্তর-পূর্বাঞ্চলের স্থানীয় জনগণের দ্বারা মেছোবিড়াল হত্যার ধরণ ও উদ্দেশ্য নিরীক্ষা করি। আমরা হত্যার প্রকৃতি ও উদ্দেশ্য নির্ণয় করার জন্য স্থানীয় জনগণের সাক্ষাৎকার গ্রহণ করেছি এবং তথ্যের গুণগত বিষয়বস্তু বিচার ও বর্ণনামূলক বিশ্লেষণ করেছি। অধিকাংশ মেছোবিড়াল হত্যার ধরণ ছিল, ১০-১৫ জন লোক জড়ো হয়ে কোনও সহজলভ্য হাতিয়ার দিয়ে হত্যা করা। এমনকি হত্যার পরে মৃতদেহগুলোকেও ব্যবহার করা হয়নি, যা ইঙ্গিত করে প্রানিটিকে হত্যা করাই ছিল একমাত্র উদ্দেশ্য। জরিপের ফলাফল থেকে দেখা যায়, ভয়ই ছিল মেছোবিড়াল হত্যার প্রধান উদ্দেশ্য যা অন্য স্থানীয় মাংসাশী প্রাণি হত্যার উদ্দেশ্য থেকে আলাদা। সুতরাং আমরা এই সিদ্ধান্তে উপনীত হয়েছি যে, কেবলমাত্র আর্থিক সমাধানের মাধ্যমে এই প্রাণিনিধন কমানো যাবে না। বরং এই প্রজাতির কার্যকর সংরক্ষণের জন্য জরুরি এর প্রতি স্থানীয় জনগোষ্ঠীর মনোভাবের পরিবর্তন ঘটানো।

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Author contributions: MNS, AS, SN, and MAA contributed to conceiving and designing the questionnaires. MNS and AP implemented the interview surveys. MNS performed the analyses with the assistance of SN and AS and prepared the first draft of the manuscript. All authors contributed to writing the manuscript.

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INTRODUCTION

Human–wildlife interactions happen in the area where both people and wildlife occur, but it depends on the attitude of society whether it results in conflict or not (Bruskotter & Wilson 2014; Young et al. 2015; Dorresteijn et al. 2016; Frank & Glikman 2019). Interactions between human and wildlife vary from species to species and location (Frank & Glikman 2019). In broad stroke, conflict with large-sized carnivores differ from conflict with small- and medium-sized carnivores in the magnitude and severity of damage caused (Ahmad et al. 2016). For instance, the Forest Department in Bangladesh recorded an average of 20–30 people killed each year by Tigers *Panthera tigris* in the Bangladesh Sundarbans (Inskip et al. 2013), whereas damage caused by small carnivores are generally restricted to small livestock or poultry (Rawshan et al. 2012). Although the damage from small- or medium-sized carnivores is limited, they often live close to human settlements. Consequently, they have more chance to come into contact with people such as Jungle Cat *Felis chaus* in Pakistan (Anjum et al. 2020), Golden Jackal *Canis aureus* in Bangladesh (Jaeger et al. 2007), and Jungle Cat, Golden Jackal and Indian Fox *Vulpes bengalensis* in India (Katna et al. 2022).

This is a conservation concern since killing small- and medium-sized carnivores is relatively easier than killing large carnivores. Even without the significant damage for people's life, the negative interactions between people and small-sized carnivores could be driven by perceived damage (Holmern & Røskaft 2014).

The Fishing Cat *Prionailurus viverrinus* is a small wild cat listed as Vulnerable on the IUCN Red List of Threatened Species; it is thought to be declining across its range (Mukherjee et al. 2016). In Bangladesh, it is categorized as Endangered on the national Red List and is widely distributed throughout the country (Feeroz 2015). It is fully protected throughout the country since 1973 under the Bangladesh Wild Life (Preservation) Order, 1973, and currently under the Bangladesh Wild Life (Conservation and Security) Act, 2012. The killing of Fishing Cats by local people is observed in most of Bangladesh and is possibly carried out in retaliation for perceived predation on small livestock, fish and poultry (Chowdhury et al. 2015). However, little information is available as to how and why local people kill Fishing Cats.

With our present study we sought to clarify the pattern of Fishing Cat killing and to find hints at potential approaches that can assist to modify people's attitude. We conducted in-depth interviews to investigate: 1) how local people in the study area killed Fishing Cats and 2) whether their motives for killing Fishing Cats differed from those for killing sympatric carnivore species like Jungle Cat and Golden Jackal.

Study area

Our study site was the Hakaluki Haor Wetland (HHW), a marshy wetland ecosystem in Bangladesh, which is a bowl or saucer shaped depression that has the appearance of an inland sea during the monsoon floods. It is located in the northeastern part of Bangladesh (Figure 1) and has a total area of 416.14km^2 (CWBMP-DOE-CNRS Consortium 2005) in the Moulvibazar and Sylhet districts and five upazilas, namely Kulaura, Barlekha, Fenchugonj, Juri, and Golapgonj (IUCN 2005). It is surrounded by hillocks, reserve and planted forests, tea estates and rubber plantations with a floodplain area of 700km^2 (Iqbal et al. 2015). Because of its economic and ecological significance, it was declared as one of the ecologically critical areas by Bangladesh Department of Environment in 1999 (Ahmed et al. 2008).

HHW is one of the largest inland wetland ecosystems in southern Asia and encompasses more than 10 small sanctuaries for fish and birds (Khan 2012). It comprises more than 80 inter-connected permanent waterbodies ranging in width from 10m to 1km in the dry season from November to March; these waterbodies merge to a single inundated area extending over 180km^2 during the rainy season from April to October (IUCN 2005). The wetland components of HHW are managed by different government agencies (Khan 2012). Two government agencies govern waterbodies depending on their size, the Forestry Department manages the vegetation and wildlife, and some areas are managed by communities for restoration of plantations (Khan 2012).

HHW support the livelihoods of around 190,000 people. They generally have a lower middle class or middle class economic status (Aziz et al. 2021), with 32% depending on fishing and related professions, 29% on rearing of poultry and cattle, 6% on fuel wood collection, 3% sand extraction, and 2% on reed collection (Rana et al. 2009).

MATERIALS AND METHODS

Firstly, we selected our focused area where killing of Fishing Cats is likely to happen based on information collected since 2017 during a Fishing Cat conservation project as well as provided in electronic and print media and by local forest departments. Secondly, we conducted a pilot survey for testing our initial questionnaire. Thirdly, we conducted a general survey to select respondents who have information on the killing of Fishing Cats and were willing to participate in further in-depth interviews. When they agreed to have their answers recorded, we proceeded with in-depth interviews.

Sampling strategy and approach to interviews

We used non-probability convenience sampling method followed by snowball sampling to identify respondents for gaining a deeper insight on the topic in question (Ritchie et al. 2003; Pratt et al. 2004; Karanth et al. 2008; MacMillan & Han 2011; Said et al. 2016; Saif et al. 2016). The questionnaire for the general survey was designed to acquire general information from respondents about their encounters with carnivores and their presence nearby (see Annex 1). For the in-depth interviews, we prepared a semi-structured questionnaire (see Annex 2) to obtain an understanding of the general scenario and details of events (Rust et al. 2017). Interviews were conducted in Bengali.

We took special care to build trust with respondents to ask for their knowhow about the killing of Fishing Cats. We have worked in this area since 2017 in the framework of a small-scale Fishing Cat conservation project and often talked about Fishing Cat killing. This helped to build the rapport with key persons in the villages. In addition to establish local contacts, we spent time outside the formal interview process with the respondents and their family members, especially children, to gain their trust. We did not collect GPS locations of respondents' homes and did not ask for their names or addresses to avoid security issues and ensured their willingness to provide time for the interview.

Prior to the interview, we asked each respondent for permission to record the interview. We stopped recording if the respondent was not comfortable being recorded. We initially asked for general information about Fishing Cats (Annex 1). Then we conducted an in-depth interview with any person who was involved in a killing incident, or anyone who witnessed such an incident. We verified the

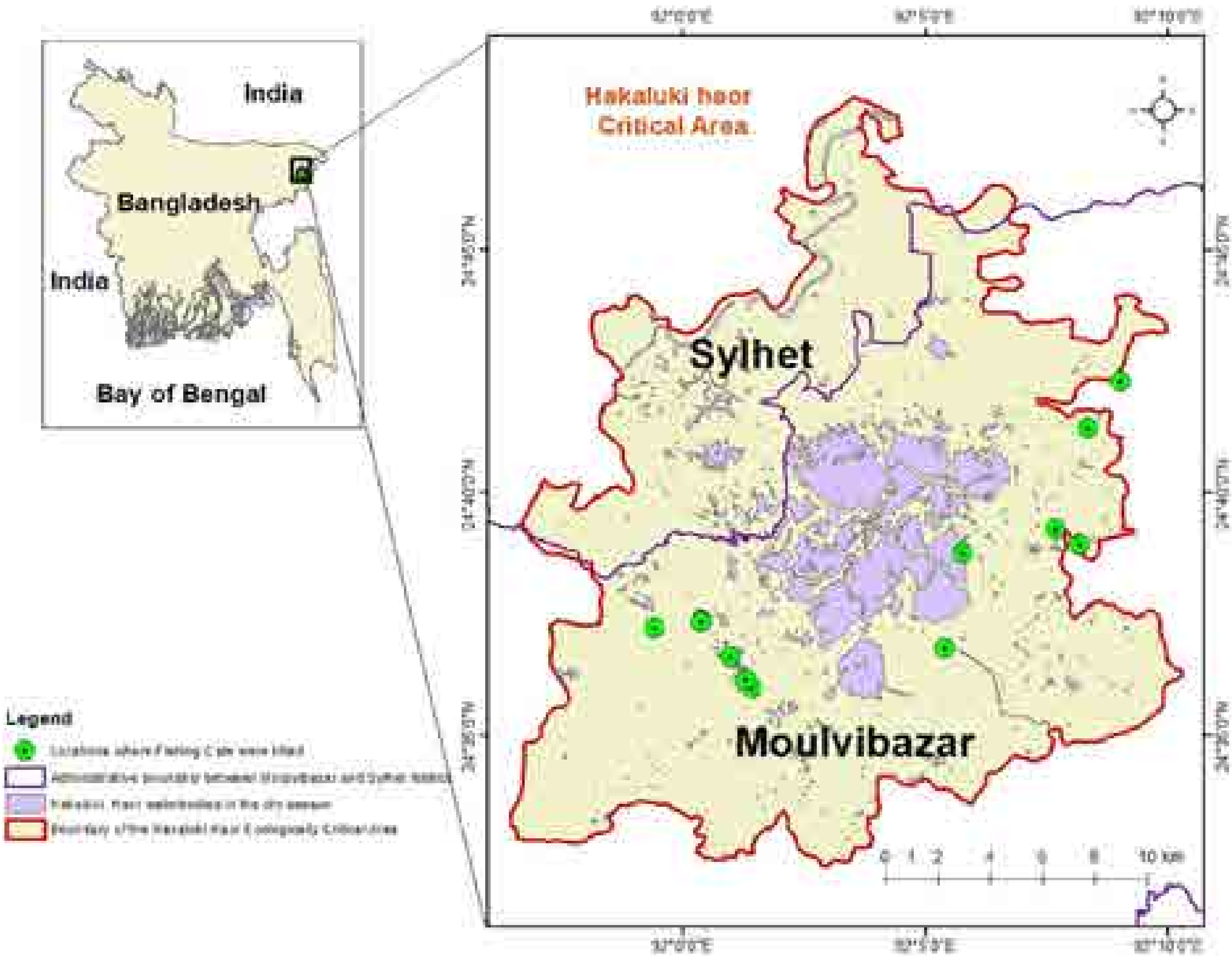

Figure 1. Location of the Hakaluki Haor Wetland in northeastern Bangladesh.

respondent's information on the sighting, encountering and killing of Fishing Cats, Jungle Cats and Golden Jackals by showing them photographs of each animal and asking them to describe the animals' external features. Interviews continued until the data reached saturation (Newing et al. 2011). When we came across the killing information, we conducted interviews in different parts of the village with different respondents in order to verify the episodes and their involvement. The reliability of the episodic data was assessed by asking details about the month, season and local activities at the time of the killing event, e.g. before or after harvesting time, monsoon or not, and how old were their children at that time.

During interviews, we ensured the respondents were not influenced or pressurized by the audience. The interviews were conducted inside respondents' homes in a secluded and silent room to avoid recording talk by other people nearby. We did not provide any financial incentives to the respondents, but spent time with them at the start of each interview to get to know them and their preferred topics of interest.

Analysis

We performed a qualitative content analysis to categorise the motives for each killing incident. We also performed a narrative analysis to describe the general killing pattern. The most common words used by the respondents in the texts and recordings were extracted as motives for the killings. We categorized the motivation mentioned by respondents for the first time as primary motivation. Other motivations mentioned in the course of interviews are considered secondary motivation. We tested the rigour and accuracy of our descriptions and interpretations by comparing seven interview recordings about reported killing events and examined common descriptions to find a common pattern of the killings. To identify major underlying motives for killing, we count the frequency of each motive and categorization of risk as high, medium and low to define the level of each motive.

RESULTS

From 17 February to 16 March 2020, we conducted 133 interviews with a total of 107 respondents in 37 villages of Moulvibazar District (Table 1). Each interview took around 1–2 hours to complete.

General survey

Fishing Cats were sighted in the dry season by 64 respondents (85% of all). Of the 75 respondents, 18 respondents (24%) answered that Fishing Cats came to their village for poultry, 21 respondents (28%) answered that they were looking for a hiding place, and the remaining 36 respondents (48%) did not know the reason. However, 49 of them (65%) have no idea about the trend of the number of killings of Fishing Cat, Golden Jackal, and Jungle Cat.

In-depth survey

From the general survey, we identified 26 respondents (35%) who had joined or witnessed the killing of Fishing Cats and who were willing to answer questions about the process of killing during the in-depth survey. They reported 13 incidents of Fishing Cat killing and three incidents of Fishing Cat rescues in 11 different villages around the HHW in the period from November 2010 to January 2020 (Table 2). Twelve incidents occurred inside villages and one in the wetland area. Local villagers

Table 1. Details of respondents participating in the interview survey.

Interview type	Total number of respondents	Sex	Age class 18–37	Age class 38–57	Age class 58–77	Professions
Pilot survey	32	25 men 7 women	17 men 3 women	5 men 4 women	3 men	10 farmers 5 fishers 4 shopkeepers 5 students 6 daily labourers 2 unemployed
General survey	75	60 men 15 women	-	-	-	-
In-depth survey	26	25 men 1 woman	10 men 1 woman	8 men	7 men	7 farmers 3 fishers 1 hunter 4 shopkeepers 5 students 4 daily labourers 1 housewife 1 businessman

Table 2. Description of each killing incident with the factors involved in killing and the story line for each killing incident.

Case	Year	Season	Who killed	First encounter	What killer did	What happened	Dead body	Other people joined	Assumed species	Incident frequency
1	2010	Dry	Local villagers	Someone found a Fishing Cat sleeping in an unused water pipe	Came to call others to catch it	Village head used gun to kill the Fishing Cat	Buried in nearby field area	Out of fear they tried to kill it	Cheeta Bagh	First Fishing Cat incident in the village
2	2013/2014	Dry	Local villagers along with poultry owner	Observed a Fishing Cat inside a commercial poultry house	Screamed and asked for help to catch it	They caught it with net and beat it to death	Buried far away from home area	Out of fear and avoid next attack to poultry and people	Wild animal (carnivore)	Encountered this type of incident earlier
3	2013/2014	Dry	Local villagers	Regular haor worker suddenly encountered a Fishing Cat	Screamed and called others for help to catch it	They chased and killed it	Drowned in the waterbody	Out of fear that it could attack people and to avoid next attack	Bagh	Encountered many times before
4	2013/2014	Dry	Fishermen	Suddenly got face to face with a Fishing Cat in the haor	Screamed and alerted other fishermen and attacked it at once	Attacked and killed	Drowned in the waterbody	Due to fear and avoid next attack	Khuphia Bagh (Fishing Cat)	Encountered many times before
5	2015/2016	Wet	Local villagers	Suddenly encountered a Fishing Cat, and it tried to come closer	Screamed and asked help to kill the unknown cat	Others tried to catch and kill it	Drowned in nearby irrigation channel	Out of fear and to avoid next attack	Bagher bachcha (Tiger cub)	First incident in the village
6	2018	Dry	Local villagers	Suddenly observed a wild animal inside the village lying in a bushy area	Called other nearby people to identify and catch the cat	They tied the cat with a rope to a tree. People poked it with a stick, took photographs, and eventually it died	Buried the dead body far from locality	Curiosity, also fear to see unknown wild animal	Bagh	Encountered this type of incident earlier
7	2018	Dry	Local villagers	Suddenly observed a Fishing Cat hunting ducks	Screamed and called others for help to catch the cat	All chased and caught it, later beat it to death	Buried in field far from home area	Out of fear that it could attack human and to avoid next attack	Bagh	First incident in village but encountered in haor before
8	2018	Dry	Farmers, local villagers	Fishing Cat hiding in the paddy field	Screamed	Caught and beat it to death	Buried	Curiosity, help others	Cheeta (Leopard)	Encountered many times before
9	2019	Dry	Local villagers	Suddenly encountered a Fishing Cat but had a prior idea of its presence around the village	Screamed and chased it	Caught and killed it	Buried in the nearby field area	Out of fear and disturbance to calves and cow	Wild animal (carnivore)	First killing incident inside village
10	2019	Dry	Local villagers	Chased 3-4 Fishing Cat kittens when found in bush inside village	Screamed and chased them	They caught one kitten and killed it	Took with them	Curiosity to catch Tiger cubs	Cheeta cubs (Leopard cubs)	First incident in the village
11	2019	Dry	Indigenous people	Owner of the house seen before, then informed indigenous people	Search according to information	Caught and killed	Took with them	They went to the incident place out of curiosity	Wild animal (carnivore)	Encountered many times before
12	2020	Dry	Local villagers along with poultry owner	Has prior information about the presence of Fishing Cat	Called other nearby people when saw Fishing Cat sleeping in the poultry house	They chased and beat to death two Fishing Cat	Put out skin of one individual and threw the two dead bodies far away from the village	Other people joined out of fear and to avoid next attack by the same individual	Bagh	First incident in the village
13	2020	Dry	Local villagers	Saw a Fishing Cat sleeping in his cow stable	Silently called relatives living nearby to help him kill the cat	All chased and caught it, later beat it to death	Buried in field far from home area	Out of fear that it could attack human and to avoid next attack	Cheeta Bagh (Leopard)	First incident in village but identified species from Facebook post

around the HHW were the main participants in the killings (Figure 2). One killing incident was claimed to have been conducted by people from the hills who occasionally come down to Hakaluki Haor. Respondents involved in killing events were all men. Each killing generally began with an accidental encounter with a Fishing Cat.

Residents from neighbourhoods in the villages called out to each other when a Fishing Cat was observed (Figure 2). Encounters were mostly sudden, and in 10 incidents people beat Fishing Cats to death in large group gatherings of more than 25 people with any tools they could grab such as a bamboo stick or a knife. When villagers recognized the presence of a Fishing Cat sleeping, hiding or resting in a shed, poultry house and water pipe, they used the time for the preparation to kill the cat. Both situations started from calling neighbours to gather at that spot. When the crowd agreed to kill the Fishing Cat at the encounter point, then the process of killing started.

The bodies of the dead Fishing Cats were not used (Image 1). Local villagers generally disposed of the body after a killing to avoid any health hazard or odour from the decomposing carcass. In four cases, local villagers displayed the carcass in a common area of the village due to a sense of excitement after the killing. In one case, local villager kept the skin of a mature Fishing Cat and disposed of the remaining carcass.

Six constant common traits were present before a kill: 1) The collaboration of the neighbourhood with 5–10 villagers involved; 2) The absence of a knowledgeable person in terms of national wildlife laws; 3) The absence of knowledge about wild animals; 4) The agreement of participants in the killing as retaliation for previous Fishing Cat attacks on livestock and poultry; 5) Previous knowledge of a nearby carnivore attack in the same or neighbouring village; and 6) Direct sighting of a Fishing Cat and misidentification of the species at the time of encounter.

We identified five primary motives of respondents for killing Fishing Cats, namely fear, poultry loss, loss of social respect, social norms and retaliation (Table 3). The main motives given for killing Fishing Cats were "fear" and "social norm" (Figure 3). In contrast, the main motives for killing Jungle Cats and Golden Jackals were poultry loss and retaliation, respectively. Nine respondents (35%) expressed their concerns about poultry loss as their main motivation for killing Jungle Cats, and 11 respondents (42%) mentioned this motive for killing Golden Jackals. Commonly, the prevention of economic loss was the motive for the killing of Jungle Cats and Golden Jackals, but not for killing Fishing Cats. In regard to Fishing Cat, 20 respondents (77%) referred to it as 'Khuphia Bagh' meaning Tiger. Besides those main motives, excitement, and curiosity about killing wild animals, retaliation and self-satisfaction were commonly given as motives for killing Fishing Cat and other carnivore species. Five respondents (19%) emphasized the role of social bonding in their intention to join the killing of all carnivore species.

Image 1. Dead Fishing Cat in our study area.

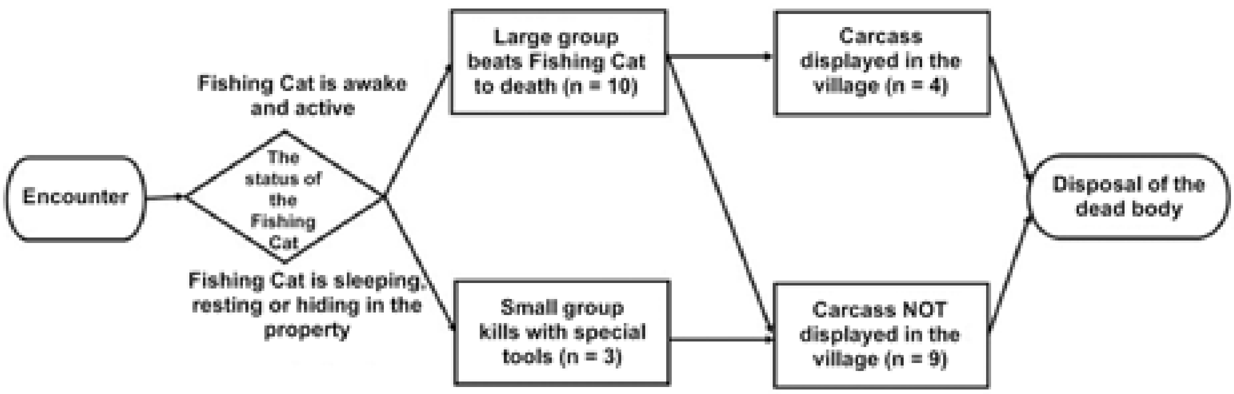

Figure 2. Flowchart of a Fishing Cat killing from the initial encounter to disposal of the carcass by local villagers after the killing had taken place.

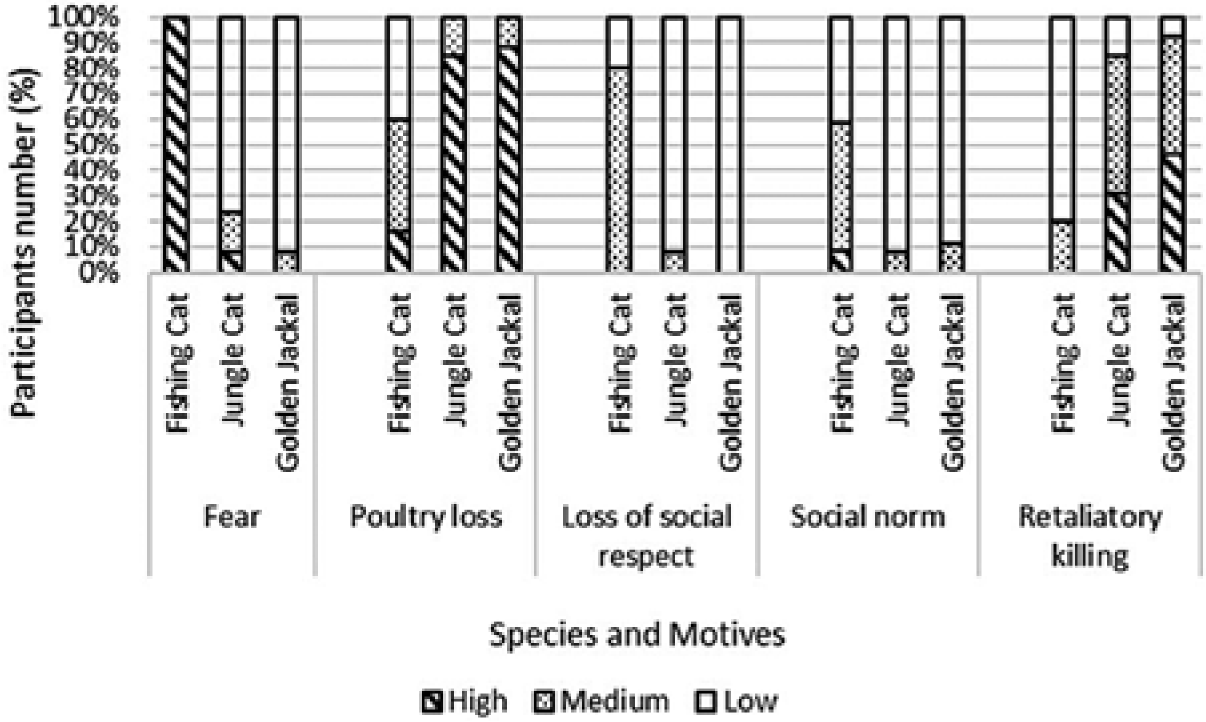

Figure 3. Analysis of respondents' motives in % for killing three sympatric carnivore species. High, medium and low indicate the degree of an individual's motivation for killing each species.

Motives for killing Fishing Cats

Five motives were identified as primary and five as secondary to join in killing Fishing Cats (Table 2). Respondents expressed fear for getting attacked by the cat. They also shared concerns to avoid an attack as a Fishing Cat had attacked poultry or cow before. Twenty respondents were worried of losing social respect if they did not join the killing. Sixteen respondents mentioned revenge for poultry loss to join the killing of a Fishing Cat.

Moreover, respondents shared concern about a sighting of a Fishing Cat as they were worried about being attacked by it, assuming Fishing Cat to be a Tiger. When asked about how often this cat comes to the village, respondents stated:

"Twice may be. I told you that last year, this Tiger attacked our religious leader. I tell we have to face it, there is no safety for us here."

"Did it ever take any poultry? Yes! They also took poultry and attacked people at night. People felt so at risk at that time, they never returned back alone from the market, always stayed in groups. Or if they had to move alone, they kept some tools with them."

"This is a communication road used for going to school, college and markets, we all the time stay in the market area, everyone in the area says there is a Tiger, do not get late to come home. It was kind of a panic situation. So, after it got killed the panic vanished as the Tiger was dead. This happened once upon a time, not now, already being killed." When asked about its spotted skin and size, a respondent showed a young animal and replied: "Yes, similar like this, and two individuals. I have seen the Tiger directly at late night after watching movie. It was crossing the road. Then someone saw it and screamed "Tiger, Tiger is there", and we ran towards it." "We call it Tiger. Leopard? Kind of that."

DISCUSSION

Our study was the first attempt to gain an understanding of the detailed process of the killing of Fishing Cats in Bangladesh and motives underlying this killing. Our interviews in villages of Hakaluki Haor revealed two types of killing patterns that depend on the activity of the Fishing Cat encountered. When it was active, people spontaneously gathered in a large group of more than 25 people and reached for any available tools to beat the Fishing Cat to death. This killing pattern is commonly seen in the killing of other carnivores, which can cause loss of livestock or threaten human life, both in Bangladesh (Inskip et al. 2014) and in India (Kolipaka 2018). Saif et al. (2018) described similar large gatherings

Table 3. Examples of respondents' narratives about their motivation for killing Fishing Cats.

Primary motives	Narrative of respondents
Fear	Eight respondents of both the general and in-depth questionnaires mentioned fear as the reason for joining a killing. Eleven respondents directly used the word fear as the primary reason, and six respondents mentioned fear as a secondary reason for joining a killing event. One 37-year-old respondent described a killing as follows: "Some saw it in the water pipeline and got scared. We were playing football in the nearby field, and they ran to us to let us know. We were all scared and ran to our chairman. He has a gun." Another respondent described the event: "It was roaming around the village for the last three or four days. One evening, one woman saw it on the way to the market, she informed others in the village that she encountered a Tiger in the village. Later some young boys planned to kill it, looked for its location. The next morning, they went to kill it in a huge group. We tried to kill to prevent a next attack on our poultry. We went with almost 100 people to kill it for future human safety." Further questioning about motives, this respondent replied: "When I saw it, it looked scary, it was angry and if got chance it would have killed me. I got scared and …"
Poultry los	Nine respondents mentioned poultry loss as motives. Three respondents used the word livestock safety as the main reason to join in the killing. One of them described his encounter as follows: "It was sleeping in the straw at our cow stable. I went to check my cows before sleeping. Suddenly I saw it and got scared. Then I immediately went back inside the house and let my other family members know. We all decided to kill it for the safety of our cows and us. Otherwise, if it awoke, it could attack our cows. So for our calf's safety we killed it."
Social norm	"If majority people go, I have to go, to chase it or kill it. All the time, it was in my mind that next time if I get attacked, they might not help if I do not join this time."
Retaliation	Local villagers have experienced carnivore attacks on poultry, and therefore some of them will attack any carnivore out of retaliation. Sixteen respondents mentioned retaliation as a motive to attack Fishing Cats. A poultry farmer described one incident as follows: "We decided to kill it because it took some poultry, and each year Golden Jackals and Jungle Cats also take poultry. We killed it to take revenge for our previous poultry losses."
Loss of social respect	Twenty respondents mentioned a medium level of risk to loss of social respect if not joining or denying help in Fishing Cat killing. One respondent explained: "I can say no to join in killing, but he might mind about it, and the rest of life he will remember that and choose not to be my friend anymore." During the general discussion, eleven respondents said it was important for them to join in with the killing as a good neighbour or relative. This thinking derived from the social setting. One incident was described as follows: "If I didn't help to kill it, next time they will not help me either. They also consider me to be brave." Joining in with a killing determines social reputation and ranking; there is some pressure from other people in the village.
Secondary motives	
Excitement and curiosity	Four respondents mentioned excitement and curiosity as a motive to participate in a killing event. Mainly young people in the age class 18–37 years mentioned this as a reason to join a killing incident. One of them described the situation as follows: "Some people took the initiative to kill it, but most people joined in from curiosity and excitement."
Medicinal use	One female respondent provided information on medicinal use of Fishing Cat body parts. She described this as follows: "Every year, a group of indigenous people come to our village to hunt wild animals. They hunt Jungle Cat, Golden Jackal, civets and rats. As far I know they eat those animals, and there are also some medicinal uses for the different parts."
Self- satisfaction	"One person kept the skin of the bigger species. He said, he wants to have it just to keep it with him." Only one such case was recorded.
Consumption	Two incidents were reported of indigenous people eating Fishing Cats.
Pos ble trade	One interviewee shared his thoughts as follows: "After that incident a forest official asked us to capture one Fishing Cat. They said they needed it for a zoo. But we could not find any Fishing Cat near our village."

of people using an array of tools for killing Tigers in the Bangladesh Sundarbans. When the Fishing Cat was resting or sleeping, people usually formed a group of 5–10 people and used guns, local fishing gear or bamboo implements to kill the cat. Both patterns are unique in regard to Fishing Cats, whereas respondents did not feel the need to gather in groups and be well equipped when encountering Jungle Cats and Golden Jackals.

Such preparation for special tools including axes, sticks, bamboo rods and billhooks are generally used in encounters with large damage-causing animals (Saif et al. 2018). We found a similar behaviour in our study area that small groups of people joined to kill Fishing Cats suggesting that people feel the need to be well equipped to make sure to kill Fishing Cats. Both killing patterns started by calling neighbours for help to form small to large groups to join the killing events of Fishing Cat. We emphasize that this behaviour is unique towards the Fishing Cat. Chowdhury et al. (2015) described similar severe beatings, strangulations and captures of Fishing Cats elsewhere in Bangladesh by mobs of villagers who later hung up the dead animals for display. In contrast, villagers in our study area attempted to kill Jungle Cats and Golden Jackals without the help of neighbours and special tools.

The motivation for killing Fishing Cats

Our results suggest that fear is a strong motivation for killing Fishing Cats. Fear is assumed to be induced by large carnivores that people perceive as harmful (Castillio-Huitrón et al. 2020). Inskip et al. (2014) found worry and fear of harm by Tigers in Bangladesh to be a stronger motivation than retaliation. Carnivore killing behaviour is complex and nuanced, sometimes driven by emotions like fear (Johansson et al. 2016). Such negative emotions represented a significant motivation for the killing of Fishing Cats. In contrast, respondents killed other medium-sized carnivores mainly in retaliation for poultry loss.

The reason why only the Fishing Cat evokes the feeling of fear within the community needs further study. The most plausible reason is that local villagers confuse Fishing Cats with animals related to Tigers and consider them to be potentially dangerous. Respondents used the word "Bagh" for Fishing Cats throughout their stories when explaining their concerns about safety and risks. The local name "Bagh" means Tiger. Their concept of "Bagh" is often likely to be more abstract concept as "kind of a Tiger", when they put other words in front of "Bagh" such as "Cheeta Bagh" (a spotted Tiger) indicating Leopard *Panthera pardus*, "Khuphia Bagh" indicating Fishing Cat. On the other hand, Jungle Cat has not been called "Bagh", as locals did not consider it being a member of the "Tiger" group.

Common motivations for killing carnivores are for the use of their body parts like skins (Datta et al. 2008), fur (Saif et al. 2016), and meat (Harrison et al. 2016). In our study area, neither parts nor the whole body of Fishing Cats were used by local people after a kill. Only the Fishing Cat's carcass was displayed in the common areas of villages out of a sense of excitement after the killing. This may indicate that the excitement of successfully killing which is also a reason to join a killing event (Røskaft et al. 2007; Saif et al. 2018).

Implications for conservation practices

Although three sympatric carnivores have been killed in our study area, an economic incentive-based conflict mitigation plan is unlikely to be effective for the conservation of the Fishing Cat. Emotional fear-based behaviour is more difficult to control (Castillo-Huitrón et al. 2020), and it is often difficult to effectively implement measures with a cognitive fix, i.e. changing attitude and behaviour by providing knowledge (Heberlein 2012). On the other hand, the technological fix, i.e. changing behaviour by addressing a particular environmental problem (Heberlein 2012) could be applied by intervening in the steps of the process of killing Fishing Cats. Six constant common traits were found across all 13 cases including collaboration with neighbours who were not aware of the illegality of the killing. The first step to make it difficult to kill Fishing Cats technically would be to explore which of those six common traits are necessary conditions in the society to kill Fishing Cats, and which of those can act as strong barriers to stop the process of killing.

It may be difficult but not impossible to reduce people's willingness for fear-based killing in the long term. Although fear often evokes automatic appraisal, the learning could change the cognitive process when the fear is based on a false perception (Jacobs & Vaske 2019). This emphasizes the importance to dispel the misconception about the Fishing Cat in the long term such as education for the younger generation. We suggest developing outreach strategies to retrieving a positive perception for animals integrated with local culture. Positive interest and attention towards species could favour changing people's perception for conserving the species. Prokop et al. (2011) suggested that if children see wildlife species in a positive way through different media showing the real facts about unpopular animals, this is more likely to decrease fear and disgust but develop empathy. Species-specific positive ecological knowledge sharing with new generations could lead to eradication of the embedded fear in the society, increase awareness, impact attitudes, and advocate empathy.

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Annexure 1. General questionnaire on Fishing Cat, Jungle Cat, and Golden Jackal.

1. Where do the Jungle Cat, Golden Jackal and Fishing Cat usually live? (GPS: Location of sighting)
2. How many years they are living in that place?
3. Why are they living there?
4. How many of them are living there? (House/ Haor/ nearby bushy area)
5. What do they eat?
6. In which season are they seen much?
7. If they are not seen all the year round, then where do they live during the rest of the time?
8. Is bush area or house enough for the survival of these species (Fishing Cat, Jungle Cat, Golden Jackal)?
9. Are they being killed around village in last five years? If not, why are not being killed?
10. What would you like to see happen to the numbers of the following animals in this area, and why?

	Increase	Decrease	Disappear completely	Stay the same	Don't know	Why?
Fishing Cat						
Jungle Cat						
Golden Jackal						
Other small carnivores						

Annexure 2. In-depth questionnaire.

Interview No. Interviewer Name: Interviewee Name: Longitude Latitude	Date: Time: Union Name: Village Name: Religion:

General information

Age				Occupation					
Sex									
How long you have been living in this village?				Since I was born	Yes				
					No: Since When?		Year:		
Education		Illiterate			Primary incomplete		Primary complete		Secondary incomplete
		Secondary complete			Higher than Secondary				

Identify Fishing Cat

Species	Description
Fishing Cat	
Jungle cat	
Golden Jackal	

Photo of the species	Yes	No	Others
Fishing Cat			
Jungle Cat			
Golden Jackal			

Identify the killing pattern

1. Have you ever been a part of killing incident?			
	Fishing Cat	Jungle Cat	Golden Jackal
Yes			
No			

2. How did you find out about the killing incident?			
Species	Someone's scream	Ask for help from neighbour, relative, village head	Later from someone in the village
Fishing Cat			
Jungle Cat			
Golden Jackal			
Other carnivore			

3. Which news you got first?			
Species	Kill	Catch	Encounter
Fishing Cat			
Jungle Cat			
Golden Jackal			
Other carnivore			

4. When did the incident happen?					
Species	Early morning (Dawn)	Day time	Late afternoon (Dusk)	Night with electricity	Night without electricity
Fishing Cat					
Jungle Cat					
Golden Jackal					
Other carnivore					

5. How many times it happened? (Within five years) and when?					Year, probable time
Species	Once	2–3 times	5–10 times	More than 10 times	
Fishing Cat					
Jungle Cat					
Golden Jackal					
Other carnivore					

6. Which season, month?					
Species	Summer (May-July)	Rainy (August-Oct)	Winter (Nov-Jan)	Spring (Feb-Apr)	All the year round
Fishing Cat					
Jungle Cat					
Golden Jackal					
Other carnivore					

8. Place of the incident						
Species	Near home area	In the Haor	Near poultry	Paddy field	Edge of the haor	Near pond
Fishing Cat						
Jungle Cat						
Golden Jackal						
Other carnivore						

9. Who took step first towards the animal?				
Species	Male, Female	Young (10–20, 21–45)	(46–60, 61–80)	Above 80
Fishing Cat				
Jungle Cat				
Golden Jackal				
Other carnivore				

10. Where encountered first?						
Species	Near home area	In the Haor	Near poultry	Paddy field	Edge of the haor	Near pond
Fishing Cat						
Jungle Cat						
Golden Jackal						
Other carnivore						

11. What were the surroundings?								
Species	Inside house	Open agricultural field	Pond	Poultry house	Small bush	Planted forest (social forestry)	Inside haor	Edge of haor
Fishing Cat								
Jungle Cat								
Golden Jackal								
Other carnivore								

12. How many people gathered at that time?				
Species	1–5 person	5–10 person	10–25 person	More than 25 person
Fishing Cat				
Jungle Cat				
Golden Jackal				
Other carnivore				

13. Who accompanied you?					
Species	Neighbour	Relatives	Forest officials	Village head	No one
Fishing Cat					
Jungle Cat					
Golden Jackal					
Other carnivore					

Species	Nearby people	Outsiders	Young (10-20/ 21-45)	(46-60/ 61-80)	above 80
Fishing Cat					
Jungle Cat					
Golden Jackal					
Other carnivore					

14. Why they accompanied you?					
Species	Social norm	Same group people	Avoid next attack	Afraid of losing respect	Money
Fishing Cat					
Jungle Cat					
Golden Jackal					
Other carnivore					

15. What you used to kill?							
Species	Stick bamboo	Iron material	Brick	Net, trap, poison	Wood	Branch of tree	Other equipment
Fishing Cat							
Jungle cat							
Golden Jackal							
Other carnivore							

16. After killing what you do with the body?						
Species	Drowned in nearby river, well, waterbody	Buried	Collected by forest officials	Just throw far away	Displayed in the village	Used some part
Fishing Cat						

Jungle Cat						
Golden Jackal						
Other carnivore						

17. Is there any official procedure after the killing?					
Species	Forest officer fined you	We informed	Got jailed	We did not inform	No procedure
Fishing Cat					
Jungle Cat					
Golden Jackal					
Other carnivore					

18. Why it came near to killing spot?						
Species	Poultry	Less prey in haor	It lives nearby	Got old	Don't know	Other reason
Fishing Cat						
Jungle Cat						
Golden Jackal						
Other carnivore						

19. How you describe the incident to others?					
Species	Share with neighbour	Share in the market	I hide it	I shared proudly	It is usual incident
Fishing Cat					
Jungle Cat					
Golden Jackal					
Other carnivosre					

20. Did you face any economic loss because of any previous attack?		
Species	Yes	No
Fishing Cat		
Jungle Cat		
Golden Jackal		
Other carnivore		

21. How much economic loss you faced?				
Species	< 1000 BDT	< 2000 BDT	< 5000 BDT	> 5000 BDT
Fishing Cat				
Jungle Cat				
Golden Jackal				
Other carnivore				

For recommendation

1. What is your relationship to people to join the killing event of Fishing Cats together?
2. If you find a Fishing Cat to kill, who are you going to call for help first?
3. Do you think what would happen if you do not join to help people to kill Fishing Cats?
4. How do you rank the importance of helping your neighbours to kill Fishing Cats in terms of your social status in your village? Not at all important, very important
5. After you and your neighbour succeeded to kill a Fishing Cat, whom are you going to tell first?
6. Did you hear of any killing information of Fishing Cat from other places?
7. What can improve the Fishing Cat human relation, co-existence? What can decrease the killing? Do nothing Habitat restoration translocation lethal control
8. Increase or decrease on killing, encounter over last 10 years? Yes No
9. Why? Explain briefly your thinking.
10. Briefly describe about how did you kill the Fishing Cat, Jungle Cat, Golden Jackal? Start the story from beginning.
11. What do you think are the most effective ways of protecting yourself from small carnivores?

Fishing Cat:
Jungle Cat:
Golden Jackal:

Other small carnivores:
12. Do you use these methods? If not, why not?
13. Do you know anything about wildlife act and laws? If yes, describe briefly.
14. Is there any legal action you know about killing wild animal or small carnivores?
15. What makes you kill the species? Rank the factors accordingly

For Fishing Cat:

Factors	Low	Medium	High
Fear			
Poultry loss			
Social respect loss			
Social norm			
Retaliatory killing			

For Jungle Cat:

Factors	Low	Medium	High
Fear			
Poultry loss			
Social respect loss			
Social norm			
Retaliatory killing			

For Golden Jackal:

Factors	Low	Medium	High
Fear			
Poultry loss			
Social respect loss			
Social norm			
Retaliatory killing			

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COMMUNICATION

Feeding ecology of the endangered Himalayan Gray Langur *Semnopithecus ajax* in Chamba, Himachal Pradesh, India

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Abstract: This study on the feeding ecology of Himalayan Gray Langur or the Chamba Sacred Langur *Semnopithecus ajax* is a crucial baseline step as very little is known about this species due to its long taxonomic uncertainty and limited distribution range. This study was done in Kalatop-Khajjiar Wildlife Sanctuary, Chamba, Himachal Pradesh using scan sampling method. A total of 71 scan samples were collected in the study area from September 2020 to November 2020 focusing on the autumn diet of the species. Group size, group composition, and distribution of the langurs were also recorded. Totally, 20 species of plants belonging to 15 different botanical families were recorded which contribute to the diet. *Hedera nepalensis, Quercus oblongata,* and *Ilex dipyrena* formed the major components of the diet. The langurs consumed a substantial portion of leaves (84.32%), followed by fruits and flowers. Mature leaves being a part of the diet of langurs has proven the broaden repertoires of langurs inhabiting the Himalayan landscape**.** Also, a difference in the diet composition of two study groups was recorded which might be the result of varying distribution with respect to elevation.

Keywords: Chamba Sacred Langur, diet consumption, food ecology, Himalaya, Kalatop-Khajjiar Wildlife Sanctuary, primate.

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Author contributions: RT— was involved in field surveys and data collection, data analysis, data interpretation, and writing of the paper. KY- providing all necessary help for permissions from forest department, guiding at every step and discussions periodically regarding the data collection and manuscript correcting at every stage till it was finalized.
PA- was involved in conceptualization of study, helped in framing methodology, provided every guidance during the whole study.

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INTRODUCTION

The Himalayan Gray Langur was first described by Pocock in 1928 as the least known langur which is found in the western Himalaya (Pocock 1928). Previously, the Himalayan Gray Langur was considered as a sub-species of *S. entellus*. In 2005, it was separated as a species (Walker & Molur 2004; Groves et al. 2005). However, a recent study confirms the species status of the Himalayan langurs (Arekar et al. 2021) which supports *Semnopithecus schistaceus* to be the single species representing Himalayan langurs. The study does not support splitting of Himalayan langurs into three species or sub-species. But, it has been recorded that the western population of Himalayan langurs do form a well-supported subclade (Arekar et al. 2021). Also, the study supports the taxonomy given by Hill (Hill 1939) in which *S. ajax* was mentioned as a sub-species. Hence, this study will consider the population in Kalatop-Khajjiar Wildlife Sanctuary (Western Himalaya), which is close to the type locality of the species, as *Semnopithecus ajax* until a detailed taxonomic study on the western population clarifies this issue according to the International Code for Zoological Nomenclature guidelines.

According to previous research, the species is known to be found in three countries including India, Nepal, and Pakistan. It was found in Great Himalayan National Park, Kalatop-Khajjiar, and Manali Wildlife Sanctuary in Himachal Pradesh (Walker & Molur 2004). Strong evidences suggest that in Himachal Pradesh, *S. ajax* is restricted to Chamba valley (Pocock 1928; Brandon-Jones 2004; Walker & Molur 2004; Groves & Molur 2008). Currently, *Semnopithecus ajax* is considered 'Endangered' globally because "the population is very small, estimated to be less than 1,500 mature individuals in 15–20 subpopulations with no subpopulation having more than 150 mature individuals" (Kumar et al. 2020).

Studying the diet composition of animals facing harsh conditions offers an insight into their interaction with the extreme environments and understanding their ecology (Mir et al. 2015). It is crucial to gain information about the diet preferred by this endangered and endemic species of the Himalaya for future conservation actions. Scan sampling method has been used in many studies to estimate the diet composition of primates where it was not possible to follow a focal group for longer periods (Marsh 1981; Stanford 1991; Newton 1992; Dasilva 1994; Li & Rogers 2004; Dela 2007; Guo et al. 2007; Mir et al. 2015). This paper presents a preliminary information about diet of Himalayan Gray Langurs in Kalatop-Khajjiar wildlife sanctuary between September 2020 to November 2020.

Study area

The study was conducted in Kalatop-Khajjiar Wildlife Sanctuary located within the geo-coordinates (32.52417–32.56611 °N & 76.01–76.06667 °E) in Chamba district, Himachal Pradesh. The area of the sanctuary has been reduced to 17.17 km^2 subsequent to rationalization by the state government (Notification No. FEE-B-F (6)11/2005-II/Kalatop-Khajjiar dated 07 June 2013). The Kalatop-Khajjiar Wildlife Sanctuary is located in the western extremity of the Dhauladhar range of western Himalaya at an altitude ranging of 1,185–2,768 m. It is one of the oldest preserved forests of Himachal Pradesh (notified on 01.vii.1949) located in the catchment area of the Ravi River (Kumar et al. 2014; Shah et al. 2016). Mean annual rainfall is 800 mm and temperature ranges -10–35 °C. The area experiences southwestern monsoon rains in July–September (Shah et al. 2016). The vegetation of the Kalatop-Khajjiar Wildlife Sanctuary is mainly moist Deodar forest and western mixed coniferous forest with alpine pastures at some higher elevations (Champion & Seth 1968).

METHODS

The study on the feeding ecology of the endangered Himalayan Gray Langur was conducted from August 2020 to January 2021. The data collection was divided into primary and secondary data.

Secondary data

Previous research papers on the diet of *Semnopithecus ajax* were studied and separately analyzed. The resulting analyses from all the literature was then compared with each other and the common elements were estimated using statistical methods in MS Excel to plot graphs.

Primary data via scan sampling

Feeding data for Himalayan Gray Langurs was collected via scan sampling method (Altmann, n.d. 1974) for two months between September 2020 to November 2020 focusing on the autumn diet of the species. The scan interval was set at 5 min for 15 min scan sample. The groups were followed from around 0900 h (first established visual contact with the group) to 1500 h (when visual contact was lost or no feeding). All the observations were done through the naked eye or DSLR (Nikon D3500). The entire wildlife sanctuary is divided into two forest divisions namely, Kalatop forest

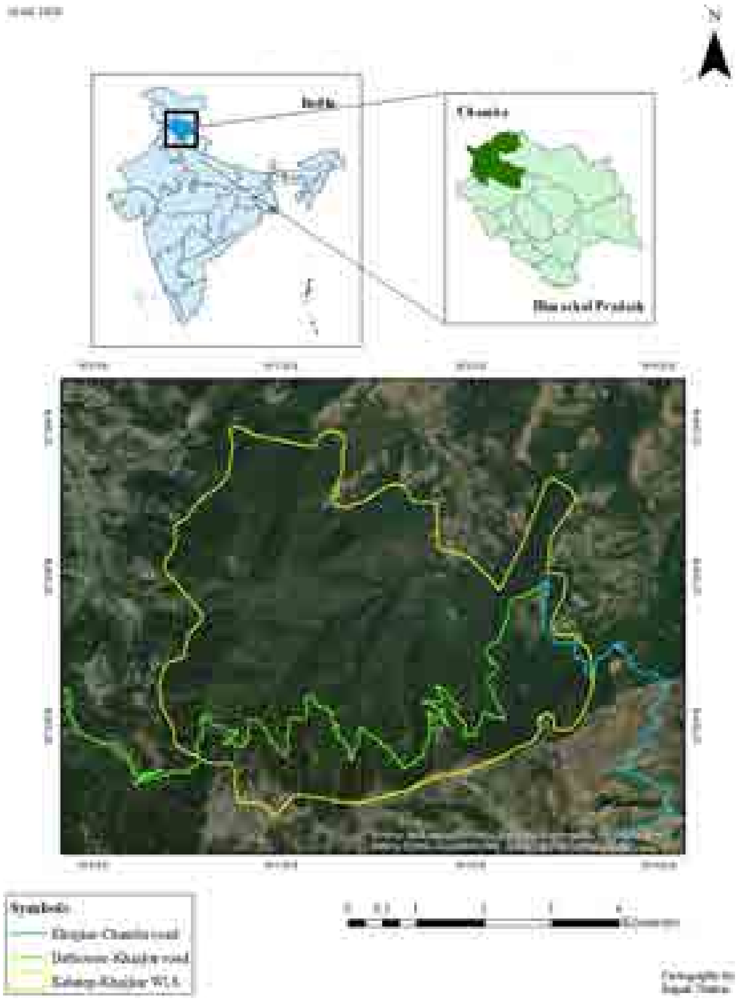

Image 1. Study area: Kalatop-Khajjiar Wildlife Sanctuary.

and Khajjiar forest. One month of sampling per forest was conducted. A total of 71 scan sampling observations were collected and later used for analysis. Data such as group identification, GPS coordinates, group composition (age-sex classification), and group size were collected in the initial 10–15 min after the encounter with langurs. During feeding behavior, each visible animal was observed for about 5–10 seconds and plant species and the part of plant eaten were observed. Plant specimens were later collected for further identification which were also used to prepare a dry herbarium. Plant parts were classified as leaves (Mature and young or leaf buds), bark or stem, fruit, flower, and seed.

Analysis

Diet: Percentage contribution of each plant species in the diet of Himalayan Gray Langurs was estimated by using the formula: $Pa = (na / N) *100$

Where, na is the total number of times feeding was observed on species a, and

N is total feeding observed for all species during the study period

Percentage of time spent feeding on different plant parts have been calculated (Guo et al. 2007) as: (Number of scans where item i was recorded as food / Total number of scans where feeding was recorded) *100

A digital herbarium has been created with the help of Microsoft PowerPoint enlisting all the food plant species eaten by the Himalayan Gray Langurs inside the sanctuary.

RESULTS

Diet composition from secondary data

Six genera (*Aesculus, Quercus, Hedera, Salix, Berberis,* and *Prunus*) contributed to the major share of Himalayan Gray Langur's diet as shown from previous studies. It also reflects that genus *Aesculus* is the most preferred by langurs.

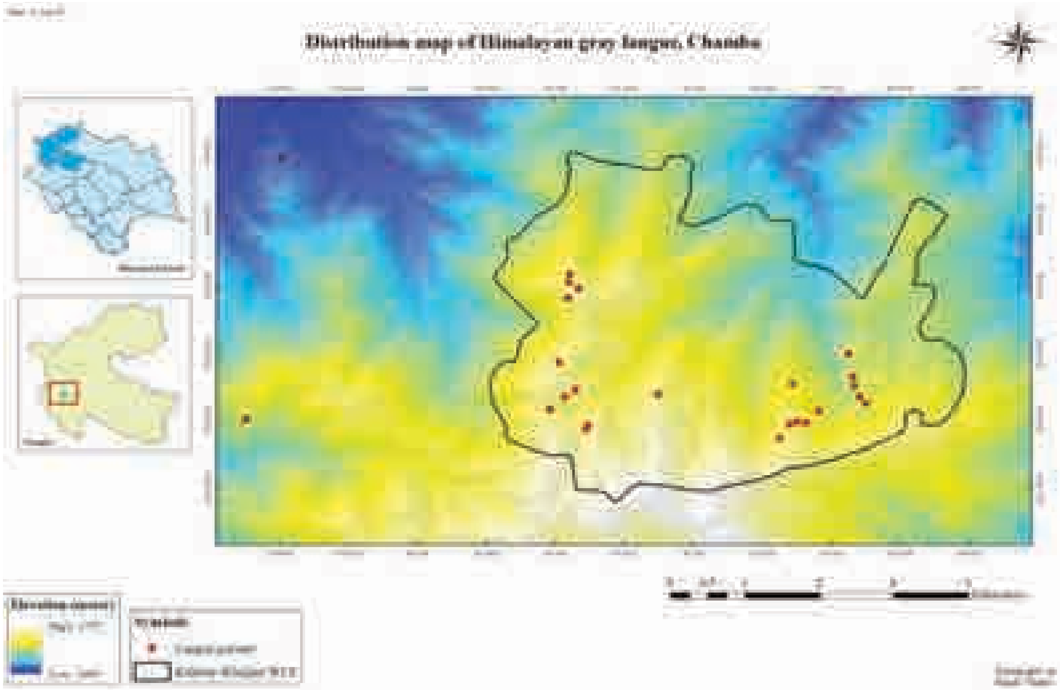

Image 2. The distribution of Himalayan Gray Langurs in and around the Kalatop-Khajjiar Wildlife Sanctuary.

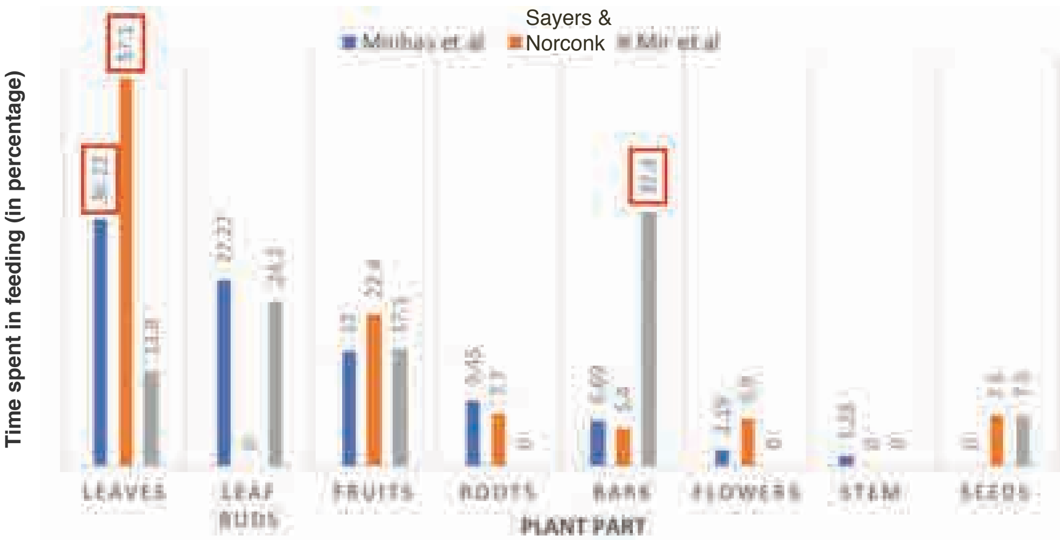

Figure 1. Time spent on different plant parts by Himalayan Gray Langurs (in percentage).

From previous studies (Sayers & Norconk 2008; Minhas et al. 2010; Mir et al. 2015) it has been shown that Himalayan Gray Langurs spent most of their feeding time on leaves and leaf parts (Figure 1) which highlights their folivorous diet that has been clearly reflected in case of both Minhas et al. and Sayers (Sayers & Norconk 2008; Minhas et al. 2010). But Mir et al. (2015) observed that bark is more preferred as compared to leaves because this particular study was conducted in the winter season and it was more focused on the winter survival strategies of these langurs in the Himalayan terrain of Dachigam National Park.

Results from primary data

Total five groups of langurs were observed during the entire study period (Table 1). Out of these five groups, two groups (A and B) were located outside the protected area near the boundaries. The distribution of Himalayan

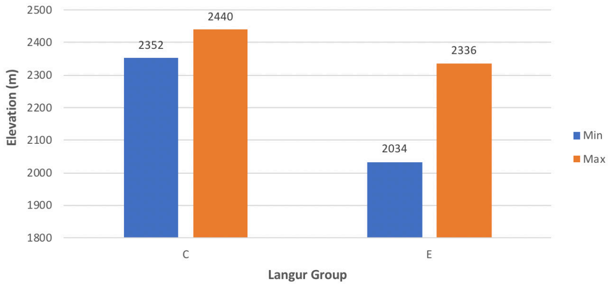

Figure 2. Distribution of Langur groups based on elevation.

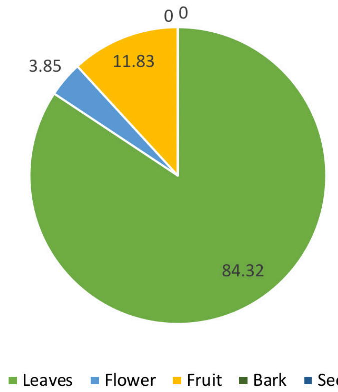

Figure 3. Composition of different plant parts (in percentage) in the diet of langurs during autumn season.

Gray Langurs inside and around the Kalatop-Khajjiar wildlife sanctuary is illustrated in Image 2 which shows the presence of langurs at varying elevations inside the study area ranging 1,400–2,500 m. Out of these five groups, two groups—Group C and Group E located in Kalatop forest and Khajjiar forest respectively—were followed for observation on diet composition as observations of all five groups were limited due to habitat characteristics. The elevation range for Group C was 2,352–2,440 m and for Group E was 2,034–2,336 m (Figure 2); average being 2,396 m for Group C (Kalatop) and 2,188 m for Group E (Khajjiar) with a difference of ~200 m.

Diet composition

Langurs in Kalatop-Khajjiar were observed to feed on 20 plant species from 15 different botanical families found naturally in their habitat during the autumn season. Nearly half of the langur diet (54.39%) was found to be made up of leaves of *Hedera nepalensis* and *Quercus oblongata*. Fruits of *Ilex dipyrena* also constituted nearly 10% of the langurs diet, followed by the leaves of *Rumex nepalensis*. The percentage contribution of other species to the langur diet is given in Table 2. Langurs from Kalatop forest were also observed to feed occasionally on a fungus species (*Russula* spp.) growing on the forest floor.

During the entire study period, langurs shown

Table 1. Group size and composition of five groups of Himalayan Gray Langurs in and around the Kalatop-Khajjiar Wildlife Sanctuary, Chamba, Himachal Pradesh.

Group	Group size	Group composition			
		Adult male	Adult female	Sub-adults	Infants
A	12	1	3	NA	2
B	20	1	7	4	NA
C	38	2	14	12	7
D	35	1	10	13	8
E	48	2	24	21	3
Total	**153**	**7**	**58**	**50**	**19**

Count of total individuals and sub-types are an estimate only (not exact) and few sub-types are marked as NA because they could not be counted accurately.

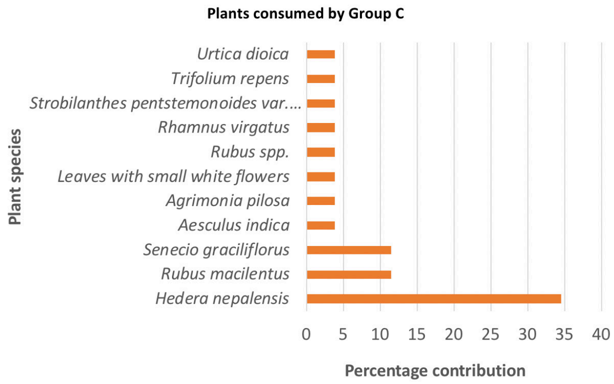

Figure 4. Percentage contribution of different plants for Group C (Kalatop).

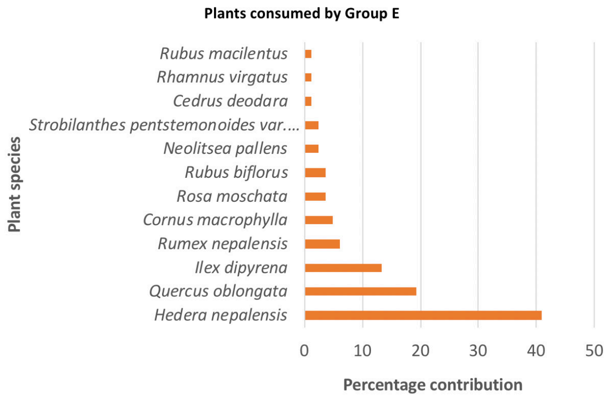

Figure 5. Percentage contribution of different plants for Group E (Khajjiar).

Plants consumed by Himalayan gray langurs in Kalatop-Khajjiar WLS during the study period

S.no	Plant Species	Local name	Family	Type	Part consumed
1	*Aesculus indica*	[illegible]	Sapindaceae	Tree	Fruit
2	*Agrimonia pilosa*	[illegible]	Rosaceae	Herb	Flower
3	*Berberis lycium*	[illegible]	Berberidaceae	Shrub	Fruit
4	*Cedrus deodara*	Dyar	Pinaceae	Tree	Leaves
5	*Cornus macrophylla*	[illegible]	Cornaceae	Tree	Fruit
6	Grass species			Herb	Leaves
7	*Hedera nepalensis*	[illegible]	Araliaceae	Climber	Leaves
8	*Ilex dipyrena*		Aquifoliaceae	Tree	Fruit
9	*Neolitsea pallens*	[illegible]	Lauraceae	Tree	Leaves
10	*Quercus oblongata*	Ban	Fagaceae	Tree	Leaves
11	*Rhamnus virgata*		Rhamnaceae	Shrub	Fruit
12	*Rosa moschata*	[illegible]	Rosaceae	Shrub	Fruit
13	*Rubus* [illegible]	Akhe	Rosaceae	Shrub	Leaves
14	*Rubus* [illegible]	[illegible]	Rosaceae	Shrub	Leaves
15	*Rubus* spp.		Rosaceae	Shrub	Leaves
16	*Rumex nepalensis*	Jangali palak	Polygonaceae	Herb	Leaves
17	*Senecio graciliflorus*	[illegible]	Asteraceae	Herb	Flower
18	*Strobilanthes pentstemonoides* var. *dalhousianus*	[illegible]	Acanthaceae	Herb	Flower
19	*Trifolium repens*	[illegible]	Fabaceae	Herb	Leaves
20	*Urtica dioica*	[illegible]	Urticaceae	Herb	Leaves

Image 3. Digital herbarium a—Title slide | b—List of plants consumed by Himalayan Gray Langurs.

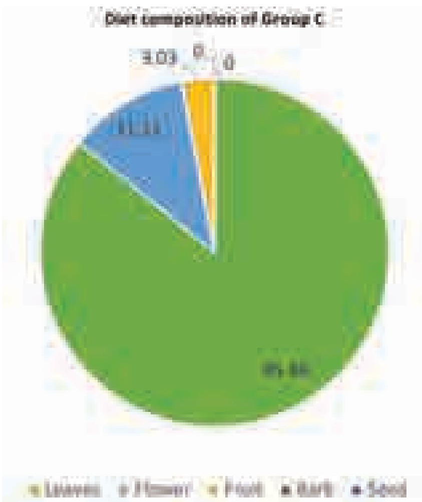

Figure 6. Diet composition of Group C.

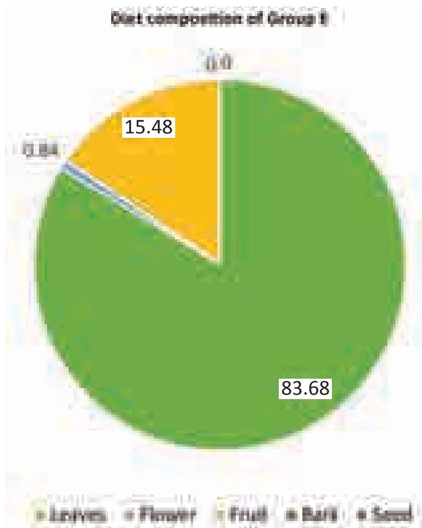

Figure 7. Diet composition of Group E.

Image 4. ***Semnopithecus ajax***: a—Adult male | b—Adult female. © Rupali Thakur.

Image 5. ***Semnopithecus ajax***: a—sub-adult | b—infant. © Rupali Thakur.

Image 6. Activities performed by ***Semnopithecus ajax***: a—feeding | b—grooming. © Rupali Thakur.

Table 2. Plant species consumed by Himalayan Gray Langurs and their percentage contribution in Kalatop-Khajjiar wildlife sanctuary, Himachal Pradesh.

	Plant Species	Local name	Family	Type	Part consumed	Percentage contribution (%)
1	*Hedera nepalensis*	Korein	Araliaceae	Climber	Leaves	38.60
2	*Quercus oblongata*	Ban	Fagaceae	Tree	Leaves	15.79
3	*Ilex dipyrena*		Aquifoliaceae	Tree	Fruit	9.65
4	*Rumex nepalensis*	Jangali palak	Polygonaceae	Herb	Leaves	4.39
5	*Rubus macilentus*	Aakhredi	Rosaceae	Shrub	Leaves	3.51
6	*Cornus macrophylla*	Haleu	Cornaceae	Tree	Fruit	3.51
7	*Senecio graciliflorus*	Kakeyi	Asteraceae	Herb	Flower	2.63
8	*Strobilanthes pentstemonoides* var. *dalhousieana*	Saunda	Acanthaceae	Herb	Flower	2.63
9	*Rubus biflorus*	Akhe	Rosaceae	Shrub	Leaves	2.63
10	*Rosa moschata*	Kareri	Rosaceae	Shrub	Fruit	2.63
11	*Cedrus deodara*	Dyar	Pinaceae	Tree	Leaves	1.75
12	*Rhamnus virgatus*		Rhamnaceae	Shrub	Fruit	1.75
13	*Neolitsea pallens*	Chirndi	Lauraceae	Tree	Leaves	1.75
14	*Berberis lycium*	Kaimlu	Berberidaceae	Shrub	Fruit	0.88
15	*Agrimonia pilosa*	Jharod	Rosaceae	Herb	Flower	0.88
16	*Trifolium repens*	Amlu	Fabaceae	Herb	Leaves	0.88
17	*Urtica dioica*	Aind	Urticaceae	Herb	Leaves	0.88
18	*Aesculus indica*	Goon	Sapindaceae	Tree	Fruit	0.88
19	*Rubus* spp.	-	Rosaceae	Shrub	Leaves	0.88
20	Grass species	-	-	Herb	Leaves	0.88

a greater preference of leaves (84.32%) in the diet followed by fruits (11.83%) and then other parts of plants. However, no such feeding on bark or seeds has been recorded during the study period.

A difference in the contribution by plant species (Figure 4,5) and plant parts eaten (Figure 6,7) by Group C and E, respectively, has been recorded as well.

On comparing the diet consumption of both the study groups in the area, it can be seen that leaves constitute the major portion of the langur diet. However, after leaves langurs from Group C fed mostly upon flowers (11.11%) while that of Group E preferred fruits (15.49%) which may depend upon the difference in their distribution in terms of elevation and availability of particular plant part.

Langurs from Group C (Kalatop forest) were observed feeding upon a fungus (*Russula* spp.).

DISCUSSION

The present study recorded 20 plant species used as food belonging to 15 botanical families and 17 genera, utilized by Himalayan Gray Langurs living in the Kalatop-Khajjiar Wildlife Sanctuary during the autumn season. The most preferred species were *Hedera nepalensis, Quercus oblongata, Ilex dipyrena*, and *Rumex nepalensis.* In other studies at different locations, these langurs were reported to feed upon 13 plant species (Mir et al. 2015), 43 species (Sayers & Norconk 2008), and 49 species (Minhas et al. 2010) but that depends upon the time period of research study and seasons. It has been observed and estimated that the diet of langurs includes 84.32% leaves, 11.83% fruits, and 3.85% flowers. Similar results have been observed by others as well where leaves contributed to a large share of primates diet (Yoshiba 1967; Stanford 1991; Sayers & Norconk 2008; Minhas et al. 2012; Nautiyal 2015). This may be the result because of high nutritional values in leaves such as high concentration of calcium in mature leaves and crude protein in young leaves and other factors such as high water content, easy digestibility, and low fiber (Oates et al. 1980; Ramanathan 1994). The second most preferred part was fruits as they are considered to contain large quantities of simple sugar in them thus a quick source of easy energy for primates (Ramanathan 1994).


Image 7. Activities performed by *Semnopithecus ajax*: a—resting | b—playing. © Rupali Thakur.

Also, on comparing the results of primary data analysis with secondary data it can be seen that leaves are the most preferred plant part in both the cases. Phenology plays a prominent role in determining the diet of these primates. Seasonal variation in phenology determines the presence of leaves, flowers, fruits in a forest. Thus, although langurs are generalist feeders, their diet selection depends upon phenology or food abundance as well (Adhikaree & Shrestha 2011).

Langurs according to this study fed upon mature leaves along with young leaves which supports that Himalayan Gray Langurs broaden the feeding repertoire by inhabiting such a difficult environment where they can feed upon mature leaves as well.

Overall, the langurs preferred leaves but; after leaves langurs from Group C fed mostly upon flowers while that of Group E preferred fruits which might depend upon the difference in their distribution in terms of elevation as Group C of Kalatop forest was located on higher elevation than Group E of Khajjiar forest with approximate difference of 200 m in elevation along with the availability of particular plant part. Altitude is a strong predictor for the diet of Colobines (Tsuji et al. 2013), but it was mostly recorded in large elevation ranges only.

RECOMMENDATIONS

An annual study on their diet is recommended. People who wish to conduct a long-term study on this primate species in the area should include a comparison of diet or behaviour in forested groups and urbanized groups as it can bring new insights. This can also help to formulate specific conservation action for both the groups. The results from this study can help in forming an initial baseline data for upcoming studies in the area.

A population census for Himalayan Gray Langurs in the district is recommended as it will help in estimating the current scenario for this primate and then further improve the conservation practices. Honking should be avoided as much as possible because the area holds immense wildlife. A pre-determined speed limit should be followed inside the sanctuary. Engagement with wild animals is highly prohibited and should be avoided. A small nature awareness area may be constructed to guide tourists on the significance of the sanctuary and the animals with some 'Dos' and 'Don'ts'.

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COMMUNICATION

Kleptoparasitic interaction between Snow Leopard *Panthera uncia* and Red Fox *Vulpes vulpes* suggested by circumstantial evidence in Pin Valley National Park, India

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Abstract: In the present study, we describe an interspecific kleptoparasitic interaction between two sympatric mammalian carnivores in the high altitudinal Trans-Himalaya region of Himachal Pradesh, India. The study was based on the inferences drawn from the circumstantial evidence (direct and indirect) noticed in the study area in Pin Valley National Park. The inferences from the analysis of the evidence suggested the interaction between a Snow Leopard *Panthera uncia*, a Red Fox *Vulpes vulpes*, and a donkey. The arrangement of evidence in a sequential manner suggested that a donkey was killed by a Snow Leopard and a Red Fox stole the food from the carrion of the Snow Leopard's prey. The Red Fox was killed by the Snow Leopard, which was caught while stealing. The present study represents an example of kleptoparasitic interaction between the Snow Leopard and the Red Fox. This study also proves that such interactions may cost the life of a kleptoparasite and supports the retaliation behaviour of Snow Leopards.

Keywords: Animal interaction, carnivore, mammals, prey, Trans-Himalaya.

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Author details: Vipin was working as a research associate II in the Snow Leopard project at LaCONES, Centre for Cellular and Molecular Biology, Hyderabad, Telangana. Tirupathi Rao Golla was a senior research fellow in the Snow Leopard project at LaCONES. Vinita Sharma is an assistant professor in the Department of Zoology, Central University of Jammu, Jammu and Kashmir. Her area of research is related to animal taxonomy, systematics and behavior, wildlife and conservation biology, human-wildlife conflict, wildlife forensics, comparative anatomy and geometric morphometrics. Bheemavarapu Kesav Kumar was working as a Junior Research Fellow in the Snow Leopard project at LaCONES. Ajay Gaur is a senior principal scientist and was the principle investigator of the Snow Leopard project at LaCONES, CSIR-CCMB, Hyderabad. The main area of his research is conservation genetics of Indian endangered species. His research focuses on the development and application of DNA markers in population genetics, evolutionary genetics, conservation breeding and wildlife forensics.

Author contributions: V, VS, AG designed the study; V, VS, TRG collected the data; V, VS, AG analysed the data and wrote the paper; TRG, BKK did the proofreading; and AG supervised the study.

Ethics statement: All data and samples were collected with due permissions of the state forest department. All ethical conditions implemented by the project running institute have been followed.

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INTRODUCTION

Species interaction is an important component of an ecological community, which also works as a balancing force in it (Purves et al. 1992). Species interactions are direct (predation and interference competition) and indirect (trophic cascades and exploitative competition) (Case & Gilpin 1974; Estes & Palmisano 1974; Menge & Sutherland 1987; Paine et al. 1990; Bengtsson et al. 1994; Wootton 1994; Menge 1995). Kleptoparasitism is a form of indirect exploitative competition that refers to the stealing of any kind of resources by intra-or inter-specific members of a community (Webster & Hart 2006; Iyengar 2008). The member that steals the resource is called a kleptoparasite, and the other is the host. Kleptoparasitic interactions can influence the evolution of behavior and morphological traits of host and kleptoparasite (Iyengar 2008). The interspecific kleptoparasitic interactions may affect the entire ecosystem if the host, which also happens to be the apex predator, has a depleted prey base. Despite many studies carried out on species interactions, very little information on their effects, direct or indirect, on food webs involving terrestrial mammalian carnivores, particularly on keystone species, is available (Terborgh & Winter 1980; Pianka 1988; Pimm 1991; Strauss 1991; Terborgh 1992; McLaren & Peterson 1994; Palomares & Caro 1999). Therefore, studies throwing light on such interactions, more particularly involving apex predators, need to be carried out. Kleptoparasitism is a type of competition that may occur (intra- or inter-specific) between unrelated individuals (Iyengar 2008). The present study documents one such example of inter-specific kleptoparasitic interaction between two sympatric mammalian carnivore species. The two species are Snow Leopard and the Red Fox. The former is a keystone species of the high mountain ecosystem in the western Himalaya of India as it has a disproportionately larger impact on its ecosystem relative to its abundance (Bhatnagar et al. 2001; The Snow Leopard Conservancy 2007). The study was part of a larger study carried out by us on the genetic diversity and conservation status of Snow Leopards *Panthera uncia* in India from 2011 to 2013. Based on inferences drawn from the observations, we tried to show how interspecific kleptoparasitic interactions may affect the lives and behaviour of participants.

MATERIAL AND METHODS

The Pin Valley National Park (31.11°–32.03°N & 77.70°–78.10°E), Himachal Pradesh, India was the study site (Image 1). The National Park is situated in the Spiti Subdivision of Lahaul and Spiti district, a Trans-Himalayan cold desert mostly occurring above 3,200 m and a stronghold of Snow Leopards and Himalayan Ibex (Anonymous 2008). The kill sites were carefully marked for incidents, measured, and ad libitum information on the carcasses and spoor was recorded. Along with that, the data in the form of opportunistic evidence (direct and indirect) of suspected animal interactions were also recorded with details of time, date, and location. All evidence was photographed with the help of a DSLR camera (Sony alpha 35) and georeferenced with GPS (eTrex 10, Garmin). The evidence found in the study is denoted here by the numbers in brackets. The area between the entry point of the National Park and Thango (7.6 km) was walked on foot for three days from 1 to 3 May 2012 (Image 1). The natural animal trails were walked on foot for a total length of 15.68 km in 15.59 days hours, the details of which are as follows: May 1: 2.38 km from Ka Dogri to Gechang Base Camp (2.45 hours), May 2: 09.25 km to the west and back (8.05 hours), May 3: 4.05 km to the east and back (5.09 hours). It is to be noted that while returning to the base camp, the track followed was always 30–100 m apart from the track covered in the reverse direction. The scrapes and pugmarks were identified as per the 'Snow Leopard Survey and Conservation Handbook' (Jackson & Hunter 1995). The scats were identified as per the 'Scat Survey Methodology for Snow Leopards' (Janecka et al. 2008). The flies were identified using morphological identification keys by Szpila (2009). The beetle identification was carried out using the Encyclopaedia of Life' (https://eol.org/pages/3383922/media).

RESULTS

On May 2, 2012, after walking around 3.4 km from the base camp at Gechang, a strong smell of something rotting attracted us to the carrion of a donkey (1) (Image 2A, 3A). A scat, possibly of Red Fox *Vulpes vulpes* or a Snow Leopard (2), was lying nearby (approx. 6 m) (Image 2A, 3B). About 30m away from the donkey carrion, a Red Fox was lying dead on the bank of the Pin River (3) (Image 2A, 3C). We labelled the area between the dead donkey and the Red Fox as an "incident site" near (approx. 2 m) the dead Red Fox was a scapula bone from the same dead

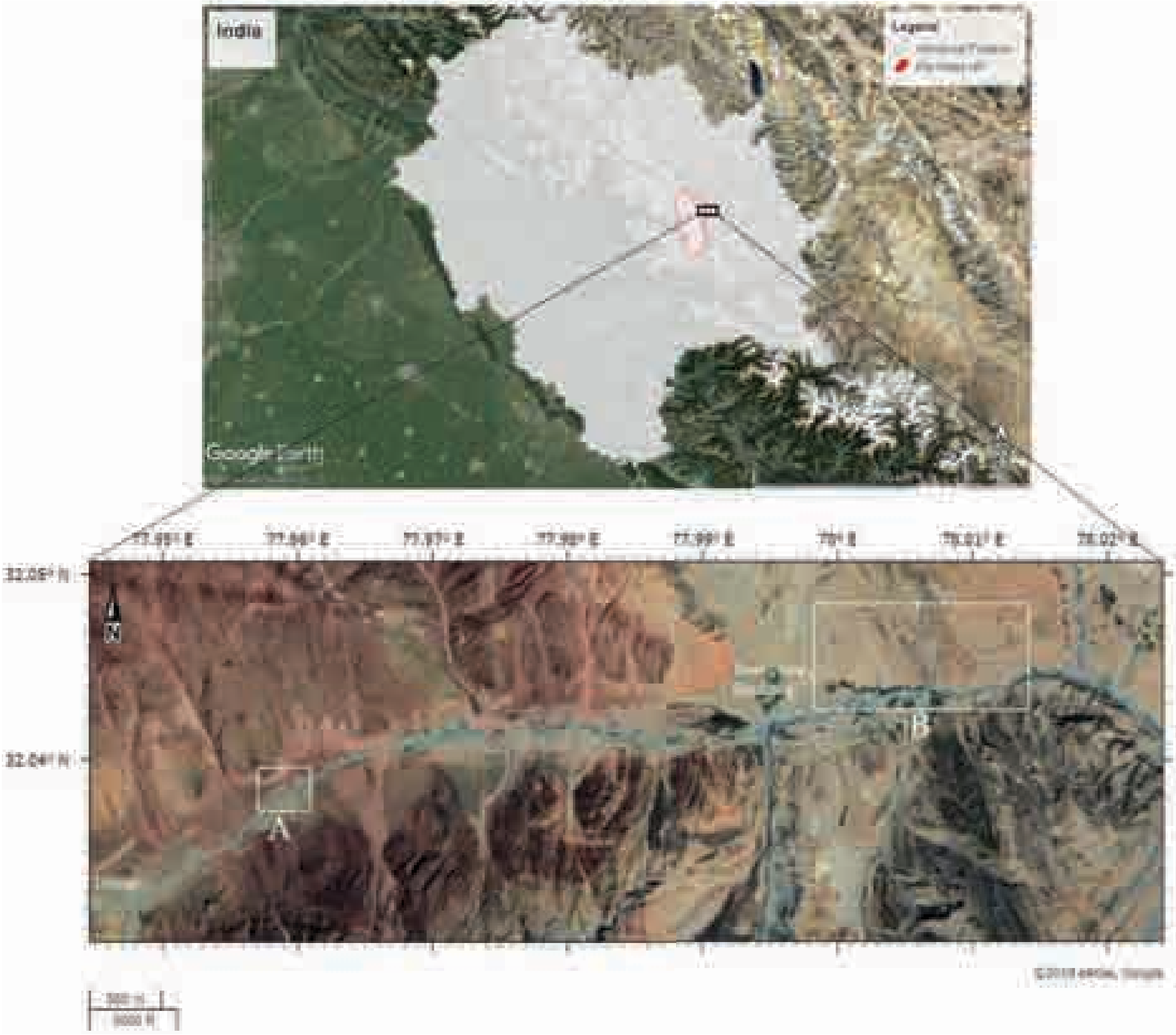

Image 1. The inset shows study area in Pin Valley National Park (Pink colour polygon with red boundary) in the state of Himachal Pradesh (White colour polygon). The areas marked as 'A' and 'B' with white boundaries shows the data collection sites.

donkey (4) and a scat (5) suspected of a Snow Leopard (Image 2A, 3D). The pugmarks of Snow Leopards were found about 120 m before the incident site (6) (Image 2A, 3E). There were wounds on the left lateral side of the Red Fox, from the neck to the mid-body, and flies were also found sitting on and around its body (Image 3F). On close observation of the fox's body, pale-yellow maggots and beetles were found on the left side of the mouth (Image 3G). Some relevant observations made about the presence of Snow Leopards in Pin Valley National Park are as follows: On May 1, many pugmarks of suspected Snow Leopards were found on the bank of the Pin River about 1 km east of the base camp (7) (Image 2B, 4A). On May 3, scrapes and urine (8) (Image 4B) of a suspected Snow Leopard were found on the slope near the base camp. Further investigation led us to an overhang resting site (9) where pugmarks of a suspected Snow Leopard (10) and exposed bone (11) were found inside it (Image 4C). Further tracing the pugmarks (12, 13, 14) (Image 4D), a freshly killed Blue Sheep (15) (Image 4E) (without any larvae and smell) was found over the den on a ridge (approx. 300 m above the Pin River). Nearby (approx. 6 m away), we found a scat, suspected to be of a Snow Leopard (16) (Image 4F). The inferences drawn from the above evidence, if connected in the correct order, may help draw a sequence of events that might have taken place between the animals involved. Flies of blue metallic color were found on and around the Red Fox's body. These were identified as blowflies. The blowflies feed on carrion and belong to the family Calliphoridae of

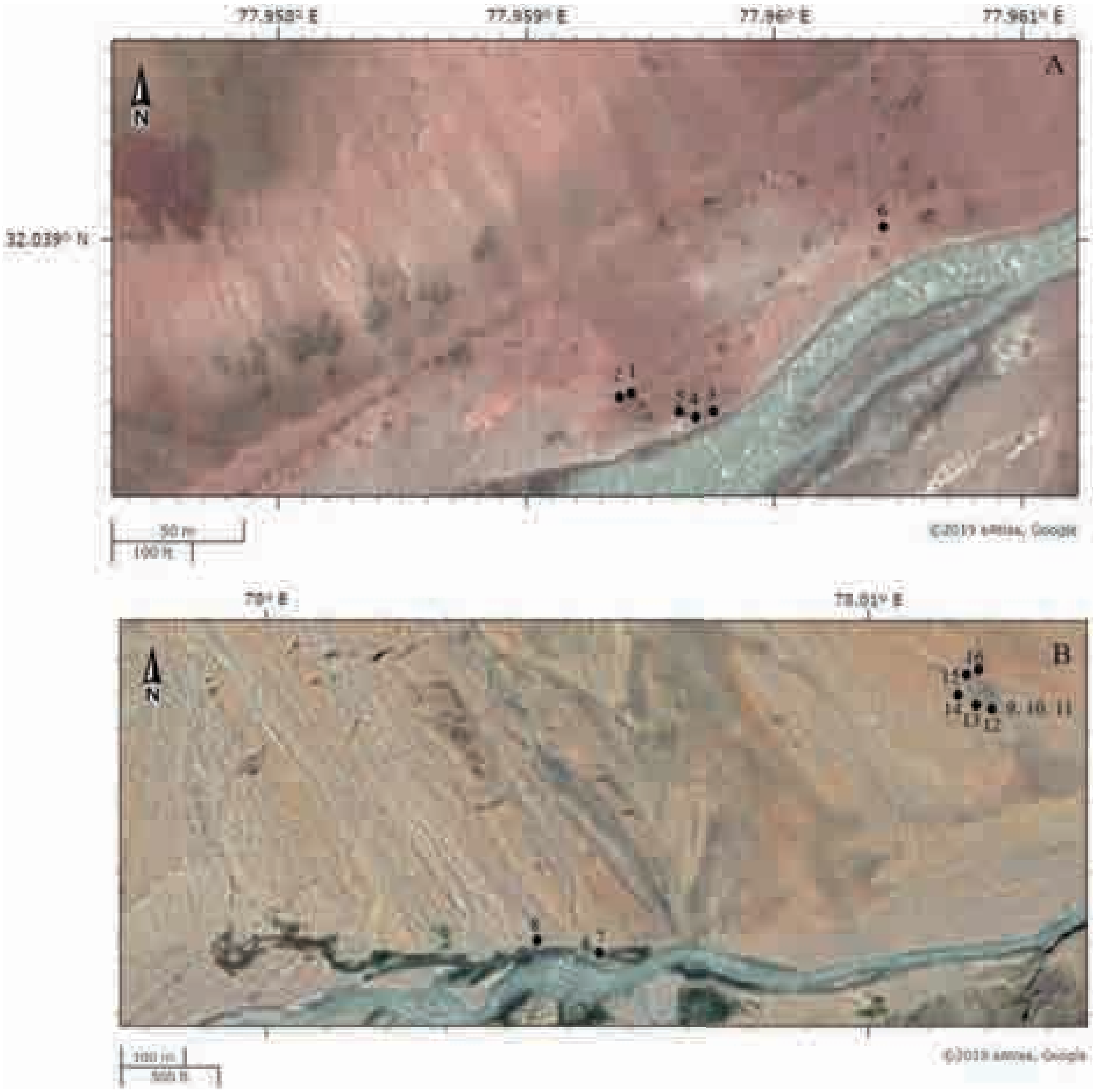

Image 2. A—evidence (1–6) recorded from the incident site on May 02 | B—evidence recorded before the base camp on 01 May (7) and 03 May (8–16).

class Insecta (ITIS 2008). A large number of larvae were present on the body of the Red Fox and no smell was coming out of it, indicating it was in the bloated stage of decomposition (Matuszewski et al. 2008). The blowflies lay eggs on carrion and, after that, the development of larval (pale yellow) stages, from the first instar to the third instar, generally takes place between 23 to 72 hours (Jordan et al. 2018). The beetle on the Red Fox's body identified, on morphological resemblance, as *Thanatophilus minutus*. *Thanatophilus minutus* is also a carrion beetle having distribution in Himachal Pradesh and is known to arrive on carrion after the blowflies (Ruzicka et al. 2011; Tariq 2020). *Thanatophilus* species larvae are darker in colour (Diaz-Aranda 2013) and did not match, in morphology, to the larvae found on the Red Fox. The donkey's carrion had a foul odor, no insect larvae were found on it, and the meat was dried. This indicated that it might either be in the active or the advanced stage of decomposition (Matuszewski et al. 2008). All this evidence proved that the donkey was killed earlier than the Red Fox. The incidents that happened, point towards the involvement of three

Image 3. A—Donkey carrion | B—Scat of either a Snow Leopard or Red fox | C—Carrion of a Red fox | D—Scapula of dead donkey and scat of suspected Snow Leopard | E—Pugmarks of suspected Snow Leopard | F—Wounds on Red fox's body and flies sitting around it | G—Maggots (in dotted circle) and beetles. © Vinita Sharma & Vipin.

species, i.e., a donkey, a Red Fox, and a Snow Leopard. There is no doubt about the donkey and Red Fox, as their carcasses were present. The pugmarks (6) (Image 2A; near the incident site), scat (5) of uniform diameter of 2.0 cm, segmented, with blunt ends, and having the presence of hairs in it point towards the involvement of a Snow Leopard. A Snow Leopard scat has an average diameter of 1.8 cm, which is uniform along its length, having constrictions and blunt ends (Janecka et al. 2008). The pugmarks (6) were identified as those of a Snow Leopard according to Jackson & Hunter (1995), which is the only large cat present in that habitat (Anonymous 2008). The shape and size of the scat (5) confirm the presence of Snow Leopard in and around the incident site. The Snow Leopard pugmarks were found frequently throughout the Pin Valley National Park on 1 & 3 May 2011. The pugmarks found near the bank of the Pin River on May 1 were found to be of Snow Leopard (Figur 4A). All the pugmarks and scrapes found on May 03 were from Snow Leopard. The scat '16' was confirmed

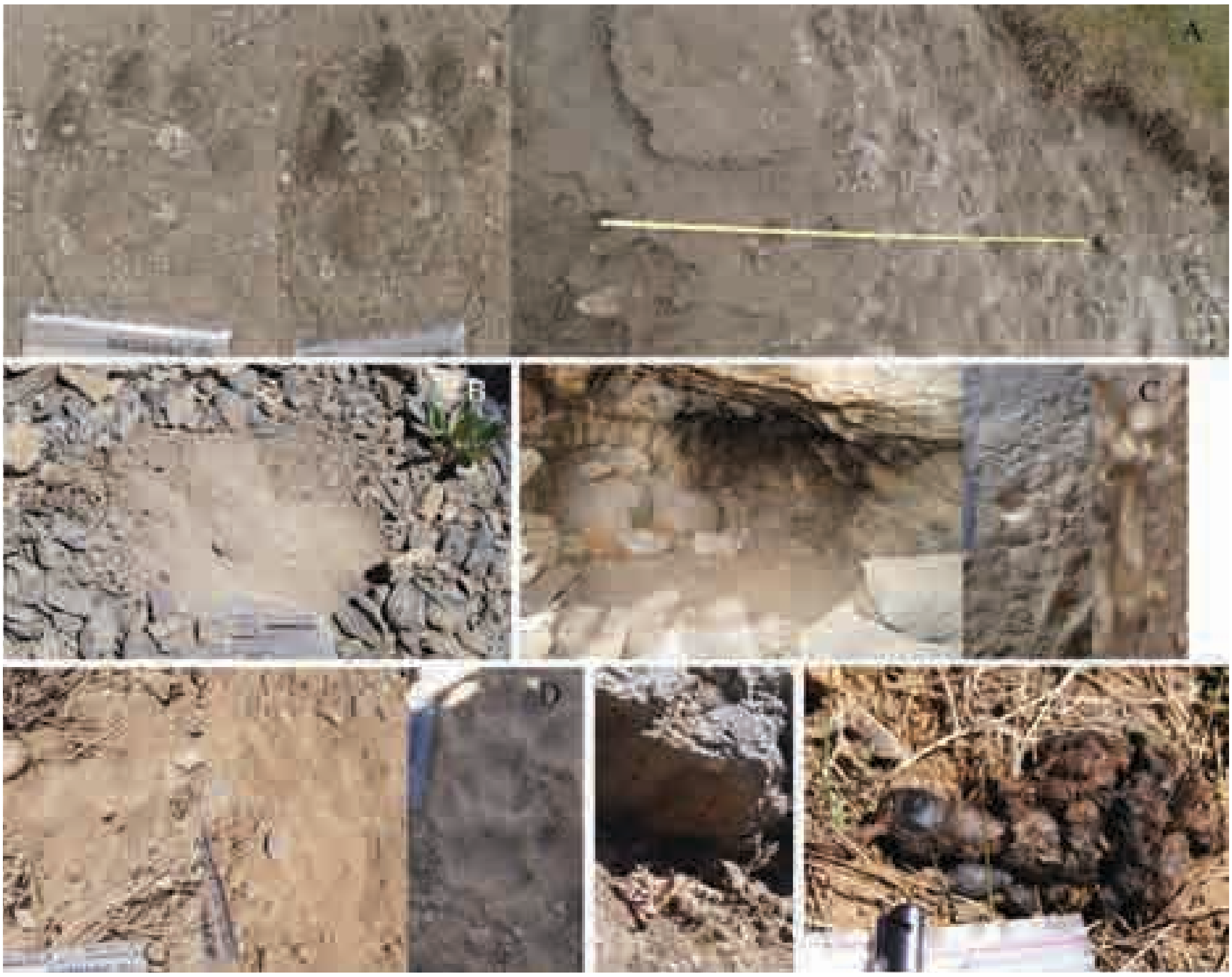

Image 4. A—Pugmarks of suspected Snow Leopard | B—Scrap and urine | C—Den and pugmarks of a suspected Snow Leopard and a bone | D—Pugmarks of suspected Snow Leopard | E—Carrion of a freshly killed blue sheep | F—Scat of a suspected Snow Leopard. © Vinita Sharma & Vipin.

to be of a Snow Leopard through the genetic analysis done at our laboratory (study unpublished). The Grey Wolves and Brown Bears are known as kleptoparasites of the Snow Leopard (Hunter 2015). But no signs of Wolf or Brown Bear pugmarks were found on the tracks we covered between 1 & 3 May in the valley. A full-grown Snow Leopard hunts a large prey every 10–15 days and remains near it for about 3–7 days until it is finished (McCarthy & Chapron 2003; Hunter 2015). The presence of scat (5), which only could be of a Snow Leopard, as per its shape and measurements, in the vicinity of the dead donkey and the Red Fox, points out that, most probably, both were killed by the Snow Leopard at different times. The presence of donkey scapula (4) near the body of the dead Red Fox indicates that it was stealing the meat from the dead donkey during which it was killed by the Snow Leopard. On arranging all the above findings, the inferences can be drawn from the circumstantial evidence that a donkey was killed by a Snow Leopard. Since a Snow Leopard takes 3–7 days to consume its prey, the Red Fox was stealing the food from the Snow Leopard's kill. At some time, the Red Fox was caught stealing food by the Snow Leopard and was killed. There are records of a Red Fox being accidentally killed by a Snow Leopard (Hunter 2015). The present findings point toward the first incident of kleptoparasitism by a Red Fox on a Snow Leopard in Pin Valley National Park, Himachal Pradesh. This incident of kleptoparasitic interactions between two sympatric mammalian carnivores also reveals the retaliatory behaviour of the Snow Leopard. The retaliatory behavior may be advocated as the Red Fox's body remained uneaten even after 23–72 hours of being killed as suggested by the presence of blowflies larval stages.

DISCUSSION

The evolution of the morphology and behaviour of participants may be influenced by kleptoparasitism (Iyengar 2008). Among the varied types of responses of a host towards a kleptoparasite, the host may retaliate if the kleptoparasite is large and can consume a substantial part of its kill (Iyengar 2008). In such conditions, a host can injure or kill the kleptoparasite (Iyengar 2008). There are many examples of it. The food of predatory birds is stolen by smaller birds (Meinertzhagen 1959), stealing of sea star's food by whelks (Rochette et al. 1995), and many spiders are killed by larger hosts while stealing their food (Whitehouse 1997). The present case suggests an example of retaliatory behaviour in Snow Leopards in Pin Valley National Park. A survey on interspecific killings among mammalian carnivores revealed that the Red Fox was the most affected victim as a kleptoparasite than other species of canids, mustelids, and felids to the killer species belonging to the families of felids and canids (Palomares & Caro 1999). There is one report of kleptoparasitism by Snow Leopards from Hemis National Park, India (Hunter 2015). The accessibility of alternative prey may be a decisive factor for interspecific mammalian carnivore killing and consumption (Macdonald 1977; Polis 1981; Ackerman et al. 1984; Stephenson et al. 1991; Palomares & Caro 1999) because the diets of sympatric carnivores often overlap (Kruuk 1972; Delibes 1980; Major & Sherburne 1987; Lindstrom 1989; Smits et al. 1989; Theberge & Wedeles 1989; Paquet 1992; Mills & Biggs 1993; Palomares 1993; Okarma 1995; Okarma et al. 1997; Palomares & Caro 1999). It has been reported that a killer species eats its prey completely, partially, does not eat, or never eats (Palomares & Caro 1999). However, the victim's characteristics have been found to make no difference in the consumption by a killer species (Palomares & Caro 1999). The other records of a Red Fox as a kleptoparasite are from central and southeastern Europe (Krofel et al. 2019). Therefore, the partially eaten-up blue sheep's body by the Snow Leopard and the presence of its alternative prey (the donkey carrion), other than the natural prey (Thiele 2003), in a sympatric habitat might also have been the reasons for the uneaten Red Fox's body which is further indicative of retaliatory behaviour in Snow Leopards. The differentiation between different larval stages of blowflies was not done here, so we gave the general time range (23–72 hours) for development from the first instar to the third instar larvae. If we compare the blowfly's larval development between the average temperature range 16°–22°C, then the time taken for the appearance of the first instar to the third instar comes in the range of 52–96 hours (Zhang et al. 2019). Therefore, the larvae found on the body of the red fox might be 2–4 days old. The insect's development varies at different temperatures and so at different habitats. Hence, it is very difficult to estimate the precise death time of an animal through forensic entomology until specific studies on blowfly development are available from that area. Comprehensive knowledge of kleptoparasitic interaction between Snow Leopard and Red Fox as well as among other sympatric carnivores is very important in Pin Valley National Park and similar habitats across the country. Because any future decline of an apex predator may jeopardize the animals at lower trophic levels through the release of mesopredators (Castle et al. 2021).

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COMMUNICATION

A comparison of the breeding biology of White-throated Kingfisher *Halcyon smyrnensis* Linnaeus, 1758 in plains and hilly areas of Bangladesh

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Abstract: The breeding biology of White-throated Kingfisher *Halcyon smyrnensis* was studied in plains and hilly areas from September 2008 to August 2011. Four villages under Savar upazilla were selected for plains, and Chittagong University Campus, Chattagram for the hilly area. The breeding season started in February in hills and April on plain. Mean (SD) time required to build a new nest was 11.3 (3.9) days in plains and 15.3 (0.57) days in hills. Clutch size was 3–4 in hills and 3–7 in plains. Mean egg parameters (length, width, and weight) and mean egg volume and surface area were similar in both areas. The mean incubation period on plains was 16.4 (1.2) days, in hills 14.1 (0.7) days. On plains fledging success was 52%, compared to 57% in hills. Theft by local inhabitants was a major reason for fledgling loss in plains, hence increased public awareness may reduce nestling mortality and increase breeding success.

Keywords: Breeding season, breeding success, fledglings, hatchling, nest, nestling mortality, ornithology.

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Author contributions: NJS has played a crucial role in monitoring and guiding the work. SIK has carried out field survey, data collection and HN also executed field study, data analysis and documentation.

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INTRODUCTION

The Least Concern, common, resident and widely distributed White-throated Kingfisher *Halcyon smyrnensis* Linnaeus, 1758 inhabits different types of habitats and water bodies (IUCN 2015) throughout Bangladesh. It feeds on fish, arthropods, amphibians, and reptiles (Naher & Sarker 2014) and prefers to nest in sandy-loam steep hills/mounds near or far from water bodies (Naher & Sarker 2016). The high porosity of sandy soils provides better ventilation, which is important to diffuse gases to maintain a tolerable level of O_2 and CO_2 in the nest cavities (White et al. 1978). Studies are available on the feeding behavior and breeding biology of White-throated Kingfisher in India (Yahya & Yasmin 1991; Balasubramanian 1992; Oomen & Andrews 1996, 1998; Asokan et al. 2009, 2010; Palkar et al. 2009). In Bangladesh, several studies have been done on feeding behavior (Naher & Sarker 2015a,b, 2016, 2018), but information on breeding is limited. As wetland habitats are rapidly declining and water pollution is increasing alarmingly, it is important to determine the breeding biology of this species to make a conservation plan. This study aimed to establish a morphometric analysis of eggs, hatchlings and fledglings, breeding success, and the causes of eggs and hatchling loss.

MATERIAL AND METHODS

Study area

The study was carried out from September 2008 to August 2011. The study was done in Madhabchala (23.886 °N & 90.253 °E), Boro-Walia (23.886 °N & 90.251 °E), Sinduria (23.883 °N & 90.236 °E), and Kashipur (23.884 °N & 90.242 °E) villages under Savar Upazilla in Dhaka district, west of the Jahangirnagar University Campus (Image 1). These villages are situated on plain land (4–7 m). At the backyard of most of the houses of these villages, people dig holes to dump their daily household wastages. At the vertical site of these holes (1–3 m deep from the ground), the kingfishers built their nests. They nested on the vertical side of the mound, which was newly cut down for other purposes. One nest was built at Madhabchala and one in Boro-Walia in 2009, which were reused in 2010. One nest was built at Kashipur in 2010 and one at Sinduria in 2011. Three nests were recorded in Chittagong University Campus (CUC) (22.281 °N & 91.472 °E) (Image 1) in Chattagram. The CUC is located at the village Fatehpur under Hathazari Upazila of Chattagram District. The CUC stretches over an area of 7 km² which is dominated by hills, valleys, creeks, streams, lakes, crop fields, grass, and fallow lands (Kabir et al. 2017). Seventy-two percent of the campus area is hilly and comprises of small hills which are 15–90 m high (Islam et al. 1979) and the remaining areas are either plains or valleys (Islam et al. 1979). Hills and plains are ornamented with hilly streams (Kabir et al. 2017) and some creeks (Islam et al. 1979). The mixed-evergreen vegetation (Champion 1936) of this area is now converted into secondary growth (Ahsan & Khanom 2005) due to anthropogenic factors (Kabir et al. 2017). About 665 plants species have been reported in CUC (Alam & Pasha 1999). The major habitats for the birds in the CUC are: Katapahar, botanical garden, south campus, Vice Chancellor's Hill, and north side of the Shaheed Abdur Rab Hall (Image 1). Residential area for students and faculty building are located on hills of CUC. Hills are connected with different roads (Image 1). Two nests were built on Vice Chancellor's Hill and another nest was built on Katapahar.

Methods

Courtship and pair formation behavior was observed on plains only, and involved key elements: (i) advertising display**:** one bird squatting on a tree branch, calling and jerking its head right and left and flying from one branch to another around the other bird, (ii) head bobbing: squatting on a tree branch, head jerking up and down while neck and nape drew back and almost or actually touched the back, (iii) mutual display: one bird displayed, and the other joined with and did the same while both birds sat side by side on the same or different branches (0.05–2 m, median = 1.5 m, no. of observations = 42), (iv) courtship flight: while the receiver sat beside the advertiser and calling one by one, in between calling the synchronized flight occurred while the pair called harshly together, 'Crack…crack…crack…crack', (v) courtship feeding: one bird offered fish to other and the other bird held the fish at the tail first and then swallowed turned to the head first, sometimes engulfed or gave it back to first bird and it engulfed while the pair spent some time through this behaviour, and (vi) mounting: while one bird mounted over another with or without cloaca contact.

Incubation period: Focal animal sampling (Altman 1974) at 5-minute intervals was recorded for incubation on different days subdivided into four time periods: 0700–1000 h (morning), 1001–1300 h (late morning), 1301–1600 (afternoon), and 1601–1900 h (evening). Two nests were followed for these activities on plains to find out the percentage of time spent in incubation at

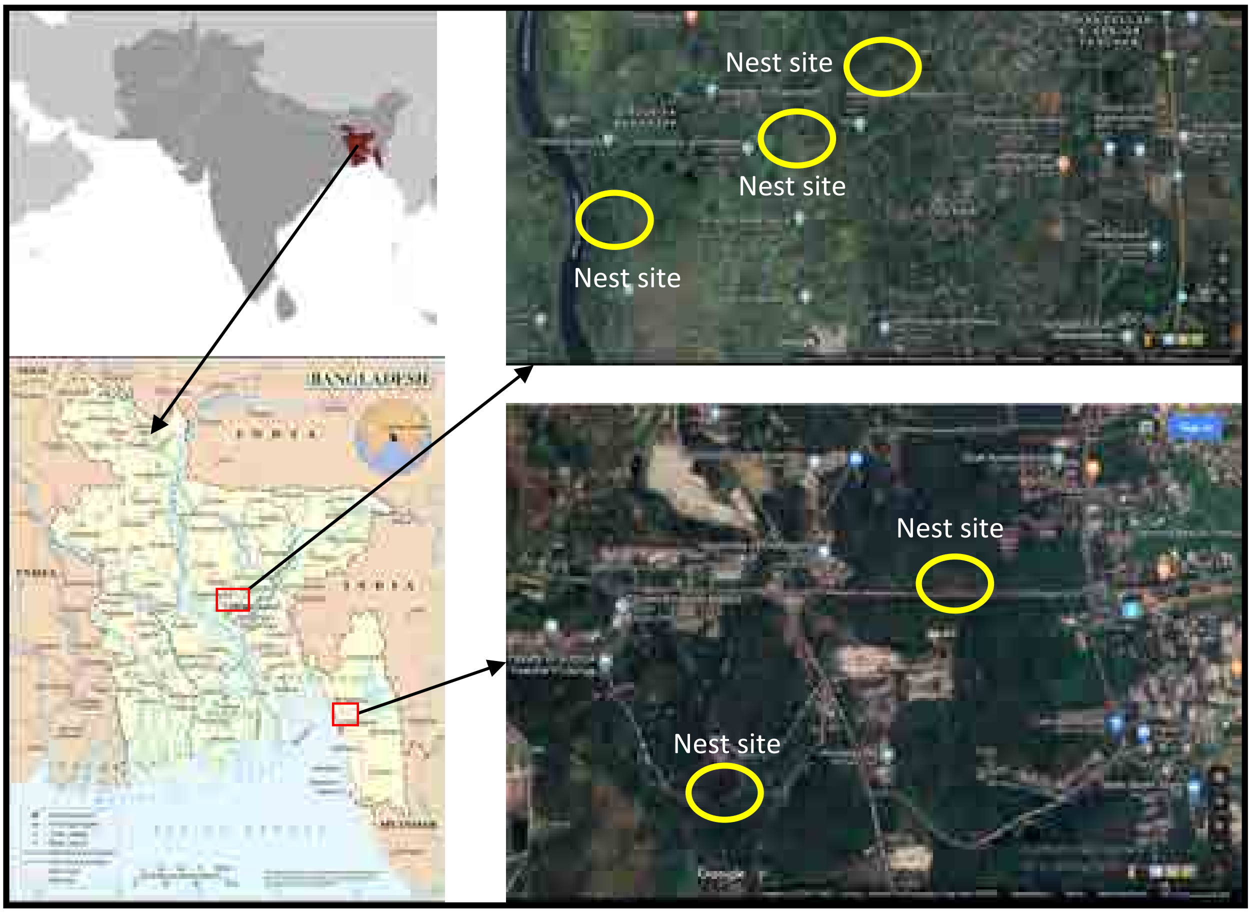

Image 1. Study area.

different day periods.

Egg measurement: Each egg was marked as I, II, III, and so on with permanent ink and measured with slide calipers and weighed to the nearest 0.5 g with a digital pan balance.

Egg volume and egg surface area were calculated using the following formula (Narushin 2005; Muzaffar et al. 2012):

Egg volume = (0.6057–0.0018B) LB^2

Where L = maximum length in mm and B = maximum breadth in mm.

Egg surface area, S, was calculated as S = (3.155 - 0.0136L + 0.0115B) LB, in which both L and B are taken in millimeters.

The breeding success was calculated by using the following formulae:

Hatching success (%) = (No. of eggs hatched / total no. of eggs laid) x 100

Fledging success (%) = (No. of nestlings fledged / total no. of nestlings hatched) x 100

Breeding success (%) = (No. of eggs laid / No. of nestlings fledged) x 100

RESULTS

Breeding season

The breeding season was February to July in hilly area and April to August in plain land. Pair formation occurred through a course of displaying behavior. At first, one bird started its advertising display to attract other bird, by squatting on bamboo, electric wire or any other support over the water which continued for 7–10 days (avg. 8.4 ± 1.3, n = 10). This behavior was followed by head bobbing which occurred 8–17 times per minute (mean 13.8 ± 3.2, n = 10). Head bobbing was followed by courtship flight which was recorded for 1–3 days (mean 1.8 ± 1, n = 6) through which pair formation occurred permanently. It involved chasing each other with calling and one bird caught fish and offered to another in between courtship flight. Mounting took place after permanent pair formation which lasted 1–3 seconds when cloaca contact did not occur, but extended up to 3–7 sec (4.5 ± 1, n = 12) while cloaca contact occurred. During mounting both birds flapped their wings and called. After mating, they flew away from each other towards the nearby branches and preened their feathers for 1–5 minutes (median 4.2, n = 12).

Nest

After pair formation, both the birds selected an abandoned, isolated and 90^0 sloppy sandy-loam area near or away from human habitation. In plains (Savar), they built their nests at the vertical edge of the ditch or pond or mound near human habitation. In hills (CUC), they built their nests near the top of the hill. They built more than 80% (81.9 ± 6.7%) false nests (1–5, 5.2 ± 2.3, n = 5) on either side of the true nest (Image 2, 3) in plains but below 30% (27.8 ± 48.1%) in hills (5 false nests in case of one true nest and other two had no false nests) which did not lead to any egg chamber but the true nests ended in a widened egg chamber. The nests were excavated at 30–118 (46.7 ± 143.31, n = 12) cm down from the hill or mound top and 10.5–483 cm (122.7cm ± 143.31, n = 12) height from the ground or above water. The nest was built at a higher height and larger horizontal length on hills than on plains (Figure 1). They followed almost the same distance down from the top of the hills, hillocks or mounds (Figure 1). The horizontal and vertical diameter (dm) of both entrance (outer opening) and egg chamber was larger in true nests in all sites (Figure 2). In the plains, they built their nests at 30–94 cm down (67.7 ± 25.3, n = 7) from the top of the mound/highland and 10.5–97 cm height from the ground. But in hills, they preferred to nest at 48–126 cm down from the top hill and 31–1,524 cm height from the base of the hills (673.7 ± 767.9, n = 3).

To build a new nest, less time was required in plains (8–17 days, 11.3 ± 3.9 days) than hills (15–16 days, 15.33 ± 0.57 days) whereas in plains it required 8–12 days to reconstruct the old nest (10.2 ± 1.8), but in hills no old nests were found to be used.

Egg laying

The eggs were laid during April in hills and May–June in plains. They laid eggs on successive days (78.4%, n = 24), one-day interval (8.1%) but two eggs were also laid in one day (13.5%) (Table 1).

Clutch size

The clutch size varied from 3–7 eggs (mean of 4.6 ± 1.3, n = 7). The clutch size was smaller (3–4; 3.5 ± 0.7, n = 2) in hills than plains (3–7; 5 ± 1.2, n = 30).

Colour, shape and morphometry of the eggs

The colour of the egg was white and they were almost round in shape (Image 4). Overall, the length of the eggs varied from 2.7–3.03 cm (2.9 ± 0.09 cm, n = 37), the width 2.4–2.7 cm (2.6 ± 0.07 cm, n = 37) and the weight 7.8–10.8 g (10.04 ± 0.7, n = 37) (Table 2). The length is significantly correlated with width (0.39, df = 35, p >0.05) and weight (0.38, df = 34, p >0.05), and width is also significantly correlated with weight (0.80, df = 35, p >0.05).

In plains, the average length (range 2.7–3.03, mean 2.87 ± 0.09 cm, n = 30) was slightly larger than the hills (length: range, 2.81–3.1 cm, mean 2.93 ± 0.09 cm, n = 7) but the mean weight was (range 7.8–10.8 g, mean 10.09 ± 0.6 g, n = 30) slightly heavier than the hills; (weight: range, 8.5–10.5 g, mean 9.8 ± 0.7 g, n = 7), the mean width was similar in hills (range, 2.5–2.7 cm, mean 2.6 ± 0.07 cm, n = 7), and plains (range, 2.4–2.7 cm, mean 2.6 ± 0.06 cm, n = 30).

Table 1. Nesting detail of White-throated Kingfisher in different sites.

NS	Year	Egg laying dates							Egg hating dates							Fledging dates
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	
M	2009	14/6	15/6	15/6	16/6	17/6	18/6		28/6	28/6	28/6	29/6	4/7	2/7	3/7	Stolen
B	2009	3/7	4/7	5/7	7/7	8/7			19/7	20/7	UH	21/7	UH			13/8
C	2009	12/4	14/4	15/4-	-	-			28/4	30/4	1/5					Died
M	2010	8/4	10/4	10/4	11/4	12/4			25/4	25/4	27/4	27/4	27/4			20/5
B	2010	12/5	13/5	13/5	-	-			UH	UH	UH					UH
C	2010	22/4	23/4	23/4	24/4	-			6/5	6/5	6/5	7/5				26/5
K	2011	2/5	3/5	4/5	5/5	6/5			18/5	19/5	21/5	20/5	20/5			13/5
S	2011	20/5	22/5	22/5	23/5	24/5			7/6	7/6	7/6	7/6	10/6			Stolen

M—Madhabchala | B—Barawalia | C—Chittagong University Campus, Chattagram | S—Shinduria | K—Kashipur | UH—Unhatched.

Table 2. Egg measurement of White-throated Kingfisher in different locations.

Yr	SA	Egg measurement (cm)																					avg± SD		
		1st egg			2nd egg			3rd egg			4th egg			5th egg			6th egg			7th egg					
		L (cm)	W (cm)	Wt. (g)	L (cm)	W (cm)	Wt. (g)	L (cm)	W (cm)	Wt. (g)	L (cm)	W (cm)	Wt. (g)	L (cm)	W (cm)	Wt. (g)	L (cm)	W (cm)	Wt. (g)	L (cm)	W (cm)	Wt. (g)	L	W	Wt.
2009	M	2.91	2.65	10.5	2.95	2.69	10.4	2.87	2.61	10.6	2.98	2.63	10.5	2.81	2.58	10.3	2.7	2.62	10.1	2.79	2.68	10.1	2.9±0.09 cm	2.6±0.07 cm	10.04±0.7 g
	B	2.97	2.6	10	2.9	2.64	10.3	2.84	2.67	10.3	2.88	2.6	10.1	2.86	2.67	9.9									
	C	2.81	2.59	10.2	2.9	2.7	10.3	2.94	2.6	9.9															
2010	M	2.94	2.63	10.5	2.89	2.67	10.3	3.03	2.63	10.4	2.92	2.59	9.9	2.86	2.59	10.2	-	-	-	-	-	-			
	B	2.83	2.52	7.8	2.8	2.4	7.9	2.81	2.53	9.4	-	-	-	-	-	-	-	-	-	-	-	-			
	C	2.9	2.6	9.2	2.9	2.5	8.5	3.0	2.7	10.3	3.1	2.7	10.5	-	-	-	-	-	-	-	-	-			
2011	K	3.01	2.7	10.6	2.98	2.68	10.7	2.9	2.6	10.1	2.85	2.68	10.2	2.97	2.6	10.8									
	S	S2.7	2.6	10.2	2.8	2.61	10.0	3.0	2.58	10.5	2.72	2.69	9.5	2.76	2.69	10.6	-	-	-	-	-	-			

M—Madhabchala | B—Barawalia | C—Chittagong University Campus, Chattagram | S—Shinduria | K—Kashipur | UH—Unhatched | L—Length | W—Width | Wt.—Weight.

Egg volume and surface area

The egg volume (EV) and the surface area (ES) were almost similar both in hills (EV: 10.8 cm^3, ES: 22.9 cm^2) and plains (EV: 11 cm^3, ES: 23.1 cm^2).

Incubation

Both the partners took part in incubation. After laying the first egg, the parents started to incubate it. If one bird incubated, the other stayed outside the nest. They continuously incubated for 2–40 min (19.3 min ± 9.5, n = 30) with taking 2–20 min (11.2 min ± 8.6, n = 30) rest and repeatedly did the same. As one bird rested, another one entered in between 10–180 sec (74.6 sec ± 49.3, n = 30). After 10 days, one of the parents left the nest. After that, only one bird incubated the egg. Time spent in incubation was found to increase as the days of incubation proceeded (Figure 3) and but this relation was not significantly correlated (r = 0.9, df = 4, P >0.05). Spending time in incubation also varied according to day periods (Figure 4).

Incubation period

The incubation period ranged from 13–18 days (15.9 ± 1.5 days, n = 37), in plains it was larger (14–18 days, 16.4 ± 1.2 days, n = 30) than hills, (13–15 days, 14.1 ± 0.7 days, n = 7), 15–17 days was the most common (65.7%) followed by 16 days (16.2%), 18 days (13.5%), 14 days (13.5%) and 13 days (2.7%). Different clutches of different nests had different incubation period and the test was statistically significant (r = 0.53, df = 6, P <0.05).

Hatching

One (66.7%) to four (4.8%) eggs was hatched in one day. The parent started to collect food for hatchlings and fed their nestlings immediately after the first egg hatched out. The parents repeatedly collected food with an interval of 1–20 min (8.7 min ± 6.3, n = 35).

Hatching success

Overall, a good number of eggs (13.5%) were destroyed due to infertility (n = 37). But it occurred only in plains (13.7%, n = 30) and no egg was reported damaged in the hills. Altogether, the hatching success was 85%. It was higher in hills (100%) than plains (83.3%). than hills (3.5 nestlings).

Physical features of the hatchling

The newly hatched hatchling was naked with transparent body skin and flesh colored (Image 5). The beak and claws were black. Their eyes were closed. Eyelids appeared large and dark gray. Egg tooth was

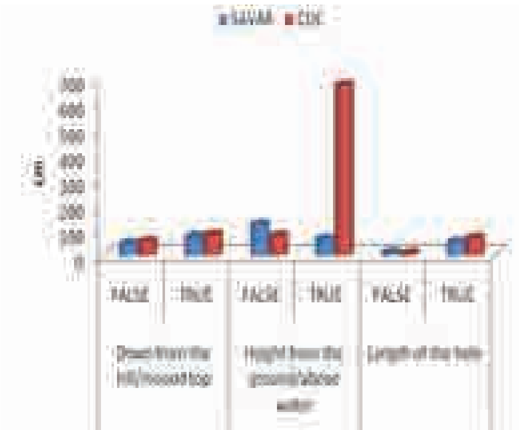

Figure 1. Measurement of location and horizontal length of false and true nests.

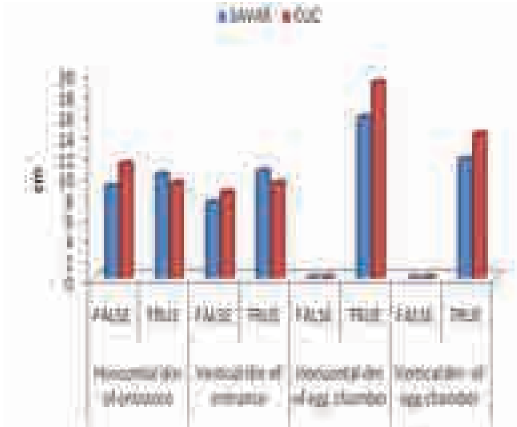

Figure 2. Measurement of outer opening and egg chamber of false and true nests.

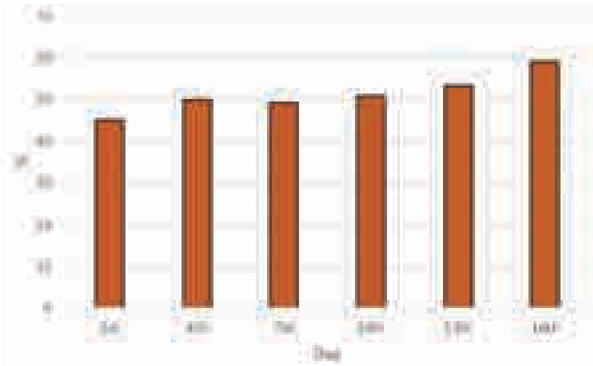

Figure 3. Incubation period at different day.

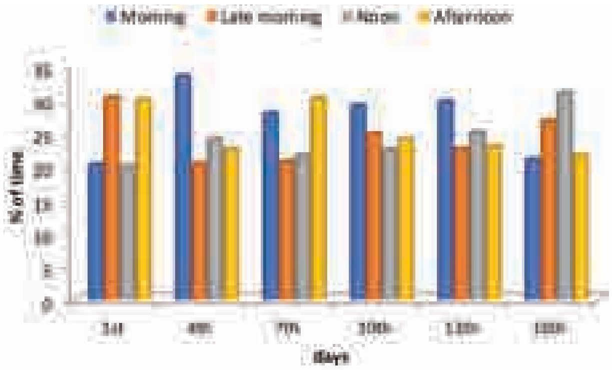

Figure 4. Incubation period at day periods at different days.

Table 3. Measurement of different body parts of the hatchling and fledgling with reference

Var	Hatching at the Catching time, range (meant sd)		Fledgling at the fledging time, Range (mean ± sd)		Adult (ADW 2020)
	Plains (SAVAR) (n = 20)	Hills (CUC) (n = 7	Plains (SAVAR) (n = 13)	Hills (CUC) (n = 4)	
BW (g)	12.5–16.5 (14.9 ± 1)	12–15.9 (14.5 ± 1.3	63.3–73.9 (69.5 ± 3.2	68.9–73.3 (71.5 ± 1.9)	65.5-81g
BL (mm)	50–69 (61.4 ± 5)	60–67 (63.5 ± 3.1)	185–230 (207.1 ± 4.1)	182–203 (192 ±10.1)	194 to 210
WL (mm)	14.1–26 (19.9 ± 4)	15–26 (21.8 ± 5.3)	108–121 (112.1 ± 3.1)	110–113.2 (111.8 ± 1.5)	
HL (mm)	8.1–15 (11.3 ± 2.1)	10.3–18 (13.9 ± 3.2)	29.1–33.7 (30.7 ± 1.4)	30–30.4 (30.1 ± 0.2)	
BeL (mm)	2–4.5 (3.1 ± 0.9)	2.4–5.2 (4.2 ± 1.3)	39.9–42.5 (40.7 ± 0.7)	36.7–42.3 (39.4 ± 2.3)	
FL (mm)	16.3–19.5 (17.7 ± 1)	18.3–19.8 (19.2 ± 0.7)	28.3–30.7 (29.6 ± 0.7)	30.1–0.1 (30 ± 30.2)	
TL (mm)	8–9.8 (8.9 ± 0.5)	9–9.9 (9.3 ± 0.4)	14.6–15.8 (15 ± 0.4)	14.4–15.5 (15 ± 0. 5)	
CL (mm)	-		4.6–5.6 (5.1 ± 4.6)	5.1–5.3 (5.3 ± 0. 1)	
PL(mm)	-		57.1–74.6 (66.8 ± 5.7)	68.4–73.1 (71 ± 2.4)	
RL(mm)	-		19.1–32.1 (27.5 ± 3.7)	25.1–31.2 (28.3 ± 2.6)	

Var—Variables | BW—Body weight | BL—Body length | WL—Wing length | HL—Head length | BeL—Beak length | FL—Feet length | TL—Tarsus length | CL—Claw length | PL—Primaries length | RL—Rectrices length.

Image 2. Nest of White-throated Kingfisher in Savar.

Image 3. Nest of White-throated Kingfisher in CUC.

Image 4. Clutch of White-throated Kingfisher.

Image 5. Physical feature of the hatchlings of White-throated Kingfisher.

Image 6. Physical feature of the nestling of White-throated Kingfisher.

present which disappeared at the 9th–10th day of hatching. The claw, wing and tail feathers were absent. The eyes were closed which were beginning to open on the 5th–7th days and fully opened at 9th–10th days after hatching.

The hatchlings were measured on the day of hatching (Table 3). The body weight and length of different body parts reached very close to an adult at the time of fledging. Physical features of the fledglings' were similar to adults except of size (Image 6).

Fledging period

Overall, the fledging periods ranged from 23–26 days (24.3 days ± 1) both in plains and hills. Most (35.3%) of the hatchlings were fledged after almost a similar number of days (24 days).

Fledging success

In total, the fledging success was 53.1% (n = 32). It was lower (52%) in plains than hills (57.1%). Overall, stealing (37.5%) and natural death (9.4%) were the causes of fledgling loss. In plains, 48% fledgling were lost due to steal by local boys and in hills 42.9% fledgling were lost due to natural death. Food shortage and starvation may be the reason in hills as reduced food resource facilities were recorded as mentioned earlier.

Breeding success

The breeding success was 53.1% in relation to eggs hatched (n = 32) and 45.9% in relation to eggs laid (n = 37) but it was lower (52%, n = 25, in relation to eggs hatched and 43.3%, n = 30, in relation to eggs laid) in plains than hills (57.1% in both eggs hatched and laid, n = 7). Only 2.1 nestlings were able to fly per nest overall. In plains it was better (2.2 nestlings per nest) than in hills (2 nestlings per nest).

Mortality rate

Overall, the mortality rate was 46.9% in relation to eggs hatched (n = 32) and 54.1% in relation to eggs laid (n = 37). It was higher in plains (16.7%) than hills (0%) both with eggs laid and to eggs hatched (48% and 42.9%, respectively). The mortality rate before hatching was less (13.5%) but after hatching it was highly increased (40.1%).

DISCUSSION

The breeding season started a little bit earlier in hilly areas than in plain lands. Most of the observers around the world found the breeding season was more or less the same as found in the present study (Whistler 1986; Ali & Ripley 1987; Grimmett et al. 1998; Govindarajalu 2008). Pair formation occurred via a course of courtship display involved head bobbing and courtship flight. Ali & Ripley (1987) and Anderton & Rassmussen (2005) observed advertising display of White-throated Kingfisher in India. Courtship flight was approached to permanent pair formation by offering food to each other. Such courtship feeding was reported during nest excavation of White-throated Kingfisher (Palker et al. 2009) and before fertilization in Pied Kingfisher *Ceryle rudis* (Cramp et al. 1988) which prepares the female to reproduce by providing her with more resources (Cramp et al. 1988). Courtship feeding led to mounting which occurred with or without cloacal contact. In between performing sexual activities, both the partners selected an abandoned place for nesting and started nest excavation. They built several false nests without egg chambers on each side of the true nest to avoid predator risk. More false nests were built in plains than hills as predator risk was high on plains. To protect eggs, the pied kingfisher built 80% false nests which had no egg chambers (Cramp et al. 1988). The nest height from the ground depends on the height of selected mounds or hills, they are excavated at the highest height. Higher height was observed in hills than in plains. Palker et al. (2009) reported the nest was excavated in a vertical bank 150 cm high from the ground. This height was higher than the present study on plains but lower than in the hills as the height of the nesting site varied from place to place. The nest contained longer horizontal lengths in hills than on plains. Nest building time was more on excavating a new nest than rebuilding an old nest which was also recorded in other species (Naher & Sarker 2016). Palker et al. (2009) observed pairs occupying the same area for 3–4 years. They suggested only ringing will confirm the reuse of a nest or site by the same pair. The mean length of the nest hole in hills (70.3 ± 14.3 cm) is similar (69.00 ± 4.74 cm) to the findings of Govindarajalu (2008) in India. The length of the nest hole in hills was larger than in plains (52.6 ± 18.5 cm). One meter-long horizontal tunnel-like nest ends excavated in a vertical cutting of earth on the bank of a river, stream, nullah or a roadside land cutting (Palker et al. 2009). The circumference of the nest entrance hole opening was 8.64 ± 0.73 cm in India (Govindarajalu 2008). The depth of the egg chamber of the true nest in plains (11.5 ± 1.04 cm) was almost similar to the findings (10.47 ± 1.86 cm) of Govindarajalu (2008) but larger (14 ± 2 cm) in hills. Both the parents shared in building or reconstructing the tunnel-like nest which was also reported by others (Palker et al. 2009; Naher & Sarker 2016). However, the White-throated Kingfisher is known to use various locations for constructing its nest (Balasubramanian 1992; Palker et al. 2009).

The egg laying period in the hills of the present study (in late March to early April) was a little bit later (May–June) in the plains. One to two days intervals were recorded in egg laying time which was similar to Palker et al. (2009) reports (24–48 h) but two eggs were laid in the same day was also observed in the present study. A larger clutch size was recorded in plains than in hills. Smaller clutch size (3–5 eggs, 3.7 ± 0.82) was recorded by Whistler (1986), Ali & Ripley (1987), and Singer (1996). Larger clutch size was recorded by Palker et al. (2009) (4–7 eggs, usually 5–6 eggs) and Govindarajalu (2008) (4 eggs). Clutches of five eggs were common in plains. Reduced clutch size in hills may be due to less food source around the nest as the site was far from agricultural lands, grooves, ponds, paddy fields, electric lines, shrubs, and trees. But on plains, they built their nests close to agricultural lands, grooves, ponds, paddy fields, electric lines, shrubs, and trees from which the parents get more opportunity to provide foods to the growing nestlings. The agricultural lands and groves provided a variety of protein rich insects and other prey for the growing nestlings as well as for the parents

(Naher & Sarker 2016). The nearest small trees, shrubs, sticks and electric lines served as a perching site for overseeing the nest and searching for prey (Asokan et al. 2010; Naher & Sarker 2016). Moreover, in hills they preferred to nest at the site where predator pressure (such as local boys, snake, and monitor lizard) was less. This factor may be responsible for larger clutch size in plains. The condition of the breeding female, availability of resources necessary to produce eggs, time of laying in the season and anticipated future availability of food for feeding nestlings may influence the variability of clutch size (Klomp 1970; O'Connor 1984; Lessels & Krebs 1989). The round-shape and white colour eggs are similar to other studies in different regions (Whistler 1986; Ali & Ripley 1987; Singer 1996; Palker et al. 2009) but spherical (Whistler 1986), spherical oval (Ali & Ripley 1987; Palker et al. 2009) shaped eggs were also reported in India. The measurement of the length and breadth of the eggs has more or less coincided with other findings (Whistler 1986). Similar sized eggs were found both in plains and hills. Govindarajalu (2008) found almost similar sized (2.9 ± 0.13 cm, width of 2.7 ± 0.13 cm) but lower weight eggs (7.9 ± 0.83 g) in comparison to present study. The physical condition and nutritional status of the birds may vary from one place to another. Alternative incubation by parents occurred in both sites which were also reported by others (Ali & Ripley 1987; Singer 1996). Almost the same incubation period was recorded by different studies (Ali & Ripley 1987; Singer 1996) but Palker et al. (2009) and Oommen & Andrews (1993) reported a longer period (21–22 days and 18–21 days, respectively). Provisioning food sharing to the nestlings occurred by parents alternatively was reported by Naher & Sarker (2018) and Palker et al. (2009). Feeding by both parents commenced two hours after the first chick hatched (Palker et al. 2009). When both the parents brought food simultaneously, only one of them entered the nest while the other waited outside (Palker et al. 2009).

Hatching success was almost similar to the findings of Govindarajalu (2008) at Nagapattinam (80%) in India. Higher hatching success was found in hills but larger brood was recorded in plains. Reduce hatching success in plains was recorded due to infertility but Palker et al. (2009) reported infertility and black ants as the causes of egg loss. The eyes of the nestlings opened at the same age found in Pied Kingfisher (9 days) (Cramp et al. 1988). Naked and pink colour hatchlings of White-throated Kingfisher were also recorded by Palker et al. (2009) in India and Cramp et al. (1988) for Pied Kingfisher. More or less similar fledging period was found in different studies in the world (Singer 1996; Palker et al. 2009; 20–21 days). Fledging success was higher in Nagapattinam (82 ± 12.05%) in southern India (Govindarajalu 2008). Human disturbances and natural died were principle reasons to fledgling loss in the present study. Palker et al. (2009) recorded weaver ants, accidental drowning, caving in of the nest chamber and, falling out of nest hole are the causes of nestling loss and speeding vehicles to adult birds loss in Western Ghat of India. Breeding success was lower in the present study than in the studies in southern India (Govindarajalu 2008; 75%) and Western Ghats of India (77.3%; Palker et al. 2009). The mortality rate after hatching was higher in the present study which was similar to another study in Western Ghats (23.7%; Palker et al. 2009).

CONCLUSION

Wetland degradation is the main threat to the White-throated Kingfisher as it lives in and around wetlands. Various anthropogenic factors are responsible to reduce their breeding success. Fish farmers used to trap them as they believed that they are a nuisance for fish farms. The use of insecticides and pesticides may affect their fertility as kingfishers built their nest beside paddy fields, fish farms, and agricultural fields. Local boys become a nuisance as they destroy the nests and nestlings just for fun. Public awareness is necessary to conserve this species. Conservation messages should be included in the textbook at the primary and secondary level to create awareness among students to prohibit the destruction of wild animals including their nests and nestlings. Inserting bamboo or stick or plantation of aquatic plants in between the crops in paddy fields and agricultural land may provide them with more food items like insects, fish or small snakes, amphibians, & tadpoles, the farmers can save money by reducing pesticides use in the crop field, and decrease water pollution.

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COMMUNICATION

An updated checklist of reptiles from Dampa Tiger Reserve, Mizoram, India, with sixteen new distribution records

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Abstract: We present an updated inventory of the reptilian fauna of Dampa Tiger Reserve based on two separate field surveys during March and September 2021. We recorded 33 species of reptiles which is about 27% of the total reptilian diversity recorded from the state. This includes new distribution records for 16 snake species with observations on rare species: *Smithophis atemporalis, Smithophis bicolor*, and *Boiga quincunciata*.

Keywords: Indo-Burma biodiversity hotspot, herpetofauna, Mizoram, natural history, northeastern India, snakes.

Abbreviations: DTR—Dampa Tiger Reserve | TR—Tiger Reserve | WS—Wildlife Sanctuary | SVL—Snout Vent Length | TL—Tail Length | IB—Inspection Bungalow.

Mizo abstract: Kum 2021 March leh September thla a Dampa Tiger Reserve-a survey neih atangin reptilian fauna (bawkvak chi – rul, laiking lam chi, satel) awm te chhinchhiah belhna tarlan a ni. He zirchianna ah hian reptile chi hrang hrang 33 hmuh a ni a, hei hi Mizoram atanga reptilian diversity record zawng zawng atanga 27% vel a ni. He survey atang hian rul chi hrang 16 te a vawikhat nan Dampa Tiger Reserve atanga chhinchhiah thar a ni a, hmun dang a hmuh tur tam lem lo: *Smithophis atemporalis, Smithophis bicolor,* leh *Boiga quincunciata* te an tel a ni.

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Isaac Zosangliana is a naturalist who developed his interest in the field of herpetology. K. Lalhmangaiha is a naturalist who developed his interest in the field of herpetology. Abhijit Das is a faculty in the department of Endangered Species Management at Wildlife Institute of India, Dehradun (WII).

Author contributions: All the authors contributed in the field study; AD conceived and designed the study; Malsawmdawngliana and BB studied the specimens; M wrote the manuscript draft; AD, BB and SL studied, reviewed and edited the manuscript drafts; all authors approved the final draft.

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INTRODUCTION

Mizoram is the southernmost state in northeastern India and is a part of the Indo-Burma biodiversity hotspot (Pawar & Birand 2001; Mittermeier et al. 2004). The geographic location lies between 23.3875–23.7055 °N & 92.2736–92.4319 °E and the tropic of cancer passes through the state. Low to mid-elevation hill slopes with extensive forested tracts are contributing factors to its native biodiversity. The reptilian diversity of the state so far comprises more than 60 species of snakes (Talukdar & Sanyal 1978; Pawar & Birand 2001; Mathew 2007; Lalremsanga et al. 2011; Lalremsanga & Lalronunga 2017; Vogel et al. 2017, 2020; Ashaharraza et al. 2019; Giri et al. 2019a; Lalbiakzuala & Lalremsanga 2019a,b, 2020; Das et al. 2021; Lalronunga et al. 2021a,b) and 41 species of lizards (Pawar & Birand 2001; Harit & Ramanujan 2002; Matthew 2007; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015; Giri et al. 2019b; Muansanga et al. 2020; Purkayastha et al. 2021, 2022; Lalremsanga et al. 2022). However, systematic herpetofauna reports from the protected areas of the state are only partially available: Nengpui Wildlife Sanctuary (Pawar & Birand 2001) and Dampa Tiger Reserve (Pawar & Birand 2001; Lalrinchhana et al. 2015; Decemson et al. 2020). We herein address the hitherto unknown reptilian species richness of Dampa Tiger Reserve and present an updated checklist on the reptile fauna.

METHODS

Study area

Dampa Tiger Reserve (hereafter DTR) is located in Mamit District of Mizoram along the Bangladesh border (Figure 1). It is situated at the western limit of the state, and falls within 23.54–23.69 °N & 92.22–92.45 °E. The natural vegetation of the area is tropical evergreen to semi-evergreen, corresponding to the Cachar tropical evergreen 1B/C3 and semi-evergreen 2B/C2 forest (Champion & Seth 1968). The elevation ranges 250–1,100 m with an average precipitation of 2,150 mm, mainly from the south-west monsoon from May to December (Raman et al. 1998). The area has one of the last remaining natural low- to mid-elevation forests in western Mizoram (FSI 1999). DTR is drained by two drainage systems: Karnaphuli and Barak. The Karnaphuli drainage consists of Aivapui, Keisalam, Seling, and Mar rivers and the Barak drainage consists of Teirei and Tut rivers (Lalramliana et al. 2020).

The study was carried out in the two forest ranges, Phuldungsei and Teirei. In the Phuldungsei range, surveys were done along the Saithah to Phuldungsei road (~5 km) and in the Teirei range, surveys were carried out along the Teirei to Damparengpui village road (~3 km). Both the road segments form the boundary between the core and buffer of DTR. We employed stratified random sampling along possible habitats such as torrent streams, dry streambeds, roadside vegetation, ponds, agriculture fields, and oil palm plantations for species inventory (Image 5).

Data collection

The data for this paper was collected from 23 to 27 March and 12 to 16 September 2021. Visual encounter surveys (Crump & Scott 1994) and opportunistic searches were deployed to assess the reptilian diversity during the survey period. Data on road-killed specimens found during the survey period were also recorded. Collected specimens were fixed in 10% formaldehyde solution and then transferred to 70% ethanol solution for longer preservation. All collected specimens were deposited at the Reptile and Amphibians Repository, Wildlife Institute of India, Dehradun, Uttarakhand, India.

RESULTS

In the present study, 10 species of lizards from four families and eight genera; 23 species of snakes from seven families and 16 genera were documented. Among the 33 species of reptiles, one species is Near Threatened, one species is Data Deficient and the rest are Least Concern or Not Evaluated as per the IUCN Red List.

Species Accounts
Class: Reptilia
Order: Squamata
Family: Agamidae

1. Emma Gray's Forest Lizard *Calotes emma* Gray, 1845

Materials examined: WII-ADR 1112, Female, SVL 93.3 mm; TL 255 mm. Image 1A.

Supraocular spine on each side, over the ears; neck with an oblique (blackish) fold on each side in front of the shoulders. This description agrees well with Gray (1845). We encountered an individual roosting at approximately 1.5 m above the ground among the roadside vegetation on 12 September at around 1845 h. Another individual was observed at 1130 h foraging on a roadside bamboo groove ~2 m above ground.

Figure 1. Map of Dampa Tiger Reserve highlighting the two range headquarter village viz., Teirei Village and Phuldungsei village.

Manthey (2008) depicted diverse morphotype of the *Calotes emma* (sensu lato) from China, Laos, Thailand, and Vietnam. The Mizoram population agrees well in live colouration with the population from Assam reported by Das et al. (2009).

In Mizoram, this species was recorded from Ngengpui WS, DTR, and Aizawl (Pawar & Birand 2001; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015).

2. Irawadi Forest Lizard *Calotes* cf. *irawadi* Zug, Brown, Schulte & Vindum, 2006

Materials examined: WII-ADR 1103 and WII-ADR 1111, both Female, SVL 62.5 mm & 97.8 mm; TL 180 mm & 270 mm. Image 1B.

Scales on neck and supra-axillary region oriented obliquely; supratympanic spines are half or less than the diameter of tympanum (Zug et al. 2006). Das et al. (2009) provisionally reported the species from adjoining Barail WS. Lalrinchhana. Solanki (2015) also provisionally reported the species from Dampa TR. The individuals were frequently encountered roosting on shrub along forest trail about 1.5 m above the ground during our survey on 12 September 2021 at around 2138 h.

Previously *C. versicolor* was reported from Ngengpui WS, DTR, Aizawl, Hmuifang (Pawar & Birand 2001; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015). *Calotes* cf. *irawadi* from DTR (Lalrinchhana & Solanki 2015). However, after Gowande et al. (2021), the validity of these records needs to be investigated.

3. Smooth-scaled Mountain Lizard *Cristidorsa planidorsata* (Jerdon, 1870)

Materials examined: WII-ADR 1071 and WII-ADR 1072, both Females, SVL 38.4 mm & 52 mm; TL 65 mm & 80 mm. Image 1C.

Flat dorsum; no nuchal or dorsal crest; a double series of slightly enlarged keeled scales; series of angularly bent larger scales. The description agrees with Jerdon (1980). The individuals were encountered roosting on shrub along a forest trail at around 0.5 m above the ground on 12 Sept 2021 at around 1900 h.

In Mizoram, this species was previously reported from DTR, Hmuifang (Pawar & Birand 2001; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015).

4. Green Fan-Throated Lizard *Ptyctolaemus gularis* (Peters, 1864)

Materials examined: WII-ADR 1152, Female, SVL 69.5 mm; TL 160 mm. Image 1D.

Body slender; with a pointed head; bluish gular pouch folded in U shape. The description agrees with Das & Das (2017). The individual was spotted on a tall isolated tree at about 2 m in a bamboo patch. When approached, the individual showed circulating movement in the tree going upwards on 16 September 2021 at around 1300 h. Liu et al. (2021) recently described *Ptyctolaemus chindwinensis* from Htamanthi Wildlife Sanctuary, Sagaing Division, Myanmar. Our specimen differs from *P. chindwinensis* in having three long bluish-black stripes which occupy most portions of the gular pouch.

In Mizoram, this species was previously reported from Ngengpui WS, DTR, Aizawl (Pawar & Birand 2001; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015).

Family: Gekkonidae

5. Jampui Bent-toed Gecko *Cyrtodactylus montanus* Agarwal, Mahony, Giri, Chaitanya, and Bauer 2018

Materials examined: WII-ADR 1077, Male, SVL 57.6 mm; TL 58 mm. Image 1E.

Dorsal coloration consisting of thick dark reticulations enclosing lighter blotches; the tail had alternating dark and lighter bands. This description agrees with Agarwal et al. (2018). We encountered the individual roosting on a shrub from a forest trail at around 0.5 m above ground on 15 September 2021 at around 1900 h. Another individual was also encountered on a wall of a small concrete roadside drain at around 2230 h.

In Mizoram, this species was previously reported from DTR (Lalmuansanga et al. 2020).

6. Tokay Gecko *Gekko gecko* (Linnaeus, 1758)

Materials examined: WII-ADR 1114, Juvenile, SVL 59.1 mm; TL 55 mm. Image 1F.

Reddish spots on a greyish dorsum; tubercles present on ventrolateral folds. This description agrees with Das

Image 1. Some saurian fauna of Dampa Tiger Reserve: A—*Calotes emma* | B—*Calotes irawadi* | C—*Cristidorsa planidorsata* | D—*Ptyctolaemus gularis* | E—*Cyrtodactylus montanus* | F—*Geeko gecko* | G—*Hemidactylus platyurus* | H—*Hemidactylus frenatus* | I—*Varanus salvator* with *Zhangixalus smaragdinus*. © Abhijit Das (A-H), Malsawmdawngliana (I).

& Das (2017). The calls of *G. gecko* were frequently heard from the buildings in the Forest IB Complex and nearby forests. Many juveniles and one adult were observed from the Forest IB Complex during the survey every night.

In Mizoram, this species was previously reported from Ngengpui WS, DTR, Aizawl (Pawar & Birand 2001; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015).

7. Flat-tailed House Gecko *Hemidactylus platyurus* (Schneider, 1792)

Materials examined: WII-ADR 1069 (Male). SVL 52.8 mm; TL 55 mm. Image 1G.

Body colour variable; brown to grey; with smooth dorsal scales; tail dorso-ventrally flattened with serrated edges. This description agrees with Das & Das (2017). We encountered one individual on a wall of Phuldungsei Forest IB Complex on 12 September 2021 at around 1900 h.

In Mizoram, this species was previously reported from Ngengpui WS, DTR, Aizawl (Pawar & Birand 2001; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015)

8. Common House Gecko *Hemidactylus frenatus* Duméril & Bibron, 1836

Materials examined: Not collected, unsexed, not measured. Image 1H.

Smooth dorsal scales; round tail bearing rings of enlarged tubercles. This agrees with the description in Das & Das (2017). We encountered the species on the wall of the guest house at the Phuldungsei Forest IB Complex on 12 September 2021 at around 1830 h.

In Mizoram, this species was previously reported from Ngengpui WS, DTR, Aizawl and Hmuifang (Pawar & Birand 2001; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015).

Family: Scincidae

9. Spotted Forest Skink *Sphenomorphus maculatus* (Blyth, 1853)

Materials examined: WII-ADR 1109, Male, SVL 31.3 mm; TL 45 mm.

Bronze dorsum and dark flanks lightly speckled with white; having two series of black spots on the side of the body. The morphological description agrees with Das & Das (2017). During night sampling a few individuals were sighted along a forest trail and one individual was encountered in a dry drain filled with leaf litter on 12 September 2021 between 2130 and 2200 h.

In Mizoram, this species was previously reported from Ngengpui WS, DTR, Aizawl, Hmuifang (Pawar & Birand 2001; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015)

Family: Varanidae

10. Water Monitor Lizard *Varanus salvator* (Laurenti, 1768)

Materials examined: None, Image 1I

Triangular head; snout elongated and flat. One individual was photographed hiding in a rock crevice along with a Large Green Frog *Zhangixalus smaragdinus* in Teirei stream near Lallen village on 24 March 2021 at around 1930 h. The species was identified as *V. salvator* from the photograph based on characters such as nostril closer to the snout and distinctly enlarged supraocular scales (Koch et al. 2013).

In Mizoram, this species was previously reported from Ngengpui WS, DTR (Pawar & Birand 2001; Lalrinchhana et al. 2011; Lalrinchhana & Solanki 2015).

Suborder: Serpentes

Family: Natricidae

1. Wall's Keelback *Herpetoreas xenura* (Wall, 1907)

Materials examined: WII-ADR 1158, Male, SVL 480 mm; TL 185 mm. Image 2A.

Subcaudals single; nostrils lateral; internasals truncated; supralabials largely light. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having dorsal rows 19:19:17, ventrals 162 and 99 (single) subcaudals. We encountered an individual on the streambed along the road on 16 September 2021 at around 2145 h.

In Mizoram, this species was previously reported from DTR, Sihhmui, Tamdil, Aizawl district, Reiek Community Reserved Forest (Pawar & Birand 2001; Das 2010; Lalremsanga et al. 2011, 2014; Hmar et al. 2020)

2. Khasi Hills Keelback *Hebius khasiensis* (Boulenger, 1890)

Materials examined: WII-ADR 1104, Female, SVL 350 mm; TL 50 mm. Image 2B.

19 dorsal scales round the mid body (19:19:17) with first dorsal scale row keeled; nine supralabials which are cream coloured with dark edges. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having dorsal scale rows 19:19:17; ventral 154; subcaudals 34 (paired). We encountered the individual on a streambed upon turning a rock in a small stream that flows along the road on 15 September 2021 at around 2030 h.

In Mizoram, this species was previously only reported from Reiek Community Reserved Forest (Hmar et al. 2020).

3. Red-necked Keelback *Rhabdophis helleri* (Schmidt, 1925)

Materials examined: WII-ADR 1151, female and WII-ADR 1155, male; SVL 490 mm & 365 mm ; TL 160 mm & 105 mm, respectively. Image 2C.

Olive green dorsum; reddish neck. Some individuals having a tear drop mark below the eye. The individual agrees with the description of *R. helleri* in having 19:19:17 dorsals scale rows; ventrals 164, 166, 84, & 91 paired subcaudals (David & Vogel 2021). One individual was encountered roosting on a shrub at about 2 m from the ground along a forest trail near Teirei Forest IB complex on 16 September 2021 at around 1930 h. Another individual was encountered on the same night under a rock from a stream flowing along the road at around 2130 h.

The species was previously identified as *R. subminiatus* with two subspecies. After David & Vogel (2021), the northeastern Indian populations of the species conferred to *R. helleri*.

In Mizoram, this species was previously reported from Ngengpui WS, DTR, all districts of Mizoram, Reiek Community Reserved Forest (Pawar & Birand 2001; Lalremsanga et al. 2011; Hmar et al. 2020).

4. Orange-collared Keelback *Rhabdophis himalayunus* (Gunther, 1864)

Materials examined: WII-ADR 1116, Female, SVL 550 mm; TL 185 mm. Image 2D.

Olive-brown dorsum; anterior part of dorsum with whitish checkering; posteriorly dorsolateral series of small yellowish or cream spots present. Neck with a cream or pinkish collar which is broad in the middle, many dorsal scales edged with white and sky blue colour. Small black bars from the eye to the labials and one large bar from behind the eye to the angle of mouth, ventral with light mottling that increases posteriorly. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having a dorsal scale rows 17:19:17; ventrals 158; subcaudals 86 (paired). We encountered the individual roosting on roadside vegetation at about 0.5m from ground on 13 September 2021 at around 2130 h. A *Xenophrys* sp. frog was recovered from the gut of this individual.

In Mizoram, this species was previously reported from Champhai and Mamit districts (Lalremsanga et al. 2011).

5. Brown Rain Snake *Smithophis bicolor* (Blyth, 1854)

Materials examined: WII-ADR 1107, Female, SVL 590 mm; TL 150 mm. Image 2E.

The individual agrees with description in Das (2010), Lalremsanga & Lalronunga (2017), and Giri et al. (2019) in having dorsal 17:17:17; ventral 194; subcaudals 64 (paired). We encountered the individual in a dry stream

Image 2. Some ophidian fauna of Dampa Tiger Reserve: A—*Herpetoreas xenura* | B—*Hebius khasiensis* | C—*Rhabdophis helleri* | D—*Rhabdophis himalayunus* | E—*Smithophis bicolor* | F—*Smithophis atemporalis*. © Abhijit Das (A-E), Malsawmdawngliana (F).

bed under rocks on 14 September 2021 at around 2035 h. Another individual was encountered on the same night in a streambed, but it disappeared tunneling through the pebbles in the stream.

In Mizoram, this species was previously reported from Mizoram university campus, Lunglei, Saiha, Aizawl district, Reiek Community Reserved Forests (Das 2010; Lalremsanga et al. 2011; Hmar et al. 2020).

6. Mizo Rain Snake *Smithophis atemporalis* Giri, Gower, Das, Lalremsanga, Lalronunga, Captain & Deepak, 2019

Materials examined: WII-ADR 1068, Male, SVL 315 mm; TL 175 mm. Image 2F.

Without temporal scales. The individual agrees with the description in Giri et al. (2019) in having dorsal scale rows 17:17:17; ventral 195; subcaudals 82 (paired). We encountered the individual on a side drain at about ~2 km from West phaileng village near watershed on 12 September 2021 at around 1530 h.

In Mizoram, this species was previously reported from Mizoram Univesity Campus, Aizawl (Type locality) by Giri et al. (2019).

Family: Colubridae

7. Tawny Cat Snake *Boiga ochracea* (Theobald, 1868)

Materials examined: WII-ADR 1156 (Male) and WII-ADR 1157 (Female), SVL 620 mm & 700 mm; TL 170 mm & 180 mm. Image 3A.

Dorsum without pattern or with faint dark transverse dorsolateral bands on yellowish-brown or reddish-brown ground. The individuals agrees with description in Das (2010) and Lalremsanga & Lalronunga (2017) in having dorsal 19:19:15; ventral 222-241; subcaudals 96-107(paired). We encountered the individual active along a roadside vegetated slope 2 m from ground 16 September 2021 at around 2100 h. Another individual was encountered on the same night at 2200 h on vegetation, 2 m above ground along a roadside stream.

In Mizoram, this species was previously reported from Tamdil, Pachhunga University campus, Reiek Community Reserved Forests (Das 2010; Lalremsanga et al. 2011, 2014; Hmar et al. 2020).

8. Assamese Cat Snake *Boiga quincunciata* (Wall, 1908)

Materials examined: WII-ADR 1115, Male, SVL 1080 mm; TL 335 mm. Image 3B.

Dorsal pattern consists of fine dark brown spots and a vertebral series of dark brown; white edged blotches on yellowish or greyish-brown ground. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having dorsal scale rows 19:19:15; ventral 254; subcaudals 128 (paired). We encountered the individual along a thick forested slope by roadside during our survey at about 0.5 m from ground on 13 September 2021 at around 2200 h.

In Mizoram, this species was previously reported from Aizawl districts (Lalremsanga et al. 2011).

9. Gunther's Kukri Snake *Oligodon* cf. *cinereus* (Gunther, 1864)

Materials examined: WII-ADR 1106, Female, SVL 445 mm; TL 70 mm. Image 3C.

Head shields finely spotted with black; no typical head marking. Anteriorly ventral scales with squarish black spots on outer edge. Posteriorly ventral almost dark; subcaudals also heavily spotted with black; 46 narrow irregular black crossbars on dorsum that develops from the dorsal scales edged with black; three bands on top of tail. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having dorsal scale rows 17:17:15; Ventral 173; Subcaudals 42 (paired). We encountered the individual from a loose rocky crevice along streamside during the survey on 14 September 2021 at around 2230 h.

In Mizoram, this species was previously reported from Ngengpui WS, Tamdil, Siaha, Reiek Community Reserved Forests (Pawar & Birand 2001; Das 2010; Lalremsanga et al. 2011; Hmar et al. 2020).

10. Gray's Kukri Snake *Oligodon dorsalis* (Gray, 1834)

Materials examined: Road-killed Specimen, unsexed, not measured.

Completely red subcaudals. The individual agrees with description in Das (2010) and Lalremsanga & Lalronunga (2017). We encountered a road killed individual on the road between Saithah and Phuldungsei village on 13 September 2021 at around 1100 h.

In Mizoram, this species was previously reported from Aizawl district and Reiek Community Reserved Forests (Lalremsanga et al. 2011; Hmar et al. 2020).

11. Zaw's Wolfsnake *Lycodon zawi* Slowinski, Pawar, Win, Thin, Gyi, Oo & Tun, 2001

Materials examined: Not collected, Unsexed, Not measured. Image 3D.

Brownish-black dorsal with narrow white cross bars best marked anteriorly; neck without any band, first band appear two head length behind. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017). We encountered the individual active on the bank of the Tuichar stream and left after photographing it on 27 March 2021 at around 2030 h.

In Mizoram, this species was previously reported from

Image 3. Some ophidian fauna of Dampa Tiger Reserve: A—*Boiga ochracea* | B—*Boiga quincunciata* | C—*Oligodon* cf. *cinereus* | D—*Lycodon zawi* | E—*Dendrelaphis proarchos* | F—*Dendrelaphis cyanochloris* | G—*Ahaetulla flavescens* | H—*Psammodynastes pulverulentus*. © Abhijit Das (A-H).

Ngengpui WS, Keifang, DTR, Aizawl and Saiha districts, Pachhunga University Campus, Reiek Community Reserved Forests (Pawar & Birand 2001; Slowinski et al. 2001; Lalremsanga et al. 2011; Dutta et al. 2013; Hmar et al. 2020).

12. White-banded Wolfsnake *Lycodon septentrionalis* (Günther, 1875)

Materials examined: Roadkill specimen, unsexed, not measured.

Purplish-black dorsum with narrow transverse white bands and a white venter. The individual agrees with description in Biakzuala et al. (2020). We came across a road killed individual on the road near Teirei Forest IB Complex on 15 September 2021 at around 1930 h.

In Mizoram, this species was previously reported from Bhumtilong (= Bungtlang), Sawleng, Aizawl, Mamit, Khawbung, Thenzawl, Pangzawl, Khawrihnim, Dampui (Taklukdar & Sanyal 1978; Lalbiakzuala et al. 2020).

13. Painted Bronzeback Treesnake *Dendelaphis proarchos* Wall, 1909

Materials examined: WII-ADR 1102, Female, SVL 275 mm; TL 115 mm. Image 3E.

Bronze coloured dorsal, distinct cream dorso-lateral lines cover half of the outermost row and the half of the scale row above it. The individual agrees with the description in Lalremsanga & Lalronunga (2017) and Lalbiakzuala et al. (2022) in having dorsal scale rows 15:15:11; ventral 193; subcaudals 150 (paired). We encountered the individual roosting on grass at about 0.2 m from ground on 14 September 2021 at around 2145 h.

Vogel & van Rooijen (2011) revalidated the occurrence of *D. proarchos* in northeast India and Biakzuala et al. (2022) reassessed the systematics of *Dendrelaphis* from Mizoram, northeastern India and removed all the records of *D. pictus* and replaced it with *D. proarchos*.

In Mizoram, this species was previously reported from Ngengpui WS, Aizawl, Aizawl district, Sialsuk, Tanhril, Mizoram University Campus, Sateek, Leng, Khawzawl, Maubuang, Kepran, Tlangnuam,, Buangpui, Durtlang, Khawlailung, Reiek, Phura, DTR, Thenhlum, and Sailam (Pawar & Birand 2001; Das 2010; Lalremsanga et al. 2011; Lalbiakzuala et al. 2022).

14. Wall's Bronzeback Treesnake *Dendrelaphis cyanochloris* (Wall, 1921)

Materials examined: WII-ADR 1117 (Female), SVL 760 mm; TL 330 mm. Image 3F.

Brozed coloured dorsal; a black temporal stripe starts behind the eye; covers the whole temporal region and extends onto the neck; ventrals and subcaudals greenish. The individual agrees with the description in Slowinski et al. (2001), Das (2010), and Lalremsanga & Lalronunga (2017) in having dorsal scale rows 15:15:11; ventral 206; subcaudals 142 (paired). We encountered the individual roosting on overhanging vegetation above road about 2 m from the ground on 14 September 2021 at around 2230 h.

In Mizoram, this species was previously reported from Tamdil, Aizawl and Kolasib districts, Reiek Community Reserved Forest (Lalremsanga et al. 2011, 2014; Hmar et al. 2020).

15. Short-nosed Vinesnake *Ahaetulla flavescens* (Wall, 1910)

Materials examined: not collected (unsexed). Image 3G.

Snout lacking pointed dermal appendage. The individual agrees with the description in Das (2010), Lalremsanga & Lalronunga (2017) and Srikanthan et al. (2022). We encountered an individual roosting on a *Mesua ferra* tree about 10 m from the ground inside Teirei Forest IB complex on 12 September 2021 at around 2030 h.

In Mizoram, this species was previously reported from Aizawl, Ngengpui WS, Tamdil, Aizawl and Mamit districts (Pawar & Birand 2001; Lalremsanga et al. 2011, 2014).

Earlier this speciese was reported as *Ahaetulla prasina* from northeast India. Srikanthan et al. (2022) recently revaluated the taxonomic identity of the northeast Indian populations of the species as *A. flavescens*.

16. Mock Viper *Psammodynastes pulverulentus* (Boie, 1827)

Materials examined: WII-ADR 1105 (Female), SVL 360 mm; TL 90 mm. Image 3H.

Brownish dorsal, scales edged with black, head with 3–4 indistinct bars, dorso-laterally three closely arranged lined and with yellowish spots. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having dorsal scale rows 17:17:15; ventral 160; subcaudals 67 (paired). We encountered the individual roosting on roadside vegetation between Saithah and Phuldungsei on 13 September 2021 at around 1945 h.

In Mizoram, this species was previously reported from Ngengpui WS, DTR, Aizawl & Champhai districts, Reiek Community Reserved Forest (Pawar & Birand 2001; Das 2010; Lalremsanga et al. 2011; Hmar et al. 2020).

17. Large-eyed False Cobra *Pseudoxenodon macrops* (Blyth, 1855)

Materials examined: WII-ADR 1101, Female, SVL 245 mm; TL 60 mm. Image 4A.

Reddish-brown or olive brown dorsal in colour; indistinct, small transverse bars on dorsum, Labials edged with faint black bars; labial and chin region whitish. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having dorsal scale rows 19:17:15; ventral 153; subcaudals 69 (paired). We encountered the individual active of slope along the side of a stream on 13 September 2021 at around 1300 h and it tried to hide when encountered.

In Mizoram, this species was previously reported from Tamdil, Aizawl district, Reiek Community Reserved Forests (Das 2010; Lalremsanga et al. 2011; Hmar et al. 2020).

18. Assam Snail Eater *Pareas monticola* (Cantor, 1839)

Materials examined: WII-ADR 1076, Female, SVL 360 mm; TL 115 mm. Image 4B.

Yellowish dorsum with series of irregular edged black bars on the two side of mid dorsal line, top of head heavily spotted with black but the mottling is defined within an arrow-head shaped space. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having dorsal scale rows 15:15:15; ventral 192; subcaudals 81 (paired). We encountered the individual on a tree branch above stream at about 5 m from the ground on 14 September 2021 at around 2030 h. Another individual was encountered on the same night on a branch on a roadside vegetation slope at about 1 m from the ground.

In Mizoram, this species was reported from Aizawl, Tamdil, Kolasib district, Reiek Community Reserved Forests (Das 2010; Lalremsanga et al. 2011, 2014; Hmar et al. 2020).

Family: Elapidae

19. Monocled Cobra *Naja kaouthia* Lesson, 1831

Materials examined: Not collected (Unsexed). Image 4C.

Hood markings usually distinct, usually a pale, oval or circular marking, with a dark center and occasionally a narrow dark outer border. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017). We encountered an adult individual during a day trek towards Dampatlang on 5 March 2021 at around 1300 h. The individual was photographed on the spot and left in the area.

In Mizoram, this species was previously reported from Ngengpui WS, Mizoram University Campus, Tamdil, All districts of Mizoram, Reiek Community Reserved Forest (Pawar & Birand 2001; Das 2010; Lalremsanga et al. 2011, 2014, Hmar et al. 2020).

20. Banded Krait *Bungarus fasciatus* (Schneider, 1801)

Materials examined: Not collected (Unsexed). Image 4D.

Black and yellow banded snake with blunt tail. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017). We encountered the individual active on a thick vegetated slope along a road near Teirei Forest IB Complex on 15 September

Image 4. Some Ophidian of Dampa Tiger Reserve: A—*Pseudoxenodon macrops* | B—*Pareas monticola* | C—*Naja kaouthia* | D—*Bungarus fasciatus* | E—*Trimeresurus erythrurus* | F—*Trimeresurus popeiorum*. © Samuel Lalronunga (A), Abhijit Das (B, D-F), C. Mazuala (C).

2021 at around 2000 h. The snake displayed head hiding behavior while being photographed in day light.

In Mizoram, this species was previously reported from Ngengpui WS, Aizawl district, Champhai district, Kolasib district, Mamit district, Reiek Community Reserved Forests (Pawar & Birand 2001; Das 2010; Lalremsanga et al. 2011; Hmar et al. 2020).

Family: Viperidae

21. Spot-tailed Pit Viper *Trimeresurus erythrurus* (Cantor, 1839)

Materials examined: WII-ADR 1119, Male, SVL 510 mm; TL 115 mm. Image 4E.

Dorsal greenish in colouration, eyes yellow; tongue dark brown; ventral yellowish-white; top of tail uninterrupted reddish in colour. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having Dorsal scale rows 25:25:19; ventral 167; subcaudals 65 (paired). We encountered five individuals of this species during the survey on saplings and tree branches along forest trails, and vegetation slopes on roadsides and on roads.

In Mizoram, this species was previously reported from Bhumtilang (= Bungtlang), All districts of Mizoram, Reiek Community Reserved Forest (Talukdar & Sanyal 1978; Lalremsanga et al. 2011; Hmar et al. 2020).

22. Pope's Pit Viper *Trimeresurus popeiorum* Smith, 1937

Materials examined: WII-ADR 1120, Male, SVL 560 mm; TL 140 mm. Image 4F.

Eyes red, background colour is uniformly green, red ventrolateral stripe below and white stripe above in males, well defined white stripe in females; the ventrolateral stripe become broken down into blotches alongside of the tail. The individual agrees with the description in Lalremsanga & Lalronunga (2017) in having dorsal 23:21:19; ventral 166; subcaudals 70 (paired). This species was quite common in the study area, we encountered >10 individuals along roadside vegetation, saplings on forest trails and a female individual in an ambush position in a small guava tree near the guest house in Phuldungsei IB complex.

In Mizoram, this species was previously reported from Aizawl and Mamit district (Lalremsanga et al. 2011). Pawar & Birand (2001) reported *Trimeresurus* cf. *stejnegeri* from DTR which supposedly would be a misidentification of *T. popeiorum*.

Family: Typhlopidae

23. Diard's Blindsnake *Argyrophis diardii* (Schlegel, 1839)

Materials examined: WII-ADR 1067, Female, SVL 32.5 mm; TL 4 mm.

Image 5. Some habitats of reptiles in Dampa Tiger Reserve: A—Dry Streambed | B—Mature Forest | C—Road and roadside vegetation | D—Bamboo grove. © Abhijit Das A-D)

Shiny blackish brown dorsum, on the neck and anterior part of body nine to ten dorsal scale rows are dark brown and shiny, little paler below, the two colours are not sharply contrasted. The individual agrees with the description in Das (2010) and Lalremsanga & Lalronunga (2017) in having a mid-row dorsal scale of 28. We encountered a fresh dead individual on the road in West Phaileng village on 12 September 2021 at around 1500 h.

In Mizoram, this species was previously reported from Tamdil, Sihhmui, Aizawl & Saiha district, Reiek Community Reserved Forest (Das 2010; Lalremsanga et al. 2011, 2014; Hmar et al. 2020).

DISCUSSIONS

The first attempt to document the herpetofauna of DTR was made about two decades ago (Pawar & Birand 2001). That study recorded 22 species of amphibians, 16 species of lizards, seven species of snakes, and four species of cheloneans from DTR.

Table 1. Annotated checklists of reptiles of Dampa Tiger Reserve. * represents the first record of the species from DTR.

Family	Species	Pawar & Birand (2001)	Lalrinchhana & Solanki (2015)	Lalmuansanga et al. (2020)	Vanlalchhuana et al. (2016)	Biakzuala et al. (2020)	Present study
AGAMIDAE							
	Calotes emma	√	√				√
	Calotes versicolor	√	√				√
	Calotes cf. *irawadi*		√				
	Draco maculatus	√	√				
	Draco sp. (cf. blandfordii-norvilli)	√					
	Cristidorsa planidorsata	√	√				√
	Ptyctolaemus gularis	√	√				√
GEKKONIDAE							
	Hemidactylus platyrus	√	√				√
	Hemidactylus brookii		√				
	Hemidactylus frenatus	√	√				√
	Hemidactylus garnotii		√				
	Hemidactylus sp.		√				
	Cyrtodactylus sp.		√				
	Cyrtodactylus montanus			√			√
	Geeko gecko	√	√				√
SCINCIDAE							
	Eutropis macularia	√	√				
	Eutropis multifasciata	√	√				
	Eutropis sp.	√					
	Tropidophorus assamensis	√	√				
	Sphenomorphus maculatus	√	√				√
	Sphenomorphus indicus		√				
LACERTIDAE							
	Takydromus sexlineatus	√	√				
VARANIDAE							
	Varunus benghalensis	√	√				
	Varunus salvator		√				√
NATRICIDAE							
	Herpetoreas xenura	√					√
	Hebius khasiensis						√*
	Rhabdophis helleri	√					√
	Rhabdophis cf. *himalayanus*						√*
	Smithophis bicolor						√*
	Smithophis atemporalis						√*
	Fowlea piscator	√					
COLUBRIDAE							
	Boiga ochracea						√*
	Boiga quinqunciata						√*
	Ahaetulla flavescens						√*
	Oligodon cf. *cinereus*						√*
	Oligodon dorsalis						√*

Family	Species	Pawar & Birand (2001)	Lalrinchhana & Solanki (2015)	Lalmuansanga et al. (2020)	Vanlalchhuana et al. (2016)	Biakzuala et al. (2020)	Present study
	Lycodon zawi	√					√
	Lycodon septentrionalis					√	√
	Dendrelaphis cyanochloris						√*
	Dendrelaphis proarchos						√
	Psammodynastes pulverulentus	√					√
	Ptyas korros	√					
PSEUDOXENODONTIDAE							
	Pseudoxenodon macrops						√*
PAREIDAE							
	Pareas monticola						√*
ELAPIDAE							
	Naja kaouthia						√*
	Bungarus fasciatus						√*
	Ophiophagus hannah				√		
VIPERIDAE							
	Trimeresurus popeiorum						
	Trimeresurus erythrurus						√*
TYPHLOPIDAE							
	Argyrophis diardii						√*
EMYDIDAE							
	Cuora mouhotii	√					
	Cyclemys gemelli	√					
	Melanochelys trijuga	√					
TESTUDINIDAE							
	Indotestudo elongata	√					

With the subsequent observations by Lalrinchhana & Solanki (2015), Lalremsanga et al. (2016), Muansanga et al. (2020), Biakzuala et al. (2020), Decemson et al. (2021), currently the reptilian fauna of DTR stands to 40 species (saurians: 26, serpentes: 9; cheloneans: 4). The present study recorded 33 species of reptiles from DTR of which 16 species of snakes, viz., *Hebius khasiensis*, *Rhabdophis himalayunus, Smithophis bicolor, Smithophis atemporalis, Boiga ochracea, Boiga quincunciata, Oligodon* cf. *cinereus, Oligodon dorsalis, Dendrelaphis cyanochloris, Ahaetulla flavescens, Pseudoxenodon macrops, Pareas monticola, Naja kaouthia, Bungarus fasciatus, Trimeresurus erythrurus*, and *Agyrophis diardii* were reported for the first time from DTR.

Pawar & Birand (2001) made a pioneer work to document the herpetofauna of DTR. They recorded 27 species of reptiles from DTR out of which one species (*Draco* sp.) cannot be determined to a species level. However, they indicated that the species in question had an affinity with *D. blanfordi* or *D. norvilli* and another two species that were conferred as *Dendrelaphis* cf. *pictus* and *Trimeresurus* cf. *stejnegeri* needs verification.

Lalrinchhana et al. (2011) recorded 22 species of lizard from DTR. Subsequently, Lalrinchhana & Solanki (2015) recorded 22 species of lizards from DTR. It is interesting to note that, even though the number of species recorded in these studies remained the same, the recorded species were not the same. Eighteen species, viz., *Calotes versicolor*, *Calotes emma*, *Draco maculatus*, *Cristidorsa planidorsata*, *Ptyctolaemus gularis*, *Gekko gecko*, *Hemidactylus platyurus*, *Hemidactylus frenatus*, *Hemidactylus brookii*, *Hemidactylus garnotii*, *Cyrtodactylus* sp., *Takydromus sexlineatus*, *Sphenomorphus maculatus*, *Eutrophis multifasciata*, *Eutrophis macularia*, *Tropidophorus assamensis*, *Varanus bengalensis*, and *Varanus salvator* were recorded in both studies. Lalrinchhana & Solanki (2015) reported four species viz., *Calotes* cf. *irawadi*, *Draco maculatus divergens*, *Draco* cf. *blanfordi*, and *Sphenomorphus indicus* which were not reported by Lalrinchhana et al. (2011). A recent study in DTR (Lalmuansanga et al. 2020) as well as the present study recorded *Cyrtodactylus montanus* from DTR. Therefore, the species previously reported as *Cyrtodactylus* sp. from DTR is likely represented by this species.

The reports of *Calotes versicolor* by Pawar & Birand (2001), Lalrinchhana et al. (2011), and Lalrinchhana & Solanki (2015) remain unclear as Gowande et al. (2021) removed *C. versicolor* from northeastern India and placed all the northeastern Indian species in *C. irawadi* clade, therefore, the revaluation of *Calotes versicolor* group in northeast India is requires further studies. Gowande et al. (2021) stated that males of *C. versicolor* attain yellowish overall coloration, the trunk and the orbital region turns bright orange, forelimbs and hind limbs turn dark to black, however in present study we documented a displaying male from Teirei river, DTR with a reddish colour around the tympanum that extends till the midbody, which resembles the revived species, *Calotes vultuosus* (Type locality Kolkata, West Bengal) and the occurrence of this species needs to be checked/ confirmed in Mizoram. Pawar & Birand (2001) also reported four chelonians during their study in DTR which were not encountered in the present study. Among other additions, Vanlalchhuana et al. (2016) reported the nesting and hatchlings of *Ophiophagus hannah* from DTR.

The maximum number of encounters during our study inhabit roadside vegetation, forest trails and streams flowing along the roadside while there were very few encounters in the oil palm plantation. The roads connecting the villages within DTR are a borderline between the core and buffer zones. The expansion of road networks is one of the major threats for wildlife as a result of habitat destruction and population fragmentation (Mader 1984; Jaarsma et al. 2006). Moreover, the impact of roads is manifested in the direct mortality of wildlife through wildlife-vehicle collisions (Bennett 2017). Vehicle collisions are a major cause of mortality for a wide variety of herpetofauna (Dutta et al. 2016). During our survey at DTR, we observed a road-killed gravid female *Trimeresurus erythrurus*. As much as road connectivity is essential for the communities living in the fringe villages of DTR, detailed studies on the impact of roads on the wildlife of DTR in general and herpetofauna, in particular, will help in formulating mitigation measures.

Biodiversity incentivization provides essential baseline data on life forms in space and time (McDiarmid et al. 2012), the local herpetofauna diversity inventory presented in this study will ultimately contribute to our understanding of biodiversity and it will be valuable information for policy makers.

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COMMUNICATION

First report of marine sponge *Chelonaplysilla delicata* (Demospongiae: Darwinellidae) from the Andaman Sea/Indian Ocean with baseline information of epifauna on a mesophotic shipwreck

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Abstract: During a biodiversity assessment on a wreck located in the Andaman Sea (Andaman Islands), a single specimen of sponge *Chelonaplysilla delicata* was recorded. Our finding confirms the species taxonomy and highlights the current observation as a first report from the Andaman Sea/Indian Ocean. The baseline information on epifaunaof the wreck is further stated in this study.

Keywords: Biodiversity, epifauna, invasive, Porifera taxonomy, *Tubastraea*.

Hindi: अंडमान सागर (अंडमान द्वीप समूह) में स्थति मलबे पर जैव ववविधता मूल्यांकन के दौरान, स्पंज का एक एकल नमूना चेलोनाप्लसिलि डेलकिाटा दर्ज कयिा गया था। हमारी खोज प्रजातयिों के वर्गीकरण की पुष्टि करती है और अंडमान सागर / हदिं महासागर से पहली रपिोर्ट के रूप में वर्तमान अवलोकन पर प्रकाश डालती है। एपफीौना की आधारभूत जानकारी इस अध्ययन में आगे बताई गई है।

Bengali: আন্দামান সাগরে (আন্দামান দ্বীপপুঞ্জ) অবস্থিত একটি ধ্বংসাবশেষের জীববৈচিত্র্য মূল্যায়নের সময়, স্পঞ্জের একটি একক নমুনা চেলোনাপ্লিসিলা ডেলিকাটা নথিভুক্ত করা হয়েছিল। আমাদের বর্তমান অনুসন্ধানটি প্রজাতিটির শ্রেণীবিন্যাস সুনিশ্চিত করে এবং আন্দামান সাগর/ভারত মহাসাগর থেকে প্রথম প্রতিবেদন হিসাবে দৃষ্টিগোচর করে। এই এপিফনার কিছু প্রাথমিক তথ্য এখানে আরও বলা হয়েছে।

Tamil: அந்தமான் கடலில் (அந்தமான் தீவுகள்) அமைந்துள்ள ஒரு கப்பல் சிதைவில் பல்லுயிர் மதிப்பீட்டிற்கான ஆராய்ச்சின்போது, கடற்பாசியின் ஒரு வகை-மாதிரியான *செலோனாப்ளிசில்லா டெலிகேட்டா* முதன் முறையாக பதிவு செய்யப்பட்டுள்ளது. எங்கள் ஆராய்ச்சியானது இந்த கடற்பாசியின் இனங்கள் வகைபிரிப்பை உறுதிப்படுத்துவதோடு மட்டுமல்லாமல் இந்த கடற்பாசி அந்தமான் கடலில் வாழ்வதை முதல் முறையாக உறுதிப்படுத்துகிறது. கடல் அடியில் ஊர்ந்து வாழும் விலங்குகளின் அடிப்படைத் தகவல்கள் இந்த ஆய்வில் மேலும் எடுத்துரைக்கப்பட்டுள்ளன.

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INTRODUCTION

The Andaman Sea, an eastern subdivision of the Indian Ocean, is bordered by countries like Thailand and Myanmar on the east and the Andaman archipelago (Andaman & Nicobar Islands/ANI) on the west (Figure 1) (Brown 2007). A large portion, however, falls within the boundary of the Coral Triangle Initiative (CTI) (Rudi et al. 2012). Studies related to its marine biodiversity or the coral reef ecosystem have been comparatively understudied or scattered (Aungtonya et al. 2000; Brown 2007). Additionally, the Andaman Sea possesses several shipwrecks (Kheawwongjan & Kim 2012) acting as artificial reef ecosystems, knowledge pertaining to which is mostly limited in the region. These sunken structures provide space for the growth and establishment of various sessile marine communities like poriferans (Walker et al. 2007; Lira et al. 2010) and other non-native species (Patro et al. 2015; Soares et al. 2020). Within the Indian Exclusive Economic Zone (EEZ), recent studies targeting shallow-water wrecks have filled important knowledge gaps (example Mohan 2013; Das 2014; Yogesh-Kumar et al. 2015) (Table 1). This article further adds essential information about these rarely studied ecosystems at a mesophotic depth and reports a marine sponge from the Andaman Sea/Indian Ocean.

MATERIAL AND METHODS

The sponge, *Chelonaplysilla delicata* (Image 1), was collected from the shipwreck HMIS SM* during a survey conducted to document epifaunal diversity from February to March 2014. The wreck is a 70-m long Royal Indian navy minesweeper that sank in the year of 1942. It is located at a depth of 33m near Chidiyatapu on the edge of the Macpherson Strait (11.477°N, 92.703°E) (Figure 1). Water transparency and temperature were recorded with a Secchi disc and a dive calculator. After collection, the specimen was preserved in 100% ethanol. A surface peel of the easily separable cortex of the specimen was removed and placed in xylene for 24 hours, after which a permanent slide of the peel was mounted with DPX. A single fibre with its base and branches intact was removed from the sponge for species-level identification under a stereo microscope (Image 1B–D). The specimen was identified following Pulitzer-Finali & Pronzato (1999). The preserved specimen is deposited in the National Zoological Collections (NZC) of the Andaman & Nicobar Regional Centre (ANRC), Zoological Survey of India (ZSI), Port Blair.

Benthic cover was assessed by randomly placing 20 (0.25 x 0.25 m) quadrats (Image 2). The photographs were analysed using open-sourced Coral-Net software (Beijbom et al. 2012), and the epifauna was classified into Unknown, Porifera, Scleractinian, *Ircinia* sp. (Porifera), Algae, *Iotrochota* sp. (Porifera), Sediment, *Tubastraea* aff. *coccinea*, *Tubastraea micranthus*, Hard Substrate, Ascidian, and Bleached Coral (modified from Zintzen et al. 2006). Other specimens not within the quadrat have been identified wherever possible to the lowest possible taxonomic level. Later, the data from the annotated quadrats was transferred and processed in Microsoft Excel® (Microsoft 365 MSO, 16.0.13001.20266/32bit). Study maps were created using the open-sourced Quantum Geographic Information System (QGIS ver. 3.6).

RESULTS AND DISCUSSION

Systematics

Phylum: Porifera
Class: Demospongiae
Order: Dendroceratida
Family: Darwinellidae
Genus: *Chelonaplysilla*

Species: *Chelonaplysilla delicata* Pulitzer-Finali & Pronzato, 1999

Paratype: ZSI/ANRC – 14321, 2014, 1 ex., India: Andaman Island: South Andaman: Chidiyatapu (11.477 °N, 92.703 °E), coll. Rocktim Ramen Das.

Diagnosis

Chelonaplysilla delicata predominantly thickly encrusting (<10 mm) but has erect lobes that are about 4–5 cm high. The sponge surface is conulose, and the acute conules separated from each other by 2–5 mm. Oscules 1–3 mm in diameter, flush with the surface and unevenly distributed all over on sponge surface. The texture is soft collapsible and feeble. The fresh specimen was dark violet or purple in colour and retained its colour even in the preserved condition. Sponge surface covered by structured regular reticulation of sand and spicule detritus, which forms regular roundish or oval meshes of 90–155 µm. This reticulation is typical of the genus. Regular rounded fibrous pores, inhalant in nature, is enclosed within these rounded meshes (Image 1D). The skeleton is dendritic, made up of pigmented fibres fragile in nature with repeated branching that originate from a basal spongin plate (Image 1 B,C) and extends towards the boundary. The primary fibre measured to be around

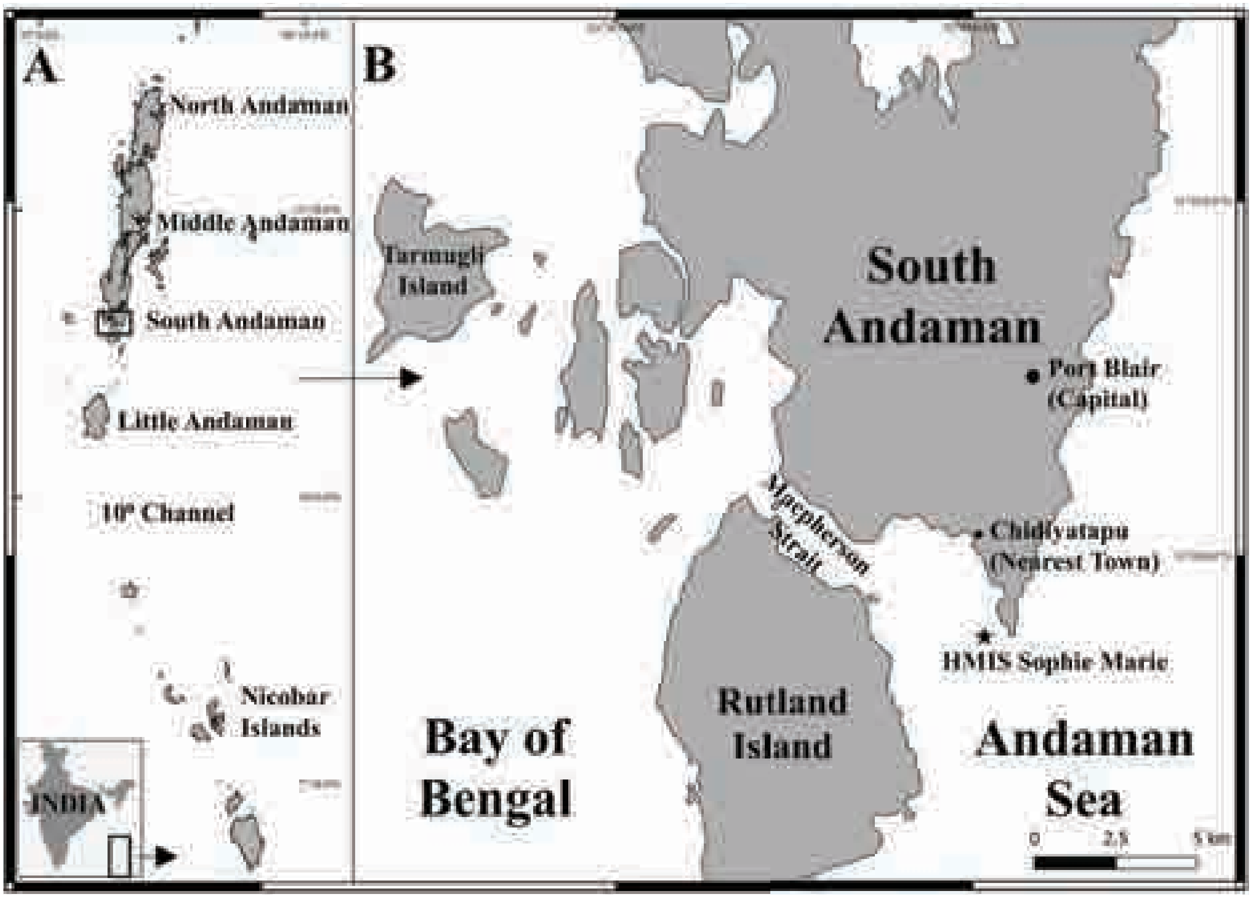

Figure 1. Location of the study area (HMIS Sophie Marie)

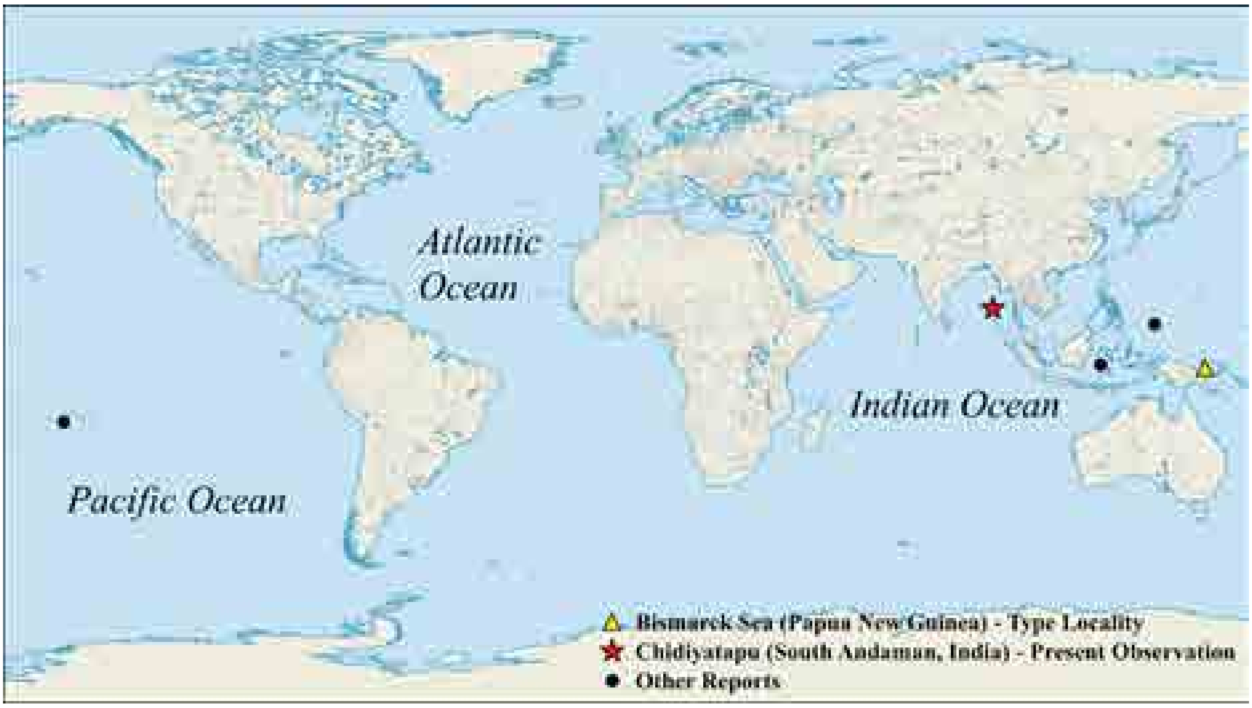

Figure 2. Global distribution of *Chelonaplysilla delicata* Pulitzer-Finali & Pronzato, 1999

Table 1. Information on biodiversity studies in shipwrecks within Andaman & Nicobar Islands

Wreck Name	Co-ordinates	Location	Date of Sinking	Depth (m)	Current Activities	Reference
SS Inchkeith	12.00658°N 92.76898°E	Kyd Island (South Andaman)	1955	14	Scuba	Mohan 2013; Das 2014; Das et al. 2016
HMIS Sophie Marie	**11.47723°N 92.70339°E**	**Chidiyatapu (South Andaman)**	**1942**	**30–33**	**Scuba**	**Present Study**
MV Mars	11.93194°N 92.9567°E	Havelock (Ritchie's Archipelago)	2006	10–16	Scuba	Das R.R. (pers. obs.)
North Bay Wreck	11.71682°N 92.76683°E	Port Blair (South Andaman)	30–40 (yrs)	10	Scuba and Fishing	Yogesh-Kumar et al. 2015
Peel Wreck	12.07339°N 92.97253°E	Havelock (Ritchie's Archipelago)	8–10	9–12	Scuba	Yogesh-Kumar et al. 2015
Japan Wreck	9.191194°N 92.83675°E	Car Nicobar (Nicobar Islands)	40–50	28	Fishing	Yogesh-Kumar et al. 2015
Sinclair Bay Shipwreck	11.8925°N 92.88556°E	Near Ross Island (South Andaman)		8		Mondal & Raghunathan 2017

0.4 mm at its thickest. Spicules are absent.

Distribution

India: Andaman Sea (ANI, South Andaman, Present study). Elsewhere: Bismarck Sea (Papua New Guinea) (Pulitzer-Finali & Pronzato 1999), Indonesia (Sulawesi) (GBIF 2000), Palau (Micronesia) (Ridley et al. 2005), French Polynesia (Alencar et al. 2017) (Figure 2).

Remarks

Chelonaplysilla delicata is very similar to *C. erecta* (Tsurnamal, 1967); however, the latter has fibres anastomosing in nature, whereas the thickness of fibres in *C. delicata* fades in diameter. The specimen mentioned in Pulitzer-Finali & Pronzato (1999) is gray, whereas our specimen is dark maroon in live condition (Image 1A). The specimen was initially misidentified as *C. erecta* (Das 2014; Das et al. 2016). Thus, there was a need for an update and filling of knowledge gaps in this species distribution range.

Comments

The family Darwinellidae possesses sponging fibres with a proper skeleton and fibrous spicules (Van Soest 1978; Bergquist & Cook 2002). It consists of five recognised genera and 45 accepted species. *Chelonaplysilla* is the only genus which is devoid of spicules but consists of a fibrous dendritic skeleton that possesses a distinct laminated bark surrounding a central pith region. A structured and separable cortex that is reinforced by a delicate reticulation of sand grains (Van Soest 1978) distinguishes this genus.

Wreck Biodiversity

Benthic cover assessment (Image 2) reveals that Poriferans were the second most abundant group on the surface of the wreck, mostly encrusting in nature. In most instances, the encrusting sponge genus *Iotrochota* was readily visible. Ahermatypic and invasive sun corals were abundant in selected localities and may have found a successful substrate for further expansion (Image 2A, 3). Few polyps of *Tubastraea micranthus* had signs of bleaching, a stark contrast to their ahermatypic nature. Updated and revised identification following Das et al. (2016) on the wreck surface includes scleractinian genera *Favia*, *Symphyllia*, *Podabacia crustacea*, and *Leptoseris*. A single individual of the Gastropod genus (*Chicoreus*) and a few crinoids. The identified poriferan families include Irciniidae (*Ircinia*), Chalinidae (*Haliclona* (*Reniera*)); Thorectidae (*Hyrtios*), Iotrochotidae (*Iotrochota baculifera*), Thorectidae (*Dactylospongia*), and Dysideidae (*Dysidea* sp.). Tunicates comprised Didemnidae (*Didemnum*), Perophoridae (*Perophora*), and other unidentified spp.

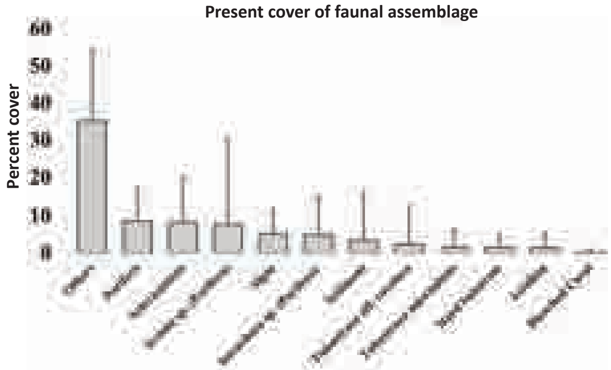

Figure 3. Mean percent cover of epifauna obtained from (0.25m x 0.25m) quadrats (n = 20).

The faunal organisms that thrive in artificial reefs (shipwrecks) are an important part of the marine community (Zintzen et al. 2006; Amaral et al. 2010).

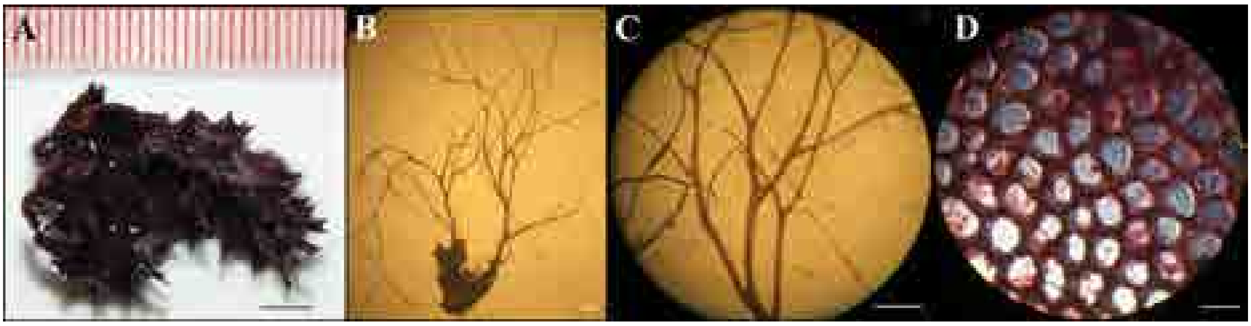

Image 1. *Chelonaplysilla delicata* [ZSI/ANRC-14321]: A—Freshly collected specimen | B—Branching fibres and basal sponging plate | C—Closer view of pigmented, branching, dendritic spongin fibre, | D—Inhalant pores surrounded by rounded meshes reinforced by sand grains. Scale (A) 5mm (B) 2 mm, (C) 2 mm, (D) 155 µm. © A—Rocktim Ramen Das, B–D—Titus Immanuel.

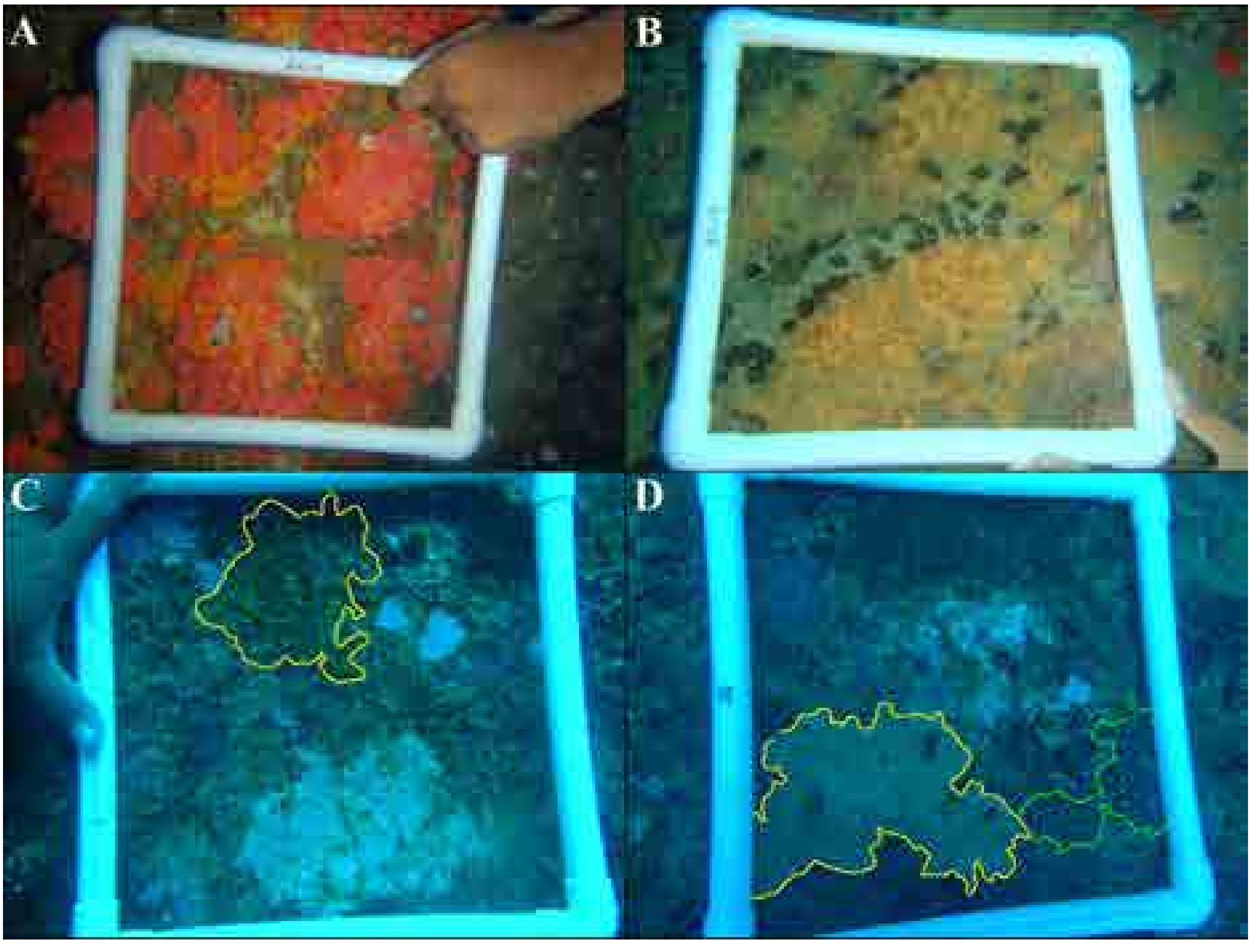

Image 2. A—*Tubastraea* aff. *coccinea* (adapted from Das et al. 2016) | B—*Ircinia* sp. | C—Mixed assemblage of communities, Encrusting sponge *Iotrochota* sp. (Green) | D—Mixed assemblage, Sponge (Yellow), coral (green). © Rocktim Ramen Das.

With increasing anthropogenic impacts on natural coral reef habitats, artificial reefs are regarded as a successful alternative (Perkol-Finkel & Benayahu 2005). As a result, it becomes important to understand the biological communities growing in these habitats (Thanner et al. 2006). Sponges, which naturally occupy shipwrecks, are one of the dominant organisms in such habitats, as evidenced in the present study. However, its diversity will be strictly limited to the environmental settings. For example, some species of the genus *Iotrochota* are found in sheltered environments (Cleary & de Voogd 2007) as seen in our observation (Image 2C). Similarly, shipwrecks

Image 3. A part of the wreck HMIS SM. (Arrow: invasive *Tubastraea micranthus*). © Karan Baath.

are also known to act as successful substrates for many non-native species, as reported from the Atlantic and the Red Sea (Perkol-Finkel et al. 2006; Soares et al. 2020). Repeated encounter of *Tubastraea* aff. *coccinea* (Image 2A) earlier misidentified as *Dendrophyllia* sp. and T. *micranthus* (Image 3) in the study site is a strong evidence from the Andaman Sea (Das et al. 2016) (Figure 1). The sponge species reported herein is at a much-extended depth compared to its initial described type locality (see Pulitzer-Finali & Pronzato 1999).

Technical difficulties have hampered studies on these habitats at mesophotic depths (Massin et al. 2002; Zintzen et al. 2006). But with the rapid scale development of remotely operated vehicles and submersibles, detailed exploration of these ecosystems can be well predicted. Further, these areas might be a hub for various underexplored flora and fauna and might be effective in reviving threatened marine life due to the loss of natural ecosystems.

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Author contributions: RRD—conceptualization, study design, writing original draft, reviewing & editing, field assessment, sample collection, data analysis, laboratory analysis. TI—writing original draft, reviewing & editing, sample identification, laboratory analysis. RKL—study design, writing, reviewing & editing, field assessment. KB—field assessment. GT—study design, writing, reviewing & editing, supervision.

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COMMUNICATION

Intertidal Ophiuroidea from the Saurashtra coastline, Gujarat, India

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Abstract: Present communication reports the diversity of intertidal Ophiuroidea (Phylum: Echinodermata) from the intertidal zones of the Saurashtra coastline, Gujarat state. Saurashtra coastlines were extensively surveyed from January 2019 to March 2022 for the Ophiuroidea diversity. A total of nine species of Ophiuroidea belonging to eight genera and six families were noted from the intertidal zones of the Saurashtra coastline. Amongst these, *Macrophiothrix variabilis, Ophiothrix savignyi* and *Ophiomaza cacaotica* are newly observed species from the Gujarat coastline. The results of similarity indices show that each sampling site has a diverse variety of brittle star, making them spatially different from each other.

Keywords: Brittle star, echinoderms, intertidal, marine invertebrate, species diversity.

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Competing interests: The authors declare no competing interests.

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Author contributions: HB and RK conceived the study; HB and BS did the field work, collected data and identification; BS survey literature; HB analyzed the data and preceded the manuscripts writing; RK review the manuscript. All authors contributed significantly to draft the manuscript.

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INTRODUCTION

The Ophiuroidea are known as brittle stars, basket stars (euryalids with branching arms) and snake stars (euryalids with non-branching arms). It is the largest group among extant living echinoderms, with 2,116 described species found in all oceans from the intertidal to the greatest depths (Stöhr et al. 2021). Among them, 160 species have been recorded from Indian waters (Samuel et al. 2017). Recently nine new brittle stars are reproted from India (Parameswaran et al. 2021). *Macrophothrix aspidota* was the first Ophiuroid reported from Gujarat (James 1969). After that, *Ophioplocus imbricatus* was recorded from Pirotan Island (Clark & Rowe 1971). A total of 12 species were reported from Gujarat (Sastry 2004; Gohil & Kundu 2012; Poriya 2015). The literature indicates that not many studies were conducted, nor significant data were available for the species diversity of intertidal ophiuroids from the Saurashtra coastline, Gujarat.

The present study aims to better document the species diversity of ophiuroids from the Saurashtra coastline, Gujarat. An extensive sampling effort in the rocky intertidal coastal zone was undertaken at eight localities around the Saurashtra coastline. Below, we discuss each species encountered and compare species composition between selected localities.

MATERIALS AND METHODS

Total of eight locations were chosen for ophiuroids sampling (Figure 1, Table 1) during the low tide from January 2019 to March 2022. In situ photography of live specimens was carried out. Voucher specimens of some species were collected by direct hand-picking method from various habitats for further identification. Specimens were relaxed with magnesium chloride and fixed in 95% ethanol and 4% formalin. Encountered Ophiuroidea species preliminary identification was done with the monograph of Clark & Rowe (1971) and Cherbonnier & Guille (1978). Confirmed determinations up to species level was done using various research articles such as O'Hara et al. (2018) for family rank and above, Hoggett (1990) for *Macrophiothrix*, Thomas (1975) for *Ophioplocus*, and Clark (1953) for Ophionereis. Voucher specimens were deposited in the Museum of the Department of Biosciences, Saurashtra University. In the present study, the Jaccard similarity index (J) was measured using R to compare the similarity and diversity of the different sampling sites.

RESULTS

Diversity of Intertidal Ophiuroidea: In the present study, nine species of ophiuroids belonging to eight genera and six families were noted from the intertidal zones of the Saurashtra coastline (Table 2). Among these, only one species was reported from Simbor, three species each from Diu, Dhamlej, Mangrol, & Shivrajpur, five from Veraval, six from Dwarka, and seven species from Okha (Table 3). Systematic position, explanation, and habitation of noted ophiuroids are as follows:

Systematics section

Family Ophiocomidae Ljungman, 1867
Genus *Ophiocomella* A.H. Clark, 1939
***Ophiocomella sexradia* (Ducan, 1887)**
Image 1A

Material: Diu (Gangeshwar coast, Jalandhar coast) - 8 specimens; Dhamlej - 3 specimens; Veraval - 6 specimens; Mangrol - 4 specimens; Dwarka - 5 specimens; Shivrajpur - 2 specimens; Okha - 6 specimens. Three specimens having Museum ID: ZEOOOO(5)19H, ZEOOOO(1)19H, ZEOOOO(8)19H, coll. Hitisha Baroliya, are deposited in the museum.

Remarks: Commonly observed six arms *O. sexradia* at the Saurashtra coast, but we observed one specimen with seven arms. Specimens have small and imbricating scales and papillae**,** narrow and oval shaped radial shield, three to five elongate and blunt arm spines, one tentacle scale. Three to eight oral papillae on each side of jaw and one to six pair of dental papillae with one to seven square-tipped teeth.

Habitat: Rock crevices and under algal holdfast.

Distribution: Common across the Indo-West Pacific (Clark & Rowe 1971).

Previous records from Gujarat: Dwarka and Okha (Sastry 2004).

Present study: Veraval, Diu, Mangrol, Dwarka, and Okha.

Family Hemieuryalidae Verrill, 1899
Genus *Ophioplocus* Lyman, 1861
***Ophioplocus imbricatus* (Müller & Troschel, 1842)**
Image 1B

Material: Dwarka - 3 specimens; Shivrajpur - 1 specimen; Okha - 4 specimens. Two specimens having Museum ID: ZEOAHO(1)19H, ZEOAHO(13)19B, coll. Bhavna Solanki and Hitisha Baroliya, are deposited in the Museum.

Remarks: Disk Covered by small and imbricating

Table 1. Detailed information about sampling localities evaluated in the study.

Site name	GPS coordinates	Description
Diu	20.70207 N, 70.91727 E	Island located on outer rim of Gulf of Kambhat. Sampling sites: Nagoa and Gangeshwar.
Simbor	20.76603 N, 71.15496 E	Small islet located at the mouth of Sahil river at the Bay of Simbor. Sandy-rocky coast. Sampling site: rocky outcrop of ~350m length.
Dhamlej	20.77034 N, 70.61462 E	Near the Sutrapada, around 2 km long rocky substratum. Flat emergent rocky habitat covered by *Zoanthus*.
Veraval	20.91691 N, 70.34221 E	Largest fish landing site, 3 km long with fully rocky substratum with coral, zoanthid and Cerithium assemblage.
Mangrol	21.0984 N, 70.11417 E	40 km west of Veraval. Coastal stretch 3 km long with fully flat rocky substratum.
Dwarka	22.23676 N, 68.9254 E	South-west part of Saurashtra coastline. Light house, 800 m long, sandy-rocky coastal area.
Shivrajpur	22.33049 N, 68.95123 E	'Blue Flag beach', located between Dwarka and Okha. 1 km in length.
Okha	22.47974 N, 69.08047 E	Located outer rim of the Gulf of Kutch, coastal length for this study was 3 km. Intertidal zone contains hard rocky substratum with sandy-rocky patches.

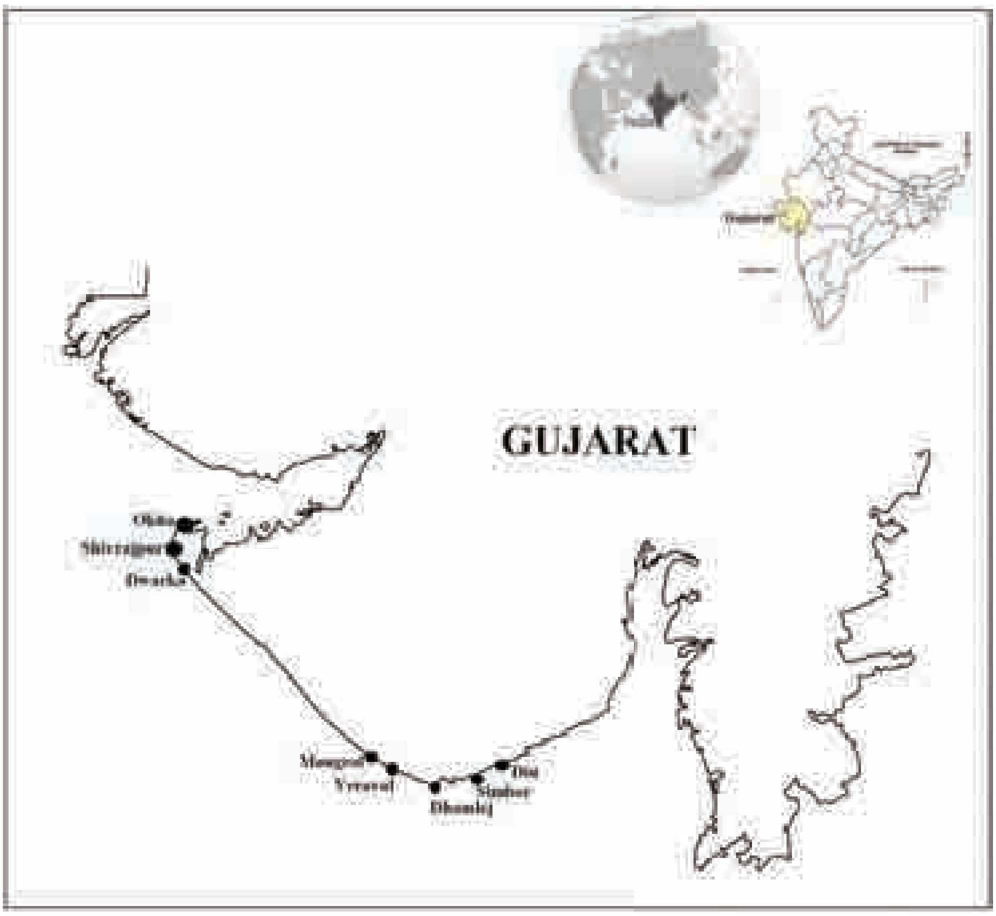

Figure 1. The sampling stations of Saurashtra coast.

scales. Dorsal arm plate fragmented into number, three short and blunt arm spines, two tentacle scales. Four square shaped oral papillae on each side while as dental papillae absent, five square tipped teeth present in each jaw.

Habitat: Underneath of rock in shallow pool.

Distribution: West India, Pakistan, Sri Lanka, Bay of Bengal, East Indies, northern Australia, Philippine, China, southern Japan, South Pacific Islands and Hawaiian Islands (Clark & Rowe 1971); eastern Africa to Hawaii (Tortonese 1980); Australia (Rowe & Gates 1995).

Previous reports from Gujarat: Okha, Beyt Island, Hanuman Dandi, and Sikka (Sastry 2004).

Present study: Dwarka, Okha, and Shivrajpur lighthouse area.

Family Ophionereididae Ljungman, 1867
Genus *Ophionereis* Lütken, 1859
***Ophionereis dubia dubia* (Müller & Troschel, 1842)**
Image 1J

Material examined: Veraval - 1 specimen; Okha - 3 specimens. One specimen having Museum ID: ZEOAOO(13)19H, coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: Rare to moderately occurred at intertidal area of the Saurashtra coast. Radial shield trapezium shaped. Three arm spine, one ellipse shaped tentacle scale. Dorsal arm plate fan triangular shaped, ventral arm plate octagonal, concave by sides, four oral papillae, quadrate shaped one tooth on infradental plate.

Habitat: Under the rock crevices.

Distribution: Persian Gulf, west coast of India, Pakistan, Maldives, Sri Lanka, Bay of Bengal, East Indies, northern Australia, Philippine, China, and southern Japan (Clark & Rowe 1971); Australia (Rowe & Gates 1995).

Previous reports from Gujarat: Sikka and Pirotan Island (Sastry 2004).

Present study: Veraval and Okha.

Family Amphiuridae Ljungman, 1866
Genus *Amphipholis* Ljungman, 1866
***Amphipholis squamata* (Delle Chiaje, 1828)**
Image 1C

Material: Diu (Gangeshwar, Jalandhar, and Nagoa) - 17 specimens; Dhamlej - 6 specimens; Veraval - 28 specimens; Mangrol - 8 specimens; Dwarka - 7 specimens; Shivrajpur - 4 specimens; Okha - 8 specimens. Five specimens having Museum ID: ZEOAAA (5)19H, ZEOAAA(8)19H, ZEOAAA(4)20H, ZEOAAA(13)19H, ZEOAAA(6)21H, coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: Most common species of Saurashtra coast. Central primary plate is clearly visible, imbricating scales on disc. Radial shields separated proximally by a scale line, two tentacle scales, dorsal arm plate broader than long, three conical, erect, arm spines with serrated tip. Two oral papillae on each side, one distal long and opercular. A pair of infradental papillae with square tipped teeth.

Habitat: Rock crevices, underneath of rock and under the algal holdfast.

Distribution: Cosmopolitan distribution in cold to tropical and temperate ocean from intertidal to 1,300 m depth (Gage et al. 1983).

Table 2. Systematic position of species recorded in present study from Saurashtra coast.

Class	Order	Family	Species
Ophiuroidea	Ophiacanthida	Ophiocomidae	*Ophiocomella sexradia*
	Amphilepidida	Hemieuryalidae	*Ophioplocus imbricatus*
		Ophionereididae	*Ophionereis dubia dubia*
		Amphiuridae	*Amphipholis squamata*
			Amphiura ambigua
		Ophiactidae	*Ophiactis savignyi*
		Ophitrichidae	*Macrophiothrix viriabilis*
			Ophiomaza cacaotica
			Ophiothrix savignyi

Previous reports from Gujarat: Diu, Veraval, Holiday camp, Narara beyt, Dwarka, and Okha (Sastry 2004).

Present study: Diu (Jalandhar, Nagoa, & Gangeshwar), Dhamlej, Veraval, Mangrol, Dwarka, Shivrajpur, and Okha.

Genus *Amphiura* Forbes, 1843
***Amphiura ambigua* (Koehler, 1905)**
Image 1D

Material: Dwarka - 1 specimen; Okha - 2 specimens. One specimen having Museum ID: ZEOAAA(1)19H coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: Rarely observed at Saurashtra coast. Five imbricating greyish black blotches clearly observed on the central part of the disc. Radial shield barrel shaped, flat, and longer, two radial shields distally separated by a single scale line and only united at proximal part. Five conical shaped arm spines.

Habitat: Underneath of rock.

Distribution: Indo west pacific (Clark & Rowe 1971); Australia (Rowe & Gates 1995).

Previous reports from Gujarat: Dwarka, Beyt Island, Balapur bay, and Hanuman Dandi (Sastry 2004).

Present study: Dwarka and Okha.

Family Ophiactidae Matsumoto, 1915
Genus *Ophiactis* Lütken, 1859
***Ophiactis savignyi* (Müller & Troschel, 1842)**
Image 1E,F

Material: Diu (Gangeshwar coast, Jalandhar, and Nagoa coast) - 13 specimens; Dhamlej - 5 specimens; Veraval - 23 specimens; Mangrol - 6 specimens;

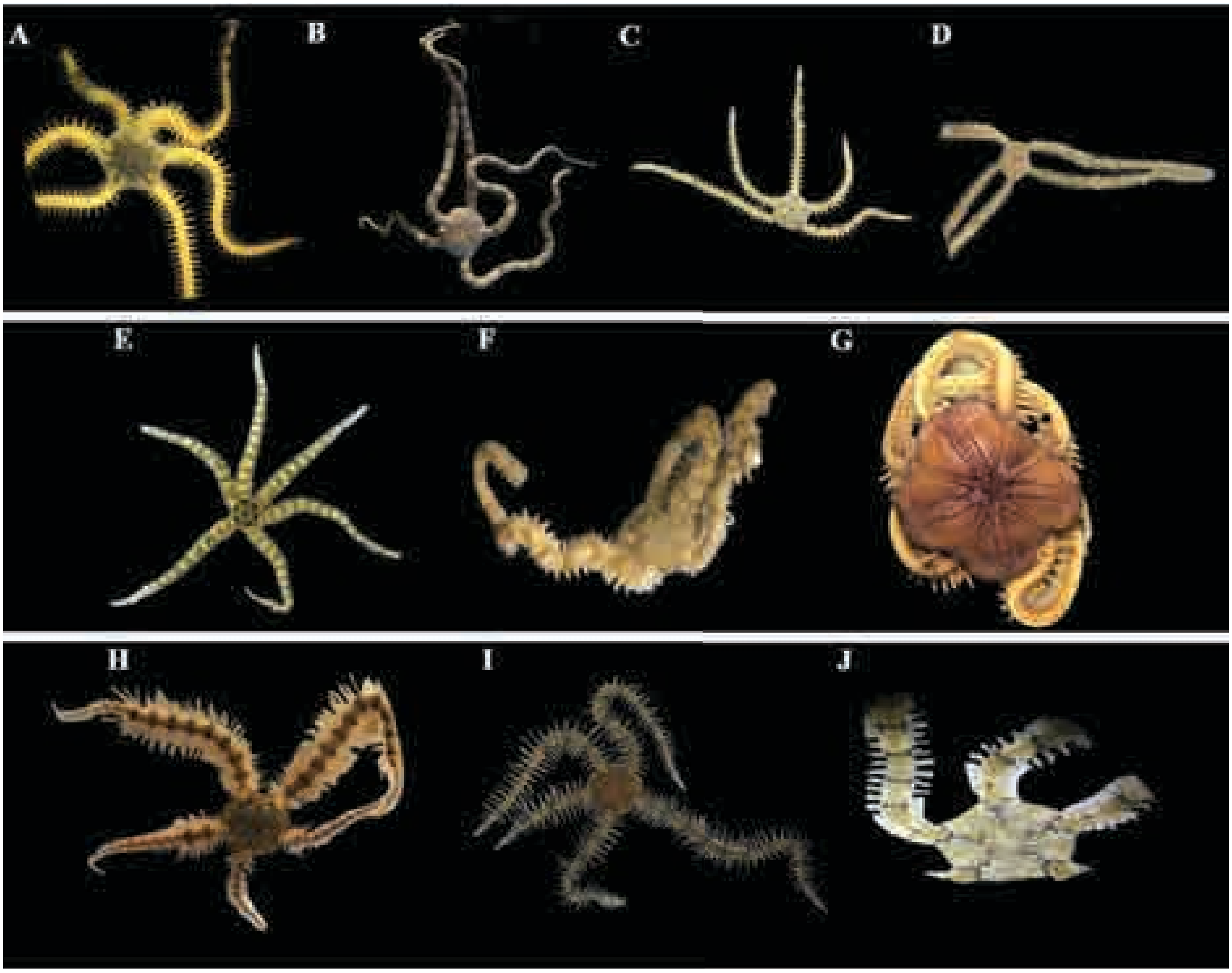

Image 1. Species reported in Saurashtra coastline: A—*Ophiocomella sexradia* | B—*Ophioplocus imbricatus* | C—*Amphipholis squamata* | D—*Amphiura ambigua* | E—*Ophiactis savignyi* | F—*Ophiactis savignyi* (color morph) | G—*Ophiomaza cacaotica* | H—*Macrophiothrix viriabilis* | I—*Ophiothrix savignyi*| J—*Ophionereis dubia dubia.* © Hitisha Baroliya

Table 3. Checklist of the recorded ophiuroids species at sampling sites. (Signs denote: '+' presence, '-' Absence). SM—Simbor | DH—Dhamlej | VRL—Veraval | MGL—Mangrol | DWK—Dwarka | SRP—Shivrajpur | OK—Okha

	Species	Rocky intertidal zone							
		DIU	SM	DH	VRL	MGL	DWK	SRP	OK
1	*Ophioplocus imbricatus*	-	-	-	-	-	+	+	+
2	*Ophionereis dubia dubia*	-	-	-	+	-	-	-	+
3	*Macrophiothrix viriabilis*	-	-	-	+	-	-	-	+
4	*Amphipholis squamata*	+	-	+	+	+	+	+	+
5	*Amphiura ambigua*	-	-	-	-	-	+	-	+
6	*Ophiactis savignyi*	+	-	+	+	+	+	+	+
7	*Ophiomaza cacaotica*	-	+	-	-	-	-	-	-
8	*Ophiocomella sexradia*	+	-	+	+	+	+	-	+
9	*Ophiothrix savignyi*	-	-	-	-	+	-	-	-

Dwarka - 8 specimens; Shivrajpur - 6 specimens; Okha - 10 specimens. Four specimens having Museum ID: ZEOAOO(8)19H, ZEOAOO(4)19H, ZEOAOO(5)19H, ZEOAOO(1)19H, coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: Most occurred species at Saurashtra coastline. Radial shields large, oval, contiguous distally. Six arm spines, with denticles along margin and at tip. Two oral papillae each side, one pair of infradental papillae with square shape former teeth. During study, color morph of *O. savignyi* was observed from Dwarka. Which has reddish brown patches over pale yellow, five arms, five arm spine and base of arm spine broad, spines present on interradius, having only one oral papillae. As mentioned in fauna de Madagascar (Cherbonnier & Guille, 1978).

Habitat: Rock crevices, under the algal holdfast and within crevices of zoanthid bed.

Distribution: Indo-west pacific, Arabian sea to East Indies (Clark & Rowe 1971).

Previous report from Gujarat: Veraval, Dwarka, Okha Pirotan Island, and Mandvi (Sastry 2004).

Present study: Diu (Jalandhar, Nagoa, & Gangeshwar), Dhamlej, Veraval, Mangrol, Dwarka, Shivrajpur, and Okha.

Family Ophiotrichidae Ljungman, 1867

Genus *Macrophiothrix* H.L. Clark, 1938

Macrophiothrix variabilis **(Duncan, 1887)**

Image 1H

Material: Veraval - 1 specimen; Okha - 5 specimen. Two specimens having Museum ID: ZEOAOM(5)19H, ZEOAOM(13)20B, coll. Hitisha Baroliya and Bhavna Solanki, are deposited in the Museum.

Remarks: Brown-purple colour. Small papillae on disc. Scalene triangular-shaped radial shield, spines present on radial shield. Eight arm spines near to disc, but distal parts have less in number, middle 2 spines large & other short, broad base of spines & denticulate structure. Hexagonal-shaped dorsal arm plate, white dots in middle, ventral arm plate, hexagonal shaped but convex by side. Cluster of dental papillae with six-seven no. of teeth in a row present on each jaw.

Distribution: Northern Australia from Shark Bay, W.A. to Mackay, Philippines, Singapore and Mergui Archipelago (Hoggett, 1990).

Present study: This is the first record from Gujarat (Veraval and Okha).

Ophiomaza Lyman, 1871

Ophiomaza cacaotica **(Lyman, 1871)**

Image 1G

Material examined: Simbor - 3 specimens. Museum ID: ZEOAOO(8)21H, coll. Hitisha Baroliya, are deposited in the Museum.

Remarks: specimen has brown color disc and mustard yellow arms. Disc smooth, very large triangular radial shield present. Five arms with four to six conical shaped arm spines. Some of the arm plates are fragmented dorsally, trapezoid shaped. Ventral side octagonal shaped arm plate. Arms covered by thick skin. Two genital slit present. Triangular shaped oral shield. Cluster of numerous tooth papillae present on each jaw.

Habitat: Associated with crinoid.

Distribution: Persian Gulf, Sri Lanka, Bay of Bengal, East Indies, northern Australia, Philippine, China, southern Japan, and South Pacific Islands (Clark & Rowe 1971); Australia (Rowe & Gates 1995).

Present study: This is the first record from Gujarat (Simbor).

Ophiothrix Müller & Troschel, 1840

Ophiothrix savignyi **(Müller & Troschel, 1842)**

Image 1I

Material examined: Mangrol - 1 specimens. Museum ID: ZEOAOO(1)22N, coll. Niyati Gajera, are deposited in the museum.

Remarks: This species differed from *O. foveolata* earlier reported by Sastry (2004). *O. foveolata* has conspicuous spines on the dorsal disc with few or no thorny stumps while

This species has stumps/thorns, trifid. Bare radial shield having few thorns. Five arms with five/six denticulate arm spines. Tiny throns/stumps present on the proximal dorsal arm plate. Distal margin of the ventral arm plates is concave. Cluster of numerous dental papillae present on each jaw. Specimen has brown color disc and arms having pattern.

Habitat: underneath of rock.

Distribution: South Eastern Arabia, Persian Gulf, West India and Pakistan (Clark & Rowe, 1971).

Present study: This is the first record from Gujarat (Mangrol).

DISCUSSION

The existing diversity of the intertidal Ophiuroidea from the Saurashtra coastline is described. Mainly rocky stations of the Saurashtra coastline were surveyed for

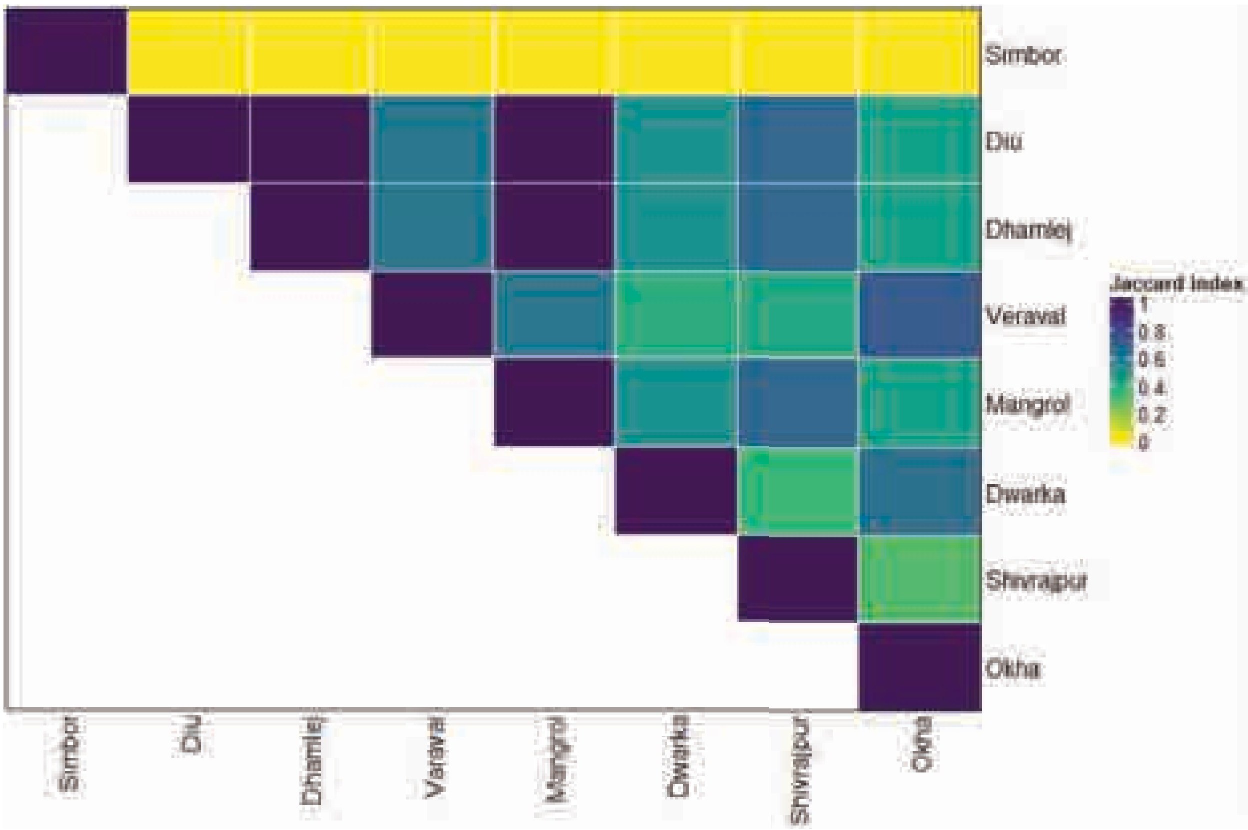

Image 2. The similarity between each sampling sites for ophiuroids species composition.

the diversity estimation. Earlier 12 ophiuroids were reported from the Gujarat coast (Sastry 2004). A recent evaluation of ophiuroids diversity fascinated with nine species, *Microphiothrix variabilis, Ophiothrix savignyi*, and *Ophiomaza cacaotica* are three new records for the Gujarat coast. This study revealed several unreported species from the intertidal areas of various station. *Ophiocomella sexradia, Ophionereis dubia dubia*, & *Microphiothrix viriabilis* first time reported from Veraval, *Ophiothrix savignyi* from Mangrol, *Ophiactics savignyi* & *O. sexradia* from Diu, *Amphiura ambigua*, *M. viriabilis*, & *O. dubia dubia* from Okha, and *Ophioplocus imbricatus* from Dwarka. Rest of the sites are first time evaluated in the present study with no previous records (Table 3). The similarity index result value varied from 0 to 1 (Image 2). Sampling site wise similarity index shows that all the seven sites were similar upto some extent in terms of species composition. Highest similarity was observed between Diu & Dhamlej, Diu & Mangrol, and Mangrol & Dhamlej because of the ophiuroid shared by this station are similar and their substratum and habitat structure are similar. While, Simbor has lowest similarity. Except two cosmopolitan species *A. squamata* and *O. savignyi*, all the species of Ophiuroidea were found to be very much confined to selected station. The results of similarity indices show that each sampling sites has diverse variety of the Brittle Star, which makes them spatially altered from each other. Some of the species were associated with other marine creatures.

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Environmental factors affecting water mites (Acari: Hydrachnidia) assemblage in streams, Mangde Chhu basin, central Bhutan

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Abstract: Water mites were sampled from 15 tributary streams of Mangde Chhu river in Zhemgang and Trongsa districts, Central Bhutan in pre-monsoon (April–May) and post-monsoon (October–November) of 2021. A total of 802 individuals were collected belonging to seven families and 15 genera. The accumulation curve suggests that the sampling efforts were adequate to give a proper overview of genera composition for elevations 500–2,700 m. Eleven genera—*Aturus, Kongsbergia, Woolastookia, Atractides, Hygrobates, Lebertia, Piona, Sperchonopsis, Monatractides, Pseudotorrenticola* and *Testudacarus*—and five families—Aturidae, Hygrobatidae, Lebertiidae, Pionidae, and Protziinae—are new records for Bhutan. Independent sample *t*-tests of genera richness (*t,* (26) = 0.244, *p* = 0.809); genera evenness (*t*, (26) = 0.735, *p* = 0.469); Shannon diversity index (*t,* (26) = 0.315, *p* = 0.755) and dominance (*t*, (26) = -0.335, *p* = 0.741) showed no significant differences between pre- and post-monsoon assemblages. Species abundance was also not significantly different (*t,* (28) = -0.976, *p* = 0.330). Principal component analysis indicated that the diversity of water mites is negatively associated with several environmental variables including chloride (*r* = -0.617), ammonia (*r* = -0.603), magnesium hardness (*r* = -0.649), total hardness (*r* = -0.509), temperature (*r* = -0.556), salinity (*r* = -0.553), total dissolved solids (*r* = -0.509) and electrical conductivity (*r* = -0.464). Diversity was positively correlated with altitude, mainly caused by the higher Palaearctic genera diversity. Similarly, Pearson's correlation test showed that there was significant negative correlation between mite abundance and the water physio-chemical parameters salinity (*r* = -0.574, *p* = 0.032), electrical conductivity (*r* = -0.536, *p* = 0.048), total dissolved solids (*r* = -0.534, *p* = 0.049), total hardness (*r* = -0.621, *p* = 0.018), and chloride concentration (*r* = -0.545, *p* = 0.036), indicating sensitivity of water mites to pollution.

Keywords: Biotic assessment, climate change, fresh water, macroinvertebrates.

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INTRODUCTION

Most lotic freshwater habitats in Bhutan, such as streams, springs, and rivers, harbora rich aquatic diversity of macroinvertebrates and fishes (Gurung et al. 2013; Gurung & Dorji 2014; Wangchuk & Dorji 2018; Dorji et al. 2020; Rai et al. 2020; Norbu et al. 2021). These habitats are also the major sources of drinking water in Bhutan, thus their preservation is essential for both the conservation of biodiversity as well as the economic well-being of Bhutanese (Dorji 2016b). Lotic freshwater systems are, however, under pressure due to anthropogenic pollution and climate change (Xu et al. 2009; Tsering et al. 2010). Thus biotic assessment of these habitats is essential to understand the health of the water.

Water mite are greatly influenced by water parameters and environmental factors (Stryjecki et al. 2016; Savić et al. 2022). Abundance of water mites is negatively influenced by water temperature and velocity (Stryjecki et al. 2018), with temperature being the major factor that influences distribution of Hydrachnidia along altitudinal gradients. Mite abundance is positively impacted by pH (range 7.3–8), dissolved oxygen, and total hardness (Stryjecki et al. 2016; Negi et al. 2021). Seasonality also impacts mite in freshwater habitats. According to Negi et al. (2021), Hydrachnidia abundance was maximum during pre-monsoon (January) and minimum in monsoon (July).

Water quality monitoring is commonly done in two ways: a) determination of physico-chemical properties of the water and b) biotic assessment of aquatic organisms. In most cases, physico-chemical assessment of water only gives an indication of the water quality at the moment when the sample was taken, and poor water quality or pollution during other parts of the year might go unnoticed. Results based on biotic assessment, in contrast, give a direct indication of water quality throughout the year, as poor water quality or pollution will be reflected in the faunal composition (Ofenbock et al. 2010; Wangchuk & Dorji 2018; Rai et al. 2020). For this reason, biological water monitoring is at least as valuable for freshwater management as physico-chemical monitoring.

Aquatic meiofauna such as water mites are excellent bioindicators of water quality (Smit & Van Der Hammen 1992; Miccoli et al. 2013; Wieçek et al. 2013; Goldschmidt 2016). They are present in both lotic and lentic habitats (Smith et al. 2001) at a large range of elevations (Mani 2013). Thus far, water mites have been ignored during freshwater habitat assessments in Bhutan and other regions, which have focused on other macroinvertebrates (Ofenböck et al. 2010; Giri & Singh 2013; Patang et al. 2018; Wangchuk & Dorji 2018; Rai et al. 2020) and fishes (Gurung et al. 2013; Wangchuk et al. 2018; Dorji et al. 2020; Norbu et al. 2021). Neglect of water mites as bioindicators can partially be explained by their diminutive size and complex life cycle (Goldschmidt 2016).

A few aquatic diversity assessments in Bhutan recorded water mites and in all cases they were lumped together as Hydrachnidia or Acari (Ryder et al. 2015; Currinder 2017; Wangchuk & Dorji 2018). However, recent faunistic studies have described and recorded several new species of water mites from Bhutan (Pešić et al. 2022a; Smit & Gurung 2022; Smit et al. 2022; Pešić et al. 2022b) and currently there are 30 species documented from Bhutan (Gurung et al. 2022). Several major biotic assessment studies in Bhutan did not record mites (Dorji 2016a; Rai et al. 2020) despite fulfilling all the criteria (Resh 2008) for use as bioindicators, including: (1) wide geographical and habitat distribution, (2) high species richness, (3) relatively sedentary to a localized microhabitat (ideal for examination of contamination spatially), (4) long life cycle for long-term integration during the biotic assessment, (5) easy and cost effective sampling, (6) clear and well known taxonomy, (7) sensitive to contamination, (8) availability of experimental data on effects of contamination for different species (Di Sabatino et al. 2002; Smith et al. 2010; Miccoli et al. 2013; Goldschmidt et al. 2016). Therefore, during biotic assessment of freshwater habitats in Bhutan, water mites should be regarded as important for monitoring.

One of the reasons that water mites have not been used as bioindicators in Bhutan is that basic data on identification and distribution is largely absent for the Himalayan region (Pesic & Smit 2007; Gerecke & Smit 2022). Identification to species level is problematic, and even identification to genus level takes some experience (Smit 2020). The key to the genera of the world recently published by Smit (2020) makes identification to genus level easier, but papers like Gerecke & Smit (2022) describing species new to science are needed to enable people to identify material to species level. Taxonomic progress is partially hampered by the complex life cycle of water mites that includes pre-larval stage, parasitic larva, protonymph (i.e., initial resting stage), deutonymph (free living form), tritonymph (second resting stage), and the final adult stage (Di Sabatino et al. 2000).

Besides problems with identification, another reason for the lack of the use of water mites as bioindicators is the lack of ecological studies for the Himalayan region. Although the link between water mite assemblages and water quality has been studied at least some times in other parts of the world basic studies on this subject from Bhutan and surrounding countries are lacking. A study on this subject would be of interest, especially as Bhutan is part of the border between the Oriental and Palaearctic region, with the species composition above 1,000 m elevation in general being of Palaearctic origin while that below 1,000 m elevation has a more Oriental affinity (Rasaily et al. 2021).

In 2021 and 2022, the first author studied water mites in Bhutan with the aim of producing new faunistic and taxonomical data providing basic information on water mite assemblages and water quality. The present paper is part of this larger study, and describes the patterns in composition and diversity in lotic waters along an altitudinal gradient. We use this information to address three questions: (1) is there a difference in water mite diversity, abundance and assemblages between pre- and post-monsoon? (2) which physico-chemical parameters correlate with the presence and abundance of water mite genera? And (3) is there a gradient from a largely Oriental fauna to a more Palaearctic fauna rising from 500 m to 2,700 m?

MATERIAL AND METHODS

Study area

Mangde Chhu river basin has catchment area of 7,380 km^2, annual flow of 11,797 million m^2, 1,173 high-altitude wetlands (such as brooks, lakes, marshy areas), and 287 glaciers (NEC 2016). Mangde Chhu River originates from Gangkhar Puensum, passes through Trongsa, and exits Bhutan through Zhemgang as Manas River after joining with Drangme Chhu River. Fifteen perennial tributary streams of Mangde Chhu River were selected for this study ranging in altitude from 500 m to 2,700 m (Figure 1). A multi-stage sampling method (Gascho-Landis & Stoeckel 2016) was adopted for classification of the study area into three groups along the altitudinal gradient to study the effect of altitude on the water mite composition, namely between 500–1,000 m (low), 1,001–1,999 m (mid) and above 2000 m (high). Ammonia concentration ranged 0.04±0.002–662±78.4, calcium hardness 40.1±5.12–1.66±0.12, magnesium hardness 30.2±6.49–8.46±0.12, total hardness 70.3±11.05–22.4±0.08, chloride 128.2±19.6–32.5±3.41, electrical conductivity 48.8±0.43–33.4±1.51, dissolved oxygen 15.7±0.66–103.5±0.42, pH 7.67±0.05–14±3.07, salinity 19.3±0.14–7.21±0.08, total dissolved solids 34.6±0.16–50.7±0.25, temperature 14.6±0.54–

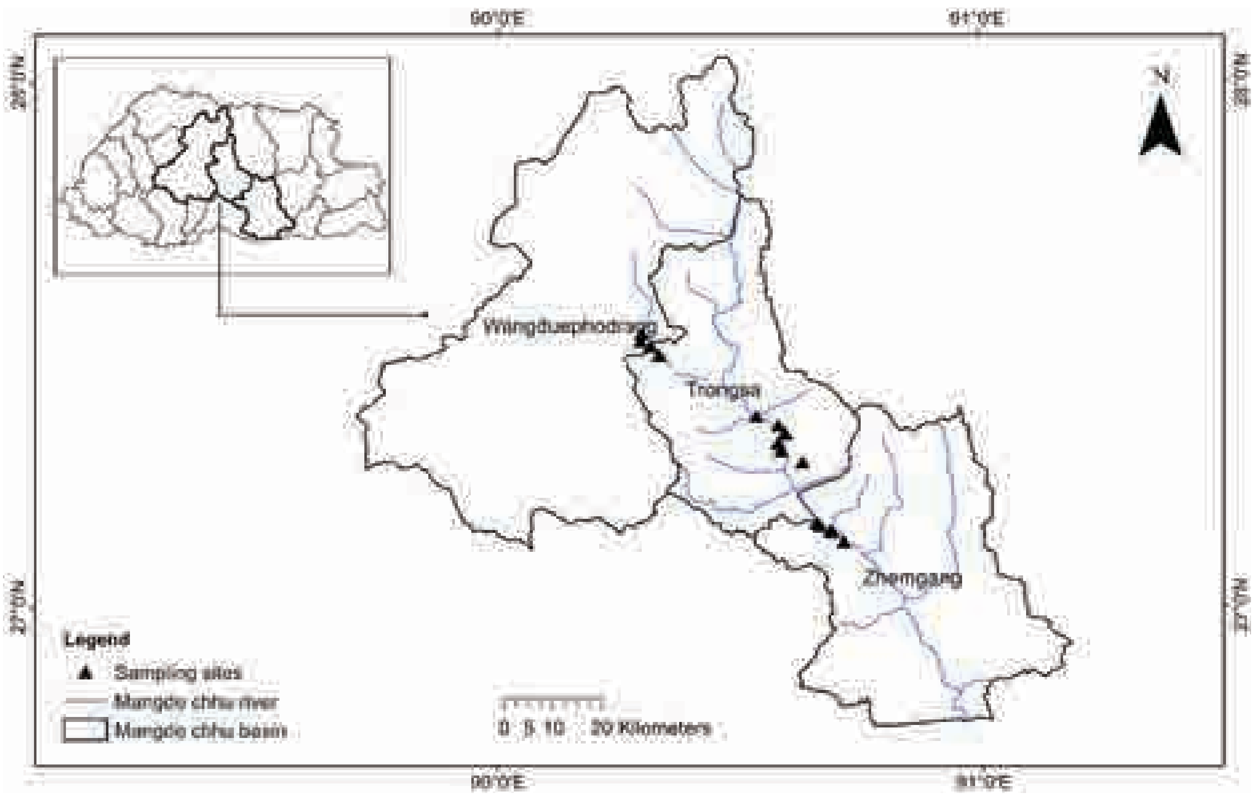

Figure 1. Streams under study in Mangde Chhu basin, central Bhutan.

44.6±0.64, and turbidity 0.62±0.20–46.5±3.41. Sampling was carried out in pre-monsoon (April–May) and post-monsoon (October–November), 2021.

Sampling sites and habitat description

MG1: Maidagang Chhu, Tingtibi, Zhemgang district, (27.12761°N, 90.71560°E, altitude 554 m, 24 April 2021; 20 October 2021) flows through a dense bushy vegetation and eventually drains into Mangde Chhu River. There is an agriculture field and a farm road above the confluence. Stream substrates mostly consist of cobbles with sand and rocks which often obstruct water forming small pools.

MG2: Berti Chhu, Berti, Zhemgang district (27.16264°N, 90.66003°E, altitude 590 m, 26 April 2021; 25 October 2021) flows through a narrow valley in deep forest. Before reaching the confluence, it passes the Berti community. The stream is adopted by the community for legal fishing in producing smoked fish (*Nyea Dhosem*). Berti Chhu substrates are predominantly composed of cobbles with sand. Riparian vegetation included ferns, climbers, and lowland grasses. Most of the sites had riffles, pools, and cascades. Water was heavily inhabited by fish fingerlings such as that of *Garra* spp. and *Danio rerio*.

MG3: Bipgang Chhu, Berti-ecolodge, Zhemgang district (27.15729°N, 90.66721°E, altitude 586 m, 28 April 2021; 25 October 2021). Bipgang Chhu flows along the mountain base parallel with the road connecting Tingtibi and Berti fishing community and it connects with Mangde Chhu River below Berti Eco-lodge camp. Stream riparian vegetation was covered by dense shrubs and grasses and the substrate was sandy with high debris content. The stream was inhabited abundantly by fishes. The natural water habitat was impacted due to frequent cleaning of the stream by the eco-lodge staff clearing the way for fish movement.

MG4: Takabi Chhu, Tingtibi, Zhemgang district (27.14782°N, 90.68833°E, altitude 543 m, 31 April 2021; 26 October 2021) stream flows through a steep mountain valley and has a high-water current. Riparian vegetation was mostly trees with underlying grasses. Substrate was mostly cobbles and sand. Rocks often obstruct the water forming pools and cascades.

MG5: Dakpay Chhu, Tingtibi, Zhemgang district (27.14621°N, 90.69220°E, altitude 539 m, 01 April 2021; 27 October 2021) flows through a thick vegetation with high water current. Water was murky. Substrate was rocky with cobbles and had less sand. Riparian vegetation had dense grasses under tall tree canopy. The submerged grasses along the streams formed a potential habitat for mites.

MG6: Yumrung Chhu, Langthel, Trongsa district (27.36691°N, 90.53618°E, altitude 1,092 m, 02 May 2021; 28 October 2021) flows along abandoned mineral mining sites. Towards the confluence, the stream passes by the Mangde Chhu hydropower house and an automobile workshop. The stream was heavily disturbed due to dumping of gravel and soils from mining of the cliff. Downstream of the river was greatly impacted by the hydropower plant and an automobile workshop.

MG7: Wana Chhu, Langthel, Trongsa district (27.34964°N, 90.58144°E, altitude 1,139 m, 03 May 2021; 29 October 2021): this small stream flows through the thickly vegetated valley by the side of the paddy field. The water was murky, and stream substrate was sandy clay with debris. Riparian vegetation was dominated by *Ageratina adenophora* (invasive species), *Alnus nepalensis, Artemisia vulgaris* and climbers.

MG8: Dangdung Chhu, Langthel, Trongsa district (27.33461°N, 90.59562°E, altitude 1,039 m, 05 May 2021; 30 October 2021) is a fast-flowing montane stream with high water current. Sampling was conducted at the divergent point which had low current water flow. Substrate composed of mostly cobbles and sand.

MG9: Kartigang Chhu, Langthel, Trongsa district (27.27896°N, 90.63088°E, altitude 1,456 m, 07 May 2021; 01 November 2021) flows through a landslide washed stream beds with greyish sediments. Substrate was mostly pebbles and cobbles with minimum sand. Surrounding vegetation was sparse with trees having less undergrowth. Water was whitish in color due to white mud bed.

MG10: Chumpigang Chhu, Langthel, Trongsa district (27.31608°N, 90.58071°E, altitude 1,018 m, 08 May 2021; 02 November 2021) stream flows through a deep forest along a narrow valley. Rock obstructs the water flow creating falls, cascades and pools. Riparian vegetation had grasses and stream substrate was mostly cobbles with sand.

MG11: Waterfall stream (name unknown), Trongsa district (27.30171°N, 90.58711°E, altitude 1,195 m, 09 May 2021; 03 November 2021) flows through a mountain gorge forming water falls; the stream substrate mostly composed of cobbles and sand with high debris content.

MG12: Nika Chhu, Trongsa district (27.52601°N, 90.29947°E, altitude 2,609 m, 10 May 2021; 04 November 2021); water current was low despite the stream being quite large. Water temperature was lowest in this stream. Substrates mostly composed of cobbles and sand mixed with debris. Riparian vegetation was mostly shrubs with tall *Pinus* and hemlock tree canopies.

MG13: Rukhubji Chhu, Pelela, Trongsa district (27.51174°N, 90.29711°E, altitude 2,587 m, 12 May 2021; 05 November 2021) flows through a valley covered with thick high-altitude conifers and underlying shrubs, the color of the water is darker throughout the year. Stream substrate was rocky covered by layers of algae and mosses. The stream connects with Nika Chhu River nearby an old Chorten (Buddhist stupa).

MG14: Chuserbu, Trongsa district (27.50246°N, 90.31782°E, altitude 2,666 m, 13 May 2021; 06 November 2021) flows through dense riparian bamboo forest with tall tree canopies, substrate were mostly sand. The stream was pristine and there were fewer disturbances with no settlements upstream.

MG15: Khabab Chhu, Chendebji, Trongsa district (27.48492°N, 90.33490°E, altitude 2,500 m, 14 May 2021; 07 November 2021) flows throw a gentle slope. Cobbles and pebbles mixed with sand and debris make up the stream substrate. Plastic waste was dumped along the stream and wastewater from the village is also discharged into the stream. In the post-monsoon, the stream was severely damaged by a flashflood, and there were huge depositions of sand and rocks washed from upstream.

Environmental characterization

At all localities, physico-chemical parameters of water were measured following APHA (2017) standards. Dissolved oxygen (mgL^{-1}), temperature (°C), electrical conductivity (μScm^{-1}), pH, and total dissolved solid (mgL^{-1}) were analyzed on site using HANNA multiparameter digital probe (Code HI2004-02, S/N C05031A5). Water samples were collected and stored in freezer (at 5°C) and brought to lab for further analysis. Salinity was measured using salinity meter, turbidity (NTU) was measured following Nephelometric method, water hardness (mgL^{-1}) following EDTA method, Chloride (mgL^{-1}) following Argentometric method (Korkmaz 2001) and ammonia (mgL^{-1}) following Phenate method (Park et al. 2009).

Mites sample collection and preservation

Water mites were collected following quantitative approach as described by Gerecke et al. (2007) with a uniform sampling duration of 10 minutes on each station. In each stream, collections were carried out at four substations using D-frame kick net (mesh size 250-µm and frame size 30cm) with 100 m distance between the sampling substations. The stream bed was dislodged with foot and the materials carried by water current were collected by keeping the D-frame net downstream ('kick-sampling'). Submerged aquatic plants along the periphery of the streams were disturbed mechanically and the material was collected downstream with the D-frame kick net. The material collected was transferred into a white tray, letting the substrate settle for a few minutes and the mobile mites were picked using a plastic pipette through visual observation. The specimens collected were preserved in Koenike-fluid (20% glacial acetic acid, 50% glycerin and 30% distilled water) for morphological study and a part of the material was also stored in ethanol (90%) for future molecular study.

Identification

Water mites were identified through morphological examination of specimens under a high-resolution microscope Olympus-829187. A Nikon D5600 DSLR-camera attached with NDPL-2(2X) converter was fixed on the eye piece of the microscope to take photographs of the specimens. Identification of the water mites were done using keys of Cook (1967) and Smit (2020). Following an identification by the first author, all identifications were confirmed by H. Smit.

Statistical test

The preliminary data processing was done using Microsoft Excel Professional Plus 2016. Genera composition curve was computed using PC-ORD v5.1 (Grandin 2006). Hydrachnidia genera diversity was examined using Shannon's diversity index, $H' = \Sigma(Pi) Ln(Pi)$ (where Pi is the proportion (n/N natural log), and Σ is the sum of the equations). Genera richness was calculated using the equation: $(S_R) = (S-1)/LogN$ (where, S is sum of the genera, N is sum of all genera). Genera evenness, and genera dominance (Simpson's index; D) was calculated using the formula, $D = \Sigma p_i^2$ (where, p_i is the proportion of genera in a community ($p_i = n_i/n$), Σ is sum of the equations). Means, standard deviations, total abundance and relative abundance values were calculated for all sites. Independent sample *t*-test was performed to compare the pre- and post-monsoon diversity indices. Before performing this test, Shapiro–Wilk's test was done in R-software to test if the data were normally distributed.

Principal component analysis (PCA) between environmental variables and the abundance of different water mite genera was performed using the distance measure of relative Sorensen (Bray-Curtis) method separately for both pre- and post-monsoon in PC-ORD v5.1 software. Pearson's correlation test was used to compute the relationship between the environmental variables and water mite assemblages.

RESULTS

A summary of environmental factors in the pre- and post-monsoon period is given in Table 1. In total of 802 water mites were collected belonging to 15 genera with an average of five genera with 26 specimens per location in pre-monsoon and five genera with 29 specimens per location in post-monsoon (Table 2). The mite genera accumulation curve for both (A) pre- and (B) post-monsoon suggests that the sampling efforts were adequate to characterize the water mite genera composition in the study area (Figure 2). Twelve genera, i.e., *Atractides*, *Aturus*, *Hygrobates*, *Kongsbergia*, *Lebertia*, *Limnesia Monatractides*, *Piona*, *Protzia*, *Pseudotorrenticola*, *Sperchonopsis*, and *Woolastookia* (Image 1 & 2) from eight families (i.e., Aturidae, Hygrobatidae, Lebertiidae, Limnesiidae, Pionidae, Hydryphantidae, Sperchontidae, Torrenticolidae) are recorded new to Bhutan. Pre-monsoon (491) mites were more abundant than that of post-monsoon (311), dominated by *Monatractides* (162) and *Torrenticola* (109) in respective seasons (Table 2).

Diversity indices

Diversity indices such as genera richness, evenness, Shannon diversity index and dominance of 15 streams were calculated (Table 3) and compared (Figure 3) for two seasons. There was a significant positive correlation between pre- and post-monsoon genera diversity (r = 0.693, p = 0.004*)*, evenness (r = 0.704, p = 0.003) and dominance (r = 0.605, p = 0.017) but genera richness (r = 0.479, p = 0.71) was not significantly correlated for the two seasons (Table 4). Independent sample t-test showed no significant differences between pre-monsoon and post-monsoon diversity indices. Genera richness for the pre- (M = 4.71, SD = 1.72) and post-monsoon (M = 4.57, SD = 1.34) was not significantly different (t (26) = 0.244, p = .809). Likewise, for genera evenness for pre- (M = 0.800, SD = 0.139) and post-monsoon (M = 0.758, SD = 0.163); (t (26) = 0.735, p = 0.469); Shannon diversity index for pre- (M = 1.18, SD = 0.389) and post-monsoon (M = 1.14, SD = 0.366); (t (26) = 0.315, p = 0.755) and dominance for pre- (M = 0.573, SD = 0.217) and post-monsoon (M = 0.598, SD = 0.175); (t (26) = -0.335, p = 0.741) were also not significantly different. In pre-monsoon stream MG13 had the highest genera diversity (H' = 1.63), however, in post-monsoon MG14 harbored maximum diversity (H' = 1.62). Further, genera abundance was also not significantly different between pre- (M = 24.3, SD = 15.2) and post-monsoon (M = 29.1, SD = 11.4); (t (28) = -0.976, p = 0.330).

Pre-monsoon correlations between assemblages and environmental factors

Principal Component Analysis (PCA) was performed between water mite assemblages and environmental factors of pre-monsoon (Figure 4). Axes with highest percentage of variance and Eigen values greater than broken-stick Eigen values were considered for the analysis.

Principal axis 1 (57%) and 2 (20%) explained 72% of the total variance. Temperature (r = 0.821) and salinity (r = 0.511), calcium hardness (r = 0.405), total hardness (r = 0.470), magnesium hardness (r = 0.417), electrical conductivity (r = 0.435), and total dissolved solids (r = 0.430) had strong to moderate positive correlation with Axis 1. However, chloride (r = -0.617), and ammonia (r = -0.603) had strong negative correlation with Axis 1. Similarly, *Hygrobates* (r = -0.755), *Lebertia* (r = -0.935), *Sperchon* (r = -0.910), *Torrenticola* (r = -0.730), *Woolastookia* (r = -0.544) and *Monatractides* (r = -0.490) exhibited strong to moderate negative correlation with the first axis.

Ammonia (r = 0.561), turbidity (r = 0.525), chloride (r = 0.442), and altitude (r = 0.434) had strong to moderate positive correlation with the second principal axis, whereas magnesium hardness (r = -0.649), total hardness (r = -0.509), temperature (r = -0.556), salinity (r = -0.553), total dissolved solids (r = -0.509) and electrical conductivity (r = -0.464) had strong to moderate negative correlation. Similarly, *Atractides* (r = -0.938) had strong negative correlation with the second axis. However, *Lebertia* (r = 0.567), *Hygrobates* (r = 0.453), *Protzia* (r = 0.432), and *Sperchon* (r = 0.499) exhibited strong to moderate positive correlation with the second principal axis.

Pearson's correlation test between environmental factors and water mite assemblages showed that Atractides (r = 0.572, p = 0.033) was positively correlated with magnesium hardness. Hygrobates had strong negative correlation with temperature (r = -0.600, p = 0.023), and salinity (r = -0.574, p = 0.032). Lebertia was positively correlated with altitude (r = 0.719, p = 0.004), but negatively correlated with temperature (r = -0.825, p = 0.002), electrical conductivity (r = -0.536, p = 0.048), salinity (r = -0.613, p = 0.020) and total dissolved solids (r = -0.534, p = 0.049). Sperchon was positively correlated with altitude (r = 0.672, p = 0.009), but negatively correlated with temperature (r = -0.746, p = 0.002). Torrenticola was negatively correlated with total hardness (r = -0.621, p = 0.018) and temperature (r = -0.633, p = 0.015). Woolastookia was positively

Table 1. Summary of environmental characterization of pre- and post-monsoon, 2021.

ID	Season	Alt	NH4	Ca. H	Cl	E.C	DO	Mg. H	pH	Sal	TDS	Tem	TH	Tur
MG 1	Pre-	516±38.4	0.02±0.002	71.02±6.36	90.9±6.75	112.8±2.49	15.95±0.9	15.2±7.49	6.72±1.81	39.2±0.61	79.9±1.60	19.4±0.38	86.2±8.53	0.85±0.24
	Post-	516±38.42	1.38±0.08	13.1±0.85	20.6±7.56	71.2±1.25	10.55±0.20	24.7±5.12	7.87±0.22	43.7±6.48	35.7±5.29	17.9±0.33	37.8±5.97	0.40±0.24
MG 2	Pre-	613±21.4	0.03±0.01	56.2±5.02	93.05±12.4	207.2±2.06	10.7±0.64	18.9±4.35	8.14±0.04	57.3±12.4	104.2±41.6	22.9±0.20	75.2±9.32	0.80±0.12
	Post-	613±21.4	1.81±0.08	38.5±3.41	50.1±3.02	116.8±0.85	9.32±0.17	8.25±1.70	8.14±0.04	52.8±0.85	46.3±0.46	21.9±0.64	46.7±5.12	0.68±0.18
MG 3	Pre-	662±78.4	0.04±0.01	35.2±4.87	88.9±7.91	148.2±5.21	11.4±0.83	12.02±5.35	7.04±0.09	48.9±0.26	102.6±0.47	20.4±1.05	47.2±8.18	0.81±0.30
	Post-	662±78.4	1.66±0.12	32.5±3.41	33.4±1.51	103.5±0.42	8.46±0.12	14±3.07	7.21±0.08	50.7±0.25	44.6±0.64	22.4±0.08	46.5±3.41	0.50±0.30
MG 4	Pre-	575±46.4	0.03±0.005	54.05±7.4	103.3±19.6	80.1±0.71	10.1±1.05	20.5±5.90	7.51±0.10	30.2±0.08	57.06±0.61	19.9±0.12	74.6±6.42	1.22±0.25
	Post-	575±46.4	0.98±0.08	12.8±0.85	18.3±7.56	46.6±1.28	10.3±0.25	13±6.83	8.06±0.12	23.2±0.08	20.1±0.12	21.2±0.34	25.8±7.68	0.19±0.08
MG 5	Pre-	565±36.6	0.03±0.002	28.2±6.39	93.05±15.6	83.5±4.95	9.01±0.94	15.5±6.55	7.47±0.008	30.9±1.57	59.5±3.77	19.4±0.12	43.7±9.46	0.97±0.17
	Post-	565±36.6	1.4±0.20	18.2±0.49	44.1±1.51	38.2±0.5	7.88±0.21	13.5±3.41	7.66±0.22	18.7±0.54	16.3±0.40	17.8±0.21	31.5±3.41	0.19±0.06
MG 6	Pre-	1103±49.9	0.04±0.002	40.1±5.12	128.2±19.6	48.8±0.43	15.7±0.66	30.2±6.49	7.67±0.05	19.3±0.14	34.6±0.16	14.6±0.54	70.3±11.05	0.62±0.20
	Post-	1103±49.9	1.21±0.13	18.6±2.56	42.1±3.02	35.1±0.85	7.781±0.08	7.12±0.85	7.51±0.08	12.5±0.18	10.9±0.16	12.6±0.12	25.7±1.70	0.75±0.13
MG 7	Pre-	1118±102.4	0.04±0.009	44±4.54	130.2±19.5	215±0.81	14.01±0.77	16±8.28	7.15±0.012	72.3±3.58	153.3±1.24	18.3±0.26	60±12.7	0.40±0.06
	Post-	1118±102.4	1.25±0.12	19.3±2.56	118.5±1.51	59.4±0.42	7.93±0.12	22.7±0.95	7.58±0.08	28.8±0.25	24.9±0.12	18.6±0.17	41.3±2.56	0.80±0.08
MG 8	Pre-	1246±43.3	0.03±0.01	59±2.16	136.4±14.3	85.4±2.18	11.7±1.46	14.5±4.79	7.48±0.01	30.03±0.55	60.8±1.32	15.1±0.40	73.5±5.19	0.42±0.07
	Post-	1246±43.3	0.61±0.08	12.8±0.85	50.07±3.02	38.8±0.85	7.55±0.33	9.75±1.70	7.7±0.34	19.3±0.14	16.8±0.05	14.7±0.08	22.6±2.56	0.66±0.10
MG 9	Pre-	1470±76.4	0.04±0.009	50±5.22	128.2±4.77	151.6±4.90	13.6±0.77	11.5±2.38	7.65±0.08	49.5±1.34	108±2.94	14.8±0.35	61.5±7.54	0.37±0.03
	Post-	1470±76.4	0.36±0.09	45.3±24.7	54.2±4.54	69.4±0.42	8.55±0.34	15.8±7.68	8.075±0.17	32.7±0.59	28.1±0.55	15.3±0.25	61.2±32.4	0.84±0.16
MG 10	Pre-	1131±169.6	0.03±0.006	49±6.17	113.7±7.91	353±0.81	12.6±1.04	79.7±6.35	8.07±0.12	112.6±0.47	250.6±0.94	17.4±0.29	128.7±6.22	0.29±0.02
	Post-	1131±169.6	0.50±0.13	97.1±0.85	77.1±18.1	209.4±0.42	11.3±0.08	23.7±11.9	8.66±0.22	103.9±0.59	90.9±1.11	16.6±0.21	120.8±12.8	0.35±0.12
MG 11	Pre-	1163±212.8	0.04±0.003	54.6±1.20	150.9±29.7	160.9±0.63	14.9±1.33	17.7±3.57	8.31±0.19	52.6±0.16	114.6±0.47	15.4±0.12	72.4±3.57	1.10±0.01
	Post-	1163±212.8	0.61±0.08	35±6.83	72.8±1.51	89.25±0.5	9.32±0.17	14.7±5.12	7.89±0.08	44.2±0.12	38.3±0.17	16.1±0.08	49.7±1.70	0.34±0.107
MG 12	Pre-	2606±5.5	0.04±0.001	63.9±1.57	167.5±27.3	231.1±44.4	13.8±0.81	14.7±3.33	7.77±0.28	66.3±9.21	158±22.6	7.66±0.24	78.6±2.72	1.57±0.02
	Post-	2606±5.5	0.6±0.14	48.5±3.4	45.1±6.05	126.2±1.70	6.68±0.21	21.5±3.41	8.64±0.17	61.2±0.34	53.4±0.59	12.5±0.38	70.5±1	0.82±0.06
MG 13	Pre-	2588±15.5	0.04±0.002	47.2±2.62	148.8±13.5	133.5±12.1	14.4±0.78	8.72±3.37	8.35±0.02	40.2±0.89	88.8±2.46	11.4±0.21	56±0.99	0.76±0.06
	Post-	3271±31.1	0.21±0.32	31.7±1.70	54.5±9.08	46.3±9.39	6.71±0.08	39.3±2.56	7.77±0.51	23.1±4.39	20.05±3.65	13.36±0.42	71.1±0.85	0.58±0.17
MG 14	Pre-	2588±49.3	0.05±0.01	38.2±6.23	148.8±20.2	43.2±2.05	10.1±0.76	10.6±1.66	7.73±0.07	14.3±0.571	30.7±1.38	7.56±0.16	48.9±7.62	1.12±0.08
	Post-	2588±49.3	0.18±0.08	17.6±9.39	67.7±3.02	21.4±0.42	8.31±0.76	23.5±10.2	8.01±0.13	9.76±0.09	8.44±0.05	13.2±0.25	41.1±0.85	0.70±0.10
MG 15	Pre-	2494±26.1	0.05±0.006	35.3±1.26	173.7±30.2	62.6±0.91	12.2±0.60	9.50±0.71	7.57±0.04	19.9±0.32	44.6±0.62	7.93±0.18	44.8±1.08	0.89±0.03
	Post-	2494±26.1	0.24±0.23	44.3±4.26	45.6±3.02	30.8±4.69	7.73±0.18	2.87±0.85	8.11±0.21	12.2±0.49	10.5±0.19	13.4±0.25	47.2±5.12	0.48±0.11

Alt—Altitude | NH4—Ammonia | Ca. H—Calcium hardness | Cl—Chloride | EC—Electrical conductivity | D.O—Dissolved Oxygen | Mg. H—Magnesium hardness | Sal—Salinity | TDS—Total dissolved solid | Tem—Temperature | TH—Total Hardness | Tur—Turbidity.

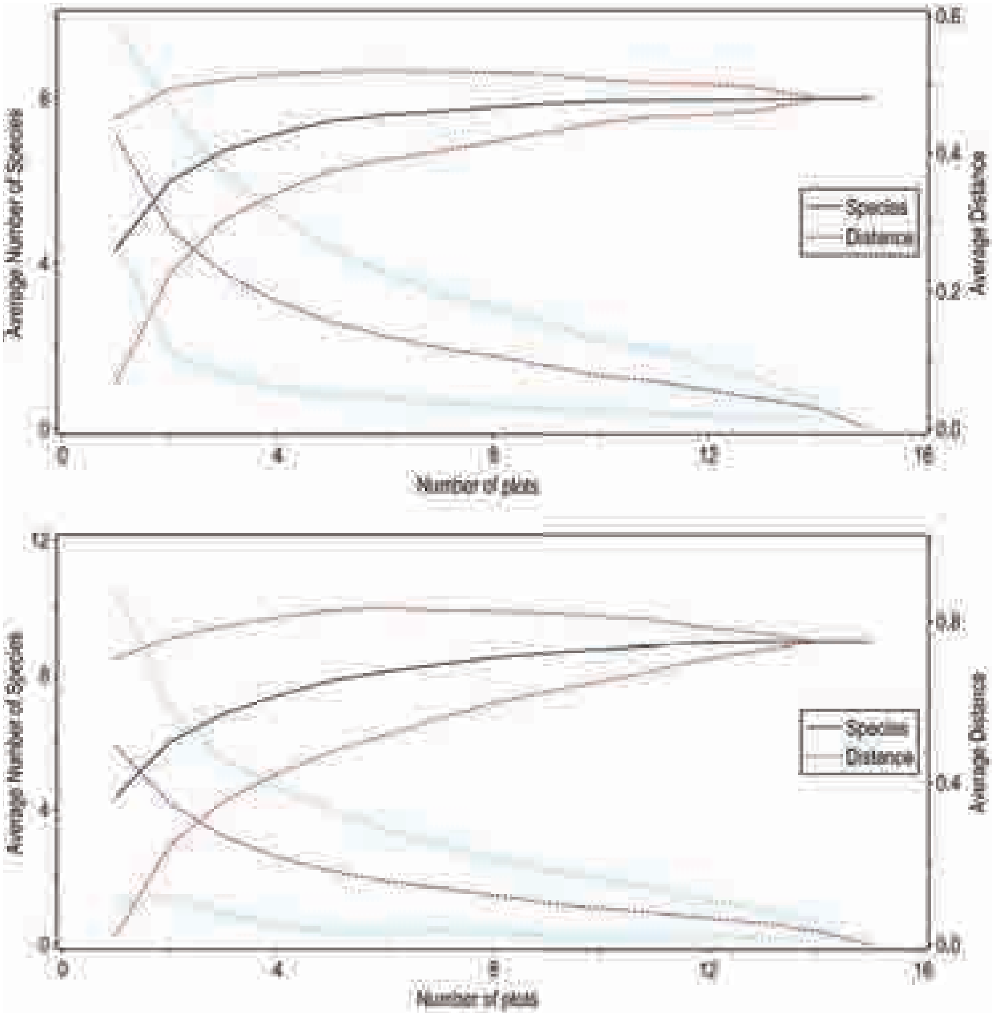

Figure 2. Water mites genera accumulation curve for (A) pre- and (B) post-monsoon seasons.

correlated with altitude (*r* = 0.583, *p* = 0.029) but negatively correlated with temperature (*r* = -0.562, *p* = 0.037).

Post-monsoon correlations between assemblages and environmental factors

Principal component analysis (PCA) was also performed between post-monsoon environmental factors and water mite assemblages (Figure 5). Principal axis 1 (53%) and 2 (24%) explained 77% of the total variability. Variables such as dissolved oxygen (*r* = 0.410), temperature (*r* = 0.445), electrical conductivity (*r* = 0.435), salinity (*r* = 0.456), and total dissolved solids (*r* = 0.453) had moderate positive correlation with first principal axis. Similarly, there was strong to moderate positive correlation between *Monatractides* (*r* = 0.841), *Torrenticola* (*r* = -0.552), *Aturus* (*r* = -0.333), and *Lebertia* (*r* = -0.327) with the first principal axis. Altitude (*r* = 0.423), total hardness (*r* = 0.496), and calcium hardness (*r* = 0.496) had moderate positive correlation with the second axis. Furthermore, *Atractides* (*r* = 0.724), *Sperchon* (*r* = 0.667), and *Lebertia* (*r* =0.361) also had

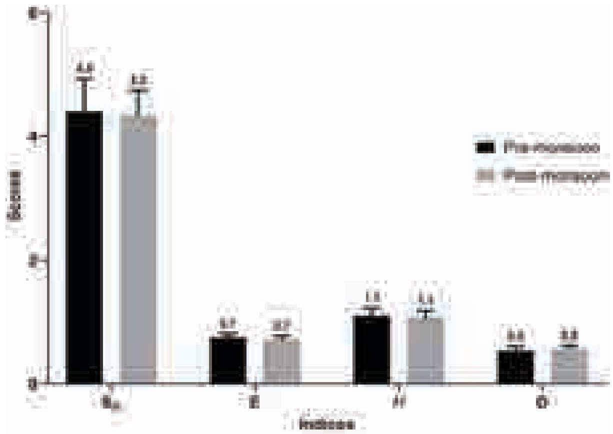

Figure 3. Pre-monsoon and post-monsoon mean diversity indices.

Table 2. Pre- and post-monsoon mite abundance at different elevations.

	Genus	Season	500–1000 m					1,001–1,999 m						>2,000 m			
			MG 1	MG 2	MG 3	MG 4	MG 5	MG 6	MG 7	MG 8	MG 9	MG 10	MG 11	MG 12	MG 13	MG 14	MG 15
1	*Atractides*	Pre	12	2	2	3	10	0	14	2	5	15	0	3	2	0	2
		Post	1	4	16	1	4	0	5	1	0	23	0	12	6	9	6
2	*Aturus*	Post	0	0	0	1	0	0	0	1	1	0	0	0	1	1	0
3	*Hygrobates*	Pre	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
		Post	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
4	*Kongsbergia*	Post	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
5	*Lebertia*	Pre	1	0	0	0	0	0	3	0	1	0	0	5	12	17	20
		Post	0	0	0	0	4	0	1	0	0	0	0	2	2	3	0
6	*Limnesia*	Post	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
7	*Monatractides*	Pre	3	3	15	3	1	0	0	0	5	1	9	2	2	1	1
		Post	19	5	16	12	4	8	33	12	23	12	17	0	0	1	0
8	*Piona*	Post	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
9	*Protzia*	Pre	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
		Post	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0
10	*Pseudotorrenticola*	Post	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
11	*Sperchon*	Pre	2	4	0	2	3	0	0	0	3	4	0	5	11	11	13
		Post	2	13	5	1	2	0	0	0	0	6	0	2	3	10	7
12	*Sperchonopsis*	Pre	1	2	1	0	0	0	0	0	3	0	0	2	0	0	0
		Post	5	2	4	1	0	0	0	3	1	0	0	4	0	2	0
13	*Testudacarus*	Post	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
14	*Torrenticola*	Pre	0	3	9	4	14	0	9	3	10	2	1	18	9	10	17
		Post	7	8	3	13	0	0	0	14	8	0	2	17	2	11	3
15	*Woolastookia*	Pre	0	0	0	0	0	0	0	0	0	0	0	2	3	0	1
	Total		**19/34**	**14/33**	**27/44**	**12/30**	**28/14**	**0/8**	**26/39**	**5/33**	**27/34**	**22/42**	**10/20**	**37/37**	**40/15**	**41/38**	**47/16**

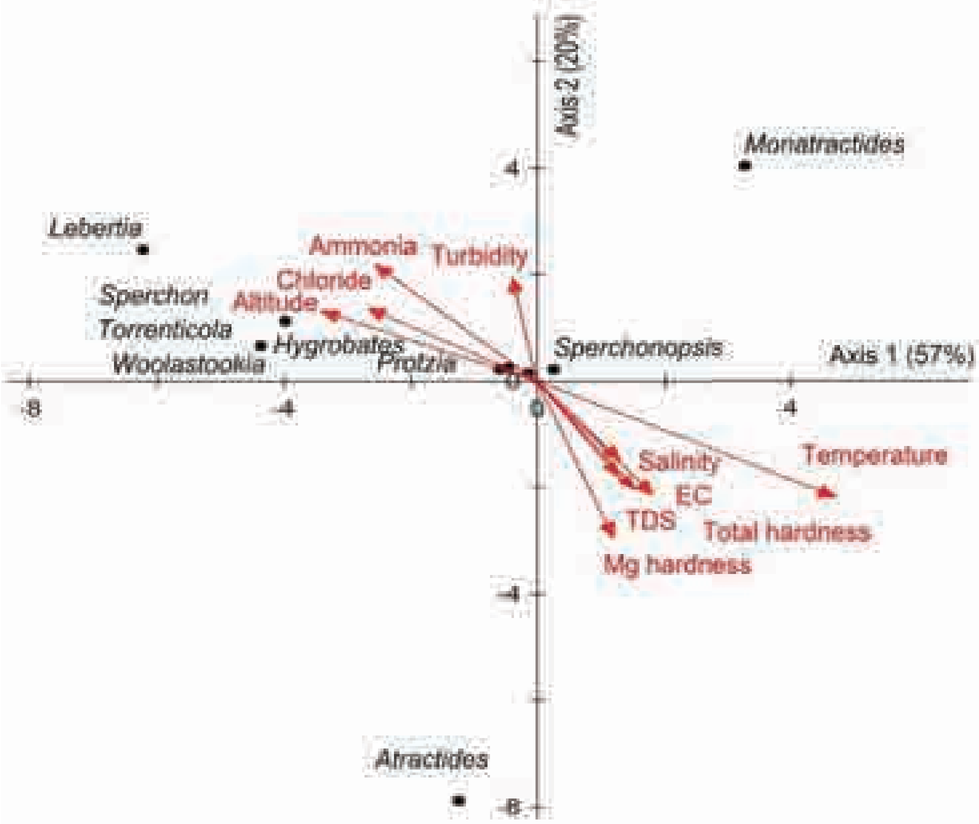

Figure 4. Principal component analysis (PCA) displaying dependence of water mites on environmental variables (pre-monsoon).

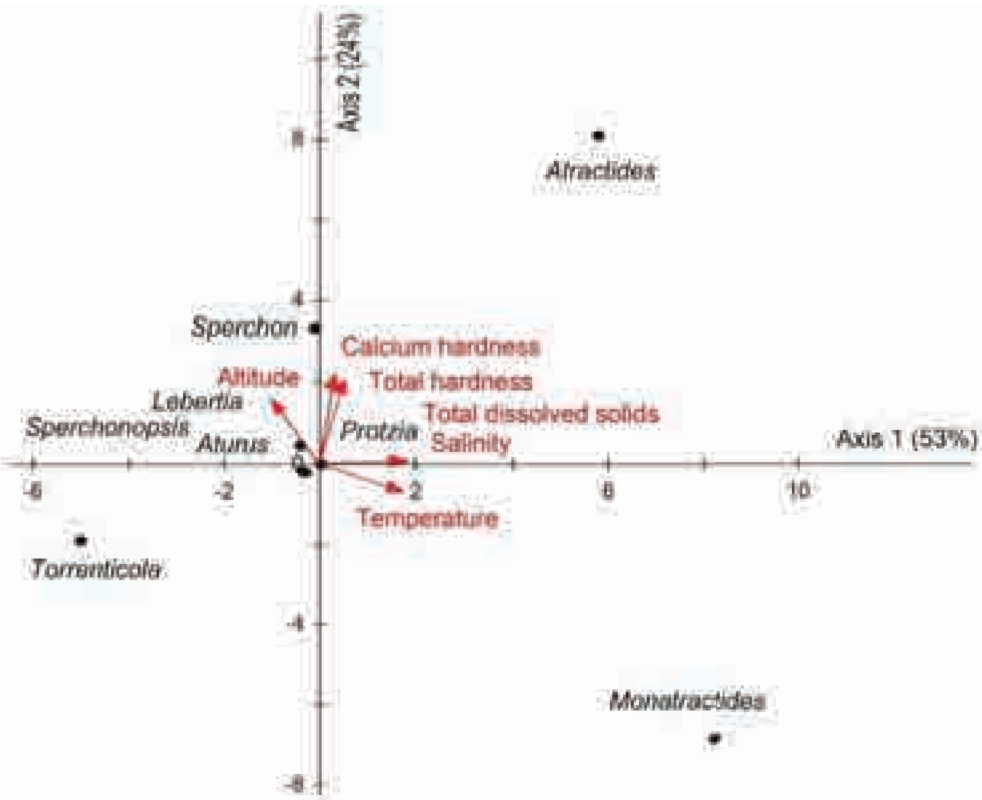

Figure 5. Principal component analysis (PCA) of association between water mites and environmental variables (post-monsoon).

Table 3. Summary of water mites genera diversity indices of two seasons in 15 streams. S_R—genera richness | *E*—evenness | *H'*—Shannon diversity index | *D*—dominance of (1) pre- and (2) post-monsoon.

Streams	Pre-monsoon				Post-monsoon			
	SR_1	E_1	H_1	D_1	SR_2	E_2	H_2	D_2
MG1	5	0.70	1.13	0.56	5	0.75	1.20	0.62
MG2	5	0.98	1.57	0.79	5	0.89	1.44	0.73
MG3	4	0.73	1.00	0.57	5	0.86	1.38	0.71
MG4	4	0.98	1.35	0.74	6	0.66	1.19	0.62
MG5	4	0.77	1.07	0.61	4	0.98	1.35	0.73
MG6	-	-	-	-	1	0	0	0
MG7	3	0.86	0.95	0.58	3	0.45	0.50	0.27
MG8	2	0.97	0.67	0.48	6	0.74	1.33	0.67
MG9	6	0.90	1.60	0.77	4	0.58	0.81	0.45
MG10	4	0.67	0.93	0.49	4	0.76	1.06	0.60
MG11	2	0.47	0.33	0.18	2	0.49	0.34	0.19
MG12	7	0.81	1.57	0.07	5	0.79	1.28	0.67
MG13	7	0.84	1.63	0.77	5	0.89	1.44	0.72
MG14	6	0.77	1.33	0.69	7	0.83	1.62	0.77
MG15	7	0.76	1.48	0.73	3	0.95	1.04	0.63
Average	**4.4±2.06**	**0.75±0.25**	**1.11±0.48**	**0.53±0.26**	**4.33±1.60**	**0.71±0.25**	**1.06±0.46**	**0.56±0.23**

Table 4. Correlation between pre- and post-monsoon mean diversity indices.

	S_{R2}	E_2	H'_2	D_2
S_{R1}	.479	.719**	.642**	.680**
E_1	.726**	.704**	.709**	.725**
H'_1	.587*	.713**	.693**	.724**
D_1	.515*	.609*	.580*	.605*

Correlation is significant at the 0.05 level (2-tailed). **—Correlation is significant at the 0.01 level (2-tailed) | S_R—genera richness | **E**—evenness | ***H'***—Shannon diversity index | **D**—dominance of (1) pre-monsoon and (2) post-monsoon (2).

strong to moderate positive correlation with principal axis 1, whereas *Monatractides* (*r* = -0.794) had negative correlation.

Pearson's correlation test between mites genera abundance and environmental variables showed that *Atractides* had positive correlation with total hardness (*r* = 0.671, *p* = 0.006), calcium hardness (*r* = 0.611, *p* = 0.015), and electrical conductivity (*r* = 0.541, *p* = 0.037). *Sperchonopsis* had strong negative correlation with chloride concentration (*r* = -0.545, *p* = 0.036).

Zoogeographical aspects

All the 15 genera found are predominantly Palearctic in distribution. The most dominant genera, i.e., *Atractides*, *Lebertia*, *Monatractides*, *Torrenticola* and *Sperchon* are also dominant genera in Palearctic streams (Di Sabatino et al. 2008). Oriental genera, such as *Nicalimnesia*, *Bharatonia*, *Khedacarus*, *Navamamersides*, *Nilgiriopsis*, *Paddelia*, and *Sinaxonopsis* were not found, also at lower altitudes (~500 m). It must be stated, however, that most of these genera occur in springs or in the hyporheic, which was not studied during this study. Moreover, the genus *Lebertia* is very rare in the Oriental region (Cook 1967; Di Sabatino et al. 2008).

DISCUSSION

There were no significant differences between indices of pre- and post-monsoon (*p* <.05). Further, genera abundance was also not significantly different (*t* (28) = -0.976, *p* = 0.33). This could be due to presence of dominant Palearctic genera and less observed variation in environmental variables in the two seasons. Similarly, Zawal et al. (2017), Pozojević et al. (2018), and Zawal et al. (2020) also suggested that there was no significant variation in seasonal abundance and assemblage of water mites in lotic habitats of Dinaric region of Croatia and ancient Lake Skadar basin in southern Europe respectively. This could be anticipated due to high degree microhabitat specialization by most genera (Di

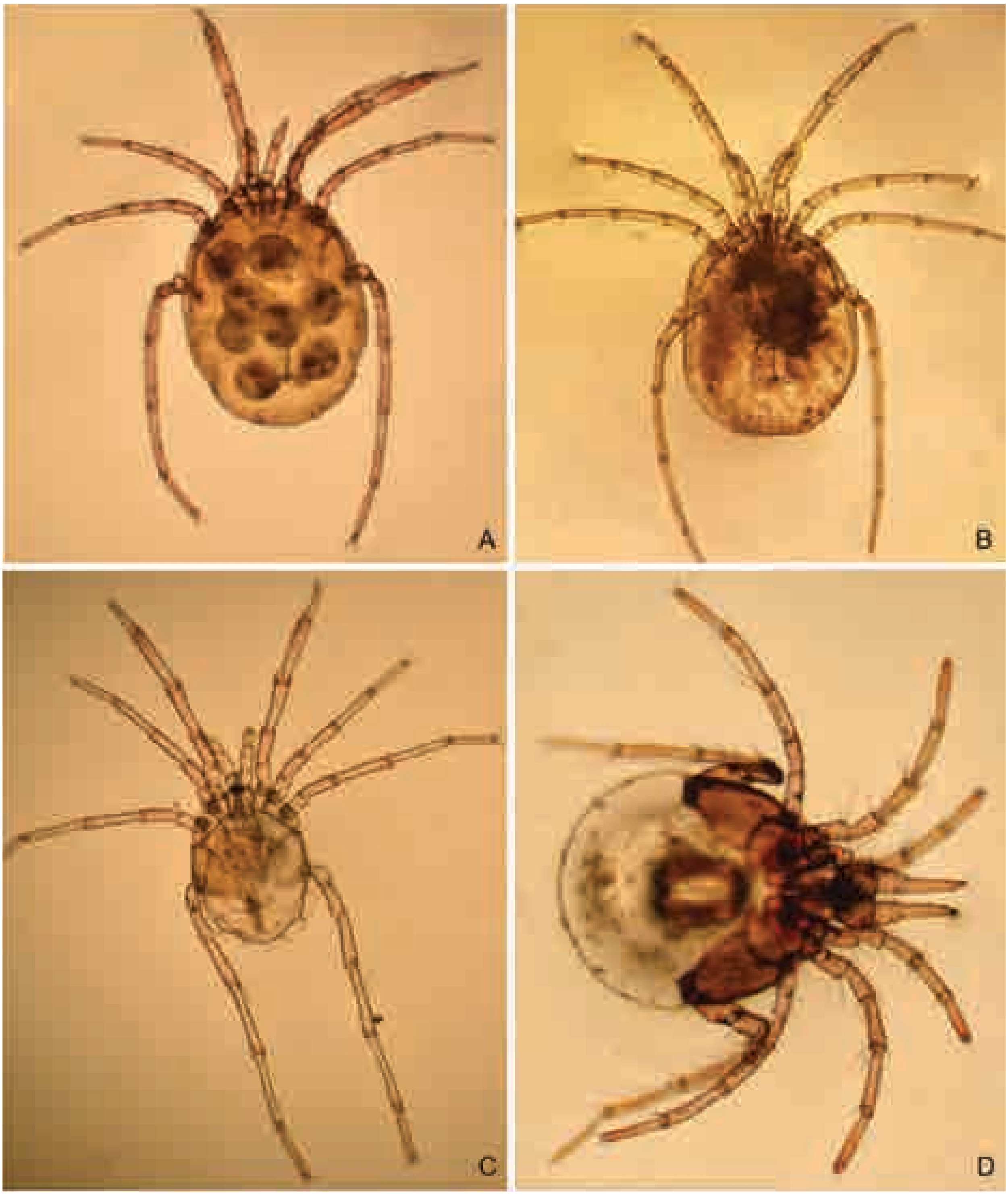

Image 1. ***Atractides*** **sp: A—Dorsal view, leg | B—Ventral view, leg. V. Pešić | C—*Atractides* sp 3. Dorsal view, leg. M.M. Gurung | D—*Limnesia* sp. Ventral view. © M.M. Gurung.**

Sabatino et al. 2000).

Most water mite genera exhibited negative correlation with water parameters indicating sensitivity to pollution (Goldschmidt 2016; Savić et al. 2022). Abelho et al. (2021), who carried out an experiment on the effect of salinity on aquatic macroinvertebrates, also suggested that genera diversity and abundance are negatively correlated with salinity as it impacts on the osmoregulation of aquatic insects and often hypertonicity can be lethal (Griffith 2017). Roberts

Image 2. A—*Monatractides* sp. Ventral view, leg. | B—*Sperchon* sp. Ventral view | C—*Torrenticola* sp. Ventral view | D—*Sperchonopsis* sp. Ventral view. © M.M. Gurung.

& Palmeiro (2008), Da Costa et al. (2014), Kent et al. (2014), and Delaune et al. (2021) suggested that exposure to high chloride concentration in water causes acute toxicity on macroinvertebrates and zooplankton. Since most of the mites collected were Palearctic genera, they exhibited positive correlation with altitude and negative correlation with temperature. Similarly, Young (1969) and Pozojević et al. (2020) also suggested that *Atractides*, *Lebertia*, *Sperchon*, and *Torrenticola* genera are negatively correlated with temperature and are more abundant at higher elevations (>1,000 m). High ammonia content in water lowers the ability to excrete digestive waste for aquatic insects causing toxic built up in the tissues and the genera abundance declines gradually (Willingham et al. 2016; Wood 2019). Magnesium and chloride ions in the water increase water hardness, salinity, and electrical conductivity. These ions also contribute to chloride toxicity modification and cause ameliorating impact on aquatic diversity (Soucek et al. 2011). Thus, diversity decreases with increase in water hardness, salinity, chloride, and TDS. During post-monsoon, *Atractides* (Hygrobatidae) exhibited a significant positive correlation with water hardness (r = 0.671, p = 0.006) and electrical conductivity (r = 0.541, p = 0.037). This genus was relatively abundant in hard water with higher electrical conductivity habitats. However, it should not be interpreted as affinity towards polluted environments but rather as higher tolerance against unfavorable conditions. Similarly, Goldschmidt (2016) indicated that genera from the family Hygrobatidae are relatively abundant in polluted environments, indicating a higher tolerance for pollutants.

The 15 streams were grouped in three altitudinal ranges, namely between 500–1,000 m (low), 1,001–1,999 m (mid) and above 2000 m (high) (Table 5, Figure 6). The abundance of water mites increased in higher altitudes. Some of the genera seem to show a preference for either lower or higher altitudinal ranges with *Woolastookia* being restricted to higher altitude, *Lebertia* preferring higher altitudes and *Monatractides* being largely absent at higher altitude. All 15 genera collected had a largely Palearctic distribution, and typical Oriental genera such as *Nicalimnesia*, *Bharatonia*, *Khedacarus*, *Navamamersides*, *Nilgiriopsis*, *Paddelia*, and *Sinaxonopsis* were not encountered. In general, the Bhutanese fauna below 1,000 m becomes increasingly dominated by Oriental genera (Rasaily et al. 2021), hence the absence of Oriental water mite taxa is surprising. It seems likely that the fast-flowing water bodies in which our sampling took place allows the Palearctic genera to occur at lower altitude and prevents the occurrence of Oriental genera. Furthermore, most mites we sampled were stream dwelling, unlike oriental genera which are more abundant in spring and standing water habitats (Pešić et al. 2012). Sampling of standing waters at lower altitude or smaller brooks fed by local sources will probably show that such habitats are at least inhabited and may be even dominated by Oriental genera. Although there is an increasing abundance of mites along the altitudinal gradient, there is no change in genera diversity. There was a uniform faunal composition throughout the altitude dominated by Palearctic genera.

Ethical standards

The research project with permit no. 17703966556045F2C2BFD63 was approved by Ugyen Wangchuck Institute for Conservation and Environmental Research (UWICER), Lamaigoenpa, Bumthang Bhutan. Specimen collections and preservation were done following standard protocols as detailed in the methods section.

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Authors contributions: MMG—carried out fieldwork and drafted the manuscript, CD—carried fieldwork with first author, DBG—reviewed the manuscript, HS—reviewed the manuscript.

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COMMUNICATION

An overview of genus *Pteris* L. in northeastern India and new report of *Pteris amoena* Blume from Arunachal Pradesh, India

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Abstract: The present paper highlights a taxonomic account of genus *Pteris* L. (Pteridaceae E.D.M. Kirchn.) with newly reported species *Pteris amoena* Blume, which was collected from the Pange range of Tale Wildlife Sanctuary and Hapoli Primary Forest, Hapoli, Lower Subansiri District of Arunachal Pradesh. The present communication is based on plant exploration and in-depth surveys done by the first two authors and through scrutiny of herbaria and literature. All the species are enumerated in this list along with worldwide distribution (outside India), local distribution in Arunachal Pradesh, northeastern India as NEI included with other Indian states. Reported species shows some morphological closeness with *P. terminalis* Wall. ex. J.Agardh but differ in having bright pink axes and more rounded and crenately toothed segment-apices. All these characters differentiate to this species to its closely related species and testifying that *P. amoena* Blume as a new report to the Arunachal Pradesh. Detailed description, distributional range, ecology and specimen examined of newly reported taxa are provided in this paper.

Keywords: Brake fern, distributional range, ferns, local distribution, Lower Subansiri district, plant, taxonomy.

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Competing interests: The authors declare no competing interests.

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Author contributions: VKR, AB and AKS conducted field survey for the detailed study of this project and identified the specimens. AKS, AK and VKR have finalized and approved the manuscript.

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INTRODUCTION

Pteris L. is a large, pantropical genus represented in all continents except Antarctica, but only a few species occur in warm temperate regions of the world. This genus is commonly called "Brake" ferns. Molecular and paleontological analyses revealed that the genus *Pteris* L. originated and diversified in the Late Cretaceous with other pteridoid ferns about 100 million years ago (Schneider *et al.* 2004) but Walker (1956) considered *Pteris* L. as a young genus. It grows in shaded places, from sea level to high mountains, less often in open places, road sides, earth cuttings, and on calcareous & other rock crevices (Tryon et al. 1990). Usually, different species of genus *Pteris* L. are used as ornamental plant e.g., *P. vittata* L., *P. ensiformis* Burm.f., and *P. cretica* L. in homes and gardens, while some of the species are widely used as heavy metal accumulators. Of these, *P. vittata* L. is considered as an excellent model organism in experimental plant biology. The majority of the species are grouped into a number of complexes of various sizes and these complexes show very different biological behaviors, according to whether they are predominantly apogamous or a mixture of apogamous and sexual species (Walker 1962). The members of this family are usually characterized by the absence of true indusia, the protective covering layer of sporangia, though some genera frequently develop recurved leaf margins to serve the same function. These structural modifications in the leaves are referred to as 'false-indusia' or 'pseudo-indusia'. The other identifying characters of the family are free leaf veins, linear, sub-marginal sori and usually trilete to rarely monolete spore (Soni et al*.* 2020). It is estimated to contain 200–280 species (Copeland 1947), 300 species (Walker 1956), 250 species (Holttum 1968; Tryon et al. 1990), 200 species (Tryon & Tryon 1982), in the world. Of these, 57 species are present in India (Fraser-Jenkins et al. 2016) though Dixit (1984) had reported 48 species. Most of the *Pteris* L. species are present in the Western Ghats and Indian Himalayan Region (IHR) of India. But according to the Fraser-Jenkins et al*.* (2016) there are 50 taxa followed by 12 ssp. including one hybrid species (*P. vittata* notho ssp. × *nayariana* Fraser-Jenk., S.C.Verma & Khullar) and one cultivated species (*P. parkeri* hort. ex J.J.Parker) of genus *Pteris* L. in northeastern India. Of these 42 species of genus *Pteris* L. are from Arunachal Pradesh except the newly reported species *P. amoena* Blume. So, as per this datum Arunachal Pradesh also has the most number of species of the depicted genus and is the dominant zone for pterido-diversity and richness of India.

The pterido-geographical region of India deals with Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura, the seven states located in the northeastern part of the country and command special importance in India, not only because of their location but also their cultural and historical uniqueness. All these states of northeastern India have rich natural resources of flora. Therefore, if the region is called a paradise for botanists, there is no doubt.

The present paper deals with all species of genus *Pteris* L. of northeastern India with newly reported taxa to Arunachal Pradesh and are presented here, based on personal collection (field surveys) of the first two authors, herbarium consultation, literature scrutiny such as Fraser-Jenkins et al. (2008, 2016) and provides an enumerative checklist of the most puzzled genus of Pteridaceae for northeastern India in Table No. 01.

MATERIAL & METHODS

Field survey and collection

In the case of the newly reported species *P. amoena* Blume, while studying taxonomy of Pteridophytes of Lower Subansiri District of Arunachal Pradesh, the first authors came across a new specimen, which was collected from the Pange range of the Tale Wildlife Sanctuary and Hapoli primary forest of Arunachal Pradesh. The newly reported taxa was recognized by its smooth, reddish stipe and lower rachis, black costae and upper rachis; pinnule-apices crenately toothed, acute, not aristate; on critical evaluation and perusal of literatures, the authors identified and confirmed it as *P. amoena* Blume. So far this species was previously reported from the neighboring states of NEI (northeastern India; Assam, Manipur, and Meghalaya) but there was no report from this state till date, so this communication testifies a new Pteridophytic record of *P. amoena* Blume from Arunachal Pradesh. All the specimens collected from the research site are deposited in the herbarium and provisional identification was made with the help of available literature and later determined in various Herbaria (ARUN, ASSAM, CAL, and BSA). The depicted list provided for species of genus *Pteris* L. in northeastern India are based on voucher specimens, which are deposited in the Herbarium ARUN, Botanical Survey of India, Arunachal Pradesh Regional Centre, Itanagar, Arunachal Pradesh. Description and mentioned photo plates with relevant notes of newly reported taxa are provided here for easy identification and future collection.

SYSTEMATIC TREATMENT

Pteris amoena Blume, Enum. PL Javae 2: 210. 1828. (Image. 1)

Type: from Indonesia, Java, boven Tjibodas, C.L. von Blume, L.

Pteris purpureorachis Cope L, Philipp. J. Sci., C, 12: 48. 1917., *Pteris maclurei* Ching, Bull. Dept. Biol. Sun Yatsen Univ. 6: 28. 1933., *Pteris tokioi* Masam., Trans. Nat. Hist. Soc. Taiwan 25: 13. 1935., *Pteris porphyrophlebia* C.Chr. & Ching, in Ching, Lingnan Sci. J. 15(3): 393. 1936., *Pteris nakasimae* Tagawa, Act. Phytotax. Geobot. 7: 84. 1938., *Pteris yakusimensis* Tagawa, Act. Phytotax. Geobot. 5: 107. 1936., *Pteris tokioi*var. *Yakusimensis* (Tagawa) Sa.Kurata, Hokuriku J. Bot. 6: 10. 1957.

Adults terrestrial, about 70–90 cm tall; Rhizome stout, erect, ca. 1–2 cm in diam., tufted, bearing fronds close together, Rhizome scale basifixed, dark brown, ca. 03–04 mm, sparsely scaly, scales hair like, 2–3 cells widest base, above uni-seriate. Fronds ca. up to 90 × 20 cm, ovate in shape; Stipes ca. 40–50 cm long, 2–3 mm thick, laterally grooved, not adaxially and abaxially, dark blackish at base to shiny brown upwards, glossy; Rachis similar but too much thin compared to stipes; Lamina ca. 35–40 cm; ovate-oblong, bipinnatifid, texture chartaceous; Pinnae up to 4–6 pairs, opposite, sometimes 2-pinnatipartite, lateral pinnae shortly stalked, upper pinnae sessile, lanceolate, base rounded-cuneate, apex acute, caudate (ca. 05–07) cm, ca. 20 × 05 cm; terminal pinna similar to lateral pinnae but wider with long stalked (ca. 02 cm), ca. 22 × 07 cm; basal pair of pinnae well developed often with a basiscopic pinnule near base, similar in shape to main part of pinna but smaller, ca. 15 × 04 cm; Pinnules ca. 20 pairs in each pinnae, alternate, ca. 02 × 04 mm apart, sinuses wide and U shaped, margins serrulate, apex obtuse or mucronate, basal pinnules of pinnae slightly shorter and more widely spaced, basally decrescent to costules; Costae and Costules adaxially straw-colored, grooved, with spines along groove and bases of midribs; abaxially sorrel-red, shiny, glabrous, prominent abaxially; Veins conspicuous, oblique, apical pairs of veins simple, remainder bi-forked, basal basiscopic arising from costae and reached just below the sinus but not connected, others arising from veinlets, areoles present between the costae; Venation free; Sori indusiate, cup shaped, dark brown, confined to the terminals on 1 or 2 venation, solitary at the apex of each segment; Indusia indusium membranaceous, entire from base of segments upward to about one-third from the serrate apex. Spores monolete, exine smooth (Image 1).

Distribution: China, India (Assam State, Manipur, Meghalaya (Mawryngkaeng, *X Rup Chand,* MICH) Indonesia, Japan, Malaysia, Myanmar, Taiwan, Thailand, Tibet, Vietnam; Australasia: New Guinea. (Fraser-Jenkins et al. 2016).

Distribution in Arunachal Pradesh: New report from Tale Wildlife Sanctuary and Hapoli Primary Forest, Lower Subansiri district, Arunachal Pradesh (Figure 1).

Phenology: Vegetative phase: June–September; Reproductive phase: October–December

Ecology: Terrestrial collected from wild floor of Hapoli Primary Forest, Hapoli and Tale Wildlife Sanctuary, Lower Subansiri District of Arunachal Pradesh 1,625–1,959 m.

Specimens examined: 42833, Acc no., 31689 (ARUN), 11.i.2020, Hapoli Primary Forest, at the back of Arunachal Guest House, Lower Subansiri District, Arunachal Pradesh, India, 27.536 N. 93.809 E, 1,625 m, Soni A.K. (Image 1, Figure 1); 43969, Acc. No., 31690, 31691 & 31692 (ARUN), 16.ii.2021, Pange Range, Tale Wildlife Sanctuary, Lower Subansiri District, Arunachal Pradesh, India, 27.587 N. 93.985 E, 1,959 m, 16.ii.2021, Soni A.K. (Image 1, Figure 1).

IUCN Status: CR.

RSEULT AND DISCUSSION

The Pteridaceae E.D.M.Kirchn. is a large and diverse family of nearly worldwide distribution with around 50 genera and more than 1,000 species, and roughly 10% of the extant lepto-sporangiate fern diversity (Schuettpelz et al. 2007). In northeastern India, it is represented by 14 genera with a total of 93 species and 14 subspecies from this region. Of these, the most dominant, critical and puzzled genus *Pteris* L. (Pteridaceae) has 50 taxa followed by 12 ssp. including one hybrid and one cultivated species also (Soni et al. 2020). The bar chart (Figure 3) and distributional map of northeastern India (Figure 2) showing the state-wise status, including species, subspecies, hybrid and cultivated taxa of genus *Pteris* L. of northeastern India and depicted table also prove that Arunachal Pradesh has the most diverse status of the mentioned genus in northeastern India including 42 taxa (11 subspecies); Assam follows with 19 species, seven subspecies and one cultivar taxa; Manipur is in third position in this list, which has 27 (seven subspecies) taxa. Meghalaya follows with 32 taxa of this genus (nine subspecies and one hybrid species); Mizoram (15 taxa including four subspecies) and Nagaland has 18 taxa with seven subspecies. Following the above listing, we can say that the state Tripura with

Image 1. *Pteris amoena* Blume A—Whole plant | B—Habitat with basal pinnae | C—Abaxial surface of lamina showing sori | D—Pinnae showing venation | E—Rhizome | F—Pinnules showing margin | G—Apex of Pinnae | H—Mounted desiccated specimens. © Ashish K. Soni.

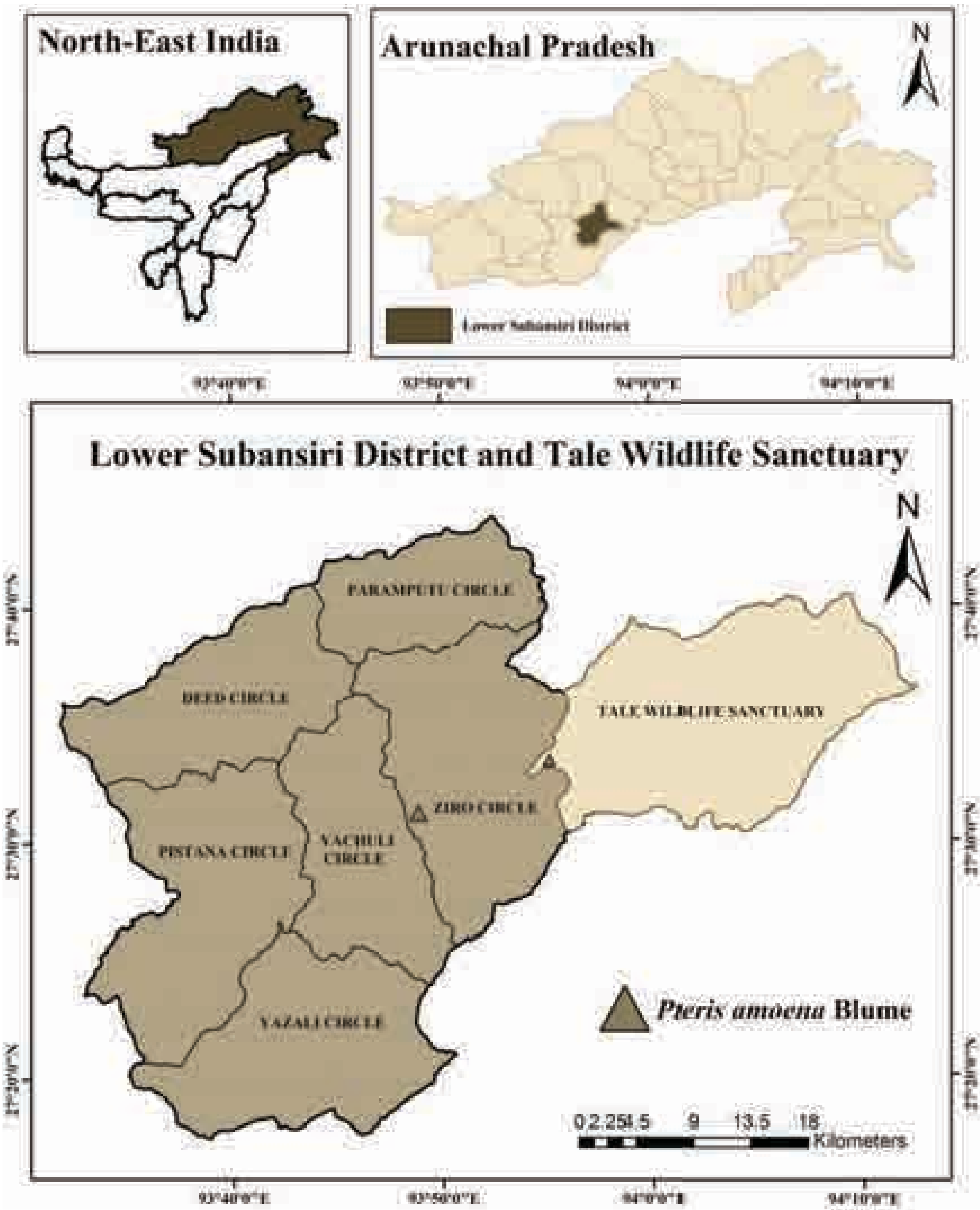

Figure 1. Representative map showing northeastern India including with localities in Lower Subansiri District of Arunachal Pradesh where *Pterisa moena* Blume were reported.

four sub species has the lowest number, 11 taxa, for the genus *Pteris* L. in northeastern India. The detailed listing of all species of genus *Pteris* L. of northeastern India on worldwide distribution pattern with localities in Arunachal Pradesh presented here are totally based on the personal collection of the first two authors and another collector, Mr. Chhandam Chanda (Senior researcher at BSI, APRC, Itanagar), followed by the actual specimens of herbariums consultation personally, ARUN, ASSAM, CAL and BSA also. The collected plants were preserved following Bridson & Forman, (1998) and subsequently identified with the help of standard Indian

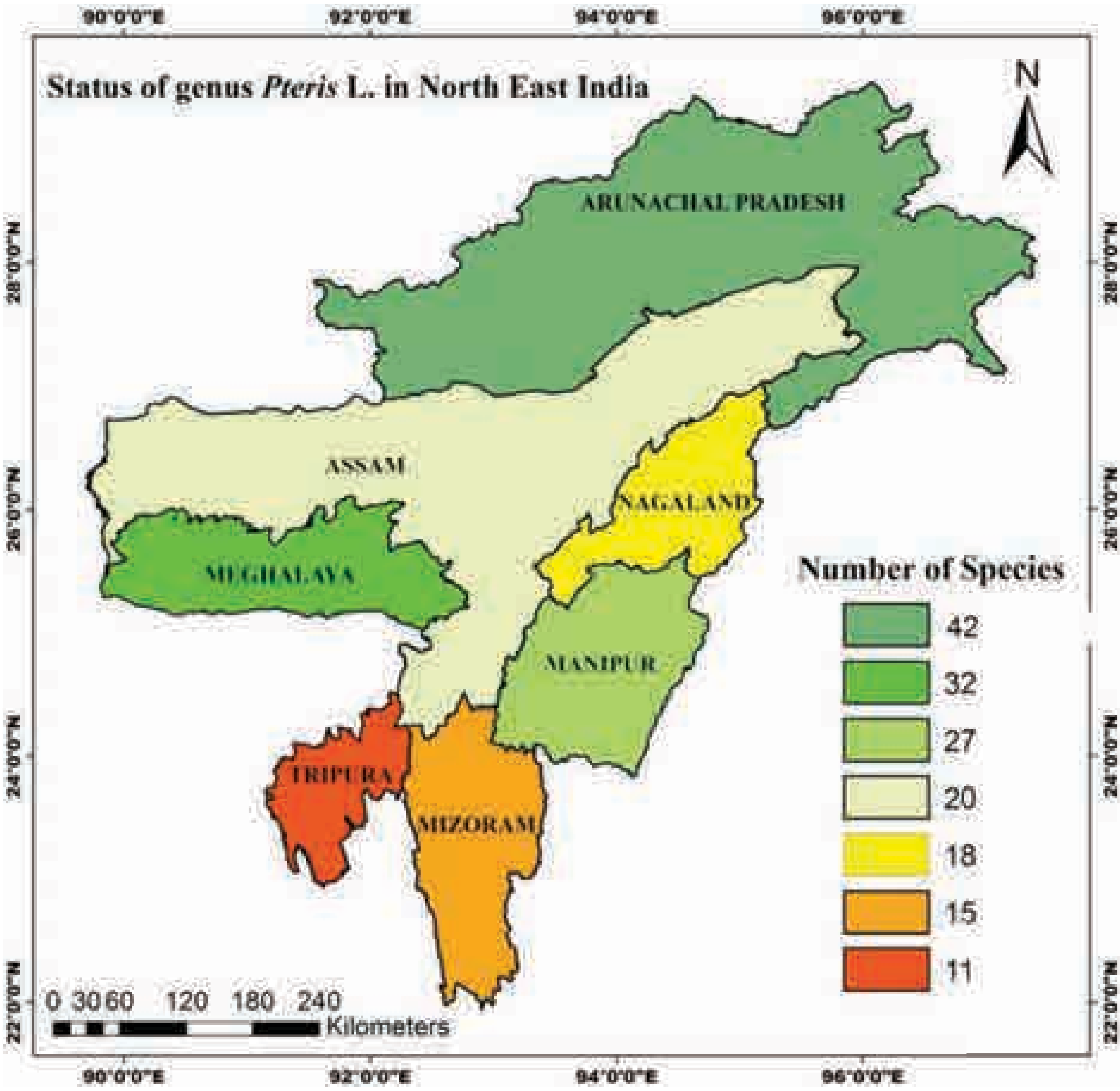

Figure 3. Representative map showing state-wise status of genus *Pteris* L. in northeastern India.

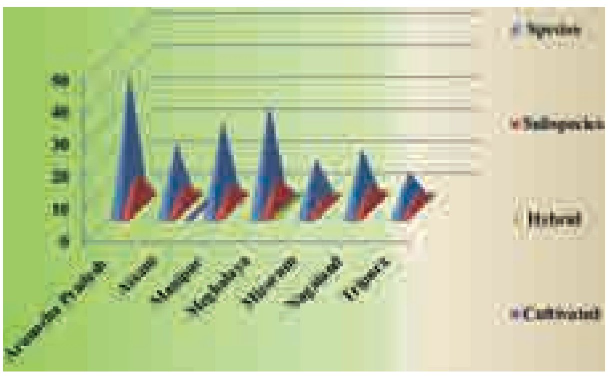

Figure 2. Statewise status of genus *Pteris* L. in northeastern India.

and foreign literature (Beddome 1866; Lyell 1870; Jamir & Rao 1988; Borthakur et al. 2001; Ghosh et al. 2004; Singh & Panigrahi 2005; Gangmin et al. 2013; Fraser-Jenkins et al. 2016) (Table 1).

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Bridson, D. & V. Forman (1998). *The Herbarium Handbook.* Edition 3. Royal Botanic Gardens, Kew, 320 pp.

Table 1. List of species of *Pteris* L. from northeastern India with worldwide distribution and localities in Arunachal Pradesh, India.

	Taxa of genus *Pteris* L. in northeastern India	Distribution of genus *Pteris* L. in NEI with locality in Arunachal Pradesh	Worldwide distribution of genus *Pteris* L.
1	*Pteris actiniopteroides* Christ	Arunachal Pradesh (Lower and Upper Dibang) and Meghalaya.	Asia: China.
2	*Pteris alata* L.	Arunachal Pradesh (Changlang, Kameng, Lohit, Papum Pare, Siang, Lower Subansiri District and Tirap), Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura.	Asia: Bangladesh, Bhutan, China, Indonesia, Japan, Laos, Malaysia, Myanmar, Nepal, Sri Lanka, Taiwan, Thailand and Vietnam.
3	*Pteris amoena* Blume	Arunachal Pradesh (First time reported from Tale Wildlife Sanctuary and Hapoli Primary Forest of Lower Subansiri District), Assam, Manipur and Meghalaya.	Asia: China, Myanmar, Taiwan, Tibet and Vietnam.
4	*Pteris arisanensis* Tagawa	Arunachal Pradesh (Changlang, Debang Valley, Kameng, Lohit, Papum Pare, Siang, Lower Subansiri District and Tirap), Manipur, Meghalaya and Nagaland.	Elsewhere in India and Asia.
5	*Pteris aspericaulis* Wall. ex J.Agardh	Arunachal Pradesh (Debang Valley, Kameng, Lohit, Lower Subansiri District, Siang and Tawang), Manipur and Meghalaya.	Elsewhere in Western Himalaya and Asia.
6	*Pteris assamica* Fraser-Jenk. & T.G.Walker	Arunachal Pradesh (Kameng, Lower Subansiri District and Papum Pare), Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura.	Elsewhere in Asia.
7	*Pteris barbigera* Ching	Arunachal Pradesh	Asia: Vietnam.
8	*Pteris biaurita* L. ssp. *fornicata* Fraser-Jenk.	Arunachal Pradesh (Changlang, Kameng, Lohit, Lower Subansiri and Papum Pare), Assam, Manipur, Meghalaya, Mizoram Nagaland and Tripura.	Elsewhere in India; Asia and Africa.
9	*Pteris biaurita* L. ssp. *walkeriana* Fraser-Jenk. & Dom. Rajkumar	Arunachal Pradesh (Changlang, Debang Valley, Itanagar, Kameng, Lohit, Namdapha, Papum Pare, Siang, Lower Subansiri District, Tirap, Upper Siang, and West Kameng), Assam, Manipur, Meghalaya, Mizoram and Nagaland.	Elsewhere in India; Asia and Africa.
10	*Pteris blumeana* J.Agardh	Arunachal Pradesh (Papum Pare and Siang), Assam, Manipur, Meghalaya and Tripura.	Elsewhere in India and Asia.
11	*Pteris cadieri* Christ ssp. *dimorpha* (Copel.) Fraser-Jenk.	Arunachal Pradesh (Changlang)	Asia: Bangladesh, China, Taiwan and Vietnam.
12	*Pteris cadieri* Christ ssp. *walker* Fraser-Jenk.	Assam, Manipur and Meghalaya.	China
13	*Pteris cretica* L. ssp. *cretica*.	Arunachal Pradesh (Kameng, Lohit, Siang and Lower Subansiri District), Meghalaya, Nagaland and Tripura.	Asia: Bhutan, China, Myanmar, Nepal, Pakistan, Sri Lanka, Taiwan, Thailand and Tibet.
14	*Pteris cretica* L. ssp. *laeta* (Wall. ex Ettingsh.) Fraser-Jenkins	Arunachal Pradesh (Changlang, Debang Valley, Kameng, Siang, Lower Subansiri District and Tirap), Assam, Manipur, Meghalaya, Nagaland and Tripura.	Elsewhere in India; Asia and Africa.
15	*Pteris dactylina* Hook.	Arunachal Pradesh (Debang Valley, Kameng and Siang).	Asia: Bhutan, China, Myanmar, Nepal, Taiwan and Tibet.
16	*Pteris dixitii* Fraser-Jenk. & Pariyar	Arunachal Pradesh (Debang Valley, Lohit, Lower Subansiri District, Papum Pare and Siang), Manipur, Meghalaya, Mizoram, Nagaland and Tripura.	China and Myanmar.
17	*Pteris ensiformis* Burm.f.	Arunachal Pradesh (Changlang, Kameng, Papum Pare, Lower Subansiri District and Tirap), Assam, Manipur, Mizoram, Meghalaya, Nagaland and Tripura.	Elsewhere in India and Asia, Australasia, Pacific Islands, North America.
18	*Pteris grevilleana* Wall. ex J.Agardh ssp. *grevilleana*	Arunachal Pradesh (Changlang), Assam and Meghalaya.	Asia: Bangladesh, China, Myanmar, Singapore, Taiwan, Thailand and Vietnam.
19	*Pteris griffithii* Hook.	Arunachal Pradesh (Kameng, Siang and Lower Subansiri District).	Asia: Bhutan and Myanmar
20	*Pteris hirtula* (C.Chr.) C.V.Morton	Arunachal Pradesh (Changlang, Papum Pare, Siang and Upper Subansiri District) and Manipur.	Asia: Bhutan, China, Myanmar, Tibet and Vietnam
21	*Pteris inaequalis* Baker	Arunachal Pradesh (Kameng, Lower Subansiri District) and Manipur.	Asia: China, Japan and Nepal.
22	*Pteris kathmanduensis* Fraser-Jenk. & T.G.Walker	Arunachal Pradesh (Papum Pare and Lower Subansiri District) and Meghalaya.	Asia: China and Nepal.
23	*Pteris khasiana* (C.B.Clarke) Hieron. ssp. *khasiana*	Arunachal Pradesh (Kameng, Papum Pare, Siang and Tirap), Assam, Manipur, Meghalaya and Nagaland.	Asia: Bangladesh, Bhutan, China, Myanmar and Nepal.

	Taxa of genus *Pteris* L. in northeastern India	Distribution of genus *Pteris* L. in NEI with locality in Arunachal Pradesh	Worldwide distribution of genus *Pteris* L.
24	*Pteris longipinnula* Wall. ex J.Agardh	Arunachal Pradesh (Changlang, Papum Pare and Tirap), Assam, Manipur, Meghalaya, Mizoram and Nagaland.	Asia: Bangladesh, China, Myanmar and Nepal
25	*Pteris mawsmaiensis* Fraser-Jenk. & Benniamin	Arunachal Pradesh (Siang) and Meghalaya.	Asia: Myanmar.
26	*Pteris medogensis* Ching & S.K.Wu	Arunachal Pradesh (Lower Subansiri District) and Meghalaya.	Asia: Bhutan, China, Nepal and Tibet.
27	*Pteris normalis* D.Don	Arunachal Pradesh (Kameng, Lohit, Siang, Lower Subansiri District and Tirap), Manipur, Meghalaya, Mizoram and Nagaland.	Asia: Bhutan, China, Myanmar, Nepal, Taiwan, Thailand and Tibet.
28	**Pteris parkeri* hort. ex J.J. Parker	Assam	Asia: Nepal. Commonly worldwide cultivated taxa.
29	*Pteris pellucens* J.Agardh	Arunachal Pradesh (Debang Valley, Kameng, Lohit, Siang and Upper Subansiri District), Assam, Manipur, Meghalaya and Nagaland.	Asia: Bhutan, China, Indonesia, Nepal, Philippines, Sri Lanka, Taiwan, Thailand and Vietnam.
30	*Pteris pseudopellucida* Ching	Arunachal Pradesh (Changlang, Papum Pare, Siang and Tirap), Manipur, Meghalaya and Mizoram.	Asia: Bangladesh, China, Laos, Myanmar, Thailand and Vietnam.
31	*Pteris puberula* Ching	Arunachal Pradesh (Kameng and Siang), Manipur, Meghalaya and Mizoram.	Asia: Bhutan, China, Myanmar, Nepal, Thailand and Tibet.
32	*Pteris roseolilacina* Hieron.	Meghalaya and Mizoram.	Asia: China, Myanmar and Nepal.
33	*Pteris scabripes* Wall. ex J.Agardh.	Assam and Meghalaya.	Asia: Indonesia, Malaysia, Myanmar and Thailand.
34	*Pteris scabririgens* Fraser-Jenk., S.C.Verma & T.G.Walker	Arunachal Pradesh (Debang Valley, Kameng and Siang), Meghalaya, Manipur and Nagaland.	Asia: Bhutan, Nepal and Tibet.
35	*Pteris spinescens* C.Presl	Arunachal Pradesh (Debang Valley, Kameng and Lower Subansiri District), Manipur, Meghalaya and Nagaland.	Asia: Bhutan, China, Japan, Myanmar, Nepal and Tibet.
36	*Pteris subindivisa* C.B.Clarke	Arunachal Pradesh (Debang Valley, Kameng, Lower Subansiri District, Papum Pare, Siang and Subansiri), Assam and Mizoram.	Asia: Bhutan, China, Myanmar and Nepal.
37	*Pteris subquinata* Wall. Ex J.Agardh	Arunachal Pradesh (Kameng).	Asia: Bhutan, China, Myanmar, Nepal and Thailand.
38	*Pteris taiwanensis* Ching	Arunachal Pradesh (Kurung-kumey and Lower Subansiri District).	Asia: Bhutan, China, Nepal and Taiwan.
39	*Pteris terminalis* Wall. ex J.Agardh	Arunachal Pradesh (Kameng, Lower Subansiri District and Siang) and Manipur.	Asia: Bhutan, China, Indonesia, Myanmar, Nepal, Pakistan, Philippines, Taiwan, Tibet and Vietnam.
40	*Pteris tricolor* Linden	Manipur and Mizoram.	Asia: China and Myanmar.
41	*Pteris tripartita* Sw.	Arunachal Pradesh (Siang).	Asia: China, Indonesia, Malaysia, Philippines, Sri Lanka, Taiwan, Thailand and Vietnam.
42	*Pteris venulosa* Blume	Manipur, Mizoram and Tripura.	Asia: Indonesia and Malaysia.
43	*Pteris venusta* Kunze, ssp. *matsudae* (Masam.)	Arunachal Pradesh (Changlang and Siang), Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura.	Asia: Bangladesh, Bhutan, Cambodia, China, Laos, Myanmar, Nepal, Taiwan, Thailand, and Vietnam.
44	*Pteris vittata* L. ssp. *vittata*	Arunachal Pradesh (Changlang, Debang Valley, Kameng, Papum Pare, Siang and Lower Subansiri District), Assam Manipur, Meghalaya, Mizoram, Nagaland and Tripura.	Asia: Bangladesh, Bhutan, China, Nepal, Pakistan, Sri Lanka, Taiwan, Thailand and Vietnam.
45	*Pteris vittata* ssp. *emodi* Fraser-Jenk.	Arunachal Pradesh (Changlang, Lohit, Siang and Subansiri) and Meghalaya.	Asia: Bhutan, China, Myanmar, Nepal, Pakistan and Tibet.
46	*Pteris vittata* L. ssp. *vermae* Fraser-Jenk.	Arunachal Pradesh (Kameng, Papum Pare, Subansiri and Siang).	Asia: Bhutan, China, Nepal and Tibet.
47	*Pteris wallichiana* J.Agardh	Arunachal Pradesh (Debang Valley, Kameng, Tirap, Siang, Lower Subansiri District and Papum Pare), Assam, Manipur and Nagaland.	Asia: Bhutan, China, Indonesia, Myanmar, Nepal, Philippines, Taiwan, Thailand, Tibet and Vietnam.
48	#*P. vittata* nothosubsp. × *nayariana* Fraser-Jenk., S.C. Verma & Khullar	Meghalaya	Asia: only reported from India.

*—cultivated taxon | #—hybrid taxon.

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COMMUNICATION

Nectar robbing by bees on the flowers of *Volkameria inermis* (Lamiaceae) in Coringa Wildlife Sanctuary, Andhra Pradesh, India

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Abstract: Floral traits that shape the floral architecture are important to allow or disallow flower visitors to access nectar and effect pollination. Specialization in floral architecture is vulnerable to flower visitors that exploit nectar by robbery without effecting pollination. In Coringa Wildlife Sanctuary in Andhra Pradesh, India, studies on the exploitation of nectar by robbery in plant species with specialized flowers are completely lacking. We carried out a study on the foraging activity of insect foragers and nectar robbing by bees on the specialized nectariferous flowers of an evergreen shrub, *V olkameria inermis* growing in the landward side of this sanctuary. Field observations indicated that the flowers of this species facilitate legitimate probing only by butterflies and diurnal moths which while seeking nectar effect pollination. However, two bee species *An thophora dizona* and *Xy locopa pubescens* seek nectar illegitimately as primary nectar robbers by making a slit/hole into the corolla tube from outside bypassing the flower front. Additionally, *A. dizona* gathers pollen legitimately from the stamens which are exposed and placed outside the corolla tube. The stigma is also placed outside the corolla tube but this bee indiscriminately makes attempts to collect pollen from the stigma, as a result of which pollination occurs. Nectar robbing by these bees leads to a reduction in nectar volume in robbed flowers and brings about variability in the standing crop of nectar. As a result, the pollinating butterflies increase the number of nectar foraging visits and shuttle between populations of *V. inermis* in quest of more nectar to meet their daily metabolic requirements. Such a foraging behavior increases pollination rate in general and cross-pollination in particular, which in turn increases plant fitness in *V. inermis*. Therefore, the nectar robbing by bees appears to have a positive effect on plant fitness through change in seed set rates.

Keywords: *Anthophora dizona,* butterflies, nectariferous flowers, plant fitness, tubular corolla, *Xylocopa pubescens*.

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INTRODUCTION

Floral adaptations that promote pollen transport by pollinators are treated as evidence of specialization to a particular pollinator type (Castellanos et al. 2003, 2004). Specialization in floral architecture is vulnerable to exploitation by flower visitors which remove or steal nectar without effecting pollination which in turn may show detrimental effects on plant fitness (Navarro 2001). Nectar robbers display a particular behaviour to steal nectar. A common form is primary nectar robbing in which the flower visitor makes a hole, slit, or tear in corolla tissue to steal nectar bypassing the floral opening used by legitimate pollinators; this form of robbing is most common on flowers with hidden nectar. The flowers with tubular corolla are vulnerable to nectar robbing (Rojas-Nossa et al. 2016). Another form is secondary nectar robbing in which the flower visitor acquires nectar through holes made by primary nectar robbers bypassing the floral opening used by legitimate pollinators (Irwin & Maloof 2002). Irwin et al. (2010) reported that all flower visitors are not pollinators. Some visitors rob nectar bypassing the contact with the anters and/or stigma and the effects of this nectar robbing behaviour by robbers range from negative to positive on female and male components of plant reproduction. Rojas-Nossa et al. (2021) reported that nectar robbing behavior has negative, neutral and positive consequences according to life history traits of the interacting animals and the ecological mechanisms involved. These authors reported that nectar robbing has neutral effects on the reproduction of *Lonicera etrusca*. In this species, the nectar robbers act as pollinators and decrease the visitation rates of legitimate foragers.

The available information on the foraging activity and pollination in mangrove plant species of Coringa Wildlife Sanctuary indicates that different insect species act as pollinators there. *Ceriops decandra* is pollinated by bees and wasps, *C. tagal* by flies and honey bees (Raju & Karyamsetty 2008), *Avicennia alba, A. marina*, *A. officinalis* by insects (Raju et al. 2012), *Caesalpinia crista* by bees (Raju & Raju 2014), *Derris trifoliata* by bees (Raju & Kumar 2016a), *Scyphiphora hydrophyllacea* by bees and wind (Solomon Raju & Rajesh 2014), *Suaeda maritima, S. monoica, S. nudiflora* by wind and insects (Raju & Kumar 2016b), *Brownlowia tersa* by carpenter bees and honey bees (Raju 2019a), *Sarcolobus carinatus* by insects (Raju 2019b), *Xylocarpus granatum* and *X. moluccensis* by hawk moths (Raju 2020). In all these plant species, none of the insects have been reported as nectar robbers. Inouye (1983) reported that among insects, bees, wasps and ants are the most common primary nectar robbers of which bees make up the vast majority, and include carpenter bees, bumble bees, stingless bees, and some solitary bees. These bees also act secondary nectar robbers. These bees use their mouthparts to pierce the floral tissues. Bumble bees use their maxillae, proboscis, or toothed mandibles to make holes. Gerling et al. (1989) reported that carpenter bees use their maxillae to make slits in the sides of the flowers. The insects that act as nectar robbers in some plants pay legitimate visits to the flowers of others growing in the same area and act as pollinators.

The aim of the present study was to carry out field studies on legitimate and illegitimate foraging visits to the flowers of a mangrove associate, *Volkameria inermis* L. (Lamiaceae) to collect nectar in Coringa Wildlife Sanctuary, Andhra Pradesh, India.

MATERIALS AND METHODS

The Coringa Wildlife Sanctuary is a wildlife sanctuary and estuary situated near Kakinada (16.716 ^{0}N, 82.245 ^{0}E) in Andhra Pradesh State, India. It is the second largest expanse of mangrove forest ecosystem in India with several viviparous, crypto-viviparous, oviparous mangrove plant species, and also with several mangrove associate plant species. In this sanctuary, *Volkameria inermis* is a mangrove associate that grows well with bushy habit in landward locations. It is a perennial with leaf shedding taking place year-long but this phenological event is quite prominent during summer season (March–May). The flowering occurs during rainy season from August to October but prolific flowering occurs during September. The study was carried out during the flowering season of 2019 and 2020 to observe the foraging activity of flower visitors in the collection of pollen and/or nectar. The flower visitors were observed on five sunny days in each month of the flowering season for their flower approaching, probing and forage collection behaviour. Nectar volume was measured by using a graduated pipette while its sugar concentration was recorded by using a hand sugar refractometer (Erma, Japan); twenty flowers were used for recording these two aspects. For the analysis of sugar types, paper chromatography method described by Harborne (1973) was followed. Nectar was placed on Whatman No. 1 of filter paper along with standard samples of glucose, fructose and sucrose. The paper was run ascendingly for 24 hours with a solvent system of n-butanol-acetone-water (4:5:1), sprayed with aniline oxalate spray reagent and dried at 120 °C in an electric oven for 20 minutes for the development of spots from the nectar and the standard sugars. Then, the sugar types present were recorded.

The foraging activity was observed from sunrise to sunset to record the flower-visiting schedules of individual species. Bee species visiting the flowers were captured and identified by Zoological Survey of India, Howrah. Butterfly species visiting the flowers were identified instantaneously by consulting the book of Kunte (2007). The field methods described in Dafni et al. (2005) and Suvarnaraju & Raju (2014) were followed for the collection of data on foraging visits made, foraging schedule, foraging mode and flower handling time. The number of foraging visits made by each insect species were recorded for 10 minutes at each hour throughout the day from 0600 to 1800 for five days at random in July and August 2019 and again for five days at random in August and September 2020. Based on these visits, the mean number of total foraging visits made per day were calculated. The foraging mode employed for forage collection were also recorded while the insects were probing the flowers. The time spent for probing and collecting the floral reward by each insect species was counted in seconds by using a stop watch; the number of observations made was according to the foraging visits made to the flowers during observation period. Based on the data, the mean time for handling flowers to collect the forage by each insect species was calculated to understand the flower to flower mobility rate. Among the flower visitors, bees were found to exhibit nectar robbing behaviour; this behaviour was carefully observed in the field in order to quantify the number of flowers robbed from the total standing stock of flowers. A sample of 650 flowers from five populations was observed for recording the percentage of unrobbed and robbed flowers. The flower morphological characters were also noted to evaluate their specialized traits that contribute to the exploitation by nectar robbing bees. Further, the observations on the foraging activity of these bees on other plant species growing in the same area were also made to note whether they are resorting to display illegitimate or legitimate foraging behaviour to collect nectar.

RESULTS

Volkameria inermis flowers throughout the year with intense flowering during rainy season from July to September (Image 1a). It produces 3-flowered cymes in leaf axils (Image 1b) which open on the same day (Image 1c) or in 2–3 days, between 1500–1800 h depending on the stage of the bud development. The flowers are pedicellate, large, fragrant, zygomorphic and functionally hermaphroditic. Calyx is green, cup-shaped at base and valvate apically. Corolla is white and tubular with 4–5 lobes separated from each other and reflexed. The stamens are 4 or 5, epipetalous and protrude out of the corolla mouth at flower-opening. The ovary is bicarpellary with 2–4 ovules and extended into a long style tipped with stigma. The flowers initiate nectar secretion soon after flower-opening but its secretion continues until the noontime of the third day. Individual flowers produce 3.6 ± 1.3 µl of nectar with 17 ± 2.13% (sugar concentration made up of three sugar types, sucrose, glucose and fructose, and it is stationed around the ovary which is completely concealed due to tubular corolla.

The floral architecture is highly specialized and the stamens and stigma are exposed far beyond the rim of the corolla tube in synchrony with the unfolding of the petals. A diurnal hawk moth, *Macroglossum gyrans* Walker began visiting the flowers for nectar almost immediately after flower-opening (1530 h) and continued its activity until sunset (1800 h), again started visiting the flowers the next day during dawn hours from 0430 h to 0600 h and stopped its foraging activity thereafter; its foraging activity favors both self- and cross-pollination. The butterflies *Pareronia valeria* Cramer (Image 1d), *Danaus genutia* Cramer (Image 1e), & *Borbo cinnara* Wallace (Image 1f), the digger bee *Anthophora dizona* Engel (Image 2a,b), and the carpenter bee *Xylocopa pubescens* Spinola (Image 2c), visited the flowers regularly during day time (Table 1).

Of these, only butterflies probed the flowers legitimately from the flower-opening side to insert their proboscis to reach the location of nectar; their proboscis length facilitated to access and collect nectar with great ease (Table 1). In bees, *A. dizona* foraged for both pollen and nectar while *X. pubescens* foraged for nectar only. Both bee species rob nectar by making a slit/hole into the corolla tube from outside bypassing the flower front. This nectar robbing behavior indicates that they are primary nectar robbers. *A. dizona* slit the corolla tube tissue nearly at the flower base to rob nectar during which the flower did not bend downwards due to its light body weight. On the contrary, *X. pubescens* made a hole in the middle portion of the corolla tube to rob nectar; the hole is usually at the origin point of the epipetalous stamens which are covered by short hairs. During this activity, the flower hangs downwards

Table 1. List of insect foragers on *Volkameria inermis*.

Order	Family	Insect species	Foraging period	No. of foraging visits/day* (n = 10 days)	Mode of foraging	Forage sought	Flower handling time (in seconds)
Hymenoptera	Apidae	*Xylocopa pubescens** Spinola	08:30–17:00	35 ± 5.3	Illegitimate Primary nectar robber	Nectar	2.8 ± 0.09 (n = 42)
		Anthophora dizona Engel	08:00–17:00	28 ± 4.2	Illegitimate Primary nectar robber	Nectar + pollen	3.2 ± 0.06 (n = 38)
Lepidoptera	Pieridae	*Pareronia valeria* Cramer	09:00–16:30	54 ± 3.4	Legitimate	Nectar	2.5 ± 1.2 (n = 32)
	Nymphalidae	*Danaus genutia* Cramer	09:30–16:00	42 ± 2.5	Legitimate	Nectar	2.1 ± 1.1 (n = 39)
	Hesperiidae	*Borbo cinnara* Wallace	09:00–15:30	32 ± 1.9	Legitimate	Nectar	2.8 ± 1.3 (n = 27)
	Sphingidae	*Macroglossum gyrans* Walker	15:30–18:00; 04:30–06:00	63 ± 6.7	Legitimate	Nectar	2.1 ± 0.04 (n = 46)

No. of flowers under observation: Approximately 150 each day on a different population in each flowering season.
*Collecting nectar legitimately from the flowers of *Acanthus ilicifolius*, *Caesalpinia crista*, *Malachra capitata*, and *Cucumis maderaspatanus*.

due to its heavy body weight. In the standing crop of flowers, the flowers that were not robbed accounted for 61% while the robbed flowers accounted for 39%. *A. dizona* had collected pollen from individual anthers and in doing so they did not discriminate the stigma from the anthers and hence invariably made attempts to collect pollen from the stigma. The inability of this bee to distinguish the anthers from the stigma was considered to be effecting pollination. Butterflies being large in size were able to contact both anthers and stigma with their wings/abdomen and effect self- and cross-pollination while collecting nectar from the flower-opening side on clear sunny days. Flower-handling time (in seconds) for forage collection varied with each insect species (Table 1). *X. pubescens* had collected nectar only legitimately from the flower-opening side from other plant species growing in the same area (Table 1); they include *Acanthus ilicifolius* L. (Acanthaceae) (Image 2d), *Caesalpinia crista* L. (Fabaceae) (Image 2e), *Malachra capitata* (L.) L. (Malvaceae) (Image 2f) and *Cucumis maderaspatanus* L. (Cucurbitaceae) (Image 2g). The flowers of all these species are nectariferous but not specialized and facilitated legitimate foraging behaviour by all insects that seek nectar.

DISCUSSION

Specialized flowers are vulnerable to exploitation by other flower visitors (Mainero & del Rio 1985) by removing nectar without pollinating (Navarro 2001). Nectar robbing takes place in nectariferous flowers with morphological restrictions for illegitimate foragers but nectar robbing foragers overcome these restrictions with their behavioural and physical capacity to rob indicating that this nectar robbing activity is an outcome of the ability of some flower foragers to rob nectar without effecting pollination (Inouye 1980; Maloof & Inouye 2000). However, the flower foragers that act as nectar robbers pay legitimate visits and pollinate the flowers of other species growing in the same area indicating that the floral traits of some plants are responsible for triggering this behaviour in some flower foragers (Newman & Thomson 2005).

In the present study, it is found that *Volkameria inermis* flowers are highly specialized as they possess long corolla and abundant nectar with moderate sugar concentration containing all the three common sugars and restrict the nectar access to illegitimate foragers. The flowers are morphologically adapted for visits by moths and butterflies which act as legitimate foragers-cum-pollinators while collecting nectar. Since the long corolla tube of the flowers restricts access to nectar for bees, *A. dizona* and *X. pubescens*, they resort to rob nectar by making slit or hole into the corolla tube from outside bypassing the flower front. Both bee species act as primary robbers as they do not acquire nectar from the slit/hole made by the other bee. Further, the place where each bee species makes slit on the corolla tube is different. *A. dizona* slits at the base of the corolla tube while *X. pubescens* at the middle part of the corolla tube; the selection of the place on the corolla tube appears to be related to the physical strength they exert to cause the nectar to flow to the place where the bees make slit. *A. dizona* is relatively small-bodied when compared to *X. pubescens*; the landing of the former on the corolla

Image 1. *Volkameria inermis* and butterflies visiting its flowers: a—Plant in flowering phase | b—3-flowered cyme in bud stage | c—Simultaneous anthesis of all the three flowers of a cyme | d—Pierid butterfly, *Pareronia valeria* collecting nectar | e—Nymphalid butterfly, *Danaus genutia* collecting nectar | f—Hesperiid butterfly, *Borbo cinnara* collecting nectar. © A.J. Solomon Raju.

Image 2. Bees visiting *Volkameria inermis* and other plants: a—*Anthophora dizona* collecting nectar by puncturing the corolla tube (primary nectar robber) | b—*Anthophora dizona* collecting pollen | c—*Xylocopa pubescens* collecting nectar by puncturing corolla tube (primary nectar robber) | d–g: *Xylocopa pubescens* collecting nectar – legitimate pollinator: d—*Acanthus ilicifolius* | e—*Caesalpinia crista* | f—*Malachra capitate* | g—*Cucumis maderaspatanus*. © A.J. Solomon Raju.

tube does not change the orientation of the latter to cause the nectar to flow downwards for its collection while that of the latter changes the orientation of the corolla tube causing the nectar to flow downwards which is then easy for its collection. Since *A. dizona* is unable to bring down the corolla tube by landing, it is compelled to move to the flower base to make a slit to rob nectar. On the contrary, *X. pubescens* is able to bring down the corolla tube considerably by landing due to which there is a rapid flow of nectar from the flower base to the point where slit is made by it. These findings agree with Inouye (1980) and Maloof & Inouye (2000) who stated that the nectar robbing foragers overcome the morphological restrictions imposed by nectariferous flowers for illegitimate foragers by changing their legitimate flower foraging behaviour and by using their physical capacity. Further, *X. pubescens* is using certain other plant species located in the same area, *Acanthus ilicifolius*, *Caesalpinia crista*, *Malachra capitata* and *Cucumis maderaspatanus* as nectar sources by probing the flowers legitimately. Such a flower-probing behaviour displayed by *X. pubescens* indicates that it has the ability to use physical capacity and employ legitimate and illegitimate foraging behaviours to exploit the standing crop of nectar from different nectariferous flowers with different floral morphologies for its survival.

Newman & Thomson (2005) reported that the pollinators may need to increase the number of flowers they visit to meet their daily metabolic requirements if they visit the nectar-robbed flowers in which there is usually a reduction in nectar volume. Maloof & Inouye (2000) and Irwin et al. (2001) reported that changes in pollinator behaviour due to nectar robbing may have positive, negative and neutral effects on plant fitness through change in seed set rates. The present study finds that nectar robbing by bees reduces nectar reward and increases variability in nectar standing crop which in turn may make the pollinating butterflies to increase the number of foraging visits and shuttle between populations of *V. inermis* frequently. Further study is needed to evaluate the effect of primary nectar robbing by bees on pollination rate, genetic variation and plant fitness in *V. inermis*.

CONCLUSIONS

In *Volkameria inermis*, the pollinators are butterflies and diurnal moths. However, bees, *Anthophora dizona* and *Xylocopa pubescens* act as primary nectar robbers. *A. dizona* is also a pollen gatherer and its attempts to probe the stigma for pollen results in pollination. Nectar robbing by bees reduces nectar volume in robbed flowers and at the same time brings about variability in the standing crop of nectar. As a result, the pollinating butterflies increase the number of nectar foraging visits and shuttle between populations of *V. inermis* in quest of more nectar to meet their daily metabolic requirements. Such a foraging behavior may promote pollination rate in *V. inermis*. Further study is recommended to evaluate the effect of nectar robbing by bees on the reproductive success and plant fitness in *V. inermis*.

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COMMUNICATION

Contribution to the moss flora of northern Sikkim, India

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Abstract: Study of species composition and community structure is an essential requirement for maintaining the ecosystem functions, conservation, and sustainable use. Bryophytes are integral components of biodiversity and resilient during perturbation. The present investigation was, therefore, a survey in North Sikkim district (India) to study the diversity and distribution of mosses resulting in a total of 113 species in 74 genera and 28 families as new records to the study area. Of these, 14 species are considered rare based on their frequency of occurrence. The family Meteoriaceae which consists of mainly epiphytic taxa is found to be dominant and widely spread in the study area followed by Pottiaceae, Leucobryaceae, and Dicranaceae families. Sixteen species are found to be remarkable in contributing major biomass to the forest floors and as epiphytes. Five species are recorded to be endemic to this area. Most of the epiphytic species are found to be abundant in the area, indicating the good health of ecosystem. The data would be useful in the planning of conservation and management of biodiversity.

Keywords: Biodiversity, Bryophyta, ecosystem, endemicity, *Hylocomium himalayanum*, Meteoriaceae, northeastern India.

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Author contributions: HY and AD studied the detailed morphological characters for the identification and also prepared the herbarium of the samples. PLU surveyed the area and made the collection the of plant material and established the identity of the specimens.

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INTRODUCTION

Ecosystem functioning and stability is dependent on the richness of biodiversity (Noble & Dirzo 1997). Forest composition, species richness, diversity pattern, and spatial or temporal distribution are important ecological attributes significantly correlated with prevailing environmental as well as anthropogenic variables (Gairola et al. 2014). Bryophytes are abundant in some ecosystems and play an important role in providing resilience to environmental changes (Muscolo et al. 2014). Understanding species diversity and distribution patterns is crucial for evaluating the roles of plant groups in the ecosystem at a micro-level. Regular surveys for species occurrence are required for developing models for biodiversity management and ecological restoration. Variations in species composition cover at spatial and temporal scales reflect the heterogeneity of the environmental conditions (Whitmore 1984), which is the basis for the complexity and diversity of any ecosystem. Climatic conditions and developmental activities have led to an unusual loss of biodiversity and ecosystem services (Dierick & Hölscher 2009).

Bryophytes also play an important role in nutrient cycling, water retention, succession, and providing microhabitat for many plants and animals. Despite their small size, they comprise major components of biomass and photosynthetic production. The gap dynamics in the forest is influenced by the bryophyte diversity and micro- communities (Levin 1992; Kimmerer & Young 1996). Bryophyte diversity also adds to the aesthetic value and integrity of the environment. They are considered as bioindicators of air and water quality and can be used in developing an "Index of Atmospheric Purity" (IAP) (Larsen 2007). In recent years, bryophytes have been widely used for bioremediation and pollution monitoring as well as in molecular biology studies. The factors controlling the distribution of species and population dynamic of bryophytes is unfortunately poorly understood. Such studies can provide a model for the management of biodiversity.

Sikkim is situated within the Himalaya Biodiversity Hotspot and is rich in affluent flora and fauna diversity (Rahman 2012). It harbours tremendous biodiversity, though it just covers 0.2% of the geographical area of India. Currently, many species are subjected to various threats, including the biological, natural, and anthropogenic activities, which limit the regeneration of species. These concerns should be addressed with strategic methods.

Pradhan & Badola (2008) reported the use of *Sphagnum squarrosum* (peat moss) in dressing and bandaging cuts and wounds and as an important resource for fuel in the Dzongu Valley of Sikkim. Singh & Singh (2013) studied the liverworts of a part of Sikkim. Gangulee (1969–80) described the mosses of a few areas in Sikkim. The area of northern Sikkim is unexplored in terms of bryodiversity assessment and is home to many endemic and monotypic taxa. We wanted to check the influence of moss diversity on the community composition of the area. The present study is, therefore, planned to document the mosses of the North Sikkim district.

Area of Study

Sikkim State (27°31'58.699"N & 88°30'43.985"E) is located on the northeastern side of India bordered by Bhutan, Tibet, and Nepal. It has an altitudinal range varying from 300–4,000 m, representing tropical, temperate, sub-tropical, and alpine regions, and a small portion of cold desert. Approximately 80% of its geographical area is under forest cover (Sikkim Biodiversity Action Plan 2012). Present surveys were made in the North Sikkim District, especially in Lachung-Yumthang Valley and Lachen-Thangu Valley (Figure 1).

Lachung and Yumthang (27°49'33.3336''N & 88°41'44.9916''E) is a mountain valley situated at an altitude of 2,900 m. The valley is filled with temperate vegetation, especially Rhododendrons and conifers, and is rich in myriad waterfalls and streams which maintain the moisture in the valley. The Lachen and Thangu (27°43'59.99"N & 88°32'59.99"E and 27°53'31.94"N & 88°32'11.33"E) valley is situated at an altitude of 2,750 m, consisting of Rhododendrons, conifers, and alpine vegetation.

MATERIALS AND METHODS

During March 2013, mosses were collected from various areas of the North Sikkim District, particularly the Lachung-Yumthang and Lachen-Thangu Vallies. The moss patches were peeled off with a knife and collected in small polythene bags. To keep the sample pure, each population was kept separate. The moss samples were air-dried and some related data such as date of collection, locality, and habitat along with the substratum type were marked on the packets. Voucher specimens are deposited in the herbarium of Department of Botany, University of Delhi (DUH), Delhi (India). For identification of the samples, the dried materials were soaked in water for a few minutes. Morphologically, different speciemens

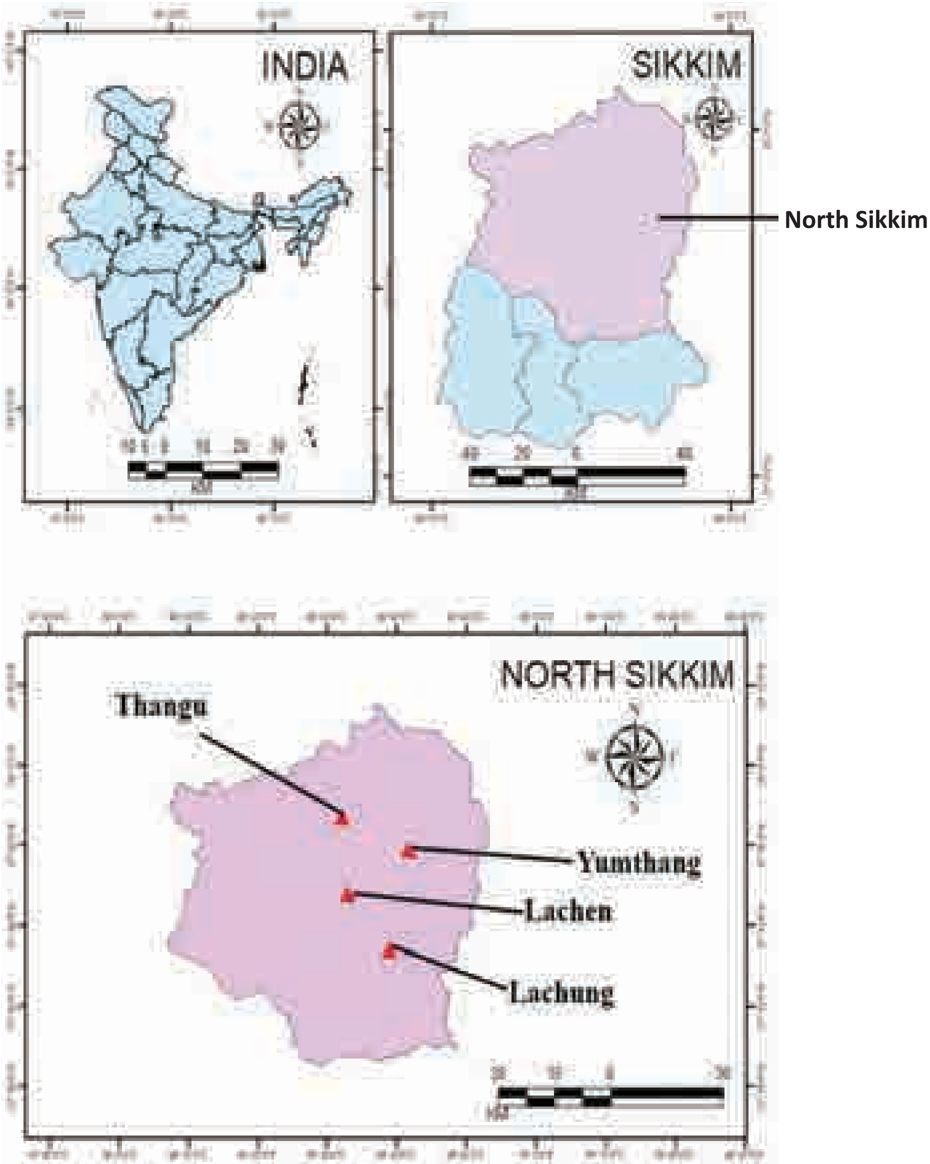

Figure 1. Map showing the study area.

were separated on the basis of microscopic observations. Different parts of each sample were observed under the microscope and identified with the help of various Floras (Gangulee 1969 – 1980; Chopra 1975; Flora of North America Editorial Committee 2007; Flora of China 2008; Koponen & Sun 2017).

RESULTS AND DISCUSSION

The study is based on the species diversity of mosses recorded during the survey undertaken in various sites of North Sikkim District. The present study reveals 113 species of mosses belonging to 74 genera and 28 families (Table 1).

Most frequently encountered species in the study area were *Brachythecium kamounense*, *Rhynchostegiella humillima*, *Ptychostomum capillare*, *Bryum cellulare*, *Campylopus richardii*, *Dicranum scoparium*, *Entodon nepalensis*, *Hylocomium himalayanum*, *Hypnum sikkimense*, *Barbella pendula*, *Floribundaria sparsa*, *Trachypodopsis serrulata*, *Pogonatum microstomum*, *Barbula angustifolia*, *Hyophila rosea*, and *Thuidium sparsifolium*. Few investigated sites act as refugia for native bryophyte species. These sites provide specific microhabitat and should be protected from any disturbance. Some of the photographs of mosses are presented in Image 1 and Image 2. Present study

Table 1. List of recorded species of mosses, with their habitat and growth form. Families are arranged according to Shaw et al. (2009).

	Taxa	Growth form and habitat
Polytrichaceae		
1	*Atrichum obtusulum* (Müll. Hal.) A. Jaeger ++	Turf, shaded soil
2	*Atrichum subserratum* (Harv. & Hook. f.) Mitt.	Turf, exposed soil
3	*Pogonatum fuscatum* Mitt.	Turf, exposed soil
4	*Pogonatum microstomum* (R. Br. ex Schwägr.) Brid.	Turf, exposed soil
5	*Pogonatum neesii* (Müll. Hal.) Dozy	Turf, shaded Soil
6	*Pogonatum urnigerum* (Hedw.) P. Beauv.	Turf, shaded soil
7	*Polytrichastrum formosum* (Hedw.) G.L. Sm. +	Turf, shaded soil
Fissidentaceae		
8	*Fissidens geppii* M. Fleisch.	Turf, termite mound
9	*Fissidens grandifrons* Brid.	Turf, rocks in streams
Bruchiaceae		
10	*Trematodon conformis* Mitt.	Tall turf, shaded soil
Rhabdoweisiaceae		
11	*Oncophorus virens* (Hedw.) Brid. +	Turf, wet rocks
12	*Oncophorus wahlenbergii* Brid. +	Turf, wet rocks
13	*Oreoweisia laxifolia* (Hook. f.) Kindb.	Turf, shaded rocks
14	*Symblepharis reinwardtii* (Dozy & Molk.) Mitt.	Turf, shaded rocks
15	*Symblepharis vaginata* (Hook. ex Harv.) Wijk & Margad.	Turf, shaded rocks
Dicranaceae		
16	*Ceratodon stenocarpus* Bruch & Schimp.	Turf, exposed rocks
17	*Cynodontium polycarpum* (Hedw.) Schimp. +	Turf, wet rocks
18	*Dicranoloma subreflexifolium* (Müll. Hal.) Paris	Tall Turf, shaded rocks
19	*Dicranum assamicum* Dixon	Tall Turf, shaded rocks
20	*Dicranum crispifolium* Müll. Hal.	Tall Turf, shaded rocks
21	*Dicranum himalayanum* Mitt.	Tall Turf, tree base
22	*Dicranum scoparium* Hedw. ++	Tall Turf, exposed rocks
23	*Ditrichum flexicaule* (Schwägr.) Hampe	Turf, exposed rocks
24	*Ditrichum tortipes* (Mitt.) Kuntze	Turf, exposed rocks
Leucobryaceae		
25	*Campylopus ericoides* (Griff.) A. Jaeger	Tall Turf, rocks
26	*Campylopus fragilis* (Brid.) Bruch & Schimp. ++	Tall Turf, exposed rocks
27	*Campylopus milleri* Renauld & Cardot	Tall Turf, exposed rocks
28	*Campylopus richardii* Brid. ++	Tall Turf, exposed rocks
29	*Campylopus savannarum* (Müll. Hal.) Mitt.	Tall Turf, exposed rocks
30	*Campylopus zollingerianus* (Müll. Hal.) Bosch & Sande Lac.	Tall Turf, exposed rocks
31	*Dicranodontium asperulum* (Mitt.) Broth.	Tall Turf, shaded rocks
32	*Dicranodontium didictyon* (Mitt.) A. Jaeger	Tall Turf, shaded rocks
33	*Ochrobryum kurzianum* Hampe +	Turf, wet rocks
Pottiaceae		
34	*Anoectangium stracheyanum* Mitt.	Turf, wet rocks
35	*Barbula angustifolia* Brid. ++	Short Turf, exposed rocks
36	*Didymodon vinealis* (Brid.) R.H. Zander	Short Turf, exposed rocks
37	*Gymnostomum calcareum* Nees & Hornsch. ++	Cushion, wet rocks
38	*Hydrogonium arcuatum* (Griff.) Wijk & Margad.	Short Turf, wet rocks
39	*Hydrogonium pseudoehrenbergii* (M. Fleisch.) P.C. Chen	Turf, wet rocks
40	*Hymenostomum edentulum* (Mitt.) Besch. ++	Cushion, wet rocks
41	*Hymenostylium recurvirostrum* (Hedw.) Dixon ++	Cushion, exposed rocks
42	*Hyophila rosea* R.S. Williams ++	Turf, exposed rocks
43	*Syntrichia princeps* (De Not.) Mitt.	Turf, exposed rocks
Bryaceae		
44	*Brachymenium longicolle* Thér.	Turf, shaded rocks
45	*Bryum bessonii* Renauld & Cardot	Turf, tree branches
46	*Bryum cellulare* Hook. ++	Turf, shaded rocks
47	*Bryum recurvulum* Mitt.	Turf, shaded rocks
48	*Bryum badhwarii* Ochi	Turf, soil
49	*Ptychostomum capillare* (Hedw.) D.T. Holyoak & N. Pedersen ++	Turf, tree branches
Mniaceae		
50	*Epipterygium tozeri* (Grev.) Lindb.	Turf, tree branches
51	*Mielichhoferia assamica* Dixon	Turf, rocks
52	*Plagiomnium confertidens* (Lindb. & Arnell) T.J. Kop.	Mat, wet rocks
53	*Plagiomnium cuspidatum* (Hedw.) T.J. Kop.	Mat, wet soil
54	*Plagiomnium drummondii* (Bruch & Schimp.) T.J. Kop.	Mat, wet soil
55	*Plagiomnium japonicum* (Lindb.) T.J. Kop.	Mat, wet rocks
56	*Plagiomnium medium* (Bruch & Schimp.) T.J. Kop.	Mat, tree branches
57	*Pseudobryum cinclidioides* (Huebener) T.J. Kop.	Mat, tree bases
Climaciaceae		
58	*Climacium americanum* Brid. +	Dendroid, tree base
Amblystegiaceae		
59	*Amblystegium serpens* (Hedw.) Schimp.	Mat, aquatic
60	*Hygrohypnum choprae* Vohra	Mat, aquatic
Helodiaceae		
61	*Actinothuidium hookeri* (Mitt.) Broth.	Mat, wet rocks
Thuidiaceae		
62	*Pelekium velatum* Mitt.	Mat, moist rocks
63	*Thuidium glaucinum* (Mitt.) Bosch & Sande Lac.	Weft, forest floor
64	*Thuidium pristocalyx* (Müll. Hal.) A. Jaeger	Weft, forest floor
65	*Thuidium recognitum* (Hedw.) Lindb.	Weft, shaded rocks

	Taxa	Growth form and habitat
66	*Thuidium sparsifolium* (Mitt.) A. Jaeger	Weft, shaded rocks
Brachytheciaceae		
67	*Brachythecium kamounense* (Harv.) A. Jaeger +	Mat, exposed rocks
68	*Brachythecium longicuspidatum* (Mitt.) A. Jaeger	Mat, exposed rocks
69	*Bryhnia decurvans* (Mitt.) Dixon +	Mat, shaded rocks
70	*Homalothecium nilgheriense* (Mont.) H. Rob.	Mat, tree bark
71	*Oxyrrhynchium vagans* (A. Jaeger) Ignatov & Huttunen +	Mat, wet rocks
72	*Rhynchostegiella divaricatifolia* (Renauld & Cardot) Broth.	Mat, wet rocks
73	*Rhynchostegiella humillima* (Mitt.) Broth. ++	Mat, wet rocks
74	*Rhynchostegiella menadensis* (Sande Lac.) E.B. Bartram	Mat, wet rocks
Meteoriaceae		
75	*Aerobryidium filamentosum* (Hook.) M. Fleisch.	Pendent, tree branches
76	*Barbella convolvens* (Mitt.) Broth.	Pendent, tree branches
77	*Barbella pendula* (Sull.) M. Fleisch. ++	Pendent, tree branches
78	*Barbella spiculata* (Mitt.) Broth.	Pendent, tree branches
79	*Chrysocladium flammeum* (Mitt.) M. Fleisch.	Mat, tree branches
80	*Diaphanodon blandus* (Harv.) Renauld & Cardot	Mat, tree bark
81	*Floribundaria sparsa* (Mitt.) Broth.	Pendent, tree branches
82	*Meteorium polytrichum* Dozy & Molk. ++	Pendent, tree branches
83	*Pseudospiridentopsis horrida* (Mitt. ex Cardot) M. Fleisch.	Mat, tree bark
84	*Trachypodopsis auriculata* (Mitt.) M. Fleisch.	Pendent, tree bark
85	*Trachypodopsis serrulata* (P. Beauv.) M. Fleisch. ++	Pendent, tree branches
86	*Trachypodopsis himantophylla* (Müll. Hal. ex Renauld & Cardot) M. Fleisch.	Creeping and Pendent, tree trunk and branches
87	*Trachypus bicolor* Reinw. & Hornsch.	Creeping, tree trunk and branches
Fabroniaceae		
88	*Levierella neckeroides* (Griff.) O'Shea & Matcham	Mat, fallen logs
Hypnaceae		
89	*Ectropothecium dealbatum* (Reinw. & Hornsch.) A. Jaeger	Mat, shaded forest floor
90	*Hypnum macrogynum* Besch. ++	Mat, shaded soil and rocks
91	*Hypnum sikkimense* Ando	Mat, shaded soil
Hylocomiaceae		
92	*Hylocomium himalayanum* (Mitt.) A. Jaeger ++	Feather, forest floor
93	*Macrothamnium leptohymenioides* Nog.	Weft, forest floor
94	*Meteoriella soluta* (Mitt.) S. Okamura	Pendent, tree branches
Rhytidiaceae		
95	*Rhytidium rugosum* (Ehrh. ex Hedw.) Kindb.	Mat, forest floor
Symphyodontaceae		
96	*Chaetomitriopsis glaucocarpa* (Reinw. ex Schwägr.) M. Fleisch.	Mat, tree
Plagiotheciaceae		
97	*Plagiothecium neckeroideum* Schimp.	Mat, tree base
98	*Plagiothecium nemorale* (Mitt.) A. Jaeger	Mat, tree base
Entodontaceae		
99	*Entodon luteonitens* Renauld & Cardot	Turf, exposed rocks
100	*Entodon nepalensis* Mizush. ++	Mat, fallen logs
Pylaisiadelphaceae		
101	*Brotherella pallida* (Renauld & Cardot) M. Fleisch.	Mat, wet rocks
102	*Pylaisiadelpha capillacea* (Griff.) B.C. Tan & Y. Jia	Mat, forest floor
103	*Taxithelium nepalense* (Schwägr.) Broth.	Mat, rocks
Sematophyllaceae		
104	*Meiothecium jagorii* (Müll. Hal.) Broth.	Mat, fallen wood
105	*Sematophyllum humile* (Mitt.) Broth.	Mat, tree branches
106	*Sematophyllum phoeniceum* (Müll. Hal.) M. Fleisch.	Mat, tree bark
Pterobryaceae		
107	*Symphysodontella subulata* Broth.	Mat, wet rocks
Neckeraceae		
108	*Dixonia orientalis* (Mitt.) H. Akiy. & Tsubota +	Mat, wet rocks
109	*Macrocoma tenuis* (Müll. Hal.) Vitt	Turf, tree branches
110	*Thamnobryum macrocarpum* (Brid.) Gangulee	Feather, wet rocks
111	*Zygodon brevisetus* Wilson ex Mitt. +	Turf, tree branches
Myuriaceae		
112	*Myurium rufescens* (Reinw. & Hornsch.) M. Fleisch. +	Mat, wood pieces
Anomodontaceae		
113	*Anomodon acutifolius* Mitt.	Tail, tree trunk

+—Rare | ++—Widely distributed.

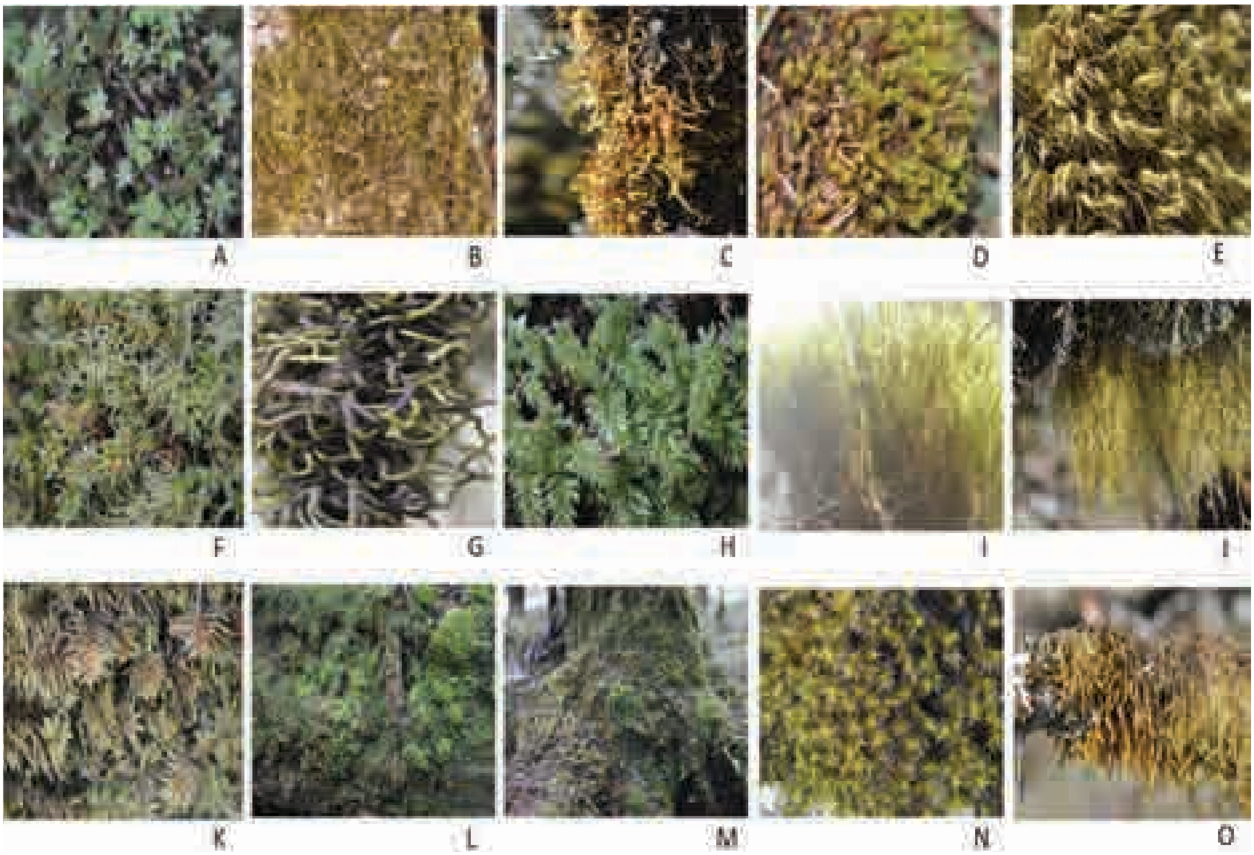

Image 1. The habitat of different bryophytes: A—*Atrichum subserratum* | B—*Diaphanodon blandus* | C—*Pseudospiridentopsis horrida* | D—*Syntrichia princeps* | E—*Dicranum crispifolium* | F—*Rhytidium rugosum* | G—*Meteorium Polytrichum* | H—*Pseudobryum cinclioides* | I—*Dicranoloma subreflexifolium* | J—*Barbella pendula* | K—*Hylocomium himalayanum* | L—*Hymenostomum edentulum* | M—*Barbula angustifolia* | N—*Oreoweisia laxifolia* | O—*Aerobryidium filamentosum*. © Prem Lal Uniyal.

highlights the relationship between variability of habitat and the species diversity, which can be used as a model. These species are recorded from more than five distant locations of the study area found on variety of substrata. Seventeen species are of frequent occurrence which appear to be highly tolerant and possess adaptability and high regeneration potential. Epiphytic species were found in abundance and their occurrence in large number indicate congenial environment provided by associated vegetation. Species richness in the communities was found to be considerably higher. The family Meteoriaceae was found to be the most prevalent with the highest diversity and species richness in the study area, with 13 species, followed by Pottiaceae with 10 species, and Leucobryaceae and Dicranaceae with nine species each. Meteoriaceae was found on tree bark and hanging from tree branches. Members of these families are ecologically important as they retain large amounts of water. The wide occurrence of these families is due to their habitat adaptation and favourable environmental conditions. Diverse tree and shrub species play a major role in the wide occurrence of epiphytic mosses.

A few species such as *Hygrohypnum choprae*, *Oxyrrhynchium vagans*, *Climacium americanum*, *Ochrobryum kurzianum, Chaetomitriopsis glaucocarpa*, *Myurium rufescens*, *Dixonia orientalis*, *Polytrichastrum formosum*, *Oncophorus virens*, and *Oncophorus wahlenbergii* are found only in very few locations (only one or two samples) and considered to be rare and highly specific to the habitats in the study area. Acrocarpous mosses are generally considered as more drought tolerant than pleurocarpous taxa. Most of the taxa are found growing on exposed sites with hard substrata like stones and rocks. *Bryum cellulare* and *Hyophila rosea* are observed to be common invader of every type of substrate such as rocks, cement floor, bricks, mortar, small rocks, and boulders. They are presumed to be highly tolerant to drought, disturbance, pollution etc. They have a high reproductive potential and found with capsules as well as gemmae. However, many of the taxa are found in sterile conditions which indicate their reproduction by vegetative means only.

Image 1. Some identified bryophyte taxa: A—*Anomodon acutifolius* | B—*Taxithelium nepalense* | C—*Thuidium recognitum* | D—*Polytrichum formusum*,E—*Barbella spiculata* | F—*Pelekium velatum* | G—*Leviereela fabroniacea* | H—*Macrothamnium leptohymenoides* | I—*Hymenostomum edentulum* | J—*Entodon luteonitens* | K—*Rhynchostegiella divariatifolia* | L—*Rhynchostegium pellucidum* | M—*Leucomium decolyi* | N—*Epiterygium tozeri* | O—*Amblystegium serpens* | P—*Homalothecium nilgheriense* | Q—*Thamnobryum macrocarpum* | R—*Hydrogonium pseudoehrenbergii* | S—*Syntrichia princeps* | T—*Anoectangium stacheyanum* | U—*Brachythecium kamounense* | V—*Hydrogonium arcuatum* | W—*Ditrichum flexicaule* | X—*Macromitrium perrottetii*. © Himani Yadav.

Growing on calcium and magnesium rich substrata, *Brachymenium longicolle*, *Fissidens geppi*, *F. grandifrons*, *Gymnostomum calcareum*, *Hydrogonium arcuatum*, and *H. pseudoehrenbergii* can occupy exposed surfaces of rocks and boulders with no trace of vegetation. Members of Thuidiaceae are widely found and observed under shady conditions, specifically on the thick litter. Turf growth form is considered as dominant in the study area and their distribution can be correlated with local climate. Some green algae are also found to be associated with moss colonies of the collected taxa.

The taxa reported as new from the Sikkim region are: *Barbella spiculata*, *Campylopus milleri*, *Fissidens geppii*, and *Mielichhoferia assamica.* Earlier, they were recorded to be restricted to nearby regions such as Meghalaya and Darjeeling only. Extended distribution of *Barbella spiculata* (Mitt.) Broth., *Campylopus milleri*, *Fissidens geppii*, *Mielichhoferia assamica*, and *Zygodon brevisetus* were also recorded in the area. These species were earlier reported to be endemic to nearby areas of Darjeeling and Meghalaya also.

Most preferred colonization substrates were found to be exposed rocks where the representation was nearly 51% of the recorded taxa. This can be explained by the fact that in the favorable environment the rocky habitat was free of competition and thus available for mosses. Living tree trunks were the second most used substrate occupied by 32% of the recorded taxa. However, the biomass of the mosses on the living trees was found more usually. The tree trunk species followed by decaying trunks are reported as the suitable substrates for bryophytes in tropical forests (Richards 1984).

The study area seems to harbour many new and unique taxa of mosses. Epiphytic species play an important role in protecting the host species by providing continuous moisture and retaining nutrients. Mosses are highly sensitive to the alteration of habitat by recreational activities, which may alter the distribution pattern of the sensitive species of their own kind and cause a decrease in their population size, which consequently may alter the species composition of the associated invertebrate fauna. Also, there is a need to explore and identify the moss species of the concerned contrasting sites to prepare a database. A comprehensive report of the species composition and their role in the functions of the ecosystem and, subsequently, for the conservation of these species together with their habitats is also required. Sikkim is typified by its richness, high diversity, and endemic species of plants (Singh et al. 2008; Singh & Pusalkar 2020). The high richness of species marks the area as a gene bank for many plant species.

Plant species composition is considered as a marker of ecosystem health and the existence of various ecological factors influences species diversity (Sefidkon et al. 2005). The present study area shows diverse topographic features and microhabitats, which has a great potential for prospering with a rich biodiversity. The use of such natural diversity can be related to the interaction among the species. Most of the habitats of the sites were covered during the present study, and species composition was variable in different aspects.

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SHORT COMMUNICATION

Firefly survey: adopting citizen science approach to record the status of flashing beetles

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Abstract: Fireflies are magnificent beetles, under the family Lampyridae (order Coleoptera). They form an exceptional part of a natural landscape. However, natural firefly populations are threatened by several stressors, predominantly driven by anthropogenic development. Evaluation of firefly abundance through counts of their flashes provides an insight into the good health of the ecosystem, which could be easily observed and recorded by citizen scientists. On the occasion of World Firefly Day (3–4 July 2021), a firefly counting survey was conducted to record their occurrence, by engaging people from all over India, using the online platform. A datasheet with appropriate questions was prepared; barcodes and links were generated for the people. Through the survey, we received suitable participation and fitting data from 14 states of India—Uttar Pradesh, Uttarakhand, Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, West Bengal, Assam, and Ladakh. The total number of fireflies that were observed from all these states together was more than 26,000. Through the present study, significant data on fireflies occurrence have been recorded from various parts of the country. In addition to this, we get an understanding of using this citizen science approach on a bigger spectrum for varieties of projects and an effortless system of educating people.

Keywords: Anthropogenic development, beetles, bioindicators, bioluminescence, citizen scientists, ecosystem, Lampyridae, watch, World Firefly Day.

Citizen science is an approach of engaging non-technical people in gathering information, used by scientists to investigate research problems (Bonney et al. 2009). With this method of data collection, immense information could be gathered, and this could lead to a larger database (Trumbull et al. 2000).

Fireflies are known for showcasing the astonishing property of bioluminescence. The encounter with these charismatic beetles, left behind beautiful memories in people of all ages (Ho et al. 2009). Many people show interest and curiosity to know about their bioluminescent phenomena. There are several citizen science projects on fireflies in the USA, which worked successfully (Chow et al. 2014). Scientists have used this approach for the evaluation of many insects population around the world. But in India, we still lack these kinds of practices. There are more than 2,000 species of fireflies all over the world (Lewis 2016). They provide conspecific light signals for mating and predation (Lewis & Crastely 2008), and being holometabolous their life cycle completes in four different life stages namely- egg, larva, pupa, and

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adult. Unlike adults, the larva is a well-known predator of our garden pests like snails and slugs, and other small invertebrates, hence work as biocontrol agent and maintain the health of an ecosystem (Bogahawatta 2009). Other than this, fireflies are considered a flagship species, their conservation can also lead to the conservation of other flora and fauna sharing the same habitat (Fallon et al. 2019).

However, their population is declining (Lewis et al. 2020). Recently, 18 species of fireflies were characterized as threatened as per IUCN Red list (Fallon et al. 2021). Fireflies are not only important for our ecosystem but also play an appreciable role in boosting the economy (Lewis et al. 2021). As in countries like the USA, Malaysia, Thailand, and Mexico, they have set up firefly parks and sanctuaries for conservation purposes, which provides livelihood to the local people and helps in generating funds (Lewis et al. 2021). Not only in these countries but also in India we have places like Purushwadi, Bhandardara in Ahmednagar district of Maharashtra, where they have camping sites along with firefly trails. However, such practices make fireflies susceptible to numerous tourism-associated threats. But with proper training programs for guides, conserving the much needed habitats, and by local stakeholder involvement, these issues can be resolved (Lewis et al. 2021). Firefly populations are declining over the globe (Lewis et al. 2020; Chatragadda 2020), which attracted our attention and we came up with the citizen science approach as an appropriate tool for conducting the survey. We used the online platform to engage people in the survey. To address the importance of these magnificent beetles the whole world celebrates World Firefly Day on the 3–4 July every year. In 2021, the day was also celebrated in Dehradun (India) with an aim of generating information on fireflies occurrence from different areas of the country.

Material and Methods

The current study was a subset of a larger citizen science approach to assess occurrence reports of fireflies across various areas of the country. For this preliminary assessment an online survey on the occasion of World Firefly Day (3–4 July 2021) was conducted. For the event, a cover page was designed using MS PowerPoint with the theme of the event 'firefly watch' (Image 1). Datasheets (Image 2), two barcodes, and three links were generated using the software (ArcGIS Survey 123). One of the three links was for pinpointing the location in the dashboard so that exact coordinates of the fireflies sighting area could be extracted. Number of relevant questions were also provided for the collection of the database (Image 2). All of these datasheets were circulated two days before the World Firefly Day, through personal contacts and also get uploaded on the website of the Wildlife Institute of India, Dehradun. In India, no study on fireflies has been done involving citizen scientists till date, there are no standardised protocol for doing such observations over the globe. However, a firefly watch project was organized in USA, which was solely based on the questionnaire and does not provide any standardised protocols useful for such citizen science programs. Thus, in this survey the participants were guided to observe the fireflies between 2000 h and 2200 h (peak time of sighting fireflies as per previous observation) around their nearby areas. The organizing team, covered the Kaduapani area of the Asharodi range in Dehradun district, Uttarakhand, India (30.288°N, 77.913°E) to observe the fireflies on the occasion, and in general in a 100-m walk they observed around 500 fireflies flying and flashing making it one of the potential areas to sight fireflies.

Results

The data has been received from more than 71 individual sites from 14 different states of India. The total number of fireflies observed through the survey was more than 26,000 across the country. After analysing the numbers of fireflies from different regions of the country (Image 3), it was concluded that Makhala and Kolkas forest areas of Amravati district (Maharashtra), Kaduapani beat in Asharodi range (Uttarakhand), and Fulkamli village (West Bengal) were the most potential sites where fireflies were sighted in large numbers.

Discussion

Over the world, there are several molecular and taxonomic studies on fireflies (Ballantyne & McLean 1970; Ballantyne et al. 2019). However, in India there is not much attention has been given to these beetles till date, which makes it data deficient, although, there are some studies related to the bioluminescence emission of fireflies from Guwahati (Barua et al. 2007). A study on the declining population of the genus *Abscondita* from Barrankula village of Andhra Pradesh (Chatragadda 2020), and a study discussing the records of two new species of subfamily Luciolinae has been found for the first time in India (Ghosh et al. 2020). But still, these studies are not enough and there is a lot more scope for evaluating firefly diversity and abundance throughout the country. Thus, this study aimed to generate preliminary information regarding their occurrence, across several observing areas from all over the country

Image 1. Cover page for World Firefly Day.

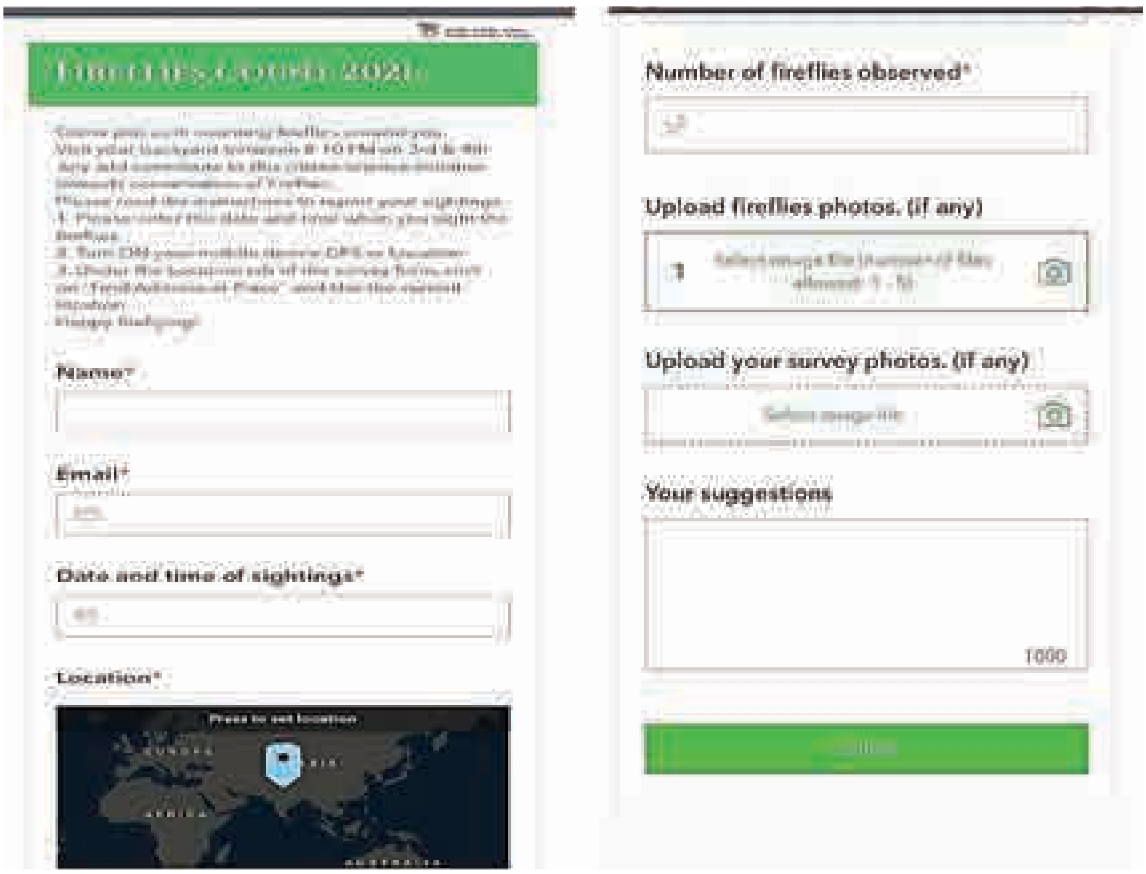

Image 2. Datasheets provided for the survey through online channels.

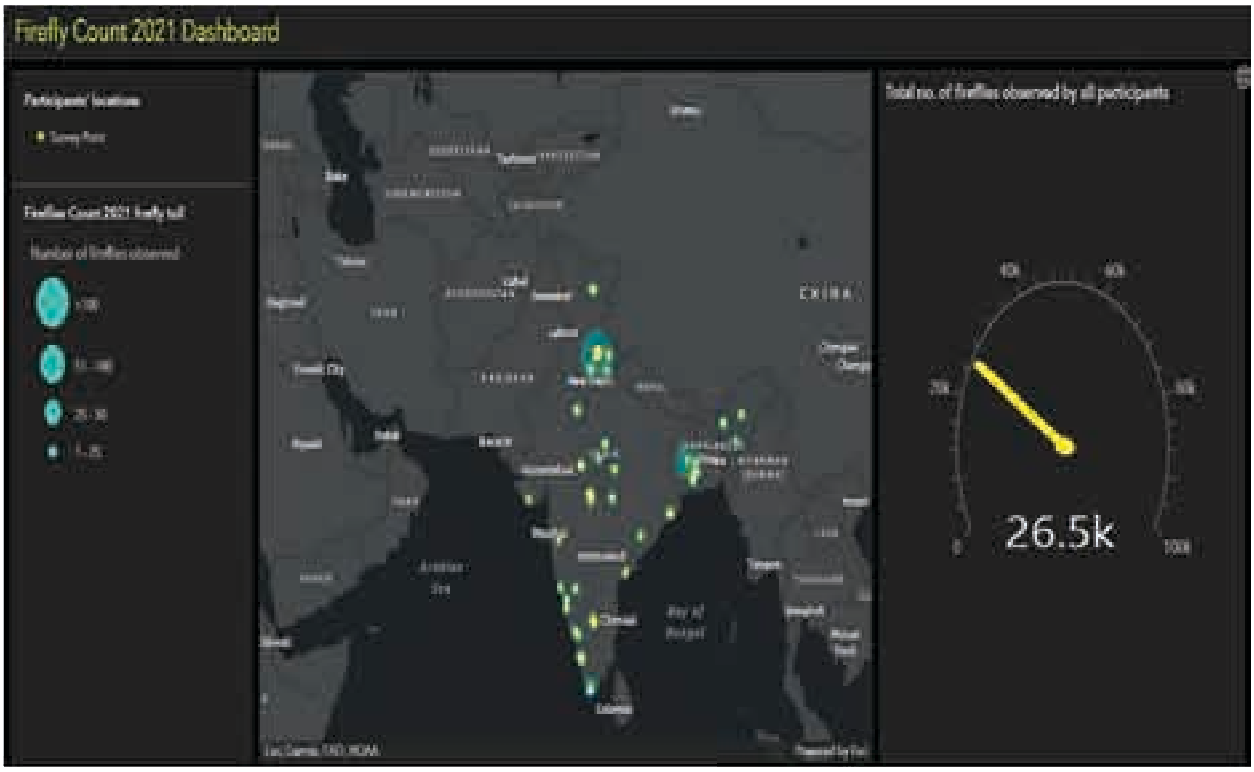

Image 3. Dashboard representing the abundance of fireflies from different surveyed areas.

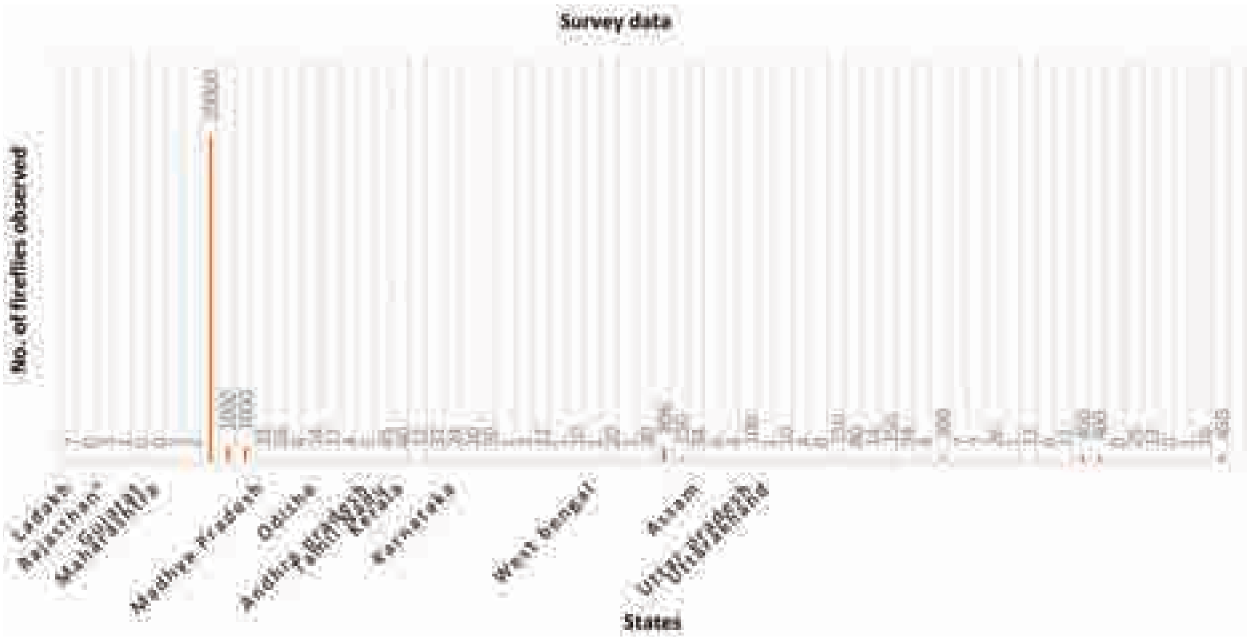

Figure 1. Bar graph representing the number of fireflies observed from different states.

through the citizen science program. But, as we did not receive data from half of the states, further projects and surveys by engaging people from all over the country must be developed to have an estimate of the status of fireflies. The citizen science approach will also help in escalating awareness among people.

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SHORT COMMUNICATION

First report of *Gymnopilus ochraceus* Høil. 1998 (Agaricomycetes: Agaricales: Hymenogastraceae) from India and determination of bioactive components

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Abstract: A rare *Gymnopilus* species *G. ochraceus* Høil. collected from live *Ficus platyphylla* Del. tree is described and illustrated for the first time from India. Morphological and microscopic characters with molecular and biochemical analysis has been discussed. To indicate that, 25 species of *Gymnopilus* have previously been recorded from India and the species *Gymnopilus ochraceus* is hereby reported for the first time, thus making a total of 26 species from India.

Keywords: Biochemical analysis, *Ficus platyphylla,* fungi, microscopic characters, mushroom, taxonomy.

The genus *Gymnopilus* (family Hymenogastraceae) is represented by 200 species in the world (Kirk et al. 2008). Members of the genus are characterized by yellow to brown, ferruginous or purple fruiting bodies, saprotrophic nature, cortinoid to membranous veil and a rusty brown spore print (Kaur et al. 2015). The genus was confirmed by roughened basidiospores that range from verrucose to rugulose; capitate to sub-capitate, ventricose cheilocystidia and clamp connections present on almost all kinds of hyphae (Khan et al. 2017). Shape and size of the spores and cystidia are considered important characters for distinction among the species (Rees et al. 2004). Based on the pigments and the non-mycorrhizal habit, Kühner (1984) classified *Gymnopilus* together with *Galerina* Earle in the Strophariaceae family. Later, Singer (1986) placed it in family Cortinariaceae due to the ornamentation and lack of germinal pore of the basidiospores. Currently, according to the results of phylogenetic analysis, *Gymnopilus* forms an independent clade called "Gymnopilae" which is not related to any of the two families mentioned above by Matheny et al. (2006) and is currently placed in the family Hymenogastraceae (Kirk et al. 2008). 25 species of *Gymnopilus* have been reported from India (Kulkarni 1990; Thomas et al. 2003; Ministry of Environment and Forests 2011; Farook et al. 2013; Kumar et al. 2014; Kaur et al. 2015). Two species of *Gymnopilus* have been described from Maharashtra viz. *G. karnalensis* S.M.Kulk. and *G. chrysopellus* (Berk. & Crutis) Murril (Senthilarasu 2014; Patil 2019).

During the present study, mature fruiting body of *G. ochraceus* were collected on the living tree of *Ficus platyphylla* Del. from Kate Bhogaon, Panhala, Kolhapur district (M.S.), India. Morphological and microscopic analysis have been described in this paper. Analysis of ITS rDNA sequence was done to evaluate phylogenetic relationships and Gas Chromatography–Mass Spectrometry (GC-MS) was done for determination of bioactive components.

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Material and Methods

a) Morphological and microscopic analysis

Morphological and ecological characters were noted in the field. Microscopic observations of fresh fruiting body was done with the help of 1.5% phloxine B staining and Lawrence & Mayo N-300M research microscope.

b) Identification of fungal strains

The identification of isolates was carried out at the sequencing facility of National Centre for Microbial Resource (NCMR), National Centre for Cell Science, Pune. At the facility, genomic DNA was isolated by the standard phenol/chloroform extraction method (Sambrook et al. 1989), followed by PCR amplification of the ITS regions using universal primers ITS1 [5'-TCC GTA GGT GAA CCT GCG G-3'] and ITS4 [5'-TCC TCC GCT TAT TGA TAT GC -3']. The amplified ITS PCR product was purified by PEG-NaCl precipitation and directly sequenced on an ABI® 3730XL automated DNA sequencer (Applied Biosystems, Inc., Foster City, CA) as per manufacturer's instructions. Essentially, sequencing was carried out from both ends so that each position was read at least twice. Assembly was carried out using Lasergene package followed by NCBI BLAST against sequences from type material for tentative identification (Boratyn et al. 2013).

c) GC-MS analysis

10% methanolic extract of dried fruiting bodies was sonicated for 60 minutes at 35°C followed by centrifugation at 10,000 rpm for five minutes. Supernatant was used for GC-MS analysis using Shimadzu, Japan TQ 8050 plus HS 20. Helium was used as the carrier gas at a flow rate of 1ml/min and an injection volume of 1.0 µL. Injector temperature was 250˚C; ion source temperature 250˚C. The oven temperature was 60˚C isothermal for 2.0 min, with an increase of 10˚C/min to 250˚C, then 5˚C/min to 275˚C, ending with 10 min. isothermal at 275˚C. Detector voltage was 0.7ev.

Results and Discussion

Habitat: Growing on live *F. platyphylla* stem in a cluster (Image 1 A–G)

Pileus 2–8 cm wide, convex to plane, scaly, with appressed squamules at the centre, surface pale brown, honey brown, pale ochraceous to pale yellow brown, squamules pale to honey brown; lamellae adnexed to adnate, dark yellow brown; stipe 2–9 x 0.5–1.2 cm, cylindrical to somewhat clavate, fibrillose, concolourous with pileus, with an membranous pale yellow brown ring, context yellowish to pale buff, with bitter taste; Basidiospores (5.5) 5.6–7.1 (7.5) x (4) 4.2–5.3 (5.5) µm, ellipsoid to ovoid, verrucose to punctate, pale to yellow brown, dextrinoid; Basidia 16–26 x 5–6 µm with four sterigmata; Cheilocystidia 15–18 x 4.5–7 µm, ventricose-rostrate with a clavate or rounded apex with 3–3.5 µm broad content; Pleurocystidia not seen; hyphae of pileipellis 6–18 µm broad, smooth, yellow brown, hyaline, clamp connections present (Figure 1 A–D).

GC-MS analysis (Table 1 & Figure 2)

In GC-MS analysis three components are detected viz. 4,4'-Bipyridine, 9,12-Octadecadienoic acid, methyl ester and 9,12-Octadecadienoic acid (Z,Z). Application of 4,4'- 4,4'-bipyridine is a prototypical bridging ligand and an ideal connector between the transition metal atoms (Biradha et al. 2006). Heufler et. al. (1987) stated that 4,4'- bipyridne derivate orellanine causes acute renal failure in man. 9,12-Octadecadienoic acid (Z,Z)- methyl ester is used as fuel and fuel additive. It has potential cancer preventive, anti-inflammatory and anti-arthritic activities (Hagr et al. 2018).

Conclusion

The above described species *G. ochraceus* is reported for the first time from India. It clearly indicates that *G. ochraceus* is extremely rare species. Morphological and microscopic study along with ITS rDNA analysis confirms the species authentication. Many species of *Gymnopilus* are bitter or foul to taste, some are hallucinogenic and edibility of majority is unknown. There are many species and little consensus on identifying them. Microscopically they can be confused with *Pholiota* species and with the

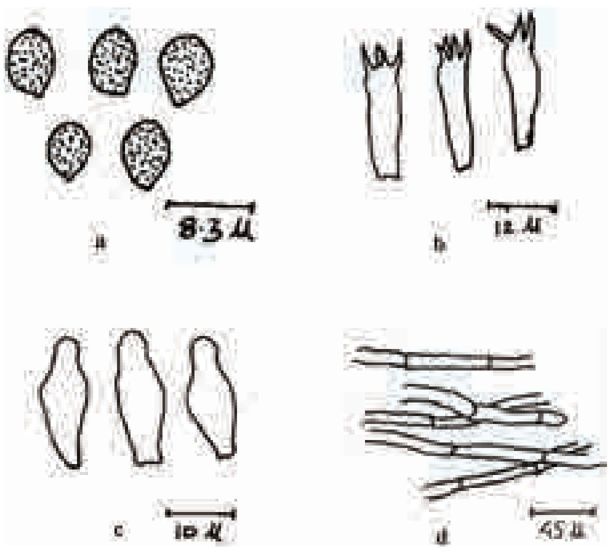

Figure 1. A—Basidiospores | B—Basidia | C—Cheilocystidia | D—Pileipellis hyphae.

Table 1. GC-MS analysis of *Gymnopilus ochraceus.*

Peak#	R.Time	I.Time	F.Time	Molecular formula	Area%	Name
1	16.395	16.070	16.875	C10H8N2	95.47	4,4'-Bipyridine
2	24.655	24.580	24.715	C19H34O2	3.41	9,12-Octadecadienoic acid, methyl ester
3	25.590	25.530	25.605	C19H34O2	1.12	9,12-Octadecadienoic acid (Z,Z)-
					100	

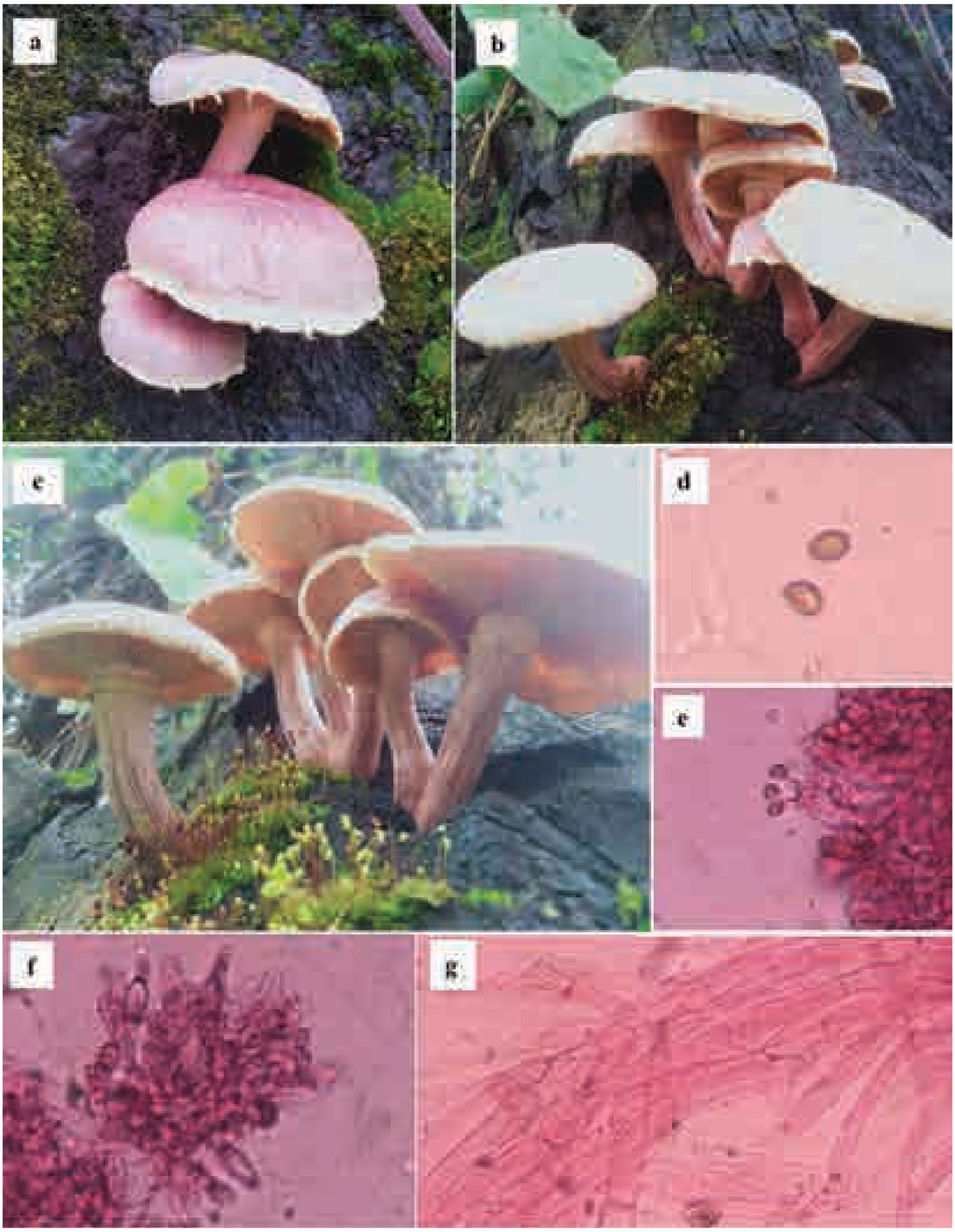

Image 1. *Gymnopilus ochraceus* Høil: A–C—Habit | D—Basidiospores | E—Basidia | F—Cheilocystidia | G—Pileipellis hyphae. © Sushant Ishwar Bornak

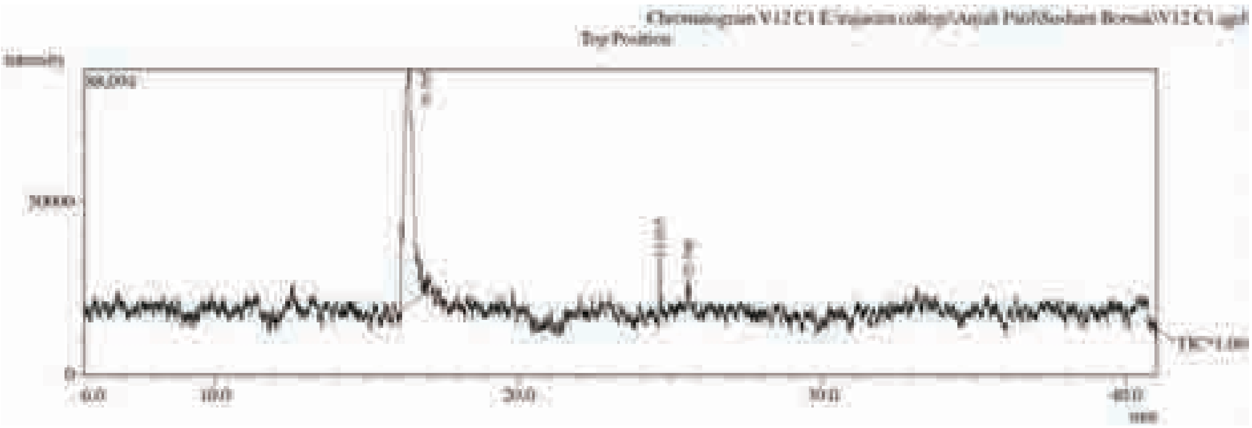

Figure 2. GC-MS chromatogram of *Gymnopilus ochraceus*

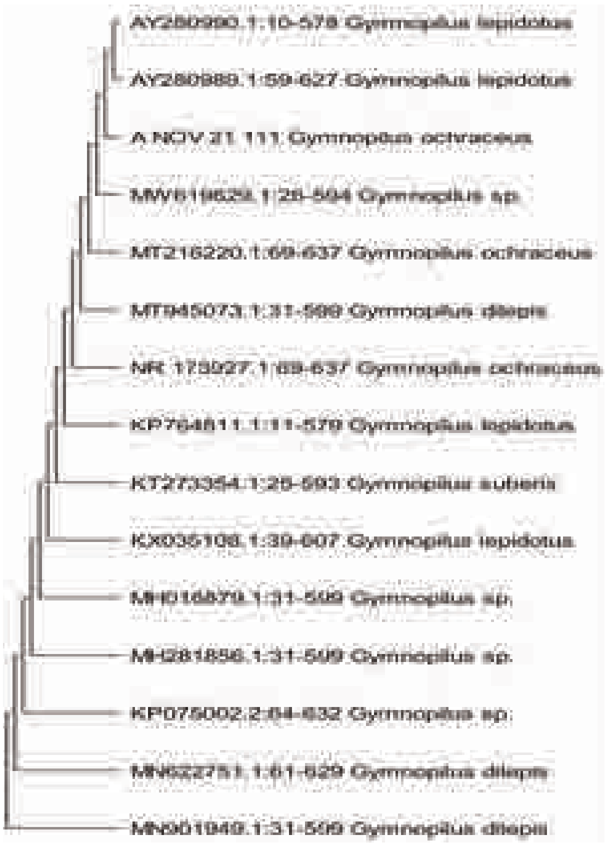

Figure 3. Phylogram of *G. ochraceus* represented by A NOV 21 111

deadly *Galerina marginata* complex. Microscopically, spores of *Gymnopilus* species are finely roughened (warty) and lack an apical pore.

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NOTE

A coastal population of Honey Badger *Mellivora capensis* at Chilika Lagoon in the Indian east coast

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The Honey Badger or Ratel *Mellivora capensis* (family Mustelidae) is the only species in its genus. It is distributed widely all across Africa and southwestern Asia with the easternmost distribution being the Indian subcontinent (Prater 1980; Harrison & Bates 1991; Neal & Cheeseman 1996). It has a very wide habitat tolerance, occurring from sea-level to >2,500 m and from desert steppes to rainforests but prefers drier arid landscapes and avoids regions with very heavy rainfall (Proulx et al. 2016). Its status and distribution in Africa and western Asia are well documented (Proulx et al. 2016). However, it remains one of the least studied small carnivores in India with a majority of occurrences reported from central and western India but barely from the northeastern states (Kumara & Singh 2007; Gupta et al. 2012; Gubbi et al. 2014; Krishnan et al. 2016). Only recently has its presence been documented from the Papikonda National Park situated in the Eastern Ghats (Aditya et al. 2020).

We report the Honey Badger, for the first time, from human-dominated landscapes of the Chilika lagoon, Odisha, roughly 500 km to the north-east of the recent record from the northern Eastern Ghats in the state of Andhra Pradesh (Aditya et al. 2020). There are no previous reports of the Honey Badger from the landscape in literature.

Chilika is Asia's largest brackish water lagoon and one of India's oldest Ramsar sites. It is partially encompassed by the Eastern Ghats in the north, is drained by tributaries of the Mahanadi River in the north-east and is connected to the Bay of Bengal in the south. The lagoon is situated in a human-dominated multi-use landscape. We got three independent reports of Honey Badgers from the northern sector of Chilika (drained by Mahanadi's tributaries and partially encompassed by the Eastern Ghats fringes) and the lower central sector (islands separating Chilika from the Bay of Bengal).

These reports were collected during interview

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Acknowledgements: We thank the villagers residing around Chilika lagoon, without whose documentation, the presence of the Honey Badger in Chilika would have remained unknown. We remain grateful to Mohamed Bin Zayed Species Conservation Fund for supporting our Fishing Cat research and conservation work which resulted in this documentation. We would also like to thank Will Duckworth and Dr. Ajith Kumar for their comments on the manuscript.

Image 1. Locations of Honey Badger sightings in Chilika, India.

Image 2. Dead Honey Badger Mellivora capensis from near Chilika Lake, Mangalajodi, Odisha, India, in November 2019.

Location details of Honey Badger occurrences in Chilika.

Name of village	Latitude	Longitude
Mangalajodi (Northern sector)	19.909°N	85.445°E
Baliabanka (Northern sector)	19.846°N	85.379°E
Titipa (Central sector)	19.625°N	85.327°E

surveys conducted by us to understand Fishing Cat *Prionailurus viverrinus* distribution in Chilika. The Honey Badger at Mangalajodi on November 2019 was found by villagers who upon seeing such an animal that they had never seen before, reportedly beat it to death (Image 2). The Honey Badger in Baliabanka fell into a well in January 2020 and was rescued and released by the fire department. We identified the species from videos that villagers took. The one at Titipa was from June 2018 when a juvenile fell into a dry well but escaped during the night. We confirmed the identity of the species from video records taken by villagers.

In all three cases local villagers could not identify the badger and thought it was a bear (Ursidae), and in one case, a panda *Ailuropoda melanoleuca*. Our findings highlight the need to conduct awareness campaigns on the species among local communities to dissipate fear of the species and promote acceptance and tolerance.

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NOTE

New distribution record of Black Softshell Turtle *Nilssonia nigricans* (Anderson, 1875) from Manas National Park, Assam, India

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Nilssonia is a genus of softshell turtles under the family *Tionychidae* distributed widely in southern Asia including Pakistan, India, Afghanistan, Nepal, Bangladesh, and Myanmar (Rhodin et al. 2021). The Black Softshell Turtle *Nilssonia nigricans* is listed as 'Critically Endangered' and the population is decreasing as per the latest IUCN Red List (Praschag et al. 2021). Back in 2002, the IUCN Red List categorized the *N. nigricans* as 'Extinct in the wild' (IUCN 3.1) - only surviving in restricted temple ponds in Bangladesh and Assam (IUCN Red List 2002). But gradually, individuals started getting reported from the Brahmaputra River Basin in India as well, Meghna River Basin in Bangladesh (Praschag et al. 2021), and Koach Behar of West Bengal (Yasmin et al. 2021). It is also known to be distributed in some isolated sub-populations in several temple ponds of Assam and Tripura (Praschag & Gamel 2002; Ahmed & Das 2010). The presence of *N. nigricans* has been reported from Kaziranga National Park, Nameri Tiger Reserve, and Pakke Tiger Reserve, and may also be distributed in Assam's Kaziranga-Orang Riverine Landscape (KORL) (Ahmed & Das 2010). Little is known about its distribution and much work needs to be done concerning its habitat and ecology. This diurnal large softshell turtle inhabits large rivers and wetlands but its diet in the wild is still unknown, while in the temple ponds, its diet consists of different types of fruit, animal viscera and other substances like puffed rice and bananas (Ahmed et al. 2009).

This species is also observed in wildlife trade as documented from the Brahmaputra River basin (Baruah & Sharma 2010). The targeted exploitation pressure on this species is also known for human consumption but with a small range (Praschag et al. 2021). However, *N. nigricans* is facing extensive local exploitation including sustained and targeted egg collection for local consumption (Ahmed & Das 2010).

During a field visit to the Manas National Park, we came across a large softshell turtle in a stream (Durabeel Nala of Rupahi River) located in the transitional area between woodland and grassland (26.72°N & 91.075°E) (Figure 1). It was sighted at around 1000 h on 02 May 2021. The turtle was identified as a Black Softshell Turtle *N. nigricans* using description and taxonomic keys (Prachag & Gamel 2002; Ahmed et al. 2009). In addition to the characters observed on several live specimens along with the one presented with photographs here: a. High dome carapace grey in colour (Image 2); b. Mid-dorsal carapace concave; c. Distinct groove between the bony carapace and the

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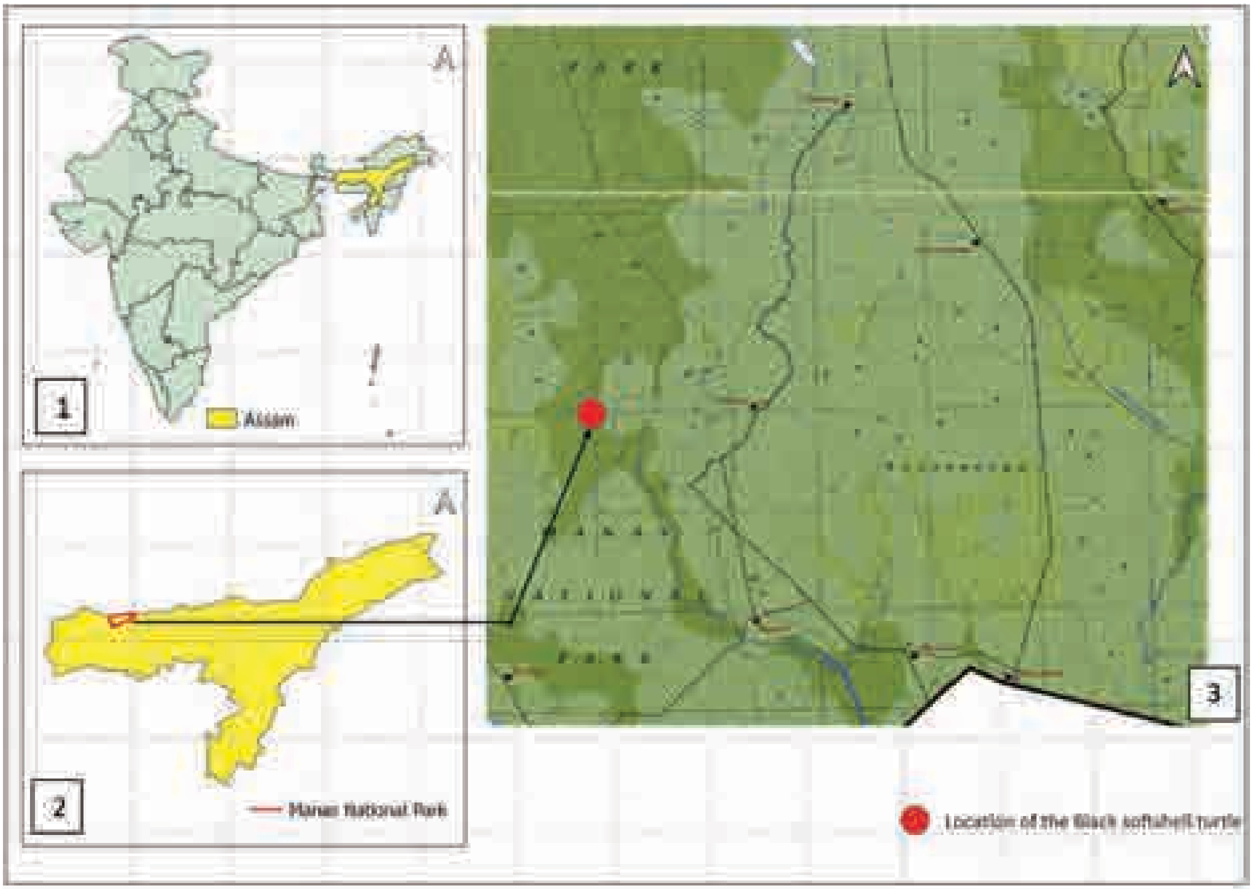

Figure 1. Location of the area where the *Nilssonia nigricans* was sighted in Manas National Park, Assam.

Image 1. Lateral profile of the *Nilssonia nigricans* observed in the Manas National Park, Assam, India. © Gayatri Dutta.

Image 2. The dorsal view of the *Nilssonia nigricans* in a muddy stream from the Manas National Park, Assam, India. © Gayatri Dutta.

cartilaginous flaps; d. a visibly sharp fall of carapace dome to the posterior (in lateral view (Image 1)); and e. Thick and muscular nuchal fold on carapace.

This is the first confirmed distribution record of the *N. nigricans* with an adult individual from the Manas National Park, Assam. Earlier, Ahmed & Das (2010) observed small (app. 4 cm carapace width) young ones in streams originating inside Manas NP which were believed to be juvenile *N. nigricans*. This observation confirms that the species is also found in protected areas other than the PAs mentioned above, increasing its population coverage to more PAs. This also signifies that the species uses more tributaries of the Brahmaputra river to inhibit in addition to the Jia Bhoroli river, that flows by the Nmaeri TR and Pakke TR on the north bank of the Brahmaputra. This occurrence is reported from a stream of the Pahumara River, a tributary of Beki River that drains into the Brahmaputra River in western Assam.

The Manas National Park (26.6594° N, 91.0011° E) is located in the Bodoland Territorial Region (BTR) of Assam in the districts of Baksa and Chirang and spread over an area of 500 km^2 (Das et al. 2014). It is located in the sub-Himalayan landscape of northeastern India, contiguous with the Royal Manas National Park, Bhutan, and forms the core of the Indo-Bhutan Transboundary Manas Conservation Area (TraMCA) that covers app. 6,500 km^2 area (Borah et al. 2013). It falls under the Key Conservation Area- Jigme Dorji-Manas-Bumdaling conservation landscape in the eastern Himalayan ecoregion (Wikramanayake et al. 2001). In and around Manas National Park, the turtles and their habitats are threatened by loss of habitats due to extensive siltation of riverbed (landslide and mining in Bhutan hills), overfishing, and catching of turtles for meat consumption. The population of this species might be affected given the above threats over the last two-to-three decades. Systematic efforts are needed to study and monitor this species to understand the ecology, food habit, and conservation threats associated.

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NOTE

First report of melanism in Indian Flapshell Turtle *Lissemys punctata* (Bonnaterre, 1789) from a turtle trading market of West Bengal, India

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Melanism is excessive production of the dark-colored pigment melanin in the skin or skin appendages either as intraspecific polymorphisms or as fixed differences between closely related species (Chavin 1969; True 2003). The Indian Flapshell Turtle *Lissemys punctata* (Bonnaterre, 1789), is a freshwater softshell turtle species distributed throughout Bangladesh, India, Myanmar, Nepal, and Pakistan (Bhupathy et al. 2014). This omnivorous species is found in a variety of natural aquatic habitats, ranging from rivers and streams to reservoirs, marshes, ponds, lakes, salt marshes, rice fields and can adapt to polluted aquatic systems, e.g., irrigation canals, tanks gutter, drainage systems, and canals in municipal areas (Das 1991; Moll & Moll 2004; Shah & Tiwari 2004; Hossain et al. 2008). Three subspecies of *L. punctata* are currently recognized namely; *L. punctata punctata*, *L. punctata vittata*, *L. punctata andersoni* (Bhupathy et al. 2014). According to the Wildlife Protection Act, 1972 of India, *L. punctata* is under Schedule-I and listed in CITES Appendices II and listed in IUCN as Vulnerable (Rahman et al. 2021). However, this turtle is one of the most overexploited and traded turtle species for its meat and medicinal products in local markets and international markets across its geographic ranges (Choudhury & Bhupathy 1993; Krishnakumar et al. 2009; Bhupathy et al. 2014; Mendiratta et al. 2017). From the early 1990s to date published reports suggest that the West Bengal state involves huge exploitation of *L. punctata* for the local market and international trade (Saha 1986; Das 1991; Whitaker 1997; Choudhury et al. 2000; Mendiratta et al. 2017). Mahapatra et al. (2009) reported *L. punctata* traded from coastal districts of Odisha to West Bengal on regular basis. The species is covertly sold as food in many markets of West Bengal till date. A kilogram of turtle meat can be sold for a minimum of INR 400 (USD 5.24) in these markets (Patra 2019). For the first time we report melanism in *L. punctata* from an illegal meat market near Alangiri, East Medinipur District, West Bengal. During a market survey on 08 March 2020, we found three turtle sellers in Alangiri bazaar, Purba Medinipur district, West Bengal (21.86°N & 87.46°E, elevation 11 m) one of them was selling turtles along with fishes (Image 1). Each seller brought approximately 60 kg of turtles (approx. 48 individuals) to market and sold INR 430 (USD 5.64). Locals and the turtle vendors revealed that they sell turtles throughout the year on two market days a week and the turtles were mostly imported from the neighboring state, Odisha. We rescued nine turtles from the seller who was selling turtles along with fishes

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Image 1. Turtle sold along with fishes by one seller out of three sellers in an open market. Turtles were rescued from him.

and brought to our lab. The melanistic turtle was found among these rescued turtles (Image 1). The melanistic turtle and other turtles were identified as *L. punctata*, based on the following morphological characteristics: domed-shaped oval carapace, femoral flaps, and nasal septal ridges. The turtles were placed in a 12 × 8 ft room and the surface of the ground was covered by 5:5 soil and sand mixtures. Turtles were fed by small fishes and aquatic plants (*Eichhornia crassipes*). Turtles were released after 5 days in a canal containing floating vegetation. The following morphometric measurements were taken in melanistic *L. punctata*: Curve Carapace length (CCL) = 172 mm; Curve Carapace Width (CCW) = 157 mm; Plastron Length (PL) = 159 mm; Plastron Width (PW) = 127 mm; Weight = 630 g; sex not identified. The turtles were sold out in less time but at a higher price compared to fishes. The melanistic individual had black-colored dorsum, limbs, neck, and head. The irises of the eyes were slightly darker compared to the normally colored individual of the same species. The anterior corneal corner/nictitating membrane is slightly white. A thin white strip was present over the upper eyelid. The point of the nostril contains a few white spots. Scattered black spots are present across the plastron. The forelimbs and hind limbs are completely black. Carapace, neck, and plastron was contains many injuries, may be due to capture, transport, and keeping (Image 2B–E).

Two types of color anomaly, e.g., albinism and leucism have been reported between three subspecies of *L. punctata*. Albinism was observed in *L. p. vittata* reported by D'Abreu (1928) and in *L. punctata* by Vyas (1997), Palot & Radhakrishnan (2004), Rufus (2009), Mahapatra et al. (2009), Vaghela & Kamble (2021), Vittapu et al. (2022) from India, and Hossain & Sarkar (1999) also reported an albino *L. punctata* from Bangladesh. Chromatic leucism in *L. punctata* has been reported by Devkota et al. (2020) from Nepal and Rabbe et al. (2021) reported from Bangladesh.

Despite being a legally protected species under Schedule-I in the Wildlife Protection Act, 1972 of India, *L. punctata* is sold in open markets in different parts of West Bengal. Turtles are sold throughout the year and the distance from the turtle trading market (Alangiri) to Forest Range Office and Police Station (Egra) is about 10 km, but no legal action has been taken against these illegal activities. A systematic market survey and study

Image 2. A—Full body of melanistic *Lissemys punctata* | B—Carapace of melanistic *L. punctata* shows injuries | C—Plastron of melanistic *L. punctata* with the discrete distribution of black patches | D—Close-up view of snout to neck of melanistic *L. punctata*. © Ardhendu Das Mahapatra

on community perception are needed to understand the dynamics and factors influencing turtle trading in West Bengal. Enforcement of laws and mass community awareness are suggested to stop illegal turtle trading and consumption.

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NOTE

The Fawcett's Pierrot *Niphanda asialis* (Insecta: Lepidoptera: Lycaenidae) in Bandarban: an addition to the butterfly fauna of Bangladesh

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Niphanda asialis de Nicéville, 1895 is a widely distributed butterfly that occurs from southern Assam-Meghalaya-Mizoram (northeastern India) to Myanmar, Thailand, Laos, Vietnam, and Yunnan (http://yutaka.it-n.jp/lyc4/81450001.html). This species is 'rare' in India (Kehimkar 2016). *Niphanda asialis* (earlier known as *Azanus asialis*) was first described by de Nicéville (1895), based on a single collected specimen from Hofrath Dr. L. Martin.

This survey was carried out for three days in the month of January 2022 at Nilgiri Hill resort area. The area is situated at Bandarban district (21.18–22.35 ^{o}N, 92.05–92.67 ^{o}E) under Chittagong hill tracts in the southeastern part of Bangladesh. This hill tracts range is usually enveloped with mixed sub-tropical evergreen forest and most of the natural forests. During the expedition, the first author sighted and photographed an individual of unknown butterfly species (Image 1) at Nilgiri Hill resort (21.912 ^{o}N, 92.326 ^{o}E; 661 m) using Canon 77D at 1230 h (GMT +6.00) on 21 January 2022 (Image 2). The butterfly was basking about 1.5–2 m above ground on an unknown leaf. Later, the individual was compared with Ek-Amnuay (2012), and keys characterized by de Nicéville (1895). The observed individual was tailless in the hindwing (Kehimkar 2016). Additionally, it had narrow fuscous band on the costa and outer margin at upperside of forewings, black obscurely tipped with white cilia and a marginal row of white encircled lunules at both wings (de Nicéville 1895). Moreover, prominent, dark black sub marginal spot in space 2 of underside of forewings with male shining purple colour of upperwings provides evidence to species level recognition (Ek-Amnuay 2012; Kehimkar 2016). *Niphanda asialis* is quite similar to *Niphanda cymbia* but it can be distinguished by the following keys. The upperside of *N. asialis* (male) having violet or shining purple with sparse presence of androconia, while in *N. cymbia*, it is dull purple and lack of androconium. The female of *N. asialis* is browner with some basal blue scaling which is absent in *N. cymbia* (Corbet et. al 1992). Though none of the species of *Niphanda* is previously reported from Bangladesh (Larsen 2004; Chowdhury & Hossain 2013; IUCN Bangladesh 2015; Roy et. al 2021), but *Niphanda asialis* and *Niphanda cymbia* are recorded from adjoining regions of northeastern India (Varshney & Smetacek 2015).

Previously the species was recorded from North Kanghmun (in Mamit district) of Mizoram state of India (https://www.gbif.org/occurrence/3333343760) which is close to Bangladesh, and Vanghmun village (in

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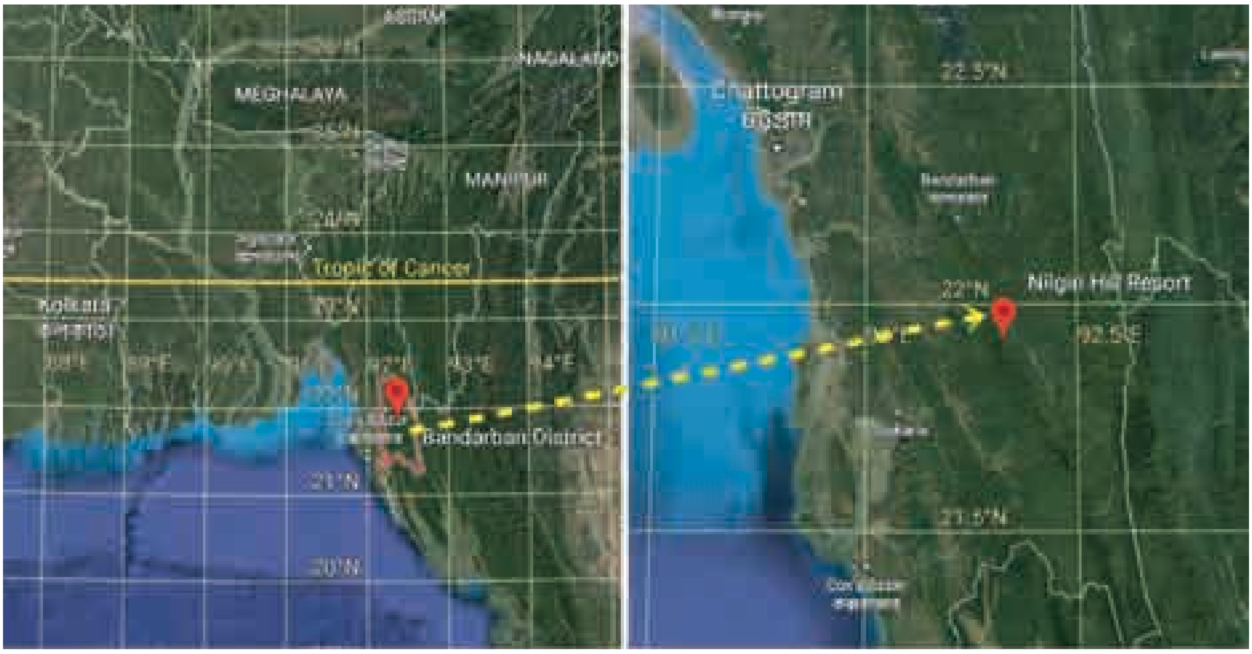

Image 1. Distribution of the *Niphanda asialis* in Bangladesh.

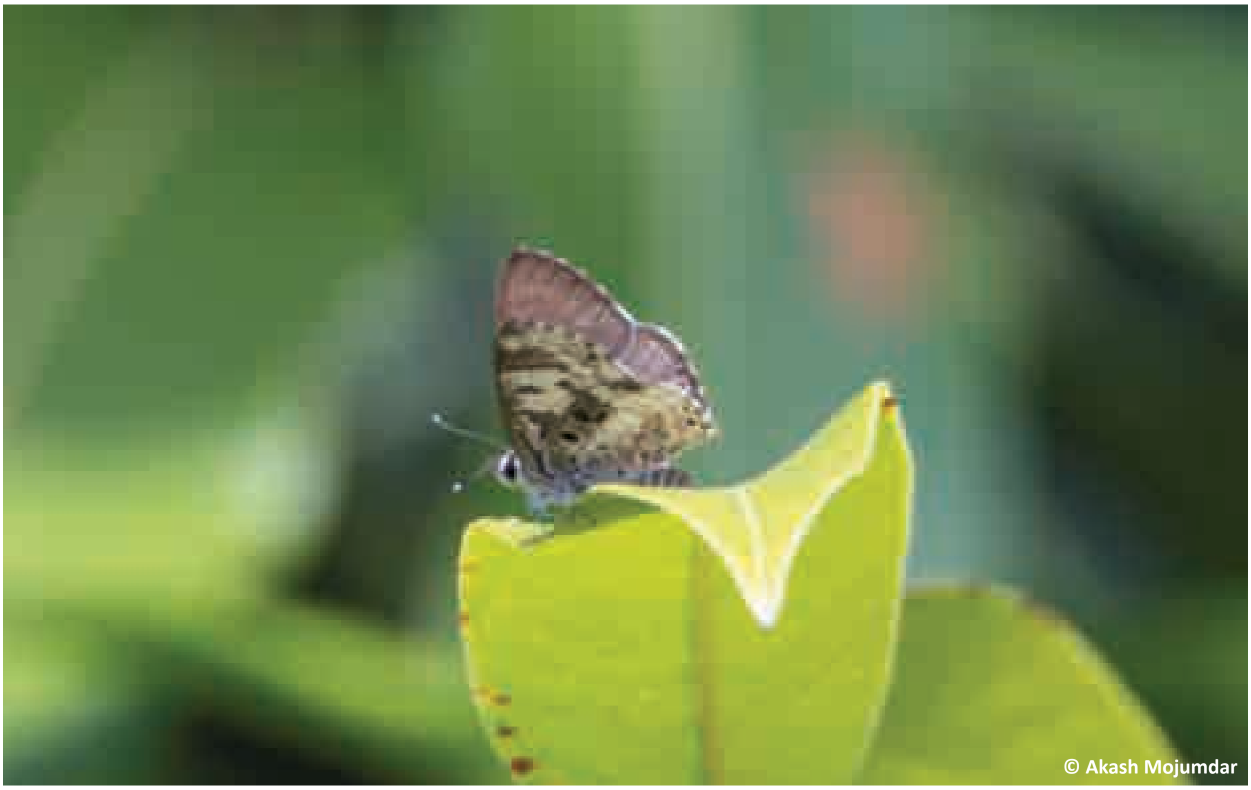

Image 2. Basking behaviour of *Niphanda asialis* in Nilgiri Hill resort, Bangladesh.

North Tripura district) of Tripura (https://www.gbif.org/occurrence/2540788739) and Barail Wildlife Sanctuary of Assam (Gogoi et. al 2016). Consequently, the species was recorded from Nilgiri Hill of Bangladesh (aerial distance: ~184 km from North Kanghmun, ~228 km from Vanghmun, ~346 km from Barail Wildlife Sanctuary). The northeastern region (greater Sylhet) of Bangladesh is also home to some mixed evergreen forested areas similar to the Nilgiri Hill forest. The northeastern part is also very close to Barail Wildlife Sanctuary. As a result, the species may also be found in northeastern mixed evergreen areas of Bangladesh.

The current study thus establishes the presence of *Niphanda asialis* in Nilgiri Hill of Bandarban district by effectively presenting the first photographic proof from Bangladesh.

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