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Caption: Malabar Slender Loris *Loris lydekkerianus malabaricus* © Dileep Anthikkad.

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ARTICLE

Understanding human-flying fox interactions in the Agusan Marsh Wildlife Sanctuary as basis for conservation policy interventions

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Abstract: There is no documented flying fox hunting study done in the Agusan Marsh Wildlife Sanctuary (AMWS) which is known to harbor many threatened wildlife species. The Large Flying Fox *Pteropus vampyrus* is known to be threatened by hunting in the AMWS despite existing laws, such as the Wildlife Act. We conducted semi-structured interviews from September 2017 to January 2018 with 240 hunters in 10 villages through purposive sampling to determine the socio-demographic and economic profile of the hunters, their conservation awareness, perceptions on the monitoring scheme and enforcement, possible hunting patterns, and hunting drivers. Results showed that farming and fishing are the most common livelihoods of hunters. Most hunters achieved an education at the elementary level (42.9%), and belong to a household with 4–6 members (55.5%), often with only one member having a meager daily income (80.7%). Annual flooding was the main economic constraint to the hunters. Largely comprised of indigenous *Manobos* (62.9%), the majority of hunters did not believe in avoiding taboo species (85.4%). Most of the hunters were unaware of laws protecting Wildlife (62.9%) and unable to differentiate between threatened and non-threatened species (86.3%). Poor implementation of the monitoring scheme and insufficient enforcement were also observed in AMWS. Kites with hooks (55%) and guns (31.7%) were used to hunt *P. vampyrus* mostly for local consumption (83.3%). Multivariate analysis revealed that daily income and engagement in conservation negatively affected hunting intensity. With many constraints in totally banning hunting in poor and wildlife-dependent indigenous communities in AMWS, flexible policies must be considered. It is more reasonable and realistic to consider science-based hunting quotas in policy interventions to balance conservation and human welfare. Positive behavioral change towards sustainable hunting and trading bans requires a combination of effective education campaigns, engagement of indigenous communities in conservation, improved enforcement, and sustainable livelihood programs.

Keywords: Hunting, indigenous people, Manobo, *Pteropus vampyrus*, protected area, subsistence, threatened.

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INTRODUCTION

The Philippines is a megadiverse country, recognized for its exceptional richness and endemism of wildlife (Myers et al. 2000; Posa et al. 2008). However, the country is facing rapid forest loss (WRI 2003; Apan et al. 2017) and is known to be a biodiversity hotspot (Myers et al. 2000; Gonzalez et al. 2018). To conserve and protect a high number of threatened species, a network of protected areas was established (Mallari et al. 2016). The Giant or Large Flying Fox *Pteropus vampyrus* Linnaeus, 1758 is a threatened wildlife species found in the Philippines, which also occurs in other southeastern Asian countries (Bates et al. 2008). Like other flying foxes, it plays a very important role in seed dispersal, pollination, and forest regeneration (Corlett 1998; Kunz & Jones 2000; McKonkey et al. 2006; Nakamoto et al. 2008; Shilton & Whittaker 2009; Aziz et al. 2021). It is currently listed as 'Near Threatened' by the International Union for the Conservation of Nature (IUCN 2021) but is locally listed as Endangered in the Department of Environment and Natural Resources Administrative Order (DAO 2019-09) due to intense hunting pressure, continuous roost disturbance, and reduction of its lowland forest habitat (Bates et al. 2008; Gonzalez et al. 2018). *Pteropus vampyrus* is listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and occupies broad trans-national home ranges (Epstein et al. 2009).

Half of all extant large-bodied species in the genus, *Pteropus* are unsustainably hunted across Indonesia, Malaysia, the Philippines, and several islands in the Pacific and Indian Oceans (Mickleburgh et al. 2009; Wiles & Brooke 2009; IUCN 2014). Increasing flying fox hunting pressure in North Sulawesi for example is brought about by intense trading and consumption (Sheherazadee & Tsang 2015). This is of major conservation concern because flying foxes are vulnerable to overhunting due to their slow rate of reproduction (Mildenstein et al. 2016), long gestation, and slow fetal growth (Racey & Entwistle 2000; McIlwee & Martin 2002). Hence, the survival of many chiroterophillic plant species that rely on bats particularly flying foxes for pollination and seed dispersal will be adversely affected by the decrease in their abundance and diversity (Claytn & Milner-Gulland 2000). Decreasing population of flying foxes has economic impacts which may directly affect local communities, e.g., farmers who are dependent on bat-pollinated fruit crops (Aziz et al. 2021).

There are still cases of hunting and trade even within protected areas, e.g., flying fox trading from protected areas on Sulawesi which are supposed to protect natural habitats and animal populations (Lee at al. 2005; Worboys & Winkler 2006). Despite the enactment of the Wildlife Resources Conservation and Protection Act (Wildlife Act, RA No. 9147), the hunting of flying foxes is still prevalent in several protected areas of the Philippines such as in the Mountain Ranges of the Sierra Madre (Scheffers et al. 2012), Mt. Apo National Park (Tanalgo 2017), and in the Agusan Marsh Wildlife Sanctuary (AMWS).

Agusan Marsh is one of the most ecologically significant wetlands in the Philippines and is one of Asia's most important transit points for migratory birds. Freshwater swamp forests comprise 49% of the total area in AMWS. Three major forest types were identified, namely, mixed swamp forests, peat swamp forests or pygmy forests, and the inundated lowland evergreen forest. There were 25 threatened species recorded, of which 84% are endemic to the country such as the threatened flying foxes, e.g., the Endangered Giant Golden-crowned Flying Fox *Acerodon jubatus* and the Near Threatened Giant or Large Flying Fox under IUCN which are already Critically Endangered and Endangered respectively under DAO 2019-09 (Department of Environment and Natural Resources-Caraga 2015).

Both indigenous and non-indigenous people inhabiting the sanctuary were reported to hunt *P. vampyrus* for local consumption and local trading. Hunting is the greatest threat to Philippine bats particularly the frugivorous species such as flying foxes (Tanalgo & Hughes 2019). However, there is no known quantitative research conducted on flying foxes within the AMWS (Tanalgo & Hughes 2018).

Regulation of *P. vampyrus* hunting requires baseline information on hunting patterns and its potential drivers. The findings of hunting research in AMWS will inform adaptive wildlife conservation programs, policy interventions, resource prioritization, and a more effective protected area management (Friant et al. 2015). Understanding human-flying fox interaction is essential to effective long-term conservation, efficient law enforcement, and persistence of the flying fox population. In this paper, we show the demographic, socio-economic, and cultural profile of the hunters, their level of conservation awareness, and perceptions. Here, we also present *P. vampyrus* hunting patterns, the frequency and number of individuals hunted across different periods and the main drivers of Giant or Large flying fox hunting within AMWS. All this information is important to design an adaptive flying fox conservation program in AMWS and other protected areas.

METHODS

A. Study Site and Focal Species

A series of surveys were conducted within Agusan Marsh Wildlife Sanctuary located at 8.316N and 125.866E covering eight municipalities in the province of Agusan del Sur, Mindanao Island (Figure 1 & Image S2). Agusan Marsh is the catchment basin for tributaries flowing from surrounding areas of Compostela Valley, Agusan del Norte and Agusan del Sur, and Bukidnon provinces. AMWS has an area of 19,196 ha which was proclaimed a protected area under RA No. 7586 or the National Integrated Protected Areas System (NIPAS) Act under Presidential Proclamation 913 dated 31 October 1996 (Department of Environment and Natural Resources (DENR-Caraga 2015). In 1999, the AMWS was designated as a Wetland of International Importance by the Ramsar Convention (Primavera & Tumanda 2007).

The *Manobos* represent the most dominant (70% of the population) indigenous group among the five identified tribes within the protected area, including the Kamayo, Higaonon, Banwaon, and Talaandig (Bendsen et al. 2017). Four Certified Ancestral Domain Titles (CADT) cover 55% of this area and one other claim is currently being processed (Bendzen et al. 2017). The biological diversity within the AMWS is being threatened by illegal destructive practices including hunting and trapping of wildlife species (PEF et al. 2008).

The Large Flying Fox is one of the world's largest bats (Stier & Mildenstein 2005). It is one of the largest flying foxes (11 species) out of the total 27 species of the Old World fruit bats (Order Chiroptera, Family Pteropodidae) recorded in the Philippines (Heaney et al. 1998; Tanalgo & Hughes 2018). By contrast, the endemic Giant Golden-crowned Flying Fox is the world's heaviest bat at up to 1.4 kg. Similar in size and weight, both have completely blackish-brown fur on the upper back. The Common Island Flying Fox *Pteropus hypomelanus* Temminck, 1853 is similar in appearance to the Giant Flying Fox but smaller in size and weight with a golden dorsal pelage that is never completely black on the upper back. It occurs from Thailand to Australia, and throughout the Philippines (Ingle & Heaney 1992; Heaney et al. 1998). Of the 13 species of bats recorded within AMWS, including nine fruit bats, *P. hypomelanus* has not been observed in AMWS (Ibanez & Bastian 2015).

Pteropus vampyrus roosts in the top of large trees, with single colonies numbering from 12 to 100,000 individuals often forming mixed roosts with *A. jubatus*. Populations of both flying foxes have declined dramatically in the last century, principally due to the loss of their natural forest habitats. To distinguish the two species in mixed roosts, the dorsal pelage of *P. vampyrus* is usually blackish-brown and golden on the upper back, with the posterior margin sharply defined by a dark brown transverse line on the lower back, that ends in a narrow "V" at the nape and shoulders (Image S2). The ear tips are nearly pointed. In contrast, the dorsal pelage of *A. jubatus* is not completely blackish-brown, and has a golden patch on top of the head extending to the ears, but lacks the dark brown transverse line on the lower back. The ear tips are bluntly rounded. *P. vampyrus* is widely distributed from Indochina to the Lesser Sundas, while *A. jubatus* is endemic only to the Philippines (Ingle & Heaney 1992; Heaney et al. 1998).

B. Study Design, Questionnaire and Ethical Note

After securing the AMWS Protected Area Management Board (PAMB) and free prior and informed consent (FPIC) approval (signed by the tribal leaders), a purposive sampling was done in the identification of *P. vampyrus* hunting "hotspots" (barangays and municipalities where illegal hunting was most prevalent) with the help of key informants such as the protected area superintendent, and local government officials. Snowballing was also used to identify hunters where the preceding hunter-interviewees provided contacts to be included in the succeeding interviews. The first draft of the questionnaire was tested with 30 respondents in one of the identified hunting hotspots (not subsequently included during actual surveys) for questionnaire validation in September 2017. Feedbacks from the respondents on the construction of questions (degree of comprehensibility, flow of questions, length of questionnaire, and level of sensitivity) served as the basis for questionnaire revisions. Actual interviews with a total of 240 hunters (face-to-face semi-structured interviews in Cebuano dialect) were carried out in six municipalities within AMWS including San Francisco (33.3%, n= 80), Loreto (13.3%, n= 32), La Paz (17.1%, n= 41), Talacogon (9.6%, n= 23), Bunawan (12.9%, n= 31), and Rosario (13.8%, n= 33) from October 2017 to January 2018. The head of the household was the main target of the interview. Alternatively, if the head of the household was already deceased, the eldest male child who also participated in hunting was instead interviewed.

In the first part of the questionnaire, we asked about the socio-demographic and economic information such as age, the number of family members, ethnicity, length

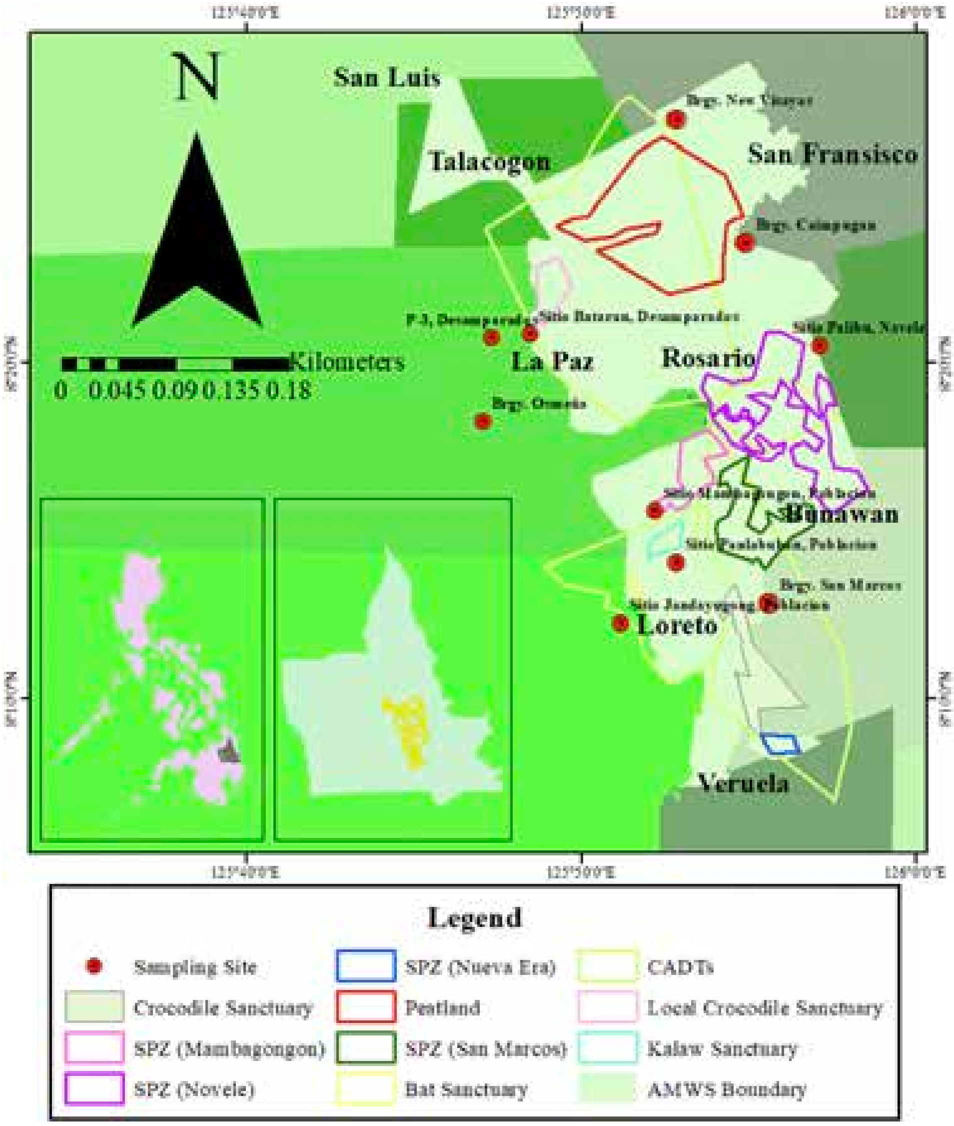

Figure 1. Map showing sampling sites within and the surroundings of Agusan Marsh Wildlife Sanctuary (AMWS) including the municipalities, special protection zones and the major zones.

of residency, and educational attainment (Appendix 1). Socio-economic data were also gathered, such as the main source of livelihood, supplementary livelihood, average daily income incurred during the dry and wet seasons, number of family members with income, and constraints to economic opportunities. We also asked for cultural information in the second part of the questionnaire such as the hunter's beliefs on 'species-specific taboos' and traditional cultural practices related to hunting.

In the third part of the questionnaire, we asked questions about the awareness and perceptions of the hunters such as their awareness of conservation-related activities (1 – no; 2 – yes), Wildlife Act (1 – not totally aware of the law, and its content; 2 – aware of the law but do not fully understand the content and its implication to wildlife conservation; 3 – fully aware of the law and understand its content and conservation implication) and recognition and differentiation of threatened and non-threatened species (picture cards were shown and the concept of 'threatened species' were explained first to the respondents using their dialect before asking this question). Hunter's attendance to information, education, and communication campaigns (IEC) explaining the ecological services provided by flying foxes were also assessed (1 – did not attend any IEC on flying foxes; 2 – was able to attend but IEC did not include the ecological services provided by flying foxes; 3 – was able to attend and the IEC included the ecological services and importance of flying foxes). This information is essential to inform adaptive and effective awareness and outreach campaigns.

We also asked about hunters' engagement in conservation-related activities, e.g., reforestation, conservation of flying fox, and other wildlife (1 – no; 2 – yes). Information on patrolling schemes and law enforcement is quite useful as a basis for designing a sustainable flying fox protection plan without compromising the welfare of the indigenous communities. Hence, the frequency of monitoring, hunting, and trade by the local forest wardens, and the patrolling frequency by the DENR enforcers at AMWS were also determined as perceived by the hunters (1 – never; 2 – hardly ever or <once a month; 3 – regularly or more than once a month; 4 – frequently or more than once a week). The extent of Wildlife Act enforcement was also investigated such as the number of violators fined, convicted, or jailed (anyone that they know in the community). The willingness of hunters to regulate hunting and minimize consumption of *P. vampyrus* was also assessed.

Quantitative assessment of hunting patterns was also carried out through direct interviews. Picture cards of bats were shown to each respondent to confirm the identity of the species hunted, and their motivation for hunting flying foxes was recorded. The most used hunting places within AMWS were identified and distance from the hunter's dwelling in kilometers was estimated. Moreover, hunting techniques used were also described and documented. The estimated hunting frequency (number of times a hunter hunts per time period) and hunting success (number of individuals hunted per time period) were investigated across different periods (conducted a month before the interview - 2017, also in 2016, and in 2012 with data spanning five years).

Descriptive statistical analysis in Paleontological Statistics or PAST (Hammer et al. 2001) was done for the demographic and socio-economic characteristics of the hunters and their hunting pattern responses. Mann-Whitney U test was performed to test if there was a significant difference between the hunting frequency and hunting success recorded between 2016 and 2012 at p value= 0.05 (per year basis). Multiple regression analysis in SPSS was used to determine the factors that influence hunting frequency and hunting success (number of bats taken in 2016). Numerical predictor variables included the hunter's age and length of residency at AMWS (in years), average daily income in Philippine peso (PHP), distance to the hunting zone from the hunter's dwelling (in kilometers), and allocated time for hunting time (in hours). Categorical predictor variables used were the hunter's educational attainment, engagement in any conservation-related activities, attendance to IEC, and awareness of conservation-related activities conducted within AMWS. The dependent and independent variables were subjected to diagnostic tests to check the normality of the residuals. Pearson's correlation analysis was conducted before running the regression models to avoid multicollinearity among independent variables. All reported statistical tests were conducted at a 95% confidence level.

RESULTS

Demographic and Socio-economic Profile of Hunters

All the respondents engaged in hunting *P. vampyrus* (n= 240) within AMWS were males. Nearly 75% (n= 174) of the hunters were between 21–50 years old (Table 1). Most of the hunters have a family size of 4–6 members (55.5%, n= 132). More than half of the hunters were comprised of the 'Manobo' ethnic group (62.9%, n= 151), followed by migrant ethnolinguistic groups, Bisaya (18.5%, n= 44), and Hilonggos (17.6%, n= 42). Half of the hunters (50%, n= 121) lived in their respective villages for 21–40 years. A good number of hunters (42.9%, n= 102) graduated with elementary education, followed by high school undergraduates (23.1%, n= 76) which formed nearly a quarter of the total. Only a few were considered illiterate (1.7%, n= 4) and there was a very low percentage of those who finished college (3.3%, n= 8).

Most of the hunters engaged in rice farming during the dry season (60%, n=144), and some of them did fishing during the wet season (35.4%, n= 85) (Table S1). Most of the hunters considered flood (87.9%, n= 211) as a key constraint to economic opportunities and agricultural productivity followed by bad roads (38.8%, n= 93%) and drought (25.8%, n= 62).

Most of the hunters (80.7%, n= 192) mentioned that there is only one family member with income. We also found that more than half of the hunters had no supplementary source of income during the dry season (51.3%, n= 123) and there were even more of those who do not have any supplementary income source during the wet season (66.7%, n= 160) (Table 2).

The 42.1% (n= 101) of the flying fox hunters have an estimated daily income of Php 101–200 (42.1%, n= 101). The average daily income earned during the dry season (Php 182.50) was found to be significantly higher than during the wet season (Php 123.63) (p <0.001).

More than half of the hunters interviewed were ethnic 'Manobos' (62.9%). Most of them (85.42%, n=

Table 1. Demographic Characteristics of the *P. vampyrus* hunters in Agusan Marsh Wildlife Sanctuary (n=240).

	Frequency	Percentage (%)
Age (years)		
11-20	5	2.1
21-30	60	25.0
31-40	57	23.8
41-50	57	23.8
51-60	39	16.3
61-70	17	7.1
71-80	5	2.1
Number of Family Members		
1-3	63	26.5
4-6	132	55.5
7-9	37	15.5
10-12	7	2.9
13-15	1	0.42
Ethnicity		
Bisaya	44	18.5
Butuanon	1	0.42
Hilonggo	42	17.6
Ilocano	21	0.84
Manobo	151	62.9
Length of Residency		
1-10	23	9.7
11-20	17	7.1
21-30	76	31.9
31-40	45	18.9
41-50	43	18.1
51-60	20	8.4
61-70	12	5
71-80	3	1.3
81-90	1	0.42
Educational Attainment		
None (illiterate)	4	1.7
Elementary undergraduate	8	3.4
Elementary graduate	102	42.9
Highschool undergraduate	55	23.1
Highschool graduate	29	12.2
College undergraduate	34	14.3
College graduate	8	3.3

Table 2. Socio-economic Profile of *P. vampyrus* hunters (number of supplementary income sources and estimated daily income in peso (PHP) during the dry and wet season in Agusan Marsh Wildlife Sanctuary

	Wet Season (%, n)	Dry Season (%,n)	Overall (%,n)
Number of supplementary income sources			
0	66.7%(160)	51.3% (123)	59.1% (142)
1	24.20% (58)	27.9% (67)	26.3% (63)
2	7.5% (18)	7.9% (19)	7.9% (19)
3	1.7% (4)	2.9% (7)	2.5% (6)
Estimated daily income in peso (PHP)			
0	10.3% (25)	8.3% (20)	0
50-100	44.2% (106)	31.7% (76)	39.2% (94)
101-200	23.3% (56)	40% (96)	42.1% (19)
201-300	13.8% (33)	23.8% (57	18.3% (44)
301-400	0	3.3% (8)	0

Table 3. Awareness of *P. vampyrus* hunters in Identifying and Differentiating Threatened and Non-threatened Flying Fox Species, Wildlife Act (RA 9147) and their attendance to Information, Education and Communication Campaign on Flying Fox Conservation in Agusan Marsh Wildlife Sanctuary.

	f	%
Knowledge on identifying and differentiating threatened and non-threatened flying fox species		
No	207	86.3
Slightly Yes	31	12.9
Definitely Yes	2	0.83
Awareness of Wildlife Act (RA 9147)		
No	151	62.9
Slightly Yes	60	25
Definitely Yes	29	12.1
Attendance to Information, Education and Communication Campaign on flying fox conservation		
Never (*Did not attend any IEC on flying fox conservation*)	180	75
Slightly Yes (*Attended but IEC did not include the ecological services provided by flying foxes*)	28	11.7
Definitely Yes (*Attended the IEC including the ecological services and importance of flying foxes*)	32	13.3

205) did not believe in the practice of species-specific taboos (avoidance of wildlife as food or cultural taboos on hunting and killing certain species). Only eight of the respondents (3.3%. n= 8) mentioned that *P. vampyrus* and other flying foxes were recognized as taboo species (flying foxes are considered as sacred and can most likely cause misfortune or death when they are killed and eaten).

Awareness and Perceptions of Hunters

Most of the hunters (89.58%, n= 215) were not engaged in any conservation-related activities in their respective villages although, most of the hunters (87.5%, n= 210) mentioned that they were aware of the existing conservation-related activities implemented in AMWS such as reforestation projects, field research conducted by students and visiting scientists as well as the patrolling of the lake and swamp forest by forest wardens.

More than half of the hunters (62.9%, n= 151) were totally unaware of the Wildlife Act and its content, while 25% (n= 60) were aware of this law, but did not fully understand its content and its implication to wildlife conservation (Table 3). A large proportion of hunters (86.3%, n= 207) reported that they were unable to identify and differentiate threatened from non-threatened species of flying foxes. Three-quarters of the hunters in AMWS (75%, n= 180) were not able to attend any flying fox conservation-focused information education and communication (IEC) campaign in their village. However, some 28 hunters (11.7%) mentioned that they were able to attend IEC campaigns conducted in their village (mostly by DENR personnel and some by NGOs), but the ecological services provided by flying foxes were not given emphasis.

Half of the respondents (50%, n= 120) mentioned that local forest and lake wardens within AMWS rarely (less than once a month) performed their duties in patrolling known hunting areas for illegal poachers and detect trading of wildlife products (49.6%, n= 119) (Figure 2). Moreover, many hunters (74.2%, n= 178) also observed that government employees duly assigned as enforcers hardly ever visited the hunting areas. In terms of enforcement, no *P. vampyrus* hunter has been fined, convicted, or jailed within AMWS during the period 2017–2018 as mentioned by 100% of the hunters. Nevertheless, most of the hunters expressed high willingness to regulate the hunting of *P. vampyrus* in AMWS (69.2%, n= 166) and to effectively regulate the consumption of Large Flying Foxes in the area (87.1%, n= 208) (Table 4).

Hunting Patterns of Large Flying Foxes

Results showed that *P. vampyrus* was hunted mostly for subsistence (83.3%, n= 212) (Figure 3). Some hunters (9.6%, n= 9.6) hunted Large Flying Foxes both for consumption and local trading (selling residual catch). Flying fox hunting mostly occurs in open spaces, e.g., dry rice fields, unplanted cornfields, roadways, and cleared spaces, during fly-out in the late afternoon (55%, n= 132) (Table 5). Other common hunting grounds for flying foxes were in the inundated forest (25%, n= 60) and in peat swamp forest (4.6%, n= 11). Some other hunters (5%, n= 12) also mentioned that they shot *P. vampyrus* while feeding at night in fruiting trees like Marang *Artocarpos odoratissimus* and Mango *Mangifera indica*.

The five most common hunting grounds for large flying foxes were on average <2 km from the hunters' dwellings which implies that it was accessible and easy for them to hunt flying foxes. Kite and hook trapping was the most used hunting technique (55%, n= 132) (Table 6; Image S3-S5), particularly in open areas. Shooting was the next common technique used by the hunters (31.7%, n= 76) while the large flying foxes were in their roost sites or while feeding on fruiting trees.

A few respondents who were engaged in fishing sometimes observed Large Flying Foxes being caught in fishhooks (3.8%, n= 9) and fishnets (2.9%, n= 7). Using slingshot (2.5%, n= 6) was the least common hunting technique used. Hunters incurred the least time in shooting (0.8 h) and in hunting flying foxes using a slingshot (0.83 h). On the other hand, hunters spent an average of three hours hunting flying fox using a kite trap. Hunters revealed that the length of time incurred

Table 4. Willingness of the flying fox hunters to regulate hunting and consumption in Agusan Marsh Wildlife Sanctuary.

	f	%
Willingness to regulate flying fox hunting		
No	35	14.6
Slightly Yes	39	16.3
Definitely Yes	166	69.2
Willingness to regulate consumption of flying fox		
No	20	8.3
Slightly Yes	11	4.6
Definitely Yes	209	87.1

Table 5. Five Most Common Hunting Grounds of *P. vampyrus* in Agusan Marsh Wildlife Sanctuary with their respective Proximity (in kilometer) from the Hunters' Dwellings.

Hunting Place	N	%	Range (km)	Average Distance (km)	Standard Error
Open space/ areas (rice field, roadways, cornfield *etc*)	132	55	0.001 - 6	1.3	0.120
Inundated forest	60	25	0.02 - 7	1	0.270
Fruiting trees (feeding ground)	12	5	0.02-3	1	0.270
Peat swamp forest	11	4.6	0.03-4	1.9	0.390
Settlements	7	2.9	0.001-3	0.67	0.330

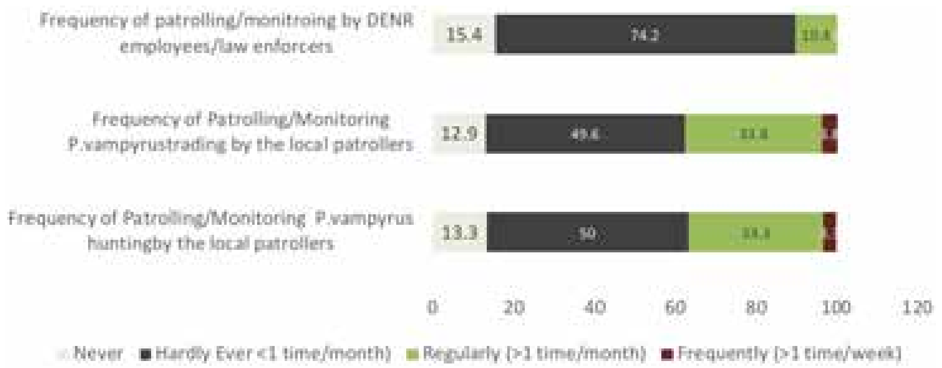

Figure 2. Frequency of Monitoring or Patrolling by the forest wardens and government enforcers in the hunting grounds of *P. vampyrus* as perceived by the hunters in Agusan Marsh Wildlife Sanctuary.

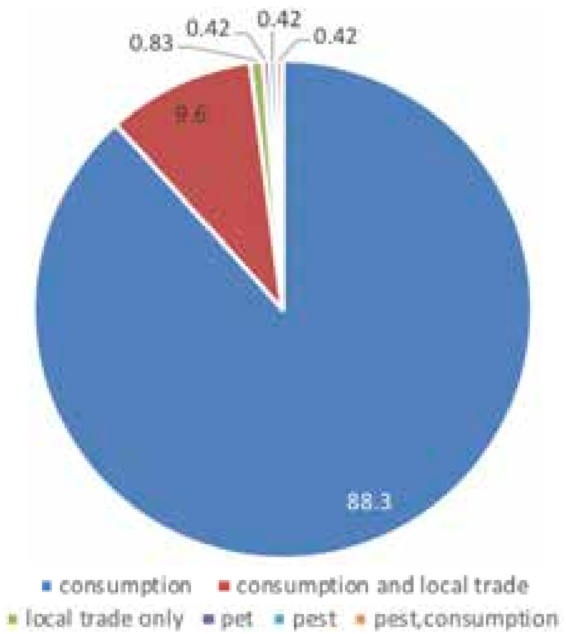

Figure 3. Motivations of hunters in hunting *P. vampyrus* in Agusan Marsh Wildlife Sanctuary

for hunting is primarily dependent on weather, wind direction, hunting skill, and location. Hunters using kite traps usually set up the kite at 1600–1900 h.

It was also found that the hunting frequency in 2012 (mean= 9.5) was higher than in 2016 (mean= 4.6) (Table S2). A Mann-Whitney U test indicated that this difference was statistically significant, U (N_{2012}= 188, N_{2016}= 91,) = 7969.5, z= -0.932, *p*= <0.01. Likewise, the number of individuals hunted per year was also higher in 2012 (mean= 25.6) than in 2016 (mean= 10.3). A Mann-Whitney U test indicated that this difference was statistically significant, U (N_{2012}= 188, N_{2016}= 91,) = 7568, z= -1.5639, *p*= <.01.

Table 6. Five Most Common Techniques Used in Hunting *P. vampyrus* in Agusan Marsh Wildlife Sanctuary with their respective Hunting Time Allocation (hour).

Hunting technique	N	%	Range (hr)	Average Time (hr)	Standard Error
Kite and hook trapping	132	55	1-5	3	0.060
Shooting (gun)	76	31.7	0.2-4	0.80	0.050
Fishhook	9	3.8	5-8	7	0.410
Fish netting	7	2.9	5-12	7.6	1.050
Using slingshot	6	2.5	0.5-1	0.83	0.110

Driving Factors that Influence Flying fox Hunting

A multiple regression model explained a statistically significant amount of variance in hunting frequency, F= 4.123, *p*= 0.003, R^2= 0.07 (Table S3). Average daily income was a significant predictor of hunting frequency, *β*= -0.019, *t*= -2.025, *p*= 0.04. The lower the daily income of the hunter, the more likely that he would hunt *P. vampyrus* more often than those with higher income. Engagement of the hunter in any conservation-related activities (*β*= -4.728, *t*= -0.230, *p*= 0.20) and distance of the hunter's dwelling to the hunting area (*β*= -0.965, *t*= -2.025, *p*= 0.04) were likewise predictors of hunting frequency. Hunters who are not engaged in any conservation-related activities and those who live nearer to the hunting area are those who would hunt more frequently.

Similarly, a statistically significant amount of variance in hunting quantity was explained by a multiple regression model, F= 5.084, *p*= 0.02, R^2= 0.06 (Table S4). Average daily income (*β*= -0.046, *t*= -2.50, *p*= 0.010) and hunter's engagement in any conservation-related activities (*β*= -11.285, *t*= -2.51, *p*= 0.010) were also found to be negatively associated with hunting quantity.

Moreover, hunting time allocation ($β$= 1.495, t= 2.077, p= 0.040) was found to be positively associated with hunting quantity. The more time allocated in hunting *P. vampyrus*, the higher the catch.

DISCUSSION

Understanding human-flying fox interaction is essential to effective long-term conservation, efficient law enforcement, and persistence of the flying fox population without compromising human welfare. This study shows the importance of determining the demographic, socio-economic and cultural background of flying fox hunters; level of conservation awareness, perceptions, and hunting drivers in informing adaptive flying fox conservation in AMWS and other protected areas in the Philippines and in other tropical countries.

Socio-demographic and economic background of hunters

The study shows the socioeconomic vulnerability of the indigenous and local communities in AMWS due to low daily wage (Php 182.50 or <4 USD during the dry season and Php 123.63 or <3 USD during the wet season) which is below the poverty threshold (Albert et al. 2018). Other contributing factors to the poor economic condition in AMWS include a high number of household dependents, lack of diversified income sources, and annual flooding. Most economic activities are influenced by the seasonal flood cycle in the marsh, availability of natural resources, and occurrence of drought (DENR 2001; Tomas et al. 2011). Rice and corn farming and fishing are the most common livelihoods in AMWS. It is during the first quarter of the year (December–March) that hunger among the communities is greater due to reduced economic activities and decreasing food supply, e.g., limited farm produce and low fish catch as this is the flood season (Tomas et al. 2011). Switching from farming to fishing is a common survival strategy in the flooded areas. It has been more challenging to those who do not have any fishing skills and no other supplementary income during the flood season.

The second quarter (April–July) is the dry season and the financial crisis is still commonly experienced due to the depletion of financial resources during the flood period and high expenses incurred for land preparation (planting season) and for school expenses of their children in March and June as the closing and opening of classes, respectively (Tomas et al. 2011). Drought is one of the most challenging phenomena to farmers during the dry season which adversely affects their produce. Unpredictable weather is experienced from August to November resulting in varying crop yield and fish catch (Tomas et al. 2011). The study also shows that only a few households have a supplementary source of income, e.g., rubber tapping, fish vending, food peddling, livestock raising (pigs and chickens), small stores, seasonal carpentry, farm services, motor driving, boat driving, and domestic services.

Flying Fox Hunting Patterns and Intensity in AMWS

Excessive hunting is considered a major threat particularly to the pteropodid bats (Schipper et al 2008; Mickleburgh et al. 2009; Mildenstein et al. 2016). Flying fox hunting is rampant in southeastern Asian countries where bats are abundant; poverty and food insecurity are high and enforcement is poor (Jenkins & Racey 2008; Scheffers et al. 2012; Raymundo & Caballes 2016; Mildenstein et al. 2016; Tanalgo et al. 2016; Tanalgo 2017). Hunting aside from logging and agricultural conversion is identified as the major threats specifically to Philippine bats (Tanalgo & Hughes 2019). But even in protected areas of the country, subsistence hunting is rampant, e.g., Sierra Madre (Scheffers et al. 2012) and Mt. Apo National Park (Tanalgo 2017). Financially poor communities are more likely to hunt wildlife to satisfy their basic needs (Duffy et al. 2016), e.g., households with low living standards and smaller farms in Palawan were found to more likely hunt wildlife and spend greater hunting effort (Shively 1997). Likewise, this study shows that the low income of the hunters explains the prevalent flying fox hunting in AMWS.

The use of kite with string hooks was the most common flying fox hunting tool (Image S3) in AMWS which according to some indigenous key informants was introduced by a non-indigenous hunter. Although the use of kites and hooks has become famous in the area, some hunters still use air guns to hunt flying foxes in their roost sites. It is of major conservation concern when kite-and-hook hunters frequently catch females with lactating pups due to a lack of seasonal hunting regulation. Likewise, shooting is also of conservation concern because flying foxes have high roost site fidelity and they likely return to their preferred roost sites where hunting occurred (Stier & Mildenstein 2005; Mildenstein 2016) which will likely cause population reduction (Mildenstein 2012).

Most of the flying fox hunters are 21–50 years old since the kite-and-hook trapping technique requires skill, strength and stamina. It requires a kite operator to fly the kite at 1600 h in the afternoon when the flying foxes start to come out from the roost sites. Ideal kite-and-hook hunting sites are in open areas such as dried rice fields and unused corn fields. Hunters who live nearer to hunting areas are those who hunt more intensely due to greater ease and better accessibility. The adult kite operator would skillfully maneuver the kite and hooks with two other assistants (mostly 9–12 years old) who kill the catch by smashing the head with a hard object (Image S4). Both adult and child hunters did not mind the hunting risks at all, e.g., snake bite and injury, to meet their subsistence needs.

Some of the adult Manobo hunters (40–50 years old) mentioned that in 2000–2005, they used to see plenty of flying foxes and catch >10 Large Flying Foxes in 2–3 hours. Currently, based on ocular observation, they said that there is a gradual decrease in the flying fox population in AMWS and their catch has reduced to <10 in 2–3 hours. Hunting time allocation came out as one of the significant factors that influence hunting quantity in this research. If the hunters wanted to have more catch, they had to extend their kite trapping time. Besides, some older hunters also observed that flying fox roosting sites are now farther from the settlements, usually in undisturbed areas. Hence, kite and hook hunting has become more commonly preferred technique.

If the three hunters catch more than five flying foxes, the residual catch will be sold to their neighbors for Php 25–50 (<1 USD) each for quick cash to buy food, e.g., rice, viand, spices, and snacks in school for the kids. Some hunters will sell the residual catch to a certain middleman or reseller nearby who would resell the flying foxes (live or dressed) to a nearby town for Php 40–150 (<1–3 USD) depending on the flying fox size and the buyer. In Pisan, Cotabato, the price is also <1 USD (Tanalgo et al. 2016). The price in Sierra Madre is >3 USD where even local officials and law enforcers actively hunt Pteropus bats (Scheffer et al. 2012). Some local officials, government employees, enforcers and businessmen in AMWS were also mentioned by the hunters as their flying fox buyers on an order basis via mobile phone for Php 50–150 or 1–3 USD each usually for social drinking. There was one restaurant owner in a certain town who mentioned that in 2012–2013, he used to buy dressed flying foxes for Php 40 (<1 USD) each on an order basis or from walk-in peddlers. He served best seller cooked flying fox meat for Php 200 (4 USD) per serving. Warning from some enforcers has eventually stopped him from serving flying fox meat.

Potential Solutions to regulate flying fox hunting in AMWS

Based on what we have learned from the socio-economic, cultural, and environmental conditions as well as the hunting intensity in AMWS, we propose the following bottom-up conservation approaches:

Engagement of indigenous and local communities in conservation

The current study has emphasized that engagement of the communities with any conservation-related activities is negatively associated with hunting intensity in AMWS. This suggests that the involvement of indigenous and local people in relevant activities is vital for sustainable conservation action in the sanctuary and in other protected areas. Engaging local communities coupled with the increase of conservation awareness may effect positive changes in attitudes and behavior (Aziz et al. 2017). Encouraging participation of the local communities can help instill positive support to successful governance including law implementation and human-wildlife management (Velho et al. 2016; Milda et al. 2020) particularly if the local communities have high motivation towards wildlife protection (Conney et al. 2017).

The majority of them have recognized conservation-related activities in the sanctuary. However, only a few of them were engaged in the said activities. Hence, training and hiring them as local research assistants in any flying fox research, e.g., population monitoring, human-bat conflict investigations, and involving them in the establishment of local conservation sites (e.g., Baral et al. 2014), creation of wildlife information centers, and in local outreach programs might increase their conservation awareness and divert their time to hunt. With proper capacity building, empowerment, and good incentives, hunters can be employed as patrollers to protect flying foxes using the “poachers to protectors” mechanism.

Adaptive Information, Education and Communication Campaign (IEC)

The involvement of 9–12-year old kids as hunting assistants to either their father, uncle, brother or neighbor is quite disturbing. This suggests the urgent need to integrate wildlife conservation in K-12 curricula. Conservation education must be provided to school children since conservation attitude is developed right from the earliest years (Jacobson 1995). The academe (nearby universities) and conservation experts must coordinate with the Department of Education to train the grade school and secondary (junior and senior levels) school teachers on flying fox conservation. Science books and lessons must integrate ecological services of threatened flying foxes, e.g., *P. vampyrus* and the implication of Wildlife Act or RA 9147 to conservation. Younger audiences might be receptive to positive information about flying foxes (Aziz et al. 2017). Educating the kids will surely have positive outcomes in their attitudes and disposition (Ardoin et al. 2018) towards wildlife conservation. Hence, flying fox-conservation-themed science fair activities, e.g., quiz bees, debates, essay writing contests, and the poster-making contests might help develop the emotional attachment of children to flying foxes.

The parents and teachers association assembly can be a strategic avenue where the trained teachers can promote conservation to the older generation. The environmental education programs and approaches for schools and the local communities shared by Trewhella et al. (2005) and Kingston et al. (2006) can be adopted. It must include a simplified and comprehensible illustration of the indirect benefits of flying foxes to their livelihood as farmers and fishermen and the disadvantages of excessive hunting. Given the hunters' low awareness of the Wildlife Act, there must be a clearer explanation of its content and its conservation implication.

The target audience of conservation IECs must also include enforcers, government employees, and business owners since some of them were found to be part of the local trade chain. Flying fox conservation and wildlife act posters must be posted in hunting areas, e.g., fly-outs and roosting sites; public places, e.g., churches, markets, public transport terminals, government offices, and schools. Famous festivals, e.g., the 'Naliyagan' festival in Agusan del Sur may also include flying fox mascot parade, relevant film showing, games, and contests. Periodic assessment of IEC impacts is also important to improve awareness and outreach programs in regulating hunting, trading, consumption, and protecting habitats.

Improved law enforcement

It is stated in Chapter 3, Article 1, Section 7 of the Philippine Wildlife Act or RA 9147 that the collection of wildlife by indigenous people may be allowed for traditional use (e.g., food and medicine) and not primarily for trade: Provided, furthermore, that collection and utilization for said purpose shall not cover threatened species (DENR 2011). The difficulty of enforcing RA 9147 in AMWS can be explained by the strong dependence of the indigenous and local communities on the threatened flying fox, e.g., *P. vampyrus* meat for consumption. There were already confiscations of kites and guns, warnings, and restrictions given by the DENR in 2015–2016. But the poor communities in AMWS who lack adequate understanding of RA 9147, ecological values of flying foxes, and their conservation status continued hunting and engaged in local trading.

Furthermore, the infrequent or irregular patrolling scheme of the local wardens and the DENR enforcers could be attributed to a few local wardens and their minimal compensation (more or less Php 1,500 or <30 USD per quarter). No flying fox hunter was fined, convicted, and jailed in 2017–2018. Is the criminalization of hunting a threatened flying fox (e.g., *P. vampyrus*) an ethical or practical solution to protect the species in areas where hunting is part of their culture and which also serves as their safety net? This question is not only for AMWS context but also to other areas where the main hunting motivations are subsistence and economic incentives.

In this context, hunting limits (science-based quota per week or month) or perhaps allowing the hunters to focus on non-threatened (locally abundant) mammals may be a more effective and culturally adaptive regulation scheme than through strict legal enforcement. However, to balance species conservation and human welfare, there must be sustainable and seasonal hunting policies. This primarily requires hunting sustainability studies that include periodic flying fox population monitoring, hunting yields, hunting intensity, consumption rate, human population, and scenario building which are among the major research gaps in the Philippines. These are important information to accurately quantify the impacts of harvest in the future and the species extirpation tipping point. More research of this kind must be conducted within and outside Protected Areas to inform sustainable hunting policy interventions.

Increased investment in patrolling is necessary for hunting regulation and for increased detection of illegal activities (Jachman & Billeouw, 1997; Johnson et al. 2016), e.g., flying fox trading and violation against science-based hunting quotas in AMWS. The government must provide funds for capacity building, regular patrolling, a sufficient number of patrollers with good compensation, patrolling equipment, and technology. These are very important for hunting regulation (Milda et al. 2020) particularly to monitor hunting considering hunting quotas and prescribed hunting season.

Local food security and sustainable livelihood

As discussed above, flying fox hunting in AMWS has been part of 'Manobo's' culture and has become the safety net (protein source) of the poor indigenous communities. The strong dependence on wild meat in AMWS is quite common in rural areas of other marginalized and poor countries where wildlife provides immediate food security, protein source, livelihood, and income source (MEA 2005; Pailler 2005; Nasi et al. 2008; Brashares et al. 2011; Swamy & Pinedo-Vasquez 2014; Fa et al. 2015).

Hence, poverty alleviation will likely help in regulating wildlife resources (Robinson & Bennett 2002; Swamy & Pinedo-Vasquez 2014). Alternative income-generating strategies must be promoted in AMWS to reduce dependence on flying foxes. Appropriate and adequate support must be provided for the fisheries and agricultural sector to increase local food security. Support measures must include capacity-building for sustainable agriculture (e.g. organic vegetable farming, livestock husbandry, use of flood and drought-resistant crops) and sustainable fisheries (no using of electric and other illegal fishing techniques), indigenous handicraft making, providing micro-finance for farming, subsidizing farming and aquaculture inputs and improvement of farm-to-market accessibility.

Further measures to increase livelihood security include eco-tourism. AMWS has been identified as the primary tourism resource of the province of Agusan del Sur (DENR 2011). With appropriate planning, adequate government support, and effective implementation, ecotourism in AMWS will provide livelihood and income source diversification to the local communities and promote conservation. AMWS has terrestrial, wetland, and freshwater ecosystems (59 lakes and 5 rivers), harboring unique and pristine types of habitats, several species, and important nesting sites for migratory and resident birds (DENR 2011). Appropriate eco-tourism products and packages will be developed employing the local communities, e.g., river cruise, bird and flying fox watching, kayaking, and eco-trail on boardwalks, among others.

CONCLUSIONS

Flying fox hunting in AMWS is intricately linked with the economic, social, cultural, environmental, and ethical challenges. Low income, lack of engagement in conservation-related activities, the proximity of hunter's dwelling to the hunting area, and hunting time allocation came out as the significant contributing factors to hunting intensity in AMWS. Although low awareness of the Wildlife Act, no attendance to IECs on ecological values of flying foxes, infrequent patrolling, and poor law enforcement were not among the significant drivers but to some extent, are also important factors to consider in the design of long-term flying fox conservation programs. To make policy interventions more realistic and sustainable, the approaches in regulating flying fox hunting in AMWS must not be solely focused on flying fox conservation at the expense of livelihood and food security, nutrition, and well-being of the communities.

Adaptive and flexible approaches that reconcile and balance the dependence of the poor communities on wild meat and the conservation of threatened flying fox population, e.g., *P. vampyrus* must be considered. With many constraints in totally banning hunting in areas with poor and wild resource-dependent indigenous people, sustainable flying fox hunting is the most reasonable option to promote conservation and food security. This requires intensive research on the dynamics of flying fox hunting, consumption and trading extent, population data (spatial and temporal) and scenario building for the predictive impacts of hunting on the depletion particularly of threatened flying fox species, e.g., *P. vampyrus.* This will scientifically inform policy interventions on the setting of sustainable hunting quota (number of catch per time period) in the sanctuary with the prescribed hunting technique, in the right hunting areas during the prescribed season.

Achieving successful conservation and positive behavioral change requires a combination of effective information and education communication to different sectors, engagement of the local communities in research and conservation, improved patrolling scheme to assure sustainable hunting limits (quota) and to ban trading, capacity building for sustainable livelihood programs and diversification of income sources.

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Image S1. Agusan Marsh Wildlife Sanctuary (Sitio Panlabuhan, Poblacion, Loreto, Agusan del Sur, Philippines).

Image S3. Kite and hook materials commonly used in hunting flying foxes in Agusan Marsh Wildlife Sanctuary (upper picture: kite used by hunters; lower picture: kite string hooks to trap flying foxes)

Image S2. Morphological differences of the Endangered *P. vampyrus* (Large Flying Fox) shown in the top picture and Critically Endangered *Acerodon jubatus* (Golden-crowned Flying Fox) shown in the bottom picture. The dorsal pelage of *P. vampyrus* is usually blackish brown and golden on the upper back, with the posterior margin sharply defined by a dark brown transverse line on the lower back, that ends in a narrow "V" at the nape and shoulders. Whereas, the dorsal pelage of *A. jubatus* is not completely blackish brown, and has a golden patch on top of the head extending to the ears, but lacks the dark brown transverse line on the lower back.

Image S4. Kite and hook hunting of flying foxes in Agusan Marsh Wildlife Sanctuary starting at 1600–1700 h in the afternoon (upper left picture: adult kite operator (main hunter); upper right picture: child hunting assistant with a wooden material used to kill the catch; lower picture: young hunting assistants (9-12 years old).

Image S5. *Pteropus vampyrus* caught by a hunter using kite and hook hunting technique in Agusan Marsh Wildlife Sanctuary.

Table S1. Five most common livelihoods of the *P. vampyrus* hunters in Agusan Marsh Wildlife Sanctuary during the dry and wet season (n=240).

Main livelihood	Dry Season		Wet Season	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Rice farming	144	60	84	35
Corn farming	26	10.8	9	3.8
Fishing	14	5.8	85	35.4
Rubber tapping	11	4.6	8	3.3
Motorcycle Driving	8	3.3	5	2.1
None	2	0.83	37	15.4

Table S2. Hunting Frequency and Quantity of *P. vampyrus* across different periods (1 month before the surveys in 2017, 2016 and 2012) in Agusan Marsh Wildlife Sanctuary as revealed by the hunters.

Variables	1 month before the surveys in 2017 (n=27)			2016 (n=91)			2012 (n=188)			Sig. 2016 vs 2012
	Range	Mean	SE	Range	Mean	SE	Range	Mean	SE	
Hunting Frequency	0-12	0.54	0.13	0-96	4.6	0.70	0-50	9.5	0.79	0.001
Hunting Quantity	0-50	1.5	0.41	0-100	10.3	1.4	0-100	25.6	1.9	0.001

Table S3. Driving factors of the frequency of hunting *P. vampyrus* in Agusan Marsh Wildlife Sanctuary.

Variables	Unstandardized Coefficients		t	p-value
	Estimates, B	Std. Error		
(Constant)	11.415	3.299	3.460	0.001***
No. of Family Members with income	0.581	0.317	1.835	0.070[ns]
Average Daily Income	-0.019	0.009	-2.025	0.040*
[a]Engagement in conservation-related activities	-4.728	2.287	-2.067	0.040*
Distance to the hunting area (in km)	-0.965	0.419	-2.303	0.020*

Legend: *** highly significant (significant at α=0.001); ** significant at α=0.01; * significant at α=0.05 [ns] not significant at α=>0.05
[a] categorical variable: 1= member; 0= non-member
Dependent Variable: Frequency of Hunting; R^2=0.07; ANOVA, F-statistic= 4.123 with p- value=0.003

Figure S5. *Pteropus vampyrus* caught by a hunter using kite and hook hunting technique in Agusan Marsh Wildlife Sanctuary.

Variables	Unstandardized Coefficients		t	p-value
	Estimates, B	Std. Error		
(Constant)	26.022	6.114	4.256	<0.001***
Average Daily Income	-0.046	0.018	-2.500	0.010**
[a]Engagement in conservation-related activities.	-11.285	4.492	-2.512	0.010**
Hunting Time Allocation	1.495	0.720	2.077	0.040*

Legend: *** highly significant (significant at α=0.001); ** significant at α=0.01; * significant at α=0.05 [ns] not significant at α=>0.05
[a] categorical variable: 1= member; 0= non-member
Dependent Variable: Frequency of Hunting; R^2=0.06; ANOVA, F-statistic= 5.084 with p-value=0.002.

Tagalog abstract: Walang dokumentadong pag –aaral sa panghuhuli ng mga paniki ang ginawa sa Agusan Marsh Wildlife Sanctuary (AMWS) na kilalang nagtataglay ng maraming nanganganib na mga buhay-ilang. Ang mga uri ng paniki tulad ng Large Flying Fox o *Pteropus vampyrus* ay nanganganib sa AMWS dahil hinuhuli sila ng mga tao kahit ito ay pinagbabawal ng Wildlife Act. Nagsagawa kami ng semi-structured na panayam mula Setyembre, 2017 hanggang Enero, 2018 kasama ang 240 na mga mangangaso mula sa sampung nayon upang malaman ang pang sosyolohiya, pang ekonomiko at pangkultura na mga katangian ng mga mangangaso pati ang kanilang kaalaman at pang unawa sa Wildlife Act, pangangalaga at proteksyon sa nasabing paniki, pagpapatupad ng batas, pagmamanman, mga impormasyon tungkol sa kanilang panghuhuli ng paniki at mga kadahilanan sa panghuhuli. Ipinapakita sa resulta na ang pagsasaka at pangingisda ay ang pinakakaraniwang pangkabuhayan ng mga mangangaso. Karamihan sa mga mangagaso ay nakamit ang edukasyon sa antas ng elementarya (42.9%), at nabibilang sa isang sambahayan na mayroong 4-6 na miyembro (55.5%), madalas na may isang miyembro lamang na mayroon kunting kita sa araw-araw (80.7%). Ang taunang pagbaha ay ang pangunahing hadlang sa ekonomiya ng mga mangangaso. Mga katutubong Manobo ang karamihan sa mga mangangaso (62.9%) at karamihan din sa kanila ay hindi naniniwala sa pag-iwas sa mga taboo species (85.4%). Karamihan sa mga mangangaso ay walang kamalayan sa Wildlife Act (62.9%) at hindi alam ang pagkakaiba ng nanganganib at hindi nanganganib na species ng paniki (86.3%). Ang pagmamanman ng mga bantay-gubat at bantay-lawa at mga tagapagpatupad ng batas ng gobyerno ay napag-alamang hindi regular (mas mababa pa sa isang beses kada buwan) at walang ni isa man lang na mangangaso ang nakitang nahuli o nakulong sa AMWS sa taong 2017-2018. Ang mga saranggola na may mga kawit (55%) at baril (31.7%) ay kadalasang ginagamit sa panghuhuli ng mga paniki na *P. vampyrus*. Karamihan sa mga mangangaso ay nanghuhuli ng paniki upang may makakain (83.3%). Napag-alaman din sa pag-aaral na ito na ang mababang pang-araw araw na kita at kakulangan sa pakikipag ugnayan sa konserbasyon ang posibleng dahilan sa mas madalas na pangangaso at mas maraming huli na paniki. Samakatuwid, mas makatwiran at makatotohanang isaalang-alang ang mga science-based quotas sa pangangaso sa AMWS kung saan naninirahan ang mga mahihirap na katutubo. Ang pagpapabuti at pagpapatupad ng mga batas na may kinalaman sa proteksyon sa mga buhay ilang sa AMWS ay dapat nakabatay sa masusing pag-aaral upang mapanatili ang balanse ng pangangalaga sa kalikasan at kapakanan ng mga tao lalong lalo na ang mga mahihirap na katutubo. Ang positibong pagbabago sa pag-uugali at ang mas mabisa na pagbabawal sa pangangaso at pagbibinta ng mga paniki ay nangangailangan ng kumbinasyon ng mabisang mga kampanya at edukasyon, pakikipag-ugnayan ng mga katutubo sa konserbasyon, mas mahusay na pagpapatupad ng quota sa panghuhuli ng paniki at napapanatiling mga programa sa pangkabuhayan. Ang regular na pag-aaral sa populasyon ng mga *P. vampyrus* at iba pang uri ng mga paniki ay mahalaga din upang silay mas lalo pang mapangalagaan ng wasto at hindi tuluyang mauubos.

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ARTICLE

Argentinian odonates (dragonflies and damselflies): current and future distribution and discussion of their conservation

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Abstract: In terms of conservation, Argentinian odonates have not been assessed using a quantitative approach. One way to achieve this is by modelling their distribution to gather the extent of occurrence. Thus, we modelled the current and future (projected year, 2050) potential distribution of 44 odonate species that occur in Argentina as well as in neighboring countries. Our models of current times indicate a fairly wide distribution for most species but one exception is relevant for conservation purposes: *Lestes dichrostigma* has less than 30,000 km^2 and falls in the 'Near Threatened' category according to the IUCN Red List. Another seven species have less than or close to 100,000 km^2: *Elasmothemis cannacrioides, Erythemis credula, E. paraguayensis, Heteragrion angustipenne, H. inca, Lestes forficula*, and *Mecistogaster linearis.* Future distribution estimates suggest that: a) 12 species will lose or gain around 10%, four species will increase their distribution beyond 10% (up to 2,346%), and 28 species will lose more than 10% (up to 99%). Although current protected areas embrace most odonate species in Argentina, it is still premature to conclude whether this situation will remain in the future given the physiological tolerance and dispersal abilities of the study species among other drivers of distribution.

Keywords: Argentina, global change, IUCN, Odonata, potential distribution, status.

Resumen: En términos de conservación, los odonatos argentinos no han sido evaluados usando un enfoque cuantitativo. Una manera de hacer esto es modelando su distribución para obtener la extensión de la ocurrencia. En este trabajo modelamos la distribución actual y futura (año proyectado, 2050) de 44 especies de odonatos que se distribuyen en Argentina y países vecinos. Los modelos actuales indican una distribución amplia para la mayoría de especies aunque existe una excepción para propósitos de conservación: *Lestes dichrostigma* con menos de 30,000 km^2 y que cae en la categoría de "cercana a la amenaza" según la lista roja de la UICN. Otras siete especies tienen menos o cerca de 100,000 km^2: *Elasmothemis cannacrioides, Erythemis credula, E. paraguayensis, Heteragrion angustipenne, H. inca, Lestes forficula* y *Mecistogaster linearis.* Las estimas futuras sugieren que: a) 12 especies perderán o ganarán alrededor de 10% de área, cuatro especies incrementarán su distribución por más de 10% (hasta 2346 %), y 28 especies perderán más del 10% (hasta 99%). Aunque las áreas naturales protegidas actuales albergan la mayoría de especies en Argentina, es aún prematuro concluir que esta situación prevalecerá en el futuro dada la tolerancia fisiológica y capacidad de dispersión de las especies incluidas en este estudio así como otros efectores de su distribución.

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INTRODUCTION

Given their analytical strength, species distribution models have been widely used to assess the potential area where a species occurs as predicted by environmental variables (Peterson 2006). Odonates have not been an exception to this practice with at least 30 different studies in distinct world regions (reviewed by Collins & McIntyre 2015). Such interest is partly understood on the basis of the intrinsic threat that humankind has posed to freshwater bodies (e.g. Sala et al. 2000) related to the direct dependence of odonates on these bodies. Furthermore, a more recent analysis indicated that odonates can be used as the indicators of global change given their practicality as study models (i.e. large body size), well-described macro-ecological responses, key role as predators in aquatic and terrestrial habitats and their trend of becoming field-animal models for temperature-mediated responses (Hassall 2015). Paradoxically, our current knowledge of the extinction risk for most odonates is extremely limited. For example, the IUCN (2018) shows a shortage of species with strong geographical biases, with country-based assessments frequently lacking firm quantitative-supporting data (see for example, Paulson 2004). One case is that of Argentina: 86 species are listed of which one is 'Endangered', one is 'Vulnerable', two are 'Near Threatened', four are 'Data Deficient', and 78 are 'Least Concern' (IUCN 2018). This implies that a proper assessment is badly needed for this country.

Distribution models of odonates have provided clues of how current distribution will be affected by increases in temperature (reviewed by Collins & McIntyre 2015). These studies have covered up to 25% of the total world odonate diversity, and have shown that in general there will be shifts in distribution, with lotic species and narrow-distribution species (e.g., endemic) showing a tendency to have their areas reduced (reviewed by Collins & McIntyre 2015). In this paper, we have carried out an exercise of calculating current and future distribution models for Argentinian odonates to supplement current studies of distribution gathered from provincial records (e.g. Muzón et al. 2014, 2015; von Ellenrieder & Muzón 1999, 2008; von Ellenrieder 2009, 2010). Our analysis is based on a fraction of the 271 species currently known to occur in Argentina (Muzón & von Ellenrieder 1999; von Ellenrieder & Muzón 2008). Our aim is to use our assessment to guide the current IUCN risk categories for Argentinian odonates based on criteria A and B, that define extent of occurrence.

MATERIAL AND METHODS

Occurrence data of species

Presence of odonate species was compiled from literature records, GBIF records (www.gbif.org as of 20 December 2017; GBIF Occurrence Download http://doi.org/10.15468/dl.mf6nh7), and odonate specialists (Rosser Garrison, Natalia von Ellenrieder, and Dennis Paulson). All data were checked carefully for geographic accuracy by removing duplicates and records with inconsistent georeferencing, for example coordinates on the sea, or missing as recommended in the literature of data cleaning (Chapman 2005). Most records were gathered by odonate experts, so we are confident that identification bias should be minimal. Niche models were built only when more than 10 records per species were available. Thus, the final data set included 1,734 unique presences of 44 species (see Table 1) which were those species with enough collecting data (range 11–158, see Table 1). The database of records is available upon request.

Study area, background and environmental predictors

We have modeled the potential distribution of Argentinian species including cases outside the country's boundaries. Our study area included land between latitudes -55.08 and -21.55S, and longitudes -75.30 to -53.13W. As bioclimatic variables, we used the WorldClim 1.4 (www.worldclim.org) data set (Hijmans et al. 2005) at 0.041666669 cell size. To establish a background and a set of uncorrelated climatic variables, we intersected the variables with target group points, and with 10,000 points randomly selected in the extension of the study area (M). We eliminated some variables with an exploratory data analysis and Pearson correlation analysis (values >0.7). Thus, we selected variables with low correlation and high contribution to reduce the parametrization of the models. After this, the final data set included uncorrelated variables which had more biological importance for our study species, and contributed the most according to the jackknife analysis. Variables were: mean diurnal range (bio 02), isothermality (bio 03), temperature seasonality (bio 04), mean temperature of driest quarter (bio 09), mean temperature of warmest quarter (bio 10), precipitation of wettest month (bio 13), precipitation seasonality (bio 15), precipitation of driest quarter (bio 17), precipitation of warmest quarter (bio 18), and precipitation of the coldest quarter (bio 19).

Table 1. Argentinian odonates species modeled, number of records, potential distribution of species in km², TSS values and current and proposed IUCN categories.

Species	Records	Current area (km²)	TSS	Current IUCN status	Suggested IUCN status
Acanthagrion aepiolum Tennessen, 2004	23	206259	0.90	N/A	LC
A. cuyabae Calvert, 1909	55	1136583	0.86	LC	LC
A. floridense Fraser, 1946	47	166257	0.89	N/A	LC
A. gracile (Rambur, 1842)	43	865415	0.85	N/A	LC
A. hidegarda Gloger, 1967	27	112352	0.90	N/A	LC
A. lancea Selys, 1876	48	645339	0.87	N/A	LC
Elasmothemis cannacrioides (Calvert, 1906)	12	79208	0.83	N/A	LC
Erythemis attala (Selys in Sagra, 1857)	70	368120	0.89	LC	LC
E. credula (Hagen, 1861)	16	67990	0.86	N/A	LC
E. peruviana (Rambur, 1842)	72	1056558	0.86	LC	LC
E. plebeja (Burmeister, 1839)	94	1523637	0.84	LC	LC
E. vesiculosa (Fabricius, 1775)	132	2228200	0.81	LC	LC
Erythrodiplax fusca (Rambur, 1842)	22	173798	0.90	LC	LC
E. paraguayensis (Förster, 1905)	11	40995	0.80	LC	LC
E. umbrata (Linnaeus, 1758)	59	184811	0.90	LC	LC
Heteragrion angustipenne Selys, 1886	14	74209	0.84	N/A	LC
H. inca Calvert, 1909	13	102730	0.82	N/A	LC
Ischnura capreolus (Hagen, 1861)	139	734839	0.88	N/A	LC
I. fluviatilis Selys, 1876	158	1714797	0.83	LC	LC
I. ultima Ris, 1908	34	11808573	0.90	N/A	LC
Lestes dichrostigma Calvert, 1909	11	28823	0.80	LC	NT
L. forficula Rambur, 1842	14	72423	0.83	N/A	LC
L. spatula Fraser, 1946	30	504657	0.88	N/A	LC
L. undulatus Say, 1840	34	195329	0.89	LC	LC
Mecistogaster linearis (Fabricius, 1777)	13	71030	0.82	N/A	LC
Miathyria marcella (Selys in Sagra, 1857)	44	4166276	0.87	LC	LC
Micrathyria hesperis Ris, 1911	19	7900041	0.87	N/A	LC
M. hypodidyma Calvert, 1906	33	653996	0.88	N/A	LC
M. longifasciata Calvert, 1909	48	416857	0.89	LC	LC
M. tibialis Kirby, 1897	11	184013	0.80	LC	LC
Orthemis ferruginea (Fabricius, 1775)	13	1401215	0.79	LC	LC
Pantala flavescens (Fabricius, 1798)	17	387339	0.85	LC	LC
Perithemis mooma Kirby, 1889	15	829042	0.83	N/A	LC
Rhionaeschna absoluta (Calvert, 1952)	133	934413	0.86	N/A	LC
R. bonariesis (Rambur, 1842)	158	1417407	0.84	N/A	LC
R. confusa (Rambur, 1842)	52	261179	0.88	N/A	LC
R. diffinis (Rambur, 1842)	40	226574	0.89	LC	LC
R. pallipes (Fraser, 1947)	26	142412	0.89	N/A	LC
R. planaltica (Calvert, 1952)	51	163524	0.89	LC	LC
R. variegata (Fabricius, 1775)	41	365158	0.88	N/A	LC
R. viginpunctata (Ris, 1918)	47	155497	0.90	N/A	LC
Tramea darwini Kirby, 1889	16	321819	0.85	LC	LC
Uracis fastigiata (Burmeister, 1839)	17	760515	0.85	N/A	LC
U. imbuta (Burmeister, 1839)	22	830556	0.84	N/A	LC

Background selection

To choose the best background, preliminary species distribution models were generated with Maxent 3.3.3k (Phillips et al. 2006) with target group points (with 10,000 points randomly selected in the extension of the study area, M), and with a special extent delineating M for each particular species with ecoregions (World Wildlife Fund; www.worldwildlife.org/ date accessed 20 January 2018). Models were constructed by setting several parameters to default ('Auto features', convergence= 10-5, maximum number of iterations= 500). However, we used random seed (with a 30 test percentage), 10 replicates, removed duplicate records, ran bootstrap replicated type, with no extrapolation and no clamping. All this to find which combination of settings and variables generated the best outcomes (highest area under the curve, or AUC) while minimizing the number of model parameters, as well as producing 'closed', bell-shaped response curves guaranteeing model calibration (Elith et al. 2010). The best background by the preliminary analyses was 10,000 points randomly selected in the extension of the study area.

Training ecological niche models

Final models were built with BIOMOD (Biodiversity Modelling) package in R software. This package is a platform for predicting species' distribution, including the ability to model the distribution using various techniques and test patterns (Thuiller et al. 2009). We trained models using four widely used algorithms: maximum entropy (Maxent), random forest (RF), generalized boosting methods (GBM), and multivariate adaptive regression splines (MARS). These models have shown good performance in terms of predictive power (Broennimann et al. 2012; Pliscoff & Fuentes-Castillo 2011; Reiss et al. 2011). From individual models obtained with these different algorithms, we generated a 'consensus model'. Such model combination is the best logistic compromise to avoid either overfitting and overpredicting (Merow et al. 2014). In other words, this reduces biases and limitations of using only individual models. Seventy percent of data was used for training, and 30% for validation with 10 replicates. Final model validation was performed with TSS (True Skill Statistics), average net rate of successful prediction for sites of presence and absence (Liu et al. 2009), ranging from -1 to 1, where the more positive values indicate a higher degree of accuracy and discrimination model (Allouche et al. 2006) (Table 1). Notice that the result of these models is not the area that species occupy absolutely, because they do not consider population dynamics, dispersibility, interactions with other species, and human impacts. However, these models predict where species can be potentially found given their environmental conditions. This assumes that the distribution known of each species provides enough information to characterize its environmental requirements.

A total of 224 models were generated, whose performance was assessed by means of the AUC and TSS statistics (Table 1), while minimizing the number of model parameters, and the best presence/absence models using the '10 percentile-training presence' are shown. This threshold was used because we prefer to err in the side of caution accepting that a 10% of our presences could be problematic (for a similar rationale, see Sánchez-Guillén et al. 2013). The best models of current climatic conditions of species were used to generate projections.

Future projections

The best models of current climatic conditions of species were used to generate projections for the 2050 year assuming climatic change scenarios. The data for future projections were: Global Climate Models (GCM) (CNRM-CM5, HadGEM2-ES, and MPI-ESM-LR) in WorldClim (http://worldclim.org/CMIP5v1; date accessed 12 December 2017), these climate projections were gathered from the Fifth Assessment (CMIP5) (http://cmip-pcmdi.llnl.gov/cmip5/ date accessed 19/7/2017) report of The Intergovernmental Panel on Climate Change (IPPC) (http://www.ipcc.ch/). The representative concentration pathways used (RCP) were 4.5 and 8.5, for year 2050. A RCP 8.5 is considered a pessimistic scenario, where CO_2 emissions would continue to rise while a RCP 4.5 is considered a more optimistic situation.

We estimated areas of potential distribution of odonate species occurring within Argentinian borders in km^2, and calculated the percentage of loss or gain of geographic areas with respect to current potential distribution. 2050 distribution was represented by a consensus model where only pixels-predicted-present by all models were considered as representing the presence of the species. We estimated areas with a function with stringr and raster packages in R (R Core Team 2017).

RESULTS

Table 1 shows the potential current distribution (in km^2) for each species, and the summary of the performance of the best models (with TSS). This table also shows the current IUCN Red List categories (as of 28 January 2018) and the new categories we suggest based on our analysis of distribution area. From these data, only *Lestes dichrostigma* Calvert, 1909 appears as 'Near Threatened' as its estimated distribution area is 28,823 km^2 (Figure 1). This as well as other seven species deserve some attention given that their distribution is less than- or close to 100,000 km^2 (Figure 1): *Elasmothemis cannacrioides* (Calvert, 1906), *Erythemis credula* (Hagen, 1861), *Erythrodiplax paraguayensis* (Förster, 1905), *Heteragrion angustipenne* Selys, 1886, *H. inca* Calvert, 1909, *Lestes forficula* Rambur, 1842 and *Mecistogaster linearis* (Fabricius, 1777). Distributions of all species are included in supplementary material Figure 1.

In regard to climate change projections for the year 2050 the RCP 8.5 estimated the following: 12 species would maintain their distribution with loss or gain of only around 10% of change of their current distribution, four species would increase their distribution beyond 10%, and 28 species would lose their area of their distribution for more than 10% (Table 2). These changes, in general, were fairly consistent with the scenario RCP 4.5 with three species keeping their distribution for around 10% of change, 11 species increasing their distribution beyond 10%, and 30 species losing their distribution for more than 10% (Table 2). These coincidences for both scenarios include, for example, *Micrathyria tibialis* Kirby, 1897 and *Heteragrion angustipenne* Selys, 1886 which represent the extremes in terms of gaining and losing area, respectively.

DISCUSSION

One benefit species distribution models can bring about is the conservation aspects. In this extent, our results suggest that although most Argentinian species have relatively large distributions, a few species deserve some attention. According to the current IUCN Red List (IUCN 2018), the following species face some risk: *Andinagrion garrisoni* von Ellenrieder & Muzón, 2006 and *Progomphus kimminsi* Belle, 1973 (Near Threatened), *Phyllogomphoides joaquini* Rodrigues Capitulo, 1992 (Vulnerable) and *Staurophlebia bosqi* Navás, 1927 (Endangered). The remaining 82 are categorized as Data Deficient (4 species) or Least Concern (78 species). The threatened four species were classified as such given the paucity of collecting records and their restricted areas of distribution. We were not able to locate enough collecting points for any of these four species. However, our work suggests that *Lestes dichrostigma* Calvert, 1909 deserves some attention, as its area is above but close to 20,000 km^2. Although the remaining 43 species can be categorized as least concern, another five have less than 100,000 km^2 so we suggest their populations should be also monitored: *Elasmothemis cannacrioides* (Calvert, 1906), *Erythemis credula* (Hagen, 1861), *Erythrodiplax paraguayensis* (Förster, 1905), *Heteragrion angustipenne* Selys, 1886, *H. inca* Calvert, 1909, *L. forficula* Rambur, 1842, and *Mecistogaster linearis* (Fabricius, 1777). Of course, several other population parameters should be gathered to complement IUCN categorization for all species, for example to detect the population reduction or less of variability. Notice that future projections would not help most species we modelled as 28–30 species would reduce their distribution dramatically in some cases. According to this, some other species not in danger currently would face threat according to these future scenarios: *Acanthagrion hidegarda* Gloger, 1967, *Heteragrion angustipenne* Selys, 1886, *Lestes dichrostigma* Calvert, 1909, *Mecistogaster linearis* (Fabricius, 1777), and *Rhionaeschna viginpunctata* (Ris, 1918). These five species may reduce their area to less than 20,000 km^2.

Essential to our present estimates of area is the fact that 70% of Argentinian species are currently present in protected areas (Muzón & von Ellenrieder 1999). However, given that global change will lead to shifts in current distribution (Sánchez-Guillén et al. 2016), a necessary step is to define whether current Argentinian protected areas will still embrace future odonate geographical distributions. A key issue here is to carry out more intensive collections to construct models for the remaining 227 odonate species that occur within Argentinian boundaries (von Ellenrieder & Muzón 2008). Moreover, research should pay attention to answer whether dispersal abilities can allow odonates catch up with different habitats located at different temperature regimes (Bush et al. 2014).

Related to global change scenarios, it is not surprising to find an inter-specific variation in projected responses to raising temperatures in odonates. Our explanations for this are incomplete yet but may have to do with odonate physiological abilities that affect themoregulatory responses (e.g., Corbet & May 2008) and development (especially at egg and larval stages; Pritchard & Leggot 1987). Given this, it is also not surprising that the largest

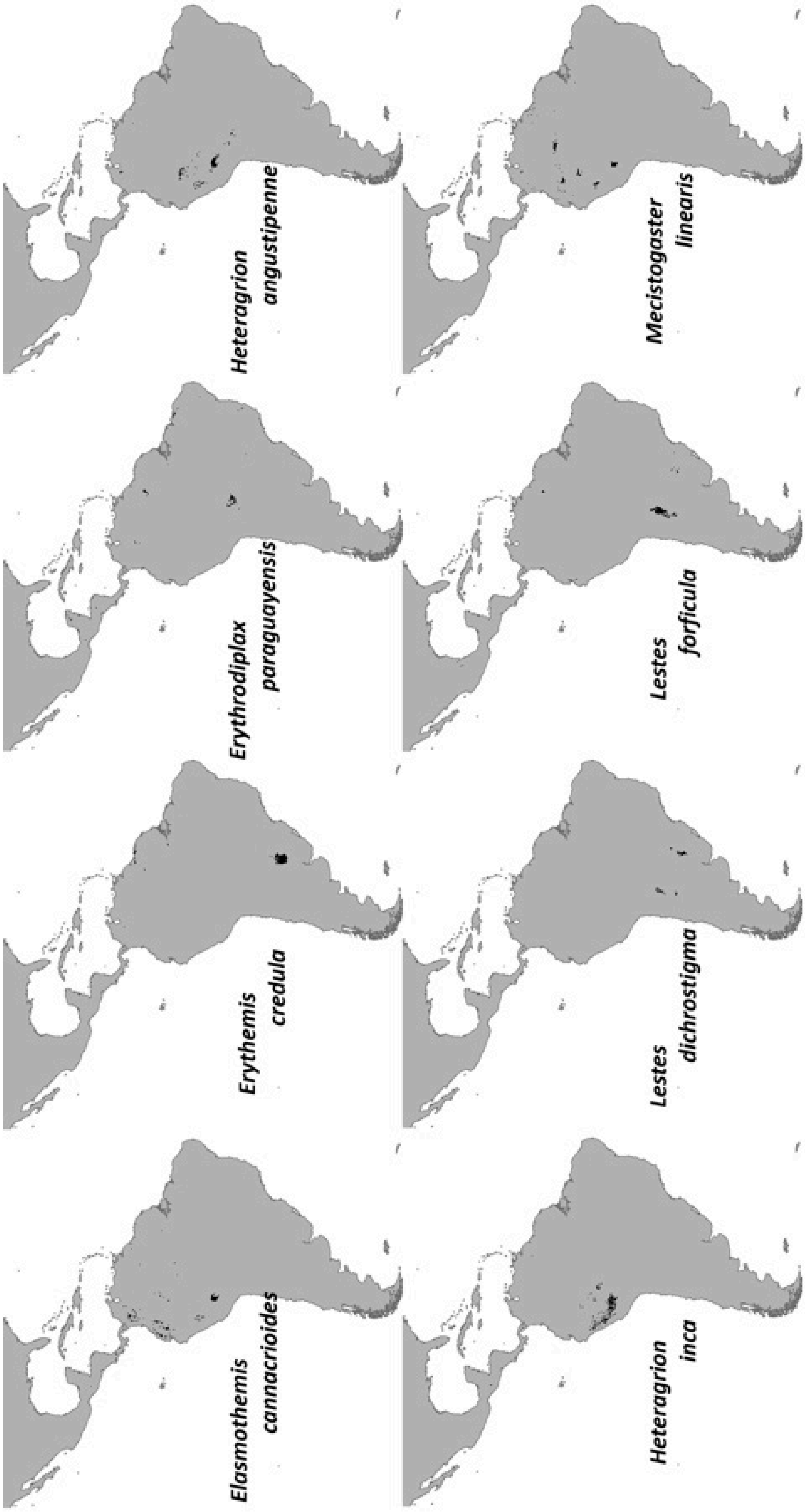

Figure 1. Potential distribution of a subset of Argentinian odonate species as predicted by ecological niche models: *Elasmothemis cannacrioides, Erythemis credula, E. paraguayensis, Heteragrion angustipenne, H. inca, Lestes dichrostigma, L. forficula*, and *Mecistogaster linearis*.

Table 2. Absolute (in km²) and relative changes in suitable area per Argentinian odonate species according to different climatic changes scenarios. Losses are shown as negative values while gains are shown as positive values.

Species	2050 (km²) RCP4.5	2050 (km²) RCP8.5	2050 (%) RCP4.5	2050 (%) RCP8.5
Acanthagrion aepiolum Tennessen, 2004	95025	77268	-53.93	-62.54
A. cuyabae Calvert, 1909	1085251	1128738	-4.52	-0.69
A. floridense Fraser, 1946	124121	148521	-25.34	-10.67
A. gracile (Rambur, 1842)	511056	459049	-40.95	-46.96
A. hidegarda Gloger, 1967	7430	7418	-93.39	-93.40
A. lancea Selys, 1876	334559	328591	-48.16	-49.08
Elasmothemis cannacrioides (Calvert, 1906)	26652	20123	-66.35	-74.59
Erythemis attala (Selys in Sagra, 1857)	1040509	1672709	182.65	354.39
E. credula (Hagen, 1861)	104121	181602	53.14	167.10
E. peruviana (Rambur, 1842)	3475030	3977046	228.90	276.42
E. plebeja (Burmeister, 1839)	2875597	3578859	88.73	134.89
E. vesiculosa (Fabricius, 1775)	6394736	8249237	186.99	270.22
Erythrodiplax fusca (Rambur, 1842)	203928	185469	17.34	6.72
E. paraguayensis (Förster, 1905)	29488	30549	-28.07	-25.48
E. umbrata (Linnaeus, 1758)	1107621	1462042	499.33	691.10
Heteragrion angustipenne Selys, 1886	2709	566	-96.35	-99.24
H. inca Calvert, 1909	27552	18234	-73.18	-82.25
Ischnura capreolus (Hagen, 1861)	5444382	6676849	640.89	808.61
I. fluviatilis Selys, 1876	1087445	1034849	-36.58	-39.65
I. ultima Ris, 1908	1438693	1637097	-87.82	-86.14
Lestes dichrostigma Calvert, 1909	1497	1456	-94.81	-94.95
L. forficula Rambur, 1842	61821	78055	-14.64	7.78
L. spatula Fraser, 1946	297025	323398	-41.14	-35.92
L. undulatus Say, 1840	177025	181143	-9.37	-7.26
Mecistogaster linearis (Fabricius, 1777)	5896	2538	-91.70	-96.43
Miathyria marcella (Selys in Sagra, 1857)	8903701	9675724	113.71	132.24
Micrathyria hesperis Ris, 1911	1325471	1539839	-83.22	-80.51
M. hypodidyma Calvert, 1906	360230	360273	-44.92	-44.91
M. longifasciata Calvert, 1909	301298	304006	-27.72	-27.07
M. tibialis Kirby, 1897	3288689	4500751	1687.21	2345.89
Orthemis ferruginea (Fabricius, 1775)	856545	573823	-38.87	-59.05
Pantala flavescens (Fabricius, 1798)	345606	358468	-10.77	-7.45
Perithemis mooma Kirby, 1889	586843	671876	-29.21	-18.96
Rhionaeschna absoluta (Calvert, 1952)	775879	740279	-16.97	-20.78
R. bonariesis (Rambur, 1842)	713468	711143	-49.66	-49.83
R. confusa (Rambur, 1842)	211253	216912	-19.12	-16.95
R. diffinis (Rambur, 1842)	262980	259209	16.07	14.40
R. pallipes (Fraser, 1947)	70805	75227	-50.28	-47.18
R. planaltica (Calvert, 1952)	45782	44497	-72.00	-72.79
R. variegata (Fabricius, 1775)	295227	300756	-19.15	-17.64
R. viginpunctata (Ris, 1918)	89497	89484	-42.44	-42.45
Tramea darwini Kirby, 1889	343101	337055	6.61	4.73
Uracis fastigiata (Burmeister, 1839)	223876	175053	-70.56	-76.98
U. imbuta (Burmeister, 1839)	416894	126006	-49.81	-84.83

species turnover will occur at intermediate altitudes where drastic changes in temperature currently occur (Maes et al. 2010). The case of Argentina is actually very relevant to this altitude phenomenon given its sharp changes in elevation. Thus, special attention should be given to these areas. Given the small number of records for most species, we are far from ensuring a well-known distribution for a large number of Argentine species, where field work, as well as the digitization of records, is advisable to document regions that are poorly explored. One tool to help in this regard is the use of repositories of citizen science photographs.

Apart from North America (Canada and USA; Hassall 2012; Rangel-Sanchez et al. 2018) and Brazil (Nóbrega & De Marco 2011), our study adds a substantially high number of odonate species with projected distributions for America. Considering that there exist around 5,680 described odonate species, of which 25% had been modelled (Collins & McIntyre 2015), our study makes a valuable global contribution for the Southern Hemisphere. This importance can be seen not only in terms of conservation as discussed above, but also in terms of biogeography given the southerly location of our study species (currently, the southern extreme was Brazil with mainly tropical species; De Marco et al. 2015; Nóbrega & De Marco 2011). Thus our results can be used to understand biogeographical patterns based on odonate ecology (e.g., preference for lentic and lotic waters and global distribution; Hof et al. 2006).

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Supplementary material figure. Current potential distribution of Argentinian odonate species as predicted by ecological niche models. Predictions of suitable area appear in black.

Acanthagrion aepiolum

Acanthagrion cuyabae

Acanthagrion floridense

Acanthagrion gracile

Acanthagrion hidegarda

Acanthagrion lancea

Elasmothemis cannacrioides

Erythemis attala

Erythemis credula

Erythemis plebeja

Erythemis peruviana

Erythemis vesiculosa

Erythrodiplax umbrata

Erythrodiplax fusca

Ischnura capreolus

Ischnura fluviatilis

Ischnura ultima

Lestes undulates

Lestes spatula

Mecistogaster linearis

Miathyria marcella

Micrathyria hypodidyma

Micrathyria hesperis

Micrathyria longifasciata

Rhionaeschna absoluta

Rhionaeschna bonariesis

Rhionaeschna pallipes

Rhionaeschna planaltica

Rhionaeschna variegata

Rhionaeschna viginpunctata

Tramea darwini

Uracis fastigiate

Uracis imbuta

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COMMUNICATION

The diel activity pattern of small carnivores of Western Ghats, India: a case study at Nelliampathies in Kerala, India

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Abstract: The diel activity pattern of small carnivores was studied using the camera trap technique at Nelliampathy Reserve Forest, Kerala, India. Six species of small carnivores were recorded during the study. These include Brown Palm Civet *Paradoxurus jerdoni,* Small Indian Civet *Viverricula indica*, Stripe-necked Mongoose *Herpestes vitticollis*, Brown Mongoose *Herpestes fuscus,* Nilgiri Marten *Martes gwatkinsii*, and Leopard Cat *Prionailurus bengalensis*. The maximum diel activity overlap was detected between the Brown Palm Civet and Small Indian Civet, while the activity overlap was minimal between the Stripe-necked Mongoose and Small Indian Civet.

Keywords: Activity overlap, camera traps, civet, endemism, marten, mongoose, otter, Palakkad district, small cat, southern India.

Malayalam: പശ്ചിമഘട്ടമലനിരകളിലെ നെല്ലിയാമ്പതി വനമേഖലയിൽ ക്യാമറട്രാപ്പുകൾ ഉപയോഗിച്ച് ചെറിയ മാംസഭുക്കുകളെക്കുറിച്ചുള്ള ഒരു പഠനം നടത്തുകയുണ്ടായി. പ്രസ്തുത പഠനത്തിനിടയിൽ ആറ് ഇനം ചെറിയ മാംസഭുക്കുകളുടെ സാന്നിധ്യം നെല്ലിയാമ്പതി വനമേഖലയിൽനിന്നും രേഖപ്പെടുത്തിയിട്ടുണ്ട്. തവിടൻ വെരുക്, പൂവെരുക്, ചെങ്കീരി, തവിടൻ കീരി, മരനായ, പുലിപ്പൂച്ച എന്നിവ ഇതിൽ ഉൾപ്പെടുന്നു.

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Author details: P.O. Nameer is Professor and Head of Centre for Wildlife Studies, Kerala Agricultural University. His research interest include the taxonomy, biogeography and ecology of vertebrates of Western Ghats (except fishes). Devika Sanghamithra is the PhD scholar in the Department of Wildlife Sciences, Kerala Agricultural University, and this paper is an outcome of part of her PhD thesis.

Author contributions: Both the authors conceived and developed the idea, the field work was performed by the first author, both authors contributed equally in the data analysis and writing the manuscript.

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INTRODUCTION

Small carnivores are medium-sized mammals belonging to the order Carnivora. There are 195 species of small carnivores globally belonging to 10 families (Wilson & Mittermiere 2009). The Western Ghats has 14 species, out of which 13 are present in Kerala (Nameer 2015, 2020). Understanding the geographical and ecological distributions and abundance of each species is the foundation for effective management.

A study on the impact of various factors on habitat selection of Smooth-coated Otters *Lutrogale perspicillata* in Periyar Tiger Reserve (PTR) found that the otters showed affinity towards areas with less rocky and gently sloped banks with vegetation and adjoining streams (Anoop & Hussain 2004). The central part of the *L. perspicillata* diet in PTR was fishes (96%), among which tilapia was the primary food item during both lower and higher water levels in the lake (Anoop & Hussain 2005). While comparing the abundance of small carnivores between an intact rainforest and adjoining forest fragments, it was observed that the intact forests have a higher abundance of small carnivores than the fragmented landscapes (Mudappa et al. 2007). Pools in the streams, particularly the second-order streams, were preferred by the Asian Small-clawed Otter *Aonyx cinereus* in the mountainous forests of Eravikulam National Park (Perincherry et al. 2011). Small carnivores of Mudumalai Tiger Reserve showed a negative relationship to the distance from the villages. Indian Grey Mongoose *Herpestes edwardsii* showed an affinity towards degraded forests, whereas Stripe-necked Mongoose *H. vitticollis* preferred subtropical evergreen and dry deciduous forests. Jungle Cat *Felis chaus* and Common Palm Civet *Paradoxurous hermaphroditus* preferred dry thorny and dry deciduous forests of the reserve. Open dry forests with moderate canopy were chosen by Ruddy Mongoose *H. smithii* and Small Indian Civet (Kalle et al. 2013a). The niche of Brown Mongoose *H. fuscus fuscus* was greatly influenced by temperature, rain and topography (Raman et al. 2020).

Brown Palm Civet *P. jerdoni* was believed to have distribution ranges from Kalakkad Mundanthurai Tiger Reserve, Tamil Nadu, to Bhagvan Mahaveer Wildlife Sanctuary in Goa. However, the distribution of Brown Palm Civet has extended further north of Goa up to Satara district of Maharashtra (Bhosale et al. 2013; Sayyed et al. 2019). Punjabi et al. (2014) have reported the northern extension of Stripe-necked Mongoose distribution from Maharashtra and Goa. Recent records of Brown Mongoose from Bilgiri Rangaswamy Temple Tiger Reserve points towards the southeast extension of the distribution of the species from its known range (Suthar et al. 2020).

Studies on the species richness of small carnivores from the Western Ghats reported varying species from the different regions. Kumara & Singh (2006) and Kumara et al. (2014) reported 11 species of small carnivores from the forests of Karnataka. Parmbikulam Tiger Reserve reported 11 species, with Small Indian Civet and Common Palm Civet as the common ones (Sreehari & Nameer 2016). The drier tracts of Wayanad Wildlife Sanctuary reported nine species, and similar to Parambikulam Tiger Reserve, Small Indian Civet was the most frequently sighted species at Wayanad WS. (Sreekumar & Nameer 2018). The high-altitude landscape in Eravikulam National Park recorded nine species, and Jungle Cat and Leopard Cat were the common small carnivores (Nikhil & Nameer 2017). The rain forest landscape of Silent Valley National Park recorded only seven species. The Small Indian Civet was the most common small carnivore in the rainforest habitat (Sanghamithra & Nameer 2018). Anil et al. (2018) reported on the social behaviour, feeding habits, and activity pattern of *Martes gwatkinsii* from the Pampadum Shola NP.

Diel activity pattern is one of the critical factors which determines the ecological niche of a species. It is also an essential tool for the co-living of the species (Gerber et al. 2012). Interspecific competition is reduced by the chronological separation between the species (Selvan et al. 2019). Variation in activity peaks was observed among sympatric species with similar activity (Su & Sale 2007; Chen et al. 2009).

All the three species of the civets recorded from Wayanad Wildlife Sanctuary in the Western Ghats were nocturnal with varying temporal activities, while the mongooses were diurnal (Sreekumar & Nameer 2018). In Sumatra, a study on the activity pattern of the small carnivores found that all the six species of viverrids in the study area were nocturnal with temporal variations in the activity peaks in an oil palm plantation. At the same time, the Yellow-throated Marten *Martes flavigula* was diurnal (Solina et al. 2018), the Nilgiri Marten of Pampadum Shola NP in the Western Ghats was also diurnal in habit (Anil et al. 2018). The nocturnal nature of the Small Indian Civets was proved in other studies from the Western Ghats, too (Pillay 2009; Chen et al. 2019; Kalle et al. 2013b). However, Selvan et al. (2019), in a study in the Villupuram district of Tamil Nadu, observed that Small Indian Civets were active during daytime hours.

The present study is expected to gather additional information on the diel activity pattern of the small carnivores of Western Ghats.

STUDY AREA AND METHODS

Study Area

The study was conducted at Nelliyampathy Reserve Forests (NRF), in the Anamalai Hills, southern Western Ghats, India (Figure 1). The Nelliampathy reserve forest lies between 10.374–10.686 ^{0}N latitudes and 76.518–76.752 ^{0}E longitudes in the Palakkad district, Kerala, and has an extent of 206 km^2. The altitude varies from 40 m to 1,530 m, and the primary vegetation type is west coast tropical evergreen forest. The dominant trees are *Cinnamomum malabatrum*, *Drypetes roxburghii*, *Holigarna arnottiana*, *Mesua ferrea*, *Palaquim ellipticum*, *Schleichera oleosa*, *Syzygium cumini*, and *Vateria indica*. The average temperature ranges 21–41 ^{o}C during summer, and the temperature can be as low as 10^{o}C during the winter in the upper reaches of the Nelliampathies. The mean annual rainfall is 2,500mm (Varghese 2015).

Methods

A total of 30 camera trapping stations were selected in the NRF based on indirect evidence such as scats, pugmarks, and scratches of the small carnivores. We deployed camera traps (Cuddeback attack model C1: digital scout cameras with passive infra-red sensors for heat and motion detection) at these locations during January 2019 at the height of 30 cm from the ground, and two cameras were placed at least 250 m from each other (Mudappa et al. 2007; Sreehari & Nameer 2016; Nikhil & Nameer 2017; Sanghamithra & Nameer 2018; Sreekumar & Nameer 2018). The cameras were set up in default settings. The time delay between the pictures during the day was set as fast as possible, and during the night, it was set with a time delay of five seconds. Garmin GPS etrex 30 was used to mark the camera trap stations. The cameras were kept open for 24 hours a day for 28 days at each location. Thus, 840 camera trap days, monitoring for 20,160 hours of trap effort, were carried out in NRF during the study period.

Camera trap success rate

The camera trap success rate is the ratio of independent photo events to the whole camera trap days and the value multiplied by 100 (Rovero & Marshall 2009). The number of independent images of small carnivore camera trapped from NRF was used to calculate the camera trap success rate.

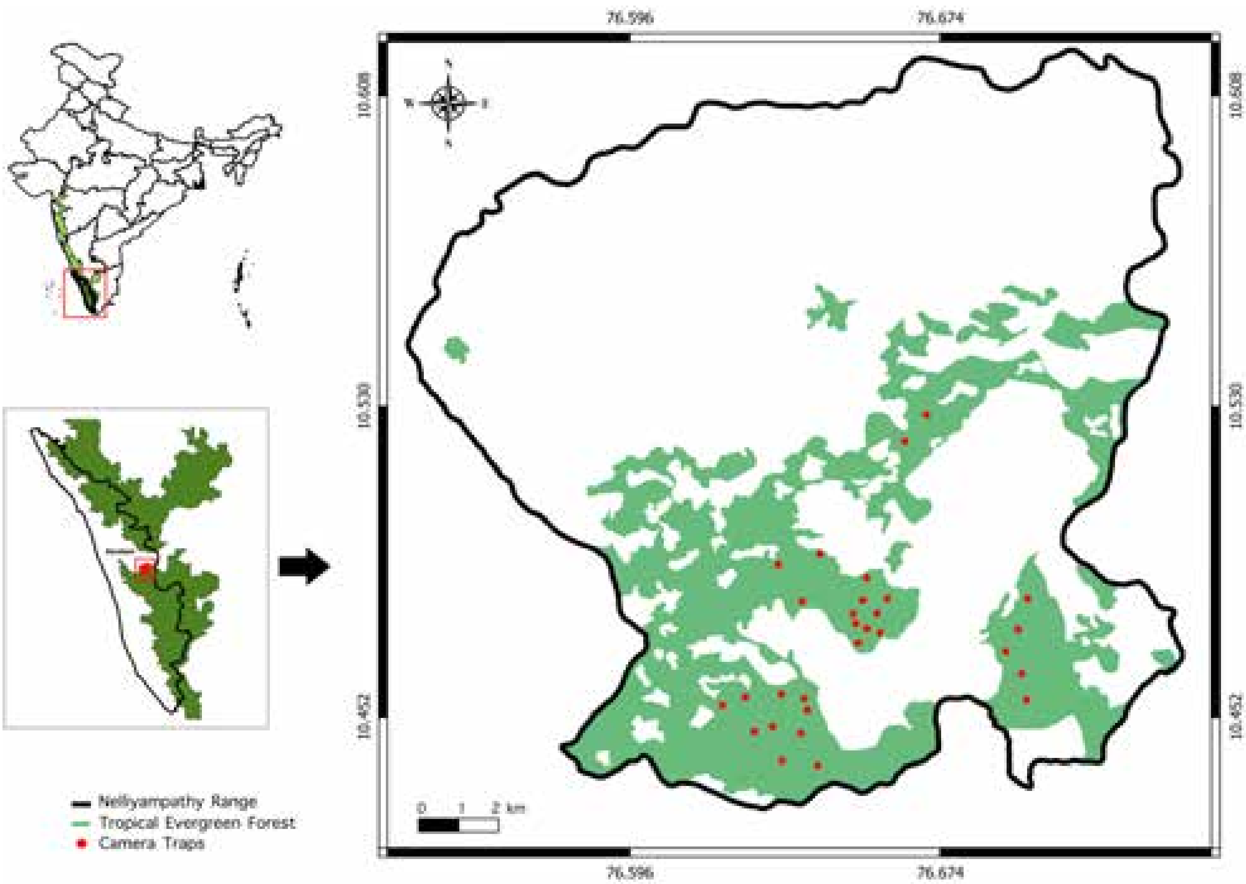

Figure 1. Camera trap locations at Nelliampathy Reserved Forest, Western Ghats, southern India.

Line transect survey for indirect evidence

The transects were done on the existing trails, forest roads, and streams, searching for indirect evidence of small carnivores. A total of 104km was walked through the various trails in search of indirect evidences of small carnivores. The scats were identified to the family level of small carnivores or the species level (Silveria et al. 2003; Sridhar et al. 2008; Mudappa et al. 2010; Perincherry et al. 2011).

Analysis of diel activity

We recorded species of small carnivores, date, time, and geocoordinates of the trap location for every camera trap image captured. To ensure the independence of the capture, we have defined successive images of the same species at the same camera trap station within a recess of ≤30 minutes as a single event (Linkie & Ridout 2011; Mukherjee et al. 2019; Selvan et al. 2019). However, if more than one individual of similar or different species were captured in a single image, each individual was considered a discrete incident (Mukherjee et al. 2019). The timings of dawn and dusk in the study area were recorded during the study period. Sunrise and sunset were at about 0645 h and 1815 h local time (GMT+5), respectively (IMD 2019). Based on dawn and dusk, the day was divided into three periods, 0745–1715 as day, 1915–0545 as night, and 0545–0745 (dawn) & 1715–1915 (dusk) as crepuscular (Gerber et al. 2012; Selvan et al. 2019).

The diel activity of species was categorized as diurnal (<10% of records at night), nocturnal (>90%of records at night), primarily diurnal (10–29 % of records at night), mostly nocturnal (70–89 % of records at night) or cathemeral (30–69 % of records at night) (Gomez et al. 2005; Azevedo et al. 2018; Selvan et al. 2019).

The diel activity pattern and activity overlapping were determined using a non-parametric circular Kernal density method. Soothing parameter of 0.8 (sample size <50) was used to generate coefficient of overlap (Δ) (Ridoout & Linkie 2009). The range of coefficient of activity overlap varies from 0 (zero overlaps) to 1 (100% overlap) (Ridoout & Linkie 2009). R-package' OVERLAP' was used to analyze activity patterns of single species and coefficient of overlapping between two species (Meredith & Ridout 2018). To obtain a bias-corrected percentile, we estimated the 95 % confidence interval of Δ with 1,000 bootstrap (Meredith & Ridout 2018).

RESULTS AND DISCUSSION

Diversity of small carnivores at Nelliampathy Reserve Forests, Western Ghats

We recorded six species of small carnivores from NRF representing four families. This comprises two species each of herpestids and viverrids and one species each of felids and mustelids (Table 1). A total of 677 images of 24 species of mammals were obtained during the study period. Two-hundred-and-thirty-one images were of carnivores, out of which 199 (86.15 %) were of small carnivores (Figure 2). The small carnivores recorded from NRF include Brown Palm Civet *P. jerdon*i (43.65 %) (Image 1), Stripe-necked Mongoose *H. vitticollis* (26.39 %) (Image 2), Brown Mongoose *H. fuscus* (13.19 %) (Image 3), Small Indian Civet *V. indica* (13 %) (Image 4), Nilgiri Marten *M. gwatkinsii* (3 %) (Image 5), and Leopard Cat *Prionailurus bengalensis* (1 %) (Image 6) (Figure 3).

The small carnivore camera trap success rate from the evergreen forests of NRF was 22.14 per 100 trap nights. The camera trap success rate of NRF is much higher than earlier camera trap studies from various locations in the Western Ghats. For example, the camera trap success rate of Silent Valley National Park was 10.90 per 100 camera trap nights (Sanghamithra & Nameer 2018), Parambikulam Tiger Reserve was 4.40 (Sreehari & Nameer 2016),

Table 1. Small carnivores of Nelliampathy Reserve Forest, Western Ghats, southern India.

Common name	Scientific name	Family	IUCN Red List status	CT	IE
Brown Palm Civet	*Paradoxurus jerdoni*	Viverridae	LC	*	*
Small Indian Civet	*Viverricula indica*	Viverridae	LC	*	
Brown Mongoose	*Herpestes fuscus*	Herpestidae	LC	*	
Stripe-necked Mongoose	*Herpestes vitticollis*	Herpestidae	LC	*	
Nilgiri Marten	*Martes gwatkinsii*	Mustelidae	VU	*	
Asian Small-clawed Otter	*Aonyx cinereus*	Mustelidae	VU		*
Leopard Cat	*Prionailurus bengalensis*	Felidae	LC	*	

CT—Camera trap | IE—Indirect evidence.

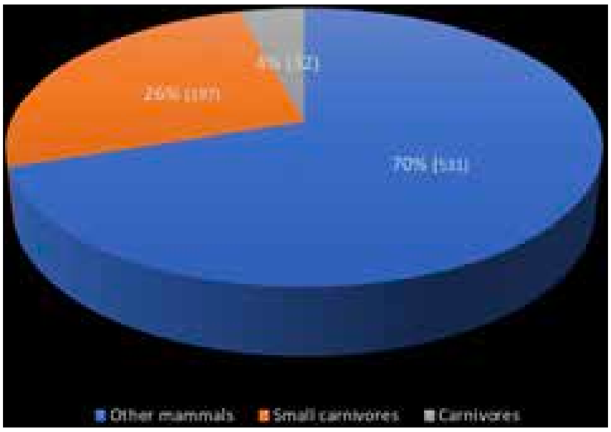

Figure 2. Relative abundance of mammals captured in the camera traps in Nelliyampathy Reserve Forest, Western Ghats, southern India.

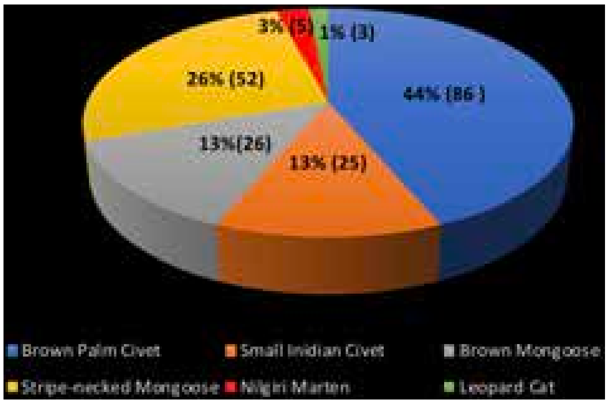

Figure 3. Relative abundance of small carnivores captured in the camera traps in Nelliyampathy Reserve Forest, Western Ghats, southern India.

and Eravikulam National Park was 2.10 (Nikhil & Nameer 2017). However, a higher camera trap success rate 41.10 per 100 trap nights was recorded from Kalakkad Mundanthurai Tiger Reserve (Mudappa et al. 2007).

Diel activity of small carnivores at Nelliampathy Reserve Forests, Western Ghats

The maximum diel activity overlap was detected between Brown Palm Civet and Small Indian Civet with Δ of 0.81 (0.66-0.92) (Fig. 4a), followed by Brown Mongoose and Small Indian Civet (Δ= 0.76, 0.58–0.91) (Figure 4b), and then Brown Mongoose and Brown Palm Civet (Δ= 0.70, 0.53–0.83) (Figure 4c). Whereas, the minimal diel activity overlap was observed between Stripe-necked Mongoose and Small Indian Civet (Δ= 0.08, 0.01–0.18) (Figure 4f), Stripe-necked Mongoose and Brown Palm Civet (Δ= 0.13, 0.06–0.21) (Figure 4e), and between Stripe-necked Mongoose and Brown Mongoose (Δ= 0.20, 0.08–0.33) (Figure 4d).

The most significant diel activity overlap was between Brown Palm Civet and Small Indian Civet. Even though they are similar in size and activity, the competition for resources may be minimized by the dissimilarity in their dietary preferences. Brown Palm Civet is primarily frugivorous (Rajamani et al. 2002; Mudappa et al. 2010), whereas Small Indian Civet is a generalist and omnivorous (Mudappa et al. 2007).

Brown Palm Civet, Small Indian Civet, and Brown Mongoose displayed nocturnal activity patterns, and they have the most significant overlap in the diel activity. However, they all showed varying activity peaks, probably to reduce the competition. Activity peaks of Brown Palm Civet were just before dawn (0400–0600 h) and just after dusk (1800–2000 h), whereas Small Indian Civet had activity peaks were during midnight hours (0000–0100 h) and soon after sunset (1900–2030 h). Brown Mongoose showed peak activity during the midnight hours from 2300 to 0100 h. Similar activity patterns and overlap were observed among the Small Indian Civet and Brown Palm Civet in Wayanad Wildlife Sanctuary (Sreekumar & Nameer 2018). The diel overlap between Common Palm Civet and Small Indian Civet both showed nocturnal activity but varying activity peaks (Su & Sale 2007).

The activity pattern not only depends on factors like limited resources and competition but also on seasonal changes (Ikeda et al. 2016), changes in diurnal temperatures (Fuller et al. 2016) prey-predator interactions (Harmse et al. 2011; Linkie & Ridout 2011) and human interventions and human activity (Cruz et al. 2018). It needs to be further investigated to understand how the sympatric species with overlapping diel activity perform the resource partitioning.

CONCLUSION

Depending on the time of the activity of a species, the small carnivores are generally grouped into two, nocturnal and diurnal. Species within the same temporal group have a more significant overlap in their activity. Maximum overlap was observed between two nocturnal small carnivores, Brown Palm Civet and Small Indian Civet. At the same time, the lowest overlap in activity was observed between Stripe-necked Mongoose and Small Indian Civet.

Diel activity patterns are a vital feature of animal behaviour with important implications for a wide range of ecological and physiological processes. Diel activity patterns are an adaptation to environmental variability throughout the day. They reflect a complex compromise

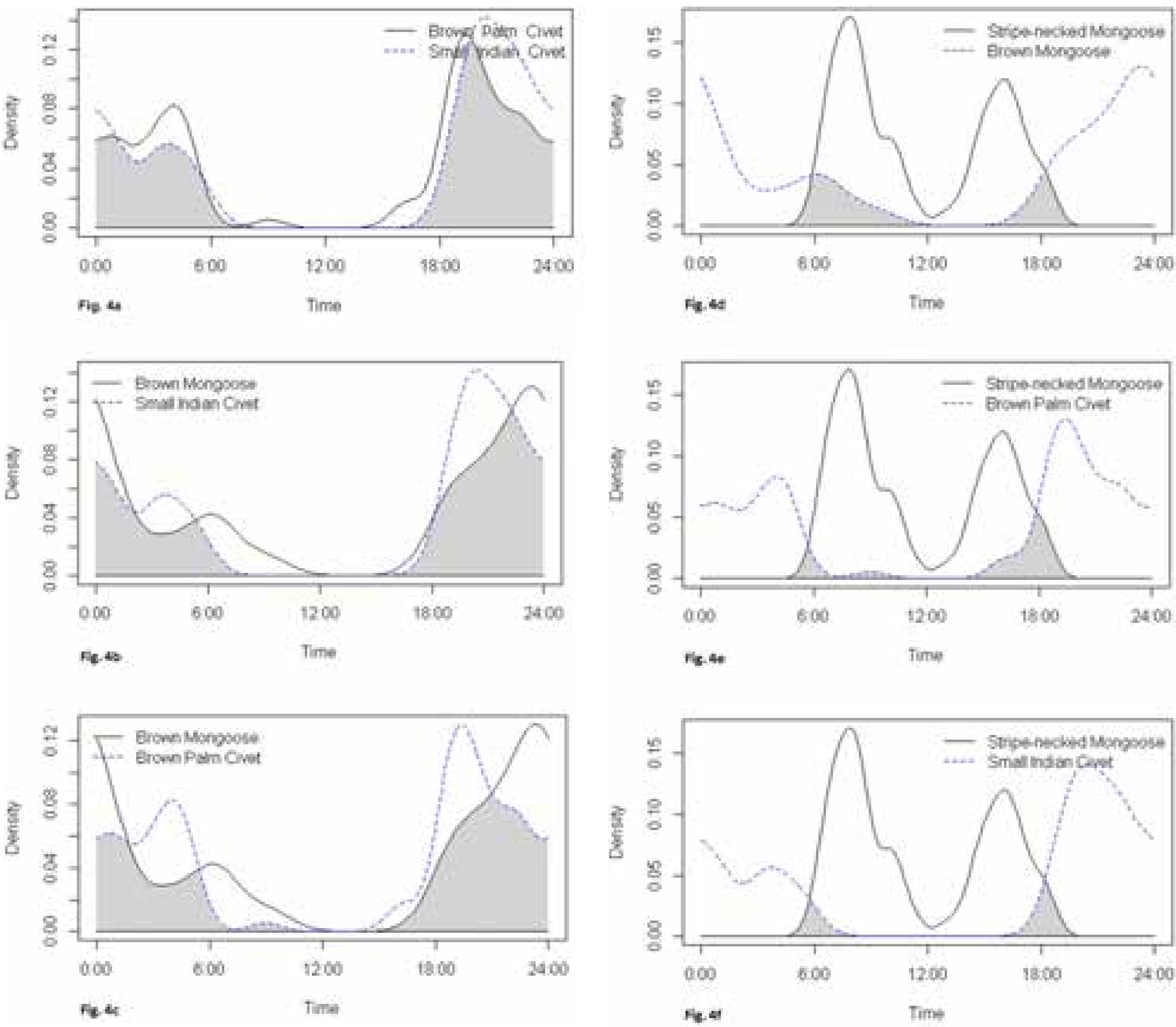

Figure 4. The activity pattern of small carnivores of Nelliyampathy Reserve Forest, Western Ghats, southern India: a—Brown Palm Civet & Small Indian Civet | b—Brown Mongoose & Small Indian Civet | c—Brown Mongoose & Brown Palm Civet | d—Stripe-necked Mongoose & Brown Mongoose | e—Stripe-necked Mongoose & Brown Palm Civet | f—Stripe-necked Mongoose & Small Indian Civet.

between foraging, resting, predator avoidance, competition, social activities and environmental constraints determining fitness. Thus, the diel activity studies may enable us to perform more robust comparisons of activity patterns and levels across sites and species to better understand ecological and human drivers of these processes and thus have management and conservation significance.

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Image 1. Brown Palm Civet *Paradoxurus jerdoni* in Nelliyampathy Reserve Forest, Western Ghats, southern India.

Image 2. Stripe-necked Mongoose *Herpestes vitticollis* in Nelliyampathy Reserve Forest, Western Ghats, southern India.

Image 3. Brown Mongoose *Herpestes fuscus* in Nelliyampathy Reserve Forest, Western Ghats, southern India.

Image 4. Small Indian Civet *Viverricula indica* in Nelliyampathy Reserve Forest, Western Ghats, southern India.

Image 5. Nilgiri Marten *Martes gwatkinsii* in Nelliyampathy Reserve Forest, Western Ghats, southern India.

Image 6. Leopard Cat *Prionailurus bengalensis* in Nelliyampathy Reserve Forest, Western Ghats, southern India.

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COMMUNICATION

Distribution and threats to Smooth-Coated Otters *Lutrogale perspicillata* (Mammalia: Carnivora: Mustelidae) in Shuklaphanta National Park, Nepal

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Abstract: This article aims to assess the distribution, threats and perceptions regarding otters in Shuklaphanta National Park (SNP). It also provides an overview of the conservation efforts of the Nepal government within and outside the protected areas. The study was carried out through preliminary survey of the wetlands using direct sighting techniques, plus indirect evidence including fur, spraints, dead remains, pugmarks, transect survey, key informant survey (n= 15), and questionnaire survey of households (n= 70) in buffer zone. This study found that otter signs were mostly concentrated in the moist soil near the wetlands area. Otter distribution was mostly recorded in Radhapur river, Kalikhich lake, Chaudhar river, Hattinala near hattisar area of pipraiya, Bahuni river, Shikari lake, and Salgaudi lake of Shuklaphanta National Park. Fire and extraction of construction materials from wetlands were identified as severe threats through social survey and key informant survey. For the maintenance of viable population of otters these threats should be minimized through effective biodiversity conservation techniques such as awareness programs and enforcement of laws inside the park. In recent decades, the populations have declined as a consequence of hunting and the overall loss of natural habitats. Overall, our study shows that information on the status, distribution and population trends of Smooth-coated Otters is limited. Therefore, we recommend that more studies should be carried out in this region to establish status, distribution and ecology to improve our understanding of otters in the face of increasing impacts on their habitats. In addition, it is mandatory for the implementation of conservation activities such as awareness to the locals and policy makers, appropriate habitat management and initiating scientific research to ensure a minimum viable population of the species in the country.

Keywords: Biodiversity, conservation techniques, ecosystem, habitat, perception, threats, wetlands.

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INTRODUCTION

Otters are elusive mammals of the family Mustelidae (Acharya & Rajbhandari 2011) in the order Carnivora. They are top predators of wetland ecosystems (Yonzon 1998; Acharya et al. 2010) and require fresh water for feeding adjacent to undisturbed forest and scrub for dwelling. Otters spend 3–5 hours a day fishing and hunting for crab, frogs, and insects (Kafle et al. 2008). Of 13 species of otters found in the world, three occur in Nepal: 1) The Eurasian Otter *Lutra lutra*, 2) The Smooth-coated Otter *Lutrogale perscipillata*, and 3) The Asian Small-clawed Otter *Aonyx cinereus*, (Acharya & Rajbhandari 2011; Basnet et al. 2020). The Eurasian Otter is distributed along mountain streams, rivers, and lakes (Acharya 2006), and according to Shrestha (2003) the Smooth-coated Otter has been recorded from major river basins of Nepal: Koshi, Narayani, Karnali, and Mahakali. Asian Small-clawed Otters were reported in Nepal, China, and India (Hodgson 1839) and later (Biodiversity Profile Project 1995) in Kailali and Kanchanpur districts of Nepal. Although these species are not included in the protected list under the national parks and Wildlife Conservation Act 1973; the act restricts killing, hunting and capturing them, and imposes rules and regulations to curve illegal trade of this species (Acharya & Rajbhandari 2011). The Amendment (2002) of the Aquatic Life Protection Act 1961 has given legal protection to the Eurasian Otter and Smooth-coated Otter. The Smooth-coated Otters are listed as Vulnerable in the IUCN Red List of Threatened Species, and in Appendix II of CITES. As with the other species, the distribution of the Smooth-coated Otter in Nepal is still poorly known, although it has been reported from major river basins: Koshi, Narayani, and Mahakali (Thapa 2002; Acharya et al. 2010). It was also reported from Annapurna conservation area, Makalu Barun National Park, Bardia National Park, Chitwan National Park, Koshi Tappu Wildlife Reserve, Shuklaphanta National Park, and districts of Kailali & Kanchanpur (BPP 1995; Acharya & Rajbhandari 2011). The Smooth-coated Otters have been reported from Geruwa, Khaura, Batahani, Patkanunua, Banjara Ghat, Gaida Machan area, Lamak tal, and Bagaura phant (Thapa 2002; Acharya & Rajbhandari 2011). Smooth-coated Otters are more common along the length of the Naryani river, where it relies heavily on fish (Houghton 1987). They live in holts which may be burrows under tree roots, or within rock piles, and many more are found in Nepal near the banks of lakes which are covered with ferns (Acharya & Gurung 1991; Acharya & Rajbhandari 2011).

Loss of wetland habitats due to construction of large-scale hydroelectric projects, encroachment of wetlands for settlements and agriculture, diminishing prey biomass, poaching and contamination of water ways by pesticides are continuously deteriorating freshwater ecosystems and nearby forest (Joshi 2009), which imposes major threats to Smooth-coated Otters and other freshwater animals. Overfishing, poisoning, industrial and water pollution, and sand and boulder extraction are also contributing to declining otter populations (Acharya & Rajbhandari 2014). Otters have been depicted as symbols of undamaged nature, of clean water and pure vegetation (Acharya et al. 2010). Habitat fragmentation/destruction, fire, intentional killing and lack of awareness, degradation of wetlands, has had a significant impact on otter populations, and over hunting, especially for the illegal fur trade, threatens their survival in many parts of Nepal. In recent decades, its populations have probably declined as a consequence of hunting and the overall loss of natural habitats (Acharya & Gurung 1994; Acharya 2006).

Research on otters is inadequate in Nepal and the distribution of Otter species is still poorly known. Despite its importance as an indicator of the health of aquatic habitats (Foster-Turley et al. 1990; Yonzon 1998), until recently its conservation has not been considered in Nepal. There is a little on distribution and status of otters (Acharya 1998), but their populations do appear to have declined as a consequence of overall loss of natural habitat and deliberate killing (Acharya & Rajbhandari 2014). Therefore more information is needed to develop conservation measures to the protection of these species. This paper will contribute in formulating appropriate policies for their conservation so that sound conservation measures by protected areas could be implemented. Inside Shuklaphanta National Park, there are many small wetlands but previous research inside Shuklaphanta National Park focused only two wetlands Chaudhar river and Kalikhich lake. That is why this research has been conducted to assess the distribution of otters inside the park wetlands. In order to identify the threats and people's perception towards the otter conservation this research was focused. The main objective of this study was to determine the distribution pattern and threats to otter inside park area as well as to understand people's perception towards its conservation.

MATERIALS AND METHODS

Study area

The study was conducted in Shuklaphanta National Park (Figure 1) a protected area in the Terai of the Far-Western Province, covering an area of 305 km^2 at an altitude of 174 to 1,386 m. It was gazetted in 1976 as Royal Shuklaphanta Wildlife Reserve. A small part of the reserve extends north of the east-west highway creates a corridor for seasonal migration of wildlife into the Siwalik hills. The Syali river forms the eastern boundary southward to the international border with India, which demarcates the reserve's southern and western boundary. The protected area is part of the Terai-Duar savanna and grasslands ecoregion and is one of the best-conserved examples of floodplain grassland. It is included in the Terai Arc Landscape. Shuklaphanta National Park supports a wide range of biodiversity which is naturally and globally important. The aquatic and terrestrial habitats of SNP contain more than 665 plant species belonging to 438 genera and 118 families, which is the highest diversity reported for any protected area in Terai (DNPWC 2005). Similarly, a total of 46 species of mammals, five species of amphibians, 12 species of reptiles and 28 species of fish, 450 species of birds have been recorded so far (DNPWC 2005).

The study area has tropical monsoon climate with four different seasons; winter, spring, summer and monsoon with hot temperature range of 6.8 °C to 40 °C. An average annual precipitation was estimated to 1832 mm for the period 1992–2001 at Mahendranagar, 94% of which falls between May and September. The maximum of 639.17 mm precipitation was recorded in August and minimum of 3.98 mm was recorded in November. The monsoon typically begins from July and continues until late September to early October. The common soil types found in the park are sandy loam, silty loam, and clay loam (DNPWC 2003).

Data collection

This study was based on field and social surveys to collect information for distribution patterns and assess threats to Smooth-coated Otter. Direct surveys included field observations, while social surveys incorporated key informant surveys and questionnaires with local people, fishermen, nature guides working in the park, park administrators, non-governmental organization (NGO) and governmental organization officials. Reconnaissance field visits were conducted before starting field data collection. This was done through consultation with

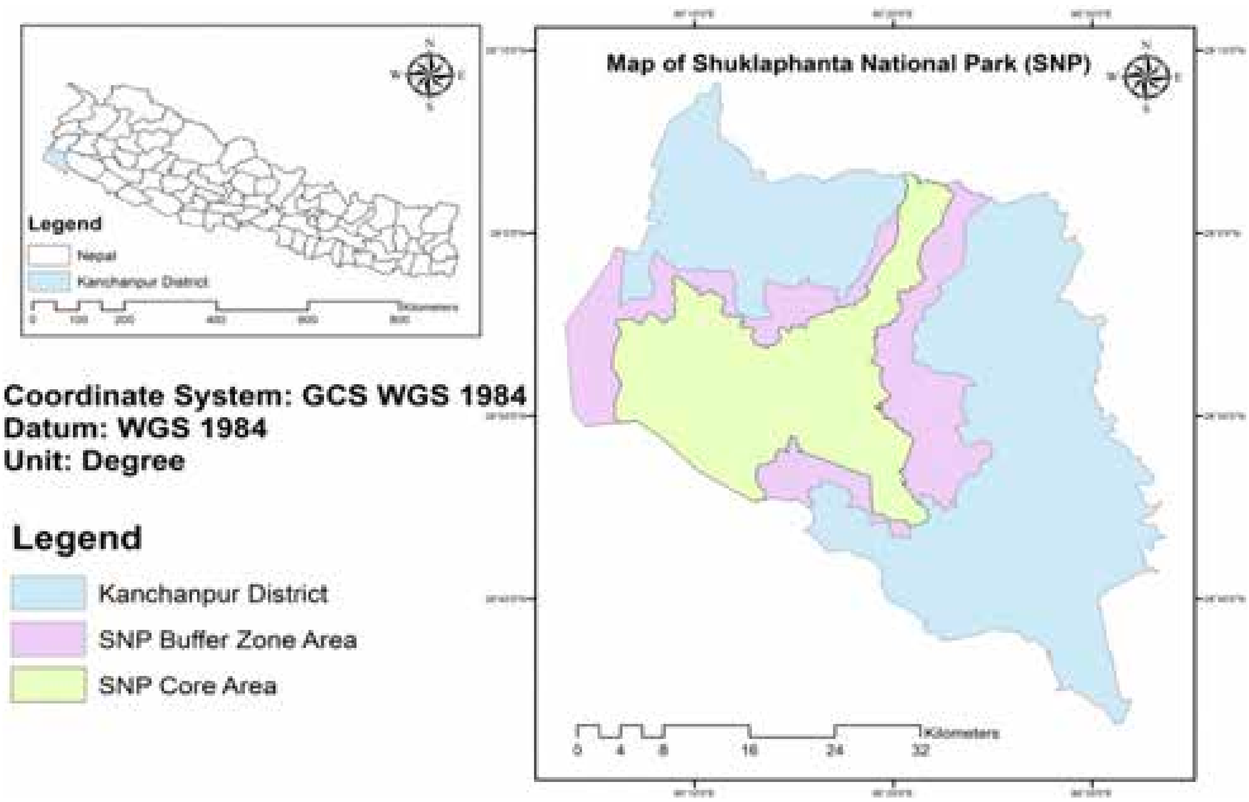

Figure 1. Map of the study area.

park senior officials and park rangers, nature guides and fishermen from the local community. This has helped to known about the existing wetlands, distance between the wetlands, previous research selected site and condition of wetlands, and enhance the data collection process. Observations were carried out in the fields. Location, situation and actions of Smooth-coated Otters were observed. GPS points of each sign sited area were taken for distribution mapping. Different from our study site, Kafle (2011) used social surveys and observation of scat in streams of the Pyaudikhola Watershed and Kapring Khola Watershed of Marsyangdi River in the same district. He reported Otter presence based on local people's perception and characteristics of the scat he collected: dark grey, with fragments of fish, frog and crab remnants, fragile, and smelling of fish. During field observations; photos of live Smooth-coated Otter and their signs (e.g., latrine sites, tracks, scats and dens) was also taken into consideration for this study to determine the presence of the Smooth-coated Otters. After field observation, information obtained was analyzed through MS excel, Arc GIS, to find out the desired outputs as objectives.

Field survey

Wetlands inside the Shuklaphanta National Park were visited for Otter survey. Survey was done in order to directly observe the presence of live Smooth-coated Otter, locating and recording reliable sign such as tracks, spraints, dens and scats on altogether 20 transects of 1.5 km each along the wetlands bank of SNP. The transects were chosen purposively based on our key informant and preliminary surveys. The field survey was conducted in November-December, 2019 when river was low and sand banks were remained exposed.

The Smooth-coated Otters typically leave spraints on visible habitat features (stones, rocks and base of trees). The conspicuous nature of Smooth-coated Otter's spraint markings enables researchers to easily verify the presence of Otters in an area (Reuther et al. 1999, 2001). The tracks of the Smooth-coated Otter were identified by a round impression of five toes and faint webbing marks (Jamwal et al. 2016).

Key informant survey

To collect the information, firstly we conducted key informant interview (KII) to gain the overall idea about the status, distribution and threats to Smooth-coated Otters. For KII, one having detailed and concrete information were chosen like park staffs, nature guides, fisherman, local peoples and owners of the hotels living in the vicinity of the park were taken as key informants as they have more information in Smooth-coated Otters. Altogether 15–20 people were chosen as key informants and separate questionnaire survey was conducted to gather information on status, distribution and threats to otters.

Checklist was prepared for interviewing the key informants to determine the major threats to Smooth-coated Otters and their perception towards conservation of otter. Major threats to Smooth-coated Otter including climatic threats were also assessed through the people who are chosen as key informant. They were asked about the effect of climate. SNP staffs and fisherman from the local community were mainly focused as most of the time they visit to the wetlands and known about the Otter's habitat, occupancy, population and migration route.

Questionnaire survey

Semi-structured questionnaire form was prepared for interviewing local inhabitant particularly among fisher communities, buffer zone households and Rana-Tharu homestay council members to identify the distribution, threats, condition of Otter and their perception towards otter conservation in the study area. The local respondents were surveyed using semi-structure questionnaire to a sample of 70 purposively selected households living in the vicinity of the SNP and purposive sampling was done for this study. The perception of the local peoples towards Smooth-coated Otter was measured in three points Likert scale.

Secondary data

Secondary data relevant to the study was collected from various published and unpublished documents. Information was also collected from various news and journal articles. Academic and research institutions like IOF (Institute of Forestry), NTNC (National Trust for Nature Conservation) were also enquired as needed. Similarly, the camera trap data were also used which were conducted before by the researcher, national park for different wildlife counts.

Data analysis

Data collected from field survey was thoroughly analyzed, both qualitatively and quantitatively, using appropriate statistical tools or programs and interpreted in the form of, figures, charts or table depending upon the nature of the data. Collected data was entered in MS-Excel 2010, *p* value was collected with the help of excel and otter distribution map was prepared with the help of

Arc Map 10.3 version. The output from the MS-Excel and Arc GIS 10.3 was used to analyze data and results were shown through simple table and graphs. Descriptive statistics like mean, percentage, and frequency was used to interpret the result. All these statistical analysis was done by using the SPSS and R software.

RESULT AND DISCUSSIONS

Distribution of Otters

Wetlands of Shukaphnata National Park

Main wetlands of Shuklaphnata National Park include Bahuni river, Rani lake, Salgaudi lake, Kalikhich lake, Chaudhar river, and Haatikunda lake (Figure 2). Most of the wetlands inside the park were partially covered with water during the field days.

Distribution of Otters in Shuklaphanta National Park

Smooth-coated Otters were mostly sighted in Chaudhar river, Kalikhich lake, Radhapur river, Bagh pokhari lake, Rani lake, Shikari lake, Bahuni river, respectively (Figure 2). They were mostly seen along the river bank and lake surroundings (Image 1). The distribution map was made based on the direct observation of Smooth-coated Otter and sign presence.

Types of sign

During the field visit in different wetlands inside the national park, most of the observations were scats (42.63%) followed by tracks (36.14%) and live sightings (21.23%) (Figure 3). Most of the scats were observed during the field survey as it was performed in summer season and most of the wetlands have less water content due to which the scat was not washed away easily and were visible during the field observation.

During the field study, the signs (footprints and scat) of the Smooth-coated Otters were observed in both fresh and in old condition (Figure 4). The study conducted by Hussian & Chaudhary (1997) explained that by February to March the swamps begin to dry and the fish biomass appears to be depleted, consequently Otters move to perennial river. Similar result was observed during the study.

Threats to Otters

Threats identified through household survey of questionnaires

Different types of threats to Smooth-coated Otters identified through the social survey are as mentioned in Figure 4.

Excessive extraction of construction materials

From the data obtained through questionnaire survey with the buffer zone community people, (42%) of respondents said that major threat to Smooth-coated Otter was excessive extraction of construction of material from the rivers as most of local infrastructure development works relied on locally available construction materials (Figure 4). Without any initial environment examination (IEE)/ environment impact assessment (EIA) excessive extraction of stones, gravels and sand was in progress that ultimately disturbed the habitat of Smooth-coated Otter.

Excessive fishing

Nowadays population is increasing day by day and joint family of Tharu community is changing into single family because of this also the percentage of family for fishing is increasing. About 17% people during social survey identified fishing as one of threat to Smooth-coated Otter population. The main food of Smooth-coated Otter is fish, if fish number decreases ultimately Smooth-coated Otter population decreases. Thus, high fishing areas shows inverse relationship with the presence of Smooth-coated Otter.

Water pollution

The drainage pipe, wastes from the settlements, the drained soil from the road construction were making the water sources polluted. During the questionnaire survey, 9% of respondents reported water pollution may be one of the threats to Smooth-coated Otter. About 22% of the total respondents said that they are unknown about the reasons for the threats to Smooth-coated Otter (Figure 4).

Threats identified by the key informant survey

Fire

Uncontrolled fire during the summer season affects the habitat of Smooth-coated Otter. Most of the key informant (46.66%) identified fire as most vulnerable threat to the Smooth-coated Otter population (Figure 5). The buffer people for the succession of primary grasses people initiate the fire. Rise in temperature and burnt debris inside the rivers and lakes and ponds causes' habitat destruction of Smooth-coated Otters.

Water pollution

Out of the total respondents 19.76% key informants identified water pollution as one of most threat to the Smooth-coated Otter population.

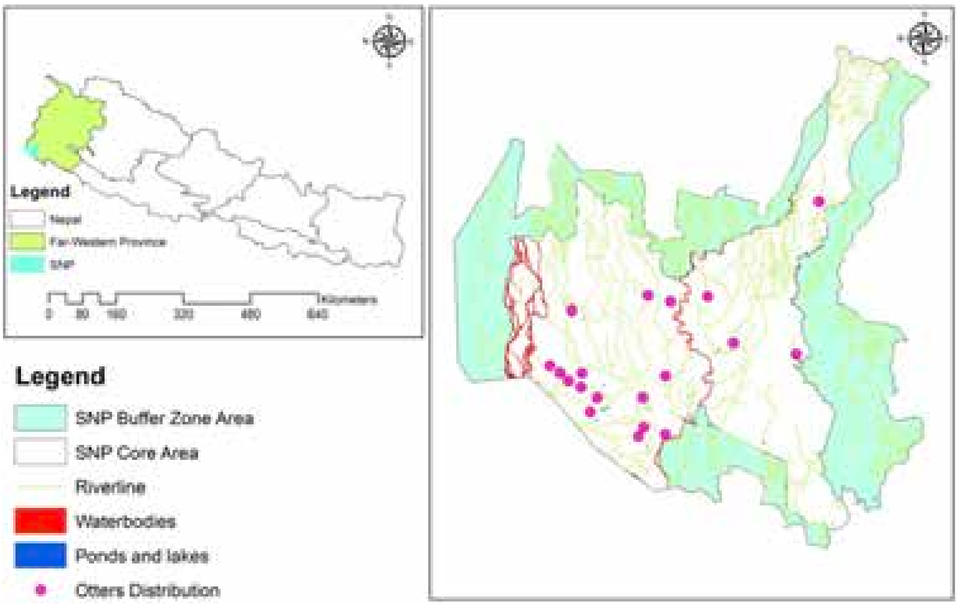

Figure 2. Distribution of Smooth-coated Otter in wetlands of Shuklaphanta National Park.

Image 1. Presence of Smooth-coated Otters in SNP: a—Radhapur River | b—Chaudhar River. © Yam Raut.

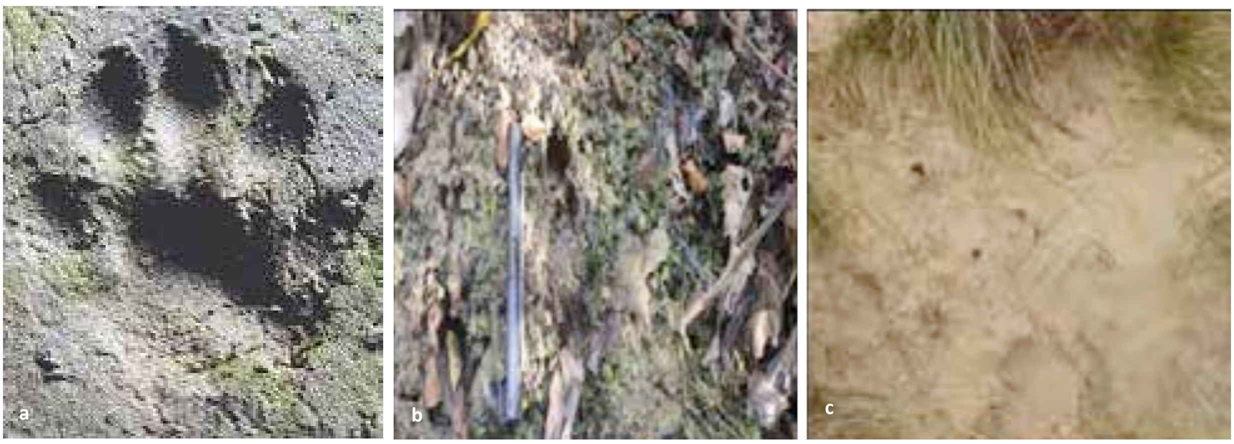

Image 2. Foot print of Smooth-coated Otter: a—fresh signs | b—old signs | c—scat of otters. © Yam Raut.

Poisoning

Sometimes the buffer people use drugs for fishing. Out of the total respondent 13.38% key informants identified poisoning as one of most threat to the Smooth-coated Otter population. As both Smooth-coated Otter and fish share the same habitat poisoning for one species also harms the other species.

Other factors (climate change, invasive species, habitat alternation)

Key informant (20.20%) identified climate change; spread of invasive species such as *Lantana camara* inside the park area was changing the habitat. Similarly, riverine forest is changing towards the Sal *Shorea robusta* forests inside the park; area of grassland is declining yearly due to the intrusion of woody trees in grassland area.

Population trend

Out of the total respondents, 17% of the respondents said that the Smooth-coated Otter population has been increasing while 45% of the respondents said that the Smooth-coated Otter population is decreasing (Figure 6). Most of the Tharu community people said that the population is decreasing; 'we used to saw the Smooth-coated Otters in buffer wetlands frequently but this trend had decreased these days'. Our questionnaire survey of households revealed that local respondents older than 60 years who had sighted Smooth-coated Otters long ago have seen little presence of otters in the study area in the last decade. Similar results was found in the study conducted by Basnet et al. (2020), an otter survey along the Budigandaki River and adjoining streams that lie in Bhimsen Rural Municipality and Sahid Lakhan Rural Municipality of Gorkha District.

Perception towards Otter conservation

Since in Tharu community, both male and female were found engaged in fishing activities and most of fisher communities are illiterate, therefore the gender and education categories were selected. In case of gender, majority of male and female (42.5%) agreed on the statement, 31.6% were stable and 26.25% disagreed on the statement (Table 1). Difference among the responses was significant (p <0.1). Similarly, in the case of education category, 49.05% of the total respondents were agreed, 27.1% were stable and 23.85% disagreed on the statement. The difference among the responses varied significantly (p <0.1). Majority of people had knowledge about Smooth-coated Otter and most of them gave positive response on conservation of Smooth-coated Otter. Only few people including the fisher

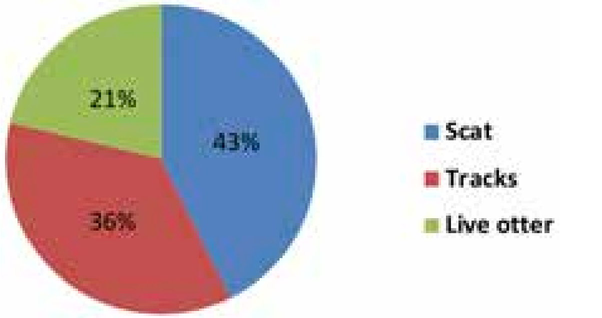

Figure 3. Direct sightings and indirect signs of Smooth-coated Otter in the study area.

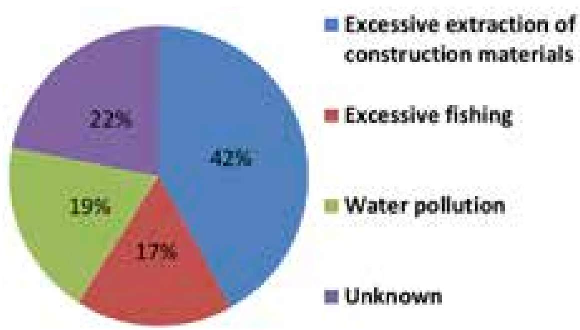

Figure 4. Different threats to the Smooth-coated Otter in the study area.

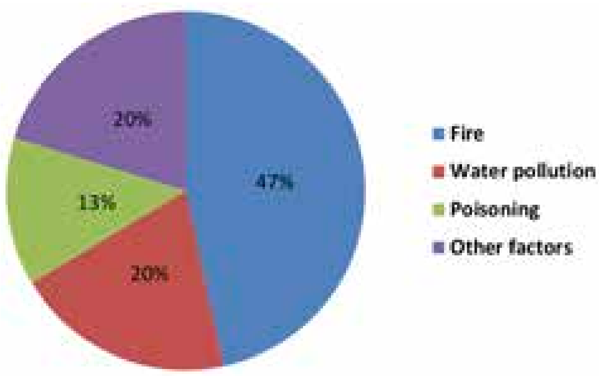

Figure 5. Threats to Smooth-coated Otter through key informant survey.

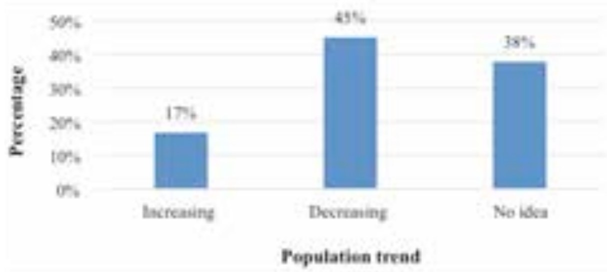

Figure 6. Status of the Smooth-coated Otter population.

Table 1. As Smooth-coated Otters are the indicator of fresh water, they should be conserved.

Categories		Response in % within categories			Mean response	d.f	Chi-square value	*p* value
		Agree	Stable	Disagree				
Gender	Male	56.1	23.2	20.7	1.5891	2	5.435	0.0594
	Female	28.2	40	31.8	2.0565			
Average		42.15	31.6	26.25	1.8228			
Education	Illiterate	23.1	43	33.9	2.1167	2	19.4841	0.000
	Lliterate	75	11.2	13.8	1.1342			
Average		49.05	27.1	23.85	1.62546			

Note: At 10% significance

communities were negative towards otter conservation as Smooth-coated Otter eat up all the fishes which they wanted to capture. This result was similar with the findings mentioned by Thapa (2019).

Distinctive roles by buffer zone user committee/parks for Otter conservation

Respondents were asked about the methods implemented by the park and buffer zone user committee (BZMC) for the Smooth-coated Otter's conservation; 92% of respondents agreed that park was protecting the Smooth-coated Otter's through enforcing strong laws and only 8% of the respondents agreed that park and BZMC is protecting Smooth-coated Otter's population through awareness program. In order to conserve the Smooth-coated Otter's population awareness program should be conducted frequently.

CONCLUSION

This study found that Smooth-coated Otter's field signs were mostly concentrated in the moist soil near the wetland area. Otter's distribution was mostly recorded in Radhapur river, Kalikhich lake, Chaudhar river, Hattinala near hattisar area of Pipraiya, Bahuni river, Sikari lake and Salgaudi lake of Shuklaphanta National Park**.** But Smooth-coated Otter's populations in buffer wetlands were decreased due to the excessive extraction of the construction materials (stones, gravels, sand etc.), poisoning, and water pollution. There was no anthropogenic disturbance inside the park as it was strictly protected with army officials but domesticated livestock inside the park area was creating a problem for habitat destruction, uncontrolled fire, and habitat alternation were some of the threats identified inside the park area. People were positive although the Smooth-coated Otter eat the fish and affects Tharu communities who mostly depend on fishing for their livelihoods.

RECOMMENDATION

∑ Park officials should focus on yearly census of otters during camera trapping surveys of other mega wildlife such as tiger.

∑ Research and findings related to otters are to be taken into considerations while developing park strategies and management plans for otter conservation.

∑ Excessive fishing, excessive extraction of construction materials in buffer areas river, infrastructure development works should be minimized.

∑ Conservation education and awareness programs relating to otters, their ecological behaviors need to be conducted in the local level.

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COMMUNICATION

Wildlife hunting practices of the Santal and Oraon communities in Rajshahi, Bangladesh

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Abstract: Humans have been depending on wild animals from ancient times for food, medicine, economy, tools, and others. Santal and Oraon are two of the indigenous communities present in the Rajshahi district of Bangladesh. They practice wildlife hunting as part of their traditions. We investigated the wildlife hunting practice of these indigenous communities using a closed-ended questionnaire survey. We interviewed 100 households of both communities from four villages. The study indicated that 76% of respondents hunted (88% Santal and 67% Oraon); and they usually hunt mammals, birds, reptiles, and amphibians, of which the bird is the most preferred (73%) and snake the least (1%). The response of hunting among the two communities significantly differed for tortoise, bird, rabbit, mongoose, jackal, and the Jungle Cat. Eighteen sets of animal taxa were significantly correlated indicating that households exercised preferences in terms of prey. The result also showed that only 14% of Santal and 7% of Oraon were familiar with the Bangladesh Wildlife (Conservation and Security) Act, 2012. Although the impact of wildlife hunting of these indigenous groups is still ambiguous, the present study provides a preliminary database of hunting practices of these communities for future conservation management.

Keywords: Correlation, hunting material, indigenous community, investigation, questionnaire survey, traditions, wildlife act.

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Author details: Azizul Islam Barkat and Sumaiya Akter are enthusiastic researchers majoring in Zoology currently. Ashikur Rahman Shome is a fellow graduate and his field of expertise is Zoology (Wildlife Biology). Fahmida Tasnim Liza is a postgraduate researcher in Zoology, and her research interests extend to wildlife parasitology and conservation. Md. Fazle Rabbe is also a fellow postgraduate who majored in Zoology (Wildlife Biology) and his research interests are biodiversity, wildlife disease and conservation.

Authors contributions: AIB and MFR designed the study and author AIB collected field data. FTL managed the analysis of the study and MFR produced the map. AIB, SA and ARS wrote the first draft of the manuscript. MFR and FTL edited the final version of the manuscript. AIB and MFR contributed equally in the study. All authors read and approved the final manuscript.

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INTRODUCTION

Wildlife has an economic, nutritional, cultural, and ecological role in human society (Chardonnet et al. 2002). Wild animals are a source of food (e.g., protein, fat), medicine, clothes, tools, and adornments as well as rituals and trade (Redford & Robinson 1991; Stearman & Redford 1995; Milner-Gulland & Bennett 2003; Bodmer et al. 2004). However, high rates of wildlife harvest for food and other needs has led to their depletion (Redford & Robinson 1991). Hunting is considered one among the major threats to wildlife worldwide and cause of species extinction (Aiyadurai 2011).

The southern Asian region is rich in wildlife, but has unsustainable hunting practices (Shackleton 2001; Aiyadurai et al. 2010; Nekaris et al. 2010; Aiyadurai 2011; Velho et al. 2012; Selvan et al. 2013). Communities living near the forest area largely depend on hunting for sustenance and cash income (Wilkie & Godoy 2001; Albrechtsen et al. 2007; Aiyadurai et al. 2010). Modern hunting technology increases threat to species due to high success rates (Aiyadurai et al. 2010).

Bangladesh is rich in wildlife as its' in the transition zone of the Indo-Himalayan and Indo-Chinese biogeographical regions (IUCN Bangladesh 2015a; Khan 2018). Indigenous communities, which number around 54, form 1.8% of the population of Bangladesh (BBS 2011; IWGIA 2019). They primarily rely on forest products for their religious, cultural, and socio-economic needs (Khisa 1998; Ferreira et al. 2009). Hunting is among their traditional practices that has led to the endangerment of several species in Bangladesh (Khisa 1998; Rana et al. 2009; IUCN Bangladesh 2015a; Khan 2018).

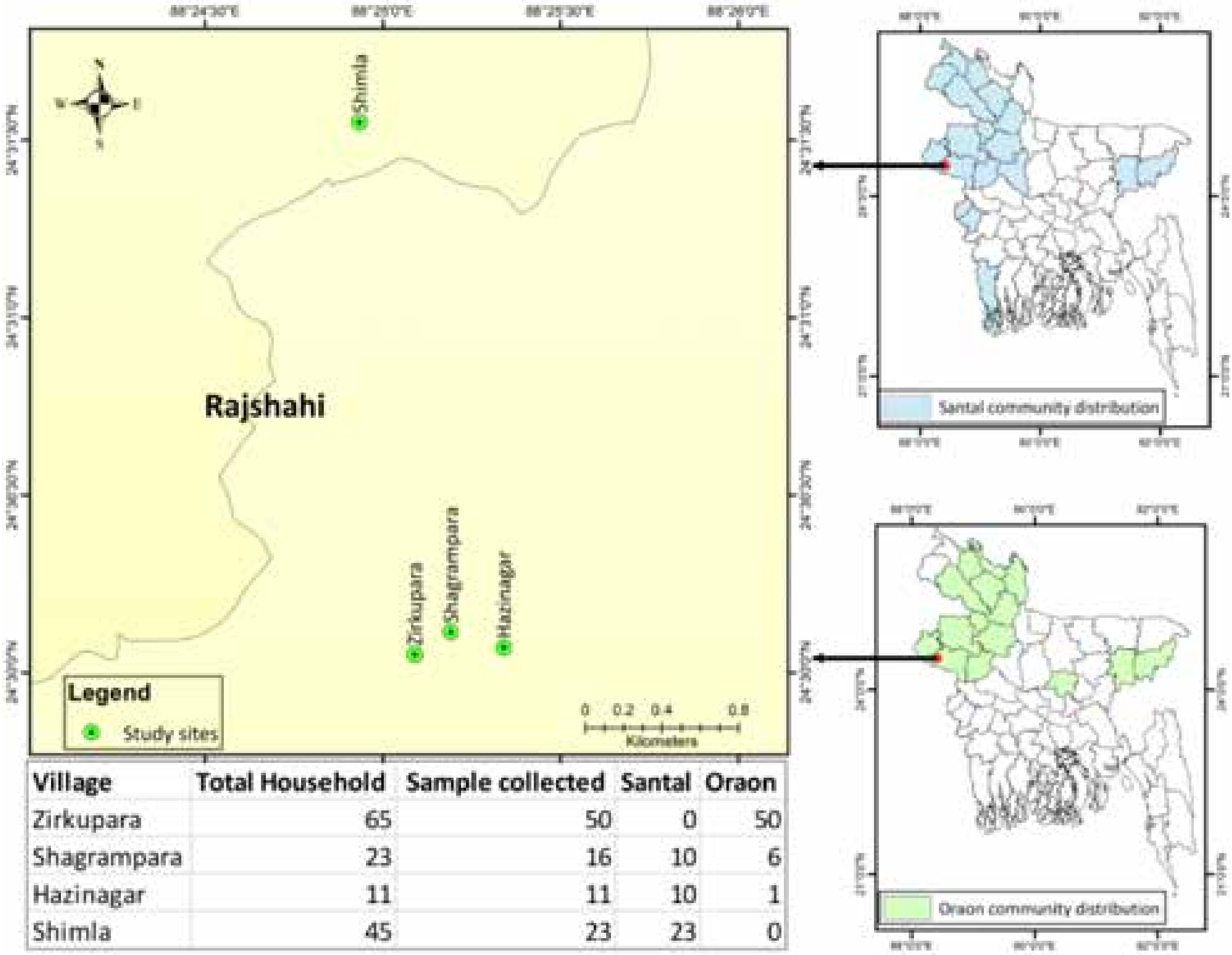
Indigenous people in Bangladesh are mainly clustered in the north, northeastern borders, northcentral region, and the greater Chittagong Hill Tracts (Chowdhury et al. 2014). Santal and Oraon are two indigenous communities living in Rajshahi and the surrounding area (Toppo et al. 2016). About 20% Santal people of Bangladesh are known to live in Rajshahi district whereas the population of Oraon community is increasing (Banglapedia 2014; Shamsuddoha & Jahan 2018). Every year, wild animals are hunted from char, beel and riparian areas of Rajshahi region. There is little information on how many animals are killed each year (Rana et al. 2009; Alliance 2016; Khan 2018). In this study, we have investigated the hunting practices of the indigenous groups in the Rajshahi district, Bangladesh as well as the correlation among the hunted animals.

MATERIALS AND METHODS

We conducted a study on wildlife hunting practices of two indigenous groups (Santal and Oraon) in four villages (Zirkupara, Shagrampara, Hazinagar, and Shimla) of Godagari Upazila at Rajshahi district from March to June 2020. The villages have a total of 144 households, and we collected data from 100 houses across all villages using a random sample method (Yates et al. 2008) (Figure 1). In the studied location, only males go hunting. Hence, we interviewed either male or female (if male respondent was absent) from a household and the female respondent was inquired about the male member's hunting habits. To cross-check the female's response, we asked comparable questions to other adult members of the family. Interviews were carried out with the aid of a field assistant who lived in the study area. The questionnaire was entirely close-ended and delivered in Bangla language (see supplementary file). We stayed up to 20 minutes per session to complete each interview mainly on their hunting practices.

We identified the wildlife hunted by the indigenous people through a pilot survey in the study area. We showed them photographic guides of wildlife (Khan 2018) to get an idea about the wildlife species hunted. Most of them could not identify the animal to species level, only as rabbit, jackal, mongoose, and jungle cat. Hence, we sorted the hunted animals into nine groups (Table 1). The respondents were found to be most familiar with mammals rather than other groups (e.g., birds, frogs). Thus, we finalized the questionnaire prioritizing the response of the interviewees by grouping Amphibia as frog, Reptilia as snake and tortoise, Aves as bird, and Mammalia as rabbit, mongoose, jackal, jungle cat, and rat. We sorted the questionnaires in a series of dichotomous (yes-no) questions, with the information of the wildlife being hunted. Besides, we asked interviewees if they actively hunt and if they were familiar with the Wildlife (Conservation and Security) Act, 2012 of Bangladesh.

To compare the hunting preferences and practices of the two communities, we used chi-square test with a 0.05 significance level. We also calculated the association between the hunted animals using Kendall's tau-b coefficient (R version 1.2.5001).



Village	Total Household	Sample collected	Santal	Oraon
Zirkupara	65	50	0	50
Shagrampara	23	16	10	6
Hazinagar	11	11	10	1
Shimla	45	23	23	0

Figure 1. Map of the study area with the current distribution of Santal (Shamsuddoha & Jahan 2018) and Oraon (Banglapedia 2014) communities in Bangladesh. The table represents the collected sample size for each group with total household number.

Image 1. Oraon male processing hunted rats for consumption. © Azizul Islam Barkat

RESULTS

Wildlife hunting practice of the indigenous communities

Overall, 76% of respondents (88.37% Santal & 66.67% Oraon) responded positively in the question of going hunting. The response varied significantly in two indigenous communities (χ^2= 6.331, p= 0.012). Among the nine animal groups, bird (73%) was the most hunted while snake (1%) was the least. Of the herpetofaunal animal groups, only 5% interviewees were found to hunt frogs, and 64% to hunt tortoises. We found rats as the most hunted mammal group (61%) and jackals the least (6%). Among other mammals, 44% of respondents hunted mongoose, 31% jungle cats, and 28% rabbits (Figure 2).

The positive responses of Santal and Oraon were significantly varied for hunting tortoise (p= 0.006), bird (p= 0.036), rabbit (p< 0.000), mongoose (p< 0.000), jackal (p= 0.040), and jungle cat (p< 0.000) (Table 1). In questioning whether they know about the Wildlife (Conservation and Security) Act, 2012, we found no significant difference among the indigenous groups (χ^2= 1.310, p= 0.252). Only 10 respondents (13.95% Santal & 7.02% Oraon) knew about the act but not many details of it.

Correlation of hunting different wildlife groups

Table 2 represents the correlation of hunting animals that consists of 36 pairs. The dual-trail verification showed that 18 pairs are significantly correlated. The correlativity of hunting 'mongoose' and 'jungle cat' demonstrates the maximum of '0.626'; indicating a significant fairly large overlap in hunting these two wildlife groups. The second highest value (0.545) of correlation is found for 'jungle cat' and 'rabbit' hunting. We also found some negative correlation pairs among the groups (e.g., jungle cat-frog, jungle cat-snake, rat-jackal).

DISCUSSION

The result showed that birds are most vulnerable to hunting (Figure 2). Among wild birds, doves (*Spilopelia* spp., *Streptopelia* spp.) are mostly hunted because of their availability and ease of capture. Besides, wild birds are a free source of meat. Locals hunt them with a variety of hunting materials such as catapults, snares, traps, and baits. Other indigenous communities in Bangladesh also use these techniques to hunt birds (Chowdhury et al. 2007, 2014). Besides, locals often steal chicks and juvenile from nests. Hunting, poisoning, and trapping of birds remain a big threat despite the strong law and popular sentiment against it (IUCN Bangladesh 2015b).

We found neither Santal nor Oraon are habituated to eating herpetofauna (excluding tortoises). We assume that locals do not regard herpetofauna as a good source of protein. But, in India both the indigenous groups eat snakes, frogs, and other herps (Ghosh-Jerath et al. 2015, 2016). We found only 5% (1% Santal & 4% Oraon) people eating frogs, 1% eating snakes and these did not differ significantly between the two communities (Table 1). For tortoises, the result showed a significant difference between the indigenous groups (p= 0.006). Tortoises used to be hunted on a regular basis, but their population number have suddenly plummeted in the area. So, locals either search for these animals in nearby habitats or purchase them from markets

Table 1. Wildlife hunting practices of the two indigenous groups with a list of animals hunted in the study area.

Genus/Species name	Group	Class	χ2	Yes (percentage)	
				Oraon (n=57)	Santal (n=43)
Hoplobatrachus spp.	Frog	Amphibia	1.136	4(7.01)	1(2.33)
Naja spp.	Snake	Reptilia	0.762	1(1.75)	0(0)
Morenia petersi, *Nilssonia* spp., *Pangshura* spp., *Lissemys punctata*	Tortoise[#]		7.436**	30(52.63)	34(79.07)
Spilopelia sp., *Streptopelia* spp., *Ardeola grayii*, *Ardea* spp., *Amaurornis phoenicurus*, *Acridotheres* spp., *Passer* sp., *Microcarbo niger*	Bird	Aves	4.399*	37(64.91)	36(83.72)
Lepus nigricollis	Rabbit	Mammalia	33.992***	3(5.26)	25(58.14)
Herpestes edwardsii	Mongoose		24.163***	13(22.81)	31(72.09)
Canis aureus	Jackal		4.237*	1(1.75)	5(11.63)
Felis chaus	Jungle cat		41.049***	3(5.26)	28(65.12)
Rattus spp., *Bandicota* spp.	Rat		0.853	37(64.91)	24(55.81)

Tortoise ([#]) is the only group that is either consumed by hunting or buying from nearby markets. p-value is represented in asterisk (*p≤0.05, **p≤0.01, ***p ≤ 0.001).

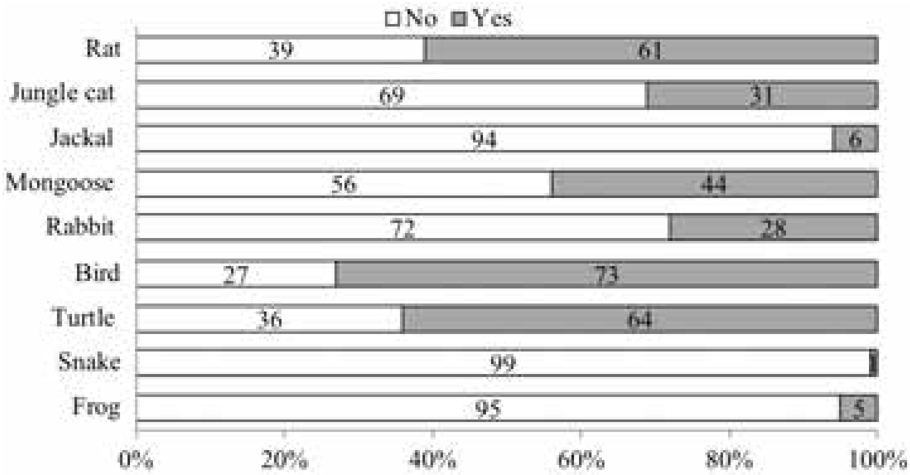


Figure 2. Percentage of hunting different groups of wildlife by indigenous communities.

Table 2. Kendall's tau-b coefficient results in hunting different groups of wildlife with p-value in asterisk mark.

Groups	Snake	Tortoise	Bird	Rabbit	Mongoose	Jackal	Jungle cat	Rat
Frog	0.438 ***	0.172	0.140	0.061	0.166	0.328 ***	-0.055	0.183
Snake		0.075	0.061	0.161	0.113	0.398 ***	-0.067	0.08
Tortoise			0.295 **	0.282 **	0.413 ***	0.014	0.232*	0.425 ***
Bird				0.221*	0.221*	0.059	0.213*	0.068
Rabbit					0.479 ***	0.218*	0.545 ***	0.179
Mongoose						0.200*	0.626 ***	0.296**
Jackal							0.286 **	-0.057
Jungle cat								0.181

(*p≤0.05, **p≤0.01, ***p≤ 0.001)

(BDT 700–800 per kilogram). Because of the high price, many cannot afford it and thus, actively go for tortoise hunting. Tortoises are highly-priced for both food and medicinal value (Harrison et al. 2016). Other than nutritional value, we also observed that people of these indigenous communities believe tortoise flesh has curative properties. They believe, it improves vision and keeping tortoise bone in cattle's feeding pot can heal foot and mouth diseases of cattle. Tortoise is also hunted by other indigenous communities such as Mro in Chittagong hill tracts of Bangladesh (Chowdhury et al. 2007, 2014).

Among mammals, rats are hunted mostly by the locals and there is no specific season for rat hunting (Image 1). The indigenous people hunt rats if they find them while working in cultivated land. However, they hunt the animal in huge number after harvesting the crops, so it becomes easier to look for rat nests or holes. We found that 55.81% Santal and 64.91% Oraon hunt rats for meat but their response was not significantly different (Table 1). This practice can lead to decreased use of rodenticides and not hunt the other ecologically useful wild species (Meyer-Rochow et al. 2015).

The hunting percentage for other mammals (except rats) differed significantly among the two communities (Table 1). Table 1 also shows that Santals prefer hunting mammals (e.g., jackal, rabbit, jungle cat) than Oraons. For example, 58.14% of Santal participated in rabbit hunting, whereas only 5.26% of Oraon did. Both communities go for traditional hunting early or late in the winter season. They generally go hunting in char lands, the adjacent area of their settlements, and nearest districts (e.g., Chapainawabganj) but sometimes, they travel further away to other districts (e.g., Naogaon, Joypurhat, Bogura, Kushtia, Pabna, Khulna) for 2–7 days. When they travel a long distance, they use turmeric powder on skinned prey for preservation. Usually, they go hunting with traditional arms (bow & arrow) in winter (Image 2) (Aiyadurai et al. 2010; IUCN Bangladesh 2015b).

We found that the majority of Santals are hunters (88.37%). Hunting is a common source of animal protein for their households. The studies of Sarker et al. (2017) and Das (2011) showed that Santals are very skilled in hunting different wildlife species (e.g., rats, birds, snakes) in Bangladesh though they are facing vulnerability in present times due to deforestation. Thus, they have started cultivating agricultural lands for livelihood. The Oraon community (66.67%) also harvests wildlife as well, but to a lesser extent than the Santal community. We observed during the survey that although most of the Oraon people are farmers, still a portion has selected other jobs and businesses that reduce their need to go hunting. Besides, the household members with higher economic status are more knowledgeable about wildlife conservation issues than others (Randolph et al. 2007).

Many studies on hunting showed correlation with different factors, like- number of hunters and catch (e.g., Nielsen 2006); distance and hunting rate (e.g., Chutia 2010); hunted species and body weight (e.g., Constantino 2016). We calculated the relationship of hunting different groups of wildlife in this study. The result showed a significant hunting relationship between two carnivores (mongoose-jungle cat). Small carnivores have similar habits and live in similar types of habitats (Chutipong et al. 2017). Hunters can easily hunt multiple species in similar habitats spending minimum effort. The relationship signified that hunters' response in hunting one of these species increases the chance of hunting the other one and vice versa. The negative relationship among other groups such as jungle cat-frog also supports our explanation.

The present study revealed that only 10% of the respondents were familiar with Bangladesh Wildlife Act 2012, as most of the older people of Santal and Oraon are uneducated or illiterate. They were even unaware that hunting wildlife is a crime. We found very few respondents who keep certificates of hunting permission from the police station or union chairman so they can go hunting. But, they could not show us any kind of certificates during the survey. Higher education is still lacking along with the workshops on wildlife hunting and conservation on behalf of the government. Because it is seen that the more these communities are educated, the more they are aware of wildlife conservation (Kaltenborn et al. 1999).

CONCLUSIONS

Indigenous communities harvest wild animals worldwide for different purposes which constitute essential ingredients in daily livelihoods (Ferreira et al. 2009). Santal and Oraon are two closely related indigenous communities of Bangladesh that rely on agricultural day labor. They are unable to buy meat from markets due to their poverty. As a result, they are compelled to hunt wildlife, especially for animal protein consumption. Again, it is seen that they go hunting whenever they are free or jobless. However, many of the respondents of this study also think that the wildlife population is declining due to hunting. We recommend some measures for the conservation of hunted animals in the area.

Image 2. Bow and arrow for hunting mammals like Jungle Cat and Jackal. © Azizul Islam Barkat

1. According to Bangladesh Wildlife (Conservation and Security) Act, 2012, wildlife hunting is a punishable offence; hence the law should be executed strictly to prevent illegal hunting. The government can impose a coordination committee to facilitate the quick execution of the existing law.

2. The respective authorities have to ensure the availability of suitable jobs (e.g., agro-farming, agribusiness) for indigenous people throughout the year.

3. Conservation education and awareness about wildlife should be disseminated among all the stakeholders for future wildlife conservation purposes and management.

4. Existing natural habitats should be conserved and more emphasis should be imposed to ensure undisturbed breeding and feeding grounds.

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Ethnozoological use of primates in northeastern India

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Abstract: Ethnozoological practices to cure various diseases have a long history. Communities that reside near the forest collect wild animals and their derivatives to prepare medicines and get relief from diseases. Northeastern India is home to many tribes with vast traditional ethnobiological knowledge, and there are many reports of zootherapeutic uses in the region. In an attempt to understand primate-based ethnozoologic use in the area a literature survey was carried out using different sources. The findings revealed that *Hoolock hoolock* was the most used species among the primates (48 %), followed by *Macaca assamensis* (20 %) and *Macaca mulatta* (10 %). Among the materials used, the flesh of primates was the most dominant (43 %), followed by the blood (20 %) and brain (14 %). This paper highlights the negative effects of ethno-medicinal uses of primates to draw the attention of conservationists and encourage conservation education to address the damage to primates in the name of health care. Government agencies are also requested to strengthen health care systems to discourage the killing of valuable primate species.

Keywords: Biate tribe, Hoolock Gibbon, Mizoram, traditional medicine.

Dimasa: Manang gda nising ning Dao-Mi jadzi nising gibin gibin glim-gasa khe ham ri yaba yawaithai phai pha bu lang ba. Hagra ni rogong ha dongyaba jadzi buthu hagra ni dao mi nising muli sandi slamhi glim gasa khe hamridu. North-East India ha gibin gibin jadzi buthuni muli sandi slamma ni ringma bangbi odehe mitsiba lai tsikhade, Dao-Mi ni bahain bugur khe bo muli sandi ne yawai ba ibu hathan ha bangbi. Magusa khe lahi muli-sandi yawaiyaba khe mitsimane mashi survey khlaiba. Survey ni yahon ha mitsikha je, magusa jadzi ni bising ha 'hulao' hoolock khe yawaidaothao (48%), buni yahon ha *Macaca assamensis* (20%) odehe *Macaca mulatta* (10%). Buha, magusha ni bahain khe yawaidaothao (43%), buni yahon ha bitsi (20%) odehe bikhlim (14%). Ibu lai ha magusa ni basao khe muli sandi ne yawaiba hamya ba khe phunu du odehe dao-mi khasaoyarao ode raokhiyarao khe ibu sibringmane thiladu. Government khe bo health care hamdaorimane bilahadu nabani tsikhade healthcare hamkha she nolaisarao bo dao-mi ni beher jang muli sandi slamba sai dao ma.

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INTRODUCTION

Faunal resources play vital roles in human life and societies (Alves 2012), where the importance of animals is manifested in religion, culture, art, music, dance, literature, food, economy, and magico-religious practices (Alves 2012). Use of animals and animal products to cure ailments is popularly known as 'zootherapy' and has been passed down generations through cultural transmission in several ethnic communities around the globe (Berkes 2009; Solanki & Chutia 2009; Nekaris et al. 2010; Jugli et al. 2019).

Non-human primates are an integral element in ethnozoology (Alves et al. 2010; Lee 2010; Svensson et al. 2015), which has can a range of effects on animals and their habitats (Hockings 2016). In Asia, Africa, and America primates are protected and revered to some extent due to their significant role in a number of agricultural, religious and cultural practices (Hockings 2007). On the other hand, primates are also considered a menace in agricultural and urban areas for stealing crops and food from fields and kitchens, inflicting economic damage (Mittermeier et al. 2005, 2007). This forms the basis of man-animal conflict resulting in retaliation killing, illegal trade, hunting for meat, fur, ornamental and medicinal purposes, and capture to be kept as pets (Mittermeier et al. 2005, 2007; Srivastava 2006; Hockings 2007; Alves et al. 2010; Devi & Radhakrishna 2013). Hunting and trade of primates for their medicinal value is an important factor for the decline of their populations (Nekaris et al. 2010). Alves et al. (2010) recorded a total of 101 species of primates that were used in ethnozoological practices and in magico-religious rituals all over the globe. Out of the 101 recorded primate species, 12 were classified as 'Critically Endangered' (CR), 23 as 'Endangered' (EN), 22 as 'Vulnerable' (VU), seven as 'Near Threatened' (NT), 36 as 'Least Concern' (LC), and one as 'Data Deficient' (DD) (IUCN Red List 2020). The species recorded were also included in Appendices I or II of CITES.

Northeastern India comprises eight states, viz, Assam, Arunachal Pradesh, Mizoram, Manipur, Meghalaya, Nagaland, Sikkim, and Tripura. The entire area falls under the Indo-Burma hotspot that harbors diverse species of plants and animals, most of which are endemic to the region. The region is home to *Nycticebus bengalensis* (Bengal Slow Loris), *Macaca mulatta* (Rhesus Macaque), *Macaca arctoides* (Stump-tailed Macaque), *Macaca assamensis* (Assamese Macaque), *Macaca leonina* (Pig-tailed Macaque), *Macaca munzala* (Arunachal Macaque), *Macaca leucogenys* (White-cheeked Macaque), *Macaca thibetana* (Milne-Edwards' Macaque, Tibetan Macaque), *Semnopithecus schistaceus* (Central Himalayan Langur, Nepal Grey Langur), *Trachypithecus pileatus* (Capped Langur), *Trachypithecus phayrei* (Phyare's Leaf Monkey), *Trachypithecus geei* (Golden Langur), *Hoolock hoolock* (Western Hoolock Gibbon) (Choudhury 2013; Talukdar et al. 2021). Their distribution varies, and some areas have higher diversity than others (Chetry et al. 2003; Choudhury 2013). The damaging scenario of ethno-primatology, i.e., the interactions between human and non-human primates, leading to decline of the latter is more or less same in northeastern India as elsewhere (Nekaris et al. 2010; Riley 2010; Riley & Feuntes 2011; Lee 2010; Alves 2012; Alexander et al. 2014; Svensson et al. 2015; Stafford et al. 2016). Most of the primates of northeastern India are categorized as vulnerable or threatened. The continuation of ethnozoological practices by the tribes is depriving them of modern medical advances and also resulting in rapid declines of primate populations in the region.

The Northeast region of India is the abode of about 145 tribes constituting around 12 % of the Indian ethnic population (Ali & Das 2003). In northeastern India, different workers have reported ethnozoological practices with various animals by different tribes (Solanki 2006; Solanki & Chutia 2009; Alves et al. 2010; Alves & Alves 2011; Ferreira et al. 2012; Betlu 2013; Devi & Radhakrishna 2013). Most recently, Jugli et al. (2019) studied the ethnozoological practice among the Tangsa and Wancho of eastern Arunachal Pradesh. However, none of the above studies have specifically focused on the detrimental scenario emanating out of the ethnozoological uses of primates. Therefore, the present study was attempted to identify the uses of primate species in traditional medicines in northeastern India and suggest remedial measures.

MATERIALS AND METHODS

To analyze the diversity of primates in the utilization of traditional medicines in northeastern India, available literature on folk remedies based on primate resources was reviewed. As majority of the works on ethnobiology have the primary focus on ethnobotany, a total of 11 papers were found related to the ethnozoological uses, especially in northeastern India. Scientific papers were downloaded from Google Scholar, PubMed, Research Gate and Academia using relevant keywords such as ethnozoology, ethno-zoology, traditional folk medicine, zootherapy, and primate. A database was created containing detailed information on primate species, body part used for medicine, mode of usage and name of the tribes.

RESULTS AND DISCUSSION

The study found that seven out of eleven primates in northeastern India are used in traditional medicine for the treatment of various ailments by different indigenous tribes. The utility of primates in the field of health care by the indigenous tribes of northeastern India is diverse (Table 1). Primates of the northeastern India are reported to be used for 38 different ailments. Large percentages (48%) of these ailments were reported from a single tribe while others had no information (Figure 1). Diseases such as malaria (10 %), tuberculosis (9 %), small pox (7 %), and typhoid (7 %) were found to be treated by using primates by multiple tribes. Among the primate used for ethnozoological practices, Hoolock gibbon is mostly used (57 %), followed by different *Macaca* sp. (40 %) (Figure 2). Capped Langur was mentioned only in one work from Arunachal Pradesh (Solanki & Chutia 2009).

Body parts of primates are used for treating various health conditions ranging from common ailments like headache and general body weakness to serious ones such as diabetes, malaria, typhoid, tuberculosis, and hernia (Table 1). Among the body parts of primates used for ethnozoological purposes, flesh was significantly preferred for the ethnozoological purposes ($\chi 2= 123$, $df= 9$, $p <0.001$). It was found that flesh of primates was mostly used (43 %), followed by blood (20 %), brain (14 %), and bone (8 %) (Figure 3). Body parts used for the treatment of some diseases are common irrespective of the tribes. For example, blood of Hoolock gibbon is used for the treatment of colic, and flesh of primates is used for the treatment of small pox and typhoid. Such common patterns of uses of body parts by ethnic people are important to understand the hunting pressure on the species. Flesh of Hoolock Gibbon is used by the Biate tribe for remedy of pertussis (Ronghang et al. 2011). Flesh of the same primate is used for cure against fever, typhoid, malaria, pox, asthma, tuberculosis, and liver cirrhosis in Arunachal Pradesh (Solanki & Chutia 2004, 2009; Jugli et al. 2019). Pregnant women of Lushai tribes of Mizoram take gibbon flesh to gain physical strength (Lalramnghinglova 1999; Chinlampianga et al. 2013). Flesh of Assamese macaque is used against pathogenic diseases like malaria, typhoid, tuberculosis, and

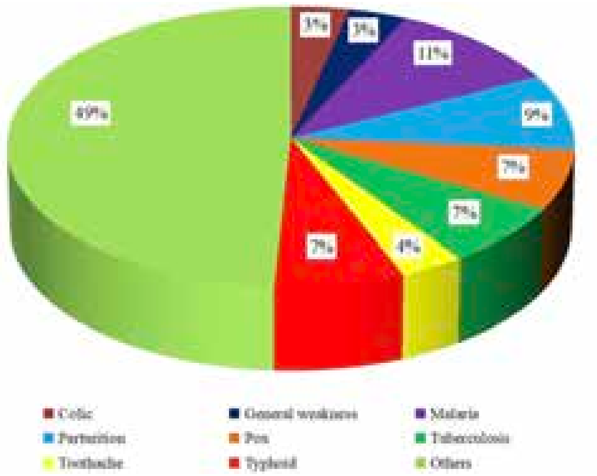

Figure 1. Ethnozoological practices of primate against various diseases in northeastern India.

Figure 2. Contribution of different primates of northeastern India in ethno-zoological practices.

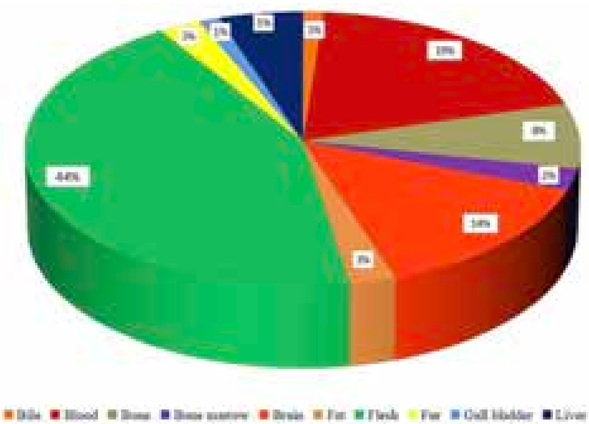

Figure 3. Body parts of primate use for the ethno-zoological practices in the northeastern India.

Table 1. List of primates and their body parts traditionally used as medicines for the treatment of various ailments by different ethnic tribes of northeast India.

State	Tribe	Animal	Body part used	Dried / fresh	Ailments	Mode of preparation	Reference	Conservation status		
								IUCN Red List status	WPA	CITES
Assam	Biate	*Hoolock hoolock*	Brain	Fresh	Painless parturition	Brain tissues are cooked and consumed with rice	Betlu 2013	EN	Sch I (Part1)	I
			Bone	Dried	Rheumatism	Bone pieces are tied to affected body part of man				
			Skull bone	Dried	Diziness	Gibbon skull bone pieces are tied to the head of human subject.				
			Hand	Dried	Hernia	Sun dried gibbon hands are rubbed onto the affected areas of man.				
		Macaca assamensis	Brain	Fresh	General weakness in pregnant women	Brain tissues are cooked and taken with rice to get body strength during pregnancy.		NT	Sch II (Part 1)	-
			Gall bladder	Dried	Diabetes	Dried up pieces are taken in with rice or sometimes with water.				
			Limb	Dried	Mumps	Dried up pieces are used for massage on the affected area.				
Assam	Karbi	*Hoolock hoolock*	Flesh / Bones	Dried	Pertussis	The powdered bone of Hoolock gibbon is taken in combination with of the flesh of *Acridotheres tristis* (Common myna), salt and water and made into a tablet and thus consumed.	Ronghang et al. 2011	EN	Sch I (Part1)	I
Arunachal Pradesh	Monpa	*Hoolock hoolock*	Flesh	Fresh	Serious fever, Typhoid, Malaria, Pox	Flesh, liver and blood are cooked and consumed.	Solanki & Chutia 2004, 2009	EN	Sch I (Part1)	I
		Macaca assamensis	Flesh	Fresh	Malaria, typhoid, Tuberculosis, small pox	Cooked and ingested.		NT	Sch II (Part1)	–
		Macaca mulatta	Flesh	Fresh	Malaria, typhoid, small pox	Cooked and ingested.		NT	Sch II (Part1)	–
		Trachypithecus pileatus	Flesh	Fresh	Malaria, typhoid, dysentery, small pox	Cooked and ingested.		VU	Sch I (Part1)	I
	Tangsa	*Hoolock hoolock*	Flesh, Liver, Blood	Fresh	Asthma, Malaria, Tuberculosis, Liver cirrhosis	Flesh, liver and blood are cooked and consumed.	Jugli et al. 2019	EN	Sch I (Part1)	I
			Blood	Fresh	Hypovolemia	Fresh raw blood is drunk.				
		Nycticebus bengalensis	Body fat	Fresh	Body pain and burns	Fresh body fats are preserved in the bamboo jar made up of bamboo (or in glass bottle) and massage given on the affected area as and when required.		VU	Sch I (Part1)	I
		Macaca assamensis	Brain	Fresh	Blood pressure, nausea	Brain is cooked and ingested directly.		NT	Sch II (Part 1)	-

State	Tribe	Animal	Body part used	Dried / fresh	Ailments	Mode of preparation	Reference	Conservation status		
								IUCN Red List status	WPA	CITES
Mizoram	Lushai	*Hoolock hoolock*	Flesh	Fresh or dried	Painless parturition	Cooked and consumed.	Lalramnghinglova 1999; Chinlampianga et al. 2013	EN	Sch I (Part1)	I
			Blood	Fresh	Colic, Hepatitis, Hemicrania	10ml fresh blood is taken at a time				
					Tuberculosis, Colic, Anaemia	Blood and country liquor (homemade) are mixed and taken.				
					Fracture of bone	Blood of Hoolock gibbon is taken, mixed it with turpentine oil and applied on the affected area.				
			Brain	Fresh	Toothache, Headache	Hairs on skull are removed by fire; it is then cooked. After that applied on the affected teeth and also taken or eaten for cure against headache.				
			Brain	Dried	Tooth decay, Bee sting	Cooked brain preserved in a container over fire is grounded to powder and applied on tooth decay and bee sting				
			Bone marrow	Fresh	Sciatica, Paralysis	Bone marrow is taken out from Tibia fibula and is cooked and rubbed on the affected areas.				
			Bone	Dried	Prevent attack of diseases	A small part of the bone is tied with thread that hangs on the wrist or waist.				
		Nycticebus bengalensis	Fur	Dried	Wounds and cuts Haemostatics	Fur is wrapped around the affected area		VU	Sch I (Part1)	I
		Macaca assamensis	Flesh	Fresh	Easy labour during pregnancy	Flesh is cooked and consumed		NT	Sch II (Part1)	–
			Brain	Fresh	General weakness	Brain is cooked and served to the children for consumption.				
			Bile	Fresh	Malaria	Bile is cooked and taken.				
Manipur	Meitei community	*Macaca mulatta*	Brain	Fresh	Postnatal women	Brain is cooked and taken as food.	Devi & Radhakrishna 2013	NT	Sch II (Part 1)	-
Tripura	Tribes in Khowai district of Tripura.	*Macaca mulatta*	Flesh	Fresh	Joint pain	Flesh is cooked and taken as food.	Das 2015	NT	Sch II (Part 1)	
Nagaland	Naga	*Macaca sp.*	Flesh	Fresh	Tuberculosis, stomach disorder, general weakness	Flesh is cooked and taken as food.	Jamir & Lal 2005			

IUCN—International Union for Conservation of Nature and Natural Resource | WPA—Wildlife Protection Act of India, 1972 | CITES—Convention on International Trade in Endangered Species of Wild Flora and Fauna | EN—Endangered | VU—Vulnerable | NT—Not Threatened.

smallpox in Arunachal Pradesh, while in Mizoram, tribal people believe that consumption of flesh of the same species helps in painless parturition. Flesh of Stump-tailed Macaque is used against pathogenic diseases such as malaria, typhoid, and smallpox in Arunachal Pradesh, while Naga tribe of Nagaland use the flesh of the same species for cure of tuberculosis, stomach disorder and general weakness (Jamir & Lal 2005). Tribal people in Khowai district of Tripura use the flesh of Stump-tailed Macaque as pain killer (Das 2015). Flesh of Capped Langur is used against malaria, typhoid, dysentery, and smallpox by the tribes of Arunachal Pradesh.

Brain of Hoolock Gibbon, Rhesus and Assamese macaques was reported to be used against different diseases (Lalramnghinglova 1999; Betlu 2013; Chinlampianga et al. 2013; Devi & Radhakrishna 2013). Fresh brain tissues of Hoolock Gibbon was found to be used by Biate tribes of Dima Hasao district, Assam as they believe that it acts as an invigorating stimulant for pregnant women (Betlu 2013). In Mizoram, brain tissue in paste form is applied for toothache, taken orally to get rid of headache, and sometimes the brain tissues are dried up, and the dry powder is used against tooth decay and as a cure for bee sting (Lalramnghinglova 1999; Chinlampianga et al. 2013). Brain of Assamese macaque is used to gain physical strength during pregnancy by the Biate tribes of Dima Hasao district of Assam (Betlu 2013) while some local tribes of Arunachal Pradesh believe that the consumption of a fresh brain of the macaque controls blood pressure and cures one of nausea (Chinlampianga et al. 2013). Lushai tribes of Mizoram consume it for gaining physical strength (Lalramnghinglova 1999). The Meitei women of Manipur take the brain of Rhesus Macaque during postnatal period (Devi & Radhakrishna 2013). Blood of many primate species is used by various tribes of northeastern India for a variety of purposes. In Arunachal Pradesh, the Tangsa tribe use the fresh blood of Hoolock Gibbon to cure diseases such as asthma, malaria, tuberculosis, liver cirrhosis, and weakness caused by hypovolemia (decreased blood volume). Among the tribes of Mizoram, blood of Hoolock Gibbon was reported to be used for hepatitis, hemicrania, tuberculosis, anemia, bone fracture, and colic problem in children.

Bones of primates are used for different ailments (Table 1). Dried bone of Assamese Macaque is used by the Biate tribe to cure mumps. The bone of Hoolock gibbon is used by the Biate tribe of Dima Hasao district (Assam) against hernia, rheumatism, dizziness, and against pertussis by the Karbi tribe of Karbi Anglong district, Assam (Ronghang et al. 2011). The tribal people of Mizoram use bone of gibbon as they believe it acts as a vaccine and prevents attack of diseases. Gall bladder of non-human primates is used by the tribes of Arunachal Pradesh for getting relief from high fever caused by malaria and typhoid (Solanki & Chutia 2009).

In several cases, ethnic communities prepare the animal-based medicines either singly or in combination, and some are consumed raw or preserved. In some cases, the animal body parts are preserved by drying under the sun or are smoked or fire-dried (Betlu 2013; Jugli et al. 2019). Although Rhesus Macaque is commonly used as ethnozoological medicine among all the tribes of the region, there has been no published literature on this and the other primates except Hoolock gibbon, which is mostly reported for its uses against multiple diseases (Figure 3).

Apart from their uses as ethnomedicines, body parts of primates are also used for a variety of other purposes by the ethnic communities. They are hunted for food, sport or ceremonial and ritualistic purposes (Devi & Radhakrishna 2013). For instance, the fur of primates is used in making the local hat 'Yangcha' of the Monpa people of Arunachal Pradesh (Solanki & Chutia 2004). Betlu (2013) reported that Hoolock Gibbons are kept as pets by Biate tribe of Dima Hasao district of Assam. It was also reported that the smoked meat of Capped Langur and Hoolock Gibbon was in high demand and would cost approximately INR 350–400 per kilogram.

The study found multiple ethnozoological uses of same organs of primates by the tribes while some organs are commonly used by the different tribes for the same disease. This needs to be prevented and deserves sincere attention of conservationists. Among a few tribes there exist myths or folktales about the demerits of consumption of animal species. Though most of the communities think that body parts of slow loris are useful, the tribal communities of Manipur believe that consuming their flesh causes severe illness. There also exist other beliefs among the tribal communities that are helpful in upholding the ethos of conservation. According to some communities of Manipur, Hoolock Gibbons reproduce at full moon and also die at full moon, thus a circle is maintained. For the sake of conservation, such belief systems need to be promoted on a large scale as they can contribute to reducing the hunting pressure for ethno medicines. As the primates in the area are also facing innumerable threats like scarcity of food, habitat fragmentation and shrinkage, the tribal people should be prevented from hunting them. The tribes should be made aware of the penal provisions as contained in the Wildlife (Protection) Act, 1972, CITES etc. To spread the message of conservation, sufficient numbers of awareness campaign needs to be given among the tribes to reduce their dependence on primates.

CONCLUSION

This study documents the negative uses of primate resources in traditional healthcare systems by the indigenous people of northeastern India. Many endangered and vulnerable primates that are used for zoo-therapeutical purposes are collected from the wild and killed to obtain the desired organs or body parts. This sets pressure on the survival of the species in particular and on the biodiversity of the region in general. All the primates of northeastern India are facing multiple threats, and hence the tribes should not be allowed to hunt them. Unlike plants, there is no scientific basis/ evidence for the medicinal values of primates, and since cheaper and easier medicines are available almost everywhere, communities should be barred from killing such precious animals. Governments should also take up initiatives to open adequate health care centers and hospitals in the interior villages, so that the tribal people are exposed to scientific health care systems. In order to strengthen their conservation, community awareness needs to be undertaken to reduce dependency on primates for traditional healthcare.

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COMMUNICATION

Factors influencing the flush response and flight initiation distance of three owl species in the Andaman Islands

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Abstract: Effects of anthropogenic pressures on birds of the Andaman Islands have been documented to some extent, however studies on the effect of human activities on the behavioural response of these birds are limited. This study assessed the anti-predatory behaviour (flush response - FR and flight initiation distance - FID) of three owl species (*Otus sunia*, *Otus balli*, and *Ninox obscura*) in response to human stimuli and factors influencing it on the Andaman Islands. In total, 63 % of owls flushed from their roost sites in response to approaching human, and such a response varied between species. Similarly, FID varied widely among the species ranging from 4.23 to 6.73 m. The FR of *N. obscura* was influenced by the count of climbers, presence of spine, and branch status, while roost height, ambient temperature, and lower count of climbers contributed to a higher FID. For the two *Otus* species, camouflage and pairing were found to influence their FR while FID of *O. balli* was influenced by roost height, pairing, and presence of spines. Our results indicated that the anti-predatory behaviour of owls on the Andaman Islands was species- and site-specific and prolonged disturbance to their roost sites may affect the survival and reproductive rate of these owls.

Keywords: Anti-predatory behavior, camouflage, human disturbance, predator avoidance, roost site.

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Author contributions: SS, SB & HNK designed the study; SS & NR collected data; SS analyzed and wrote the article with inputs from SB and HNK.

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INTRODUCTION

The presence of people in bird habitats can be considered as a form of disturbance to the birds because they may perceive humans as potential predators, much like their natural predators (Walther 1969). In such situations, birds either flee or show alertness by assessing the level of threat that such human presence poses to them (such as the mode and direction of approach by people) (Grubb & King 1991; Cooper 1997; Sapolsky et al. 2000; Papouchis et al. 2001; Cooper 2003). Alertness and fleeing have been linked to insufficient parental care (Zuberogoitia et al. 2008), lower foraging times (Velando & Munilla 2011) and a lack of attention to other potential predators (Anderson & Keith 1980). When a threat is detected, some birds would not fly immediately but assess the intensity of such a threat by showing extreme alertness. The response (flight) of birds to humans has been evaluated in different ways and the most common measures are flush responses (FR) and flight initiation distance (FID), the distance at which the bird decides to flee in response to an approaching human.

Diurnal roost sites play an important role in determining the fitness and survival of owls, and hence the selection of a roost plays an important role in the birds' life history characteristics (Ganey et al. 2000). Suitable roost sites may provide owls with the required microclimate which may reduce the energetic costs of thermoregulation (Barrows 1981), provide protection from predators (Bradsworth et al. 2021) and also help avoid parasites to increase their fitness (Rohner et al. 2000; Solheim et al. 2013). To certain extent, a species' social behaviour such as pair bonding (Collins et al. 2019), camouflage and plumage (Møller et al. 2019) also found to have an influence on their predator avoidance tactics. There have been many studies on the effects of human disturbance on the nesting of various bird species (Watson 1993; Dowling & Bonier 2018; Collins et al. 2019) but, except for one study, research on the effect of human activities on roosting owls is limited.

The Andaman & Nicobar Islands has been recognized as an endemic bird area due to the high number of endemic birds. These islands (and in turn, birds found on the islands) have been facing severe anthropogenic pressures including the impacts of selective logging, extraction of climbers (canes), invasive species, tourism, and collection of non-timber forest products. While the effects of these threats on birds have been documented to a certain extent, research on the effect of human activities on endemic birds, especially nocturnal animals, are limited. Out of three species selected for this study, two (*Otus balli* and *Ninox obscura*) are endemic to Andaman Islands. Hence, this study assessed the FID and FR of three species of owls, *i.e. Otus balli*, *Otus sunia*, and *Ninox obscura*, in the Andaman Islands, and examined the factors influencing the FID and FR of these species.

MATERIALS AND METHODS

Study site

This study was conducted on the four large islands of the Andaman archipelago (North, Middle, Baratang, and South Andaman Islands), which covers an area of about 3,447km^2. The land is an uplifted earth surface (Malik et al. 2006) and the altitude of Andaman Islands ranges from 0m to 731m (in Saddle Peak). The Andaman forests can be classified into 11 different forest types based on floral composition. This study was conducted only in three forest types, namely, evergreen, moist deciduous, and secondary moist deciduous. The evergreen forests are dominated with large trees of evergreen with dense understory vegetation, mostly climbers. Having irregular canopy, the moist deciduous forest stands are distinguishable by large deciduous trees with the understory stratum dominated by cane and other climbers. The secondary moist deciduous forests are selectively felled areas and thus with reduced structural complexity (Champion & Seth 1968). Other than the wood-based industry, tourism, fishery and agriculture are the major option to maintain the socio-economic balance on the Andaman Islands.

Study species

The Andaman archipelago supports five owl species namely the Andaman Scops-owl *Otus balli*, Oriental Scops-owl *Otus sunia*, Hume's Boobook *Ninox obscura*, Andaman Boobook *Ninox affinis*, and Andaman Barn Owl *Tyto deroepstorffi* (Rasmussen & Anderton 2005). Among them, we selected only three species namely *O. balli, O. sunia*, and *N. obscura* for this study (Image 1–3) as we had sufficient roost locations for these species. *N.obscura* and *O. balli* are endemic to these islands, whereas *O. sunia* is found throughout the tropical countries of central Asia as well as eastern Asia from Japan to the Malay Peninsula. *Otus balli* was considered as stenotopic in habitat use whereas the other two species are found to be eurytopic (Babu et al. 2019).

Image 1. Andaman Scops-owl *Otus balli*

Image 2. Oriental Scops-owl *Otus sunia*

Image 3. Hume's Boobook *Ninox obscura*

Data collection

All the experiments were conducted on roosting owls of the three species during summer season (February–May) for three consecutive years (2014–2017). We selected this season because of the accessibility to all forest types and feasibility to conduct the experiments on roosting owls. Since this period is coinciding with the breeding season of these owls, we made sure that none of the experiments were conducted on breeding owls by avoiding experiments on owls that were roosting in tree holes. In general, Andaman owls are known to utilize tree holes during breeding season. Prior to the experiments, we located roosting owls by tracing their last vocalization locations during the early morning hours. After marking roost location, we visited the same site around noon (1100–1200 h) and conducted our experiments. Roosting owls, which were detectable from around 10m distance were considered for the experiment. We located roosting of all owls from a approximate distance of 10m because in some roost sites, we could not see the owls at 10m distance from their roost site due to the thick vegetative cover around the roost site and smaller size of the owls. In the selected sites, the experiment was conducted by a single observer with the same dress by walking directly

Table 1. Factors hypothesized to influence the flight initiation distance and flush responses in owls from the day-time roost sites in Andaman Islands.

	Descriptions of factors	Abbreviation	Coding in the analysis	Unit
1	Roosting as pair either with or without physical contact but on the same tree	PAIR	1	Binary
	Solitary		2	
2	Displaying camouflage behaviour when observer approach (for example: closing eyes, elongating body)	CAMFG	1	Binary
	Staring at the observer without any physical changes		2	
3	Presence of spines at the roosting branch	SPINE	1	Binary
	Absence of spines at the roosting branch		2	
4	Number of climbers on the roosted plant	CLIMB		Count
5	Status of the roosting branch - alive	STATUS	1	Binary
	Status of the roosting branch - dead		2	
6	Roost height of owls (*i.e.* from the ground)	HEIGHT	Continuous	Meters (m)
7	Distance at which the observer started to walk towards the roosted owl	BENNG	Continuous	Meters (m)
8	Temperature at the roost site	TEMP	Continuous	Degree Celsius (°C)
9	Relative humidity at the roost site	HUMI	Continuous	Percentage (%)

towards roosting owls with a minimum speed of one step per second and recorded the response behaviour of the owls. If the owl was flushed from the roost site, then the observer stopped to proceed further and measured the distance from the roost site with the digital range finder. In case of a pair, even one bird being flushed from the roost was considered as FR. If the owl did not flee at all even at 1 m distance, it was categorized as not-flushed. While conducting the experiment, we recorded all camouflage behaviours of owls such as elongating its body, erecting their ear tufts and sliding to an angle. We measured all habitat and climatic variables at the roost sites regardless if birds were flushed or otherwise. The detailed description of the variables and method of measuring and coding are given in Table 1.

Statistical analysis

Since the roost site selection of the owls may vary across the habitat (unpublished data), to maintain the uniformity in the experiment, we retained only the experiments conducted in evergreen forest and moist deciduous forests for *O. balli* and *O. sunia*, respectively. However, roosts of *N. obscura* were mostly found along the edges of the evergreen and moist deciduous forests. To know whether the FID and FR of *N. obscura* vary between habitat types, we ran univariate t tests for FID and chi-square test for FR of *N. obscura*. We found no difference in the FID (t= -0.959, df= 51, p= 0.342) and FR (X^2= 0.02, df= 1, p= 0.886) between the habitat types and hence we pooled our data for *N. obscura*.

We arranged the data species-wise and checked for normality by Shapiro-Wilk statistic for continuous variables and examined the histogram and boxplots to identify outliers and residuals (Miles 2014). Since the starting distance was not normally distributed, it was $\log_{10}$ transformed to meet the normality assumption beforehand. One-way ANOVA was applied to find out the difference in FID and FR between species. We ran logistic regression analysis for each species separately to predict the most important variable(s) that influence FR in owls. We applied multiple linear regression analysis to assess the importance of variables' contribution to FID. For both analyses, we generated global model by including all predictor variables (temperature, humidity, starting distance, number of climbers, branch, presence of spines, species camouflage behaviour, roost height and pair. Later, we removed variables that were not statistically significant (p ≥0.05) from the model using backward selection. We used R^2 values for linear regressions and drop-in-deviance test for the logistic regression to assess goodness-of-fit of each resulted model (Swarthout & Steidl 2001).

RESULTS

In total, 180 experiments with an average starting distance of 11.99 ± 3.18 m for *O. balli,* 21.52 ± 2.47 m for *N. obscura*, and 13.94 ± 4.57 m for *O. sunia* were used for analysis. Of these, owls were flushed from their roost during 133 attempts (63 %) (Table 2). We found significant difference in FR ($F_{2,\ 177}$= 7.472, p <0.001) among the three species. *N. obscura* (x^2= 12.262, df= 1, p <0.001) and *O. sunia* (x^2= 9.779, df= 1, p <0.05) were more likely to be flushed than did *O. balli*. However, *N. obscura* and *O. sunia* were not significantly different in terms of FR (x^2= 0.163, df= 1, p >0.05).

When looking into the variable that influence the FR of all three species, the negative influence of pairing (β= -2.248 ± 1.0725, p <0.05), and camouflage behaviour (β= -2.723 ± 1.3687, p <0.05) of *O. balli* were found to be the reason for their tolerance to approaching human, compared to the other two species (Table 3). However, the FR of *N. obscura* was largely influenced by the roost tree characteristics *i.e.* presence of climbers (β= -0.787 ± 0.6963, p <0.05), spines (β= -1.623 ± 0.7583, p <0.05) and status of the branch (β= -1.660 ± 0.7413, p <0.05). The FR of *O. sunia* was influenced by species pairing (β= -1.884 ± 0.8611, p <0.05), roost height (β= 0.604 ± 0.2585, p <0.05) and camouflage behaviour (β= 1.283 ± 0.6393, p <0.05) (Table 3).

We recorded relatively a higher FID for *N. obscura* (6.78 ± 0.22 m) than the other two sympatric owls (*O. sunia*= 5.48 ± 0.3 m and *O. balli*= 4.23 ± 0.42 m). The FID among three species of owls was significantly different ($F_{2,110}$= 13.066, p <0.05) and post-hoc test showed significant differences in FID between *O.balli* and *N. obscura* (p <0.001), and *O. sunia* and *N. obscura* (p <0.001). But there was no significant difference in FID between *O. balli* and *O. sunia* (p >0.05). Ninety-five percent of *O. balli* flew at a distance of 8 m in response to approaching human while the distance was around 11 m for both *O. sunia* and *N. obscura* (Figure 1). The maximum FR was observed at a distance of 3 to 6 m for *O. balli* and *O. sunia* while it was 6 to 9 m distance for *N. obscura* (Figure 02). Roost height, pairing and presence of spine were the important predictors for the FID of *O. balli* while it was roost height, temperature and count of climbers for *N. obscura* (Table 4). None of the quantified variables contributed significantly to the FID of *O. sunia*.

DISCUSSION

In 63% of the trials, owls were flushed out from their roost sites when humans approached. Several factors such as the predator's approaching direction, speed and mode have been reported to influence flush response in birds (Spaul & Heath 2017). Though we did not test the effect of different approaching methods on the FR of owls, Grubb & King (1991) reported that birds perceive a higher threat from humans on foot than any other mode of approach. Our observation also corroborated with Holmes et al. (1993) where grassland raptors in Colorado were reported to be flushed out more frequently in response to human on foot (97%)

Table 2. Mean flight initiation distances and percent of flush responses of three owl species to approaching human in Andaman Islands.

Species	*n*	Number of owls flushed (%)	Flight Initiation Distance (m)		
			$\bar{x}$	SE	Range
O. balli	38	14 (37)	4.23	0.42	1.36 – 07.30
O. sunia	69	47 (68)	5.48	0.30	1.42 – 11.25
N. obscura	73	52 (71)	6.78	0.22	3.05 – 10.36
Total	180	113 (63)	5.93	0.19	1.36 – 11.25

Table 3. Factors influencing the flush response of three owl species to approaching human in Andaman Islands.

Species	*n*	Factors [a]	β	SE	Wald's X^2	*p*	Odds ratio
O.sunia	69	PAIR	-1.884	0.8611	-2.188	0.028	0.123
		HEIGHT	0.604	0.2585	2.339	0.019	0.448
		CAMFG	1.283	0.6393	2.008	0.044	5.761
O.balli	38	PAIR	-2.248	1.0725	-2.096	0.036	0.106
		CAMFG	-2.723	1.3687	-1.990	0.046	0.066
N.obscura	73	CLIMB	-0.787	0.6963	-1.130	0.037	0.455
		SPINE	-1.623	0.7583	-2.141	0.032	5.071
		STATUS	-1.660	0.7413	-2.239	0.025	0.190

[a]—Refer Table 1 for description of variables.

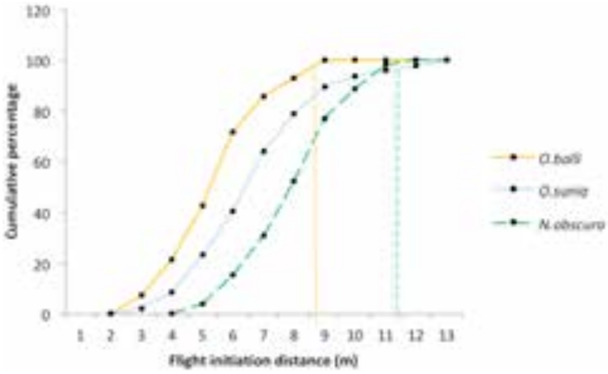

Figure 1. Flight initiation distance of flushed owls in response to approaching human and the straight line indicates the 95 % of sampled flushes occurred at the distance from the human.

Table 4. Factors influencing flight initiation distance of *O. balli* and *N. obscura* to approaching human in Andaman Islands.

Species	*n*	Factors [a]	Estimate	SE	*t*	*P*
O. balli	14	Intercept	19.40	9.25	2.098	0.081
		HEIGHT	-1.312	0.43	-3.031	0.023
		PAIR	2.305	0.89	2.588	0.041
		SPINE	-3.526	0.96	-3.642	0.011
N. obscura	52	Intercept	-17.65	9.45	-1.867	0.068
		HEIGHT	-0.413	0.13	-2.984	0.004
		TEMP	0.898	0.32	2.779	0.007
		CLIMB	-1.697	0.78	-2.158	0.036

[a]—Refer Table 1 for description of variables.

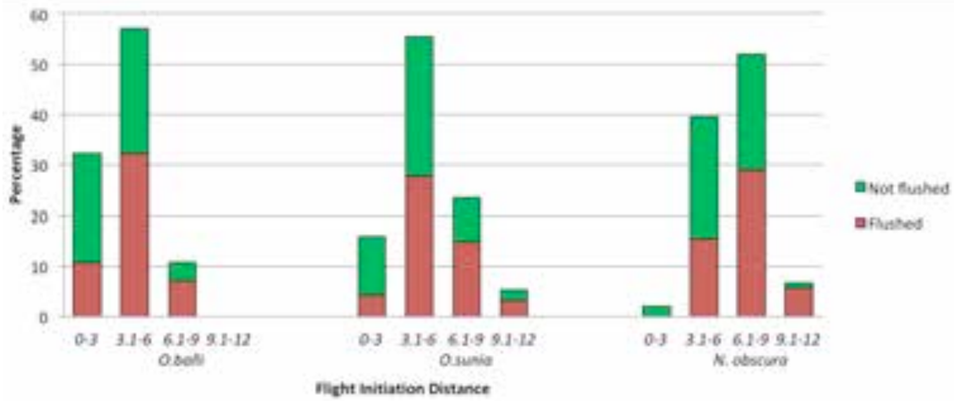

Figure 2. Closest distance (in m) an observer approached three owl species at their roost sites and the percentage of the responses.

than vehicular ones (38%).

The average FID of all three species in the Andamans (Table 2) was very low compared to the Mexican Spotted Owl (≥24 m) (*Strix occidentalis lucida*; Swarthout & Steidl 2001), and this might be due to the availability of potential refuge sites and the size of the owl. The FID of Mexican spotted owls was studied in open canyons that have limited refuge sites in the vicinity of roosts. In contrast, the availability of refuge sites around the roosting sites of three owls were higher (unpublished data). The Mexican spotted owls are relatively larger (wing span 302–328 mm) compared with our study species *O. balli* (wing span 133–143 mm), *O. sunia* (wing span 137–145 mm) and *N. obscura* (wing span 197–220 mm) (König et al. 1999).

We also found species-specific FID and FR, which corroborated with other studies (Burger & Gochfeld 1998; Blumstein et al. 2003; Braimoh et al. 2018). Previous studies demonstrated species-specific responses that are driven by several factors such as previous exposure to humans (Sproat et al. 2020), individual experiences (Martín & López 2015), hunting pressure (Stankowich 2008; Sproat et al. 2020) and life history strategies (Bennett & Owens 2002). In this study, *N. obscura* showed a higher FR and FID compared to the other two species. Possible explanations for a higher FR and FID in *N. obscura* could be its larger body size and dark plumage, as well as the poaching pressure on the islands. Among the three species, the body size of *N. obscura* is relatively larger. It has been widely recognized that body size is an important factor to elicit higher FRs in many organisms (Gotanda et al. 2009). The darker plumage of *N. obscura* also attracts more attention from humans as it is more visible against the green surroundings of its habitat, which could result in a higher FR. Similarly, Holmes et al. (1993) observed higher FRs and FIDs in the dark morphs of Rough-legged Hawks *Buteo lagopus* and Ferruginous Hawks *Buteo regalis* than in light morph birds. Our unpublished data on perceptions about owls among the residents of the Andamans revealed that

N. obscura and *O. sunia* are highly susceptible to being poached on the basis of various myths and superstitious beliefs that surround these species. On the islands, *O. balli* occupies undisturbed evergreen forest stands leading to minimal interactions with human and hence it showed a lower FID in this study. This observation corroborated with the results of a study on the FID of Capercaillie *Tetrao urogallus* in central Europe (Thiel et al. 2007), where a low hunting pressure and the occupancy of an undisturbed habitat by the species had been found to reduce its FID.

The count of climbers, presence of thorny vegetation and status of the branch (whether they were dead or live) influenced the FR of *N. obscura* (Table 3) while the count of climbers, roost height and temperature influenced its FID (Table 4). Higher number of climbers in a roost tree could influence the FR & FID in two ways; first, climbers on the roost tree may provide better concealment by increasing vegetative complexity around the roosting substratum, thus providing good hiding spots from predators. Secondly, dense climbers around the roost site may provide a more favorable microclimate by breaking down hot gusts of wind and providing insulation against the diurnal heat (Walsberg 1985). The presence of spines in the roost branch decreased the FR nearly fivefold (Table 3) because spines could physically impede predators from reaching the roosting owl. The positive association of atmospheric temperature with species' FIDs implies that an increase in temperature increases the FID and it is also evident that *N. obscura* initiated flight quickly in response to the approaching predator when the temperature of roost site was unbearable (Table 4). An experimental study on the captive Mexican Spotted Owls found that the birds initiated flight swiftly when temperature was higher (Ganey et al. 1993). At higher temperatures, an owl could be in heat-related stress.

Unlike *Ninox obscura*, the FR and FIDs of the two sympatric *Otus* species were largely determined by the species' behavioural mechanisms rather than their selection of roosting microhabitats. We found that pairing and camouflage behaviour influenced the FR of both species. Pair status negatively influenced the FR of both *Otus* species. Owls roosting solitarily were flushed out faster in response to an approaching human than those roosted in pair. The reason for a lower FR while in pair is to increase their reproductive fitness. In such cases, such birds use camouflage as a defensive behaviour to avoid detection and secure breeding opportunities.

In our study, the camouflage mechanisms of species were identified as a possible influencing factor in the FR of *O. balli* and *O. sunia* but their relationship was opposite. Camouflage behaviour might work in two different ways for the two owl species. When a predator approaches, usually prey species would move immediately to a safer place, whereas a cryptic species like owls are flushed out slowly (Hemmingsen 1951). Their late department is an unusual response that is expected to scare and startle the predator, which is termed close-quadrat effect (Nishiumi & Mori 2015). Another advantage of using camouflage behaviour prior to a FR is to maximize energy by freezing before initiating an energy-intensive escape flight (Samia et al. 2016). In *O. sunia*, individuals showing camouflage behaviour are likely to be flushed out more than individuals not showing any response to the approaching human. In this study, habituation might be an important reason for the observed responses from *O. sunia.*

Roost height influenced the FID of *O. balli* and *N. obscura*. In both species, roost height was negatively associated with their FID, which could be due to the decrease in predation risk at a higher roost (Tables 3 & 4). A similar relationship has also been reported in other raptors (Holmes et al. 1993; Steidl & Anthony 1996). Higher perches afford greater visibility of approaching disturbances, which has been shown to increase the FR rate and FID of Bald Eagles *Haliaeetus leucocephalus* (Steidl & Antony 1996). In Utah and Arizona, the female Mexican Spotted Owls that nested at higher locations changed their activity budgets in response to hikers more so than females that nested at lower locations (Swarthout 1999). Higher perches are considered safer and are also likely to facilitate the display of aggression to other group members (Portugal et al. 2017).

Both the FID and FR of *N. obscura* are negatively influenced by the count of climbers, and in particular, canes. Therefore, the extraction of canes on the islands may affect the roosting habitat and behaviour of this species compared to other two *Otus* species. Further studies focusing on the effect of cane extraction and selective logging on the roost selection of these endemic owl species is warranted. Our results indicated that the anti-predatory behaviour of the owls on the Andaman Islands was species and site specific and prolonged disturbance to their roost sites may affect the survival and reproductive rate of these owls.

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Birds of Barandabhar Corridor Forest, Chitwan, Nepal

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Abstract: Long term monitoring of bird species was conducted in Barandabhar Corridor Forest, one of the important bird areas of Nepal (IBA). Bird species were identified by the point count method in transect surveys in two-time frames from 2002–2012 and 2015–2016 to obtain the bird species list. We compared our bird list with previously published (after 2000) checklists and compiled the updated checklist of birds of Barandabhar Corridor Forest. We documented 372 bird species belonging to 80 families in Barandabhar, including five Critically Endangered, three Endangered, eight Vulnerable, and 15 Near Threatened species. The Accipitridae family included the highest number of species (n= 32), followed by Muscicapidae (n= 30) and Anatidae (n= 18). Approximately, half of the total confirmed bird species were insectivorous. The list included 63% resident, 27% winter migratory, 7.5% summer migratory, and 2.9% passage migrant species. According to the habitat type, there were 181 species of forest, 74 species of wetland, 24 species of grassland, 70 species of open field, and 23 species of partially wetland birds. This updated checklist of bird species will serve as a reference guide for bird watchers, biodiversity researchers, and support managers for conservation effort; and can be used to track any changes in the composition of bird species in the future.

Keywords: Avifauna, checklist, IBA, transect survey, wetland birds.

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Author contributions: SL, BRL, RCK, CP: conceptualize the study; SL, BRL, TPD, SB, AG, KP, PG, TR: conducted the field survey of 2015 and 2016 and compiled the rest data; SL, BRL: finalized the manuscript; RCK, CP, BRL: supervised the study

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NTNC

INTRODUCTION

Nepal is a biodiversity hotspot supporting 9.5% of the world's bird species, i.e., 886 species (DNPWC & BCN 2019). Birds are one of the most studied groups in Nepal, and information on birds is well documented in the form of field guides and reference books (Inskipp et al. 2013). The status and distribution of birds in Nepal has been studied by various researchers (e.g., Fleming et al. 1976; Inskipp & Inskipp 1985; Cocker & Inskipp 1988; Inskipp & Inskipp 1991; Baral et al. 1996; Baral & Inskipp 2004; Inskipp & Inskipp 2012; Baral et al. 2012; Grimmett et al. 2016; Inskipp et al. 2017). In Nepal, wetland birds are the only vertebrate taxon that have been monitored every year since 1987. This survey has gained attention as the mid-winter water bird count (Baral 2009). Such long-term studies on birds and their associated habitats have become pivotal in the designation of Important Bird and Biodiversity Areas (IBAs) in Nepal. Nepal now has 32 IBAs listed (27 declared and 5 proposed with IBA codes) (BCN 2020). One of these IBAs is the Barandabhar Corridor Forest (BCF), which is important for bird conservation. Beeshazar and adjacent lakes are located to the south of the BCF and were designated as a Ramsar Site (Site no. 1313) in 2003.

The global loss of biodiversity is continuing at an alarming rate and increasing anthropogenic impacts are exacerbating the trend of species loss. Despite a significant increase in conservation activities, the rate of loss of species has not decreased (Butchart 2010; Schrauth & Wink 2018). In addition, there are staggering losses of birds in the world (Dirzo 2014; Hallmann et al. 2017; Rosenberg 2019). To monitor and document environmental health and ecosystem integrity such as food availability, birds act as indicator species because they are easy to detect and observe, widely distributed, cover different levels of ecological pyramids, and the links among bird communities, vegetal associations and territory have been clearly demonstrated (Petty & Avery 1990; Padoa-Schioppa et al. 2006; Schrauth & Wink 2018; Rosenberg 2019). Hence, it is necessary for long-term monitoring and to keep baseline records of bird species. The previous studies by Adhikari et al. (2000, 2018) of birds and wetland birds in BCF were of short duration and have missed many bird species.

BCF, representing the IBA, lacks an updated checklist prepared from long-term monitoring of birds. Our study attempted to fill the gap of previous studies by providing the most recent data with revised nomenclature, vernacular names for public awareness including long-term data from 2002–2012 and 2015–2016 along with a checklist of birds of BCF from other studies after 2000. This checklist will serve as a reference for researchers, conservationists, planners, and bird enthusiasts.

Study Area

Barandabhar Corridor Forest (BCF) covers 87.9 km^2 areas in the north of Chitwan National Park (CNP). It is the only remaining forest patch in Nepal that connects CNP with the Mahabharat range in the north (Bhattarai & Basnet 2004; Lamichhane et al. 2018). BCF has a subtropical climate with winter, spring, and monsoon seasons (Bhattarai 2003). The area of BCF is dominated by Sal *Shorea robusta* forest and partly by riverine and mixed hardwood forest (Bhattarai 2003; NTNC 2003). This forest acts as a migratory route for different bird species (Adhikari et al. 2000, 2018).

The East-West highway (Mahendra Highway) bisects this corridor. The southern part falls under the buffer zone of Chitwan National Park and is guarded by the Nepali army (Lamichhane et al. 2018). Human disturbance is relatively low in the southern part. The northern part falls under the jurisdiction of the Divisional Forest Office, Chitwan and is managed as a protected forest. Despite its legal status of protected forest, human pressure in this part is relatively high due to the dependence of local communities on forest resources such as fodder, fuelwood, timber, grazing, NTFPs, and lack of strong enforcement. BCF is surrounded by heavily populated settlements of municipalities, namely, Ratnanagar Municipality on the east, Kalika on the north-east, and Bharatpur metropolitan city in the west (Figure 1). This has added human-pressure to this corridor and timely consideration for the conservation and management of BCF is needed.

METHODS

Bird species present in BCF were assessed by recording direct sightings. The survey was conducted by a team of experts and field staff of the National Trust for Nature Conservation (NTNC) in two-time frames: 2002–2012 and 2015–2016. NTNC in collaboration with the Divisional Forest Office and Chitwan National Park Office administered both surveys by mobilizing field technicians and researchers. Six survey routes of length ~6 to 11 km were set for the bird survey from 2002 to 2012. For 2015 to 2016, the number of transects were increased to 16 with a length of ~4 to 8 km and changed the orientation of the transects to a cross-section of the corridor (Figure 1). The transects were designed

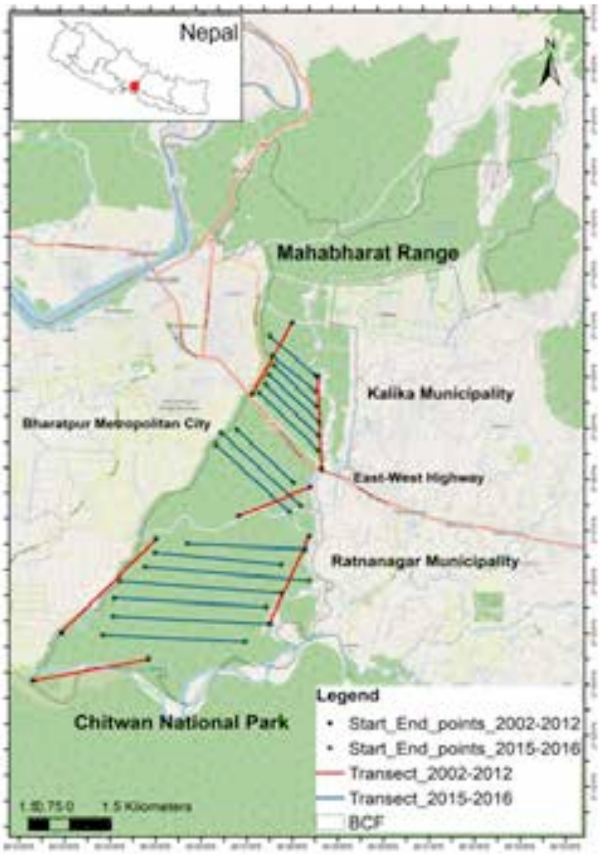

Figure 1. Transects set to identify bird species of Barandabhar Corridor Forest.

to cover all habitat types (wetlands, grasslands, open areas, forest) of BCF. At each starting point and at every 250 m throughout the transect, there was a minute disturbance pause and five-minute observation pause to sight the birds. Bushnell binoculars (8 x 42) were used to sight the birds. Every year, pre-monsoon (March–April) and post-monsoon (October–November) surveys were conducted to detect the summer and winter visitors, respectively. Since the activities of the birds are high in the morning period, we chose the survey time from 0700 to 0900 h. Only one transect was surveyed each day to limit the research in the morning (0700–0900 h). For long transects (>4 km), we either mobilized multiple groups of the surveyors (3–4 surveyors/group on foot) or the same team surveyed on multiple days depending on the length of the transect. For example, an 11-km transect was surveyed in three days (average 4 km transect survey in a day in two hours survey period). The survey in a transect was continued the next day from the point it was left in the previous day. The total number of bird species encountered was recorded in this period. We also collated the bird checklist previously published (Adhikari et al. 2000, 2018) to prepare the updated bird checklist. We only included bird records after 2000.

RESULTS

BCF was found to support 372 bird species belonging to 20 orders and 80 families (Annexe 1) with a total survey effort of 1,506 km. A total of 287 species was recorded during the survey of 2002–2012 and an additional 39 species were detected during 2015–2016. Twenty species recorded during 2002–2012 were not found during 2015–2016 surveys. In addition, the bird checklists of Adhikari et al. (2000, 2018) included 12 and 6 bird species, respectively, which were not recorded during our survey (2002–2012 and 2015–16) in Barandabhar. In November 2019, Great White Pelicans *Pelecanus onocrotalus* were spotted in BCF (Kathmandu Post 2019) which is also included in our checklist. Accipitridae family consisted of the highest number

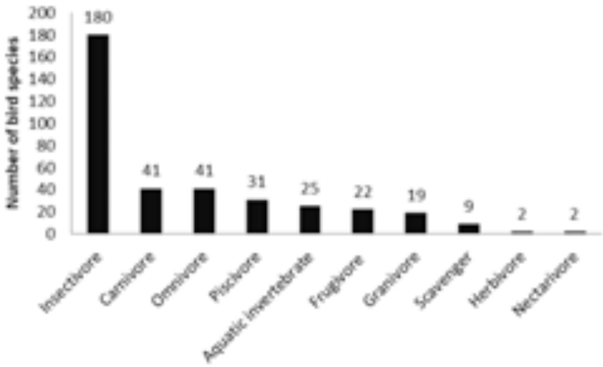

Figure 2. Foraging guild of bird species of Barandabhar Corridor Forest.

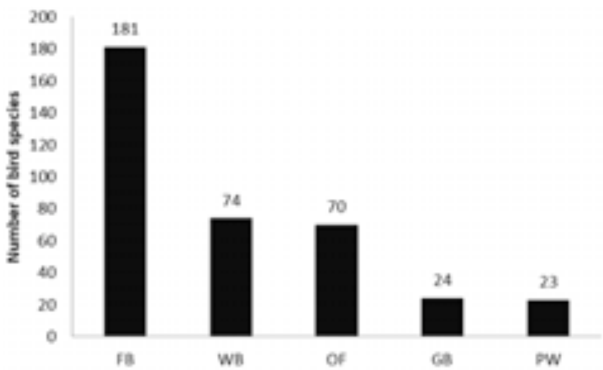

Figure 3. Habitat types and number of bird species of Barandabhar Corridor Forest. FB—Forest Bird | WB—Wetland bird | GB—Grassland bird | OFB—Open Field bird | PW—Partially water bird (near water habitat).

Table 1. IUCN status and migration group of bird species of Barandabhar Corridor Forest.

Migration group	CR	EN	VU	NT	LC	Total
Passage				2	9	11
Resident	3		6	10	215	234
Summer migratory					28	28
Winter migratory	2	3	2	3	89	99
Total	5	3	8	15	341	372

CR—Critically endangered | EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concern.

of species (n= 32) followed by Muscicapidae (n= 30), and Anatidae (n= 18). According to the foraging guild, insectivorous bird species were highest (n= 180 species) followed by equal number of carnivorous (n= 41) and omnivorous (n= 41) species (Figure 2). Out of the total bird species recorded, 62.9%, 26.6%, 7.5%, and 2.9% of bird species of BCF are resident (R), winter migrants (W), summer migrants (S), and passage migrants (P), respectively (Table 1). The bird list also includes globally threatened species: five Critically Endangered, three Endangered, eight Vulnerable, and 15 Near Threatened species. In CITES enlisted categories, we recorded a single bird species each in CITES I and CITES III, and 53 bird species in CITES II category. According to the habitat type, there were 181 bird species of forest, 74 species of wetland, 24 species of grassland, 70 species of open field, and 23 species of partially wetland birds (Figure 3). The checklist is presented in Annexe 1.

DISCUSSION

Our study reported a high diversity of bird species in Barandabhar including 16 globally threatened species (Critically Endangered, Endangered, and Vulnerable) which further justifies the stronghold of its IBA status. The proximity to Chitwan National Park, one of the global biodiversity hotspots may have contributed to the high species diversity of birds. The southern portion (south of the highway of BCF) is the buffer zone of CNP and includes the Ramsar listed Beeshazar and associated lakes. CNP has a total of 544 recorded bird species (CNP 2019). As a contiguous habitat, the movement of the birds from CNP to adjoining BCF area is obvious.

Insectivorous bird species are dominant amongst the various species in BCF consisting of 48.38% of the total species. A recent study suggests that 40% of the insect species globally are in decline due to intensification of agriculture using a large volume of pesticides and fertilizers (Hallmann et al. 2017; Dougals 2019). Schrauth & Wink (2018) stated that the decrease in insect abundance affects higher trophic levels like insectivorous birds. There is no cultivation inside BCF and human movements are also limited. We do not have data on the insect communities of BCF. However, we can hypothesize that the high number of insectivorous bird species in BCF means good insect communities are likely to be thriving in the area. Besides the insectivores, the carnivore and omnivore are the second largest group by species diversity (11% each) in BCF.

A total of nine scavenger species was recorded from BCF, of which four are Critically Endangered, and among them three are resident. BCF is immediately surrounded by municipalities with agricultural fields and pasture for livestock. The scavengers are dependent on dead wildlife/ livestock in and around BCF. The use of diclofenac is detrimental to the survival of these scavengers (Oaks et al. 2004; Swan et al. 2006). So, a conservation awareness program to communities on the use of meloxicam which is an alternative for diclofenac would be a good solution for the survival of a viable population of scavengers (Swarup et al. 2007; Thapa 2009) in BCF.

BCF supports 62.9% resident, 26.6% winter migratory, 7.5% summer migratory, and 2.9% passage migrant birds. These migratory species have different breeding sites, wintering sites, and stopover sites or passage routes. These are sensitive species because a disturbance in any of these sites can cause a decline in their population. Since, BCF is a small biological corridor for migratory and passage birds, we must focus on to return the healthy breeding population so that they visit the area every year.

The transect used for the 2015–2016 surveys seems more effective because 10% more species were recorded in these two years compared to 2002–2012. Even so, the data lack the total species present in the survey of 2002–2012. This may be because the survey efforts of 2015–2016 covered 384 km compared to the survey efforts of 1,122 km during the 2002–2012 surveys.

One of the major challenges of the 21st century is to globally reduce the rate of species loss (Barnosky et al. 2011; Pimm et al. 2014; Rosenberg 2019). In order to reduce threats to existing bird diversity in BCF, the government has endorsed the Barandabhar Corridor Forest Management Plan and the Beeshazari Lake Management Plan that aim to conserve the flora and fauna and their habitat in BCF. The proper implementation and timely revision of these existing plans and policies of BCF help to address the difficulties to protect bird diversity. Raising conservation awareness, removal of alien species, indigenous fish spawning in the wetlands, and incorporating birds as a separate chapter in management plans will help to sustain a healthy bird community in BCF.

This long-term data on bird species in BCF may act as the base-line for future reference, help in further research works, support managers for conservation efforts, and to record any changes in the composition of bird species of BCF. Despite BCF being divided into two portions, i.e., north and south portions, we believe the conservation intervention should be integrated and managed as a single ecological unit.

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Annexe 1. Checklist of the birds of BCF.

	Order/ Family/ Common name	Scientific name	Nepali name	IUCN	CITES	Foraging guild	Migration group	Habitat Type
	ACCIPITRIFORMES							
	Accipitridae							
1	Besra	*Accipiter virgatus* (Temminck, 1822)	बेसरा	LC	II	Carnivore	R	FB
2	Black Baza	*Aviceda leuphotes* (Dumont, 1820)	गोमायु महाचील	LC	II	Carnivore	S	FB
3	Black Eagle	*Ictinaetus malayensis* (Temminck, 1822)	द्रोणक चील	LC	II	Carnivore	R	FB
4	Black Kite	*Milvus migrans* (Boddaert, 1783)	कालो चील	LC	II	Scavenger	W	OF
5	Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	मुसे चील	LC	II	Carnivore	R	OF
6	Booted Eagle	*Hieraaetus pennatus* (Gmelin, 1788)	काँडचन्द्र चील	LC	II	Carnivore	W	FB
7	Changeable Hawk-eagle	*Nisaetus cirrhatus#* (Gmelin, 1788)	सदल चील	LC	II	Carnivore	R	FB
8	Cinereous Vulture	*Aegypius monachus* (Linnaeus, 1766)	राज गिद्द	NT	II	Scavenger	W	FB
9	Crested Goshawk	*Accipiter trivirgatus* (Temminck, 1824)	कल्की बाज	LC	II	Carnivore	R	FB
10	Crested Serpent-eagle	*Spilornis cheela*(Latham 1790)	काकाकुल	LC	II	Carnivore	R	FB
11	Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)	सेतो गिद्द	EN	II	Scavenger	W	OF
12	Eurasian Buzzard	*Buteo buteo* (Linnaeus, 1758)	श्येनबाज	LC	II	Carnivore	W	FB
13	Eurasian Sparrowhawk	*Accipiter nisus* (Linnaeus, 1758)	वनबाज	LC	II	Carnivore	W	FB
14	Greater Spotted Eagle	*Clanga clanga* (Pallas, 1811)	जोबहर महाचील	VU	II	Carnivore	W	OF
15	Grey-headed Fish-eagle	*Icthyophaga ichthyaetus#* (Horsfield, 1821)	माछाकुल	NT	II	Piscivore	R	PW
16	Griffon Vulture	*Gyps fulvus*(Hablitz, 1783)	खैरो गिद्द	LC	II	Scavenger	W	OF
17	Hen Harrier	*Circus cyaneus* (Linnaeus, 1766)	चल्लाचोर भुइँचील	LC	II	Carnivore	W	OF
18	Himalayan Griffon	*Gyps himalayensis* (Hume, 1869)	हिमाली गिद्द	NT	II	Scavenger	R	OF
19	Indian Spotted Eagle	*Clanga hastata* (Lesson, 1834)	लघु महाचील	VU	II	Carnivore	R	OF
20	Indian Vulture	*Gyps indicus** (Scopoli, 1786)	लामो ठूँडे गिद्द	CR	II	Scavenger	R	OF
21	Long-legged Buzzard	*Buteo rufinus* (Cretzschmar, 1829)	लाम्खुट्टे स्यनबाज	LC	II	Carnivore	W	FB
22	Oriental Honey-buzzard	*Pernis ptilorhyncus* (Temminck, 1821)	मधु चील	LC	II	Carnivore	R	FB
23	Pallas's Fish-eagle	*Haliaeetus leucoryphus* (Pallas, 1771)	बोक्सी चील	EN	II	Piscivore	W	PW
24	Pied Harrier	*Circus melanoleucos* (Pennant, 1769)	माले भुइँचील	LC	II	Carnivore	R	OF
25	Red-headed Vulture	*Sarcogyps calvus* (Scopoli, 1786)	सुन गिद्द	CR	II	Scavenger	W	OF
26	Shikra	*Accipiter badius* (Gmelin, 1788)	सिक्रा	LC	II	Carnivore	R	FB
27	Short-toed Snake Eagle	*Circaetus gallicus** (Gmelin, 1788)	सर्पहरि चील	LC	II	Carnivore	P	FB
28	Slender-billed Vulture	*Gyps tenuirostris* (Gray, 1844)	सानो खैरो गिद्द	CR	II	Scavenger	R	OF
29	Steppe Eagle	*Aquila nipalensis* (Hodgson, 1833)	गोमायु महाचील	EN	II	Carnivore	W	FB
30	White-eyed Buzzard	*Butastur teesa* (Franklin, 1831)	जमल श्वेतबाज	LC	II	Carnivore	R	FB
31	White-rumped Vulture	*Gyps bengalensis* (Gmelin, 1788)	डङ्गर गिद्द	CR	II	Scavenger	R	OF
32	White-tailed Sea-eagle	*Haliaeetus albicilla* (Linnaeus, 1758)	कंगम चिल	LC	II	Carnivore	R	PW
	Pandionidae							
33	Osprey	*Pandion haliaetus* (Linnaeus, 1758)	मलाहा चील	LC	II	Piscivore	R	PW
	ANSERIFORMES							
	Anatidae							
34	Common Goldeneye	*Bucephala clangula* (Linnaeus, 1758)	स्वर्ण नयन् हाँस	LC	-	Omnivore	P	WB

	Order/ Family/ Common name	Scientific name	Nepali name	IUCN	CITES	Foraging guild	Migration group	Habitat Type
35	Common Pochard	*Aythya ferina* (Linnaeus, 1758)	कैलो टाउके हाँस	VU	-	Carnivore	W	WB
36	Common Teal	*Anas crecca* (Linnaeus, 1758)	बिजुलागईरी	LC	-	Omnivore	W	WB
37	Cotton Pygmy-goose	*Nettapus coromandelianus* (Gmelin, 1789)	हरि हाँस	LC	-	Omnivore	W	WB
38	Eurasian Wigeon	*Mareca penelope* (Linnaeus, 1758)	सिन्दुरे हाँस	LC	-	Omnivore	W	WB
39	Ferruginous Duck	*Aythya nyroca* (Guldenstadt, 1770)	मालक हाँस	NT	-	Omnivore	W	WB
40	Gadwall	*Mareca strepera#* (Linnaeus, 1758)	खड्खडे हाँस	LC	-	Omnivore	W	WB
41	Garganey	*Spatula querquedula $* (Linnaeus, 1758)	श्वेताआँखीभौँ	LC	-	Omnivore	R	WB
42	Goosander	*Mergus merganser** (Linnaeus, 1758)	मणितुण्डक	LC	-	Piscivore	W	WB
43	Indian Spot-billed Duck	*Anas poecilorhyncha** (Forster, 1781)	नदुन हाँस	LC	-	Omnivore	W	WB
44	Lesser Whistling Duck	*Dendrocygna javanica* (Horsfield, 1821)	सिलसिले	LC	-	Herbivore	R	WB
45	Mallard	*Anas platyrhynchos* (Linnaeus, 1758)	हरियो टाउके हाँस	LC	-	Omnivore	W	WB
46	Northern Pintail	*Anas acuta* (Linnaeus, 1758)	सुईरोपुच्छे	LC	-	Omnivore	W	WB
47	Northern Shoveler	*Spatula clypeata* (Linnaeus, 1758)	बेल्चा ठुडे हाँस	LC	-	Omnivore	P	WB
48	Red-crested Pochard	*Netta rufina* (Pallas, 1773)	सुनजुरे हाँस	LC	-	Omnivore	W	WB
49	Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	चखेवा	LC	-	Omnivore	W	WB
50	Smew	*Mergellus albellus* (Linnaeus, 1758)	देवदुत माणीतुन्दक	LC	-	Omnivore	W	WB
51	Tufted Duck	*Aythya fuligula* (Linnaeus, 1758)	कालीजुरे हाँस	LC	-	Carnivore	W	WB
	APODIFORMES							
	Hemiprocnidae							
52	Crested Treeswift	*Hemiprocne coronata* (Tickell, 1833)	जुरे गौंथली	LC	-	Insectivore	R	FB
	BUCEROTIFORMES							
	Bucerotidae							
53	Great Hornbill	*Buceros bicornis* (Linnaeus, 1758)	राज धनेश	VU	I	Frugivore	R	FB
54	Indian Grey Hornbill	*Ocyceros birostris* (Scopoli, 1786)	खैरो धनेश	LC	-	Omnivore	R	FB
55	Oriental Pied Hornbill	*Anthracoceros albirostris* (Shaw & Nodder, 1807)	कालो धनेश	LC	II	Frugivore	R	FB
	Upupidae							
56	Common Hoopoe	*Upupa epops* (Linnaeus, 1758)	फाप्रे चरा (दशैं चरा)	LC	-	Insectivore	R	OF
	CAPRIMULGIFORMES							
	Apodidae							
57	Alpine Swift	*Tachymarptis melba** (Linnaeus, 1758)	बतासी गौँथली	LC	-	Insectivore	W	OF
58	Himalayan Swiftlet	*Aerodramus brevirostris#* (Horsfield, 1840)	थिचिका गौँथली	LC	-	Insectivore	W	OF
59	House Swift	*Apus nipalensis #* (Hodgson, 1837)	फिर्फिरे घर गौँथली	LC	-	Insectivore	R	OF
60	Little Swift	*Apus affinis@* (JE Gray, 1830)	फिर्फिरे घर गौँथली	LC	-	Insectivore	R	OF
61	Pacific Swift	*Apus pacificus@* (Latham, 1801)	पुछुरकापे गौँथली	LC	-	Insectivore	R	OF
62	Silver-backed Needletail	*Hirundapus cochinchinensis* (Oustalet, 1878)	चण्डी ढाडे गौँथली	LC	-	Insectivore	R	OF
63	White-rumped Spinetail	*Zoonavena sylvatica* (Tickell, 1846)	सानो वन गौँथली	LC	-	Insectivore	R	OF
	Caprimulgidae							
64	Large-tailed Nightjar	*Caprimulgus macrurus* (Horsfield, 1821)	लाम्पुछे चैते चरा	LC	-	Insectivore	R	FB
65	Savanna Nightjar	*Caprimulgus affinis* (Horsfield, 1821)	चुइयाँ चैते चरा	LC	-	Insectivore	R	GB

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	CHARADRIIFORMES							
	Burhinidae							
66	Eurasian Thick-knee	*Burhinus oedicnemus* (Linnaeus, 1758)	बगरबट्टाई	LC	-	Insectivore	R	WB
	Charadriidae							
67	Grey-headed Lapwing	*Vanellus cinereus* (Blyth, 1842)	खरानी टाउके हुटिट्याउँ	LC	-	Aquatic invertebrates	W	WB
68	Kentish Plover	*Charadrius alexandrinus* (Linnaeus, 1758)	अलकचन्द्र राजपुत्रीका	LC	-	Carnivore	W	WB
69	Little Ringed Plover	*Charadrius dubius* (Scopoli, 1786)	लघु राजपुत्रीका	LC	-	Aquatic invertebrates	R	WB
70	Northern Lapwing	*Vanellus vanellus* (Linnaeus, 1758)	जुरे हुटिट्याउँ	NT	-	Aquatic invertebrates	W	WB
71	Pacific Golden Plover	*Pluvialis fulva* (Gmelin, 1789)	प्रसान्त सर्षपी	LC	-	Aquatic invertebrates	P	WB
72	Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	हुटिट्याउँ	LC	-	Aquatic invertebrates	W	WB
73	River Lapwing	*Vanellus duvaucelii* (Lesson, 1826)	खोले हुटिट्याउँ	NT	-	Aquatic invertebrates	R	WB
74	Yellow-wattled Lapwing	*Vanellus malabaricus* (Boddaert, 1783)	पहेंलो गाले हुटिट्याउँ	LC	-	Insectivore	R	WB
	Glareolidae							
75	Small Pratincole	*Glareola lactea* (Temminck, 1820)	पानी गौंथली	LC	-	Insectivore	R	PW
	Haematopodidae							
76	Eurasian Oystercatcher	*Haematopus ostralegus* (Linnaeus, 1758)	सिपि चरा	NT	-	Aquatic invertebrates	P	WB
	Jacanidae							
77	Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	कमल चरी	LC	-	Aquatic invertebrates	R	WB
78	Pheasant-tailed Jacana	*Hydrophasianus chirurgus* (Scopoli, 1786)	जलअपसरा	LC	-	Omnivore	R	WB
	Laridae							
79	Common Tern	*Sterna hirundo* (Linnaeus, 1758)	वायु फ्यालफ्याले	LC	-	Piscivore	P	PW
80	River Tern	*Sterna aurantia* (J.E. Gray, 1831)	कुरारी फ्यालफ्याले	NT	-	Carnivore	R	PW
	Recurvirostridae							
81	Black-winged Stilt	*Himantopus himantopus* (Linnaeus, 1758)	प्रवालपाद	LC	-	Aquatic invertebrates	P	WB
	Rostratulidae							
82	Greater Painted-snipe	*Rostratula benghalensis* (Linnaeus, 1758)	चित्राङ्गद	LC	-	Omnivore	R	WB
	Scolopacidae							
83	Black-tailed Godwit	*Limosa limosa* (Linnaeus, 1758)	मलगुजा	NT	-	Carnivore	P	WB
84	Common Greenshank	*Tringa nebularia* (Gunnerus, 1767)	टिमटिमा	LC	-	Aquatic invertebrates	W	WB
85	Common Redshank	*Tringa totanus* (Linnaeus, 1758)	लालखुट्टे टिमटिमा	LC	-	Aquatic invertebrates	W	WB
86	Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)	चन्चले सुढसुढिया	LC	-	Aquatic invertebrates	W	WB
87	Common Snipe	*Gallinago gallinago* (Linnaeus, 1758)	पानी चाहा	LC	-	Aquatic invertebrates	W	WB
88	Eurasian Woodcock	*Scolopax rusticola* (Linnaeus, 1758)	ठूलो चाहा	LC	-	Insectivore	W	WB
89	Green Sandpiper	*Tringa ochropus* (Linnaeus, 1758)	रुख सुढसुढिया	LC	-	Aquatic invertebrates	W	WB
90	Little Stint	*Calidris minuta* (Leisler, 1812)	काली खुट्टे जलरङ्ग	LC	-	Aquatic invertebrates	W	WB
91	Pintail Snipe	*Gallinago stenura* (Bonaparte, 1831)	भरक्चाहा	LC	-	Aquatic invertebrates	W	WB
92	Temminck's Stint	*Calidris temminckii* (Leisler, 1812)	जलरङ्ग	LC	-	Aquatic invertebrates	W	WB

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93	Wood Sandpiper	*Tringa glareola* (Linnaeus, 1758)	वन सुढसुढिया	LC	-	Aquatic invertebrates	P	WB
	Turnicidae							
94	Common Buttonquail	*Turnix sylvatica* (Desfontaines, 1789)	सानो गट्टेबट्टाई	LC	-	Granivore	R	OF
	CICONIIFORMES							
	Ciconiidae							
95	Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	चिम्टे गरुड	LC	-	Piscivore	W	WB
96	Black Stork	*Ciconia nigra* (Linnaeus, 1758)	कालो गरुड	LC	II	Piscivore	W	WB
97	Black-necked Stork	*Ephippiorhynchus asiaticus** (Latham, 1790)	कृष्णकण्ठ गरुड	NT	-	Piscivore	R	WB
98	Lesser Adjutant	*Leptoptilos javanicus* (Horsfield, 1821)	भुंडिफोर गरुड	VU	-	Piscivore	R	WB
99	Asian Woolly-necked Stork	*Ciconia episcopus* (Boddaert, 1783)	कपाशकण्ठ गरुड/ लो भिपापी	VU	-	Piscivore	R	WB
	COLUMBIFORMES							
	Columbidae							
100	Common Wood Pigeon	*Columba palumbus* (Linnaeus, 1758)	ठूलो वनपरेवा	LC	-	Granivore	W	FB
101	Spotted-dove	*Spilopelia chinensis#* (Scopoli, 1768)	कुर्ले ढुकुर	LC	-	Granivore	R	OF
102	Eurasian Collared-dove	*Streptopelia decaocto* (Frivaldszky, 1838)	कण्ठे ढुकुर	LC	-	Granivore	R	OF
103	Grey-capped Emerald Dove	*Chalcophaps indica* (Linnaeus, 1758)	सुन ढुकुर	LC	-	Frugivore	R	FB
104	Orange-breasted Green-pigeon	*Treron bicinctus* (Jerdon, 1840)	सुन्तलेछाती हलेसो	LC	-	Frugivore	R	FB
105	Oriental Turtle-dove	*Streptopelia orientalis (Latham, 1790)*	तुम्मे ढुकुर	LC	-	Granivore	W	OF
106	Red Turtle-dove	*Streptopelia tranquebarica* (Hermann, 1804)	तामे ढुकुर	LC	-	Granivore	R	OF
107	Sri Lanka Green-pigeon	*Treron pompadora* (Gmelin, 1789)	फुस्रो टाउके हलेसो	LC	-	Frugivore	R	FB
108	Thick-Billed Green-pigeon	*Treron curvirostra@* (Gmelin, 1789)	मोटोठुँडे हलेसो	LC	-	Insectivore	R	FB
109	Yellow-footed Green-pigeon	*Treron phoenicoptera* (Latham, 1790)	ठूलो हलेसो	LC	-	Frugivore	R	FB
	CORACIIFORMES							
	Alcedinidae							
110	Black-capped Kingfisher	*Halcyon pileata* (Boddaert, 1783)	कालोटाऊके माटीकोरे	LC	-	Piscivore	W	PW
111	Blue-eared Kingfisher	*Alcedo meninting* (Horsfield, 1821)	निलकर्ण माटीकोरे	LC	-	Piscivore	R	PW
112	Common Kingfisher	*Alcedo atthis* (Linnaeus, 1758)	सानो माटीकोरे	LC	-	Piscivore	R	PW
113	Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	छिरबिरे माटिकोरे	LC	-	Piscivore	R	PW
114	Stork-billed Kingfisher	*Pelargopsis capensis* (Linnaeus, 1766)	ठूलो माटीकोरे	LC	-	Piscivore	R	PW
115	White-breasted Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	सेतोकण्ठे माटीकोरे	LC	-	Piscivore	R	PW
	Coraciidae							
116	Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	ठेऊवा	LC	-	Insectivore	R	OF
117	Oriental Dollarbird	*Eurystomus orientalis* (Linnaeus, 1766)	निलठेऊवा	LC	-	Insectivore	S	FB
	Meropidae							
118	Green Bee-eater	*Merops orientalis* (Latham, 1801)	मुरली चरा	LC	-	Insectivore	R	OF
119	Blue-bearded Bee-eater	*Nyctyornis athertoni* (Jardine & Selby, 1830)	निलकण्ठ मुरली चरा	LC	-	Insectivore	R	FB
120	Blue-tailed Bee-eater	*Merops philippinus* (Linnaeus, 1766)	निलपुछ्रे मुरली चरा	LC	-	Insectivore	S	OF

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121	Chestnut-headed Bee-eater	*Merops leschenaulti* (Vieillot, 1817)	कटुसे टाउके मुरली चरा	LC	-	Insectivore	S	OF
	CUCULIFORMES							
	Cuculidae							
122	Banded Bay Cuckoo	*Cacomantis sonneratii* (Latham, 1790)	धर्के खैरो कोइली	LC	-	Insectivore	R	FB
123	Chestnut-winged Cuckoo	*Clamator coromandus* (Linnaeus, 1766)	ठूलो जुरे कोईली	LC	-	Insectivore	S	FB
124	Common Cuckoo	*Cuculus canorus* (Linnaeus, 1758)	कुक्कु	LC	-	Insectivore	S	FB
125	Common Hawk-cuckoo	*Hierococcyx varius* (Vahl, 1797)	भैरब चरो	LC	-	Insectivore	R	FB
126	Greater Coucal	*Centropus sinensis* (Stephens, 1815)	ढोढे गोकुल	LC	-	Insectivore	R	OF
127	Green-billed Malkoha	*Phaenicophaeus tristis* (Lesson, 1830)	हरित माल कौवा	LC	-	Insectivore	R	FB
128	Grey-bellied Cuckoo	*Cacomantis passerinus* (Vahl, 1797)	सुत्तरि कोईली	LC	-	Insectivore	S	FB
129	Indian Cuckoo	*Cuculus micropterus* (Gould, 1837)	काफल पाक्यो	LC	-	Insectivore	S	FB
130	Jacobin Cuckoo	*Clamator jacobinus* (Boddaert, 1783)	जुरे कोईली	LC	-	Insectivore	S	FB
131	Large Hawk-cuckoo	*Hierococcyx sparverioides* (Vigors, 1832)	बिऊ कुईयो कोइली	LC	-	Insectivore	S	FB
132	Lesser Coucal	*Centropus bengalensis* (Gmelin, 1788)	सानो गोकुल	LC	-	Insectivore	R	GB
133	Lesser Cuckoo	*Cuculus poliocephalus* (Latham, 1790)	सानो कोईली	LC	-	Insectivore	S	FB
134	Oriental Cuckoo	*Cuculus saturatus** (Gould, 1845)	पूर्विय कोईली	LC	-	Insectivore	S	FB
135	Sirkeer Malkoha	*Taccocua leschenaultii* (Lesson, 1830)	न्याउरी मालकौवा	LC	-	Insectivore	R	FB
136	Square-tailed Drongo-cuckoo	*Surniculus lugubris* (Horsfield, 1821)	चिबे कोईली	LC	-	Insectivore	S	FB
137	Asian Koel	*Eudynamys scolopacea* (Linnaeus, 1758)	कोईली	LC	-	Insectivore	S	OF
	FALCONIFORMES							
	Falconidae							
138	Collared Falconet	*Microhierax caerulescens* (Linnaeus, 1758)	पौरी बाज	LC	II	Insectivore	R	FB
139	Common Kestrel	*Falco tinnunculus* (Linnaeus, 1758)	बौडाई	LC	II	Carnivore	W	OF
140	Peregrine Falcon	*Falco peregrinus* (Tunstall, 1771)	शाही बाज	LC	II	Carnivore	W	FB
141	Red- necked Falcon	*Falco chicquera* (Daudin, 1800)	रातो टाउके बौडाइ	NT	II	Carnivore	R	FB
	GALLIFORMES							
	Phasianidae							
142	Black Francolin	*Francolinus francolinus* (Linnaeus, 1766)	तीत्रा	LC	-	Granivore	R	OF
143	Common Quail	*Coturnix coturnix** (Linnaeus, 1758)	बट्टाई	LC	-	Granivore	W	OF
144	Indian Peafowl	*Pavo cristatus* # (Linnaeus, 1758)	मयुर	LC	III	Omnivore	R	FB
145	Red junglefowl	*Gallus gallus* (Linnaeus, 1758)	लुँईचे	LC	-	Omnivore	R	FB
	GRUIFORMES							
	Rallidae							
146	Brown Crake	*Zapornia akool* (Sykes, 1832)	ध्वाँसे सिम कुखुरा	LC	-	Aquatic invertebrates	R	WB
147	Common Coot	*Fulica atra* (Linnaeus, 1758)	सेतो थोप्ले सिमकुखुरा	LC	-	Aquatic invertebrates	W	WB
148	Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	बगाले सिमकुखुरा	LC	-	Aquatic invertebrates	R	WB
149	Western Swamphen	*Porphyrio porphyrio* (Linnaeus, 1758)	कुर्मा	LC	-	Omnivore	R	WB
150	Ruddy-breasted Crake	*Zapornia fusca* (Linnaeus, 1766)	घोल कस्दरी	LC	-	Omnivore	R	WB

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151	Watercock	*Gallicrex cinerea* (Gmelin, 1789)	जल कुखुरा	LC	-	Herbivore	S	WB
152	White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	सिमकुखुरा	LC	-	Aquatic invertebrates	R	WB
	PASSERIFORMES							
	Acrocephalidae							
153	Blyth's Reed-warbler	*Acrocephalus dumetorum* (Blyth, 1849)	ट्याक-ट्याके	LC	-	Insectivore	w	FB
154	Paddyfield Warbler	*Acrocephalus agricola* (Jerdon, 1845)	सानो ट्याक-ट्याके	LC	-	Insectivore	W	OF
155	Thick-billed Warbler	*Arundinax aedon* (Pallas, 1776)	मोटोठुँडे ट्याक-टयाके	LC	-	Insectivore	W	OF
	Aegithinidae							
156	Common Iora	*Aegithina tiphia* (Linnaeus, 1758)	सुसेली चरी	LC	-	Insectivore	R	FB
	Alaudidae							
157	Bengal Bushlark	*Mirafra assamica* (Horsfield, 1840)	भार्दवाज	LC	-	Insectivore	R	OF
158	Oriental Skylark	*Alauda gulgula#* (Franklin, 1831)	ब्रहमीचटी भार्दवाज	LC	-	Insectivore	R	OF
159	Sand Lark	*Alaudala raytal** (Blyth, 1845)	बगर भार्दवाज	LC	-	Insectivore	R	OF
	Artamidae							
160	Ashy Woodswallow	*Artamus fuscus* (Vieillot, 1817)	मिथुन	LC	-	Insectivore	R	OF
	Campephagidae							
161	Black-headed Cuckooshrike	*Lalage melanoptera#* (Rüppell, 1839)	कालो टाउके बिरहि चरा	LC	-	Insectivore	R	FB
162	Black-winged Cuckooshrike	*Lalage melaschistos#* (Hodgson, 1836)	कालो बिरहि चरा	LC	-	Insectivore	R	FB
163	Indian Cuckooshrike	*Coracina macei* (Lesson, 1830)	लठसक् बिरहि चरा	LC	-	Insectivore	R	FB
164	Rosy Minivet	*Pericrocotus roseus* (Vieillot, 1818)	गुलाफी रानीचरा	LC	-	Insectivore	R	FB
165	Scarlet Minivet	*Pericrocotus flammeus* (Latham, 1790)	रानीचरा	LC	-	Insectivore	R	FB
166	Small Minivet	*Pericrocotus cinnamomeus* (Linnaeus, 1766)	सानो रानीचरा	LC	-	Insectivore	R	FB
	Cettiidae							
167	Aberrant Bush-warbler	*Horornis flavolivaceus #* (Blyth, 1845)	पित हरितझाडी फिस्टो	LC	-	Insectivore	R	FB
	Chloropseidae							
168	Golden-fronted Leafbird	*Chloropsis aurifrons* (Temminck, 1829)	कृण्ण कण्ठे हरितचरी	LC	-	Insectivore	R	FB
	Cisticolidae							
169	Ashy Prinia	*Prinia socialis* (Sykes, 1832)	टुनुक् घाँसेफिस्टो	LC	-	Insectivore	R	GB
170	Common Tailorbird	*Orthotomus sutorius* (Pennant, 1769)	सोलिफिस्टो	LC	-	Insectivore	R	FB
171	Grey-breasted Prinia	*Prinia hodgsonii* (Blyth, 1844)	फुस्रोछाति घाँसेफिस्टो	LC	-	Insectivore	R	FB
172	Grey-crowned Prinia	*Prinia cinereocapilla** (Moore, 1854)	घेघरी घाँसेफिस्टो	VU	-	Insectivore	R	GB
173	Jungle Prinia	*Prinia sylvatica* (Jerdon, 1840)	जङ्गल घाँसेफिस्टो	LC	-	Insectivore	R	GB
174	Plain Prinia	*Prinia inornata* (Sykes, 1832)	झाक्री घाँसेफिस्टो	LC	-	Insectivore	R	GB
175	Yellow-bellied Prinia	*Prinia flaviventris* (Delessert, 1840)	पिठोदर घाँसेफिस्टो	LC	-	Insectivore	R	GB
176	Zitting Cisticola	*Cisticola juncidis* (Rafinesque, 1810)	सिरु फिस्टो	LC	-	Insectivore	R	GB
	Corvidae							
177	Grey treepie	*Dendrocitta formosae @* (R. Swinhoe, 1863)	पहाडी कोकले	LC	-	Frugivore	R	FB
178	House Crow	*Corvus splendens* (Vieillot, 1817)	कण्ठे काग	LC	-	Omnivore	R	OF
179	Large-billed Crow	*Corvus macrorhynchos* (Wagler, 1827)	कालो कौवा	LC	-	Omnivore	R	OF
180	Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	कोकले	LC	-	Frugivore	R	FB

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	Dicaeidae							
181	Pale-billed Flowerpecker	*Dicaeum erythrorhynchos #* (Latham, 1790)	रातोठुंडे पुष्पकोकिल	LC	-	Frugivore	R	FB
182	Plain Flowerpecker	*Dicaeum minullum* (R. Swinhoe, 1870)	समरुप पुष्पकोकिल	LC	-	Frugivore	R	FB
183	Thick-billed Flowerpecker	*Dicaeum agile@* (Tickell, 1833)	मोटोठुँडे पुष्पकोकिल	LC	-	Frugivore	R	FB
184	Yellow-vented Flowerpecker	*Dicaeum chrysorrheum@* (Temminck, 1829)	पितनिर्गम पुष्पकोकिल	LC	-	Frugivore	R	FB
	Dicruridae							
185	Ashy Drongo	*Dicrurus leucophaeus* (Vieillot, 1817)	ध्वाँसे चिबे	LC	-	Insectivore	S	FB
186	Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	चिबे	LC	-	Insectivore	R	OF
187	Bronzed Drongo	*Dicrurus aeneus* (Vieillot, 1817)	आकाशे चिबे	LC	-	Insectivore	R	FB
188	Crow-billed Drongo	*Dicrurus annectans* (Hodgson, 1836)	कागठुँड चिबे	LC	-	Insectivore	S	FB
189	Greater Racket-tailed Drongo	*Dicrurus paradiseus* (Linnaeus, 1766)	भीमराज चिबे	LC	-	Insectivore	R	FB
190	Hair-crested Drongo	*Dicrurus hottentottus* (Linnaeus, 1766)	केसराज चिबे	LC	-	Insectivore	R	FB
191	Lesser Racket-tailed Drongo	*Dicrurus remifer* (Temminck, 1823)	भृङ्गराज चिबे	LC	-	Insectivore	R	FB
192	White-bellied Drongo	*Dicrurus caerulescens** (Linnaeus, 1758)	सेतोपेटे चिबे	LC	-	Insectivore	R	FB
	Emberizidae							
193	Crested Bunting	*Emberiza lathami* (Gray, 1831)	जुरे बगेडी	LC	-	Granivore	R	OF
194	Yellow-breasted Bunting	*Emberiza aureola* (Pallas, 1773)	बगाले बगेडी	CR	-	Granivore	W	OF
	Estrildidae							
195	Red Avadavat	*Amandava amandava* (Linnaeus, 1758)	रातो मुनिया	LC	-	Granivore	R	GB
196	Scaly-breasted Munia	*Lonchura punctulata* (Linnaeus, 1758)	कोटेरो मुनिया	LC	-	Granivore	R	OF
197	Tricoloured Munia	*Lonchura malacca* (Linnaeus, 1766)	कालेटाउके मुनिया	LC	-	Granivore	S	GB
198	White-rumped Munia	*Lonchura striata@* (Linnaeus, 1766)	सेतो ढाढे मुनिया	LC	-	Granivore	R	GB
	Eurylaimidae							
199	Long-tailed Broadbill	*Psarisomus dalhousiae $* (Jameson, 1835)	चित्रकुट	LC	-	Insectivore	R	FB
	Fringillidae							
200	Common Rosefinch	*Carpodacus erythrinus* (Pallas, 1770)	अमोगा तितु	LC	-	Granivore	W	FB
	Hirundinidae							
201	Asian Plain Martin	*Riparia chinensis* (J. E. Gray, 1830)	भित्तेगौथली	LC	-	Insectivore	R	OF
202	Barn Swallow	*Hirundo rustica* (Linnaeus, 1758)	घर गौंथली	LC	-	Insectivore	R	OF
203	Sand Martin	*Riparia riparia* (Linnaeus, 1758)	गलहरी भित्ते गौंथली	LC	-	Insectivore	R	OF
204	Nepal House Martin	*Delichon nipalense $* (Moore, 1854)	नेपाल भिर गौंथली	LC	-	Insectivore	R	OF
205	Red-rumped Swallow	*Cecropis daurica#* (Laxmann, 1769)	गेरुकाटी गौंथली	LC	-	Insectivore	R	OF
	Laniidae							
206	Brown Shrike	*Lanius cristatus* (Linnaeus, 1758)	खैरो भद्राई	LC	-	Insectivore	W	OF
207	Grey-backed Shrike	*Lanius tephronotus* (Vigors, 1831)	हिमाली भद्राई	LC	-	Insectivore	W	OF
208	Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	भद्राई	LC	-	Insectivore	R	OF
	Leiotrichidae							
209	Common babbler	*Argya caudata$*(Dumont, 1823)	कुरुबाहुक् भ्याकुंर	LC	-	Insectivore	R	GB
210	Jungle Babbler	*Turdoides striata#* (Dumont, 1823)	बगाले भ्याकुंर	LC	-	Insectivore	R	FB

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211	Striated Babbler	*Argya earlei@* (Blyth, 1844)	खर भ्याकुंर	LC	-	Insectivore	R	GB
	Locustellidae							
212	Bristled Grassbird	*Chaetornis striata#* (Jerdon, 1841)	चिप्लिक घाँसे चरी	VU	-	Insectivore	R	GB
213	Spotted Bush Warbler	*Locustella thoracica** (Blyth, 1845)	थोप्ले झाडीफिस्टो	LC	-	Insectivore	R	GB
	Monarchidae							
214	Black-naped Monarch	*Hypothymis azurea* (Boddaert, 1783)	कालो गर्धन राजचरी	LC	-	Insectivore	R	FB
	Motacillidae							
215	Citrine Wagtail	*Motacilla citreola* (Pallas, 1776)	बेसारे टिक्टिके	LC	-	Insectivore	W	PW
216	Forest Wagtail	*Dendronanthus indicus* (Gmelin, 1789)	वन टिक्टिके	LC	-	Insectivore	P	FB
217	Grey Wagtail	*Motacilla cinerea* (Tunstall, 1771)	फुस्रो टिक्टिके	LC	-	Insectivore	W	PW
218	Olive-backed Pipit	*Anthus hodgsoni* (Richmond, 1907)	रुख चुइँया	LC	-	Insectivore	W	FB
219	Paddyfield Pipit	*Anthus rufulus* (Vieillot, 1818)	आलि चुइँया	LC	-	Insectivore	R	OF
220	Richard's Pipit	*Anthus richardi* (Vieillot, 1818)	लामाऔंले चुइँया	LC	-	Insectivore	W	OF
221	Rosy Pipit	*Anthus roseatus* (Blyth, 1847)	गुलाफी कण्ठे चुईया	LC	-	Insectivore	W	PW
222	Tawny Pipit	*Anthus campestris* (Linnaeus, 1758)	ढुलिका चुइँया	LC	-	Insectivore	W	OF
223	Western Yellow Wagtail	*Motacilla flava** (Linnaeus, 1758)	पहेंलो टिक्टिके	LC	-	Insectivore	W	PW
224	White Wagtail	*Motacilla alba* (Linnaeus, 1758)	सेतो टिक्टिके	LC	-	Insectivore	W	OF
225	White-browed Wagtail	*Motacilla maderaspatensis* (Gmelin, 1789)	खोले टिक्टिके	LC	-	Insectivore	R	PW
	Muscicapidae							
226	Asian Brown Flycatcher	*Muscicapa dauurica* (Pallas, 1811)	धुसर अर्जुनक	LC	-	Insectivore	S	FB
227	Black Redstart	*Phoenicurus ochruros* (S. G. Gmelin, 1774)	ध्याप्ची खञ्जरी	LC	-	Insectivore	W	OF
228	Black-backed Forktail	*Enicurus immaculatus* (Hodgson, 1836)	कालोढाडे खोलेधोबिनी	LC	-	Insectivore	R	PW
229	Blue Rock-thrush	*Monticola solitarius* (Linnaeus, 1758)	उमा चाँचर	LC	-	Insectivore	R	FB
230	Blue Whistling-thrush	*Myophonus caeruleus* (Scopoli, 1786)	कलचौडे	LC	-	Omnivore	R	FB
231	Bluethroat	*Cyanecula svecica* (Linnaeus, 1758)	भुमिचर निलकण्ठ	LC	-	Insectivore	W	FB
232	Common Stonechat	*Saxicola torquatus* (Linnaeus, 1766)	झेकझेक भ्याप्सी	LC	-	Insectivore	W	GB
233	Dark-sided Flycatcher	*Muscicapa sibirica* (Gmelin, 1789)	ध्वाँसे अर्जुनक	LC	-	Insectivore	W	FB
234	Grey Bushchat	*Saxicola ferreus* (Gray & Gray, 1847)	हिमाली झयाप्सी	LC	-	Insectivore	W	OF
235	Himalayan Rubythroat	*Calliope pectoralis#* (Gould, 1837)	साईबेरियन रातोकण्ठ	LC	-	Insectivore	W	FB
236	Little Forktail	*Enicurus scouleri* (Vigors, 1832)	गंगा खोलेधोबिनी	LC	-	Insectivore	R	PW
237	Oriental Magpie-robin	*Copsychus saularis* (Linnaeus, 1758)	धोबी चरा	LC	-	Insectivore	R	OF
238	Pale-Chinned Flycatcher	*Cyornis poliogenys* (Brooks, 1879)	नौनि कण्ठे अर्जुनक	LC	-	Insectivore	R	FB
239	Pied Bush Chat	*Saxicola caprata* (Linnaeus, 1766)	काले झयाप्सी	LC	-	Insectivore	R	GB
240	Plumbeous Water Redstart	*Phoenicurus fuliginosus* (Vigors, 1831)	निलाम्बर जलखञ्जरी	LC	-	Aquatic invertebrates	W	PW
241	Pygmy Blue-flycatcher	*Ficedula hodgsoni* (Moore, 1854)	नीलढाडे अर्जुनक	LC	-	Insectivore	W	FB
242	Red-breasted Flycatcher	*Ficedula parva** (Bechstein, 1792)	लालबक्स अर्जुनक	LC	-	Insectivore	W	FB
243	Red-throated Flycatcher	*Ficedula albicilla* (Pallas, 1811)	रातो कण्ठे अर्जुनक	LC	-	Insectivore	W	FB
244	Rufous-bellied Niltava	*Niltava sundara@* (Hodgson, 1837)	सुन्दर निलताभा	LC	-	Insectivore	R	FB
245	Rusty-tailed Flycatcher	*Ficedula ruficauda* (Swainson, 1838)	धुसार अर्जुनक	LC	-	Insectivore	S	FB
246	Siberian Rubythroat	*Calliope calliope* (Pallas, 1776)	हिमाली रातोकण्ठ	LC	-	Insectivore	W	FB

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247	Slaty-backed Forktail	*Enicurus schistaceus* (Hodgson, 1836)	फुस्रोढाडे खोलेधोबिनी	LC	-	Insectivore	R	PW
248	Slaty-blue Flycatcher	*Ficedula tricolor@* (Hodgson, 1845)	टिक्टिके अर्जुनक	LC	-	Insectivore	R	FB
249	Ultramarine Flycatcher	*Ficedula superciliaris $* (Jerdon, 1840)	निलश्वेत अर्जुनक	LC	-	Insectivore	R	FB
250	Verditer Flycatcher	*Eumyias thalassina* (Swainson, 1838)	निलतुथो अर्जुनक	LC	-	Insectivore	W	FB
251	White-browed Bush Robin	*Tarsiger indicus@* (Vieillot, 1817)	सेतो आँखीभउँ रविन	LC	-	Insectivore	R	FB
252	White-capped Water Redstart	*Phoenicurus leucocephalus#* (Vigors, 1831)	सेतोटाउके जलखञ्जरी	LC	-	Aquatic invertebrates	R	PW
253	White-rumped Shama	*Kittacincla malabarica#* (Scopoli, 1788)	श्यामा	LC	-	Insectivore	R	FB
254	White-tailed Blue Robin	*Myiomela leucura* (Hodgson, 1845)	सेतोपुच्छे रबिन	LC	-	Insectivore	R	FB
255	White-tailed Stonechat	*Saxicola leucurus#* (Blyth, 1847)	काँसे झयापसी	LC	-	Insectivore	R	GB
	Nectariniidae							
256	Crimson Sunbird	*Aethopyga siparaja* (Raffles, 1822)	सिपचराबुङ्गेचरा	LC	-	Nectarivore	R	FB
257	Purple Sunbird	*Cinnyris asiaticus#* (Latham, 1790)	कालो बुङ्गेचरा	LC	-	Nectarivore	R	FB
	Oriolidae							
258	Black-hooded Oriole	*Oriolus xanthornus* (Linnaeus, 1758)	कालो टाउके सुनचरी	LC	-	Omnivore	R	FB
259	Eurasian Golden Oriole	*Oriolus oriolus* (Linnaeus, 1758)	गाजले सुनचरी	LC	-	Omnivore	S	FB
	Paridae							
260	Great Tit	*Parus major* (Linnaeus, 1758)	चिचिल्कोटे	LC	-	Insectivore	R	FB
	Passeridae							
261	Yellow-throated Sparrow	*Gymnoris xanthocollis#* (Burton, 1838)	पितकण्ठे भंगेरा	LC	-	Granivore	R	FB
262	Eurasian Tree Sparrow	*Passer montanus* (Linnaeus, 1758)	रुख भँगेरा	LC	-	Granivore	R	OF
263	House Sparrow	*Passer domesticus* (Linnaeus, 1758)	भँगेरा	LC	-	Granivore	R	OF
	Pellorneidae							
264	Indian Grassbird	*Graminicola bengalensis* (Jerdon, 1863)	घाँसे चरी	NT	-	Insectivore	R	GB
265	Puff-throated Babbler	*Pellorneum ruficeps* (Swainson, 1832)	थोप्ले भ्याँकुर	LC	-	Insectivore	R	FB
	Phylloscopidae							
266	Blyth's Leaf-warbler	*Phylloscopus reguloides* (Blyth, 1842)	तालुधर्के फिस्टो	LC	-	Insectivore	W	FB
267	Chestnut-crowned Warbler	*Phylloscopus castaniceps* (Hodgson, 1845)	रातो टाउके फिस्टो	LC	-	Insectivore	R	FB
268	Common Chiffchaff	*Phylloscopus collybita* (Vieillot, 1817)	चिप्चिप फिस्टो	LC	-	Insectivore	W	FB
269	Dusky Warbler	*Phylloscopus fuscatus* (Blyth, 1842)	गोधूली फिस्टो	LC	-	Insectivore	W	FB
270	Green-crowned Warbler	*Phylloscopus burkii#* (Burton, 1836) [	सुनचस्मे फिस्टो	LC	-	Insectivore	W	FB
271	Greenish Warbler	*Phylloscopus trochiloides* (Sundevall, 1837)	जिभल फिस्टो	LC	-	Insectivore	W	FB
272	Grey-hooded Warbler	*Phylloscopus xanthoschistos#* (Gray & Gray, 1846)	तुमुलकारी फिस्टो	LC	-	Insectivore	W	FB
273	Hume's Leaf-warbler	*Phylloscopus humei* (Brooks, 1878)	चन्चले फिस्टो	LC	-	Insectivore	R	FB
274	Large-billed Leaf-warbler	*Phylloscopus magnirostris*(Blyth, 1843)	ठूलोठुँडे फिस्टो	LC	-	Insectivore	W	FB
275	Smoky Warbler	*Phylloscopus fuligiventer* (Hodgson, 1845)	ध्वाँसे फिस्टो	LC	-	Insectivore	W	GB
276	Sulphur-bellied Warbler	*Phylloscopus griseolus* (Blyth, 1847)	पीतोदर ढुङ्गेफिस्टो	LC	-	Insectivore	S	FB

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277	Tickell's Leaf-warbler	*Phylloscopus affinis* (Tickell, 1833)	पीतोदर फिस्टो	LC	-	Insectivore	W	FB
278	Western Crowned Warbler	*Phylloscopus occipitalis** (Blyth, 1845)	ठूलो तालुधर्के फिस्टो	LC	-	Insectivore	W	FB
279	Whistler's Warbler	*Phylloscopus whistleri#* (Ticehurst, 1925)	सुसेली फिस्टो	LC	-	Insectivore	R	FB
	Pittidae							
280	Indian Pitta	*Pitta brachyura* (Linnaeus, 1766)	गाजले पिट्टा	LC	-	Insectivore	S	FB
281	Hooded Pitta	*Pitta sordidida* (Statius Müller, 1776)	चित्रक पिट्टा	LC	-	Insectivore	S	FB
	Ploceidae							
282	Baya Weaver	*Ploceus philippinus* (Linnaeus, 1766)	तोपचरा	LC	-	Granivore	R	GB
	Pnoepygidae							
283	Nepal Cupwing	*Pnoepyga immaculata* (Martens & Eck, 1991)	नेपाल ढिकुरेभ्याकुर	LC	-	Insectivore	R	FB
	Pycnonotidae							
284	Black Bulbul	*Hypsipetes leucocephalus* (Gmelin, 1789)	बाखे जुरेली	LC	-	Omnivore	R	FB
285	Black-capped Bulbul	*Pycnonotus melanicterus* (Gmelin, 1789)	कालोकल्की पहेंलो जुरेली	LC	-	Omnivore	R	FB
286	Himalayan Bulbul	*Pycnonotus leucogenys* (Gray, JE, 1835)	तार्के जुरेली	LC	-	Omnivore	R	FB
287	Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	जुरेली	LC	-	Omnivore	R	FB
288	Red-whiskered Bulbul	*Pycnonotus jocosus* (Linnaeus, 1758)	श्वेतभक्ष जुरेली	LC	-	Omnivore	R	FB
	Rhipiduridae							
289	White-browed Fantail	*Rhipidura aureola* (Lesson, 1830)	कुमथोप्ले मारुनी चरी	LC	-	Insectivore	R	FB
290	White-throated Fantail	*Rhipidura albicollis* (Vieillot, 1818)	नक्कले मारुनी चरी	LC	-	Insectivore	R	FB
	Scotocercidae							
291	Chestnut-headed Tesia	*Cettia castaneocoronata* (Burton, 1836)	रातो टाउके टेसिया	LC	-	Insectivore	R	FB
292	Pale-footed Bush-warbler	*Hemitesia pallidipes** (Blanford, 1872)	घेघरी झाडीफिस्टो	LC	-	Insectivore	R	FB
	Sittidae							
293	Chestnut-bellied Nuthatch	*Sitta cinnamoventris* (Blyth, 1842)	कटुसे मट्टा	LC	-	Insectivore	R	FB
294	Velvet-fronted Nuthatch	*Sitta frontalis* (Swainson, 1820)	मखमली मट्टा	LC	-	Insectivore	R	FB
	Stenostiridae							
295	Grey-headed Canary-flycatcher	*Culicicapa ceylonensis* (Swainson, 1820)	चन्चले अर्जुनक	LC	-	Insectivore	W	FB
296	Yellow-bellied Fairy-fantail	*Chelidorhynx hypoxanthus $* (Blyth, 1843)	पहेंलो मारुनीचरी	LC	-	Insectivore	R	FB
	Sturnidae							
297	Asian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	करचुली मैना	LC	-	Omnivore	R	OF
298	Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	भित्ते सारौं	LC	-	Omnivore	R	OF
299	Brahminy Starling	*Sturnia pagodarum#* (Gmelin, 1789)	जुरे सारौं	LC	-	Omnivore	R	OF
300	Chestnut-tailed Starling	*Sturnia malabarica#* (Gmelin, 1789)	बगाले सारौं	LC	-	Omnivore	R	FB
301	Common Hill Myna	*Gracula religiosa* (Linnaeus, 1758)	मैनाचरी	LC	II	Omnivore	R	FB
302	Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	डाङग्रे सारौं	LC	-	Omnivore	R	OF
303	Jungle Myna	*Acridotheres fuscus* (Wagler, 1827)[	काली सारौं	LC	-	Omnivore	R	FB
304	Spot-winged Starling	*Saroglossa spilopterus* (Vigors, 1831)	कटुसकण्ठे सारौं	LC	-	Omnivore	R	FB

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	Sylviidae							
305	Yellow-eyed Babbler	*Chrysomma sinense* (Gmelin, 1789)	तामे घाँसेभ्याँकुर	LC	-	Insectivore	R	GB
	Timaliidae							
306	Black-chinned Babbler	*Cyanoderma pyrrhops* (Blyth, 1844)	कालो चीउँडे वनभ्याँकुर	LC	-	Insectivore	R	FB
307	Chestnut-capped Babbler	*Timalia pileata* (Horsfield, 1821)	रातो टाउके घाँसेभ्याँकुर	LC	-	Insectivore	R	GB
308	Pin-Striped Tit Babbler	*Mixornis gularis#* (Horsfield, 1822)	चर्याचर्यारि फिस्टेभ्याँकुर	LC	-	Insectivore	R	FB
	Turdidae							
309	Alpine Thrush	*Zoothera mollissima** (Blyth, 1842)	सादाढाडे चाँचर	LC	-	Insectivore	W	FB
310	Black-throated Thrush	*Turdus atrogularis* (Jarocki, 1819)	बगाले चाचर	LC	-	Insectivore	W	FB
311	Grey-winged Blackbird	*Turdus boulboul* (Latham, 1790)	मदना चाचर	LC	-	Insectivore	R	FB
312	Orange-headed Thrush	*Geokichla citrina* (Latham, 1790)	सुन्तले चाचर	LC	-	Insectivore	S	FB
313	Red-throated Thrush	*Turdus ruficollis* (Pallas, 1776)	रातो कण्ठे चाचर	LC	-	Omnivore	W	FB
314	Scaly Thrush	*Zoothera dauma* (Latham, 1790)	गोब्रे चाचर	LC	-	Insectivore	R	FB
315	Tickell's Thrush	*Turdus unicolor* (Tickell, 1833)	फुस्रे चाचर	LC	-	Insectivore	W	FB
	Vangidae							
316	Bar-winged Flycatcher-shrike	*Hemipus picatus* (Sykes, 1832)	आसकोटे	LC	-	Insectivore	R	FB
317	Common Woodshrike	*Tephrodornis pondicerianus* (Gmelin, 1789)	टेन्था	LC	-	Insectivore	R	FB
318	Indian Paradise-flycatcher	*Terpsiphone paradisi* (Linnaeus, 1758)	श्वर्ग चरी	LC	-	Insectivore	R	FB
319	Large Woodshrike	*Tephrodornis virgatus#* (Temminck, 1824)	ठुलो टेन्था	LC	-	Insectivore	R	FB
320	Red-billed Blue Magpie	*Urocissa erythroryncha* (Boddaert, 1783)	स्यालपोथरी लामपुछ्रे	LC	-	Frugivore	R	FB
	Vireonidae							
321	White-bellied Erpornis	*Erpornis zantholeuca#* (Blyth, 1844)	सेतोपेटे जुरेफिस्टो	LC	-	Omnivore	R	FB
	Zosteropidae							
322	Oriental White-eye	*Zosterops palpebrosus* (Temminck, 1824)	कांकीर	LC	-	Insectivore	R	FB
	PELECANIFORMES							
	Ardeidae							
323	Black-crowned Night-heron	*Nycticorax nycticorax* (Linnaeus, 1758)	बाँके बकुल्ला देउकाग	LC	-	Piscivore	S	WB
324	Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	बस्तु बकुल्ला	LC	-	Piscivore	R	WB
325	Cinnamon Bittern	*Ixobrychus cinnamomeus* (Gmelin, 1789)	गेरु बकुल्ला	LC	-	Piscivore	S	WB
326	Great White Egret	*Ardea alba#* (Linnaeus, 1758)	ठूलो सेतो बकुल्ला	LC	-	Piscivore	R	WB
327	Green-backed Heron	*Butorides striata* (Linnaeus, 1758)	छोटोखुट्टे बकुल्ला	LC	-	Piscivore	R	WB
328	Grey Heron	*Ardea cinerea* (Linnaeus, 1758)	फुस्रे बकुल्ला	LC	-	Piscivore	W	WB
329	Indian Pond-heron	*Ardeola grayii* (Sykes, 1832)	भक्ति बकुल्ला	LC	-	Piscivore	R	WB
330	Intermediate Egret	*Ardea intermedia#* (Wagler, 1827)	मझौला सेतो बकुल्ला	LC	-	Piscivore	R	WB
331	Little Egret	*Egretta garzetta* (Linnaeus, 1766)	सानो सेतो बकुल्ला	LC	-	Piscivore	R	WB
332	Purple Heron	*Ardea purpurea* (Linnaeus, 1766)	प्याजी बकुल्ला	LC	-	Piscivore	R	WB
333	Yellow Bittern	*Ixobrychus sinensis* (Gmelin, 1789)	पहेंलो जुन बकुल्ला	LC	-	Carnivore	S	WB
	Pelecanidae							
334	Great White Pelican	*Pelecanus onocrotalus%* (Linnaeus, 1758)	ठूलो घाउँके हावासील	LC	-	Piscivore	P	WB

	Order/ Family/ Common name	Scientific name	Nepali name	IUCN	CITES	Foraging guild	Migration group	Habitat Type
	Threskiornithidae							
335	Red-naped Ibis	*Pseudibis papillosa* (Temminck, 1824)	कर्रा साँवरी	LC	-	Aquatic invertebrates	R	WB
	PICIFORMES							
	Megalaimidae							
336	Blue-throated Barbet	*Psilopogon asiaticus#* (Latham, 1790)	कुथुर्के	LC	-	Frugivore	R	FB
337	Coppersmith Barbet	*Psilopogon haemacephalus#* (Statius Müller, 1776)	बाँणा चरो (मिलचरो)	LC	-	Frugivore	R	FB
338	Great Barbet	*Psilopogon virens#* (Boddaert, 1783)	न्याउली	LC	-	Frugivore	R	FB
339	Lineated Barbet	*Psilopogon lineatus#* (Vieillot, 1816)	छिर्के कुथुर्के	LC	-	Frugivore	R	FB
	Picidae							
340	Black-rumped Flameback	*Dinopium benghalense* (Linnaeus, 1758)	कालोढाडे लाहाँचे	LC	-	Insectivore	R	FB
341	Buff-spotted Flameback	*Chrysocolaptes lucidus* (Scopoli, 1786)	गर्दनथोप्ले लाहाँचे	LC	-	Insectivore	R	FB
342	Eurasian Wryneck	*Jynx torquilla* (Linnaeus, 1758)	खर लाहाँचे	LC	-	Insectivore	W	GB
343	Fulvous-breasted Woodpecker	*Dendrocopos macei#* (Vieillot, 1818)	काष्ठकुट	LC	-	Insectivore	R	FB
344	Greater Yellownape	*Chrysophlegma flavinucha* (Gould, 1834)	ठूलो सुनजुरे काठफोर	LC	-	Insectivore	R	FB
345	Grey-capped Woodpecker	*Picoides canicapillus#* (Blyth, 1845)	फुस्रे टाउके काष्ठकुट	LC	-	Insectivore	R	FB
346	Grey-faced Woodpecker	*Picus canus* (Gmelin, 1788)	कालो गर्धने काठफोर	LC	-	Insectivore	R	FB
347	Himalayan Flameback	*Dinopium shorii* (Vigors, 1832)	तीनऔंले लाहांचे	LC	-	Insectivore	R	FB
348	Lesser Yellownape	*Picus chlorolophus* (Vieillot, 1818)	सुन जुरे काठफोर	LC	-	Insectivore	R	FB
349	Rufous Woodpecker	*Micropternus brachyurus#* (Vieillot, 1818)	सानो तामे काष्ठकुट	LC	-	Insectivore	R	FB
350	Scaly-bellied Woodpecker	*Picus squamatus* (Vigors, 1831)	ठूलोकत्ले काठफोर	LC	-	Insectivore	R	FB
351	Streak-throated Woodpecker	*Picus xanthopygaeus* (Gray & Gray, 1847)	कत्ले काठफोर	LC	-	Insectivore	R	FB
352	Yellow-crowned Woodpecker	*Leiopicus mahrattensis@* (Latham, 1801)	पहेंलोटाउके काष्ठकुट	LC	-	Insectivore	R	FB
	PODICIPEDIFORMES							
	Podicipedidae							
353	Black-necked Grebe	*Podiceps nigricollis* (Brehm, 1831)	कालीकण्ठे डुबुल्के चरा	LC	-	Carnivore	W	WB
354	Great Crested Grebe	*Podiceps cristatus* (Linnaeus, 1758)	सिउरे डुबुल्केचरा	LC	-	Piscivore	W	WB
355	Little Grebe	*Tachybaptus ruficollis* (Pallas, 1764)	डुबुल्केचरा	LC	-	Carnivore	R	WB
	PSITTACIFORMES							
	Psittacidae							
356	Alexandrine Parakeet	*Psittacula eupatria* (Linnaeus, 1766)	कर्रा सुगा	NT	II	Frugivore	R	FB
357	Plum-headed Parakeet	*Psittacula cyanocephala* (Linnaeus, 1766)	टुइसी सुगा	LC	II	Frugivore	R	OF
358	Red-breasted Parakeet	*Psittacula alexandri* (Linnaeus, 1758)	कागभेला सुगा	NT	II	Frugivore	R	FB
359	Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	कण्ठे सुगा	LC	-	Frugivore	R	FB
360	Slaty-headed Parakeet	*Psittacula himalayana** (Lesson, 1832)	मदना सुगा	LC	II	Frugivore	R	FB
	STRIGIFORMES							
	Strigidae							
361	Asian Barred Owlet	*Glaucidium cuculoides* (Vigors, 1831)	पाते लाटोकोसेरो	LC	II	Carnivore	R	FB
362	Brown Boobook	*Ninox scutulata* (Raffles, 1822)	हुक्के लाटोकोसेरो	LC	II	Carnivore	R	FB

	Order/ Family/ Common name	Scientific name	Nepali name	IUCN	CITES	Foraging guild	Migration group	Habitat Type
363	Brown Fish-owl	*Ketupa zeylonensis* (Gmelin, 1788)	हुचील	LC	II	Carnivore	R	FB
364	Collared Owlet	*Glaucidium brodiei** (Burton, 1836)	सानो डुन्डुल	LC	II	Carnivore	W	FB
365	Indian Scops-owl	*Otus bakkamoena #* (Pennant, 1769)	चित्री उल्लु	LC	II	Carnivore	R	FB
366	Jungle Owlet	*Glaucidium radiatum* (Tickell, 1833)	कुर्कुरे लाटोकोसेरो	LC	II	Carnivore	R	FB
367	Oriental Scops-owl	*Otus sunia* (Hodgson, 1836)	लोखके उल्लु	LC	II	Carnivore	R	FB
368	Spot-bellied Eagle-owl	*Bubo nipalensis* (Hodgson, 1836)	कत्ले उल्लु	LC	II	Carnivore	R	FB
369	Spotted Owlet	*Athene brama* (Temminck, 1821)	कोचलगाडे लाटोकोसेरो	LC	II	Carnivore	R	OF
	SULIFORMES							
	Anhingidae							
370	Oriental Darter	*Anhinga melanogaster* (Pennant, 1769)	सुइरोठुडे जलचरी	NT	-	Piscivore	R	WB
	Phalacrocoracidae							
371	Great Cormorant	*Phalacrocorax carbo* (Linnaeus, 1758)	जलेवा	LC	-	Piscivore	W	WB
372	Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	सानो जलेवा	LC	-	Piscivore	R	WB

W—winter migratory | S—summer migratory | P—passage | R—Resident | *—not recorded in 2015–2016 survey | #—not recorded in 2002–2012 survey | @ & $—Adhikari et al. 2003 & Adhikari 2000 that were not recorded in both surveys | %—spotted by Bird Education Society. Migration group and foraging guild were taken from IUCN Red List (IUCN 2020) and Indian Biodiversity Portal (2020).

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COMMUNICATION

On some additions to the amphibians of Gunung Inas Forest Reserve, Kedah, Peninsular Malaysia

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Abstract: A survey on amphibian fauna was conducted in compartments 15, 16, and 17 of Gunung Inas Forest Reserve (GIFR), Kedah, Peninsular Malaysia for a period of two-and-a-half years, starting from January 2016 to May 2018, with a total of 20 visits. Observations and collections of amphibian species were carried out in and along the rivers, forest streams, forest pools, rock pools, cascade areas, waterfalls, ditches, temporary pools, forest floors, and forest trails. In total, 41 species of amphibians, belonging to 25 genera, and seven families were collected over the survey period. Of these, 11 species were ranids, followed by 10 dicroglossids, seven rhacophorids, six microhylids, four bufonids, two megophryids, and a single ichthyophiids (*Ichthyophis* sp.). From these observations, it is being pointed out that 15 species of amphibians represent new records for GIFR, while two species were not detected. This increases the known amphibian diversity of Gunung Inas Forest Reserve from 28 to 41 species.

Keywords: Anura, checklist, diversity, mountain, rainforest, river.

Bahasa Malaysia: Tinjauan ke atas fauna amfibia telah dijalankan di kompartmen 15, 16 dan 17 Hutan Simpan Gunung Inas (GIFR), Kedah, Semenanjung Malaysia, selama dua tahun setengah, bermula pada Januari 2016 sehingga Mei 2018, sebanyak 20 kali lawatan. Pemerhatian dan pengumpulan spesies amfibia telah dijalankan di dalam dan di sepanjang sungai, alur sungai hutan, lopak air hutan, lopak batu, kawasan jeram, air terjun, parit, lopak air sementara, lantai hutan dan trek hutan. Keseluruhannya, 41 spesies amfibia, daripada 25 genera dan tujuh keluarga telah dikumpul sepanjang tempoh tinjauan. Daripada jumlah ini, 11 spesies adalah ranid, diikuti 10 dicroglossid, tujuh rhacophorid, enam microhylid, empat bufonid, dua megophryid, dan satu ichthyophiids (Ichthyophis sp.). Daripada pemerhatian ini, telah dikenalpasti 15 spesies amfibia merupakan rekod baru bagi GIFR, sementara dua spesies tidak dapat dikesan. Ini telah meningkatkan diversiti amfibia yang diketahui di Hutan Simpan Gunung Inas daripada 28 ke 41 spesies.

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UNIVERSITI SAINS MALAYSIA

INTRODUCTION

Banjaran Bintang Hijau is the third largest mountain range in Peninsular Malaysia, and located on the west coast. Its structure, which include hills, slopes, peaks, plateaus, streams, and rivers influences the landscape of northern Peninsular Malaysia. This important mountain range extends approximately 140 km from Bukit Besar, Thailand to the central Malaysian state of Perak. The highest peak in this mountain range is Gunung Bintang (1,862 m), followed by Gunung Bintang Utara (1,835 m) and Gunung Inas (1,801 m), which is within the state of Kedah. The Gunung Inas Forest Reserve (GIFR) is part of Banjaran Bintang Hijau, and placed in the district of Baling, Kedah. This forest reserve is managed by the South Kedah Forest Department. This forest reserve covers 37,346 ha of lowland dipterocarp, hill dipterocarp, lower montane and upper montane forests (Kiew 1998; Manokaran 1998). Tree species, such as *Shorea curtisii* (Meranti Seraya), *Shorea leprosula* (Meranti Tembaga), *Shorea macroptera* (Meranti Melantai), *Scorodocarpus borneensis* (Kulim), *Artocarpus elasticus* (Terap Nasi), *Ficus conglomerata* (Ara), *Artocarpus lanceifolius* (Keledang), *Callophyllumm* sp. (Bintangor), *Koompassia excelsa* (Tualang), *Alstonia angustiloba* (Pulai), *Macaranga* sp. (Mahang), and *Dipterocarpus* sp. (Keruing) can be found here. The understorey of the forest is dominated by bushes, ferns, herbs, palms, bamboos, climbers, fungi, and epiphytes. The forest floor receives little light and is covered by leaf litter, twigs, tree branches, and logs. Several important rivers, including the Sungai Sedim, Sungai Reyau, Sungai Teruna, Sungai Badang, and Sungai Tawar drain through this forest reserve. These rivers flow to Sungai Muda which empties into the Straits of Malacca.

Research on the amphibian fauna has been undertaken at various locations in Kedah. These include a study in Ulu Muda Forest Reserve (UMFR), which recorded 56 species of frogs (Norhayati et al. 2005); Gunung Jerai where 14 species were recorded (Ibrahim et al. 2006a); Langkawi Island where 16 and 24 species were recorded respectively (Grismer et al. 2006; Ibrahim et al. 2006b); Beris Valley where 14 species were recorded (Shahriza et al. 2011a); Lata Bukit Hijau where 18 species were recorded (Shahriza et al. 2011b); Gunung Inas Forest Reserve (GIFR) where 28 species were recorded (Ibrahim et al. 2012a); Bukit Perangin Forest Reserve (BPFR) where 15 species were documented (Ibrahim 2012b); Tupah Recreational Forest (TRF) where 13 species were documented (Shahriza et al. 2013a); and Ulu Paip Recreational Forest (UPRF) where 20 species were documented (Shahriza & Ibrahim 2014).

Previous studies on the amphibian diversity (Ibrahim et al. 2012a) and reptile diversity (Shahriza et al. 2013b) have been conducted in GIFR. Ibrahim et al. (2012a) reported 28 species of amphibians, belonging to 21 genera and six families. This included 10 species of ranids, eight dicroglossids, four bufonids, three rhacophorids, two megophryids, and one microhylid (Ibrahim et al. 2012a). This study was undertaken over a period of six months. In this study, we surveyed a larger area including compartments 15, 16, and 17 of GIFR and for a longer duration of 30 months, in the hope that additional amphibian species would be recorded with greater survey effort.

MATERIALS AND METHODS

We observed and collected amphibians in compartments 15, 16, and 17 of GIFR (5.416N, 100.782E; elevation <300m) (Figure 1), between January 2016 and May 2018, with a total of 20 visits. Surveys were carried out along the Gunung Bintang Trail (Trail 1), Sungai Reyau Trail (Trail 2), Sungai Sedim Trail (Trail 3), Sungai Teruna Trail (Trail 4), and around Sungai Sedim Recreational Forest. Amphibians were observed and inspected in and along the rivers, forest streams, ditches, swampy areas, forest pools, rock pools, animal wallows, waterfalls, cascade areas, forest floors, among leaf litter, and under logs or buttress.

Specimens were collected at night, between 2000 and 2400 h, via active sampling or opportunistic encounters, by teams of three to five people. The amphibians were captured by hand or sweep nets. The specimens were kept in moist plastic bags and brought back to the laboratory for measurements and further inspections. In the laboratory, the snout-vent length (SVL) and head width (HW) of the captured specimens were measured using a digital calliper (LC= 0.1 mm). Voucher specimens were prepared by euthanizing the specimens with tricane. Specimens were fixed with 10% formalin, stored in 70% ethanol and deposited at the School of Pharmaceutical Sciences, Universiti Sains Malaysia (USM) for reference. Tissue samples (thigh muscles) of some selected species were collected, stored in 95% ethanol and deposited at the same location for further analysis. The specimens were photographed in situ or in the laboratory, using an Olympus digital camera, model SP800. Species identification was based on morphological characteristics, such as body shape, colour, pattern, webbing, fingers and toes following

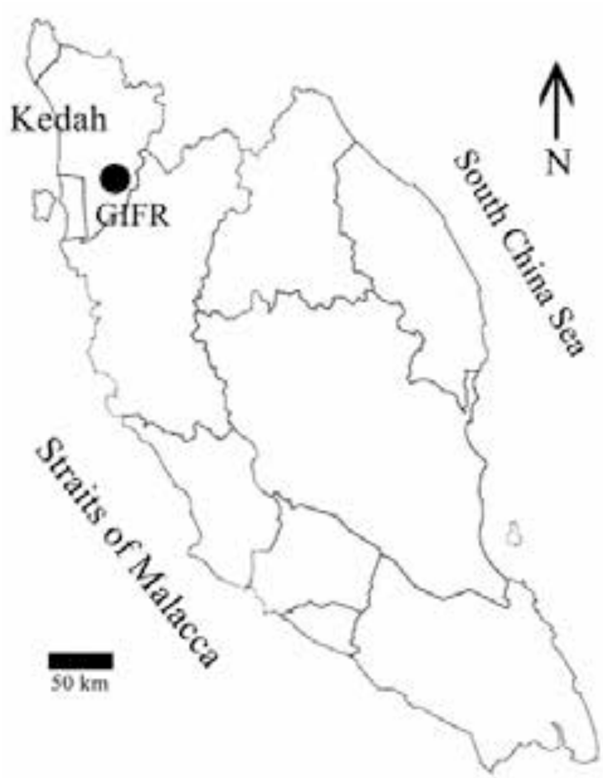

Figure 1. Map of Peninsular Malaysia, showing Gunung Inas Forest Reserve (GIFR) in Kedah

Berry (1975), Ibrahim et al. (2008), and Grismer (2011), while taxonomic nomenclature followed Frost (2021). Identification of *Rentapia flavomaculata* followed Chan et al. (2020a), *Limnonectes deinodon* followed Dehling (2014), *Microhyla mukhlesuri* followed Hasan et al. (2014), and *Pulchrana sundabarat* followed Chan et al. (2020b).

RESULTS

Forty-one amphibian species, belonging to 25 genera and seven families were recorded from compartments 15, 16, and 17 GIFR. These included 11 ranids, 10 dicroglossids, seven rhacophorids, six microhylids, four bufonids, two megophryids, and a single ichthyophiid (Table 1). Comparison of amphibian species recorded by Ibrahim et al. (2012a) and this study is presented in Table 2.

Species accounts

Family Bufonidae

***Duttaphrynus melanostictus* (Schneider, 1799)**

16USM-GIFR-DM01

Adult male, SVL= 58 mm, HW= 27 mm

An adult male was captured beside the road, along the way to Sungai Sedim Recreational Forest, in January 2016. The choruses of this species were recorded in November 2016 and October 2017, along the roadside ditches.

***Ingerophrynus parvus* (Boulenger, 1887) (Image 1)**

16USM-GIFR-IP01

Adult male, SVL= 47 mm, HW= 21 mm

The specimen was collected in November 2016, hiding among leaf litter on the forest floor, along Sungai Reyau trail.

***Rentapia flavomaculata* Chan, Abraham & Badli-Sham, 2020**

This tree toad was observed in September 2016 and October 2017, perched on the branches of a tree situated adjacent to the river (4–6 m above ground). In October 2017, seven adult males were detected, while actively calling from tree branches along the banks of Sungai Sedim.

***Phrynoidis asper* (Gravenhorst, 1829) (Image 2)**

This river toad and its chorus were observed in every visit to GIFR. The toad was very common and often sighted perched on the wet granite rocks or bounders, hiding under big rocks or resting on the ground along the banks of Sungai Sedim, Sungai Reyau, and Sungai Teruna. Additionally, the toads were also encountered living along the small forest streams, forest floors, ditches, near the base camp and in the toilets. Sometimes they can be found resting on tree branches, 2–3 m above the ground.

Family Dicroglossidae

***Fejervarya cancrivora* (Gravenhorst, 1829)**

An adult was sighted in June 2016 and October 2017. When first observed, it was found on the ground, at the edge of a temporary ditch, along the way to Sungai Sedim Recreational Forest.

***Fejervarya limnocharis* (Gravenhorst, 1829)**

16USM-GIFR-FL01,02

Adult male, SVL= 44, 49 mm, HW= 19, 21 mm

This medium-sized dicroglossid and its choruses were recorded in every visit to GIFR. It was very common and

Table 1. Amphibian checklist of Gunung Inas Forest Reserve, Kedah, Peninsular Malaysia

	2016				2017				2018	
Taxa	**Jan.**	**Jun.**	**Sep.**	**Nov.**	**Mar.**	**Jul.**	**Oct.**	**Dec.**	**Feb.**	**May.**
Bufonidae (4 species)										
Duttaphrynus melanostictus	X	-	-	X,V	-	-	X,V	-	-	-
Ingerophrynus parvus	-	-	-	X	-	-	-	X	-	X
Rentapia flavomaculata	-	-	X,V	-	-	-	X,V	-	-	-
Phrynoidis asper	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V
Dicroglossidae (10 species)										
Fejervarya cancrivora	-	X	-	-	-	-	X	-	-	-
Fejervarya limnocharis	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V
Limnonectes blythii	X	-	X	-	-	-	X	X	-	X
*Limnonectes utara**	-	-	-	-	-	-	X	-	-	-
Limnonectes deinodon	-	-	-	-	X	X	-	-	-	-
Limnonectes malesianus	-	-	-	X	-	-	-	X	-	-
Limnonectes plicatellus	-	-	-	-	X	-	-	X	-	-
Occidozyga sumatrana	-	X	X	X	-	-	-	-	X	-
Occidozyga lima	X	-	-	-	-	-	X	-	-	-
*Occidozyga martensii**	-	-	X	-	-	X	-	-	-	-
Megophryidae (2 species)										
Leptobrachium hendricksoni	-	X	-	-	-	-	-	X	-	X
Pelobatrachus nasutus	-	-	-	V	-	-	X	V	-	V
Microhylidae (6 species)										
*Kaloula pulchra**	-	-	-	X	-	X	-	-	-	-
*Microhyla berdmorei**	-	-	X,V	X,V	-	-	-	-	-	-
*Microhyla butleri**	-	X	-	-	-	X	-	-	-	X
*Microhyla mukhlesuri**	-	-	-	-	-	X	X	-	-	-
Microhyla heymonsi	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V
*Phrynella pulchra**	-	-	-	-	-	-	-	X	-	-
Ranidae (11 species)										
Abavorana luctuosa	-	X	-	-	-	-	-	X	-	-
Hylarana nicobariensis	-	-	-	-	-	X	-	-	-	X
Amolops larutensis	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V
Chalcorana labialis	X	-	X	-	-	-	X	X	-	-
Humerana miopus	-	-	-	X,V	-	-	-	X	-	-
Hylarana erythraea	-	X	X	-	-	X	-	-	X	-
Odorrana hosii	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V	X,V
Odorrana monjerai	-	-	-	X	-	-	-	X	-	-
*Pulchrana glandulosa**	-	-	-	V	V	X,V	V	-	-	V
*Pulchrana laterimaculata**	-	-	-	-	-	X,V	-	-	-	-
*Pulchrana sundabarat**	-	-	X,V	-	-	-	-	-	-	X,V
Rhacophoridae (7 species)										
Nyctixalus pictus	-	-	X	-	-	-	-	-	-	-
*Polypedates discantus**	-	-	-	X,V	X,V	-	-	-	-	-
Polypedates leucomystax	-	X,V	-	-	X,V	-	X,V	X,V	-	-
*Polypedates macrotis**	-	-	-	-	-	-	-	-	X	-
*Raorchestes parvulus**	-	-	X	-	-	-	-	-	-	-
*Rhacophorus nigropalmatus**	-	-	-	-	-	X	X	-	-	-
Zhangixalus prominanus	-	-	-	X	-	-	X	-	-	-
Ichthyophiidae (1 species)										
Ichthyophis sp.*	-	X	-	-	-	-	-	-	-	-
Number of species (41 species)	**9**	**13**	**15**	**17**	**10**	**15**	**18**	**17**	**8**	**13**

X—Observed | -—Not observed | V—Vocalisations | *—New record.

Table 2. Comparison of amphibian species in GIFR between past and present studies

Taxa	Ibrahim et al. (2012a)	Present study (2018)
Bufonidae (4 species)		
Duttaphrynus melanostictus	X	X
Ingerophrynus parvus	X	X
Rentapia flavomaculata	X	X
Phrynoidis asper	X	X
Dicroglossidae (10 species)		
Fejervarya cancrivora	X	X
Fejervarya limnocharis	X	X
Limnonectes blythii	X	X
Limnonectes utara	-	X
Limnonectes deinodon	X	X
Limnonectes malesianus	X	X
Limnonectes plicatellus	X	X
Occidozyga sumatrana	X	X
Occidozyga lima	X	X
Occidozyga martensii	-	X
Megophryidae (2 species)		
Leptobrachium hendricksoni	X	X
Pelobatrachus nasutus	X	X
Microhylidae (6 species)		
Kaloula pulchra	-	X
Microhyla berdmorei	-	X
Microhyla butleri	-	X
Microhyla mukhlesuri	-	X
Microhyla heymonsi	X	X
Phrynella pulchra	-	X
Ranidae (13 species)		
Abavorana luctuosa	X	X
Hylarana nicobariensis	X	X
Amolops larutensis	X	X
Chalcorana labialis	X	X
Hoplobatrachus rugulosus	X	-
Humerana miopus	X	X
Hylarana doriae	X	-
Hylarana erythraea	X	X
Odorrana hosii	X	X
Odorrana monjerai	X	X
Pulchrana glandulosa	-	X
Pulchrana laterimaculata	-	X
Pulchrana sundabarat	-	X
Rhacophoridae (7 species)		
Nyctixalus pictus	X	X
Polypedates discantus	-	X
Polypedates leucomystax	X	X
Polypedates macrotis	-	X
Raorchestes parvulus	-	X
Rhacophorus nigropalmatus	-	X
Zhangixalus prominanus	X	X
Ichthyophiidae (1 species)		
Ichthyophis sp.	-	X
Number of species (43 species)	**28 species**	**41 species**

X—Observed | -—Not observed.

occupied various habitats, such as open areas, car parks, fields, bushes, under tall grasses, roadside ditches, cement ditches, and swamps. They breed in stagnant water bodies, including temporary puddles, rock pools, and isolated pools. The two voucher specimens were collected in open area, near a car park, after heavy rain in November 2016.

Limnonectes blythii **(Boulenger, 1920) (Image 3)**

16USM-GIFR-LB01

Adult, SVL= 127 mm, HW= 48 mm

This riparian species can be found along the banks of Sungai Sedim, Sungai Reyau and Sungai Teruna. It also can be encountered along the small forest streams, swampy areas and on the forest floors. In September 2016, an adult was captured, perched on tangled roots, on the banks of Sungai Teruna.

Limnonectes utara **Matsui, Daicus & Norhayati, 2014 (Image 4)**

17USM-GIFR-LU01

Adult, SVL= 68 mm, HW= 34 mm

An adult was collected perched on the wet mossy rock, in a small forest stream (1–2 m width), which flows to Sungai Sedim in October 2017. The area was shaded and surrounded by lowland dipterocarp forest. This species, earlier known by the name *L. kuhli*, represents a new record for GIFR.

Limnonectes deinodon **Dehling, 2014**

17USM-GIFR-LD01

Adult, SVL= 38 mm, HW= 20 mm

A single specimen was captured resting on a rotten log, on the banks of a small forest stream, along Sungai Reyau trail in July 2017.

Image 1. *Ingerophrynus parvus*

Image 2. *Phrynoidis asper*

Image 3. *Limnonectes blythii*

Image 4. *Limnonectes utara*

Image 5. *Limnonectes plicatellus*

Image 6. *Leptobrachium hendricksoni*

***Limnonectes malesianus* (Kiew, 1984)**

The frog was observed in November 2016 and December 2017. When first observed, it was found on the wet ground, near a temporary puddle, along Sungai Sedim trail after heavy rain.

***Limnonectes plicatellus* (Stoliczka, 1873) (Image 5)**

17USM-GIFR-LP01

Adult, SVL= 45 mm, HW= 22 mm

The 'rhinoceros' frog was collected in March 2017, hiding among leaf litter, near a swampy area, along Sungai Sedim trail.

***Occidozyga sumatrana* (Peters, 1877)**

16USM-GIFR-OS01,02

Adult, SVL= 37, 39 mm, HW= 15, 15 mm

In November 2016, two specimens were collected submerged in a temporary rain pool, along Sungai Reyau trail after heavy rain. Later three more individuals were also sighted in another rain pool along this trail.

***Occidozyga lima* (Gravenhorst, 1829)**

16USM-GIFR-OL01

Adult, SVL= 39 mm, HW= 16 mm

An adult was captured hiding among leaf litter, near a rock pool, at the edge of Sungai Sedim in January 2016.

***Occidozyga martensii* (Peters, 1867)**

16USM-GIFR-OM01

Adult, SVL= 35 mm, HW= 15 mm

A single specimen was captured in September 2016, hiding among the grasses, in a temporary rain pool, along Gunung Bintang trail. This is a new record for GIFR.

Family Megophryidae

***Leptobrachium hendricksoni* Taylor, 1962 (Image 6)**

16USM-GIFR-LH01, 02

Adult, SVL= 53, 55 mm, HW= 32, 32 mm

Two specimens were caught, hiding under rotten log and dead leaves on the forest floor, along Sungai Reyau trail in June 2016. Tadpoles of this species were found inhabits in the rock pools and isolated pools along Sungai Sedim.

***Pelobatrachus nasutus* (Schlegel, 1858)**

17USM-GIFR-PN01

Adult, SVL= 69 mm, HW= 37 mm

In October 2017, an adult male was captured hiding under a big rock, near a small forest stream, which flow to Sungai Sedim. The chorus ('*thak*') of this species were heard in November 2016, December 2017, and May 2018.

Microhylidae

***Kaloula pulchra* Gray, 1831**

The frog was sighted in November 2016 and July 2017. On first observation, it was on the water surface, in a roadside ditch, along the way to Sungai Sedim Recreational Forest, after heavy rain. This is a new record for GIFR.

***Microhyla berdmorei* (Blyth, 1856) (Image 7)**

16USM-GIFR-MB01

Adult, SVL= 42 mm, HW= 19 mm

A single specimen was captured concealed under dead leaves, near a rock pool, on the banks of Sungai Sedim in September 2016. The choruses of this species were heard in September and November 2016, along the banks of Sungai Sedim. This species represents a new record for GIFR.

***Microhyla butleri* Boulenger, 1900**

This species was spotted in June 2016, July 2017, and May 2018, and often observed hiding under tall grasses, bushes, under dead leaves or under rotten log around Sungai Sedim Recreational Forest. They breed in stagnant water bodies, such as temporary puddles, rock pools and rain pools. This species represents a new record for GIFR.

***Microhyla mukhlesuri* Hasan, Islam, Kuramoto, Kurabayashi & Sumida, 2014**

An adult was spotted in July and October 2017. When first observed, the frog was camouflaged among the grasses, in a temporary puddle, along Sungai Teruna trail. This species, previously known by the name *M. fissipes*, represents a new record for GIFR.

***Microhyla heymonsi* Vogt, 1911**

16USM-GIFR-MH01, 02

Adult, SVL= 28, 30 mm, HW= 14, 14 mm

This microhylid and its chorus were observed and recorded in every visit to GIFR. They are ubiquitous and occupied various habitats, including disturbed and undisturbed areas. Two specimens were collected in November 2016, hiding under leaf litter and rocks, on the banks of Sungai Sedim.

***Phrynella pulchra* Boulenger, 1887 (Image 8)**

A single specimen was observed perched on a twig, approximately 0.5 m above ground, along Gunung Bintang trail in December 2017. This is a new record for GIFR.

Image 7. *Microhyla berdmorei.*

Image 8. *Phrynella pulchra*

Image 9. *Chalcorana labialis*

Image 10. *Humerana miopus*

Image 11. *Odorrana hosii*

Image 12. *Pulchrana sundabarat*

Family Ranidae

***Abavorana luctuosa* (Peters, 1871)**

An adult was detected in June 2016 and December 2017. On first observation, the frog was perched on a rotten tree buttress, near a puddle, along Sungai Reyau trail.

***Hylarana nicobariensis* (Stoliczka, 1870)**

The frog was spotted in July 2017 and May 2018. On being first sighted, the specimen concealed itself among grasses, near a roadside ditch, along the way to Sungai Sedim Recreational Forest.

***Amolops larutensis* (Boulenger, 1899)**

17USM-GIFR-AL01, 02

Adult, SVL= 46, 48 mm, HW= 25, 25 mm

This torrent frog and its chorus were observed in every visit to GIFR. They were very common and often perched on the wet mossy granite rocks or boulders, near waterfalls or cascades. When approached, the frogs jumped into the river or were seen hiding inside the rock crevices near the streams. In December 2017, two specimens were collected, perched on granite rocks, near cascade areas in Sungai Sedim.

***Chalcorana labialis* (Schlegel, 1837) (Image 9)**

16USM-GIFR-CL01, 02

Adult, SVL= 47, 48 mm, HW= 22, 22 mm

Two adult males were collected in September 2016, perched on leaves of low vegetation, near swampy area, along Sungai Sedim trail. Other individuals were detected in January 2016, October 2017 and December 2017.

***Humerana miopus* (Boulenger, 1918) (Image 10)**

17USM-GIFR-HM01

Adult, SVL= 85 mm, HW= 37 mm

In December 2017, a single specimen was captured at the edge of a forest pool, along Sungai Sedim trail. Two other individuals were also sighted in November 2016, at the same location, though they weren't collected.

***Hylarana erythraea* (Schlegel, 1837)**

17USM-GIFR-HE01

Adult, SVL= 74 mm, HW= 33 mm

This human-commensal species was observed several times. In July 2017, an adult male was captured, hiding among tall grasses, near a roadside ditch, along the way to Sungai Sedim Recreational Forest.

***Odorrana hosii* (Boulenger, 1891) (Image 11)**

17USM-GIFR-OH01, 02

Adult, SVL= 57, 59 mm, HW= 26, 26 mm

This poisonous rock frog is very common, and often found along the fast-flowing streams or cascade areas of the rivers. They were often perched on wet mossy rocks or boulders, rotten logs, creepers, small vegetation or tangle of roots, along the river banks. Sometimes, this species was sighted perched on tree branches or leaves, up to 2 m above the ground. Two adult males were captured in February 2018, perched on creeping plants (approximately 1.5 m above ground), on the banks of Sungai Sedim. This species and its call were detected in every visit to GIFR.

***Odorrana monjerai* (Matsui & Ibrahim, 2006)**

An adult was sighted perched on rotten tree buttress, near a small forest stream, along Sungai Reyau trail in November 2016. Another specimen was observed in December 2017, along Gunung Bintang trail.

***Pulchrana glandulosa* (Boulenger, 1882)**

The chorus of this species was recorded in November 2016, March 2017, July 2017, October 2017, and May 2018, along the banks of Sungai Teruna and roadside ditches. A single specimen was observed in July 2017, hiding among aquatic plants, in the roadside ditch, along the way to Sungai Sedim. This species denotes a new record for GIFR.

***Pulchrana laterimaculata* (Barbour & Noble, 1916)**

In July 2017, an individual was observed, perched on a tree fern, at the swampy area, along Sungai Sedim trail. This species represents a new record for GIFR.

***Pulchrana sundabarat* Chan, Abraham, Grismer & Brown, 2020 (Image 12)**

16USM-GIFR-PS01

Adult, SVL= 47 mm, HW= 21 mm

An adult male was collected in September 2016, while actively calling on a rotten log, along Gunung Bintang trail. Another specimen was observed in May 2018, and this species, previously by the name *P. picturata*, represents a new record for GIFR.

Rhacophoridae

***Nyctixalus pictus* (Peters, 1871)**

An individual was observed resting on the leaves of small vegetation (approximately 0.5 m above ground), along Sungai Reyau trail in September 2016.

Image 13. *Polypedates discantus*

Image 14. *Rhacophorus nigropalmatus*

Image 15. *Zhangixalus prominanus*

Image 16. *Ichthyophis* sp.

***Polypedates discantus* Rujirawan, Stuart & Aowphol, 2013 (Image 13)**

17USM-GIFR-PD01

Adult, SVL= 53 mm, HW= 24 mm

In March 2017, an adult male was captured perched on the twig of a creeping plant (approximately 2 m above ground), at the edge of Sungai Sedim. Another individual was spotted in November 2016 along Gunung Bintang trail. This species, earlier known by the name *P. leucomystax*, denotes a new record for GIFR.

***Polypedates leucomystax* (Gravenhorst, 1829)**

17USM-GIFR-PL01

Adults, SVL male= 48 mm, SVL female= 77 mm, HW male= 22 mm, HW female= 34 mm

An amplected pair was captured in December 2017, sitting on the ground, near an intermediate-sized rock pool, on the banks of Sungai Sedim. The choruses of this species were also recorded in June 2016, March 2017, October 2017 and December 2017, along Sungai Sedim and roadside ditches.

***Polypedates macrotis* (Boulenger, 1891)**

An adult was observed, resting on a tree branch (approximately 2 m above ground), near a temporary puddle, along Sungai Reyau trail in February 2018. This is a new record for GIFR.

***Raorchestes parvulus* (Boulenger, 1893)**

An individual was sighted, perched on the leaves of a creeping plant (approximately 1.5 m above ground), along Gunung Bintang trail in September 2016. This represents a new record for GIFR.

Rhacophorus nigropalmatus **Boulenger, 1895 (Image 14)**

17USM-GIFR-RN01

Adult, SVL= 93 mm, HW= 41 mm

In October 2017, an adult was captured perched on leaves (approximately 2.5 m above ground), near an intermediate-sized forest pool, along Sungai Sedim trail after heavy rain. Another specimen was also observed in July 2017 at the same location, and this species denotes a new record for GIFR.

Zhangixalus prominanus **(Smith, 1924) (Image 15)**

16USM-GIFR-ZP01

Adult, SVL= 61 mm, HW= 27 mm

A single specimen was collected in November 2016, sitting on tree branch (approximately 1.5 m above ground), near a temporary rain puddle, along Gunung Bintang trail. Another individual was also sighted in October 2017 along Sungai Sedim trail.

Ichthyophiidae

Ichthyophis **sp. (Image 16)**

A juvenile, approximately 15 cm long, was sighted crawling on the mud, near a forest pool and later disappeared under leaf litter. It was encountered along Sungai Sedim trail in June 2016 and represents a new record of this caecilian genus for GIFR.

DISCUSSION

Fifteen species of amphibians, including *Limnonectes utara, Occidozyga martensii, Kaloula pulchra, Microhyla berdmorei, M. butleri, M. mukhlesuri, Phrynella pulchra, Pulchrana glandulosa, P. laterimaculata, P. sundabarat, Polypedates discantus, Raorchestes parvulus, Polypedates macrotis, R. nigropalmatus*, and *Ichthyophis* sp. were incorporated to the list as new records for GIFR. Two species of frogs, *Hylarana doriae* and *Hoplobatrachus rugulosus*, which were detected in a previous study (Ibrahim et al. 2012a) were not detected during this survey. Thus, the diversity of amphibian in GIFR was increased from 28 to 41 species.

Limnonectes utara is a representative of *Limnonectes kuhlii* species complex, and was first described by Matsui et al. (2014) from Bukit Larut, Perak. The specimen from GIFR was congruent with that of *L. utara* in having dense warts on the tibia, full interdigital webbing between the toes and the first finger being slightly longer than the second (Matsui et al. 2014). This finding expands the northernmost distribution of *L. utara* by 110 km from its type locality. *Polypedates discantus* is a member of *Polypedates leucomystax* species complex, and was described by Rujirawan et al. (2013) from Songkhla Province, southern Thailand. The morphology of the specimens found in GIFR were congruent with the description of *P. discantus* in having the following characters; the skin of the head does not co-ossify with the skull, and white dots on the thighs were absent (Rujirawan et al. 2013). Accordingly, the distribution of *P. discantus* was extended to 253 km south of its type locality. A single species of caecilian, *Ichthyophis* sp. was encountered. This juvenile caecilian had a yellow dorsolateral line on each side, and was not assigned to a species.

Rhacophorus nigropalmatus or Wallace's flying frog is probably not uncommon, but it is rarely encountered because of their arboreal behaviour. They only descend from the canopy during the breeding season (Dring 1979; Inger & Stuebing 1997) and prefer forest pools or animal wallows to breed (Inger & Stuebing 1997). In GIFR, *R. nigropalmatus* was found perched on tree branches or leaves, overhanging a stagnant water of forest pools. The intermediate-sized pool (approx. 4 m length x 2 m width) was shady and sheltered by lowland dipterocarp forest. Its water was turbid, had a muddy bed, and dead leaves and twigs accumulated at the bottom of the pool. Other frog species, such as *P. leucomystax, L. blythii*, and *Humerana miopus* were also sighted in the same pools. Tadpoles of two or three unknown frog species were also encountered in the pool. This might indicate the importance of forest pools as a breeding site for several frog species, including *R. nigropalmatus*. Two frog species, *Hylarana doriae* and *Hoplobatrachus rugulosus* recorded in GIFR by Ibrahim et al. (2012a) were not detected. We reviewed the material deposited by Ibrahim et al. (2012a), and we assigned the specimen they identified as *H. doriae* to *L. blythii* based on the morphological characters (large and stout body, broad head, obvious tympanum, supratympanic fold present, dark brown coloration on dorsal surface and dirty white on ventral surface). However, we could not confirmed the identity of the specimen Ibrahim et al. (2012a) assigned to *H. rugulosus* as the specimen was missing. To date, the only confirmed records of *H. rugulosus* in Malaysia are from disturbed areas in Sabah, where they are invasive (Inger & Stuebing 1989; Inger 2005).

Ibrahim et al. (2012a) referred to 11 frog species encountered in GIFR as rare (*P. nasutus, L. hendricksoni, D. melanostictus, L. malesianus, L. deinodon, L. plicatellus, H. erythraea, A. luctuosa, H. miopus, N. pictus*, and *Z. prominanus*). They are not rare species but are species with elusive and secretive behaviours that could otherwise be recorded with suitable /specialised sampling methods. For example, both *P. nasutus* and *L. hendricksoni* are typical forest frog species, which can be found on the forest floors of old secondary forests or primary rain forests. They are usually encountered hiding among leaf litter, under big rocks or under rotten logs (Berry 1975; Ibrahim et al. 2008; Grismer 2011). Additionally, its dorsal pattern and colouration are very similar to their surrounding environments (ground, leaf litter, and twigs), thus providing a perfect camouflage.

Duttaphrynus melanostictus and *H. erythraea* are frequently seen, human-commensal species living in disturbed environment where they breed in stagnant water bodies (Inger 2005; Grismer 2011). In our study, both of these species were more frequently observed around villages, chalets or toilets when compared to that within the forest reserve areas. They can also be encountered around the roadside ditches, especially after heavy downpour. Although not many individuals of *Limnonectes deinodon* were observed in GIFR, this species is not considered rare. They can be found if more effort and careful observation were made during sampling periods. Usually, these small dicroglossids are encountered perched on rocks or boulders, sitting on the ground or hiding under leaves along the rivulets. *Humerana miopus* also is not a rare species and is often found around swampy areas and forest pools in GIFR. This species is very sensitive to sound and can immediately disappear, making it very difficult to detect.

Some species of frogs were reported at nearby areas, but were not recorded in GIFR. They are *Limnonectes paramacrodon* which was encountered at Bukit Hijau, Tupah, and Ulu Paip, *Sylvirana malayana* at Bukit Perangin, *Rentapia flavomaculata* at Ulu Paip, and *Ichthyophis nigroflavus* at Bukit Perangin. Ulu Paip, Bukit Hijau, Tupah, and Bukit Perangin are located 19, 24, 75, and 151 km from GIFR, respectively. According to Inger (2003), the presence of frog species in a particular area depends on various factors, including duration of sampling period, area of coverage, sampling technique, topography, weather, microhabitats, and activity pattern. Additionally, the physical characteristics of a stream also determine the presence and absence of frog species (Inger 1969).

From this research its shows that GIFR is very rich with amphibian species. Various type of habitats in GIFR contributed to higher richness of frog diversity. These included rivers, small forest streams, swamps, ditches, forest pools, rock pools, temporary pools, tree buttress pools and animal wallows, which provided suitable sites for amphibians to live and breed. Additionally, the presence of Banjaran Bintang Hijau with several prominent peaks such as Gunung Bintang and Gunung Inas influence the landscape of this area, which lead to the diverse amphibian species. Amphibians are essential to be conserved and protected as they play many important roles in the ecosystem. They are significant as a biological indicator, to control insects, as a prey for various types of predators and as medicinal species. Current research shows that amphibians skin secretions comprise various bioactive compounds including the antimicrobial peptides (AMPs), which is effective to various strains of bacteria (Conlon et al. 2008; Al-Ghaferi et al. 2010). These AMPs are able to use as a template, to develop and produce a new therapeutic agent (Conlon & Sonnevend 2011). Thus, amphibian species are required to be totally protected, so that the natural drugs resources, which have valuable potential are preserved forever. For a strategic conservation planning, their habitats and breeding sites must be defended and restricted from human disturbances. Deforestation and forest alteration for any purpose should be minimised or totally stopped in GIFR, so as to sustain and promote the amphibian richness and other biodiversity in general.

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REVIEW

A review of research on the distribution, ecology, behaviour, and conservation of the Slender Loris *Loris lydekkerianus* (Mammalia: Primates: Lorisidae) in India

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Abstract: The Slender Loris in India includes two subspecies, the Mysore Slender Loris and the Malabar Slender Loris, with unidentified populations at overlapping ranges of the subspecies. Prior to 1996, the knowledge on Indian lorises was mostly limited to laboratory studies, or some anecdotes from the wild. Since late 1990, several intensive field studies have been carried out which informed about the status, ecology, behaviour, conservation issues, and management of the Slender Loris in India. Here, we review all these studies, discuss the major findings and identify directions for future research.

Keywords: Distribution, habitat use, infant development, Malabar Slender Loris, Mysore Slender Loris, reproductive biology, social behaviour, survey methods, taxonomy, time-activity budget.

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Author details: Mewa Singh is a renowned wildlife biologist and has worked on a large number of species, both in the wild and in captivity. He has published over 200 research articles in internationally reputed journals and has trained a generation of students in India and in other countries. Mridula Singh teaches psychology at Maharaja's College, Mysuru and has worked on lion-tailed macaques, and other primates. She has also carried out extensive studies on laboratory rodents, testing the effect of Indian indigenous medicinal plants on behavior and learning. Honnavalli N. Kumara is a Wildlife Biologist in SACON, Coimbatore. His interest lies in understanding population dynamics, behavioural ecology, and conservation of mammals and birds. Shanthala Kumar's interest lies in exploring the population status of mammals, the behavioural ecology of mammals especially of primates, and -mammals/birds-endoparasite interaction. Smitha Gnanaolivu is an independent wildlife biologist/conservationist and has been researching the ecology, behaviour, and threats to the nocturnal primate, the Slender Loris, Loris lydekkerianus since 2012. She is actively associated with Nocturnal Primate Research Group, Oxford Brookes University, Little Fireface Project, and Association of Indian Primatologists. Ramamoorthy Sasi has worked on primates for several years, and is presently working as a Postdoctoral Fellow in SACON for the NPDF project entitled " Comparative Ecology and Behaviour of Slender Loris (Loris lydekkerianus lydekkerianus) in Dindigal - Madurai landscape, Tamil Nadu'', focusing on ecology, acoustic communication and behaviour in different habitat types.

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INTRODUCTION

Till about two decades ago, very little was known about the distribution, ecology, and behaviour of the Slender Loris in India. Because of them being nocturnal, small in size, and largely semi-gregarious, research, especially behavioural studies, on lorises has always been more difficult than on relatively large, diurnal and group living macaques and langurs. Still, considerable research has been carried out on Slender Lorises in southern India during the past two decades or so. Here, we review the status of research on the distribution, ecology, behaviour, and conservation of the Indian Slender Loris. The review would provide a vital synthesis of the published information on the Indian Slender Loris, identify the gaps in knowledge, and point to perspectives and directions for further research on the species.

TAXONOMY

The Slender Loris was first described as *Lemur tardigradus* in 1758 by Linnaeus, based on an illustration in Seba (1735). Geoffroy Saint-Hilaire (1796), under the impression that Linnaeus had described a Slow Loris, described the Slender Loris as a new genus and species *Loris gracilis*. The generic name *Loris gracilis* was conserved by the International Commission on Zoological Nomenclature (1999). Lydekker (1905) took two mounted specimens from Madras, as typical for *Loris gracilis*, and described 'The Ceylon Loris' as *Loris gracilis zeylanicus* on the evidence of another mounted specimen; this is BM 1904.10.12.3, with no precise location apart from Ceylon (Jenkins 1987). In 1908, *Loris tardigradus lydekkerianus* was described from Madras by Cabrera (1908) and *Loris tardigradus malabaricus* was described from Kutta, southern Coorg by Wroughton (1917). However, according to the presently accepted classification, the Slender Loris found in India is named *Loris lydekkerianus* (also occurs in Sri Lanka) and *Loris tardigradus* (now occurs only in Sri Lanka) (Groves 2001). In India, there are two recognised subspecies of the Slender Loris: Malabar Slender Loris, *Loris lydekkerianus malabaricus* (Image 1), found in the wet evergreen forests of the Western Ghats, and Mysore Slender Loris, *L. l. lydekkerianus* (Image 2), found in the relatively drier regions of southern India (Groves 2001; Kumara et al. 2013). However, Kumara et al. (2013) report that Slender Lorises on the eastern slopes of the Western Ghats in Kalakad-Mundanthurai and India Gandhi Wildlife Sanctuary differ from Malabar and Mysore Slender Lorises in coat colour, body size, and circumocular patches, and could be a different subspecies.

The Mysore Slender Loris is greyish-brown in coat colour with narrow circumocular patches and an adult male and a female weighed 275 g each, whereas the Malabar Slender Loris is reddish with large circumocular patches and smaller in size, and a male and a female weighed 180 g each (Kumara et al. 2006). Based on the data from a previous survey (Singh et al. 1999) and from some market animals, Nekaris (2001) reported the mean body weight of an adult Mysore Slender Loris to be 294.4 g and of female to be 259.7 g. In Kalakad-Mundanthurai Tiger Reserve (KMTR), Kar Gupta (2007) reported the mean body weights of males and females to be 205 g and 181 g. Within KMTR, the mean male body weight of 271.6 g at Thalayani was much more than the mean male weight of 181 g at Mundanthurai. Further, the male weight at Mundanthurai ranged between 164 and 260 g in pre-monsoon and between 196–270 g in post-monsoon seasons. Data on the body weight of Malabar Slender Loris are not available from different sites. The body mass, therefore, differs between seasons and habitat types with variations in resources. Extensive data on body weights, therefore, are required. The differences between the subspecies are described only for morphology, and no molecular work is carried out. Therefore, we recommend that a molecular study on the Indian Slender Loris is carried out to determine the status of its taxonomy.

SURVEY METHODS

Various survey methods have been employed depending on the purpose of the assessment. If the purpose of a survey is to determine only presence/ absence and also relative population abundance in different habitat types, at large spatial scales that could even run up to 100s of kilometres, linear surveys can be carried out on motorable roads/forest tracks in a four-wheeled vehicle, combined with short distance walks, wherever required. A team of 3–4 researchers can travel in a jeep at a speed of 5–10 km per hour, flashing lights, either hand-held torches or lamps fitted to the jeep battery, in all directions. Singh et al. (1999) first used this method to survey Slender Lorises in Dindigul, which covered 280 km, including 259 km in a jeep and 21 km walk. More extensive spatial surveys were carried out spanning a distance of 734 km covering several forest divisions in southern Andhra Pradesh (Singh et

Image 1. Malabar Slender Loris, *Loris lydekkerianus malabaricus*

Image 2. Mysore Slender Loris, *Loris lydekkerianus lydekkerianus*

al. 2000), 1,041 km, including 703 km in a jeep and 31 km walk, in northern and central Kerala (Radhakrishna et al. 2011), 641 km in a jeep in southern Kerala (Sasi & Kumara 2014), 557.1 km by walk and 844.6 km in a jeep in Tamil Nadu (Kumara et al. 2016), and almost the entire state of Karnataka (Kumara et al. 2006). In all the studies mentioned above, the encounter rate as loris/km represented abundance. In Tumkur and Bangalore forest divisions, having largely scrub forests where motorable roads were not available, a team of researchers (Das et al. 2011) divided the forest fragments into areas where only encounter rates could be determined through single walks with low detention frequency, and other fragments where 8–11 transects per forest fragment were laid and walked 6–8 times each with >40 detections. In the latter case, density estimates were done using the program DISTANCE. At a smaller scale covering 1 km^2, Gnanaolivu et al. (2020) overlaid 1-ha grid cells and walked trails covering a total length of 11.41 km as the sampling distance. Low illuminated headlamps (180 lumens) covered by red cellophane sheets were used for the surveys. The data obtained from repeated walks of 5 nights covering a total sampling distance of 57.05 km was analysed using PRESENCE to determine occupancy and abundance. Even in a further smaller area covering 7.2 ha, Kumara & Radhakrishna (2013) tested the efficacy of line transects, with transects of varying length, and belt transect with varying strip width methods against the known number of lorises in the study area. They demonstrated that both methods underestimated the loris density. However, since the underestimates were not too different from the actual density, they suggested that the line transect method and a belt transect method with a 20-m strip width could still be used for population density estimates of Slender Lorises. In a recent article, Kumara (2020) discussed random search, trail walk, line transect, total count, and belt transect survey methods employed to estimate population abundance/density of pottos and lorises and concluded that the survey designs and methods should be such that these can be replicated and ensure a precise estimate. Since surveys on lorises can be carried out only at nights with flashlights/headlamps so that reflections from the eyes of lorises could reveal their presence, care must be taken to use lights that do not hurt the eyes of the animals. If a vehicle is used and the distance between the researcher and the expected location of a loris is considerable, jeep battery fitted lights could be used as flashes. If the survey for presence/absence or encounter rate is being conducted on foot, torches such as a 3-battery Maglite or headlamps emitting red lights could be quite valuable.

Nocturnal primates have sensitive visual systems highly adapted for foraging and travelling in darkness and, therefore, can be susceptible to the adverse effects of night-time light exposure. Nocturnal primates also have retinas dominated by rod cells, which respond more strongly to white than red light. Existing evidence, therefore, suggests that exposure to white light could have deleterious effects on nocturnal primates (Weldon et al. 2020). Nocturnal subjects showed fewer behavioural and physiological impacts of exposure to night lighting when red lights were used than blue, proving that using red lights for nocturnal behavioural studies is ideal (Fuller et al. 2016). Observations from close distances should be carried out using headlamps such as Petzel headlamps, covered with red filters as lorises are not disturbed by a red light compared to white light. However, if the areas to be surveyed extend over hundreds of kilometres, where surveys are mostly carried out using jeeps on the highways, and the distance between the observer and the loris could be from 100 m to more than 500 m or so, highly diffused white light could still be used as a quick flash from a considerable distance. Once a loris is detected, the animal should be approached only with red filtered lights for closer observations.We again emphasize that even the diffused white light should be used only under exceptional circumstances and must be avoided as much as possible. There are several kinds of spotlights now available for field observations, as extra trail lights, and for spotting and filming animals from a vehicle (Nekaris et al. 2020). Since the lorises are active almost throughout the night, and in different light phases, the assessment can be carried out at any time of the night and also at any time of the light phase (Kumara & Radhakrishna 2013).

Since large areas of possible Slender Loris presence including relatively drier vegetation types in the states of Telangana, Andhra Pradesh, Odisha, Chhattisgarh, and Jharkhand, where motorable roads/forest tracks are available in many places, and relatively wetter regions in the Western Ghats where only walks are possible, are yet to be explored, a combination of methods discussed above, depending on the objectives, could be used for the surveys. Since surveying the entire distributional range of a species is often not possible, habitat modelling such as ecological niche modelling, combining occurrence records with climatic and environmental parameters, has helped to map the potential distribution of the Slender Loris (Kumara et al. 2009, 2012), and projecting the susceptibility of its habitat in the future (Subramanayam et al. 2021).

DISTRIBUTION

Schulze & Meier (1995) provided the first proper distribution map of the two subspecies of the Slender Loris. However, this map was based on anecdotal records in literature and not on direct field surveys. In the mid-1990s, the primate research team from the University of Mysore initiated systematic field surveys. Since then, Slender Lorises have been surveyed in selected regions of Dindigul (Singh et al. 1999), southern Andhra Pradesh (Singh et al. 2000), large areas of Karnataka (Kumara et al. 2006), northern and central Kerala (Radhakrishna et al. 2011), Tumkur and Bangalore forest divisions (Das et al. 2011), southern Kerala (Sasi & Kumara 2014), large areas of Tamil Nadu (Kumara et al. 2016), and Aralam Wildlife Sanctuary (Gnanaolivu et al. 2020). The actual surveys carried out so far have reported the extent of the distribution of the Malabar Slender Loris from the southern tip of the Western Ghats up to 15.8 ^{0}N in the Belgavi district of Karnataka, the subspecies occurring primarily in the wet forests on the western slopes of the Ghats. The Mysore Slender Loris, occurring from the southern tip of India in Tamil Nadu, has been observed up to 14.2 ^{0}N in the Nellore district of Andhra Pradesh, and it is found in dry deciduous and scrub forests.Using the available sight records and environmental variables, Kumara et al. (2009, 2012) have modelled the potential distribution of the Slender Loris, and it appears that the Malabar Slender Loris could be present still northwards in the Western Ghats, and the Mysore Slender Loris could occur further north-east, probably up to Odisha. Singh et al. (2000) started the surveys in southern Andhra Pradesh but the surveys had to be stopped at about 14 ⁰N as the forests north-east of the surveyed regions had presence of leftist militants, and the research team was not allowed to enter the forests in the nights. Therefore, we strongly recommend further surveys to determine the actual extent of the distribution of the Slender Loris. Even within the known distributional range, several regions still need to be explored for the presence and abundance of Slender Lorises.

The occupancy, relative abundance and densities

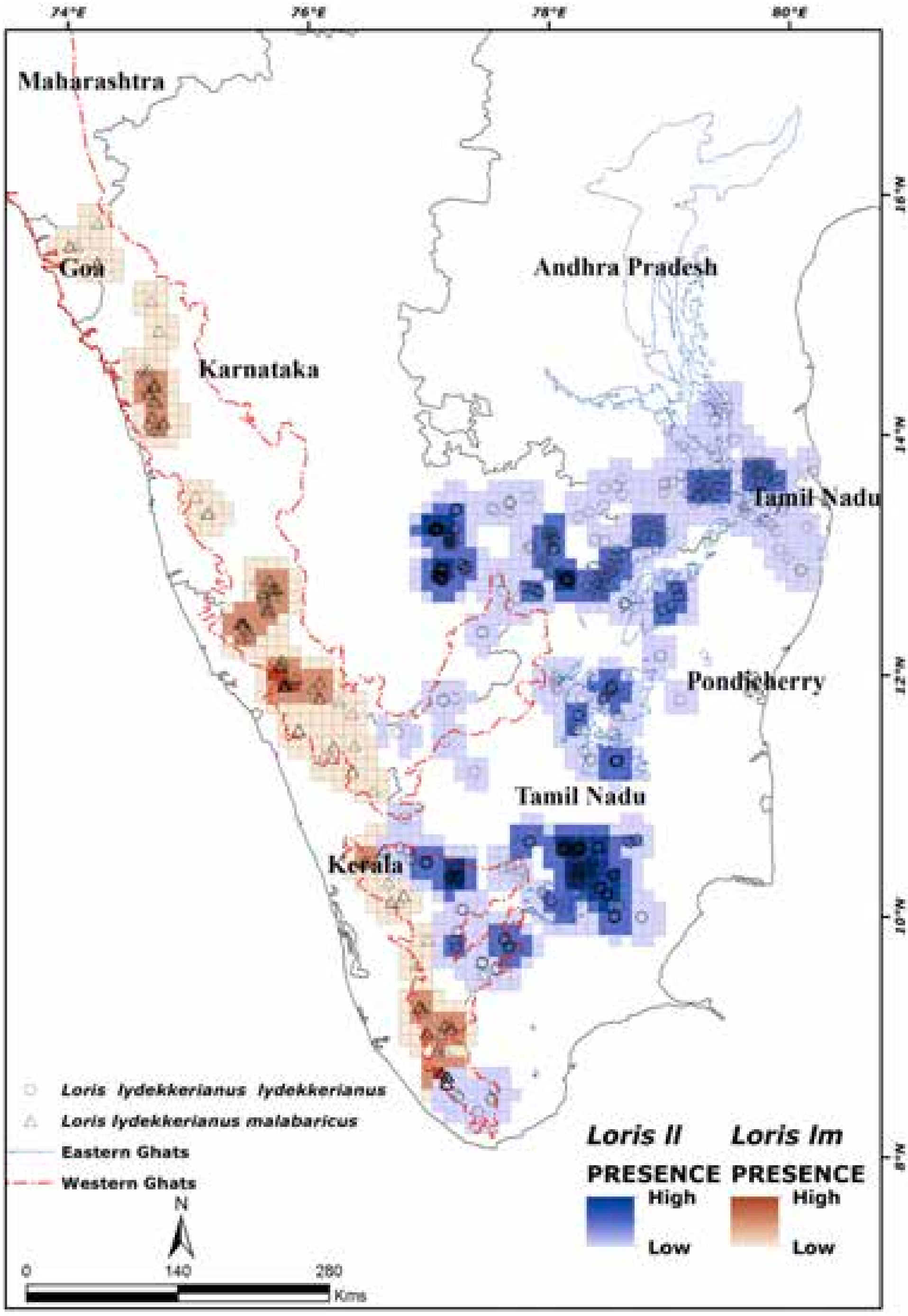

Figure 1. Distribution and hotspots of *Loris lydekkerianus lydekkerianus* and *L. l. malabaricus* in surveyed sites in India.

of Slender Lorises vary in different vegetation types and altitudes. In Dindigul (Singh et al. 1999), they were absent in dense thorn forests and were found in umbrella thorn forest and Euphorbia open forests, croplands close to forests, mixed deciduous forests and croplands away from forests with an encounter rate of 3.6, 2.8, 0.6, and 0.4 per km, respectively. They were located at 300 to 500m in southern Andhra Pradesh (Singh et al. 2000), the encounter rates of lorises in trees, bushes, and ground were 51 %, 47 %, and 2 %, respectively. The per cent sightings at heights of <3 and 3–6 m were 58 and 42, respectively. Three distinct population clusters of lorises at Kaundinya Wildlife Sanctuary complex, Tirumala Hills forests complex and Seshachalam Hills forests were identified. In the forest fragments of the Tumkur and Bangalore forest divisions, the loris encounter rates varied from 0.18 /km to 7.89 /km. Ujjani, Ippadi, Nagavalli, and Savandurga forest patches had a density of 1.85 /ha, and these areas were suggested for long term loris conservation. Though largely Malabar in most districts, both subspecies of the Slender Loris are found in Kerala with Mysore Slender loris occurring in Palakkad and Nemmara forest divisions, and in Chinnar and Neyyar wildlife sanctuaries (Radhakrishna et al. 2011; Sasi & Kumara 2014). In northern and central Kerala, lorises in evergreen, dry deciduous, moist deciduous, and plantations are 44.4, 35.0, 14.5 and 5.9 per cent, respectively. In southern Kerala, lorises were encountered with a rate of 0.31, 0.02 and 0.04 /km in moist deciduous, evergreen, and plantation vegetations, respectively. Though occurring primarily below 300 m, lorises in Kerala are found up to 1,500 m. Overall, there are three population clusters in Kerala, including Neyyar Wildlife Sanctuary up to Ariankavu Pass, from Ariankavu Pass to Palghat, and north of Palghat up to Aralam. With an encounter rate of 1.33 /km, occupancy of 0.48, and an estimate of the abundance of 2.40 /ha, Aralam appears to have the healthiest population of the Malabar Slender Loris (Gnanaolivu et al. 2020). The Mysore Slender Loris has also been reported from Peppara Wildlife Sanctuary (Kangavel et al. 2013). However, Sasi & Kumara (2014) reported Malabar Slender Loris in Peppara. This region, therefore, requires further verification. In KMTR, the loris densities in dry evergreen, dry deciduous, and scrub forests and plantations were 4.0, 1.0, and 0.3 / ha, respectively (Kar Gupta 2007). Within habitat, lorises appear in places with more tree density and canopy contiguity and less branch lopping and human disturbance (Kar Gupta 1998). Surveyed in large areas of Tamil Nadu (Kumara et al. 2016), the relative abundance of lorises varied from 0.01 /km to 2.21 /km in different regions. Most of the loris populations are found in south-central districts. Though mostly below 300 m, lorises are found up to an altitude of 1,257 m. Scrub, dry deciduous, plantations, and evergreen forests had encounter rates of 0.73, 0.18, 0.07, and 0.02 /km, respectively. Reserved forests, protected areas, and private lands had 0.79, 0.09, and 0.12 %, respectively of the loris populations. Only Mysore Slender Lorises were sighted in Tamil Nadu; however, no surveys were carried out in several hill regions with evergreen forests; it may be possible to find Malabar Slender Lorises in these wet regions. Further, even in the large surveyed areas, only presence/absence and relative encounter rates have been recorded. More systematic data through the occupancy framework in selected places with considerable loris presence needs to be collected and analysed using sophisticated modelling techniques to prioritise areas for loris conservation. Most of the surveys have been conducted in protected areas, reserve forests, and agricultural lands; we recommend surveys in urban areas also since sizable populations of lorises are reported even from large cities such as Bengaluru. Figure 1 shows the latest available information on the distribution and relative abundance of the Slender Loris in India.

BEHAVIOUR

Although field studies on the ecology and behaviour of the Slender Loris in India started in the late 1990s, only four extensive field studies are complete, and one is in progress. The completed studies are Radhakrishna (2001), who studied Mysore Slender Loris in a tropical thorn forest near Ayyalur in Dindigul Forest Division between October 1997 and June 1999, spanning over 21 months. Nekaris (2000) also studied the same population for 10 months between October 1997 and August 1998. Radhakrishna & Kumara (2010) studied Mysore Slender Loris at Malapatti in Tamil Nadu between October 2005 and June 2007. Kar Gupta (2007) studied the Slender Loris population at Kalakad-Mundanthurai intermittently for several years from 1997 to 2003. The only relatively long-term study on the Malabar Slender Loris by Smitha Gnanaolivu at Aralam, Kerala, is recently completed. In observations during studies on behaviour, the most widely used method has been instantaneous scan sampling and opportunistic sampling. Unlike diurnal primates, it is pretty challenging to keep a Slender Loris under continuous watch to employ focal animal sampling with fixed durations. Nekaris (2001) used three methods, viz., instantaneous point samples pooled, means of individual lorises, and behaviour at the moment of first contact (Opportunistic sampling) for the study of activity budgets, and found no significant difference between the three data sets. Instantaneous scan sampling, and also focal animal sampling, are suitable in dry deciduous forests or scrub forests, where the lorises are relatively easily visible. On the other hand, for the species in dense forests or wet forests, the visibility reduces, and the dense foliage hides the lorises even after we habituate them. Thereby opportunistic sampling, and if possible, instantaneous scan sampling, are better in areas with low visibility. Kar Gupta (2007) carried out the only study on Slender Lorises in India using radio telemetry which provided detailed information on home ranges, socialization, diet, and habitat.

Time Activity Budgets

In the scrub forests of Ayyalur, Slender Lorises spent 13.17, 47.27, 2.48, 26.90, 6.84, and 3.30 per cent of their time on locomotion, exploration, feeding, inactivity, social interactions, and self-directed behaviours, respectively (Radhakrishna & Singh 2002a). The time spent on exploration and social behaviour was more in the wet season, and on other activities, it was more in the dry season. Increased exploration and decreased inactivity were observed during the dark moon phase compared to the light moon phase. Locomotion and self-directed behaviours were higher before midnight whereas social behaviour was higher after midnight, as compared to other activities. The maximum temperature best predicted locomotion, rainfall predicted exploration, and inactivity, and minimum temperature and rainfall predicted self-directed behaviour. Social behaviour and feeding did not correlate with any of the environmental variables. Nekaris (2003) reported in the same population that lorises awoke between 1800 and 1900 h and ceased their activity between 0500 and 0600 h. The activity of lorises increased between 2000 h and midnight, and again at 0400 h, after which the activity decreased. Inactivity, travel, forage, feed, and groom occurred accounted for 43.6, 14.9, 33.5, 0.8, and 6.4 per cent of scans, respectively. Social grooming mainly occurred at dawn and dusk assemblies. Long-term studies in the future need to bring out details on the differences in time-activity budgets of various age-sex classes and in different seasons.

Use of Space

Animals, whether living solitary or in groups, restrict their movement to a circumscribed area generally called a home range, with more intensive use of a smaller area called core area within the home range. Data on home ranges in the Slender Loris are available from three field studies. Radhakrishna & Singh (2002b) recorded home ranges of eight adults, four subadults, and four juvenile Slender Lorises during their fieldstudy of 21 months in Ayyalur forests. A female Slender Loris had a mean home range size of 1.2 ha with a mean core area of 0.15 ha and moved over a mean path length of 119 m with a total night length of 234 m. The adult male mean home range and core area sizes were 2.36 ha and 0.37 ha, with mean path and night lengths of 241 m and 328 m. The mean home range of juveniles was 0.14 ha and 0.70 ha in the pre-and post-weaning periods, respectively, with path and night lengths of 42 m and 104 m pre-weaning, and 105 m and 255 m post-weaning. The mean home range of a subadult was 0.97 ha, and path and night lengths were 116 m and 244 m. The home ranges of adult females were almost exclusive, with a small mean overlap of 0.043 ha with no overlap in core areas. On the other hand, the home ranges of adult males had a mean of 0.73 ha overlap with the ranges of females. Interesting, a male's home range overlapped with several females, but the overlap was considerably more with one particular female. In the same study area, Nekaris (2003) reported the mean home ranges of adult males, adult females and subadult males to be 3.6 ha, 1.59 ha, and 1.17 ha, respectively. Nekaris also reported little overlap of home ranges between females and considerable overlap of male ranges with females and other males. Kar Gupta (2007), in another population in KMTR, reported adult male and adult female mean home ranges as 27.67 ha and 5.75 ha, respectively in radio-tracked animals. Male home ranges largely overlapped, and female ranges also had 11–44% overlap, but females were never seen together, indicating territoriality. Parous females had smaller home ranges than nulliparous females. Several points need to be considered here to compare the data on home ranges from these various studies. First, the study of Kar Gupta was in a mixed deciduous forest with tall trees, whereas studies of Radhakrishna & Singh and Nekaris were in a mainly scrub forest with no tall trees. Second, the taxonomic status of the KMTR population is undecided (Kumara et al. 2012). Third, the difference in the home range sizes in the same population in the studies of Radhakrishna & Singh and Nekaris is due to different home range measurement methods. In the study of Radhakrishna & Singh, the location of an animal was marked in each scan. After a study of 21 months, the outermost points of the range were connected by straight lines and physically measured on the ground, calculating the total area of the range. The area used by an animal in at least 15 % of the scans was considered as the core area. Since Slender Loris ranges were relatively small, such actual ground measurement could accurately assess the range. Nekaris, on the other hand, used the minimum convex polygon method that usually tends to overestimate the home range size, especially if rarely visited points are used in the data (Harris et al. 1990). Therefore, it is recommended that the data on home ranges of the slender loris are collected from various habitat types, and similar measurement methods are used for comparison. The home range of the Malabar Slender Loris seems to be smaller than that of the Mysore Slender Loris, as, in the occupancy sampling, two lorises were found in a grid of 1 m^2 in many of the grids (Gnanaolivu et al. 2020). Further, no systematic data on home ranges of the Malabar Slender Loris are yet available; a long-term study on this subspecies, preferably with the use of radio collars, is suggested.

Feeding and Habitat Use

Till the late 1990s, most of the information on food items of the Slender Loris came from studies in captivity, where animals often adapt to food items that may not even be available in their natural habitats. Radhakrishna & Singh (2002) first reported a 21-month-long field study on the feeding ecology and habitat use of the Mysore Slender Loris at Ayyalur. Insects, plant material and gum comprised 91.48, 6.61, and 1.9 %, respectively, of the loris diet. Lorises also fed on fruits of *Securinega leucopyrus* and *Ziziphus oenoplia* and gum from *Albizia* and *Acacia* sp. In the same population at Ayyalur, Nekaris & Rasmussen (2003) addressed three main issues related to the feeding ecology of the Mysore Slender Loris: what is the proportion of different items in the diet of the loris, how do the lorises counter toxicity, and how are the resources dispersed? They reported that 96 % of the diet of the loris consisted of vertebrate and invertebrate prey. About 49 % of the prey was unidentified, and of the identified prey (31 %), *Hymenoptera* and *Isoptera* amounted to 63 % of the prey items. Most of the prey was small, and one case of adult female feeding on a lizard was observed. Since some insects such as cockroaches, termites, some ant species, true bugs and beetles are likely to be toxic, feeding on these items was accompanied by urine washing, head shaking, sneezing, and slobbering by the lorises. Since 71 % of the loris diet was found to occur in patches indicating clumped distribution, males and females were often found to feed together without any agonistic interactions pointing to gregariousness in the Mysore Slender Loris. A comparative study on the feeding ecology by the Mysore Slender Loris was carried out by Radhakrishna & Kumara (2010) in a mosaic habitat of small agricultural farms, thickets, and orchards at Malapatti. Interestingly, insects here constituted only 60 % of the diet of lorises, along with flowers and exudates, fruits and seeds, and animal prey constituting 13 %, 24 %, and 3 %, respectively. On two occasions, an adult female was observed to feed on a mouse and a gecko. Lorises fed on flowers of *Madhuca longifolia*, pods and seeds of *Prosopis juliflora*, fruits of *Psidium guajava* & *Syzygium cumini*, and dried gum or sap from *Prosopis* & *Tamarindus indica*. At Ayyalur (Radhakrishna & Singh 2002), lorises were found in trees of *Acacia*, *Azadirachta*, *Euphorbia*, *Albizia*, and *Tamarindus* in 37.77, 15.04, 13.1, 9.92, and 6.12 per cent scans, respectively. Lorises mostly used 3–7 m height trees, and both males and females were usually found at 3–5 m height. In the KMTR population, Kar Gupta (2007) analysed 30 faecal samples of 20 lorises and found that more than 75 % of samples had insect body parts, and the rest was plant matter. Some captured animals, when given a choice, preferred live crickets to fruits. Though the lorises used 76 species of trees, only 9 % accounted for 52 % of the total use. Likewise, only three species, of the 32 species of climbers used, comprised 60 % of the total use. Lorises were at a height between 3 m and 5 m 53 % of the time. For 71 % of their time, lorises were found in tree/climber complexes with canopy continuity on all four sides. The mean height of sleeping trees was 8.4 m. On the contrary, in the only such study on the Malabar Slender Loris (Gnanaolivu et al. 2020) in Aralam, tree species richness, tree felling and branch lopping were the major positive determinants of loris occupancy and abundance and climber cover negatively correlated with loris occupancy. Nekaris (2005) reported that the Mysore Slender Lorises captured fast-moving *Lepidoptera*, *Odonata*, and *Homoptera* using both hands from terminal branches and slow-moving *Hymenoptera* and *Coleoptera* with a one-handed grab from the sturdy middle branches. Lorises mostly detected the prey visually, indicating it to play an important role in selecting visual convergence in early primate evolution, with the exploitation of fruit accounting for the evolution of other key primate traits. Kumara et al. (2005) reported a novel behaviour in a Malabar Slender Loris feeding on red ants. The animal placed its hand on a branch that had red ants in large numbers. Due to saliva on the back of the hand of loris, ants would stick on it, and the animal licked the ants from its hand. This behaviour was observed to be repeated nine times before the animal went out of sight. The above review of the feeding ecology and habitat use by the Slender Loris indicates significant differences among populations inhabiting different habitat types. Though insects appear to be the primary diet of the loris, the species appears to be quite adaptive to feed on other items, including plant matter in areas where insects abundance may be low. Further studies are needed to determine loris diet and habitat use in more habitat types and in different seasons. Resource abundance would also need to be determined seasonally in the study regions.

Predation on lorises

Are lorises preyed upon? Although several potential predators such as domestic and wild cats, snakes, owls are reported, direct attacks on Slender Lorises have rarely been observed in the field. However, Gnanaolivu & Singh (2019) reported the first direct observation of predation, perhaps in a century, by a Brown Palm Civet *Paradoxurus jerdoni* on an adult female Malabar Slender Loris in Aralam in Kerala when two civets cornered a loris female to the end of a tree branch and using its sharp teeth, one civet grabbed the loris at its neck and thorax region, and disappeared in thick foliage.

Reproductive Biology

It is known since long that there are two oestrus periods, one in June–July and another in October–November, in the Slender Loris (Ramaswami & Kumar 1962), though Ramaswami & Kumar (1965) vehemently argued that conception in a female could take place only once in a year. Slender Loris males show spermatogenic activity throughout the year (Ramakrishna & Prasad 1967), though the size and the shape of male testes in the wild have been observed to differ from night to night (Nekaris 2003). Different testes size in captive lorises was also observed depending on temperature. The big scrotal testes and enlarged veins in the auricles helped to emit heat during too high ambient temperatures (Helga Schulz, pers. comm.).

Radhakrishna & Singh (2004a) report the first systematic study based on a 21-month-long observations on the wild Mysore Slender Lorises. A female reached sexual maturity at the age of about one year. Females showed two oestrus peaks, one in April–June and another in October–December. No oestrus was observed in January and July–September. Copulation was preceded by allogrooming between the female and her sleeping male partner. The male maintained intromission lasting up to 10 minutes even after ejaculation, and often deposited copulatory plugs. Mating was promiscuous, and three to four males mated with a female in succession, including a 'stranger' male, which was never seen earlier in the area ranged by a female. Though a female never 'presented' to a male for mating, promiscuous mating even with unknown males appears to be a subtle strategy to avoid inbreeding. Males are also polygynous. Males also indulged in intrasexual fights to access a female in oestrus, and they often harassed the mating pair. The mean gestation period was 164 days with an error margin of five days. Births occurred in March–May, July and October–December. Of the 14 births recorded during the study period, eight were singletons, and six were twins. This observation indicated that a female could roughly produce up to four infants during 12–14 months. One study female produced five infants during the study period of 21 months. The mean inter-birth interval was seven months. Juvenile to adulthood survivorship was 50 %. Some variations from the above pattern were observed in the Mysore Slender Loris population at Malapatti (Radhakrishna & Kumara 2010), where the gestation period was 5.3 months, and the inter-birth interval was nine months. Further, as against the promiscuous mating at Ayyalur, the females at Malapatti encouraged the residence of a single male. Births recorded in January, May, June, and July at Malapatti differed from the pattern at Ayyalur. Infant parking and weaning at Malapatti occurred at the age of six weeks and 118 days, respectively. High loris density and low resource abundance at Malapatti compared to Ayyalur probably account for these differences in reproductive biology at these different habitats. In the Slender Loris population at KMTR, Kar Gupta (2007) reported 12 births during the study period of February 2002 and May 2003, with six birth occurring in August–October and the other six in April–May. Comparing the studies of Radhakrishna (2001), Kar Gupta (2007), and Radhakrishna & Kumara (2010), it appears that the reproductive patterns of the Slender Loris vary in different habitat types and different populations, which indicates need of further research covering a variety of habitats and regions. Further still, no systematic long-term data are available on birth patterns in the Malabar Slender Loris from any of its distributional ranges.

There has been a general assumption that the mating systems in primarily solitary species are simple and opportunistic. Poindexter & Nekaris (2020) categorised the social organization of Lorisiformes into three groups, viz., promiscuous, monogamous, and multi-female/single-male, and concluded that lorisids have the dispersed family group social organization. Kar Gupta (2007) observed a fairly complex mating system in the Slender Loris males in KMTR. She identified three types of males: Roamer, Settler paired with a female, and Settler unpaired. Roamers had home ranges overlapping with other males and several females, and had a mean number of 23.33 sleeping sites. A Paired Settler had a smaller range with a mean number of 11 sleeping sites and paired male and female slept together. Unpaired Settlers had overlapping ranges and a mean number of eight sleeping sites. Settled males were in better habitats with higher arthropod abundance than Roamers. Paired Settler males had larger testes than other males suggesting a role for sperm competition and mate guarding. Kar Gupta opined that this kind of pair living with polygyny and sperm competition elements is an unusual breeding system in primates, and it also suggests that the social organisation of Slender Loris is far more complex than previously thought. Kar Gupta suggested carrying out more research on female social interactions, specifically on roaming males' social interactions with females.

Mother-Infant Interactions and Infant Development

Observations in the laboratory maintained Slender Lorises show that the mother shows intense attachment to the new born infant (Swayamprabha & Kadam 1980). However, when infants were separated from their mothers for two weeks and then presented to the females again, there was no mutual recognition between mothers and offspring, and females became indiscriminate, and any infant settled with any lactating female when several were caged together. However, this behaviour of females was never observed in free-ranging lorises where a female never cared for infant of another female (Nekaris 2003; Radhakrishna & Singh 2004b). Nekaris (2003) and Radhakrishna & Singh (2004b) have reported the development of loris infants in their natural environments in the Ayyalur forests. Young infants spent about 43 % of their time inactive. The neonates had their eyes closed and were carried unsupported by the mothers for the first three weeks after birth. Mothers carrying infants were regularly attended to and groomed by males. 'Parking' began when an infant was three weeks old, where the mother would 'park' her infant at the sleeping place at dusk and retrieve it at dawn. Infants were more social than adults. However, a primiparous mother parked her twin infants as early as two weeks and began to park them in different trees at four weeks. On many occasions, subadult and adult males visited and socially interacted with the parked infants when their mothers were away. Twins interacted socially more with each other than with their mothers. The weaning of the infant begins when it is about four months old and lasts about a month. The mother first refuses to carry the infant and then stops joining it to sleep. As the infants grow, time spent with related conspecifics decreases and with non-related individuals increases. Females attain their first estrus at 9–10 months of age, after which they either start moving in areas more than their mothers' range or just disappear from their natal range. We recommend further systematic research to see what happens to dispersed individuals. Do the males become wanderers for specific periods of their age? How do the subadult, now adult, females establish their new territories? As it is difficult to know when a subadult would disperse and follow a dispersing individual, the study would require radio-collaring several subadult males and females to track their movements.

Social Behaviour

Radhakrishna & Singh (2002c) published the first detailed account of social behaviour of the Mysore Slender Loris in its wild habitats. Lorises spend only about 7 % of their time on social activities. The main social interactions include sleeping together, grooming, courtship and mating, agonistic interactions, and social communication. The large sleeping groups of 2–6 individuals include a female and her present and previous offspring and an adult male. Such a sleeping group is temporary and is found chiefly when a female is in oestrus. The other types of sleeping groups are mother and infant, adult male and adult female, and siblings. About 98 % of the social interactions are affiliative, and only about 2 % are agonistic. Mother-infant, siblings, adult male-female, juvenile-adult and subadult-adult accounted for 39.1, 28.7, 8.6, 14.7, and 8.8 per cent respectively of the total affiliative social interactions. Of the 31 agonistic encounters observed, 18 occurred when an adult female rejected advances by a male for sexual contact. Four agonistic interactions between females occurred when another female tried to enter the home range of a female. Most of the agonistic interactions between males occurred during copulations and at boundaries of home ranges. Emigration, which correlated with sexual maturity, was observed in three females and five males from their maternal ranges. Immigration recorded for four adult males into ranges of females resulted in sleeping associations with resident females. The immigrant males first started to play and sleep with the present offspring before making approaches to the female. This behaviour appears to be a strategy used by the males to appease and attract females. Social communication included urine-marking and vocalisations. Urine-marking may serve as a territorial signal in both sexes and a signal to indicate the oestrus status of a female as males, on some occasions, showed excitement after sniffing the substratum with female urine. Urine handwashing was also often observed. The vocalisations included whistle and chitter used mostly by adults during agonistic interactions and territorial warning calls, growl used in aggressive encounters, zic used by infant to attract mother's attention, and krik used by males as appeasement calls to females. A scream heard only once was probably indicative of fear. Nekaris (2006) in the same population reported that males were more social than female and interacted with both sexes. On the other hand, females rarely interacted intra-sexually, and associated commonly with males. Although active social interactions were nocturnal, contact associations continued even during the day. Significant differences from the above features of social behaviour were observed in the Mysore Slender Loris population at Malapatti (Radhakrishna & Kumara 2010), where affiliative and agonistic interactions were 53 % and 47 %, respectively. Most of the affiliative interactions were among kin, with some between an adult male and a female and her offspring. Female territoriality accounted for most (46.3 %) of the agonistic interactions, with 14.8 % between adult females and males when females rejected the male advances. The sleeping group pattern at Malapatti was about the same as at Ayyalur. Higher loris density and probably lesser resource abundance at Malapatti than at Ayyalur are the probable reasons for a higher degree of agonistic behaviours at Malapatti. These observations further point out that these behaviours in loris need to be studied in several different habitats with differences in population and resource abundance. Radhakrishna (2004) concluded that "the slender loris appears to be the archetype of a solitary primate species, with most of the intraspecific social interactions occurring in biological contexts like reproduction and parental investment" (p. 80). However, the possibility of adult male-adult female, adult male-juvenile, and sibling associations exists beyond biological contexts, which can be revealed only by further long-term studies on identified individuals.

THREATS AND CONSERVATION

Both Mysore Slender Loris (Kumara et al. 2020a) and Malabar Slender Loris (Kumara et al. 2020b) have been listed as 'Near Threatened' on the IUCN Red List of Threatened Species. However, lorises are facing severe threats to their survival in some areas of their distribution. In the past, when there were no institutional animal ethics committees and strict wildlife protection laws, there was an indiscriminate use of Slender Lorises in laboratory researches. For example, for one study on male reproductive organs (Ramakrishna & Prasad 1967), 151 wild lorises were captured outside Bengaluru city and autopsied within hours in the laboratory. In many places in their habitats, electric wires are running through the habitats of the Slender Loris. The height of the electric poles is about the same where most loris movement and foraging takes place. As a result, lorises accidentally touch live wires and die of electrocution. Such cases have been observed in several areas. In places where lorises occur in agricultural lands and roadside vegetation, they often have to cross the roads by walk as the canopies on the two sides of these roads and paths are not contiguous. Because of their odd and clumsy walks and freezing in response to intense vehicular lights, they often get run over by motor vehicles and bicycles. Such roadkills of lorises are reported from many regions. In some areas, local hunters consider the sighting of a loris a bad omen and often kill them. The body parts, especially the eyes, are used by people in some areas as traditional folk medicines and cultural practices (Radhakrishna & Singh 2002; Dittus et al. 2020). In some regions of Karnataka, lorises are considered harbingers of misfortune and are killed on sight (Kumara et al. 2006). Traditional use of lorises is an important component in treating different illnesses, making love potions, and treating eye problems with loris tears in Tamil Nadu (Kanagavel et al. 2013). There are superstitions that an unmarried woman in the community will remain unmarried for the rest of her life on sighting a Slender Loris; hence lorises are killed by men on sight (Kanagavel et al. 2013). These practices can be controlled through strict implementation of wildlife protection laws and public education and awareness at the same time. Unlike many other primates such as macaques and langurs, which often negatively interact with humans, Slender Lorises have little to no conflict with people either for habitats or for resources. Based on the available field studies, there is a requirement for three conservation management practices for lorises. First, there are several large areas where Slender Lorises are present in good abundance, but these regions do not have proper legal status for wildlife conservation; for example, the reserved forests in Tumkur, Karnataka, and Ayyalur, Tamil Nadu. If not elevating the status of such areas to the level of PAs, at least the regions could be declared as 'loris reserves' as a first step, which could provide legal protection for these animals. Second, some regions have substantial loris populations, but tree felling, and other habitat disturbances result in a lack of canopy contiguity. Since the lorises are anatomically incapable of jumping beyond 0.3 m (Sellers 1996), the body structure of the loris is not made for walking on the ground; canopy contiguity for easy movement of lorises in trees needs to be ensured. Third, in some areas, lorises maintain population continuity between/among scrub forest fragments through tall fences and vegetation in cultivated agricultural fields. Such areas need to be identified, and proper management practices to ensure population continuity be implemented. Most of the populations of the Mysore Slender Loris are found in forest fragments with high population density. Such fragments need additional protection.

Although indicated in the various subsections above, we specifically make the following recommendations:

· Molecular work would help in determining the extent of genetic difference between the two subspecies, and the unidentified populations.

· The survey needs to be taken up in potential areas of the distribution of Slender Loris that are not yet explored.

· The density estimation in surveyed areas with high encounter rates as potential sites would help in loris conservation.

· Behavioural studies are suggested, if possible using radio telemetry, in different habitat types, especially on the Malabar Slender Loris.

· Areas with a substantial loris population need to be prioritized to provide legal status for the conservation of loris.

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REVIEW

Bivalves (Mollusca: Bivalvia) in Malaysian Borneo: status and threats

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Abstract: Species checklists enlist the species existing within a distinct geographical biome and assist as an indispensable input for evolving conservation and administration strategies. The arenas of conservation ecology and biology face the challenge of exaggerated biodiversity, accredited to the non-recognition of taxonomic inconsistencies. The study's goals are to organize all scattered taxonomic information regarding bivalve molluscs from Malaysian Borneo, i.e. Sarawak and Sabah, under one umbrella. Available literature regarding Malaysian Borneo was reviewed. The published taxonomic data on bivalve species, conservation status, inconsistencies, habitats (marine, fresh, and brackish), research aspects, threats, and conservation strategies are presented. A critical review of the checklists and distributional records of the class Bivalvia from Malaysian Borneo and subsequent validation of species names with the World Register of Marine Species (WoRMS) database revealed that currently 76 bivalve species from 12 orders and other entities, 18 superfamilies, and 27 families have been recorded from the area. Twenty-six inconsistencies with WoRMS were found, and the corrected names are presented. The study indicates most of the enlisted bivalve species have not been evaluated by the IUCN Red List authority and have 'Least Concern' or 'Data Deficient' status for Malaysian Borneo. To date, published documents on conservation decision strategies and guidelines for future research are not good enough. Nevertheless, potential threats and their remedies for bivalves in the enriched Malaysian Borneo ecosystems are discussed herein.

Keywords. Biodiversity conservation, checklist, database, double-shelled molluscs, IUCN Red List, taxonomic inconsistency.

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INTRODUCTION

The establishment of a database and checklist of regionally present species is crucial in managing and conserving them from alpha to global ecosystem (Amano & Sutherland 2013). The lack of sufficient information at the local level regarding rare and/or endemic species potentially at risk of extinction may lead to strategies taken by different organizations, including the government, that are inadequate to avoid their extinction (Işik 2011). Nowadays, humankind faces some traumatic events, including the so-called "sixth extinction crisis". The previous five extinctions were caused by massive atmospheric, climatic, and universal phenomena, but the prediction of the next mass extinction is putting the finger on human interference in natural ecosystems (Braje & Erlandson 2013).

At regional and local level, species decline faster than the prediction of ecologists (Collen et al. 2011; Işik 2011), but this can be modified to a sustainable level if the conservation efforts would focus on protecting certain species (Reydon 2019). For example, some aquatic animal recovered their extinction risk by the conservation approach with a proper policy, legislation, and effective conservation measures. Recently, the Bangladesh government and department of fisheries initiated the conservation of red fin mahseer (*Tor tor* Hamilton, 1822). The proper breeding program and management helped this species regain their confined population (Kabir et al. 2018). Similarly, the reproduction and conservation management of butter catfish *Ompok pabda* (Hamilton-Bouchanan, 1822) changes their IUCN status from 'Near Threatened' to 'Endangered' species (Chakraborty et al. 2010; IUCN Bangladesh 2015). Now, aquaculture is very extensive for *Ompok pabda* (Hamilton-Bouchanan, 1822) in Bangladesh and the Indian region (Chaklader et al. 2016; Alam et al. 2020).

Another is to protect specific areas with high biodiversity, including rare and/or endemic species. Now governments and third-party stakeholders recognize the value of biodiversity conservation, and they convey efforts, finances, and human resources to the conservation of nature. The first step in this process is to know the present status of biodiversity (Groves et al. 2002; Martin et al. 2016), where a checklist and relevant information are considered to be essential documents to step forward. Establishing a database of locally and regionally present species allows management of the national and transboundary continental conservation process (National Research Council 1992).

Bivalves (two valves), are abundant in marine, brackish and freshwater ecosystems, both infaunal and epifaunal in nature. Most are filter-feeders, but some are carnivores. They influence food webs and aquatic ecosystems via nutrient cycling and habitat modification and act as a bio-indicator (Vaughn & Hoellein 2018). In many countries, bivalves are consumed by humans for which they are harvested from the wild, including freshwater and marine habitats (Köhler et al. 2012; Wijsman et al. 2019). As molluscs are rich in protein and fat, along with essential nutrients including vitamins and macro-micro nutrients, restaurants around the world serve them as delicious and luxury food (e.g., Venugopal & Gopakumar 2017; Olivier et al. 2020). Bivalve shells, including the waste of such meals, are also used as buffer material for soil fixation; for instance, Korean scientists applied oyster waste to increase soil pH and other micro-macro nutrients (Lee et al. 2008).

In East Malaysia (Sarawak and Sabah, including the federal territory of Labuan), bivalves are considered a delicacy, and highly nutritious consumable commodities (Hamli et al. 2012b). Some previous studies described the bivalve fauna of Peninsular Malaysia (Idris et al. 2012; Jasin 2015; Zieritz et al. 2016; Zieritz & Lopes-Lima 2018). Some studies have been conducted in the Malaysian province of Sarawak and Sabah covering different habitats, including mangroves (Hamli et al. 2015; Abu Hena et al. 2016), seagrass (Al-Asif et al. 2020), wetlands (Idris et al. 2021), and freshwater (Hamli et al. 2020). Noticeably, the bivalve species from freshwater environments have a more than four to six times higher risk of extinction than those in marine habitats (Agudo-Padrón 2011).

Currently there is no monograph of bivalves (or molluscs in general) covering Malaysian Borneo. Thus far only a small fraction of the bivalve fauna of Malaysian Borneo has been recorded. The first bivalves from modern history of Malaysian Borneo were recorded from the Pantai river, Sarawak (Turner & Santhakumaran 1989) and Sematan mangrove forest, Sarawak (Ashton et al. 2003), although the first record can be tracked back in 1791, from the Federal territory of Labuan (A small island near coast of Sarawak and Sabah in Malaysian Borneo), with the report of native bivalve species *Marcia japonica* (Gmelin, 1791) (reported as *Venus japonica* Gmelin, 1791) (Gmelin 1791). With time, the number of published documents (taxonomic and ecological studies) has increased, but the list of bivalve fauna from East Malaysia remains very incomplete. Numerous species are recorded in Huber (2010, 2015), but his records 'north Borneo' or just 'Borneo' are not specific enough to be included here. Similar taxonomic and conservation work was published on fish species of Bangladesh in which the implementation of conservation measures on local fish habitats was proposed (Parvez et al. 2019). Similarly, the current investigation intends making a checklist of bivalves in the Malaysian part of Borneo, including their conservation status. This study also discusses the existing research initiatives, future research prospective, and recommended measures toward conserving this vital living resource.

MATERIALS AND METHODS

The current study is based on published records regarding Malaysian Borneo (Sarawak and Sabah; Figure 1), including monographs, reviews, checklists, catalogues, posters, conference papers and posters, websites, and fishery reports from 1791 and 2020, but no additional material was collected. For each reported species the scientific names were confirmed based on the World Register of Marine Species (WoRMS) 2021 and MolluscaBase eds (2021) (validating unaccepted names, emendations, alternate, and representations). The identifications were not checked for correctness. In most cases this was not possible, as most publications contain no photographs of the recorded species. New records should be accompanied by photographs as misidentifications are commonplace.

The species list comprises, orders, superfamilies, family name, accepted name, unaccepted names, and emendations. The contribution (%) of different orders within the class Bivalvia and various superfamilies and families in the class was estimated. The statistical data, total species counts, and graphical presentation were analyzed using Microsoft Excel.

RESULTS

Bivalve diversity

A total of 76 species of bivalves from 12 orders/ infraclasses/ superorders/ subclasses, 18 superfamilies, and 27 families were reported from freshwater and marine habitats (seagrass meadow, intertidal, mangrove, freshwater, wetlands, and coastal region of Sarawak and Sabah) in Malaysian Borneo (Figure 2).

Figure 1. Map of the of the East Malaysian states showing Sarawak and Sabah (The green circles denote the areas covered the study).

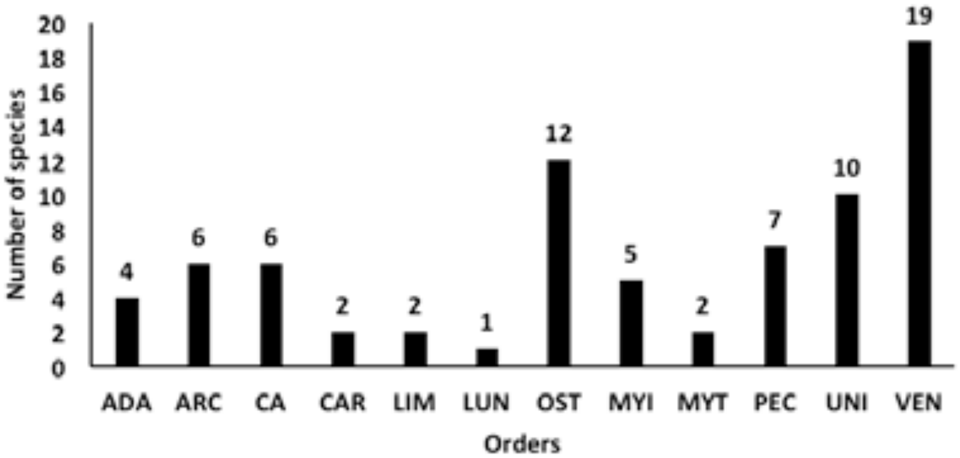

Figure 2. Number of Bivalves species based on the order recorded in Malaysian Borneo.
ADA—Adapedonta | ARC—Arcida | CA—Cardiida | CAR—Carditida | LIM—Limida | LUC—Lucinida | OST—Ostreida | MYI—Myida | MYT—Mytilida | PEC—Pectinida | UNI—Unionida | VEN—Venerida.

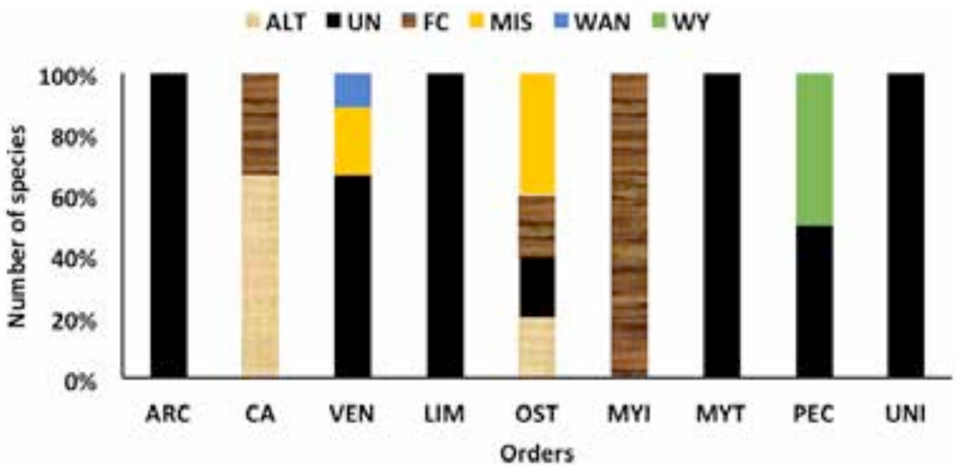

Figure 3. Extent of taxonomic inconsistencies in the orders of the class Bivalvia thus far recorded from Malaysian Borneo.
ArC—Arcida | Ca—Cardiida | Ven—Venerida | Lim—Limida | Ost—Ostreida | Myi—Myida | MYT—Mytilida | Pec—Pectinida | Uni—Unionida | ALT—Alternet representation | UN—Unaccepted | FC—Family changed | MIS—Misspelling | WAN—Wrong author name | WY—Wrong year.

A critical review of the published checklists revealed that the current literature included 26 incorrect names for bivalve species from nine orders/ infraclasses/ superorders/ subclasses and 14 families. Of these inconsistencies in the bivalve checklist over 53.84 % (14 species) was due to names not accepted in WoRMS (2021), spelling mistakes (15.38 %; 4 entities), alternative representation and inconsistency in family name (both 11.54 %; 3 entities each), and inconsistencies in author and year (both 3.85 %; 1 entity each) (Figure 3).

Knowledge gap on bivalve research in Malaysian Borneo

In the current century, macro benthic surveys were first conducted in Malaysian territory in 1981 (Morris & Purchon 1981; Way & Purchon 1981). In East Malaysia, Turner & Santhakumaran (1989) and Ashton et al. (2003) performed the first baseline study of bivalves in the Pantai River and Sematan mangrove forest, Sarawak. After that, extensive taxonomic studies were conducted by Hamli et al. (2012b); whereas Wong & Arshad (2011) published a significant checklist of bivalves. In a publication that reported edible bivalves and gastropods from different markets in Sarawak and that was published very recently which dealt with the morphometric and diversity investigation, we excluded that publication from our checklist due to the time span (1791–2020) in which it was published; however, the paper reported one new record *Arcuatula arcuatula* (Hanley, 1843) and rest of the species were already

Table 1. Bivalve fauna in Malaysian Borneo.

Order/Infra Class/ Super Order/ Sub Class	Super Family	Family	Species	IUCN	Habitat	Ref
Adapedonta	Solenoidea	Pharidae	*Sinonovacula constricta* (Lamarck, 1818)	NE	BW; MAR	Ashton et al. (2003)
		Solenidae	*Pharella acutidens* (Broderip & Sowerby, 1829)	NE	BW; MAR	Hamli et al. (2012a,b)
			Solen lamarckii Chenu, 1843	NE	BW; MAR	Hamli et al. (2012a,b)
			Solen regularis Dunker, 1862	NE	BW; MAR	Hamli et al. (2012a,b)
Arcida	Arcoidea	Arcidae	*Anadara antiquata* (Linnaeus, 1758)	NE	MAR	Al-Asif et al. (2020)
			Anadara indica (Gmelin, 1791)	NE	MAR	Al-Asif et al. (2020)
			Anadara kagoshimensis (Tokunaga, 1906)	NE	MAR	Al-Asif et al. (2020)
			Arca ventricosa Lamarck, 1819	NE	MAR	Wong & Arshad (2011)
			Barbatia amygdalumtostum (Röding, 1798)	NE	MAR	Wong & Arshad (2011)
			Tegillarca granosa (Linnaeus, 1758)	NE	MAR	Hamli et al. (2012a, 2012b); Shabdin et al. (2014)
Cardiida	Cardioidea	Cardiidae	*Tridacna crocea* Lamarck, 1819	LC	MAR	Wong & Arshad (2011)
			Tridacna maxima (Röding, 1798)	LC	MAR	Wong & Arshad (2011)
			Tridacna squamosa Lamarck, 1819	LC	MAR	Wong & Arshad (2011)
	Tellinoidea	Donacidae	*Donax faba* Gmelin, 1791	NE	MAR	Al-Asif et al. (2020)
		Solecurtidae	*Azorinus coarctatus* (Gmelin, 1791)	NE	BW; MAR	Al-Asif et al. (2020)
		Tellinidae	*Eurytellina lineata* (W. Turton, 1819) (Pink)	NE	MAR	Al-Asif et al. (2020)
Carditida	Carditoidea	Carditidae	*Beguina semiorbiculata* (Linnaeus, 1758)	NE	MAR	Wong & Arshad (2011)
	Crassatelloidea	Crassatellidae	*Bathytormus radiatus* (Sowerby, 1825)	NE	MAR	Al-Asif et al. (2020)
Limida	Limoidea	Limidae	*Ctenoides philippinarum* Masahito & Habe, 1978	NE	MAR	Al-Asif et al. (2020)
			Ctenoides scaber (Born, 1778)	NE	MAR	Wong & Arshad (2011)
Lucinida	Lucinoidea	Lucinidae	*Lepidolucina venusta* (Philippi, 1847)	NE	MAR	Al-Asif et al. (2020)
Ostreida	Ostreoidea	Ostreidae	*Crassostrea virginica* (Gmelin, 1791)	NE	MAR	Shabdin et al. (2014)
			Lopha cristagalli (Linnaeus, 1758)	NE	MAR	Shabdin et al. (2014); Wong & Arshad (2011)
			Magallana bilineata (Röding, 1798)	NE	BW; MAR	Shabdin (2010); Hamli et al. (2012b)
			Magallana rivularis (Gould, 1861)	NE	BW; MAR	Raven (2019)
			Ostrea lurida Carpenter, 1864	NE	MAR	Shabdin et al. (2014)
			Saccostrea scyphophilla (Peron & Lesueur, 1807)	LC	MAR	Matsumoto et al. (2017)
	Pterioidea	Isognomonidae	*Isognomon alatus* (Gmelin, 1791)	NE	MAR	Wong & Arshad (2011)
			Isognomon ephippium (Linnaeus, 1758)	NE	MAR	Ashton et al. (2003); Hamli et al. (2012b)
			Isognomon nucleus (Lamarck, 1819)	NE	MAR	Matsumoto et al. (2017)
		Margaritidae	*Pinctada margaritifera* (Linnaeus, 1758)	NE	MAR	Wong & Arshad (2011)
		Malleidae	*Malleus albus* Lamarck, 1819	NE	MAR	Wong & Arshad (2011)
		Pteriidae	*Pteria colymbus* (Röding, 1798)	NE	MAR	Wong & Arshad (2011)
Myida	Pholadoidea	Pholadidae	*Pholas orientalis* Gmelin, 1791	NE	BW; MAR	Hamli et al. (2012a,b)
			Lignopholas chengi Turner & Santhakumaran, 1989	NE	MAR	Turner & Santhakumaran (1989)
			Lignopholas rivicola (G.B. Sowerby II, 1849)	NE	MAR	Turner & Santhakumaran (1989)
			Lignopholas fluminalis (Blanford, 1867)	NE	FW	Turner & Santhakumaran (1989)
			Martesia striata (Linnaeus, 1758)	NE	BW	Turner & Santhakumaran (1989)
Mytilida	Mytiloidea	Mytilidae	*Byssogerdius striatulus* (Hanley, 1843)	NE	BW; MAR	Huber (2010); Raven (2019)
			Brachidontes variabilis (Krauss, 1848)	NE	MAR	Raven (2019)

Order/Infra Class/ Super Order/ Sub Class	Super Family	Family	Species	IUCN	Habitat	Ref
Pectinida	Anomioidea	Anomiidae	*Enigmonia aenigmatica* (Holten, 1802)	NE	BW; MAR	Ashton et al. (2003); Raven (2019)
		Placunidae	*Placuna placenta* (Linnaeus, 1758)	NE	BW; MAR	Hamli et al. (2012b)
	Pectinoidea	Spondylidae	*Spondylus gussonii* O.G. Costa, 1830	NE	MAR	Wong & Arshad (2011)
			Spondylus squamosus Schreibers, 1793	NE	MAR	Wong & Arshad (2011)
		Pectinidae	*Amusium pleuronectes* (Linnaeus, 1758)	NE	MAR	Hamli et al. (2012a,b)
			Mimachlamys varia (Linnaeus, 1758)	NE	MAR	Wong & Arshad (2011)
			Pedum spondyloideum (Gmelin, 1791)	NE	MAR	Wong & Arshad (2011)
Unionida	Unionoidea	Unionidae	*Ctenodesma borneensis* (Issel, 1874)	NE	FW	Zieritz & Lopes-Lima (2018); Zieritz et al. (2020)
			Monodontina walpolei (Hanley, 1871)	NE	FW	Zieritz & Lopes-Lima (2018); Zieritz et al. (2020)
			Pilsbryoconcha exilis (I. Lea, 1838)	LC	FW	Hamli et al. (2012b)
			Pressidens insularis (Drouët, 1894)	NE	FW	Zieritz & Lopes-Lima (2018); Zieritz et al. (2020)
			Rectidens sumatrensis (Dunker, 1852)	DD	FW	Zieritz & Lopes-Lima (2018)
			Schepmania nieuwenhuisi (Schepman, 1898)	NE	FW	Zieritz & Lopes-Lima (2018); Zieritz et al. (2020)
			Schepmania parcesculpta (von Martens, 1903)	NE	FW	Zieritz & Lopes-Lima (2018); Zieritz et al. (2020)
			Simpsonella gracilis (I. Lea, 1851)	NE	FW	Zieritz & Lopes-Lima (2018)
			Sinanodonta lauta (von Martens, 1877)	NE	FW	Zieritz et al. (2020)
			Sinanodonta woodiana (I. Lea, 1834)	LC	FW	Hamli et al. (2012a,b); Hamli et al. (2020); Zieritz & Lopes-Lima (2018)
Venerida	Veneroidea	Veneridae	*Callista erycina* (Linnaeus, 1758)	NE	MAR	Al-Asif et al. (2020)
			Circe scripta (Linnaeus, 1758)	NE	MAR	Hamli et al. (2012a,b)
			Gafrarium pectinatum (Linnaeus, 1758)	NE	BW; MAR	Al-Asif et al. (2020)
			Lioconcha castrensis (Linnaeus, 1758)	NE	MAR	Wong & Arshad (2011)
			Marcia hiantina (Lamarck, 1818)	NE	BW; MAR	Shabdin (2010)
			Meretrix casta (Gmelin, 1791)	NE	BW; MAR	Al-Asif et al. (2020)
			Meretrix lusoria (Röding, 1798)	NE	BW; MAR	Al-Asif et al. (2020)
			Meretrix lyrata (G. B. Sowerby II, 1851)	NE	BW; MAR	Al-Asif et al. (2020); Hamli et al. (2012a,b); Hamli et al. (2017)
			Meretrix meretrix (Linnaeus, 1758)	NE	BW ; MAR	Hamli et al. (2012a,b); Abu Hena et al. (2016); Hamli et al. (2016); Matsumoto et al. (2017)
			Paphia rotundata (Linnaeus, 1758)	NE	MAR	Wong & Arshad (2011)
			Paratapes undulatus (Born, 1778)	NE	MAR	Hamli et al. (2012a,b)
			Placamen isabellina (Philippi, 1849)	NE	MAR	Al-Asif et al. (2020)
			Pelecyora exilium (G. B. Sowerby III, 1909)	NE	MAR	Sowerby (1909)
			Marcia japonica (J. F. Gmelin 1791)	NE	MAR	Gmelin (1791)
	Cyrenoidea	Cyrenidae	*Corbicula fluminea* (O. F. Müller, 1774)	LC	FW; BW	Shabdin & Alfred (2007)
			Geloina bengalensis (Lamarck, 1818)	LC	BW	Hamli et al. (2012a,b); Hamli et al. (2015)
			Geloina expansa (Mousson, 1849)	LC	BW	Hamli et al. (2012a,b); Shabdin & Alfred (2007); Shabdin (2010); Hamli et al. (2015)
		Glauconomidae	*Glauconome virens* (Linnaeus, 1767)	NE	MAR	Hamli et al. (2012a,b)
	Arcticoidea	Trapezidae	*Neotrapezium sublaevigatum* (Lamarck, 1819)	NE	MAR	Raven (2019)

NE—Not Evaluated | LC—Least Concern | DD—Data Deficient | FW—Freshwater | BW—Brackish water | MAR—Marine.

available in our checklist (Idris et al. 2021). There are now a total of 19 published publications accessible, including a book, on the subject (Zieritz & Lopes-Lima 2018). Among the published papers, 10 were published in Scopus indexed journals, the other nine in local non-indexed journals. Six published documents discuss marine bivalves, another six discuss brackish habitats; whilst the papers cover freshwater and freshwater-marine habitats.

DISCUSSION

A comprehensive checklist on Malaysian marine molluscs by Wong & Arshad (2011) documented 581 species. Before this, Way & Purchon (1981) and Morris & Purchon (1981) reported 398 species (330 gastropods and 68 bivalves) from Malaysia and its adjacent coastal waters. In our study, we found bivalves from order Venerida (19 species) has the highest number of species, followed by Ostreida (12) and the freshwater order Unionida (10 species), while the rest of the orders or other entities have less than ten members. Among superfamilies, the Veneroidea (14 species) has the highest number of species, followed by the freshwater Unionoidea (10 species), and the rest of the superfamilies has less than 10 species (Figure 4). The family Veneridae comprises 14 species which is the highest among all families, following that the freshwater family Unionidae (10 species) has the second-highest number and the remaining 25 families comprise less than ten species each (Table 1).

For several recorded species it is evident the names are erroneous, as those species only occur in other continents. They are marked in the checklist (Table 2). The present findings suggested that some of the species were either misidentified or their introduction to Malaysian habitat might occurred; while observing their original distribution. For example, *Anadara kagoshimensis* (Tokunaga, 1906) is distributed in the temperate North Pacific (Zenetos et al. 2010), but the current study suggested that these species were found in the water of Malaysian Borneo (Al-Asif et al. 2020). The other distributional conflicts observed in *Ctenoides scaber* (Born, 1778) (Turgeon et al. 2009), *Ostrea lurida* Carpenter, 1864 (Polson et al. 2009), *Crassostrea virginica* (Gmelin, 1791) (Amaral & Simone 2014), *Isognomon alatus* (Gmelin, 1791) (Tëmkin 2010), and *Pteria colymbus* (Röding, 1798) (Tëmkin 2010) where all known distributions of abovementioned species are either North America or South America. The European *Spondylus gussonii* (O.G. Costa, 1830) (Gofas et al. 2001) was also reported from Malaysian habitat, and the geographic distribution should not be in Malaysian Borneo. Although *Saccostrea scyphophilla* (Peron & Lesueur, 1807) (reported as *Saccostrea mordax* (Gould, 1850), the materials were observed from the ''Feejee Islands''(Fiji); and the species was originally described from Australia) is considered native in Australia but in 2004 the study of Lam & Morton (2004) reported from Hong Kong coast, which might be disperse from Hong Kong to Malaysia through ocean-going ships or other means.

Additionally, some species may have been misidentified, but this cannot be determined without photographs or voucher material. In the literature we

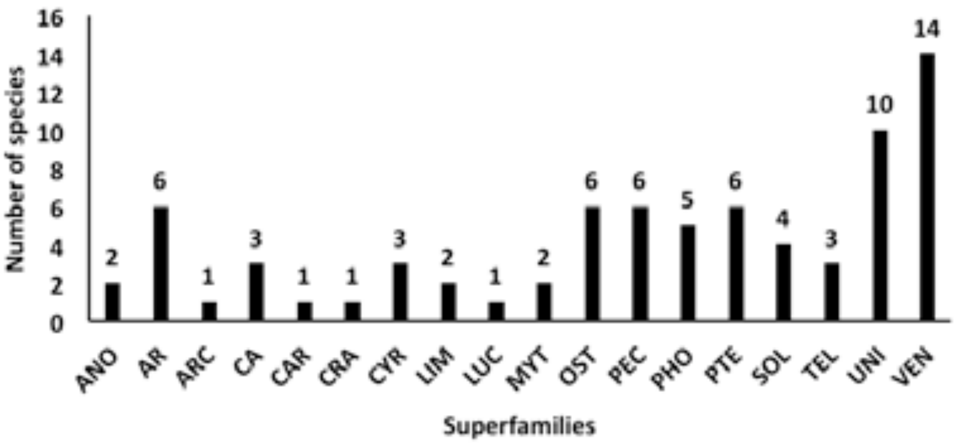

Figure 4. Number of species of bivalve superfamilies recorded from Malaysian Borneo.
Ano—Anomioidea | Ar—Arcoidea | Arc—Arcticoidea | Ca—Cardioidea | Car—Carditoidea | Cra—Crassatelloidea | Cyr—Cyrenoidea | Lim—Limoidea | Luc—Lucinoidea | Myt—Mytiloidea | Ost—Ostreoidea | Pec—Pectinoidea | Pho—Pholadoidea | Pte—Pterioidea | Sol—Solenoidea | Tel—Tellinoidea | Uni—Unionoidea | Ven—Veneroidea.

found many inconsistencies, while the present analysis revealed most inconsistencies were "unaccepted" according to WoRMS (2021) (i.e., the genus or species name is no longer valid); the rest were misspellings, alternative representations, changes in families, changes in author, and changes in year (Table 2). Moreover, there are taxonomic corrections: for instance, in freshwater family Unionidae there is no difference between *Pseudodon crassus* Drouet & Chaper, 1892 and *Pseudodon walpolei* (Hanley, 1871); therefore, WoRMS merges them into one single species *Monodontina walpolei* (Hanley, 1871). Similarly, in the Cyrenidae *Polymesoda erosa* auct. non Lightfoot, 1786 and *Polymesoda expansa* (Mousson, 1849) have recently been synonymized in WoRMS (Huber 2010) to the revised name *Geloina expansa* (Mousson, 1849). The study of Hamli et al. (2015) revealed morphological differences between these two taxa which lead to considered as they were both valid species.

The current study demonstrates that current bivalve research knowledge (ecological, taxonomic, and other aspects) are insufficient to serve as a foundation for academic, conservation, and aquaculture initiatives in Malaysian Borneo. A thorough literature search was conducted using a variety of databases (e.g., SCOPUS, Web of Science, university websites (for thesis), and CNKI), but the number of published papers on Borneo bivalves was determined to be insufficient. Bivalve research in Borneo is strongly encouraged, and areas such as populations, threats, life history, and breeding biology for aquaculture initiatives can all be considered significant research fields. While taxonomy, habitat ecology, conservation actions, area-based management initiatives, and approaches to recovery and reintroduction are all fundamental, harvesting trends are also critical (Lopes-Lima et al. 2018; Zieritz et al. 2020). A comprehensive checklist of bivalves in Malaysian Borneo is necessary to fill this knowledge gap. It is recommended that additional research on bivalves be conducted as a basis for conservation measures, as they contribute to both the ecology and economy of Malaysia.

Present status

IUCN status of bivalves in Borneo and their habitats

According to the IUCN red list status, 66 bivalve species have not been evaluated by the IUCN or any other institution that are present in Malaysian Borneo, and it is quite clear that a plethora of research work can be conducted to evaluate only the IUCN unevaluated species. Whereas nine species were determined to be least concerned and one species was determined to have data deficiency (Figure 5). Thus, these species must be protected wherever they occur in Malaysian Borneo through the imposition of reserve areas, restricted areas, or national/regional conservation sites. It is observed that 76 species of bivalve fauna have been reported from Malaysian Borneo, including 61 marine species (17 species can be found in both marine and estuarine or brackish water), three brackish water, and 12 freshwater species (one species can be found in both fresh and brackish water).

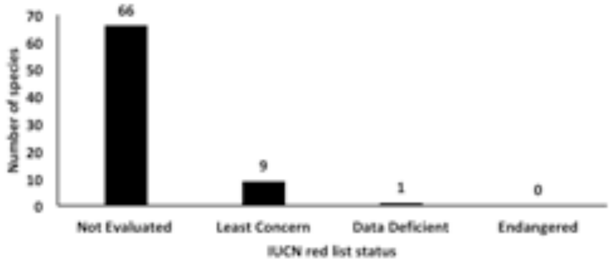

Figure 5. IUCN Red List status of bivalves in Malaysian Borneo.

Threats to the biodiversity of bivalve species

Sarawak and Sabah (the Malaysian portion of Borneo) are rich in biodiversity. Certain areas of Borneo Island remain pristine due to the lack of human intervention. Commercial logging and forest destruction due to palm plantations, on the other hand, have increased rapidly in various parts of these two provinces (Bryan et al. 2013; Shevade & Loboda 2019). As a result of soil runoff into the South China Sea, secondary pollution of marine and coastal ecosystems occurs (Morni et al. 2017). Harvesting edible bivalves from wild sources indiscriminately is also a significant threat to sustainable populations. Most importantly, there is no government or local government initiative to initiate commercial aquaculture of these bivalves in order to conserve their indigenous characteristics. A model of the global declination of bivalves was proposed by Lopes-Lima et al. (2018), in which they showed that in the Indo-Pacific region, pollution (45%) is the significant reason of decline in bivalve species, whilst freshwater bivalve species decline more rapidly than the marine species (Agudo-Padrón 2011). Other factors contributing to the decline of bivalve fauna include overexploitation (20 %), habitat modification (15 %), and urbanization (10 %) (Figure 6), mining activities, agriculture and aquaculture, transportation infrastructure, climate change and temperature rise, recreational activities, and various geological events, such as tsunamis caused by earthquakes.

Conservation prospects

Conservation is critical to preventing the extinction of vulnerable species. After discussing possible causes of bivalve species decline in the Indo-Pacific region, including Malaysia, we propose some conservation strategies for sustainable use of bivalve natural bio resources based on the global model developed by Lopes-Lima et al. (2018) (Figure 8).

To begin, bivalves are aquatic Mollusca that cannot survive without water (marine, brackish, or freshwater), and thus protection of water and water-adjacent land (40 %) should be prioritized for bivalve species conservation. Additionally, awareness-raising among stakeholders (including government, the general public, universities, non-governmental organizations, and the local populace) and communication with the local populace must be implemented (25 %). Water and adjacent land management (12 %), species management through proper conservation procedures (10 %), and incentives for local stakeholders who will carry out the conservation process (4 %) can all contribute significantly to the conservation of bivalves in Borneo. While the existing policies and regulations are sufficient for a sustainable conservation process, additional research is necessary to determine whether any revisions to those policies and regulations are necessary (3 %). Ex situ conservation (2 %) and proper enforcement of policies, legislation, and regulation (2 %). Any threatened species and those that have been suppressed by stressors, including human intervention, should be recovered through the application of appropriate management guidelines and procedures (1 %). Conservation strategies can be integrated into formal national curricula; consequently, future leaders and stakeholders should be concerned about bivalve biodiversity conservation (0.5 %). Reintroduction of species from another source is sometimes feasible. The general training received by common people, stakeholders, conservationists, and government officials is sufficient in the Indo-Pacific region and Malaysia, as there are ample training facilities and current conservation legislation is adequate, but conservation measures for bivalves should be prioritized.

Another research by Lopes-Lima et al. (2014) suggested that research on different aspects of taxonomy, systematics, anatomy, physiology, ecology, and conservation of freshwater bivalves will be helpful to conserve and reduce the extinction risk. Omics approach will also be helpful to conserve the bivalve fauna (Carducci et al. 2020). In contrast, a recent study from China suggested that awareness among people regarding ecological protections can be a helpful tool for protecting the habitat of bivalves. Reduce or suspend the commercial capture of wild bivalves, establish sanctuaries for habitat protection, extend the fishing or capture ban period which might helpful to conserve the bivalve fauna (Cao et al. 2018).

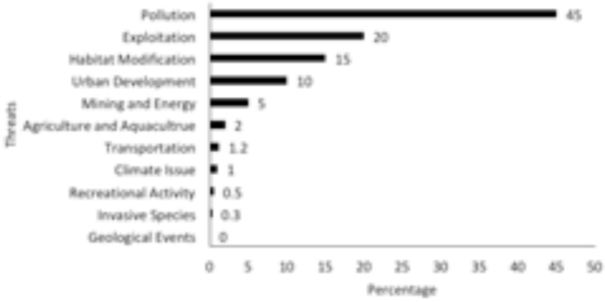

Figure 6. Reasons of bivalve decline in Malaysian Borneo (Indo-Pacific model). Adopted from Lopes-Lima et al. (2018).

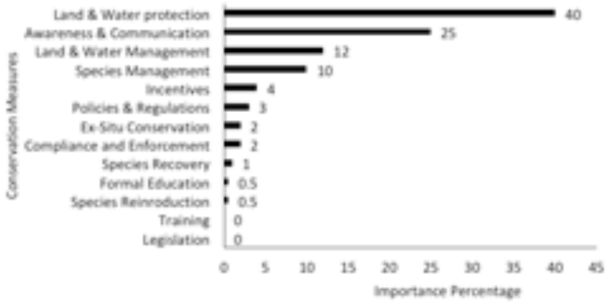

Figure 7. Conservation approach of bivalve fauna in Malaysian Borneo (Indo-Pacific Model). Adopted from Lopes-Lima et al. (2018).

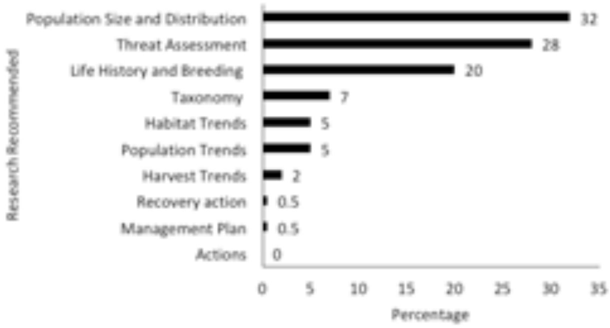

Figure 8. Recommended bivalve Research in Malaysian Borneo (Indo-Pacific Model). Adopted from Lopes-Lima et al. (2018).

Prospects and future research

The status of bivalves in Malaysian Borneo as a whole has not yet been determined. Numerous research groups comprised of provincial governments, universities, and the federal government can work in various ecological niches to determine the true number

Table 2. List of taxonomic corrections in available bivalve species in Malaysian Borneo.

Given Family	Corrected Family	Given name of species	Corrected name of species	Type of inconsistency
Arcidae	Arcidae	*Anadara granosa*	*Tegillarca granosa* (Linnaeus, 1758)	Unaccepted
Arcidae	Arcidae	*Barbatia fusca* (Bruguière, 1789)	*Barbatia amygdalumtostum* (Röding, 1798)	Unaccepted
Cardiidae	Cardiidae	*Tridacna* (*Chametrachea*) *crocea* Lamarck, 1819	*Tridacna crocea* (Lamarck, 1819)	Alternative representation
Cardiidae	Cardiidae	*Tridacna* (*Chametrachea*) *maxima* (Röding, 1798)	*Tridacna maxima* (Röding, 1798)	Alternative representation
Tridacnidae	Cardiidae	*Tridacna squamosa* Lamarck, 1819	*Tridacna squamosa* Lamarck, 1819	Family changed
Cyrenidae	Cyrenidae	*Polymesoda bengalensis*	*Geloina bengalensis* (Lamarck, 1818)	Unaccepted
Cyrenidae	Cyrenidae	*Polymesoda expansa*	*Geloina expansa* (Mousson, 1849)	Unaccepted
Glauconomidae	Glauconomidae	*Gluconome virens*	*Glauconome virens* (Linnaeus, 1767)	Misspelling
Isognomonidae	Isognomonidae	Isonomon nucleus	*Isognomon nucleus* (Lamarck, 1819)	Misspelling
Isognomonidae	Isognomonidae	*Spondylus gussonii* OG. Costa, 1829	*Spondylus gussonii* (O.G. Costa, 1830)	Wrong year
Limidae	Limidae	*Ctenoides scabra* (Born, 1778)	*Ctenoides scaber* (Born, 1778)	Unaccepted
Mytilidae	Mytilidae	*Brachidontes striatulus* (Hanley, 1843)	*Byssogerdius striatulus* (Hanley, 1843)	Unaccepted
Pteriidae	Margaritidae	*Pinctada margaritifera* (Linnaeus, 1758)	*Pinctada margaritifera* (Linnaeus, 1758)	Family changed
Ostreidae	Ostreidae	Crassostrea virginiea	*Crassostrea virginica* (Gmelin, 1791)	Misspelling
Ostreidae	Ostreidae	*Crassostrea iredalei*	*Magallana bilineata* (Röding, 1798)	Unaccepted
Ostreidae	Ostreidae	*Crassostrea rivularis* (Gould, 1861)	*Magallana rivularis* (Gould, 1861)	Alternative representation
Pectinidae	Pectinidae	*Chlamys varia* (Linnaeus, 1758)	*Mimachlamys varia* (Linnaeus, 1758)	Unaccepted (currently placed in genus *Mimachlamys*)
Myoida	Pholadidae	*Pholas orientalis*	*Pholas orientalis* (Gmelin, 1791)	Family changed
Unionidae	Unionidae	*Anodonta woodina*	*Sinanodonta woodiana* (I. Lea, 1834)	unaccepted (recombination)
Unionidae	Unionidae	*Pseudodon walpolei* (Hanley, 1871)	*Monodontina walpolei* (Hanley, 1871)	Unaccepted
Veneridae	Veneridae	*Meretrix. lyrata*	*Meretrix lyrata* (G. B. Sowerby II, 1851)	Misspelling
Veneridae	Veneridae	*Paphia undulata*	*Paratapes undulatus* (Born, 1778)	Unaccepted
Veneridae	Veneridae	*Meretrix meretrix* Roding,	*Meretrix meretrix* (Linnaeus, 1758)	Wrong author name
Veneridae	Veneridae	*Paphia alapapilionis* Röding, 1798	*Paphia rotundata* (Linnaeus, 1758)	Unaccepted
Veneridae	Veneridae	*Dosinia exilium* (G.B. Sowerby III, 1909)	*Pelecyora exilium* (G.B. Sowerby III, 1909)	Unaccepted
Veneridae	Veneridae	*Venus japonica* Gmelin, 1791	*Marcia japonica* (J. F. Gmelin 1791)	Unaccepted

and species of bivalves in Malaysian Borneo in order to create a comprehensive checklist. Aquaculture of commercially valuable bivalve species may be another area of research that could help prevent indiscriminate harvesting of bivalves from Malaysian Borneo's diverse habitats. Pollution studies can be conducted to assess the biodiversity and ecological threats posed by various industrial zones, despite the fact that water, air, and soil pollution are increasing as a result of these two provinces' rapid industrialization. A strong legislative framework could be established and enforced to protect different habitats' ecological integrity and bivalve diversity. Strict enforcement of laws may aid in the conservation of bivalve species in Malaysian Borneo.

Regrettably, there is far too little information at the moment, but provincial governments could declare some species vulnerable and also establish some protected zones in accordance with the IUCN Red List. Numerous awareness campaigns, including posters, television programmes, telecasts, documentaries, films, and cartoons, can be produced to educate the public about the critical nature of bivalve conservation. For example, state governments can take steps similar to the Chinese Giant Panda conservation approach, which is called 'Panda Diplomacy' (Buckingham et al. 2013), where China showed public awareness and scientific efforts are effective in the conservation process. Lopes-Lima et al. (2018) proposed some research aspects that will help retain the bivalve diversity's sustainability. According to them, the primary focus on bivalve research should be on the assessment of populations and their distribution (32 %), assessment of threats (28 %), and on studying their life history / breeding for future aquaculture purposes (20 %) (Figure 7). Whereas the taxonomy of specific bivalve species, the habitats and ecology of each species, the population trends of bivalves in Borneo, the harvest trends of fishers including aquaculture, recovery actions if any species faces imminent extinction, management plans for multi-ground stakeholders, and further action by various organizations can be considered as significant research arenas.

Kumar & Ravinesh (2016) recommended that the importance of taxonomic research be disseminated; thus, taxonomic knowledge can be included in national level curricula, for example, high school and college students can learn this science with joy. This initiative can be incorporated into the provincial and regional curricula of Malaysian Borneo. Additionally, they emphasized the importance of establishing accurate species databases and repositories, which will aid in future research and analysis. Kumar & Ravinesh (2016) also emphasized the resolution of scientifically dubious name categories, such as 'taxon inquirendum' and 'nomen dubium', which is commendable, and the protocols may be beneficial for the Malaysian Borneo ecosystem as well. They proposed that an integrative taxonomic approach incorporating detailed biogeography and evolutionary genetic materials could be beneficial for bivalve fauna conservation in Malaysian Borneo. Finally, citizen scientists and civil society approaches are very common and widely adopted in many developed countries; for this, a person does not have to be a scientist; rather, a keen interest in nature and biodiversity can also be beneficial for nature conservation. The research on the aforementioned criteria may be adopted and contribute to the conservation of biodiversity in Malaysian Borneo in the coming years and decades.

The current checklist is prepared by reviewing the previously published documents from Malaysian Borneo, although the published documents are few. Some of the papers we had collected were very general, and the author did not provide an appropriate format of species scientific names (Al-Asif et al. 2020). Misidentification is a widespread issue in taxonomy, and some published documents reported different bivalve species out ranged of their original distribution region. For example, the distribution of *Ctenoides scaber* (Born, 1778) (Turgeon et al. 2009) is well known from North America, but the previous study reported this species from the southeastern Asian region. This might happen because the author found similarities with southeastern Asian bivalve species with North American species or is entirely misidentified.

On the other hand, we can say it is considered either misidentification of these species or they introduced to the Malaysian habitat. Most of the published papers we had handled did not provide any pictures of bivalve species, which can be considered a considerable gap of the bivalve research in Malaysian Borneo (Shabdin 2010). In contrast, the papers that were published on the ecological phenomena or on the ecological subject matter did not include photographs or appropriate scientific nomenclature, and the samples that had been gathered were not stored in a permanent and easily accessible repository for future study. The island of Borneo does not have a natural history museum, although there is a tiny part of the 'Sarawak State Museum' that is known as the 'Natural History Museum', but there are no depositing facilities or a permanent repository in the Malaysian part of this island (Al-Asif et al. 2020; Shabdin 2010). Given the foregoing, Malaysian Borneo urgently requires a permanent and accessible repository for the collection of samples. New expeditions to different rivers and creeks in the interior of Borneo can be conducted to determine the exact number of bivalve species found in Malaysian Borneo.

CONCLUSIONS

The current work produced a comprehensive checklist of bivalves recorded from Malaysian Borneo, crosschecked with WoRMS (2021) and MolluscaBase (2021). An accurate checklist of bivalves aids appropriate resource allocation for the conservation process, and at the same time has many other functions. Accurate data on bivalve species under one umbrella will provide insight which species are present in Malaysian Borneo. It will also help revise and update the national list of molluscan fauna and periodic update of bivalve taxonomic information.

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REVIEW

Disentangling earthworm taxonomic stumbling blocks using molecular markers

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Abstract: Taxonomic classification of earthworms based on anatomical features has created several challenges for systematics and population genetics. This study examines the application of molecular markers, in particular mitochondrial cytochrome oxidase (COI), to facilitate discrimination of closely related earthworm species. Molecular markers have also provided insights into population genetics by aiding assessment of genetic diversity, lineage sorting, and genealogical distributions of populations for several species. Phylogeography—a study that evaluates the geographical distribution of these genealogical lineages and the role of historical processes in shaping their distribution—has also provided insights into ecology and biodiversity. Such studies are also essential to understand the distribution patterns of invasive earthworm species that have been introduced in non-native ecosystems globally. The negative consequences of these invasions on native species include competition for food resources and altered ecosystems. We anticipate that molecular markers such as COI and DNA barcoding offer potential solutions to disentangling taxonomic impediments in earthworms and advancing their systematics and population genetics.

Keywords: Annelida, COI, cryptic species, genetic diversity, Invasive species, Oligochaeta, phylogeography, phylogeny.

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Author details: Azhar Rashid Lone is working on the phylogenetic systematics and population genetics of Indian earthworms in natural forests based on COI gene marker. Samrendra Singh Thakur is working on the metagenomics, soil organic carbon management (SOC) through soil microbiome and bioremediation of contaminated soils in Madhya Pradesh, India. Nalini Tiwari is working on the phylogeny and phylogeography of Indian earthworms based on COI gene marker. Olusola B. Sokefun is faculty at Lagos state University, Lagos, Nigeria and expert in phylogenetic analysis. Prof. Shweta Yadav is a faculty at Dr. Harisingh Gour Vishwavidyalaya. She is an expert in molecular animal taxonomy of earthworms using various molecular markers. She focused her interest on the monitoring and conservation of fauna in natural forests of India.

Author contributions: ARL wrote the manuscript, SST and NT helped in data summarising, manuscript shaping, OSB helped in mining of phylogenetic data and SY enriched, curated and approved the final the submission of the final version of the manuscript.

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INTRODUCTION

The terrestrial Oligochaeta include annulated worms known as earthworms or megadriles, a group of invertebrate animals dispersed all over the world and having a paramount role in the development of burgeoning soil and its fertility (Lavelle et al. 1999; Edwards 2004). At present, the earthworms are investigated all over the world by approximately 300 specialists, most of them aiming at their ecology and role in terrestrial ecosystems. A few tens of earthworm scientists are considered to have expertise in Oligochaeta worm taxonomy and phylogeny. Terrestrial Oligochaeta has a relatively short and somewhat simple history. Started with the work of Savigny (1826), the study of earthworms gradually involved more specialists and consequently became more complicated as new characters and taxa were described. The contemporary terrestrial oligochaete taxonomy is considered as being rooted in the classical works of Rosa (1888–1944) and Michaelsen (1830–1930). Later Pop, Omodeo, Perrel, Zicsi, and Bouche contributed substantially to the knowledge of earthworm (especially Lumbricidae) taxonomy and phylogeny. The studies of earthworms got rapid worldwide development in the second half of the 20th century with the development of soil science and soil zoology. Scientists all over the world were invigorated to study earthworms by the general acceptance of the idea of the soil, as indispensable for agriculture and must be carefully managed to avoid its irreversible deterioration. At that time, soil-inhabiting animals began to be looked as 'main soil builders' not only by a few zoologists, but by a large circle of specialists interested in improvement and conservancy of soil productivity. Only in a few decades, the main interest of specialists targeted more and more at the ecological aspects of soil inhabiting animals. More applicable fields were separated from the theoretical aspects by the processing of organic materials by earthworms. It also proved to merit protection from the negative effects of pesticides and even some fertilizers. A large section of scientists turned their interest to the study of earthworms. But at the same time, a classical field of earthworm taxonomy and phylogeny didn't magnify equally. The novelty and ecological approaches of the animal overlapped their basic studies. The majority of active scientists turned their interest to the ecology and application part of earthworms and the earthworm taxonomy was somewhat neglected or even considered to be outdated. Nevertheless, due to large-scale faunistic investigations, promoted by the biodiversity and ecosystem structure investigations, a lot of unknown taxa were found and described. The scarcity of skilled taxonomists led to the inflation of improperly described earthworm taxa and the appearance of parallel classification. Ecologists were firstly affected, but even specialists hardly succeeded to extricate the entangled stumbling block of earthworm taxonomy. It became obvious to develop a technology to resolve taxonomic impediments with the use of molecular tools while the traditional taxonomy and modern molecular taxonomy have contributed equally to the advancement of earthworm taxonomy.

Traditionally, earthworms are characterized based on classical approaches like morphological investigations of the external body and anatomy-based dissections which take the advantage of limited taxonomic parameters like the structure of prostate, seminal vesicles, spermatheca, and calciferous glands (Lalthanzara et al. 2018). Moreover, due to simplicity of their structural organization, several diagnostic characteristics in earthworms are inconsistent and overlaps beyond taxon (Perez-Losada et al. 2009), their characterization requires experts which unfortunately are splurging. The shortage of discriminatory characters in earthworms was first divulged by Michaelsen (1900) and consequently defined these animals as 'sine systemate chaos'. Thus in all the domains of earthworm research, the existence of these taxonomic impediments is responsible for major prejudices. The use of a molecular approach may be a potential resolution to tackle the stumbling block of earthworm taxonomy. The use of a standard mitochondrial genetic marker often termed DNA barcoding has been, nowadays, considered as a reliable approach used in biodiversity studies as well as in species identification (Hebert et al. 2003, 2004). Chang et al. (2008) and Rougerie et al. (2009) have given voice to DNA barcoding as a potential solution to disentangle taxonomic impediments.

The study reviewed the prospective of molecular approaches including short sequences of the mitochondrial genome, in particular, the COI and its preponderance in resolving the stumbling block of earthworm taxonomy. The present study accentuates the contribution of this gene marker in deciphering taxonomic impediments primarily identification of species, phylogeny re-constructions, intraspecific variations; genetic structure, cryptic species, lineage sorting, and finally its role in the assessment of invasive species with phylogeographic tagging (Figure 1).

DNA Barcoding and Clitellate species identification

Before DNA barcoding earthworm taxonomy relied on the specific morpho-anatomical features, however, most of these features often overlap among taxa and it became more inadequate when recently divergent species or species complexes were entertained (Chang & James 2011). Although, the allozymes, RAPD, RFLP, and SSR techniques in the mid-19th century reflected the notion that certain earthworm species could be segregated. Nonetheless, due to their certain limitations including dominance and less reproducibility, the focus was given to the use of various gene markers to gain a better understanding of earthworm taxonomy (Kumari & Thakur 2014). DNA barcode occupies 658 bp of the mitochondrial genome for the recognition of animal species (Hebert et al. 2003). This method has diverse advantages; firstly, it is a rapid and cheaper technique in the case of massive samples for accurate identification. Secondly, it is reproducible and testable since it always keeps the record between any barcode and its voucher specimen. Above all, it could be applicable for tissues and applied to any life stages whether cocoons or a juvenile of any animal species as well as it is accessible everywhere around the globe (Rougerie et al. 2009). DNA barcoding has the potential for earthworm research in taxonomy and ecology (Decaëns et al. 2013). Moreover, in eco-toxicological studies, it is very essential to identify accurate model organisms for inferring toxicity of several compounds, as it is evident that many closely related species can react to the same toxicant differently. Otomo et al. (2009) highlighted the importance of DNA barcoding for the identification of earthworm species used in ecotoxicological tests and concluded that reliable identification is very crucial since it prevents various discrepancies when comparative studies are done involving different test species. Similarly, to evaluate the practicability and consistency of DNA barcoding, an international ring test was organized by Römbke et al. (2016) who assessed the genetic differentiation of two ecotoxicological earthworms, viz., *Eisenia fetida* and *Eisenia andrei*. These investigations have not only assessed the potential of DNA barcoding in taxon identification but specify that it could be the only way to measure an accurate level of biodiversity (Proudlove & Wood 2003). The study of Richard et al. (2010) shows the potential of DNA barcoding can be applied to identify juvenile earthworm species in soils when reference DNA barcode library is available and thus highlighted that the bias in juvenile collection and identification could be highly reduced in earthworm biodiversity assessments. Moreover, many earthworm taxonomists emphasized that integrating morpho-anatomical features with barcoding data provide more contrasting conclusions. These integrative approaches were utilized to discriminate among species and taxa that are new to science (Shekhovtsov et al. 2014; Jeratthitikul et al. 2017; Lone et al. 2020). Furthermore, compared to morpho-anatomical features that require exhaustive work, species discrimination using DNA barcoding is relatively rapid and identification measure is progressed (Gregory 2005). These in turn have addressed certain issues, including rehabilitations, synonymies, and description of new taxa. Thus it sustains the decisions of nomenclature experts and thus primarily contributes to biodiversity assessments from local to global scales. Therefore, adopting DNA barcoding has enhanced the accuracy of earthworm studies and in particular, greatly benefited the community of soil biologists in the description of many novel species over the past few years (Blakemore 2013; Zhao et al. 2015; Aspe et al. 2016; Csuzdi et al. 2017; Seesamut et al. 2018; Lone et al. 2020); see Table 1 for more details. Furthermore, DNA barcoding has also shown its congruent results with other nuclear and mitochondrial genes (Pop et al. 2007; King et al. 2008) and many such papers are published in peer-reviewed journals. Furthermore, the nuclear and mitochondrial genes greatly differ in their divergence rates at different taxonomical levels. In many studies, it has been inferred that the mitochondrial gene particularly COI has the highest sequence divergences than other mitochondrial (12S, 16S) and nuclear genes (18S and 28S) (Chang & James 2011). This indicates that at the species levels or intraspecific variations, species could be better studied when the fast-evolving genes like COI are considered. However, at higher taxonomical levels (within a genus or interfamilial) COI has a relatively weak signal than other slow evolving genes (18S, 28S) (Chang & James 2011) and should be used at the species level or within genus if the genus is not too diverse. Thus, COI has been one of the most influential gene markers which have strongly revolutionized earthworm taxonomy by avoiding taxonomic confusions and providing additional evidence for discrimination of taxa over the past few years.

Role in Phylogeny reconstructions

Dobzhansky (1973) stated that in biology, nothing makes sense without the consideration of evolution. Since species undergo evolutionary changes, the relationship of these changes at all levels provides perception in the phylogenies of diverse species. The collaboration of morphological and molecular methods

Table 1. List of publications based on molecular markers in earthworm diagnostics and taxonomy.

Marker(s)	Main focus	Region(s)	Reference
COI	New species *(Pontodrilus longissimus*) description	Thailand and Peninsular Malaysia	Seesamut et al. 2018
COI	*Description of new species Eisenia nordenskioldi mongol* and *Eisenia nordenskioldi onon*	Mongolia	Blakemore 2013
COI/ITS	Aquatic oligochaetes identification	Switzerland	Vivien et al. 2015
COI/morphology	New taxa identification	Kamchatka	Shekhovtsov et al. 2014
COI/16S/18S/28S/ H3/H4/tRNAs	Description of new species *Eiseniona gerardoi* within Lumbricidae	Extremadura, Spain	Cosín et al. 2014
16S/28S/COI/H3/ tRNAs	Description of new species *Hormogaster joseantonioi*	Teruel Aragon ranges, Aragon, Spain	Marchán et al. 2014
COI	DNA barcoding of *Kanchuria* species	Meghalaya, India	Lone et al. 2020
COI	DNA barcoding of *Eutyphoeus* species	Mizoram, India	Thakur et al. 2020
COI	DNA barcoding of earthworms species	Madhya Pradesh, India	Tiwari et al. 2020
COI	DNA barcoding	Thailand	Jeratthitikul et al. 2017
COI/16S	DNA barcoding and phylogeny in genus *Glyphidrilus*	Thailand	Jirapatrasilp et al. 2016
COI	DNA barcoding	Arunachal Pradesh, India	Lalthanzara et al. 2020
COI	DNA barcoding in *Amynthas* genus	Northeastern India	Vabeiryureilai et al. 2020
COI	DNA barcoding	Uruguay	Escudero et al. 2019
COI	Description of new taxa	Taiwanese montane	Chang et al. 2007
COI	DNA barcoding	China	Huang et al. 2007
COI	DNA barcoding	Taiwan	Chang et al. 2009
COI	DNA barcoding	Canadian Centre for DNA Barcoding (CCDB)	Rougerie et al. 2009
COI	DNA barcode for juvenile ID	Haute-Normandie, France	Richard et al. 2010

has shaped significant progress in understanding the phylogeny of most major invertebrate groups (O'Grady & DeSalle 2018). However, this is partially true for the earthworms which have not been resolved, although many attempts were made. About 100 years ago and throughout the greater part of the 20th century oligochaetes, *sensu stricto* were classified into two main groups: Megadrila and Microdrili. The classification was based largely on two parameters; size and habitat preferences. The larger group that is confined to soils was termed Megadrili and the smaller group that is mostly restricted to water was called Microdrili (Benham 1890). Later Beddard (1895) compiled the basic structure laid out by Benham, however, redefined Microdrili by adding the family Naidomorpha' (presently called Naididae) - a group that Benham considered as a subclass distinct from the rest of the oligochaetes. Following cladistic analysis and reclassification of Oligochaeta, Jamieson (1988) anticipated a new name for the Megadrili group, Metagynophora, based on the inferred loss of ovaries located anteriorly. He also proposed Crassicilitellata a less inclusive taxon for about 3,000 earthworms, containing multi-layered clitellum (composed of several epidermal cell layers). Whilst, other oligochaetes app. 120 Metagynophora species that mostly belonged to the family Alluroididae and Moniligastridae, outside Crassiclitellata, contained single-layered clitellum. The molecular phylogenetic analysis although started in the 1990s however, it was not until Siddall et al. (2001) for the first time focused on the phylogenetic study of leeches and their relatives that also included earthworms. Later, Jamieson et al. (2002) published their work on the phylogenetic study of earthworms and revealed monophyly of the Megascolecidae family based on 12S, 18S, and 16S data, besides it supported the clade Crassiclitellata (Jamieson 1988). Subsequently, many papers were published on the phylogeny of earthworms (Table 2). Moreover, to construct a phylogeny in earthworms, the selection of accurate markers would be essential. *COI* is preferred due to its simplicity of primer design and range of its phylogenetic signal (Hebert et al. 2003), rapid evolution to discriminate at the species level (Wishart & Hughes 2003), and to provide informative features (Siddall et al. 2001; Pop et al. 2003; Heethoff et al. 2004; Chang & Chen 2005; Pérez-Losada et al. 2005; Chang et al. 2007, 2008; Huang et al. 2007; King et al. 2008). Although many other genes are taken into consideration for the construction of phylogeny in

Table 2. List of some peer reviewed publications in earthworm phylogeny and systematics.

Marker(s)	Main focus	Region(s)/Platform	Reference
COI	Phylogeny of *Eisenia. nordenskioldi*	Siberian and Korean	Hong & Csuzdi 2016
COI/16S/18S/28S/H3/H4/tRNAs	Hormogastridae phylogeny	46 sites in the Iberian Peninsula to Corsica and Sardinia	Novo et al. 2011
COI/16S/18S/28S/H3/H4/tRNAs	Phylogeny reconstruction of Hormogastridae	Mediterranean	Novo et al. 2015a
COI/COII/12S/16S	Earthworm phylogeny genes	Austria, Canada, USA, Russia, Croatia, and Ireland	Klarica et al. 2012
18S/28S/12S/16S/ND1/COI /COI/I/tRNAs	Phylogeny of Lumbricidae	Iran	Bozorgi et al. 2019
COI/COII/12S/16S/18S/28S/ ND1/tRNAs	Evolution of lumbricids	Europe, USA, Brazil, Africa, UK, China, Israel, Turkey, and Vietnam	Domínguez et al. 2015
28S/12S/16S/ND1/*COII*/tRNAs	Lumbricidae phylogeny	Northwestern Spain	Domínguez et al. 2017
COI/16S/ITS2	Phylogenetic analysis of the *Dendrobaena byblica*	Balkans, the Greek islands, Anatolia, Levant and the Carpathian Basin	Szederjesi et al. 2018
COI	Hormogastrid phylogeny	Iberian Peninsula	Novo et al. 2009
COI	Phylogenetic relationships of Naidids (Annelida)	GenBank	Bely & Wray 2004
COI/28S	Monophyly and phylogeny in *Eisenia fetida* and *Eisenia andrei*	Ireland and Spain	Pérez-Losada et al. 2005
12S/16S/28S/*COII*/ND1/tRNAs	Phylogenetic relationships of *Aporrectodea caliginosa* species complex	European earthworms	Pérez-Losada et al. 2009
COI/12S/16S/28S/H3/ITS	Phylogeny of *Limnodrilus*	North America, Europe, Japan, and China	Liu et al. 2017
COI/16S/H3/ITS2	*Cognettia* diversity	Northern Europe	Martinsson & Erséus 2014
CO1/CO2/CO3/Cytb/ND5/ND4/16S/ND1	Phylogenetic relationships of 15 *Pheretima* complex	China	Zhang et al. 2016
COI/COII/28S/H3	Phylogeny of *A. caliginosa complex*	Europe, UK, USA, Egypt, Australia	Fernández et al. 2012

earthworms (see Table 2), COI is generally engaged for its rapid divergence and fast-evolving features that aid in a better understanding of evolution and phylogeny reconstructions. Irrespective of being a vital role and promising idea that DNA barcoding has given to the molecular phylogenetics, the ongoing debates on earthworm systematics still face many key challenges that need to be addressed (Chang & James 2011). Perhaps, these overwhelming challenges are not only confined to earthworms but also the whole Annelida. As McHugh (2001) stated that the poor resolution at higher levels in Clitellata is due to radiation or rapid divergence of annelid phylogeny and Martin et al. (2000) stated the same reasons for Clitellata phylogeny which was also supported by the investigation of Maekawa et al. (2001) and Su et al. (2001). This demands further research and large datasets to answer the key questions in Clitellata phylogeny. Although the molecular phylogenetic investigations were studied in the family Eudrilidae, Ocnerodrilidae, Lumbricidae, Megascolecidae, and Glossocolecidae, however, except for the support of the monophyly in Megascolecidae, the support for all the families is weak due to insufficient sampling and taxon bias. Moreover, in the family Lumbricidae, the focus is given to within genus (*Aporrectodea/ Allolobophora*, *Dendrobaena,* and *Octodriloides/ Octodrillus/Octolasion*) which led to restating the polyphyletic nature of *Allolobophora* and synonymizing *Octodrilus* with *Octodriloides*, nonetheless, there was no significant progress in phylogenetic revision (Pop & Wink 2004; Pop et al. 2003, 2007, 2008; Cech et al. 2005). Thus we can anticipate that the phylogeny of the oligochaetes Clitellata still encompasses various challenges in the present scenario, and requires further development for in-depth phylogenetic information. Moreover, DNA barcoding has no doubt interpreted many findings either alone or with the combination of other genes however, more data is required to tackle many challenges in phylogenetic studies in Clitellata and lastly the more densely the taxa are sampled, the more defined the phylogenetic estimations will be measured (Erséus 2005).

Unveiling cryptic species/species complex/intraspecific divergence in Clitellata

In the biological process, cryptic speciation results in a species group, containing individuals that are morphologically identical to each other however belong to different species (Pérez-Losada et al. 2005). With morpho-anatomical features, most of the cryptic species/species complexes remain unnoticed and it was not until with the availability of DNA sequences there was an increase in the number of cryptic species (Torres-Leguizamon et al. 2014; Marchán et al. 2017). In earthworm taxonomy, the identification of taxa at higher taxonomical levels particularly at genus or interfamilial levels can be studied effectively as there are many taxonomical characteristics that could be applied to assign taxa at family and genus levels (Pérez-Losada et al. 2005). However, when closely related species and species complexes are considered, few morpho-anatomical features are available and it makes taxonomy more complicated when these morpho-anatomical features overlap among them (Lalthanzara et al. 2018). Thus at the species level or when dealing with cryptic species, the taxonomic methods are complicated, exhaustive, labor-consuming, and demands expertise in the field (Lalthanzara et al. 2018; Thakur et al. 2020). Furthermore, due to simple body structures in earthworms, their identification is limited to mature specimens as the key taxonomical features can only be applied to them, leaving juveniles or closely related species unidentified. With DNA barcoding several cryptic species/ species complexes are identified in earthworms, most of which are widespread in several families; Lumbricidae (Heethoff et al. 2004; King et al. 2008; Fernández et al. 2011; Shekhovtsov et al. 2013, 2016a), Mediterranean Hormogastridae (Novo et al. 2010, 2011), Megascolecidae (Chang et al. 2008; Buckley et al. 2011), Glossoscolecidae (de Faria et al. 2013) respectively (see Table 3 for more published papers). Moreover, the development of DNA barcoding cryptic species in earthworms has gained pace as more and more data is being added which not only tells us the extensive occurrence of cryptic diversity in earthworms but the action of various ecological processes that has led to these divergences within them. Furthermore, many investigations revealed that several earthworm taxa may contain two to five cryptic lineages with app. 10–20 % of nucleotide substitutions among them (Nova et al. 2009; Buckley et al. 2011; Porco et al. 2013; Fernández et al. 2016). In soil-dwelling invertebrates particularly earthworms the occurrence of these cryptic lineages is common due to allopatric isolation which restricts gene flow between regions of suitable habitat (Hogg et al. 2006) as well as minimizes the change in morphological characters taking place during speciation (Bickford et al. 2007).

In addition to this, the different individuals of a given species are not genetically identical. Their DNA sequences differ to some extent, and these differences form the genetic diversity, known as the intraspecific diversity of a species (Stange et al. 2020). These genomic variations are the basic foundation of biodiversity. It refers to a process by which the characteristics of living organisms change over many generations and addresses how different species are related through the complicated family trees. Understanding diversity at the genomic level including an arrangement in taxonomic standards is, therefore, the most important parameter of biodiversity. The importance of genetic variation in biodiversity evaluation has been well recognized (Des Roches et al. 2018). Nonetheless, such studies cannot be accomplished entirely based on simple morphological examinations of different taxa and therefore demand molecular investigations to provide more tangible understandings of earthworm diversity indices. Moreover, molecular studies, for example, systematic studies involve molecular data to reveal variation among the population as well as among species. However, molecular systematics rely largely on empirical results: therefore, increasing knowledge about rates of nucleotide change is needed to improve assumptions generally used for phylogenetic inferences and deciphering the evolutionary process within or between species. While phylogenetic relationships can be deciphered through analysis of DNA sequences among species, comparisons of DNA barcodes within species furnish information about the population structure of species and their evolutionary history.

In earthworms despite their fundamental importance in soil ecosystems, their population structure as a function of intraspecific diversity or genetic diversity is poorly understood and the amount of these studies are scanty, due to either less attention that was given to earthworms or other vertebrates were studied utmost. Presently limited investigations such as the role of glacial periods and contemporary processes like habitat fragmentation on the genetic diversity (see Table 3) of earthworms are studied based on the partial sequencing of COI gene and other markers (COII, 12S, 16S, 18S, 28S, H3, H4, tRNAs) and this has opened up new challenges in the field of population genetics. Earthworms have a complicated pattern of gene flow with a weak relationship between genetic and geographic distances.

Table 3. Depicts the peer reviewed published literature of cryptic speciation/ species complex/ intraspecific divergence in earthworms.

Marker(s)	Main focus	Region(s)	Reference
COI/ morphological characteristics	Ecological process and diversification	Tropical rainforests of French Guiana.	Decaëns et al. 2016
COI	Genetic diversity and cryptic species of *E. andrei*	South Africa	Voua et al. 2013
COI/16S	*Genetic differentiation and phylogeny of Drawida ghilarovi*	Russian Far East	Atopkin & Ganin 2015
COI/AFLP	*Cryptic lineages in Allolobophora chlorotica, A. longa, A. rosea*, and *Lumbricus rubellus*	British earthworms	King et al. 2008
COI/ITS2	Genetic variations of *Eisenia nordenskioldi pallida*	Northern Asia	Shekhovtsov et al. 2016a
COI	Genetic diversity within *A. caliginosa*	Eastern Europe to the Russian Far East	Shekhovtsov et al. 2016c
COI/COII/28S/H3	Clonal diversity in *A. trapezoides*	Europe, Algeria, Egypt	Fernández et al. 2011
COI/16S/28S/tRNAs	Genetic differentiation in Hormogastrid earthworms	Iberian Peninsula	Nova et al. 2010
COI/ATP6	Lineages of the earthworm *Lumbricus rubellus*	Poland	Giska et al. 2015
COI/H3	Cryptic lineages in *L. terrestris, L. herculeus and L. rubellus*	Northern Europe, USA	Martinsson & Erséus 2017
COI/ITS2	Genetic variations in *Eisenia nordenskioldi subsp. nordenskioldi* (Eisen, 1879) populations and other lumbricids	Geographically remote areas of Siberia	Shekhovtsov et al. 2013
COI	Lineage diversity in *L. rubellus*	Britain	Donnelly et al. 2014
COI/16S/28S/H3/tRNAs	Cryptic speciation in *H. elisae* populations	Center of the Iberian Peninsula	Marchán et al. 2017
COI/7 microsatellite loci	Cryptic diversity and geography of *Aporrectodea icterica* populations	France	Torres-Leguizamon et al. 2014
COI	*Cryptic lineages in Lumbricus terrestris*	Europe, northern America	James et al. 2010
COI	Genetic diversity of *E. n. nordenskioldi*	Southern Urals and eastern Europe	Shekhovtsov et al. 2016b
COI/16S/28S/H3/H4/tRNAs	Genetic variability and cladogenesis in *Aporrectodea rosea* and *A. trapezoids*	Spain, France, Italy and Algeria	Fernández et al. 2016
COI/5.8S/ITS1/ITS2	Genetic diversity in *Rhinodrilus alatus* and *R. motucu*	Southeastern Brazil savannah	de Faria Siqueira et al. 2013

Kautenburger (2006) studied the genetic structure of *Lumbricus terrestris L* populations at different locations in Germany and revealed an absence of isolation by distance pattern. Similar observations were inferred by Cameron et al. (2008) while investigating *Dendrobaena octaedra* populations in Alberta, Canada. They pointed out that the anthropogenic activities mainly 'bait abandonment' and limited active dispersal abilities lead to the significant population differentiation of *D. octaedra.* These results are related to the ideas of Sakai et al. (2001) who underlined that earthworms have limited active dispersal and it is often animal-mediated transport or limited active dispersal abilities causing genetic differentiation patterns. The genetic variations in the infields and the outfields of *Lumbricus rubellus*, caused by the selection of effective land-use practices (example infield eutrophication) was studied by Enckell et al. (1986) while Terhivuo & Saura (1993) stated that the high clonal diversity of *Aporrectoda rosea* is attributed to dispersal activities through agricultural practices in southern Finland. Terhivuo & Saura (1997) emphasize that human activities are the main cause of passive dispersal in *Octolasion cyaneum* in northern Europe. Contrary to these results the reports of Novo et al. (2009) reflected that *Hormogaster elisae* contained cryptic species and the genetic differentiation was primarily based on the isolation by distance mechanism. The work of Torres-Leguizamon et al. (2014) on earthworm populations of *Aporrectodea icterica* reflected low genetic polymorphism and that the human-mediated favors dispersal among geographically distinct populations. Therefore these studies indicate that the population genetic structure of earthworms is strongly influenced by human activities. Giska et al. (2015) while studying the lineages of *Lumbricus rubellus* of the UK revealed that the mitochondrial lineages are deeply divergent, however not reproductive isolated and therefore may constitute a single polymorphic species rather than a complex of cryptic species. More recently, Ganin & Atopkin (2018) studied the molecular differentiation of two ecological and three color morphs of *Drawida ghilarovi*. They concluded strong genetic differentiation in two ecological forms (anecic and epigeic) with the presence of several genetic lineages in anecic forms. The genetic diversity of *Amynthas triastriatus* populations revealed two genetic lineages that were split at 2.58

Ma at the time of Quaternary glaciation in southern China as the authors (Dong et al. 2020) suggested that parthenogenesis could be an internal factor that influenced the genetic differentiation and dispersal of *A. triastriatus*. Taking together these studies, it can be anticipated that the Clitellata and in particular earthworms are heterogeneous groups and are prone to genetic differentiation. The genetic heterogeneity is due to cryptic speciation (King et al. 2008) or the amphigonic and polyploidy strains within populations (Casellato 1987). Yet, whatever the possible reasons that gave rise to genetic heterogeneity, the evolutionary and ecological consequences of its existence are ranging extensively. Furthermore, more data is required in terms of COI barcodes along with the sequencing of other mitochondrial (COII, 12S, 16S) and nuclear genes (18S, 28S) to understand how earthworms move in soils, how ecological and anthropogenic activates affect the gene flow and selection in earthworms, and how environmental stressors are manipulating the genetic differentiation in various populations of earthworm species. These studies could be essential to understand environmental changes through these 'unsung heroes' of the soil.

Phylogeography and earthworm invasions

Phylogeography is an emerging field that evaluates the geographical distribution of genealogical lineages. It is based on the analysis of DNA variations from individuals across a species range to reconstruct gene genealogies. To infer historical biogeographic events in species, phylogeography became a potent tool to understand the role of historical processes in shaping the distribution of biological species (Avise 2000). It has its role in invasion biology by improving the knowledge of invasive species. Since, the speed of invasion has dramatically increased over the past several decades due to enhanced globalization, as a result of being transported to other continents via trade either deliberately or unintentionally. This has caused the transmission of several species to other regions across water bodies where they usually are absent and now have become recognized beyond their natural ranges (Hulme 2009). Moreover, once these non-native species invade native terrestrial ecosystems, they often compete for the resources thus out-competing native species. This has attracted many ecologists and conservationists to pinpoint their concerns including alterations in native ecosystems as well threats to the native species, biodiversity, and economy (Tsutsui et al. 2000; Pejchar & Mooney 2009; Vilà et al. 2011; Qiu 2015). To overcome the invasion of these invasive species we not only need to understand their relationship with native ecosystems in terms of dynamics and establishments but also the knowledge of the history of their invasion and ecology. Nonetheless, in some instances, we even do not know the systematics of these invading species taxa (Yassin et al. 2008; Folino-Rorem et al. 2009; Bastos et al. 2011) and this makes it more problematic to predict and manage the invasion issues. Thus, the study of phylogeography is essential in the sense that it tells us the history of invasive species and the exploration of their cryptic diversity. Therefore, apart from predicting its diversity phylogeography helps in the management of the spreading of invasive species (Schult et al. 2016). Since phylogeography is based on the DNA sequences of the genome or molecular markers, the variations of patterns in DNA sequences of these molecular markers leads to the conclusions of how biogeographic events took place in all geographic scales ranging from continental to local (Avise et al. 1987; Avise 2000). Moreover, a phylogenetic tree reveals clear results of how demographic and phylogeographic forces together constitute the lineage distribution of species. Therefore, to construct a phylogeny and to depict phylogeography of taxa, the selection of accurate markers would be essential. Amongst these various molecular markers the mitochondrial genes (COI, COII, 12S, 16S) especially COI is ideal while inferring phylogeography and invasion of various terrestrial species (Chang et al. 2008; Porco et al. 2013; Shekhovtsov et al. 2018a,b). Subsequently, most of these invasions are taking place in terrestrial ecosystems therefore, it is vital to understand the ecology, population dynamics of these invading species before setting management protocols to overcome their ecological effects. Earthworms being most dominant in terrestrial soils have profound ecological consequences especially in soils where they actively participate in nutrient cycling and other soil dynamic functions (Edwards 2004). Since earthworms are an archaic invertebrate animal group, their phylogeography is quite restricted due to their little mobilities in soils and incompetency to cross rivers, seas, and mountains. However, earthworms have been widespread recently due to two main reasons: via agriculture and commerce carried by humans across the globe and secondly, the introduction of earthworms in soils for their effective functions. For example, in the coniferous forests of Finland (Huhta 1979) *Aporrectodea caliginosa* was introduced to enhance its promising results. Similarly, earthworm invasions with their middens and burrowing activities have no doubt enhance soil heterogeneity

Table 4. List of publications of phylogeography and invasion of earthworm using COI and other molecular markers.

Marker(s)	Main focus	Region(s)	Reference
COI	Genetic structure, and invasions earthworms and Collembola	Europe and North America	Porco et al. 2013
COI	Introduction earthworm *Dendrobaena octaedra*	Northern Alberta	Cameron et al. 2008
COI/16S.	the invasion history of *Amynthas agrestis*	Northern United States	Nancy et al. 2016
16S/COI/ND1	Systematics and phylogeography of *Metaphire formosae* species	Taiwan	Chang et al. 2008
COI/16S	Historical phylogeography of *Metaphaire sieboldi*	Japan	Minamiya et al. 2009
COI	Phylogeography of *E.n. nordenskioldi* populations	Russia	Shekhovtsov et al. 2018a
COI	*Dendrobaena octaedra, Lumbricus rubellus,* and *Eisenia nordenskioldi nordenskioldi*	Eurasia	Shekhovtsov et al. 2018b

and abundance of other soil invertebrates by creating microhabitats with larger pore sizes and high microbial biomass that attract micro and mesofauna, respectively. However, such functions are often transient, small, and restricted to soil habitats, and rather the invasion has more negative effects. For instance, the invasion of the *Amynthas* species that belong to the Asian Megascolecidae family has drawn major concerns in the United States and several studies have investigated their consequences in non-native habitats (Hendrix & Bohlen 2002; Schult et al. 2016). The study of Cameron et al. (2008) revealed single and multiple invasions of earthworm *Dendrobaena octaedra* in the boreal forest of Alberta. Similarly, Novo et al. (2015b) studied the invasion of *Amynthas* species namely *A. corticis* and *A. gracilis* in Miguel islands in the Azores. Table 4 provides details of some peer-reviewed papers on phylogeography and invasion of earthworm species. Thus, in the longer term, the invasion of non-native earthworms can have strong adverse impacts on native faunal groups. Other studies either field or laboratory-based investigations also provide strong evidence of physical disturbance to the soil, food competition, vegetation loss, alteration of organic horizons, and decline of significant micro and mesofauna in soils due to invasions (Bohlen et al. 2004a,b; Frelich et al. 2006). Thus, the concern of non-native earthworm species should be addressed primarily and more focus should be given to their population dynamics, cryptic speciation, and phylogeography to understand the network of their invasion and to overcome their consequences by providing enough unbiased sampling and DNA based datasets.

CONCLUSION

Regardless of the fact that earthworm fauna of India is well reported as compared to other Asian Countries mainly on the basis of classical taxonomy but to solve a large number of taxonomic disagreement, an integrated approach of taxonomy may be promising in this direction. Molecular systematics of Indian earthworms is at nascent because of limited molecular database. A total of 801 DNA sequences of Indian earthworm are available on the BOLD database, while limited numbers are published yet. It is difficult to count them for correct identification unless they published. In spite of seemingly promising idea of molecular phylogenetic of earthworms a lack of comparative phylogenetic and phylogeographic inference have been observed. To overcome the current muddle of taxonomic puzzle of earthworms there is a need to move on towards integrated taxonomy.

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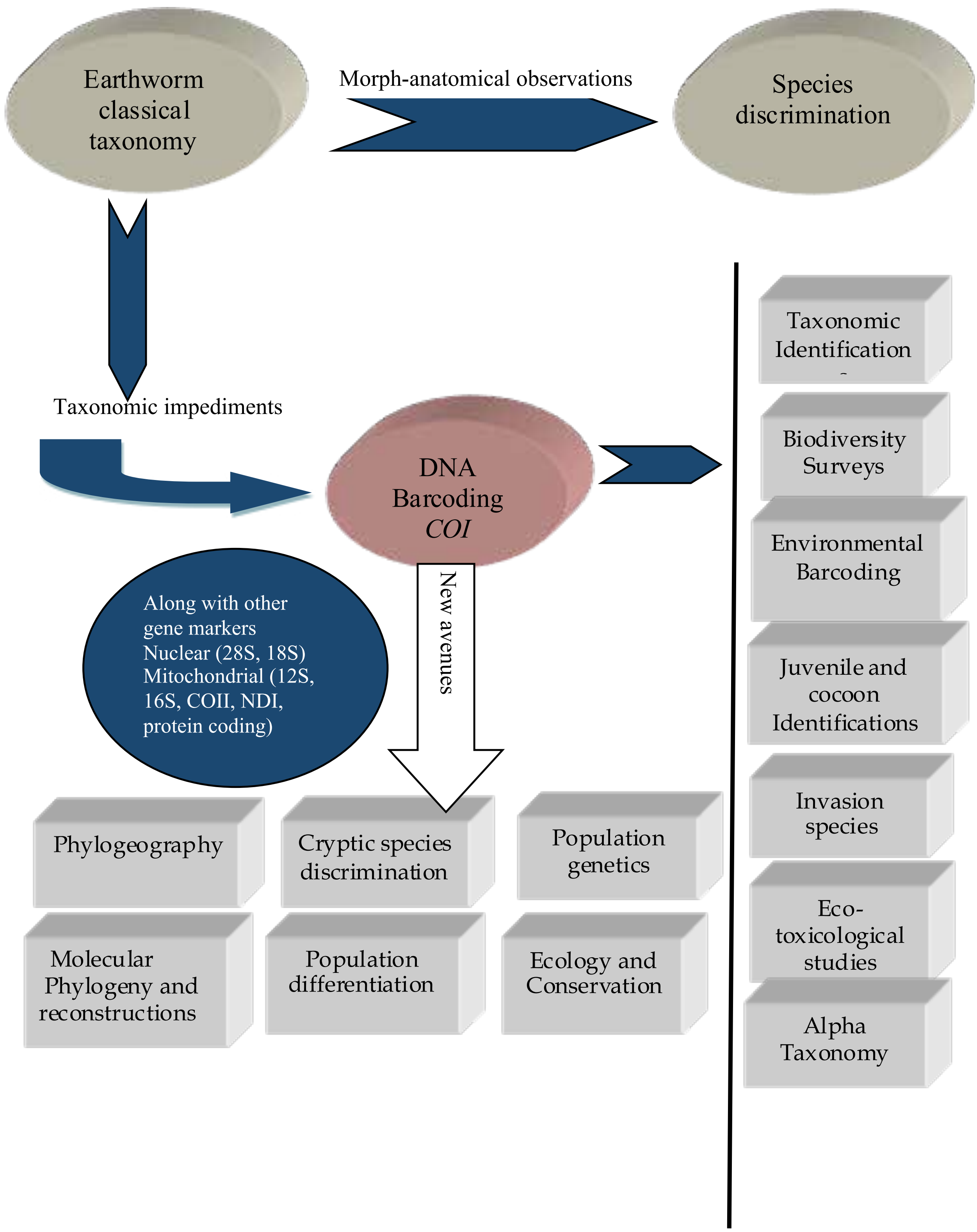

Figure 1. Lay out of charcterization and phylogenetic analysis of taxon using molecular markers and their applications in systematics, genetic diversity, and ecological studies of earthworms.

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REVIEW

A reference of identification keys to plant-parasitic nematodes (Nematoda: Tylenchida\ Tylenchomorpha)

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Abstract: The present review has documented a list of keys for identifying plant-parasitic nematodes at different taxonomic levels including superfamily, family, subfamily, genus, and species. It was compiled as a current source of information to assist students and professionals in the discipline of nematology for identification of this important group of soil nematodes.

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INTRODUCTION

While working on plant-parasitic nematodes, taxonomists have been documenting several identification keys on this group of nematodes. Although the work by Lewis et al. (1999) can be regarded as a very good documentation including a list of keys and references for identifying species of selected genera of plant-parasitic nematodes, it doesn't cover a large part of current information provided in the literature.

For having a view on classification and general identification of plant-parasitic nematodes, readers may find very helpful the following general references beside of identification keys documented in the present paper: May & Lyon (1975), Ebsary (1991), Nickle (1991), Siddiqi (2000), Andrássy (2007), Hodda (2011), and Manzanilla-López & Marbán-Mendoza (2012). The landmark collection of papers on reappraisal of Tylenchina published in Revue de Nématologie during 1987 and 1988, is also highly recommended to obtain an excellent insight on the systematics of plant-parasitic nematodes.

In the present paper, nomenclature and systematics follow that of De Ley & Blaxter (2002, 2004) and Kashi & Karegar (2018) with slight modification. We have tried that the present work to be a comprehensive reference for identification keys to plant-parasitic nematodes; however, some works may be overlooked and thus not included in the list. Keys for identifying plant-parasitic nematodes at different taxonomic levels including superfamily, family, subfamily, genus, and species level are referred. The number of treated taxa is mentioned whenever data (full paper) was available. Taxa are arranged alphabetically, and for each taxon, keys are written based on the order of the year of publication, from the newest to the oldest. Dichotomous keys are simply named 'key', and diagnostic compendiums or tabular keys as 'compendium' throughout the paper.

Keys to plant-parasitic nematodes

Phylum Nematoda Potts, 1932: Andrássy 2007, Hunt 1995, Hopper & Cairns 1959

Class Chromadorea Inglis, 1983

Subclass Chromadoria Pearse, 1942

Order Rhabditida Chitwood, 1933

Suborder Tylenchina Thorne, 1949: Mekete et al. 2012 (pictorial key for agriculturally important plant-parasitic nematodes), Andrássy 2007 (key for taxa), Eisenback 2002 (pictorial key for 23 genera), Bell 2002 (computerized key for 30 genera), Siddiqi 2000 (key for families and genera), Brzeski 1998 (key for genera), Bongers 1988 (key for nematodes of the Netherlands), Anderson & Mulvey 1979 (pictorial key for genera in Canada), Mai & Lyon 1975 (pictorial key for genera)

Note: This taxon includes plant-parasitic and bacteriovorous nematodes; the above-mentioned keys are only for plant-parasitic taxa.

Infraorder Tylenchomorpha De Ley & Blaxter, 2002

Superfamily Aphelenchoidea Fuchs, 1937: Miraeiz 2018 (key for genera) [in Persian], Kanzaki & Giblin-Davis 2012 (key for 2 families), Andrássy 2007 (key for 8 families, as order Aphelenchida), Hunt 1993 (key for 2 families)

Note: Aphelenchid nematodes have been treated under different levels of classificaton in literature: order Aphelenchida, subfamily Aphelenchina, or superfamily Aphelenchoidea. We consider them as a superfamily herein.

Family Aphelenchidae Fuchs, 1937: Kanzaki & Giblin-Davis 2012 (key for 2 subfamilies), Hunt 1993 (key for 2 subfamilies)

Subfamily Aphelenchinae Fuchs, 1937

***Aphelenchus* Bastian, 1865:** Andrássy 2007 (key for 4 European species), Nama & Soni 1981, Anderson & Hooper 1980

Subfamily Paraphelenchinae T. Goodey, 1951

***Paraphelenchus* Micoletzky, 1922:** Ryss 2013 (key and compendium for 23 species), Carta et al. 2011 (compendium for 23 species), Andrássy 2007 (key for 7 European species)

Family Aphelenchoididae Skarbilovich, 1947: Kanzaki & Giblin-Davis 2012 (key for 6 subfamilies and 29 genera), Andrássy 2007 (key for 12 genera), Hunt 1993 (key for 6 subfamilies)

Subfamily Acugutturinae Hunt, 1980: Andrássy 2007 (key for 3 genera), Hunt 1993 (key for 3 genera)

***Acugutturus* Hunt, 1980**

***Noctuidonema* Remillet & Silvain, 1988**

***Vampyronema* Hunt, 1993**

Subfamily Aphelenchoidinae Skarbilovich, 1947: Hunt 1993 (key for 7 genera)

***Aphelenchoides* Fischer, 1894:** Andrássy 2007 (key for 47 European species), Shahina 1996 (compendium for 141 species), Sanwal 1961 (key for 35 species), Thorne & Malek 1968 (key for 7 species)

***Anomyctus* Allen, 1940**

***Basilaphelenchus* Pedram, Kanzaki, Giblin-Davis & Pourjam, 2018**

***Laimaphelenchus* Fuchs, 1937:** Asghari et al. 2012 (key for 15 species), Andrássy 2007 (key for 3 European species), Oro et al. (2015) (key to 16 species).

***Punchaulus* De Ley & Coomans, 1996**

***Robustodorus* Andrássy, 2007**

***Ruehmaphelenchus* J.B. Goodey, 1963**

***Schistonchus* Cobb, 1927:** Davies et al. 2010 (key and compendium for 4 nominal species and 12 morphospecies in Australia)

***Sheraphelenchus* Nickle, 1970**

Subfamily Ektaphelenchinae Paramonov, 1964: Andrássy 2007 (key for 4 genera), Hunt 1993 (key for 4 genera)

***Cryptaphelenchus* Fuchs, 1937**

***Devibursaphelenchus* Kakuliya, 1967**

***Ektaphelenchoides* Baujard, 1984**

***Ektaphelenchus* Fuchs, 1937**

Subfamily Entaphelenchinae Nickle, 1970: Andrássy 2007 (key for 4 genera)

***Entaphelenchus* Wachek, 1955**

***Peraphelenchus* Wachek, 1955**

***Praecocilenchus* Poinar, 1969**

***Roveaphelenchus* Nickle, 1970**

Subfamily Parasitaphelenchinae Rühm, 1956

***Parasitaphelenchus* Fuchs, 1929**

***Bursaphelenchus* Fuchs, 1937:** Andrássy 2007 (key for 33 European species), Ryss et al. 2005 (key and compendium for 75 species), Yin et al. 1988 (key and compendium for 44 species), Tarjan & Aragon 1982, Maria et al. 2016 (key to 19 species of *hofmanni*-group).

Subfamily Sinurinae Husain & Khan, 1967: Andrássy 2007 (key for 3 genera), Hunt 1993 (key for 4 genera)

***Aprutides* Scognamiglio, Talame' & S'Jacob, 1970**

***Papuaphelenchus* Andrássy, 1973**

***Seinura* Fuchs, 1931:** Andrássy 2007 (key for 15 European species), Shahina & Hunt 1995 (compendium for 39 species)

Subfamily Tylaphelenchinae Kanzaki, Li, Lan & Giblin-Davis, 2014

***Pseudaphelenchus* Kanzaki & Giblin-Davis, 2009 in Kanzaki *et al.* (2009)**

***Tylaphelenchus* Rühm, 1956**

Superfamily Criconematoidea Taylor, 1936: Cid del Prado Vera & Talavera 2012 (key for 3 families), Andrássy 2007 (key for families), Siddiqi 1980 (key for families)

Note: Siddiqi (2000) considered this group as suborder Criconematina, and prodided identification keys for all taxa from genus to superfamily level.

Family Criconematidae Taylor, 1936: Cid del Prado Vera & Talavera 2012 (key for 3 subfamilies and 9 genera), Geraert 2010 (key for 18 genera), Andrássy 2007 (key for 17 genera), Wouts 2006 (key for taxa of New Zealand), Andrássy 1979 (key for taxa), De Grisse 1969 (key and compendium for taxa)

Subfamily Blandicephalanematinae Geraert, 2010

***Amphisbaenema* Orton Williams, 1982:** Geraert 2010 (description of 1 species)

***Blandicephalanema* Mehta & Raski, 1971:** Geraert 2010 (key for 5 species)

Subfamily Criconematinae Taylor, 1936

***Criconema* Hofmänner & Menzel, 1914:** Geraert 2010 (key for 99 species), Andrássy 2007 (key for 15 European species), Brzeski 1998 (key for 6 European species), Yeates et al. 1997 (key for 19 species), Golden & Friedman 1964 (key for 30 species)

***Croserinema* Khan, Chawla & Saha, 1976:** Geraert 2010 (key for 3 species), Crozzoli & Lamberti 2002 (key for 5 species from Venezuela)

***Crossonema* Mehta & Raski, 1971:** Geraert 2010 (key for 35 species), Andrássy 2007 (key for 5 European species)

***Lobocriconema* De Grisse & Loof, 1965:** Geraert 2010 (key for 19 species)

***Neolobocriconema* Mehta & Raski, 1971:** Geraert 2010 (key for 11 species), Hashim 1984

***Ogma* Southern, 1914:** Geraert 2010 (key for 77 species), Andrássy 2007 (key for 9 European species), Crozzoli & Lamberti 2002 (key for 3 species from Venezuela), Brzeski 1998 (key for 8 European species), Van den Berg & Quinéhérve 1995 (key and compendium for 10 species with predominantly 12 longitudinal rows of cuticular scales), Minagawa 1993 (compendium for 13 species)

***Orphreyus* Siddiqi, 2000:** Geraert 2010 (key for 3 species)

***Pateracephalanema* Mehta & Raski, 1971:** Geraert 2010 (key for 3 species)

Subfamily Discocriconemellinae Geraert, 2010

***Discocriconemella* De Grisse & Loof, 1965:** Geraert

2010 (key for 29 species)

***Xenocriconemella* De Grisse & Loof, 1965:** Geraert 2010 (key for 2 species), Andrássy 2007 (key for 2 European species)

Subfamily Hemicriconemoidinae Andrássy, 1979

***Hemicriconemoides* Chitwood & Birchfield, 1957:** Geraert 2010 (key for 51 species), Esser & Vovlas 1990 (compendium for species), Germani & Luc 1970, Dasgupta et al. 1969 (key for 16 species)

Subfamily Macroposthoniinae Skarbilovich, 1959

***Bakernema* Wu, 1964:** Geraert 2010 (key for 2 species), Ebsary 1982

***Criconemoides* Taylor, 1936:** Geraert 2010 (key for 45 species), Andrássy 2007 (key for 10 European species), Brzeski et al. 2002 (compendium for 34 species), Brzeski 1998 (key for 4 European species), Ebsary 1979, Mehta & Raski 1971, Tarjan 1966 (key and compendium for 89 species including *Mesocriconema* species), Raski & Golden 1966 (key for 85 species including *Mesocriconema* species), De Grisse & Loof 1965, Raski 1952 (key for 22 species)

***Mesocriconema* Andrássy, 1965:** Geraert 2010 (key for 90 species), Andrássy 2007 (key for 25 European species), Brzeski et al. 2002 (compendium for 90 species), Crozzoli & Lamberti 2001 (key for 11 species from Venezuela), Brzeski 1998 (key for 17 European species), Loof & De Grisse 1989

***Neobakernema* Ebsary, 1981:** Geraert 2010 (key for 7 species)

***Nothocriconemoides* Maas, Loof & De Grisse, 1971:** Geraert 2010 (key for 2 species)

Family Hemicycliophoridae Skarbilovich, 1959: Chitambar & Subbotin 2014 (key for 2 subfamilies), Cid del Prado Vera & Talavera 2012 (key for 2 subfamilies and 4 genera), Andrássy 2007 (key for 4 genera), Siddiqi 1980 (key for taxa)

Subfamily Caloosiinae Siddiqi, 1980: Chitambar & Subbotin 2014 (key for 2 genera)

***Caloosia* Siddiqi & Goodey, 1964:** Chitambar & Subbotin 2014 (key and compendium for 8 species)

***Hemicaloosia* Ray & Das, 1978:** Chitambar & Subbotin 2014 (key and compendium for 9 species); Zeng et al. 2012 (key and compendium for 7 species)

Subfamily Hemicycliophorinae Skarbilovich, 1959: Siddiqi 1980 (key for 4 genera)

***Hemicycliophora* de Man, 1921:** Chitambar & Subbotin 2014 (key and compendium for 132 species), Andrássy 2007 (key for 16 European species), Brzeski 1998 (key for 12 European species), Van den Berg 1987, Brzeski & Ivanova 1978, Eroshenko 1976, Loof 1976, Brzeski 1974, Loof 1968, Schoemaker 1967 (key for 44 species)

Family Tylenchulidae Skarbilovich, 1947: Ghaderi et al. 2016 (key for 4 subfamilies and 8 genera), Cid del Prado Vera & Talavera 2012 (key for 4 subfamilies and 7 genera), Raski 1991 (key for 3 subfamilies)

Subfamily Meloidoderitinae Kirjanova & Poghossian, 1973

***Meloidoderita* Poghossian, 1966:** Ghaderi et al. 2016 (key for 4 species), Raski 1991 (key for 3 species)

Subfamily Paratylenchinae Thorne, 1949: Ghaderi et al. 2016 (key for 3 genera), Andrássy 2007 (key for 5 genera), Esser 1992 (compendium for 148 species), Raski 1991 (key for 3 genera)

***Cacopaurus* Thorne, 1943:** Ghaderi et al. 2016 (description of 1 species)

***Paratylenchus* Micoletzky, 1922:** Ghaderi et al. 2016 (key for 130 species), Ghaderi et al. 2014 (key and compendium for 117 species), Andrássy 2007 (key for 30 European species under *Paratylenchus* or *Gracilacus*), Brzeski 1998 (key for 16 European species, compendium for 108 species), Raski 1991 (key for 97 species under *Paratylenchus* and *Gracilacus*), Pinochet & Raski 1977 (amended key of Raski 1975), Raski 1976 (key for 29 species with stylet longer than 40 µm), Raski 1975 (key for 47 species with stylet under 40 µm), Soloveva 1975 (key for 44 species), Wu 1975 (key for 10 Canadian species), Geraert 1965 (key for 39 species)

***Tylenchocriconema* Raski & Siddiqui, 1975:** Ghaderi et al. 2016 (description of 1 species)

Subfamily Sphaeronematinae Raski & Sher, 1952: Andrássy 2007 (key for 4 genera including *Meloidoderita*)

***Sphaeronema* Raski & sher, 1952:** Ghaderi et al. 2016 (key for 9 species), Raski 1991 (key for 8 species)

Subfamily Tylenchulinae Skarbilovich, 1947: Ghaderi et al. 2016 (key for 3 genera), Andrássy 2007 (key for 2 genera), Raski 1991 (key for 5 genera including *Meloidoderita* and *Sphaeronema*)

***Boomerangia* Siddiqi, 1994:** Ghaderi et al. 2016 (key for 2 species)

***Trophotylenchulus* Raski, 1957:** Ghaderi et al. 2016 (key for 14 species), Raski 1991 (key for 10 species under

Trophotylenchulus and *Trophonema*)

Tylenchulus **Cobb, 1913:** Ghaderi et al. 2016 (key for 5 species), Tanha Maafi et al. 2012 (key for 5 species), Raski 1991 (key for 4 species), Inserra et al. 1988 (key for 4 species)

Superfamily Tylenchoidea Örley, 1880

Family Dolichodoridae Whitehead, 1959: Hunt et al. 2013 (key for 6 subfamilies), Geraert 2011 (key for 7 subfamilies), Smart & Nguyen 1991 (key for 3 genera)

Subfamily Belonolaiminae Whitehead, 1960: Hunt et al. 2013 (key for 4 genera), Geraert 2011 (key for 4 genera), Andrássy 2007 (key for 4 genera), Smart & Nguyen 1991 (key for 5 genera)

Belonolaimus **Steiner, 1949:** Geraert 2011 (key for 5 species), Smart & Nguyen 1991 (key for 9 species), Rau 1963 (key for 5 species), Cid Del Prado & Subbotin 2012 (key to 6 species)

Carphodorus **Colbran, 1965:** Geraert 2011 (description of 1 species)

Ibipora **Monteiro & Lordello, 1977:** Geraert 2011 (key for 5 species)

Morulaimus **Sauer, 1966:** Geraert 2011 (key for 8 species), Smart & Nguyen 1991 (key for 6 species)

Subfamily Brachydorinae Siddiqi, 2000

Brachydorus **de Guiran & Germani, 1968:** Geraert 2011 (key for 3 species)

Subfamily Dolichodorinae Chitwood in Chitwood & Chitwood, 1950: Hunt et al. 2013 (key for 2 genera), Geraert 2011 (key for 2 genera), Andrássy 2007 (key for 3 genera), Smart & Nguyen 1991 (key for 3 genera), Lewis & Golden 1981 (key for 3 genera)

Dolichodorus **Cobb, 1914:** Geraert 2011 (key for 17 species), Guirado et al. 2007 (key and compendium for 17 species), Smart & Nguyen 1991 (key for 15 species), Lewis & Golden 1981 (key for 9 species), Smart & Khuong 1985 (key for 13 species), Grove et al. 1985, Loof & Sharma 1975, Esser 1989

Neodolichodorus **Andrássy, 1976:** Geraert 2011 (key for 12 species), Smart & Nguyen 1991 (key for 7 species)

Subfamily Macrotrophurinae Fotedar & Handoo, 1978

Macrotrophurus **Loof, 1958:** Geraert 2011 (description of 1 species)

Subfamily Meiodorinae Siddiqi, 1976

Meiodorus **Siddiqi, 1976:** Geraert 2011 (key for 3 species).

Family Merliniidae Siddiqi, 1971: Ghaderi et al. 2017 (key for8 genera), Hunt et al. 2013 (key for 5 genera), Sturhan 2012 (compendium for 7 genera), Geraert 2011 (key for 3 genera)

Subfamily Merliniinae Siddiqi, 1971

Amplimerlinius **Siddiqi, 1976:** Ghaderi & Karegar 2014, Geraert 2011 (key for 22 species), Andrássy 2007 (key for 11 European species), Brzeski 1998 (key for 5 European species), Shaw & Khan 1992 (key for 7 species), Bello et al. 1987 (compendium for 14 species), Brzeski 1985, Hooper 1978 (key and compendium for 9 species)

Geocenamus **Thorne & Malek, 1968:** Geraert 2011 (key for 69 species of *Geocenamus*, *Merlinius* and *Paramerlinius*), Chitambar & Ferris 2005 (key and compendium for 12 species), Smart & Nguyen 1991 (key for 7 species), Hooper 1978 (key and compendium for 3 species), Tarjan 1973 (key and compendium for 3 species)

Macrotylenchus **Sturhan, 2012:** Ghaderi et al. 2017 (key for 3 species)

Merlinius **Siddiqi, 1970:** Ghaderi et al. 2017 (key for 31 species), Andrássy 2007 (key for 9 European species), Handoo et al. 2007 (key and compendium for 32 species), Brzeski 1998 (key for 19 European species, compendium for 77 species including *Geocenamus* and *Scutylenchus* species), Brzeski 1992 (supplement for the key in Brzeski 1991), Brzeski 1991 (key for 67 species including *Geocenamus* and *Scutylenchus* species), Hooper 1978 (key and compendium for 46 species including *Scutylenchus* species), Tarjan 1973 (key and compendium for 38 species including *Scutylenchus* species)

Nagelus **Thorne & Malek, 1968:** Ghaderi et al. 2017 (key for 9 species), Geraert 2011 (key for 27 species), Andrássy 2007 (key for 8 European species), Brzeski 1998 (key for 2 European species), Powers et al. 1983 (compendium for 6 species)

Paramerlinius **Sturhan, 2012:** Ghaderi et al. 2017 (key for 11 species)

Scutylenchus **Jairajpuri, 1971:** Ghaderi & Karegar 2016 (key and compendium for 32 species including *Geocenamus* species), Xu et al. 2012 (key for 24 species), Andrássy 2007 (key for 9 European species), Skwiercz 1984 (key for 15 species)

Telomerlinius **Siddiqi & Sturhan, 2014:** Siddiqi & Sturhan 2014 (key for 2 species)

Subfamily Pratylenchoidinae Sturhan, 2012

***Pratylenchoides* Winslow, 1958:** Ghaderi & Karegar 2014 (key and compendium for 26 species), Geraert 2013 (key for 29 species), Ryss 2007 (key and compendium for 26 species) [in Russian], Andrássy 2007 (key for 17 European species), Brzeski 1998 (key for 7 European species), Talavera & Tobar 1996 (key for 23 species), Loof 1991 (key for 19 species), Baldwin et al. 1983 (key for 14 species), Ryss 1980.

Family Telotylenchidae Siddiqi, 1960: Hunt et al. 2013 (key for 9 genera), Geraert 2011 (key for 9 genera), Andrássy 2007 (key for 18 genera including those in Merliniidae), Jairajpuri & Hunt 1984 (key for 11 genera), Hooper 1978 (key for 3 subfamilies and 13 genera including those in Merliniidae), Tarjan 1973 (key for 8 genera including Merliniidae genera).

Subfamily Telotylenchinae Siddiqi, 1960: Jairajpuri & Hunt 1984 (key for 11 genera)

***Bitylenchus* Filipjev, 1934:** Hosseinvand et al. 2020 (key for 140 species including *Tylenchorhynchus* and *Sauertylenchus*), Andrássy 2007 (key for 12 European species), Jairajpuri 1982.

***Histotylenchus* Siddiqi, 1971:** Geraert 2011 (key for 7 species)

***Macrotrophurus* Loof, 1958:** Geraert 2011 (description of 1 species)

***Neodolichorhynchus* Jairajpuri & Hunt, 1984:** Geraert 2011 (key for 20 species), Andrássy 2007 (key for 6 European species), Jairajpuri & Hunt 1994 (key for 11 species under *Neodlichorhynchus*, *Dolichorhynchus* Mulk & Jairajpuri, 1974 and *Tessellus* Jairajpuri & Hunt, 1984), Erum et al. 2011 (key to 9 species).

***Paratrophurus* Arias, 1970:** Geraert 2011 (key for 18 species), Andrássy 2007 (key for 3 European species), Brzeski 1998 (key for 2 European species), Castillo et al. 1989 (key for 12 species), Hooper 1978 (key and compendium for 5 species)

***Quinisulcius* Siddiqi, 1971:** Geraert 2011 (key for 17 species), Andrássy 2007 (key for 5 European species), Maqbool 1982 (key for 10 species), Hooper 1978 (key and compendium for 9 species), Tarjan 1973 (key and compendium for 7 species).

***Sauertylenchus* Sher, 1974:** Hosseinvand et al. 2020 (key for 140 species including *Bitylenchus* and *Tylenchorhynchus*), Geraert 2011 (description of 1 species).

***Telotylenchus* Siddiqi, 1960:** Geraert 2011 (key for 19 species)

***Trichotylenchus* Whitehead, 1960:** Geraert 2011 (key for 31 species)

***Trophurus* Loof, 1956:** Geraert 2011 (key for 14 species), Brzeski 1998 (key for 2 European species), Kleynhans & Cadet 1994 (key and compendium for 14 species), Hooper 1978 (key and compendium for 7 species).

***Tylenchorhynchus* Cobb, 1913:** Hosseinvand et al. 2020 (key for 140 species including *Bitylenchus* and *Sauertylenchus*), Ganguly et al. 2013 (compendium to 158 species), Geraert 2011 (key for 133 species including *Bitylenchus* species), Andrássy 2007 (key for 16 European species), Handoo 2000 (key and compendium for 111 species), Brzeski & Dolinski 1998 (compendium for 177 species of *Tylenchorhynchus sensu lato*), Brzeski 1998 (key for 9 European species and compendium for 160 species of *Tylenchorhynchus sensu lato*), Hooper 1978 (key and compendium for 55 species), Tarjan 1973 (key and compendium for 46 species), Tarjan 1964 (key and diagnostic compendium for 88 species of *Tylenchorhynchus sensu lato*), Thorne & Malek 1968 (key for 9 species), Allen 1955 (key for 34 species of *Tylenchorhynchus sensu lato*).

Family Hoplolaimidae Filipjev, 1934: Andrássy 2007 (key for 13 genera excluding cyst and cystoid nematodes), Krall 1990 (key for 3 subfamilies)

Subfamily Acontylinae Fotedar & Handoo, 1978

***Acontylus* Meagher, 1968**

Subfamily Aphasmatylenchinae Sher, 1965

***Aphasmatylenchus* Sher, 1965**

Subfamily Ataloderinae Wouts, 1973: Ghaderi 2019 (key and compendium for 9 genera)

***Atalodera* Wouts & Sher, 1971:** Ghaderi 2019 (key for 9 species)

***Bellodera* Wouts, 1985:** Ghaderi 2019 (description of 1 species)

***Camelodera* Krall, Shagalina & Ivanova, 1988:** Ghaderi 2019 (description of 1 species)

***Cryphodera* Colbran, 1966:** Ghaderi 2019 (key for 7 species), Zhou et al. 2014 (key for 7 species), Karssen & Van Aelst 1999 (key for 6 species)

***Ekphymatodera* Bernard & Mundo-Ocampo, 1989:** Ghaderi 2019 (description of 1 species)

***Hylonema* Luc, Taylor & Cadet, 1978:** Ghaderi 2019 (description of 1 species)

***Rhizonemella* (Cid del Prado, Lownsbery & Maggenti, 1983) Andrássy, 2007:** Ghaderi 2019 (description of 1 species)

***Sarisodera* Wouts & Sher, 1971:** Ghaderi 2019

(description of 1 species)

Subfamily Heteroderinae Filipjev & Schuurmans Stekhoven, 1941: Subbotin & Franco 2012 (key for 8 genera), Subbotin et al. 2010 (key for 7 genera), Andrássy 2007 (key for 18 genera including cystoid nematodes), Handoo 2002, Wouts & Baldwin 1998 (key for 6 genera), Baldwin & Mundo-Ocampo 1991 (key for 16 genera in Heteroderinae, Ataloderinae and Meloidoderinae), Baldwin & Schouest 1990, Lamberti & Taylor 1986 (key for 6 genera and 59 species), Golden 1986 (key for 6 genera and 59 species), Wouts 1985, Mulvey & Golden 1983 (key and compendium for 6 genera and 34 species).

***Betulodera* Sturhan, 2002:** Subbotin et al. 2010 (description of 1 species)

***Cactodera* Krall & Krall, 1978:** Cid del Prado Vera & Subbotin 2014 (key for 14 species), Subbotin et al. 2010 (key and compendium for 13 species), Cid del Prado Vera & Miranda 2008 (key for 14 species), Graney & Bird 1990 (key and compendium for 7 species)

***Dolichodera* Mulvey & Ebsary, 1980:** Subbotin et al. 2010 (description of 1 species)

***Globodera* Skarbilovich, 1959:** Subbotin et al. 2010 (key and compendium for 10 species), Brzeski 1998 (key for 4 European species), Wouts & Baldwin 1998 (key for 8 species), Baldwin & Mundo-Ocampo 1991 (key for 6 species of particular economic importance), Wouts 1984 (key for 8 species)

***Heterodera* Schmidt, 1871:** Subbotin et al. 2010 (key and compendium for 80 species), Tanha Maafi et al. 2007 (compendium for 5 species in *H. avenae* group from Iran), Handoo 2002 (key and compendium for 12 species in *H. avenae* group), Brzeski 1998 (key for 18 European species), Wouts & Baldwin 1998 (key for 64 species), Wouts et al. 1995 (key for 9 species in *H. avenae* group), Baldwin & Mundo-Ocampo 1991 (key for 8 species of particular economic importance), Mulvey 1972 (key for 39 species, including 132 photomicrographs).

***Paradolichodera* Sturhan, Wouts & Subbotin, 2007:** Subbotin et al. 2010 (description of 1 species)

***Punctodera* Mulvey & Stone, 1976:** Subbotin et al. 2010 (key and compendium for 4 species)

***Vittatidera* Bernard, Handoo, Powers, Donald & Heinz, 2010**

Subfamily Hoplolaiminae Filipjev, 1934: Krall 1990 (key for 4 genera)

***Aorolaimus* Sher, 1963:** Baujard et al. 1994 (key for 33 species), Krall 1990 (key for 7 species), Sher 1963 (key for 3 species)

***Hoplolaimus* Daday, 1905:** Ghaderi et al. (Key for 36 species), Handoo & Golden 1992 (key and compendium for 29 species), Krall 1990 (key for 18 species), Anderson 1983 (key for 13 species having 6 pharyngeal gland nuclei), Jairajpuri & Baqri 1973 (key for 15 species), Sher 1963 (key for 8 species).

***Peltamigratus* Sher, 1964:** Krall 1990 (key for 11 species), Rashid et al. 1987 (compendium for 25 species), Bittencourt & Huang 1986 (key for 24 species), Mulk & Siddiqi 1982.

***Scutellonema* Andrássy, 1958:** Krall 1990 (key for 31 species), Germani et al. 1985 (key for 22 species), Van den Berg & Heyns 1973, Sher 1965, Sher 1963 (key for 11 species), Kolombia et al. 2017 (key to 50 species).

Subfamily Meloidoderinae Golden, 1971

***Meloidodera* Chitwood, Hannon & Esser, 1956:** Ghaderi 2019 (key for 10 species), Cid del Prado Vera 1991 (key for 7 species)

Subfamily Rotylenchoidinae Whitehead, 1958

***Antarctylus* Sher, 1973**

***Helicotylenchus* Steiner, 1945:** Nguyen & Anh 2019 (key for 37 species from Vietnam), Uzma et al. 2015 (illustrated compendium for 230 species, key for 32 species in Pakistan), Ganguly et al. 2013 (compendium for 203 species), Andrássy 2007 (key for 35 European species), Brzeski 1998 (key for 10 European species), Firoza & Maqbool 1994 (illustrated compendium for 190 species), Wouts & Yeates 1994 (key for 13 New Zealandian species), Diederich et al. 1991 (computerized key), Krall 1990 (key for 100 species), Fortuner 1989 (computerized key), Boag & Jairajpuri 1985 (compendium for 154 species), Fotedar & Kaul 1985 (key for 125 species), Fortuner & Wong 1984 (computerized key), Anderson & Eveleigh 1982 (key for Canadian species), Anderson 1979 (key for 50 species not included in the previous keys), Siddiqi 1972 (key for 75 species), Thorne & Malek 1968 (key for 10 species), Sher 1966 (key for 41 species).

***Pararotylenchus* Baldwin & Bell, 1981:** Baldwin & Bell 1981 (key for 8 species)

***Rotylenchus* Filipjev, 1936:** Andrássy 2007 (key for 35 European species), Castillo & Vovlas 2005 (key and compendium for 92 species), Brzeski 1998 (key for 11 European species, compendium for 96 species), Geraert & Barooti 1996 (key for 74 species), Castillo et al. 1994, Krall 1990 (key for 32 species), Boag & Hooper 1981, Sher 1965 (key for 14 species), Scotto et al. 2000 (compendium for 103 species).

Subfamily Rotylenchulinae Husain & Khan, 1967: Andrássy 2007 (key for 3 genera), Jatala 1991 (key for

3 genera)

***Rotylenchulus* Linford & Oliveira, 1940:** Andrássy 2007 (key for 5 European species), Robinson et al. 1997 (key for 10 species), Jatala 1991 (key for 10 species), Germani 1978 (key for 8 species).

***Senegalonema* Germani, Luc & Baldwin, 1984**

Subfamily Verutinae Esser, 1981

***Verutus* Esser, 1981**

***Bilobodera* Sharma & Siddiqi, 1992**

Family Meloidogynidae Skarbilovich, 1959: Hunt & Handoo 2013 (key for 3 genera), Andrássy 2007 (key for 4 genera)

Subfamily Meloidogyninae Skarbilovich, 1959

***Meloidogyne* Goeldi, 1892:** Ghaderi & Karssen 2020 (compendium for 105 species based on J2 and male), Zhao et al. 2017 (key to species in New Zealand), Hunt & Handoo 2009 (description of 12 important species), Karssen 2002 (key for 14 European species), Karssen & Van Hoenselaar 1998 (key for 14 European species), Brzeski 1998 (key for 8 European species), Eisenback & Triantaphyllou 1991 (key and compendium for 9 agriculturally most important species based on different life stages), Jepson 1987 (an illustrated monograph including key and compendium for 54 species), Jepson 1983 (key for 24 species), Ebsary & Eveleigh 1983 (key for 5 Canadian species), Hewlett & Tarjan 1983 (key and compendium for 53 species), Eisenback et al. 1981 (key and compendium for 4 main species), Taylor & Sasser 1978 (description of 24 species).

Family Pratylenchidae Thorne, 1949: Geraert 2013 (key for 5 subfamilies and 14 genera), Castillo et al. 2012 (key and compendium for 11 genera), Andrássy 2007 (key for 10 genera), Brzeski 1998 (key for 5 genera), Loof 1991 (key for 9 genera)

Subfamily Apratylenchinae Trinh, Waeyenberge, Nguyen, Baldwin, Karssen & Moens, 2009

***Apratylenchus* Trinh, Waeyenberge, Nguyen, Baldwin, Karssen & Moens, 2009:** Geraert 2013 (description of 2 species)

Subfamily Hirschmanniellinae Fotedar & Handoo, 1978

***Hirschmanniella* Luc & Goodey, 1964:** Geraert 2013 (key for 37 species), Andrássy 2007 (key for 6 European species), Brzeski 1998 (key for 2 European species), Loof 1991 (key for 25 species), Ebsary & Anderson 1982, Sivakumar & Khan 1982, Khun et al. 2015 (compendium for 29 species).

Subfamily Nacobbinae Chitwood in Chitwood & Chitwood, 1950

***Nacobbus* Thorne & Allen, 1944:** Geraert 2013 (description of 2 species), Jatala 1991 (key for 2 species), Sher 1970 (revision of 4 species)

Subfamily Nacobboderinae Golden & Jansen, 1974: Geraert 2013 (key for 2 genera and 6 species)

***Bursadera* Ivanova & Krall, 1985:** Geraert 2013 (description of 1 species)

***Meloinema* Choi & Geraert, 1974:** Geraert 2013 (key for 5 species)

Subfamily Pratylenchinae Thorne, 1949: Geraert 2013 (key for 2 genera)

***Pratylenchus* Filipjev, 1936:** Geraert 2013 (key for 98 species), Castillo & Vovlas 2007 (key and compendium for 68 species), Andrássy 2007 (key for 26 European species), Brzeski 1998 (key for 16 European species), Loof 1991 (key for 46 species), Handoo & Golden 1989 (key and compendium for 63 species), Café Filho & Huang 1989 (key for 54 species), Frederick & Tarjan 1989 (key and compendium for 89 species), Ryss 1988, Loof 1978, Thorne & Malek 1968 (key for 4 species), Ryss 2002 (key to 66 species)

***Zygotylenchus* Siddiqi, 1963:** Geraert 2013 (key for 3 species)

Subfamily Radopholinae Allen & Sher, 1967: Geraert 2013 (key for 7 genera)

***Achlysiella* Hunt, Bridge & Machon, 1989:** Geraert 2013 (key for 6 species)

***Apratylenchoides* Sher, 1973:** Geraert 2013 (key for 3 species)

***Hoplotylus* S'Jacob, 1959:** Geraert 2013 (key for 4 species), Bernard & Niblack 1982 (key for 3 species)

***Radopholoides* de Guiran, 1967:** Geraert 2013 (key for 5 species)

***Radopholus* Thorne, 1949:** Geraert 2013 (key for 23 species), Ryss 1997 (computerized key), Loof 1991 (key for the 2 most economic importance species), Sher 1968 (key for 11 species), Ryss 2003 (key and compendium to 29 species)

***Zygradus* Siddiqi, 1991:** Geraert 2013 (description of 2 species)

Family Tylenchidae Örley, 1880: Hunt et al. 2013 (key for 40 genera), Geraert 2008 (key for 42 genera), Andrássy 2007 (key for 29 genera), Brzeski 1998 (key for 20 genera), Geraert 1991 (key for 33 genera), Sumenkova 1984 (key for genera) [in Russian], Andrássy 1979a (key for genera and species).

Subfamily Atylenchinae Skarbilovich, 1959: Geraet 2008 (key for 5 genera), Andrássy 2007 (key for 2 genera)

***Aglenchus* Andrássy, 1954:** Husseinvand et al. 2016 (key for 9 species), Geraet 2008 (key for 8 species), Geraert 1991 (key for 3 species), Andrássy 1980

***Atylenchus* Cobb, 1913:** Geraet 2008 (description of 1 species)

***Coslenchus* Siddiqi, 1978:** Geraet 2008 (key for 37 species), Andrássy 2007 (key for 22 European species), Brzeski 1998 (key for 17 European species, compendium for 25 species), Geraert & Raski 1988 (key for 30 species), Brzeski 1987 (key for 23 species), Mizukubo & Minagawa 1985 (key for 31 species), Andrássy 1982, Siddiqi 1980 (key for 9 species).

***Pleurotylenchus* Szczygiel, 1969:** Geraet 2008 (description of 2 species)

Subfamily Boleodorinae Khan, 1964: Geraet 2008 (key for 8 genera), Brzeski & Sauer 1982 (key for 5 genera)

***Basiria* Siddiqi, 1959:** Geraet 2008 (key for 42 species), Andrássy 2007 (key for 12 European species), Karegar & Geraert 1998 (key for 35 species), Brzeski 1998 (key for 7 European species).

***Boleodorus* Thorne, 1941:** Geraet 2008 (key for 30 species), Andrássy 2007 (key for 4 European species), Brzeski 1998 (key for 3 European species), Geraert 1971 (key for 13 species), Thorne & Malek 1968 (key for 3 species), Khan 1963.

***Discopersicus* Yaghoubi, Pourjam, Álvarez-Ortega, Liébanas, Atighi & Pedram, 2016**

***Neopsilenchus* Thorne and Malek, 1968:** Geraet 2008 (key for 9 species), Karegar & Geraert 1997 (key for 6 species), Shahina & Maqbool 1990 (key for 11 species), Sultan et al. 1987, Khan & Khan 1975.

***Neothada* Khan, 1973:** Geraet 2008 (key for 6 species), Andrássy 2007 (key for 2 European species), Brzeski 1998 (key for 2 European species), Heyns & Van den Berg 1996 (key for 6 species).

***Ridgellus* Siddiqi, 2000:** Geraet 2008 (description of 1 species)

***Thada* Thorne, 1941:** Geraet 2008 (description of 1 species)

Subfamily Ecphyadophorinae Skarbilovich, 1959: Geraet 2008 (key for 9 genera), Andrássy 2007 (key for 9 genera)

***Chilenchus* Siddiqi, 2000:** Geraet 2008 (description of 1 species)

***Ecphyadophora* de Man, 1921:** Geraet 2008 (key for 8 species), Geraert 1991 (key for 6 species), Raski et al. 1982

***Ecphyadophoroides* Corbett, 1964:** Geraet 2008 (key for 2 species), Geraert 1991 (key for 8 species)

***Epicharinema* Raski, Maggenti, Koshy & Sosamma, 1982:** Geraet 2008 (description of 1 species)

***Labrys* Qing & Bert, 2018**

***Lelenchus* Andrássy, 1954:** Geraet 2008 (key for 3 species)

***Mitranema* Siddiqi, 1986:** Geraet 2008 (key for 2 species)

***Sigmolenchus* Gharahkhani, Pourjam, Abolafia, Castillo & Pedram, 2020**

***Tenunemellus* Siddiqi, 1986:** Geraet 2008 (key for 6 species)

***Tremonema* Siddiqi, 1994:** Geraet 2008 (description of 1 species)

***Ultratenella* Siddiqi, 1994:** Geraet 2008 (description of 1 species)

Subfamily Psilenchinae Paramonov, 1967: Andrássy 2007 (key for 3 genera)

***Antarctenchus* Spaull, 1972:** Geraet 2008 (description of 1 species)

***Atetylenchus* Khan, 1973:** Hosseinvand et al. 2020 (key for 7 species), Geraet 2008 (key for 3 species)

***Psilenchus* de Man, 1921:** Geraet 2008 (key for 21 species), Andrássy 2007 (key for 5 European species), Brzeski 1998 (key for 4 European species), Doucet 1996, Brzeski 1989 (compendium for species), Kheiri 1970 (key for 11 species), Thorne & Malek 1968 (key for 4 species).

Subfamily Tylenchinae Örley, 1880: Geraet 2008 (key for 14 genera)

***Allotylenchus* Andrássy, 1984:** Geraet 2008 (description of 1 species)

***Cervoannulatus* Bajaj, 1998:** Geraet 2008 (description of 1 species)

***Cucullitylenchus* Huang & Raski, 1986:** Geraet 2008 (description of 1 species)

***Discotylenchus* Siddiqi, 1980:** Geraet 2008 (key for 6 species)

***Filenchus* Andrássy, 1954:** Geraet 2008 (key for 95 species including *Ottolenchus* species), Andrássy 2007 (key for 27 European species), Brzeski 1998 (key for 19 European species, compendium for 79 species), Raski & Geraert 1986 (key for 60 species).

***Fraglenchus* Siddiqi, 2000:** Geraet 2008 (description of 1 species)

***Gracilancea* Siddiqi, 1976:** Geraet 2008 (description of 1 species)

***Irantylenchus* Kheiri, 1972:** Geraet 2008 (description of 1 species)

***Malenchus* Andrássy, 1968:** Geraet 2008 (key for 22 species), Andrássy 2007 (key for 16 European species), Brzeski 1998 (key for 11 European species, compendium for 33 species), Geraert & Raski 1986 (key for 24 species)

***Miculenchus* Andrássy, 1959:** Geraet 2008 (key for 4 species), Geraert 1991 (key for 3 species)

***Ottolenchus* Husain & Khan, 1967:** Geraet 2008 (key for species along together with *Filenchus* species), Brzeski 1982 (key for 4 species)

***Polenchus* Andrássy, 1980:** Geraet 2008 (key for 3 species)

***Sakia* Khan, 1964:** Geraet 2008 (key for 7 species)

***Silenchus* Andrássy, 2001:** Geraet 2008 (description of 1 species)

***Tanzanius* Siddiqi, 1991:** Geraet 2008 (description of 1 species)

***Tylenchus* Bastian, 1865:** Geraet 2008 (key for 28 species), Andrássy 2007 (key for 8 European species), Brzeski 1998 (key for 4 European species), Bello 1973 (key for 30 species including *Filenchus* species), Thorne & Malek 1968 (key for 10 species), Andrássy 1954.

Subfamily Tylodorinae Paramonov, 1967: Geraet 2008 (key for 5 genera)

***Arboritynchus* Reay, 1991:** Geraet 2008 (description of 1 species)

***Campbellenchus* Wouts, 1977:** Geraet 2008 (key for 2 species)

***Cephalenchus* Goodey, 1962:** Geraet 2008 (key for 20 species), Andrássy 2007 (key for 4 European species), Brzeski 1998 (key for 3 European species), Raski & Geraert 1986 (key for 11 species), Mizukubo & Minagawa 1985 (key for 16 species), Sultan & Jairajpuri 1981.

***Eutylenchus* Cobb, 1913:** Geraet 2008 (key for 6 species), Brzeski 1996 (key for 5 species)

***Tylodorus* Meagher, 1964:** Geraet 2008 (key for 2 species)

Superfamily Sphaerularioidea Lubbock, 1861: Andrássy 2007 (key for families)

Family Anguinidae Nicoll, 1935: Subbotin & Riley 2012 (compendium for 15 genera), Krall 1991 (key for 3 subfamilies), Andrássy 2007 (key for 14 genera), Brzeski 1998 (key for 5 genera), Brzeski 1981 (key for 8 genera)

Subfamily Anguininae Nicoll, 1935: Krall 1991 (key for 4 gall-inducing genera), Chizhov & Subbotin 1990 (key for 4 genera)

***Afrina* Brzeski, 1981**

***Anguina* Scopoli, 1777:** Andrássy 2007 (key for 4 European species), Brzeski 1998 (key for 4 European species), Krall 1991 (key for 10 species), Chizhov & Subbotin 1990 (key for species)

***Diptenchus* Khan, Chawla & Seshadri, 1969**

***Ditylenchus* Filipjev, 1936:** Hashemi & Karegar 2019 (compendium and key for 63 species), Esmaeili & Heydari, 2016 (key for 27 species including *Nothotylenchus* species from Iran), Andrássy 2007 (key for 27 European species), Das & Bajaj 2005, Brzeski 1998 (key for 29 European species, compendium for 76 species including *Nothotylenchus* species), Viscardi & Brzeski 1993 (computerized key), Brzeski 1991 (compendium for 80 species and redescription of 20 species), Sturhan & Brzeski 1991 (compendium for 82 species including *Nothotylenchus* species), Thorne & Malek 1968 (key for 6 species).

***Ficotylus* Davies, Ye, Giblin-Davis & Thomas, 2009**

***Indoditylenchus* Sinha, Ghoudhury & Baqri, 1985**

***Litylenchus* Davies, Zhao, Alexander & Riley, 2011**

***Mesoanguina* Chizhov & Subbotin, 1985:** Krall 1991 (key for 8 species), Chizhov & Subbotin 1990 (key for species)

***Nothanguina* Whitehead, 1959**

***Nothotylenchus* Thorne, 1941:** Hashemi & Karegar 2020 (compendium and key for 41 species), Andrássy 2007 (key for 27 European species), Thorne & Malek 1968 (key for 4 species),

***Orrina* Brzeski, 1981**

***Pseudhalenchus* Tarjan, 1958:** Brzeski 1998 (key for 4 European species), Grewal 1991 (key for 4 species)

***Pterotylenchus* Siddiqi & Lenné, 1984**

***Safianema* Siddiqi, 1980**

***Subanguina* Paramonov, 1967:** Brzeski 1998 (key for 4 European species)

Subfamily Halenchinae Jairajpuri & Siddiqi, 1969

***Halenchus* N.A. Cobb in M.V. Cobb, 1933**

Family Neotylenchidae Thorne, 1941: Sumenkova, 1989 (key for genera and species).

Subfamily Fergusobiinae Goodey, 1963

***Fergusobia* Currie, 1937 (Christie, 1941):** Davies et al. 2014 (key for Australian species)

Subfamily Gymnotylenchinae Siddiqi, 1980
***Gymnotylenchus* Siddiqi, 1961**

Subfamily Neotylenchinae Thorne, 1941: Andrássy 2007 (key for 7 genera)

***Anguillonema* Fuch, 1938:** Yaghoubi et al. 2018 (key for 3 species)

***Hexatyleus* Goodey, 1926:** Andrássy 2007 (key for 3 European species)

***Deladenus* Thorne, 1941:** Andrássy 2007 (key for 10 European species)

Subfamily Rubzovinematinae Slobodyanyuk, 1999
***Rubzovinema* Slobodyanyuk, 1991**

Family Sphaerulariidae Lubbock, 1861 (Skarbilovich, 1947)

Subfamily Paurodontinae Thorne, 1941
***Abursanema* Yaghoubi, Pourjam, Pedram, Siddiqi & Atighi, 2014**
***Bealius* Massey & Hinds, 1970**
***Luella* Massey, 1974**
***Misticius* Massey, 1967**
***Neomisticius* Siddiqi, 1986**

***Paurodontella* Husain & Khan, 1968:** Iqbal et al. 2010 (key for 10 species)

***Paurodontoides* Jairajpuri & Siddiqi, 1969**
***Paurodontus* Thorne, 1941**

Subfamily Sphaerulariinae Lubbock, 1861

***Prothallonema* Christie, 1938:** Geraert et al. 1984 (key for 12 species)

***Sphaerularia* Dufour, 1837**
***Tripius* Chitwood, 1935**
***Veleshkinema* Miraeiz, Heydari, Álvarez-Ortega, Pedram & Atighi, 2015**

Class Enoplea Inglis, 1983
Subclass Dorylaimia Inglis, 1983
Order Dorylaimida Pearse, 1942
Suborder Dorylaimina Pearse, 1942

Superfamily Dorylaimoidea Thorne, 1935: Vinciguerra 2006 (key for 10 families)

Family Longidoridae Thorne, 1935: Pedram 2018 (key for 8 genera) [in Persian], Decraemer & Chaves 2013 (key for 2 subfamilies, compendium for 7 genera), Hunt 1993 (key for 3 subfamilies)

Subfamily Longidorinae Thorne, 1935: Andrássy 2007 (key for 8 genera), Taylor & Brown 1997 (key for some taxa), Hunt 1993 (key for 3 genera)

***Australodorus* Coomans, Olmos, Casella & Chaves, 2004**
***Longidoroides* Khan, Chawla & Saha, 1978**

***Longidorus* Micoletzky, 1922:** Ye & Robbins 2004 (compendium for 137 species), Loof & Chen 1999 (compendium for 13 species, supplement for Chen et al. 1997), Chen et al. 1997 (compendium for 103 species), Rey et al. 1988 (computerized key for 65 species), Romanenko 1978, Zheng et al. 2001 (key for 12 species from China), Xu et al. 2018 (key for 15 species from China).

***Paralongidorus* Siddiqi, Hooper & Khan, 1963:** Escuer & Arias 1997 (compendium for 70 species)

***Paraxiphidorus* Coomans & Chaves, 1995**

***Xiphidorus* Monteiro, 1976:** Decraemer et al. 1996 (key for 6 species)

Subfamily Xiphinematinae Dalmasso, 1969

***Xiphinema* Cobb, 1913:** Lamberti et al. 2004 (key and compendium for 49 species in *X. americanum* group), Coomans et al. 2001 (compendium for over 100 species), Lamberti et al. 2000 (compendium for 51 species in *X. americanum* group), Loof et al. 1996, Robbins et al. 1996 (compendium for 114 species based on juveniles), Lamberti & Carone 1991 (key for 38 species in *X. americanum* group), Loof & Luc 1990 (compendium for 172 species in the genus, excluding *X. americanum* group), Loof & Luc 1983, Kohn & Sher 1972 (key for 50 species), Ganguly et al. 2000 (key to 12 species of group 1), Sen et al. 2010 (key to 14 species for mono-opisthodelphic species).

Subclass Enoplia Pearse, 1942
Order Triplonchida Cobb, 1920
Suborder Diphtherophorina Coomans & Loof, 1970
Superfamily Diphtherophoroidea Micoletzky, 1922

Family Trichodoridae Thorne, 1935: Niknam & Jabbari 2018 (key for 4 genera) [in Persian], Decraemer & Chaves 2012 (key for 6 genera), Andrássy 2007 (key for 5 genera), Almeida & Decraemer 2005 (key for genera and species) [in Portuguese], Decraemer & Baujard 1998 (compendium for 90 species in the family), Decraemer 1995 (key for 4 genera), Hunt 1993 (key for 4 genera), Decraemer 1991 (compendium for 4 genera), Loof 1975, Siddiqi 1974.

***Allotrichodorus* Rodriguez-M, Sher & Siddiqi, 1978:** Rashid et al. 1985 (key for 7 species based on females and males), Decraemer 1980 (key for 2 species), Rodriguez-M et al. 1978 (key for 2 species).

***Ecuadorus* Siddiqi, 2002**

***Monotrichodorus* Andrássy, 1976:** Decraemer 1980 (key for 2 species), Rodriguez-M et al. 1978 (key for 2 species).

***Paratrichodorus* Siddiqi, 1974:** Decraemer & Chaves 2013 (key for 8 virus-vector species), Decraemer 1995 (key for 31 species based on females and males), Andrássy 2007 (key for 13 European species), Decraemer 1980 (key for 16 species based on females and males), Siddiqi 1973.

***Trichodorus* Cobb, 1913:** Decraemer & Chaves 2013 (key for 4 virus-vector species), Zahedi et al. 2009 (key for 5 Iranian species), Andrássy 2007 (key for 18 European species), Decraemer & Baujard 1998a (key and compendium for 90 species), Decraemer & Baujard 1998b (additions and corrections to Decraemer & Baujard 1998a), Taylor & Brawn 1997, Decraemer 1995 (key for 48 species based on females and males), De Waele & Brzeski 1995 (key for 46 species), Decraemer 1980 (key for 22 species based on females and males), Esser 1971.

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SHORT COMMUNICATION

Catalogue of herpetological specimens from Meghalaya, India at the Salim Ali Centre for Ornithology and Natural History

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Abstract: We present a catalogue of herpetological specimens collected from select community reserves of Meghalaya, northeastern India. The collection comprises a total of 75 species of the herpetofauna, including 29 species of amphibians from 20 genera in seven families and 46 species of reptiles from 30 genera, in 10 families. We provide the details on number of examples, sex, museum numbers, and collection details including location and collector along with the relevant remarks where applicable. A total of five species of amphibians and four species of reptiles remain to be resolved systematically since no precise name could be attributed to them.

Keywords: Amphibia, Coimbatore, community reserves, museum collection, northeastern India, Reptilia, voucher specimens

The importance of natural history collections in enriching our knowledge on various aspects of organisms such as taxonomic, morphological, ontogenetic, genetic, phylogenetic, ecological, and biogeographic facets have been highlighted since the past (Lane 1996). Apart from serving as the basis for taxonomic entities, such collections of specimens serve as an important repository of historic information on species distribution patterns as well (Shaffer et al. 1998; Rocha et al. 2014; Turney et al. 2015; Yeates et al. 2016; Da Silva et al. 2017; Hill 2017; Ceríaco et al. 2019). Most of the herpetofaunal type collections within India are deposited in two museums, namely, the Zoological Survey of India (ZSI, Kolkata), and the Bombay Natural History Society (BNHS, Mumbai). Although the collections in such major museums have been catalogued at some point (Das & Chaturvedi 1998; Das et al. 1998; Chanda et al. 2000), there are several other institutions that house a sizable collection of specimens that often remain understudied. One such collection is in the Sálim Ali Centre for Ornithology and Natural History (SACON), Coimbatore, India. SACON is an institution under the Ministry of Environment, Forests and Climate Change, Government of India. A part of the herpetological collections at SACON from peninsular India has recently been catalogued (Ganesh et al. 2020). As a part of an ongoing study in select community reserves of Meghalaya, herpetofaunal specimens were collected by P. Karthik (research fellow of the project

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entitled 'Characterization of Community Reserves and Assessment of their Conservation Values in Meghalaya' funded by the National Mission on Himalayan Studies) and RSN and are deposited at SACON as vouchers. Herein, we present a catalogue of those herpetological specimens collected from Meghalaya that are maintained at SACON.

Materials and Methods

The herpetological specimens collected between the period 2018 to 2021 as a part of the ongoing surveys in community reserves of Meghalaya were preserved in ethanol and deposited in the collection of the SACON. Here, we list the collected specimens (only whole body, only non-larval) along with their voucher collection numbers. Institutional acronyms follow that of Ganesh et al (2020). Higher classification of amphibians and reptiles follow Frost (2021) and Uetz et al. (2021), respectively. Authorities are not mentioned for species with tentative identities indicated by 'cf.' Exceptional cases of more than one specimens catalogued under the same voucher number are distinguished by adding to their collection number the alphabets a, b, c etc. In cases where the specimens could not be identified precisely to the species level, the generic name only is mentioned followed by sp.

Relevant discussions based on recently published information is presented under such species to clarify their identification. Details of the collection localities mentioned below are presented in Table 1.

Catalogue of the herpetofaunal specimens from Meghalaya deposited at SACON

Amphibia Gray, 1825
Gymnophiona Müller, 1832
Ichthyophiidae Taylor, 1968

1. *Ichthyophis garoensis* Pillai & Ravichandran, 1999 (n= 3)

SACON VA 79 and VA 87 - two unsexed adult specimens from Dumitdigre and Sasatgre respectively (coll: P. Karthik), VA 169 – an unsexed adult from Dharibokgre (coll. R.S. Naveen).

Remark: Another putative species, *Ichthyophis hussaini* Pillai & Ravichandran, 1999 from Garo Hills, Meghalaya was synonymized with *I. garoensis* by Kamei & Biju (2016).

Anura Fischer von Waldheim, 1813
Bufonidae Gray, 1825

2. *Duttaphrynus melanostictus* (Schneider, 1799) (n= 3)

SACON VA 55 - one adult female and VA 56 and VA 66, two unsexed individuals, of which the former is a subadult, collected from Mongalgre (coll. P. Karthik).

3. *Duttaphrynus* sp. (n= 4)

SACON VA 103 a, b - two unsexed subadults, and VA 123 and VA 124 - two adult females, from Jirang (coll. P. Karthik).

Remark: The identity of these specimens still needs resolution. Agarwal & Mistry (2008) reported *D. stuarti* (Smith, 1929) from Arunachal Pradesh, and Das et al. (2013) described *D. chandai* from the Nagaland-Manipur border.

Microhylidae Günther, 1858

4. *Microhyla berdmorei* (Blyth, 1856) (n= 1)

SACON VA 102, an adult female from Meghalaya (precise location unknown) (coll. P. Karthik).

5. *Microhyla* cf. *mymensinghensis* (n= 4)

SACON VA 81 a, b, c - three adult females from Dumitdigre (coll. P. Karthik). VA 155 - an unsexed adult from Chimanpara (coll. R.S. Naveen).

Remark: A species described recently from the *M. ornata* complex (Hasan et al. 2014). The precise identity of these samples requires further study.

Megophryidae Bonaparte, 1850

6. *Leptobrachium* cf. *sylheticum* (n= 6)

SACON VA 57, VA 61 - two adult females from Mongalgre; VA 58, VA 59, VA 60 - three unsexed adult specimens and VA 151 - an unsexed adult from Eman Asakgre (coll. R.S. Naveen).

Remarks: The reports of another species, *L. rakhinense* Wogan, 2012, from Northeast India have been shown by Dutta et al (2013) to represent *L. smithi*. Very recently, populations of the '*L.smithi*' complex were reassessed by Al-Razi et al (2021) and described as a new species. Considering the geographic proximity of our samples to the type locality of *L. sylheticum*, we refer our specimens as *L.* cf. *sylheticum.*

7. *Leptobrachella* cf. *khasiorum* (n= 1)

VA 115 - an unsexed subadult from Jirang (coll. P. Karthik)

8. *Xenophrys major* (Boulenger, 1908) (n= 1)

SACON VA 83 - an adult female from Mongalgre (coll. P. Karthik).

Remark: The genus *Xenophrys* Günther, 1864, which was placed under the synonymy of *Megophrys* Kuhl & Van Hasselt, 1822 by Mahony et al. (2013) has now been revalidated by Lyu et al (2021).

Table 1. GPS coordinates of collection localities in Meghalaya, India.

	Community Reserves / Sites	District	Latitude (°N)	Longitude (°E)	Altitude (m)
1	Chandigre	West Garo Hills	25.5362	90.3256	833
2	Dalu	West Garo Hills	25.2206	90.2163	31
3	Daribokgre	North Garo Hills	25.47902	90.3105	1123
4	Mongalgre	West Garo Hills	25.6261	90.2064	535
5	Sakalgre	West Garo Hills	25.5143	90.3808	895
6	Sasatgre	West Garo Hills	25.5262	90.3283	895
7	Selbalgre	West Garo Hills	25.5143	90.2030	282
8	Tura	West Garo Hills	25.515	90.2027	281
9	Kitmadamgre	North Garo Hills	25.8006	90.3959	223
10	Eman Asakgre	South Garo Hills	25.36989	90.54481	174
11	Thokpara	West Garo Hills	25.2756	90.1051	94
12	Dangkipara	South Garo Hills	25.4286	90.3269	380
13	Chimanpara	West Garo Hills	25.29606	90.12145	92
14	Rongalgre	West Garo Hills	25.4574	90.1669	112
15	Dumitdigre	West Garo Hills	25.6084	92.0156	1103
16	NEHU, Shillong	East Khasi Hills	25.6126	91.8972	1404
17	Jirang	Ri Bhoi	25.8974	91.5849	647
18	Lum Jusong	Ri Bhoi	25.8948	92.0396	919
19	Nongpoh	Ri Bhoi	25.8983	91.8956	681
20	Nongsangu	Ri Bhoi	25.8717	92.0529	740
21	Raid Nongbri	Ri Bhoi	25.9152	92.0156	790

NEHU—North Eastern Hill University

9. *Xenophrys megacephala* (Mahony, Sengupta, Kamei & Biju, 2011) (n= 1)

VA 80 - an unsexed adult specimen from Dumitdigre (coll. P. Karthik).

Remark: See above for taxonomic validity of the genus *Xenophrys* Günther, 1864.

10. *Xenophrys oropedion* (Mahony, Teeling & Biju, 2013) (n= 1)

VA 67 - an adult female from Daribokgre (coll. P. Karthik)

Remark: See above for taxonomic validity of the genus *Xenophrys* Günther, 1864.

11. *Xenophrys* sp. (n= 1)

VA 86 - an unsexed subadult from Sasatgre (coll. P. Karthik), whose identity could not be determined.

Dicroglossidae Anderson, 1871

12. *Fejervarya* sp. (n= 5)

VA 54, VA 82 and VA 98 - three adult females from Mongalgre and Lum Jusong, respectively. VA 75 - an adult male from Dumitdigre. VA 107 - an unsexed subadult from Lum Jusong (coll. P. Karthik).

Remark: A large-bodied *Fejervarya* frog, *F. orissaensis* Dutta, 1997 has recently been shown to occur across most parts of Indochina (Köhler et al. 2019). The identity of our *Fejervarya* specimens still needs taxonomic resolution.

13. *Minervarya sengupti* (Purkayastha & Matsui, 2012) (n= 10)

Ten specimens. VA 117–119 - three adult females from Jirang. VA 62 - one adult female. VA 63–65 - three adult males from Daribokgre. VA 71 - one adult female from Dumitdigre. VA 89, VA 97 - two adult females from Meghalaya (precise location unavailable) (coll. P. Karthik).

Remark: A fairly recently described species from Mawphlang, Khasi Hills, Meghalaya (Purkayastha & Matsui 2012).

14. *Minervarya* cf. *pierrei* (n= 7)

VA 72, VA 73 and VA 74 - three adult males from Dumitdigre. VA 116 – an adult female from Jirang. VA 92 an adult female from Daribokgre and VA 84–85 - two unsexed adult specimens from Sasatgre (coll. P. Karthik).

Remark: The taxonomic status and distribution of *Minervarya pierrei* (Dubois, 1975) and *Minervarya agricola* (Jerdon, 1853) were recently discussed by

Chandramouli et al. (2019) and Phuge et al. (2020).

15. *Minervarya* sp. (n= 1)

VA 109 - an unsexed juvenile specimen from Meghalaya (coll. P. Karthik) that could not be identified to species level.

16. *Limnonectes khasianus* (Anderson, 1871) (n= 8)

VA 111, VA 112 - two adult males from Jirang, VA 99 and VA 69 - two adult males from Dimitdigre, VA 68 – an unsexed adult from Meghalaya (precise locality unknown) (coll. P. Karthik), VA 130–131, two unsexed adults from Rongalgre and VA 132, an unsexed subadult from Kitmadamgre (coll. R.S. Naveen).

Remark: Ohler & Deuti (2013) discussed and confirmed the synonymy of *Rana laticeps* Boulenger, 1882 with *Pyxicephalus khasianus* Anderson, 1871, thereby highlighting the seniority of the name combination *Limnonectes khasianus* (Anderson, 1871).

17. *Euphlyctis cyanophlyctis* (Schneider, 1799) (n= 4)

VA 94 - one adult female (coll. P. Karthik). VA 113, VA 114, VA 125 - three unsexed subadults from Jirang (coll. P. Karthik).

18. *Ingerana borealis* (Annandale, 1912) (n= 5)

VA 135-138, four unsexed adults from Rongalgre, VA 161 – an adult female from Rongalgre (coll. R.S. Naveen).

Ranidae Batsch, 1796

19. *Clinotarsus alticola* (Boulenger, 1882) (n= 4)

VA 95 and VA 106 - two adult females, VA 110 - a juvenile and VA 91 - a subadult from Sasatgre (coll. P. Karthik).

Remarks: Members of the genus *Clinotarsus* Minvart, 1869 show a disjunct pattern of geographic distribution. While *C. curtipes* (Jerdon, 1853) is restricted to the Western Ghats of southwestern peninsular India, the other two congeners *C. alticola* (Boulenger, 1882) and *C. penelope* Grosjean, Bordoloi, Chuaynkern, Chakravarty & Ohler, 2015 occur in the Indochinese region.

20. *Hylarana tytleri* Theobald, 1868 (n= 1)

VA 93 - one unsexed subadult from Lum Jusong (coll. P. Karthik).

21. *Hydrophylax leptoglossa* (Cope, 1868) (n= 2)

VA 100-101 - two adult females from Sasatgre (coll. P. Karthik).

22. *Amolops assamensis* Sengupta, Hussain, Choudhury, Gogoi, Ahmed & Choudhury, 2008 (n= 1)

VA 52 - an unsexed subadult from Jirang,(coll. P. Karthik).

23. *Amolops marmoratus* (Blyth, 1855) (n= 2)

VA 90a-b - two unsexed juveniles from Sasatgre (coll. P. Karthik).

24. *Amolops* sp. (n= 3)

VA 120–122 - three subadult females from Jirang. Their identity could not be determined to species level.

Rhacophoridae Hoffman, 1932

25. *Polypedates himalayensis* (Annandale, 1912) (n= 3)

VA 76, VA 77 and VA 78 - Three adult females, from Dumitdigre (coll. P. Karthik).

26. *Polypedates* cf. *leucomystax* (n= 1)

VA 162, an unsexed adult from Tura (coll. R.S. Naveen).

Remark: The identity of *P. leucomystax* from India still needs finer taxonomic resolution (Frost 2021).

27. *Raorchestes* sp. (n= 9)

VA 51 a&b, VA 105 – respectively, two adult males and an unsexed adult specimen from Mongalgre (coll. P. Karthik), VA 126–128, three unsexed adults from Sakalgre and VA 129 one from Daribokgre, VA 149–150 - two adult males from Sasatgre and Eman Asakgre respectively (coll. R.S. Naveen).

Remarks: Boruah et al (2018) presented point localities for *R. shillongensis* Pillai & Chanda, 1973 from Khasi Hills, lying to nearly 20 km to the east of Mongalgre. The identity of the specimens recorded here requires further study.

28. *Theloderma baibungense* (Jiang, Fei & Huang, 2009) (n= 2)

VA 88, VA 96 – an unsexed juvenile and an adult female from Selbalgre and Raid Nongbri respectively (coll. P. Karthik).

29. *Kurixalus naso* (Annandale, 1912) (n= 2)

VA 134, VA153 unsexed adults from Eman Asakgre and Sasatgre respectively (coll. R.S. Naveen).

Remark: Lalronunga et al. (2021) presented records of *K. yangi* from Mizoram and discussed their distribution records and confusions on the identities of the two species, indicating a possible synonymy of *K. yangi* with *K. naso*.

Reptilia Laurenti, 1768

Sauria Macartney, 1802

Gekkonidae Gray, 1825

30. *Cnemaspis assamensis* Das & Sengupta, 2000 (n= 3)

VR 237, VR 233 and VR 221 - Three adults; one male, one female and an unsexed from Raid Nongbri, respectively (coll. P. Karthik).

31. *Cyrtodactylus* cf. *agarwali* (n= 6)

VR 230–231, two adult males, from Sasatgre; VR 181–183 three adults from Daribokgre; and VR 153- one juvenile from Mongalgre (coll. P. Karthik).

Remark: Purkayasta et al. (2020) recently reported another species, *C. urbanus* Purkayastha, Das, Bohra, Bauer & Agarwal, 2020 from Nongpoh. Additionally, Purkayasta et al. (2021) described two more new species *C. agarwali* and *C. karsticola* from the Garo Hills.

32. *Hemidactylus platyurus* (Schneider, 1797) (n= 7)

VR 198, VR 218a and VR 232 - three adult males and VR 218b - one adult female from Mongalgre, VR 195, VR 200 and VR 216 three adult females from Sasatgre (coll. P. Karthik).

33. *Hemidactylus frenatus* Duméril & Bibron, 1836 (n= 1)

VR 222 - subadult from Meghalaya (no more precise locality) (coll. P. Karthik).

34. *Hemidactylus* sp. (n= 1)

VR 171 - subadult male from Meghalaya (no more precise locality) (coll. P. Karthik).

35. *Gekko gecko* (Linnaeus, 1758) (n= 1)

VR 229 - adult male from Meghalaya (no more precise location) (coll. P. Karthik).

Agamidae Gray, 1827

36. *Calotes* cf. *irawadi* (n= 9)

VR 178 a & b - an unsexed and an adult female from Sasatgre; VR 205, VR 240–245- six unsexed subadult specimens respectively from Meghalaya (no more precise location) (coll. P. Karthik).

Remarks: Zug et al. (2006) described *Calotes irawadi* from Myanmar. The exact identity of our samples from Meghalaya still needs further investigation regarding their potential conspecificity with that newly described taxon.

37. *Calotes maria* Gray, 1845 (n= 2)

VR 166, 173 – two adults respectively from Daribokgre and Sasatgre (coll. P. Karthik).

38. *Calotes emma* Gray, 1845 (n= 3)

VR 247, VR 150, VR 151 - one adult from Dumitdigre, two adults respectively from Meghalaya (no more precise location) (coll. P. Karthik).

39. *Calotes* sp. (n= 2)

VR 206, 251 – respectively, an unsexed subadult and adult male from Dumitdigre (coll. P. Karthik).

Remark: Species is uncertain and needs to be determined.

40. *Cristidorsa planidorsata* (Jerdon, 1870) (n= 4)

VR 185 and VR 169 - two adult males from Meghalaya (no more precise location); VR 184 and VR 188- one adult female each from Daribokgre and Sasatgre, respectively (coll. P. Karthik).

41. *Ptyctolaemus gularis* (Peter, 1864) (n= 8)

VR 238, VR 239, VR 207 - three adult males and, VR 201 - an unsexed juvenile from Meghalaya (no more precise location), VR 167, VR 168, VR 179 and VR 180 - four unsexed adults from Daribokgre (coll. P. Karthik).

Scincidae Gray, 1825

42. *Sphenomorphus indicus* (Gray, 1853) (n= 3)

VR 186, VR 224, VR 249 – three unsexed adults respectively from Daribokgre, Sasatgre, and Dumitdigre (coll. P. Karthik).

43. *Sphenomorphus maculatus* (Blyth, 1853) (n= 7)

VR 164, VR 165, VR 197, VR 234 a&b - five unsexed adults and VR 217 and VR 226 - two subadults from Sasatgre (coll. P. Karthik).

44. *Sphenomorphus* sp. (n= 1)

VR 227 - subadult from Meghalaya (no more precise location) (coll. P. Karthik).

45. *Eutropis multifasciata* (Kuhl, 1820) (n= 1)

VR 169 - juvenile from Nongsangu.

46. *Eutropis* cf. *macularia* (n= 4)

VR 199 - one juvenile, VR198 - one subadult and VR 235 and VR 236 - two adults from Lum Jusong (coll. P. Karthik).

Lacertidae Oppel, 1811

47. *Takydromus khasiensis* Boulenger, 1917 (n= 2)

VR 155, 208 – two unsexed adults respectively from Mongalgre and Nongsangu (coll. P. Karthik).

Serpentes Linnaeus, 1758

Typhlopidae Merrem, 1820

48. *Argyrophis diardii* (Schlegel, 1839) (n= 4)

VR 187, 223 – two adult specimens respectively from Daribokgre and Sasatgre (coll. P. Karthik), VR 255–256 – one adult and subadult respectively from Dangkipara (coll. R.S. Naveen).

49. *Indotyphlops* sp. (n= 1)

An unsexed adult specimen (VA 219) from Meghalaya (no more precise location) (coll. P. Karthik).

Remark: Superficially resembles *I. braminus* (Daudin, 1803) but the precise identity of this specimen requires further study.

Pseudaspididae Cope, 1893

50. *Psammodynastes pulverulentus* (Boie, 1827) (n= 1)

VR 152 - a subadult specimen from Meghalaya (no more precise location) (coll. P. Karthik).

Colubridae Oppel, 1811

51. *Calamaria parvimentata* Duméril, Bibron & Duméril, 1854 (n= 1)

VR 261 – an unsexed adult from Daribokre (coll. R.S. Naveen).

52. *Lycodon zawi* Slowinski, Pawar, Win, Thin, Gyi, Oo & Tun, 2001 (n= 1)

VR 204 – an unsexed adult specimen from Lum Jusong (coll. P. Karthik).

53. *Lycodon* sp. (n= 2)

VR 213, VR 215 – two subadult specimens from Meghalaya (no more precise location) (coll. P. Karthik). Their specific identity needs further study.

54. *Lycodon jara* (Shaw, 1802) (n= 1)

VR 253, an unsexed adult from Thokpara (coll. R.S. Naveen).

55. *Lycodon* cf. *aulicus* (n= 1)

VR 254, an unsexed adult from Thokpara (coll. R.S. Naveen).

56. *Oligodon juglandifer* (Wall, 1909) (n= 1)

VR 214 - unsexed adult road killed specimen from Meghalaya (no more precise location) (coll. P. Karthik).

57. *Oligodon cyclurus* (Cantor, 1839) (n= 1)

VR 254 – an unsexed adult from Thokpara.

58. *Boiga cyanea* (Duméril, Bibron & Duméril, 1854) (n= 1)

VR 228 - a large adult specimen from Nongsangu (coll. P. Karthik).

59. *Boiga gocool* (Gray, 1834) (n= 3)

VR 190–192 – unsexed subadults from Meghalaya (no more precise location) (coll. P. Karthik).

60. *Dendrelaphis proarchos* (Wall, 1909) (n= 1)

VR 210 - adult from Meghalaya (no more precise location) (coll. P. Karthik).

Remark: Vogel & Van Rooijen (2011) revalidated *D. proarchos* from the synonymy of *D. pictus* which has recently been endorsed by Hakim et al. (2020).

61. *Coelognathus radiatus* (Boie, 1827) (n= 1)

VR 189 - subadult from Meghalaya (no more precise location) (coll. P. Karthik).

62. *Elaphe cantoris* (Boulenger, 1894) (n= 1)

VR 211 - an unsexed adult (VR 211) from Meghalaya (no more precise location) (coll. P. Karthik).

Pareidae Romer, 1956

63. *Pareas monticola* (Cantor, 1839) (n= 1)

VR 212 - adult from Meghalaya (no more precise location) (coll. P. Karthik).

Natricidae Bonaparte, 1838

64. *Pseudoxenodon macrops* (Blyth, 1855) (n= 1)

VR 260 – an adult male from Chandigre (coll. R.S. Naveen).

65. *Trachischium monticola* (Cantor, 1839) (n= 3)

VR 163, VR 172, VR 220 - adults from Daribokgre (coll. P. Karthik).

66. *Hebius khasiense* (Boulenger, 1890) (n= 8)

VR 162, VR 175–177 four unsexed adults from Sasatgre, VR 209, VR 225, VR 246 - three unsexed adults from Meghalaya (no more precise precise location) (coll. P. Karthik), VR 257 – an unsexed adult from Sasatgre (coll. R.S. Naveen).

67. *Fowlea piscator* (Schneider, 1799) (n= 3)

VR 156 - adult male road killed specimen from Nongsangu. VA 202–203 - adults from Meghalaya (no more precise location) (coll. P. Karthik).

Remarks: Purkayastha et al. (2018) allocated *Xenochrophis piscator* to the genus *Fowlea* Theobald, 1868.

68. *Smithophis bicolor* (Blyth, 1854) (n= 1)

VR 194 - subadult male from Northeastern Hill University Campus, Shillong (coll. P. Karthik).

Remarks: This specimen was recently described in detail by Chandramouli et al. (2021).

Elapidae Boie, 1827

69. *Sinomicrurus macclellandi* (Reinhardt, 1844) (n= 1)

VR 159 - one adult from Meghalaya (no more precise location) (coll. P. Karthik).

70. *Naja kaouthia* Lesson, 1831 (n= 1)

VR 157 - one juvenile from Meghalaya (no more precise location) (coll. P. Karthik).

71. *Ophiophagus hannah* (Cantor, 1836) (n= 1)

VR 252 - an adult male from Meghalaya (no more precise location) (coll. P. Karthik).

Viperidae Oppel, 1811

72. *Ovophis monticola* (Günther, 1864) (n= 3)

VR 161, VR 193, VR 248 - three adults from Dumitdigre (coll. P. Karthik).

73. *Trimeresurus popeiorum* Smith, 1937 (n= 2)

VR 170, VR 174 - two adults, respectively one male and one female from Daribokgre and Sasatgre (coll. P. Karthik).

74. *Trimeresurus erythrurus* (Cantor, 1839) (n= 2)

VR 158 - subadult from Selbalgre (coll. P. Karthik), VR 259 – a subadult from Dalu (coll. R.S. Naveen).

75. *Trimeresurus* sp. (n= 1)

VR 160 - one subadult, (VR 160) from Meghalaya (no more precise location) (coll. P. Karthik), whose specific identity needs further study.

Discussion

Currently, the collection encompasses a total of 75 species of the herpetofauna, including 29 species of amphibians from 20 genera in seven families and 46 species of reptiles from 31 genera, in 10 families. Reptiles are represented by 17 species of lizards and 29 species of snakes. This collection is expected to grow as the field study continues. The collections from peninsular India at SACON have recently been catalogued (Ganesh et al. 2020) and there still are collections from other regions within India that will be cataloged in future. Herpetofaunal collections in other institutions within India are recently being catalogued (e.g., Ganesh 2010; Ganesh & Asokan 2010; Zacharias & Jose 2020) which would aid in supplementing our knowledge on herpetofaunal species and their distribution.

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SHORT COMMUNICATION

A preliminary assessment of odonate diversity along the river Tirthan, Great Himalayan National Park Conservation Area, India with reference to the impact of climate change

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Abstract: A total of 19 species of odonates, including eight species of Anisoptera (dragonflies) and 11 species of Zygoptera (damselflies), were recorded along the Tirthan River, Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh. Among these species, 17 were reported from the area for the first time. With the addition of these new records the number of odonates known from the GHNPCA is increased to 23 species representing 18 genera and eight families. *Indothemis carnatica, Agriocnemis femina*, and *Argiocnemis rubescens* are reported for the first time from the western Himalayan region. The study found a significant change in the species composition of odonates over a period of 18 years in the area, which may be due to changes in microhabitat conditions associated with climate change.

Keywords: Dragonfly, damselfly, GHNPCA, Himachal Pradesh, new records, western Himalaya.

Globally, 6,256 species in 686 genera of odonates (order Odonata) are known (Paulson & Schorr 2020) and most of them are restricted to the tropics, especially to forests, where the group has the greatest diversity (Kalkman et al. 2008). The Odonata of India is represented by 488 species and 27 subspecies in 154 genera and 18 families (Kalkman et al. 2020). The suborder Zygoptera (Damselflies) comprise 211 species in 59 genera & nine families; Anisozygoptera one species in one genus & one family; and Anisoptera (Dragonflies) 276 species in 94 genera & eight families (Subramanian & Babu 2017).

The odonates are among the most effective bioindicators of environmental health (Kutcher & Bried 2014; Miguel et al. 2017), and can be used to assess water quality (Kutcher & Bried 2014), changes in the habitat structure (Yang et al. 2017), success of wetland restoration (D'Amico et al. 2004), ecological condition of streams (de Oliveira-Junior et al. 2015), and environmental quality (Júnior et al. 2015). Odonate diversity of Himachal Pradesh has been studied by various authors (Kumar 1982, 2000; Uniyal et al. 2000; Babu & Mehta 2009; Babu & Nandy 2010; Babu & Mitra 2011; Subramanian & Babu 2018). Uniyal et al. (2000) reported six species of dragonflies from the Great Himalayan National Park.

The Great Himalayan National Park Conservation Area (GHNPCA) is a World Heritage site designated by UNESCO, situated in Kullu district of Himachal Pradesh and traversed by three tributaries of river Beas—Tirthan, Parvati, and Sainj. The Park extends from the Himalayan foothills to the alpine zone ranging from 1,300m to 6,000m of altitudinal gradient. The present study was

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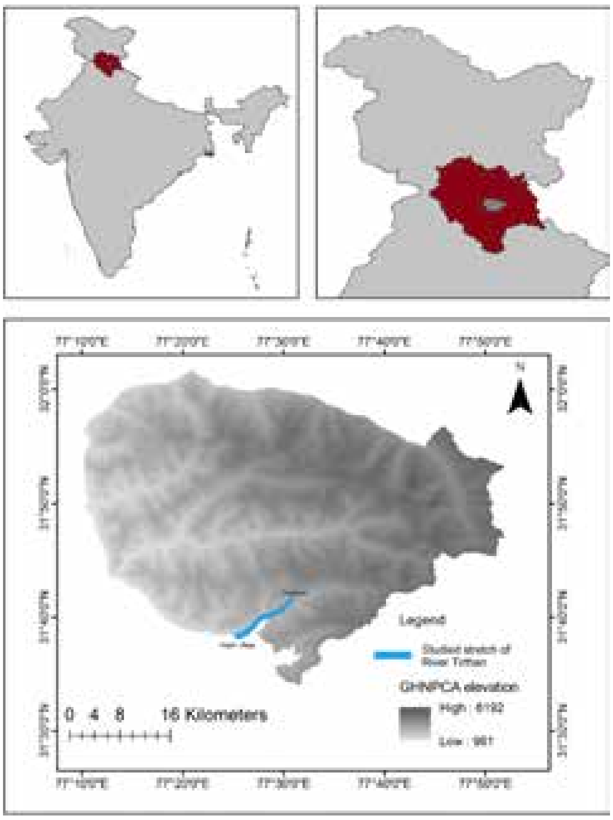

Figure 1. Map represents the studied stretch of Tirthan River, GHNPCA, Himachal Pradesh.

carried out in order to update our understanding of the diversity of odonates in the GHNPCA and to assess the changes of species composition, if any, over the period of 18 years since the previous survey (Uniyal et al. 2000).

Materials and Methods

The work was carried out along a length of about 28km of the river Tirthan (a tributary of Beas River), from Nagini village (31.640 lat. 77.398 long., 1,475m to Chalocha (31.685 lat., 77.513 long., 2,450m) monthly from June to December, 2018. The area lies near the boundary within the GHNPCA (Figure 1) located in the western Himalaya in the state of Himachal Pradesh. It was declared as a national park in 1999 and a world heritage site by UNESCO in 2014. The area comes under the 'Western Himalayan broadleaf forests' ecoregion (UNESCO 2020).

We surveyed odonate diversity following the methods of Giugliano et al. (2012). Adults were surveyed between 0930 h and 0500 h by walking slowly along the edge of the water body three times a month; and with the help of binoculars notes were made of all species observed. Most species were identified without capture. When necessary, a telescopic sweep net was used to catch odonates for identification. Species were identified using published literature (Andrew et al. 2008; Subramaniam 2009; Nair 2011) and web resources (Joshi et al. 2019).

Results and Discussion

A total of 19 species of odonates representing 16 genera were recorded; these comprised eight species of dragonflies (Anisoptera) and 11 species of damselflies (Zygoptera) (Table 1, Image 1–19). Among the dragonflies, the family Libellulidae was represented by six species in four genera, and the families Aeshnidae and Gomphidae by one species each (Figure 2). Among the damselflies, the family Coenagrionidae was represented by five species in four genera, the families Chlorocyphidae and Platycnemididae by two species each, and the families Lestidae and Calopterygidae by only one species each (Figure 2).

Among these odonates, one dragonfly *Indothemis carnatica* Fabricius, 1798 and two damselflies, namely, *Agriocnemis femina* Brauer, 1868 and *Argiocnemis rubescens* Selys, 1877, are reported for the first time from Himachal Pradesh, these being the westernmost records in the Himalaya. Rank abundance tests revealed that Libellulidae was the dominant family in the river followed by Coenagrionidae and Lestidae was the least dominant family (Figure 3).

Uniyal et al. (2000) reported the presence of six species of odonates from the GHNPCA. The present study reports another 17 species from the area which increases the total number of odonate species from the area to 23 species in 18 genera and eight families. The present study failed to register *Anax guttatus*, *Orthetrum japonicum*, *Pantala flavescens*, and *Sympetrum commixtum*, which were recorded from the area by Uniyal et al. (2000). The present work reported *Indothemis carnatica*, *Agriocnemis femina*, and *Argiocnemis rubescens* for the first time from the western Himalayan region, these species having previously been reported from the east within the Himalayan region (Subramanian & Babu 2018), however, *Indothemis carnatica* was previously reported from Andaman & Nicobar Island, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal (Subramanian et al. 2018; Payra et al. 2020) and has been recently recorded from Punjab (Singh et al. 2021).

Compared with Uniyal et al. (2000) that recorded six species, the present study was conducted more systematically along 28 km of the Tirthan River using standardised methods. Grassy, stagnant water, running water, and rocky habitats were preferred by different species (Image 20 and 21). *Orthetrum triangulare* and *Orthetrum taeniolatum* were the most common species found throughout the stretch from 1,475 m elevation

Table 1. List of odonates recorded from Tirthan River, Great Himalayan National Park Conservation Area.

	Family	Scientific name	Elevation range (m)	No. of individuals observed
		Anisoptera		
1	Aeshnidae	*Anax nigrofasciatus* Oguma, 1915	1475–1700	8
2	Gomphidae	*Paragomphus lineatus* (Selys, 1850)	1475–1600	12
3	Libellulidae	*Crocothemis servilia* (Drury, 1773)	1475–1700	18
4		*Indothemis carnatica* (Fabricius, 1798)	1475–2000	26
5		*Orthetrum pruinosum* (Burmeister, 1839)	1475–1700	22
6		*Orthetrum taeniolatum* (Schneider, 1845)	1475–2450	25
7		*Orthetrum triangulare* (Selys, 1878)	1475–2450	38
8		*Palpopleura sexmaculata* (Fabricius, 1787)	1475–1700	4
		Zygoptera		
9	Coenagrionidae	*Agriocnemis femina* (Brauer, 1868)	1475–1600	2
10		*Amphiallagma parvum* (Selys, 1876)	1475–1700	6
11		*Ceriagrion coromandelianum* (Fabricius, 1798)	1475–1700	35
12		*Ischnura forcipata* Morton, 1907	1475–1700	18
13		*Ischnura rubilio* Selys, 1876	1475–1600	2
14	Chlorocyphidae	*Aristocypha quadrimaculata* (Selys, 1853)	1475–2000	2
15		*Libellago lineata* (Burmeister, 1839)	1475–1700	2
16	Calopterygidae	*Neurobasis chinensis* (Linnaeus, 1758)	1475	4
17	Lestidae	*Indolestes cyaneus* (Selys,1862)	1495	1
18	Platycnemididae	*Calicnemia eximia* (Selys, 1863)	1475–1600	32
19		*Copera vittata* (Selys, 1863)	1475–1700	6

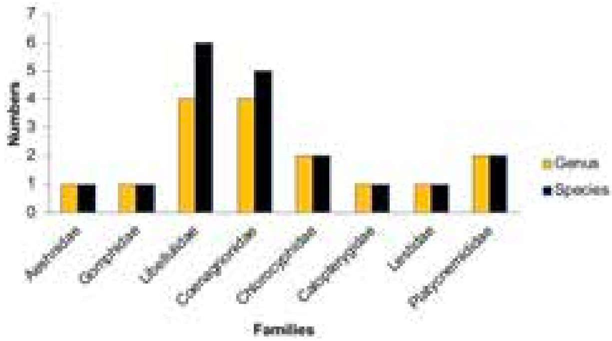

Figure 2. Comparative numbers of genera and species of odonates under eight families recorded from Tirthan River, Great Himalayan National Park Conservation Area.

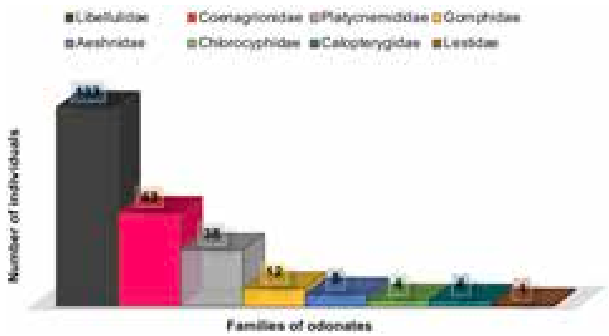

Figure 3. Rank abundance of odonate families along the Tirthan River of Great Himalayan National Park Conservation Area.

up to 2,450 m. There was higher species richness at lower elevations. *Calicnemia eximia, Ischnura rubilio*, and *Agriocnemis femina* preferred grassy habitat near the banks of stagnant ponds at a lower elevation range from 1,475–1,600 m. *Anax nigrofasciatus, Crocothemis servilia, Orthetrum pruinosum*, *Orthetrum triangulae, Amphiallagma parvum, Ceriagrion coromandelianum, Ischnura forcipate, Palpopleura sexmaculata, Libellago lineata*, and *Copera vittata* were found at stagnant or slow running grassy water channels from 1,475–1,700 m. *Indolestes cyaneus* was very rare in the region and was found away from the river under forest canopy cover at an elevation of 1,495 m. *Aristocypha quadrimaculata* and *Indothemis carnatica* preferred rocky water channels from 1,475–2,000 m. However, *Paragomphus lineatus* was found in agricultural areas near the river from 1,475–1,600 m and *Neurobasis chinensis* was collected from fast running water at 1,475 m.

The Himalayan ecosystem is a sensitive and fragile ecosystem with rich biodiversity that provides major ecosystem services (Kumar et al. 2019). As climate change phenomena become a threat to this ecosystem, monitoring climatic indicator species helps us understand the change of ecosystem functions caused by climate change. Odonates have for some time been used successfully as model organisms to study climate change (Hassall & Thompson 2008; Parr 2010; Jaeschke et al. 2013; Bush et al. 2014; Hassall 2015; Termaat et al. 2019). Studies by Flenner & Sahlén (2008) has shown that species composition and abundance may change over as short a time span as 10 years due to environmental changes as dragonflies react rapidly to climate change. The present study found significant changes in the odonate species composition relative to that found by Uniyal et al. (2000), as only two species were re-recorded with the addition of 17 new species to the region. These changes in species

Images 1–19: 1—*Anax nigrofasciatus* | 2—*Paragomphus lineatus* | 3—*Crocothemis servilia* | 4—*Indothemis carnatica* | 5—*Orthetrum pruinosum* | 6—*Orthetrum taeniolatum* | 7—*Orthetrum triangulare* | 8—*Palpopleura sexmaculata* | 9—*Agriocnemis femina* | 10—*Amphiallagma parvum* | 11—*Ceriagrion coromandelianum* | 12—*Ischnura forcipata* | 13—*Ischnura rubilio* | 14—*Aristocypha quadrimaculata* | 15—*Libellago lineata* | 16—*Neurobasis chinensis* | 17—*Indolestes cyaneus* | 18—*Calicnemia eximia* | 19—*Copera vittata.* © Amar Paul Singh

Image 20. *Anax nigrofasciatus* in stagnant and grassy water habitat.

Image 21. Rocky, grassy, and fast running water habitat.

composition may have occurred because of changes in microhabitat factors due to climate changes in the Himalayan region or due to the sampling efforts in the region.

Dragonflies have been shown to be useful for ecosystem monitoring and conservation, and recently an increased effort is being made to make information on dragonflies available to both scientists and policymakers (Kalkman et al. 2008). So, it is indispensable to document the status of diversity and ecology of odonates as well as other entomofauna from the Great Himalayan National Park Conservation Area to understand changing ecological conditions in the context of climate change.

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SHORT COMMUNICATION

A checklist of orthopteran fauna (Insecta: Orthoptera) with some new records in the cold arid region of Ladakh, India

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Abstract: The study is mainly focused on the Orthopteran fauna of Ladakh. In the current field survey and literature survey, 29 species, 24 genera, 11 subfamilies, and five families belonging to four super families of Tettigonioidea (Krauss, 1902), Acridoidea (MacLeay, 1821), Eumastacoidea (Burr, 1899), and Pyrgomorphoidea (Burnner von Wattenwyl, 1847) are reported. The subfamily Gomphocerinae, and the following species *Leva indica, Stenohippus mundus, Calliptamus italicus, Phaneroptera gracilis, Conocephalus longipennis,* and *C. maculatus* are recorded for the first time from the region.

Keywords: Checklist, Orthoptera, new record, Ladakh.

The order Orthoptera comprises katydids, grasshoppers, locusts, and crickets. It is one of the largest insect orders having more than 28,000 species around the globe and over 1,200 species reported from India (Cigliano et al. 2020). Orthopteran fauna is widely distributed in all the ecological zones of the world but their distribution is dependent upon the vegetation like grasslands, forests, and agricultural fields. Some environmental factors like temperature, rainfall, and soil conditions also determine the distribution of grasshoppers. Orthopteran fauna play a significant role in the grassland ecosystem, they being important as primary consumers (herbivores) and also as contributors of diet to many other animals (reptiles, birds, amphibians, and mammals including man). Besides, Orthoptera plays a major role in the soil ecosystem by creating plant litter for soil, simultaneously plant growth and nutrients and cycling elements (Van Hook 1971).

Based on the size of the antennae, the order is divided into two suborders, Caelifera (short-horned) and Ensifera (long-horned). The suborder Ensifera is divided into seven superfamilies—Grylloidea, Gryllotalpoidea, Hagloidea, Stenopalmatoidea, Tettigonoidea, Rhaphidophoroidea, and Schazodactyloidea; whereas the suborder Caelifera into eight super families—Acridoidea, Eumastacoidea, Pneumoroidea, Proscopioidea, Pyrgomorphoidea, Tanoceroidea, Trigonopterygoidea, and Tetrigoidea. In Caelifera the superfamily Acridoidea shows the highest diversity with 11 families out of which the family Acrididae and Pyrgomorphidae are extensively distributed in India. Family Acrididae is divided into 27 subfamilies containing more than 800 genera which are also known as the most dominant and most diversified family in the order Orthoptera (Cigliano et al. 2020). A checklist of Indian Orthoptera including 1,033 species under 398 genera and 21 families was reported by Shishodia et al. (2010).

The remarkable taxonomic work on the Indian

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Acrididae was done by (Kirby 1914) in the book 'Fauna of British India' and divided the family into eight subfamilies. The checklist of Indian Acridoidea was firstly given by Tandon (1976). Bhomik (1984), Hazra et al. (1993), Tandon & Shishodia (1995), Reshi et al. (2008), Sharma & Mandal (2008), Sharma (2011), Rafi & Usmani (2013), Rafi et al. (2014), and Kumar & Usmani (2015) have contributed to the Indian Acrididae.

The present work was carried out to prepare a checklist of Orthoptera from the Ladakh region. The comprehensive study on Indian orthopteran fauna was published by Kirby (1914) and Chopard (1969). So, far there is no consolidated work on the orthopteran fauna of Ladakh is available; only some scattered information regarding orthopteran fauna of Ladakh have been published by a few researchers; Locust swarming at the two regions of Ladakh and major destruction caused by migratory locust *Locusta migratoria migratoria* in 2006 was studied by Ramamurthy & Kumar (2009). The checklist of Jammu & Kashmir (including Ladakh) has been prepared with 15 species from Ladakh by (Gupta & Chandra 2018). Kumar et al. (2018) also reported 10 species of Orthoptera from Ladakh with some new records.

Figure 1. Map of Ladakh region.

Materials and Methods

Sampling site

Ladakh: the region is located in the northern part of the country between 30.17N latitude and 77.58E longitude having a total area 59,146km^2. The area is bounded in the north and east by China and in north-west by central Asia and Afghanistan (Figure 1). Geographically, Ladakh is the cradle inside the lofty Himalayan mountain ranges, which stretch south-east to north-east. A major part of it is inaccessible due to its high altitude which ranges from 2438 to 5486 meters above sea level. Most of the areas are infertile due to low rainfall, but those areas that are good in vegetation are where human habitation and water sources are available. Human settlement areas are richly vegetated due to irrigation. The area is commonly called 'cold desert' because it experiences both arctic and desert climate.

Sample collection

Adult specimens of both the sexes were collected from different areas comprising agricultural land, forest land, grassland, and rocky mountain areas by using the insect sweeping net and by handpicking method. The collections were made during the year 2018–2019 in the months of July, August, and September from various places of Ladakh region.

An extensive literature survey was done to add the entire reported species from the region. All published information was undertaken by various sources which served as the basis for this critical analysis.

Specimen preparation

The specimens were killed by using ethyl acetate in an insect killing jar. After killing, the specimens were pinned and stretched with the help of the stretching board, the entomological pins used for specimen stretching and pinning were 0.3–0.4 mm; the pins were inserted on the dorsum of pronotum slightly right to the median carina. The wings were stretched along with the right angle axis of the body, the hind legs slightly stretched backward along the axis of the body. The other body parts antennae, legs, and wings had to be supported with extra pins so that it could dry in the desired position. The specimens were removed from the stretching board after they were fully dried and stored in the insect collection box. Naphthalene balls were put in the corners of the collection box in order to prevent specimen deterioration.

Species Identification

After the collection, the adult specimens were studied under the binocular stereo zoom microscope and sorted out family-wise, sub-family-wise, genera-wise, and species-wise. The specimen identification was carried out with the help of key and description given by Bei-Bienko & Mischienko (1964) and other keys available in the literature and on the website of the 'Orthopteran Species File'.

Results and Discussion

During the recent survey, a total number of 29 species and 24 genera belonging to 11 subfamilies, and five families of Orthoptera were found to be represented from the Ladakh region. In the previous report of Jammu & Kashmir, a total number of 15 species and 14 genera were recorded from the Ladakh region (Gupta & Chandra 2018). Kumar et al. (2018) reported 10 species and six genera with two new records from the region. In the current study six species—*Leva indica, Stenohippus mundus, Calliptamus italicus, Phaneroptera gracilis, Conocephalus longipennis, and Conocephalus* sp.—are for the first time recorded from the region and the species *Gyabus fusiformis* rediscovered from the region (Image 1). A maximum number of species reported from the region belong to the subfamily Oedipodinae (8 genera, 12 species) followed by the subfamily Catantopinae and Gomphomastacinae (3 genera, 3 species), Calliptaminae and Gomphocerinae (2 genera, 2 species), Conocephalinae (1 genus, 2 species) and Conophyminae, Melanopolinae, Phenoropterinae, Pyrgomorphinae, and Tettigoniinae (1 genus, 1 species each) shown in Figure 2.

Order Orthoptera Latreille 1793
Suborder Caelifera Ander 1939
Superfamily Acridoidea Macleay, 1821
Family Acrididae Macleay, 1821
Subfamily Calliptaminae Jacobson, 1905
Genus *Acorypha* Krauss, 1877

1. *Acorypha glaucopsis* (Walker, 1870)

Caloptenus glaucopsis walker, F, 1870. *Cata. Of the Specimen of Der. Salt. In Coll. Of British Museum* 4:702.

Caloptenopsis glaucopsis Bolivar, I. 1917. *Rev.real. Acad.Cienc.Exat. Fisic.Natur.*16:409–410.

Acorypha glaucopsis Soomro, S. & M.S. Wagan. 2005. Pakistan J. Zool. 37(3):230.

Acorypha glaucopsis Hemp, C. 2009. *Journal of Orthopteran research* 18(2):197.

Acorypha glaucopsis. Nayeem & Usmani. 2012. *Mun. Ento. & Zoo.* 7(1):409.

Acorypha glaucopsis Nazir, Mahmood, Ashfaq & Rahim, 2014. *JoTT* 6(3):5544–5552.

Distribution: Somalia, Nigeria, Sudan, Iran, Yemen, Tanzania, Pakistan, and

India (Madhya Pradesh, Karnataka, western Himalaya, Jammu & Kashmir, Ladakh (Kargil), Tamil Nadu, Rajasthan, & Himachal Pradesh).

Genus *Calliptamus* Serville, 183 l.

2. *Calliptamus italicus* (Linnaeus, 1758)

Gryllus (*Locusta*) *italicus* Linnaeus, 1758. *Syst. Natur. Per Renga tria nature* 1:432.

Gryllus italicus Thunberg, 1815. *Mem. Acad. Imp. Sci.Sc. Peterburg* 5:227 *Calliptamus italicus*. Lucas, P.H. 1851. *Ann. Soc. ent. Fr.* 9 2:363.

Caloptenus italicus Fischer, 1853. *Ortho. Euro.*377.

Caloptenus italicus Eversmann, 1859. *Bull. Soc. Imp. Natur. Moscau* 32(1): 138.

Calliptamus italicus Uvarov, 1922. *Trans. R. Entomol. Soc. London*. 48:136.

Calliptamus italicus Nagy, 2000. *Duna. Dolg. Term. Tud. Sorozatt* 10:155.

Calliptamus italicus italicus. Galvagni. 2010. *Atti Acc. Rov. Agiati.* 8 10(B):177.

Distribution: South-western Europe, Switzerland, Spain, France, Germany, Italy, Greece, Middle Europe, Africa, Turkey, Iran, Kazakhstan, Afghanistan, India (Jammu & Kashmir and Ladakh), and China.

Subfamily Catantopinae Brunner and Wattenwyl, 1893
Genus *Diabolocatantops* Jago, 198

3. *Diabolocatantops innotabilis* (Walker, 1870)

Acridium innotabile Walker, F. 1870. *Catalogue of the spec. of Dermap. In Collection of the British Museum* 4:629.

Acridium innotabile Finot, 1907. *Annal Society Ent. Fr.* 76:336

Catantops innotabile Uvarov, 1929. *Revue Suisse de Zool.* 36:561.

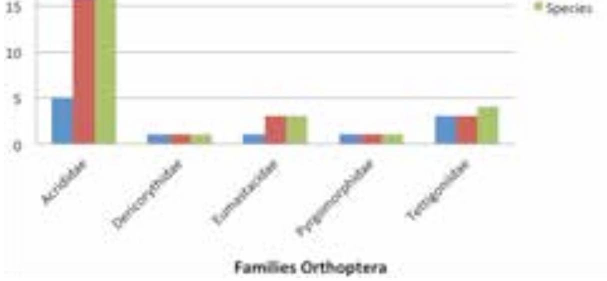

Figure 2. Showing the number of subfamilies, genera, and species of Orthoptera from Ladakh.

Image 1. Some collected specimens: A—*Stenohippus mundus* | B—*Acorypha glaucopsis* | C—*Leva indica* | D—*Locusta migratoria migratoria* | E—*Conocephalus longipennis* | F—*Oedipoda miniata miniate* | G—*Oedipoda himalayana* | H—*Gyabus fusiformis* | I—*Sphingonotus savignyi.* © Mohd Ali.

Diabolocatantops innotabilis. Jago. 1984. Trans. Amer. Entomol. Soc. 110(3):371.

Diabolocatantops innotabilis Shishodia, Chandra and Gupta, 2010. *Rec. Zool. Sur. India Misc. Pub.*314:39

Diabolocatantops innotabilis Kumar and Usmani, 2014. *J. of Entomol. And Zool. Stud.* 2(3):138

Distribution: Pakistan, India (Assam, Bihar, Jammu & Kashmir, Ladakh: Leh (Nyoma), Maldives, Himachal Pradesh, Goa, Tamil Nadu, Nepal, Maharashtra. Uttarakhand, Uttar Pradesh and West Bengal.), Sri Lanka, Nepal and Thailand.

Genus *Paraconophyma* Uvarov, 1921

4. *Paraconophyma scabra* (Walker, 1870)

Caloptenus scaber Walker, F. 1870.*Catalogue of the Specimens of Dermap. Salta.in the Collection of Brt.Mus.* 4:707.

Mesambria scabra Kirby, W.F., 1910. *A Synonymic Cat. of Orthop.* 3(2):440. *Paraconophyma scabra* Uvarov, 1921. *Ann. Mag. Nat. Hist.* 97:501.

Paraconophyma scabra Bhomik, 1986. *Zool. Surv. of India, Tech. Monogr.*14:145.

Paraconophyma scabra Shishodia & Tandon. 2004. *Fauna of Manipur - Part 2*.131.

Distribution: India (Bihar, Delhi, Himachal Pradesh, Jammu & Kashmir, Ladakh: Leh (Nyoma Taklung) and West Bengal).

Genus *Xenocatantops* Dirsh, 1953

5. *Xenocatantops humilis humilis* (Serville, 1838)

Acridium humile Serville, 1838. *Histoire naturelle des insectes. Orthopteres*. 662.

Catantops humilis Karny, 1915.*Supplementa Entomologica.* 4:88

Catantops humilis. Uvarov. 1929. *Revue Suisse de Zool.* 36:561.

Xenocatantops hum ilis humilis Dirsh and Uvarov, 1953. *Tijdschr. v. Entomologie* 96:237

Xenocatantops humilis. Ingrisch. 1990. *Spixiana (Munich)*. 13:175.

Xenocatantops humilis Cao & Yin, 2007. *Acta Zootaxonomica Sin* 32(3):523

Xenocatantops humilis humilis Shishidia, Chandra and Gupta, 2010. *Rec. Zool. Surv. India, Misc. Pub., Occas. Paper* 314:37

Xenocatantops humilis. Tan, M.K. & Kamaruddin. 2016. *Zootaxa*. 4111(1):26.

Distribution: India (Assam, Bihar, Himachal Pradesh, Uttarakhand, Jammu & Kashmir, Ladakh: Leh (Nyoma), Mizoram, Sikkim, Tamil Nadu and West Bengal) Nepal, Bangladesh, Myanmar, Thailand., Malaysia and Singapore.

Subfamily Gomphocerinae Fieber, 1853

Genus *Leva* Bolivar, 1909

6. *Leva indica* (Bolivar, 1902)

Gymnobothrus indicus Bolivar, 1902. *Ann.So. ent. Fr.* 70:596.

Leva indica Bolivar, 1902. *Bol. R. soc.Esp. Hist. Nat.* 9:292.

Leva indica Uvarov, 1929. *Revue Suisse de Zool*. 36:540.

Leva indica. Shishodia & Tandon. 2000. *Fauna of Tripura - Part 2*.217.

Leva indica Nayeem and Usmani, 2012. *Munis Ento. Zoo.*7(1):410.

Distribution: India **(**Bihar, Manipur, Ladakh: Kargil, Tamil Nadu and Rajasthan) and Sri Lanka.

Genus *Stenohippus* Uvarov, 1926

7. *Stenohippus mundus* (Walker, 1871)

Stenobothrus mundus Walker, F., 1871. *Catalogue of the Spec. of Derm. Salta.*79.

Dociostaurus mundus Kirby, 1914. *Fauna of Brit. India, Include. Ceylon and Burma. Orthoptera (Acrididae)* 117, 119.

Stenohippus mundus Johnston, 1956. *Annoat. Cata. of African Grasshoppers* 689.

Leva (Stenohippus) mundus Jago, 1971. *Proc. Acad. Nat. Sci. Philad.* 123:223.

Leva mundus Bhowmik, 1990. *Rec. Zool. Survey of India*. 87(1-4):89-94.

Stenohippus mundus. Hodjat. 2015. *J. Entomol. Res. Soc.* 17(1):98.

Distribution: West tropical Africa, Burkina, Nigeria, Palestine, Iran, and India (Jammu and Kashmir, Ladakh: Kargil, Maharashtra, Mumbai and Rajasthan).

Subfamily Melanopolinae Scudder, 1897

Genus *Dicranophyma* Uvarov, 1921

8. *Dicranophyma babaulti* Uvarov, 1925

Dicranophyma babaulti. Uvarov. 1925. *Mission Guy Babault dans*. 1914. 1925:31, 33.

Dicranophyma babaulti Mani, M.S. 1968. *Eco. And Bio. Of High Altitude Insects* 212

Dicranophyma babaulti Shishodia, Chandra and Gupta, 2010. *Rec. Zool. Sur. India, Misc. Publication, Occas. paper* 314:79

Distribution: India (Jammu & Kashmir, Ladakh: Kargil (Saliskote)).

Subfamily: Oedipodinae MacLeay, 1871

Genus *Ailopus* Fieber, 1853

9. *Ailopus simulatrix simulatrix* (Walker, 1870)

Epacromia simulatrix Walker, F., 1870. *Cata. of the Spec. of Dermap. Salta. In the collection of the British Museum* 4:773.

Acrotylus simulatrix Kirby, 1910. *A Synonymic Catalogue of Orthoptera* 3(2):267.

Aiolopus simulatrix. Ingrisch. 1983. *Nachrichtenbl. Bayer. Entom*. 32(3):93.

Aiolopus simulatrix. Ingrisch. 1999. *Esperiana*. 7:361.

Aiolopus simulatrix simulatrix. Usmani. 2008. *Zootaxa.* 1946:27.

Aiolopus simulatrix. Usmani. 2008. *Insecta Mundi*. 0041:10.

Aiolopus simulatrix simulatrix. Prabakar, Prabakaran & Chezhian. 2015. *Biolife*. 3(1):348.

Distribution: Nigeria, Libya, Egypt, Turkey, Saudi Arabia, Yemen, Iran, Pakistan and India (Ladakh: Kargil (Saliskote), Maharashtra and Tamil Nadu).

Genus *Bryodema* Fieber, 1853

10. *Bryodema luctuosum inda* Saussure, 1884

Bryodema inda Saussure, 1884. *Mem. Soc. Phys. Hist. Nat. Geneve.* 28(9):181

Bryodema india Kirby, W.F. 1914. *Fauna of British India, including Ceylon and Burma. Orthoptera (Acrididae)* 151

Bryodema luctosum inda Bey-Bienko, 1930. *Ann. Mus. ZoolAcad. Imp. Sciences St. Petersburg* 31(1):116.

Bryodema luctuosum indum. Zhang, D.-C., Wenqiang Wang & X. C. Yin. 2006. *Entomol. News*. 117(1):17.

Bryodema luctuosum indum Shishodia & Gupta. 2009. *JoTT*. 1(11):569-572.

Distribution: India (Himachal Pradesh, Jammu & Kashmir, Ladakh: Leh (Khardong La)) and China.

Genus *Gastrimargus* Saussur, 1884

11. *Gastrimargus marmoratus* (Thunberg, 1815)

Gryllus marmoratus Thunberg, 1815. *Mem. Acad. Imp. Science St. Peterburg* 5:232.

Oedaleus (Gastrimargus)marmarotus Krauss, 1890. *Zool. Jahr. Abt. Syst. Gergr. Und Biol. Der Tiere.* 5(4):659.

Oedaleus marmarotud Schulthess, 1898. *Ann. Mus, Civ. Stor. Nat. Genova* 39:187.

Gastrimargus marmoratus. Kirby, W.F. 1902. *Trans. Entomol. Soc. Londo*. 1902:71.

Gastrimargus marmoratus Willemse, C. 1930. *Tijdschr. v. Entomo.* 73:63.

Gastrimargus marmoratus Mahmood, K. Samira, Salmah & Idris, 2008. *Pakistan J. Zool.*40(5):375.

Distribution: South Africa, India (Andhra Pradesh, Assam, Bihar, Sikkim, Jammu & Kashmir, Ladakh (Nyoma), Uttarakhand, Uttar Pradesh and West Bengal) China, Myanmar, Malaysia, and Korea.

Genus *Locusta* Linnaeus, 1758

12. *Locusta migratoria migratoria* (Linnaeus, 1758)

Gryllus (Locusta) migratorius Linnaeus, 1758. *Syst. Nat. pr Regna tria nature* 1:432.

Gryllus migratorius Linnaeus, 1761. *Fauna Sueciae sistens Animalia Sueciae* 238.

Acrudium migratorium Lamarck, 1835. *Hist. nat. Anim. Sans Vert.* 4:444.

Oedipoda migratoria Selys Longchamps, 1850. *Bull. Acad. Sci. Bruxelles* 16(2):626–628.

Pachytylus migratoria Eversmann, 1859. *Bull. Soc. imp. nat. Moscuau* 32(1):139.

Pachytylus migratoria Dtein, J.P.E.F., 1878. *Dtsch. Entomol.Z.*22:233-236.

Pachytylus migratoria Schulthess, 1898. *Ann. Mus. Civ. Stor. Nat. Genova* 39:188.

Locusta migratoria Chopard, 1922. *Faune de France* 3:134, 161.

Locusta migratoria migratoria. Cejchan. 1963. *Beitrage zur Entomologie.* 13(7-8):781.

Locusta migratoria migratoria. Lemonnier-Darcemont, Puskás & Darcemont. 2015. Articulata 30:63–80.

Distribution: India (Jammu and Kashmir, Himachal Pradesh, Ladakh: Kargil, Leh, Rajasthan and Uttar Pradesh) and All over the World.

Genus *Oedaleus* Fieber, 1853

13. *Oedaleus abruptus* (Thunberg, 1815)

Gryllus abruptus Thunberg, 1815. *Mem. Acad. Imp. Sci. St. Peterburg* 5:233.

Oedalueus abruptus Saussure, 1884. *Mem. Soc. Phys. Hist. Nat. Geneve* 28(9):110, 117.

Oedaleus abruptus Bolivar, I., 1917. *Rev. Real Acad. Cienc. Exact., Fisic. Natur,* 16:385.

Oedaleus abruptus Chang, K.S.F., 1939. *Bull. Zool. Surv. India* 6(1):20, 21.

Oedaleus abruptus Bhowmik & Halder, 1984. *Bull. Zool. Surv.India* 6(1–3):48.

Oedaleus abruptus Lian, Y Hu & Y Qiao. 2000. *Entomotaxonomia*. 22(3):171–174.

Oedaleus abruptus. Ingrisch. 2001. *Senckenbergiana Biologica*. 81:156.

Oedaleus abruptus Nayeem & Usmani. 2012. *Munis Entomology & Zoology* 7(1):408.

Distribution: Pakistan, India (Bihar, Delhi, Goa, Haryana, Jammu and Kashmir, and Ladakh: Indus River bank, Rajasthan, Manipur, Uttarakhand, Sikkim, Tripura, Tamil Nadu and West Bengal) Nepal, Thailand and Vietnam.

Genus *Oedipoda* Latreille, 1829

14. *Oedipoda himalayana* Uvarov, 1925

Oedipoda himalayana Uvarov, 1925. *Mission Guy babaul dans, Acrididae* 1925:22.

Oedipoda himalayana Bhomik, 1985. *Rec. Zool. Surv. India, Mis. Pub., Occas. Paper* 78:37.

Oedipoda himalayana Shishodia & Gupta. 2009. *JoTT* 1(11):569–572.

Oedipoda himalayana. Azim, Reshi & Rather. 2010. Halteres 1(2):8.

Distribution: India (Jammu & Kashmir, Ladakh: Kargil, Himachal Pradesh and Uttarakhand) and Tibet.

15. *Oedipoda miniata miniata* (Pallas, 1771)

Gryllus miniatus Pallas, 1771. *Reise durch Verschiedene Provinzen des Russ. Reiches* 1:467.

Oedipoda miniata. Targioni-Tozzetti. 1891. *Animali ed insetti del tobacco in erba e del tabacco secco.* 152.

Oedipoda miniata Ebner, 1908. *Verh. Der Zoologisch Botanischen Gesellsch. Wein* 58:337.

Oedipoda miniata miniata Ebner, 1910. *Zool. Jahr. Abt. Syst. Geogr. Und Biol. Der Tiere* 1910: 401–414.

Oedipoda miniata Werner, 1938. *S. B. Akad. Wiss. Wien, Math. Kl.* 147:130.

Oedipoda miniata Johnston, H.B., 1956. *Annoated catalogue of African grasshoppers* 518.

Oedipoda miniata miniata Muraj, Dino & Alimehilli, 1970. *Bull. Univ. Shtet. Tiranes, Ser. Shken. Nat.*24(3):139, 145.

Oedipoda miniata miniata Massa, Fontana, Buzzetti, Kleukers & Ode 2012. *Faunal d italia.orthoptera* 48:434.

Oedipoda miniata miniata Defaut & Morichon, 2015. *Faune de france* 97(1a,b):491.

Distribution: Europe, Libya, Turkey, Palestine, Russia, Iran, Kazakhstan, Pakistan and India (Jammu & Kashmir, Ladakh: Kargil).

Genus *Sphingonotus* Fieber, 1852

16. *Sphingonotus (Sphingonotus) eurasius eurasius* Mischenko, 1937

Sphingonotus eurasius eurasius Mistshenko, 1937. *Eos* 12(3):193.

Sphingonotus eurasius Johnston, H.B., 1956. *Ann. Cata. of African Grasshoppers* 447.

Sphingonotus azurescens Harz, 1975.*Ser. Entomol.* 11:525,528.

Sphingonotus eurasius Badih & F. Pascaul, 1998. *Nouvelle Revue Ent.* 15(2):134.

Sphingonotus eurasius Massa, 2009. *Jour. Orth. Res.* 18(1):84.

Sphingonotus (Sphingonotus) eurasius eurasius Benediktov, 2009. *Trudy Russk. Entomol. Obshch* 80(1):24.

Sphingonotus eurasisus eurasius. Garai. 2010. *Esperiana.* 15:408. *Sphingonotus* (*Sphingonotus*) *eurasius eurasius*. Benediktov. 2011. *Matériaux Orthopteriques et Entomocénotiques.* 16:7.

Sphingonotus (*Sphingonotus*) *eurasius eurasius* Dey, L.S. Saboori, Hodjat, Tork, Pahlow & Husemann, 2018. *Zootaxa* 4379(2):157.

Distribution: Morocco, Libya, Turkey, Palestine, Syria, Caucasus, Iran, Kazakhstan, India (Himachal Pradesh and Ladakh: Kargil (Hugnis)).

17. *Sphingonotus (Sphingonotus) rubescens fallax* Mishchenko, 1937

Sphingonotus fallax. Mistshenko. 1937(1936). *Eos* 12(3–4):153.

Sphingonotus rubescens fallax. Bey-Bienko & Mistshenko. 1951. *Locusts and Grasshoppers of the U.S.S.R. and Adjacent Countries.* 2:620(269).

Sphingonotus rubescens fallax. Bhowmik. 1985. *Rec. Zool. Surv. India, Misc. Pub., Occas. Paper*. 78:41.

Sphingonotus (*Sphingonotus*) *rubescens fallax*. Shishodia, K. Chandra & S.K. Gupta. 2010. *Rec. Zool. Surv. India, Misc. Pub., Occas. Paper.* 314:101.

Distribution: Europe, Africa, Afghanistan and India (Jammu & Kashmir and Ladakh: Kargil, Leh).

18. Sphingonotus (Sphingonotus) rubescens rubescens. (Walker, 1870)

Oedipoda rubesens Walker, F., 1870. *Zoologist* 25(28):2301.

Sphingonotus rubescens Kirby, W.F., 1910. *A Synonymic Catalogue of Orthoptera* 3(2):274.

Sphingonotus rubescens Kirby, W,F., 1914. *Fauna of British India, including Ceylon and Burma. Orthoptera (Acrdidae)* 155.

Sphingonotus rubescens rubescens Mistshenko, 1937. *Eos* 12(3-4):169.

Sphingonotus (*Sphingonotus*) *rubescens rubescens* Dey, L.S., Saboori, Hodjat, Tork, Pahlow & Husemann, 2018. *Zootaxa* 4379(2):167.

Distribution: Spain, Europe, Africa, Libya, Egypt, Turkey, Yemen, Palestine, Iran, Kazakhstan, Afghanistan and India (Jammu & Kashmir and Ladakh: Kargil, Leh).

19. *Sphingonotus savignyi* (Saussure, 1884)

Sphingonotus savignyi Saussure, 1884. *Mem. Soc. Phys. Hist. Nat. Geneve* 28(9):198.

Sphingonotus Savignyi Krauss, 1890. *Verh. der Zool. Bota. Gesellsch. Wien.* 28(9):198.

Sphingonotus savignyi Dirsh, 1965. *The Afr. Gener. Of Acridoidea* 470.

Sphingonotus savignyi savignyi Massa, 2009. *Jour. Orth. Res.* 18(1):470.

Sphingonotus(Sphingonotus) savignyi savignyi dey, L.S., Saboori, Hodjat, Tork, Pahlow & Husemann. 2018. *Zootaxa* 4379(2):170.

Distribution: North Africa, Russia, Central Asia, Afghanistan, Pakistan and India (Jammu & Kashmir, Ladakh: Kargil, Leh, and Himachal Pradesh).

Genus *Trilophidia* Stal, 1873

20. *Trilophidia annulata* (Thunberg, 1815).

Gryllus annulatus Thunberg, 1815, *Mem. Acad. Imp. Sci. St. Peterburg* 5:234.

Trilophidia annulata Bolivar, I., 1902. *Ann. Soc. Ent. Fr.*70:604.

Trilophidia annulata Hollis, 1965. *Trans. R. Entomol. Soc. London* 117:251.

Trilophidia annulata Kumar and Usmani, 2016. *Munis Entomology & zoology* 11(1): 83.

Distribution: Iran, Pakistan, India (Bihar, Jammu and Kashmir, Ladakh: Leh, Tamil Nadu, Maharashtra, Goa, Gujarat, Rajasthan, Orissa, Uttar Pradesh and West Bengal) Sri Lanka, Nepal, China, Thailand, Malaysia, Singapore, Korea and Japan.

Family Dericorythidae Jacobson & Bianchi, 1905

Subfamily Conophyminae Mistshenko, 1952.

Genus *Conophyma* Zubovski, 1898.

21. *Conophyma kashmiricum* Mistshenko, 1950

Conophyma kashmiricum Mistshenko, 1950. *C.R. Academic Science, URSS* 72:213.

Conophyma kashmiricum Bey Bienko and Mistschenko, 1951. *Locusta and Grasshoppers of the USSR and Adjacent countries* 1:190(199).

Conophyma kashmiricum Balderson and Yin, 1991. *Ento. Gaz.* 42(3):195.

Distribution: India **(**Jammu & Kashmir and Ladakh (Kargil – Matayen)).

Superfamily Eumastacoidea Burr, 1899

Family Eumastacidae Burr, 1899

Subfamily Gomphomastacinae Burr, 1899

Genus *Gomphomastax* Brunner Wattenwyl, 1898

22. *Gomphomastax kashmirica* Balderson & Yin, 1991

Gomphomastax kashmirica Balderson & Yin, 1991. *Ento. Gazette.* 42(3):191.

Gomphomastax kashmirica Usmani, Reshi & Azim, 2008. *Insecta Mundi* 33:2

Distribution: India (Jammu & Kashmir, Ladakh (Tso-Morari)).

Genus *Phytomastax* Bey Bienko, 1949

23. *Phytomastax bolivari* (Uvarov, 1936)

Gomphomastax bolivari Uvarov, 1936.*Opuscula Entomologica* 1:18.

Phytomastax bolivari Bey Bienko & Mistshenko, 1951. *Locusta and Grasshoppers of the USSR and Adjacent Countries* 1:122(128).

Gomphomastax bolivari Mani. 1968. *Ecology and Biogeography of High Altitude Insects* 212.

Phytomastrax bolivari Balderson & Yin, 1991. *Entomologist Gazette* 42(3):192.

Distribution: India (Jammu & Kashmir and Ladakh (Tragbal Pass)).

Genus *Gyabus* Ozdikmen, 2008

24. *Gyabus fusiformis* (Bei Bienko, 1949)

Pachymastax fusiformis Bey Bienko, 1949. *C.R. Acad. Sci. URSS.* 64(5):733.

Pachymastax fusiformis Bey Bienko, 1951. *Locusta and Grasshoppers of the USSR and Adjacent Countries* 1:118(126).

Gyabus fusiformis Ozdikmen, 2008. *Zootaxa* 1763:68.

Distribution: India (Ladakh (Kargil – Choskor)).

Superfamily Pyrgomorphoidea Brunner Von Wattenwyl, 1874

Family Pyrgomorphidae Brunner Von Wattwnyl, 1874

Subfamily Pyrgomorphinae Burnner Von Wettenwyl, 1874

Genus *Atractomorpha* Saussure, 1872

25. *Atractomorpha sinensis montana* Kevan & Chen, 1969

Actractomorpha sinensis montana Kevan, D,K,M, & Y. K. Chen, *Zoological Journal of Linnean Society* 48:141.

Atractomorpha sinensis montana Kevan, D.K.M., 1977. *In Beier. Orthoperorum Catalogus* 16:396.

Atractomorpha sinensis montana Vickery, 1996. *Notes Lyman ent. Mus. Res. Lab* 19:2-11.

Distribution: India (Jammu & Kashmir and Ladakh).

Suborder Ensifera

Superfamily Tettigonioidea Krauss, 1902

Family Tettigoniidae Krauss, 1902

Subfamily Conocephalinae Burmeister, 1838
Genus *Conocephalus* Thunberg, 1815
26. *Conocephalus (Anisoptera) longipennis* (Haan, 1843)

Locusta (Xiphidium) longipennis Haan, 1843. *Temminck Verhandelingen over de Nederlansche Overzeesche Bezittingen* 19/20:188,189.

Xiphidium longipenne Burnner von Wattenwyl, 1893. *Ann. Mus. Civ. Stor. Nat. Genova*213(33):181.

Conocephalus (Xiphidion) longipennis. Karny. 1912. *Genera Insectorum.* 135:11.

Conocephalus longipennis Pitkin, 1980. *Bull. Br. Mus. (Nat. Hist) ent.* 41(5):349.

Conocephalus (Anisoptera) longipennis Zhou, M., Bi & Xian Wei Liu,2010.*Zootaxa* 2527:57.

Conocephalus (Anisoptera) longipennis . Kim, T.-W. & Hong Thai Pham. 2014. *Zootaxa* 3811(1):69.

Conocephalus (Anisoptera) longipennis. Xiao, W., S.-L. Mao, Jianfeng Wang & J.H. Huang. 2016. *Far Eastern Entomologist*. 305:14.

Conocephalus (Anisoptera) longipennis. Nagar & Ranjni Swaminathan. 2016. *Zootaxa*. 4126(1):24.

Conocephalus (Anisoptera) longipennis. Farooqi & Usmani. 2018. *Zootaxa*. 4461(3):390.

Distribution: Dakar, India (Andaman & Nicobar, Assam, Karnataka, Kerala, Ladakh: Kargil and Uttar Pradesh), Eurasia, China, Malaysia, Vietnam, and Philippines.

27. *Conocephalus (Anisoptera) maculatus* (Le Guillou, 1841)

Xiphidion maculatus. Le Guillou. 1841. *Revue et Magasin de Zoologie*. 294.

Xiphidium (Xiphidium) maculatum Redtenbacher, 1891. *Ver. der Zool. Bota. Gesellesch, Wein* 41:515.

Anisoptera maculatum Kirby, W.F., 1906. *A Synonymic Catalogue of Orthoptera (Orthoptera Saltatoria, Locustidae vel Acrididae)* 2:278.

Conocephalus (Anisoptera) maculatus Hebard, 1992. *Proc.Acad.Nat. Sci. Philad* 74:243.

Conocephalus maculatus. Chopard. 1954. *Mem. Inst. franc. Afr. Noire*. 40(2):61.

Conocephalus (Anisoptera) maculatus Storozhenko, Kim & Jeon, 2015. *Monograph of Korean Orthoptera* 45.

Conocephalus (*Anisoptera*) *maculatus*. Gaikwad, Koli, Raut, Waghmare & Bhawane. 2016. *JoTT*. 8(2):8535.

Distribution: Africa, Libya, Saudi Arabia, Yemen, Pakistan, India (Orissa, Jammu and Kashmir, Ladakh: Kargil, Uttar Pradesh, Maharashtra and Uttarakhand) Nepal, China, Bhutan, Singapore, Malaysia, and Indonesia, Korea and Japan.

Subfamily: Phaneropterinae Burmeister, 1838.
Genus *Phaneroptera* Serville, 1831
28. *Phaneroptera gracilis* Burmeister, 1838

Phaneroptera gracilis Burmeister, 1838. *Handbuch der Entomologie* 22(IVIII):690.

Phaneroptera subnotata. Burner von Wattenwyl. 1878. *Monographie der Phaneropteriden.* 2016.

Phaneroptera gracili. Karny, 1927. *Zeitschr. Gesam. Naturwiss.* 88:12.

Phaneroptera gracilis Ingrisch, 2002. *Entomologica basiliensia.* 24:124.

Phaneroptera gracilis Hugel, 2009. *Zoosystema.* 31(3):552.

Phaneroptera gracilis Shi, F.M., L.H. Zaho & J.Jiao, 2013. *Acta zootaxanomica Sin.* 38(3):510.

Phaneroptera (Phaneroptera) gracilis gracilis Kim, T.W. & Hong Thai Pham, 2014. *Zootaxa.* 38(3):510.

Distribution: South Africa, Pakistan, India (Ladakh, Uttar Pradesh, Eastern Himalaya and Tamil Nadu) Nepal, China, Bhutan and Malaysia.

Subfamily Tettigoniinae Krauss, 1902
Genus *Hyphinomos* Uvarov, 1921
29. *Hyphinomos fasciata* Uvarov, 1921.

Hyphinomos fasciata. Uvarov, 1921. *Jour. Bombay Nat. Hist. Soc*. 28:74.

Hypsinomus fasciata Mani, M.S., 1968,. *Ecology and Biogeography of High Altitude Insects* 212.

Hyphinomos fasciata. Gurney & Liebermann. 1975. *Jour. Wash. Acad. Sci.* 65(3):102–107.

Distribution: Dakar, India (Jammu & Kashmir and Ladakh: Kargil) and China.

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Chopard, L. (1969). The Fauna of India and the Adjacent Countries: Orthoptera, Vol. 2. Grylloidea. Zoological Survey of India, 415 pp.

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SHORT COMMUNICATION

New distribution records of two *Begonias* to the flora of Bhutan

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Abstract: Two species of *Begonia* are collected and described for the flora of Bhutan—*panchtharensis* and *gemmipara*. A detailed description, ecology, distribution, notes and photographs of the recorded species are provided.

Keywords: Begoniaceae, *Begonia gemmipara, Begonia panchtharensis,* conservation status, description, ecology, morphology, Thimphu.

The genus *Begonia* L. (Begoniaceae) comprises of more than 2000 accepted species (Hughes et al. 2015), currently divided into 70 sections, distributed throughout tropical, subtropical (Doorenbos et al. 1998; Moonlight et al. 2018) and temperate regions of the world. In Asia, 959 species in 19 sections have been recorded, with maximum distribution in southeastern Asia (Doorenbos et al. 1998; Shui et al. 2002; Moonlight et al. 2018). In Bhutan, Grierson (1991) described 20 species of which 13 are known, and the addition of *Begonia flaviflora* Hara by Gyeltshen et al. (2021) increased the number of species to 14. The present report provides two additional new records of *Begonia* for Bhutan.

During a recent botanical exploration to central Bhutan between June and August 2020, small natural populations of *Begonia* species were observed in the shady and moist areas in cool and warm broadleaved forests. The authors collected detailed field notes and specimens for further examination. After detailed study on its morphological characteristics and reviewing the literature (Clarke 1879; Hara 1971; Grierson 1991; Tsuechih et al. 1999; Rajbhandary et al. 2010; Camfield & Hughes 2018; Pradhan et al. 2019) and consultation of herbarium specimens available at the Global Biodiversity Information Facility (GBIF 2020), it was identified as *Begonia panchtharensis* Rajbhandary (sect. *Platycentrum* (Klotzsch) A.DC) and *Begonia gemmipara* Hook.f. & Thomson (sect. *Putyzeysia* (Klotzsch) A.DC.). Grierson (1991) incorporated brief descriptions of *B. gemmipara* in the Flora of Bhutan based on the specimens collected from Darjeeling and Sikkim states of India. *B. panchtharensis* is a recently described species and is so far known from Nepal and Sikkim state of India (Pradhan et al. 2019). Detailed morphological descriptions, phenology, ecology, distribution, notes, and photographs are provided based on the collected specimens. The voucher specimens are deposited at the National Herbarium (THIM), National Biodiversity Centre, Thimphu, Bhutan.

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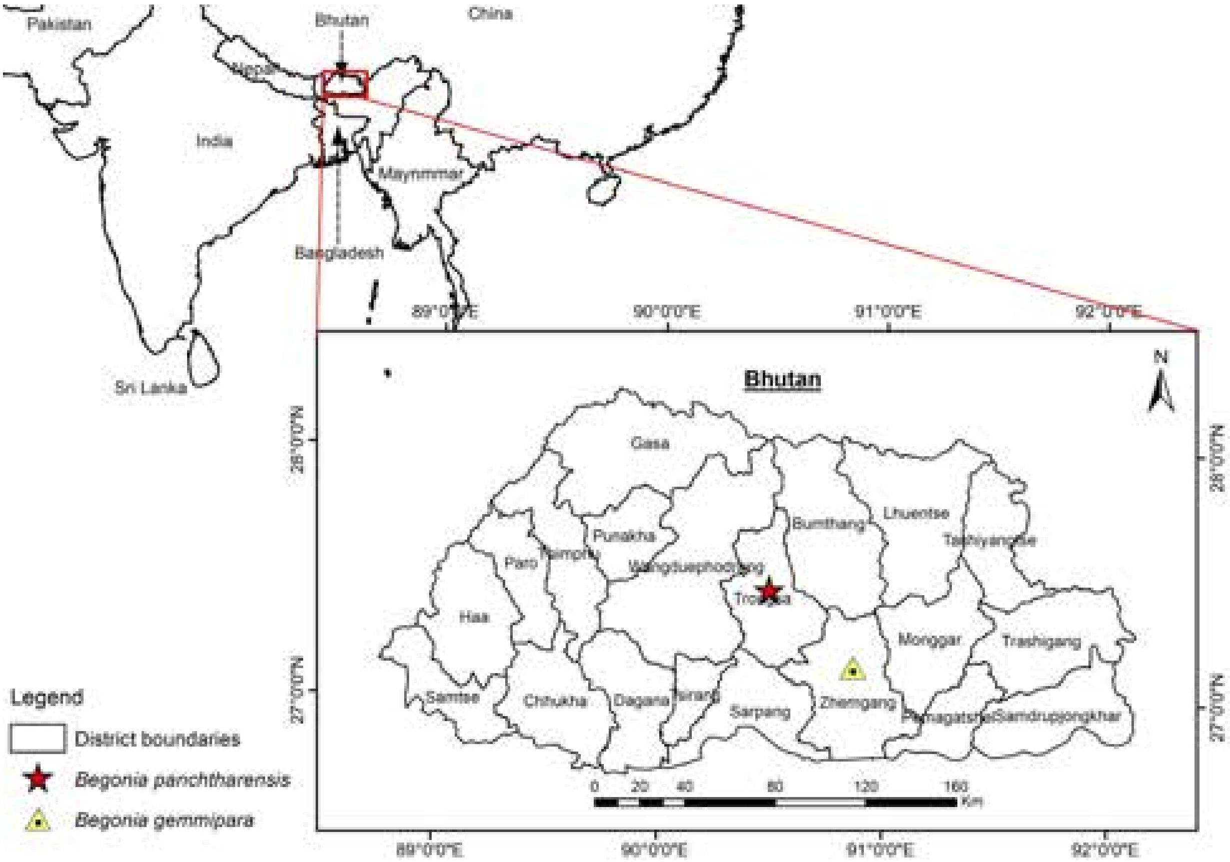

Figure 1. Distribution map for *Begonia panchtharensis* and *Begonia gemmipara* in Bhutan.

Taxonomic enumeration

Begonia panchtharensis S. Rajbhandary

Gard. Bull. Singapore 62(1): 151–162. 2010

Type: Nepal, Panchthar, Tinubote, Sisire, Prangbung, VDC, 2,240–2,300 m, 2.x.2007, *U. Thamsuhang s.n.*, vouchered as *S. Rajbhandary* S74 (holotype, E, isotype, KATH) (Image 1).

Plant monoecious, rhizomatous herb, 40–90 cm tall. Rhizomes**,** 10–25 long and 2–3.5 cm diameter covered with long adventitious roots**.** Stipules broadly ovate, 20–30 x 8.5–14 mm, caducous, membranous, pinkish-white with light green tinge, glabrous, red spotted on the abaxial surface, apex acuminate. Leaves arising from the rhizome; petioles 25–75 cm long x 7–12 mm wide, cylindrical with two parallel grooves on adaxial surface, glabrous, yellowish-green with red striated spots on the surfaces; blades slightly asymmetric, sub-orbicular, 20–42 × 18–40 cm, deeply lobed, adaxial surface dark green with sparsely white hirsute, abaxial surface pale green, glabrous with sparse white hairs on veins, base strongly cordate, margin irregularly serrulate or dentate, lobes 6–8, apex acuminate, palmately 6–8 veined.

Inflorescences terminal or axillary, cymose, dichotomously branched, 30–75 cm long, female inflorescences longer than male inflorescences; peduncles cylindrical, 25–48 cm long, glabrous, semi-woody, yellowish-green with red linear spots on the surface.

Floral bracts ovate-elliptic or elliptic, 2–3.5 x 1.5–2.0 cm, caducous, membranous, pinkish, glabrous, margin entire, apex acuminate, abaxial surface with circular or linear spots. Staminate flowers: pedicel 1.5–2.5 cm long, pale whitish-pink or white, glabrous with few red spots; tepals four, white to pale pink, 9–11 veined; outer two tepals broadly ovate, 15–24 x 10–15 mm, glabrous, apex sub-acute, base truncate, margin entire; inner two tepals oblanceolate to obovate, 20–22 x 10–12 mm, white, glabrous, apex obtuse, base cuneate, margin entire; stamens numerous, up to 5 mm long, distal filaments and anthers are longer than basal ones; filaments free, 2–3 mm long, obovate-oblong to elliptic-oblanceolate, 1.5–2 mm long, golden yellow, anther connectives extended. Pistillate flowers: pedicel up to 12–15 mm long, pale greenish-white or white with short linear red spots; tepals 5, unequal, white, glabrous, margin entire;

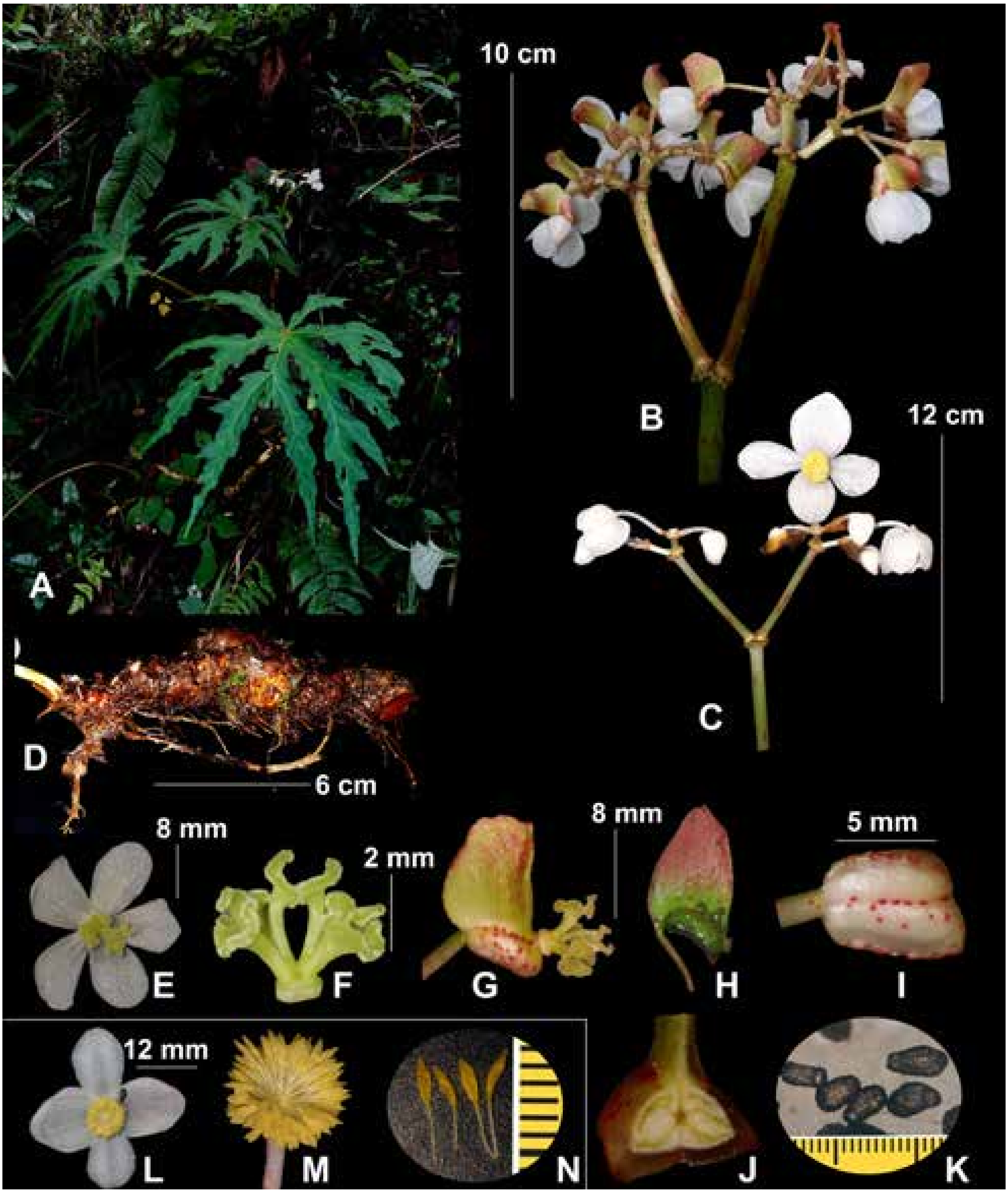

Image 1. *Begonia panchtharensis* Rajbhandary: A—Habit | B & C—Inflorescences (Female and male) | D—Rhizome | E—Pistillate flower | F—Styles | G, H & I—Fruits (Side and abaxial view) | J—Transversal section of ovary | K—Seeds | L—Staminate flower | M & N—Stamens. © Phub Gyeltshen

outer three tepals, obovate or ovate-elliptic, 15–16 x 9–12 mm, apex obtuse or rounded, base truncate, 8–9 veined; inner two tepals, obovate to oblanceolate, 13–15 x 7–11 mm, apex obtuse or rounded, base truncate; styles 2, persistent, 3–5 mm long, fused at base, golden yellow; stigma inner margins thickened and spiraled, intermediate portions flat and undulated, papillose; ovary oblong, slightly curved downwards, 6.5–8.5 x

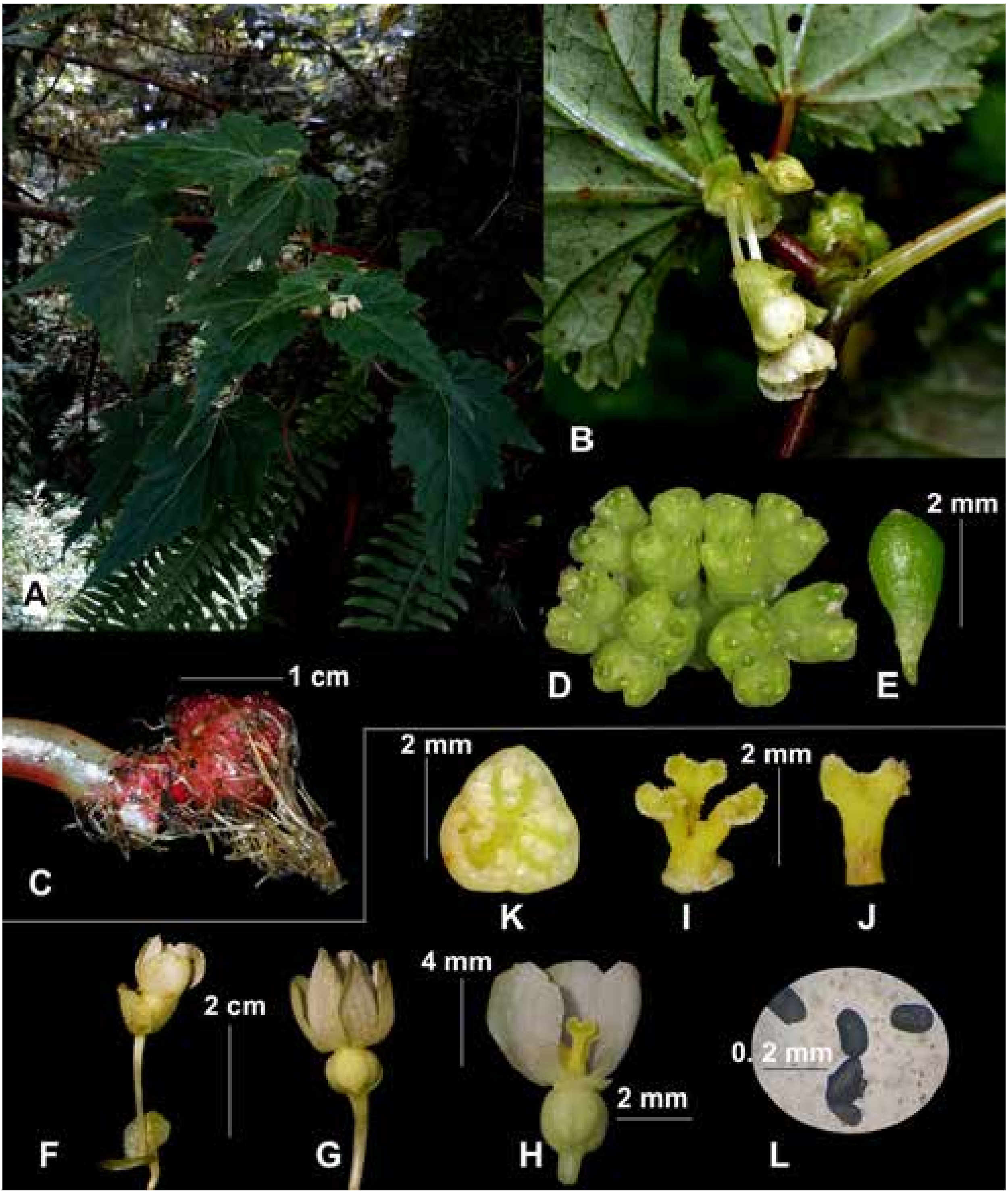

Image 2. *Begonia gemmipara* Hook.f. & Thomson: A—Habit | B—Inflorescences attached to stem | C—Tuber | D—Gemma-up like structure | E—Bulbil | F—Inflorescence | G—Inflorescence without bracts | H—Female flower showing ovary and styles | I & J—Styles | K—Transversal section | L—Seeds. © Phub Gyeltshen

4–5 mm, glabrous, red circular or linear granules on the surface with three unequal wings, dorsal wing longer than the two lateral underdeveloped ridge like wings, 2-locular, placentation axillary with two branches per locule. Fruits nodding or pendant, 7–9 x 5–6 mm, slightly falcate, yellow-green, nodding; dorsal wing obovoid or obovoid-oblong, 8–10 x 11–15 mm, wavy, margin flashed with red spots to 2/3 of upper portions; lateral wings 8–9 x 1 mm, red tubercles on the wings; seeds oblong, 0.5 mm long.

Specimens examined: Barcode No. THIM15584, 10.viii.2019, Bhutan: Trongsa, Tashidingkha, 27.4512°N, 90.4833°E, 1,898 m, coll. P. Gyeltshen, coll. no. 018 - 019.

Phenology: Flowering and fruiting July to September.

Habitat and ecology: The plant is lithophytes in the shady rocky areas in the warm broadleaved forest at 1,898–2,070 m elevation. The associated species includes *Globba clarkei*, *Elatostema* sp., *Sonerila khasiana*, *Begonia josephii*, and *Persicaria chinensis.*

Distribution: India, Nepal, and new to Bhutan (Fig. 1).

Notes: The current distribution sites are located within road buffer and the natural habitat could be disturbed or changed due to road expansion and maintenance in future. This species is encountered in the two locations with population less than 10 individuals in the field. Further study is recommended to understand its population trend and conservation status.

Begonia gemmipara **Hook.f. & Thomson III.**

Himal. Pl. t. 14. 1855

C.B.Clarke in Hook.f. Fl. Brit. India 2: 641. 1879; Hara in Flora of Eastern Himalaya 2:84.1971; Hara in Hara and Williams, Enum. Fl. Pl. Nepal 2: 181. 1979; Grierson in Grierson and Long, Flora of Bhutan 2(1): 237–246. 1991.

Putzeysia gemmipara (Hook.f. & Thomson) Klotzsch, Abh. Konigl. Akad. Wiss. Berlin 1854: 255 (1855).

Type: Holo: K000761398, 29.viii.1849, India, Sikkim, Lachoong, 2,743–3,048 m, coll. J.D. Hooker s.n. (Image 2).

Plant dioeceous with tuberous herb, 18–35 cm tall. Tubercules globose, 1.5–2 cm diameter covered with numerous roots**.** Stems erect to slightly pendent, 18–35 cm long, glabrous, 4–5 leaves per plant. Stipules narrowly ovate to lanceolate, 5–10 x 4–7 mm, green, glabrous, apex sub-acute to obtuse, base truncate, margin entire, revolute. Leaves: petioles, 2–14 cm long, red to green, glabrous; lamina asymmetric, narrowly ovate to lanceolate**,** 9–17 × 6–13 cm, adaxial surface glabrous to sparsely hairs, abaxial surface glabrous, base oblique, apex acuminate, margin irregularly serrate or dentate, palmately 5–6 veined. Inflorescence terminal or axillary, dichotomously branched, 2.5–3 cm long; peduncles cylindrical, 4–5 mm long, glabrous, pale whitish-green, bract orbicular, 5.5–6 x 8–10 mm, connate at base, 5–6 veined. Floral bracts orbicular, 6–7 x 7–14 mm, green, glabrous, margin entire, 6–7 veined. Pistillate flowers: pedicel 8–10 mm long, pale yellowish-green to whitish, glabrous; tepals 5–6, unequal, white with pale yellow tinge, glabrous, margin entire; outer tepals obovate or orbicular 6–8 x 5–7 mm, apex rounded, base truncate to obtuse, 4–6 veined; inner tepals obovate to oblanceolate, 6.5–7 x 5–6 mm, apex slightly oblique rounded, base cuneate, 1–3 veined; styles 3, distally U-shaped and V-shaped at base, 3–3.5 mm long, fused at base, golden yellow; stigma not spiraled, papillose; ovary triangular-globose, 4–4.5 x 3–3.5 mm, glabrous, wings underdeveloped, dorsal wing minute ridge like wing and lateral wings inconspicuous, three locules, placentation xillary with 2 branches per locule; seeds oblong, 0.5 mm long, white.

Specimens examined: Barcode No. THIM15585, 03.viii.2019, Bhutan: Zhemgang, Malaya, 27.14549°N, 90.86361°E, 2,628 m, coll. S. Jamtsho, coll. No. 05.

Phenology: Flowering and fruiting from late July to September

Habitat and ecology: This species is epiphytic on *Dodecadenia grandiflora* in the cool broadleaved forest at 2,628 m elevation.

Distribution: India, Nepal, and new to Bhutan (Fig. 1)

Notes: Three individual plants in a single location have been observed in the field are without staminate flowers, so we couldn't examine the morphological characters of the staminate flowers at present study and will supplement in the future studies. Further study on its population trend and distribution are required to determine the conservation status of the species. No threats have been observed in the field.

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SHORT COMMUNICATION

Rediscovery of *Aponogeton lakhonensis* A. Camus (Aponogetonaceae): a long-lost aquatic plant of India

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Family Aponogetonaceae is a monogeneric freshwater aquatic plant group belonging to the order Alismatales and comprising of around 58 species mostly distributed in the tropical and subtropical regions of Africa, Asia, and Australia (Chen et al. 2015; Yadav et al. 2015; De Silva et al. 2016). In India, the genus *Aponogeton* Linnaeus f. (1781) is known to have only eight species out of which, four are endemic (Yadav & Gaikwad 2003; Yadav et al. 2015). *Aponogeton lakhonensis* A. Camus was first described by Aimée Antoinette Camus in 1909 based on a collection made by F.J. Harmand in 1875 from Mount La-khon, Laos. It is the only species reported from the entire eastern India. Often, this species has been incorrectly labelled as *Aponogeton natans* (L.) Engler & Krause (1906) (Youhao et al. 2010). Hence a comparative analysis between both the species has been studied, enumerated and photographically presented below.

In India, this species was first collected in 1836 by an anonymous collector from Assam and again in 1898 by M.A. Hock from Jaboka, Sibsagar district, Assam post which there has been no further sightings nor any recollections from the entire country making it a regionally threatened plant species.

During a recent botanical survey to Dhemaji district of Assam conducted during 2020–2021, the authors came across an extremely striking aquatic plant with floating leaves and yellow inflorescence. On extensive studies and consultation with the existing literatures (Yadav & Gaikwad 2003; Tanaka et al. 2007; Youhao et al. 2010) and herbarium specimens (CAL499688, image!; CAL499690, image!), the aquatic plant was identified as *Aponogeton lakhonensis* A. Camus.

Aponogeton lakhonensis A. Camus, Not. Syst. 1:273. f. 18. 1909; Lecomte in Fl. Gen. Indo Chine. 6: 1226. 1942; Bruggen in Blumea 18: 479, f.2, 12, 3a. 1970; Biblioth. Bot. 51. 1985; Aqua Planta. 2: 51. 1990; Steenis, Fl. Males. 1, 7: 216. F. 1 & 3. 1971; S. Kartikeyan et al. Fl. Ind. Enum. Monocot. Sr 4. 4. 1989; C.D.K. Cook, Aquat. Wetl. Pl. India 48. 1996; Sundararagh. In Hajra & Sanjappa, Fasc. Fl. India 22: 129. 1996. (Figure 1, Image 1–4)

Aquatic, monoecious, tuberiferous, robust perennial herb, *c.* 30–50 cm tall. Tubers elongate or obovoid, 5.7–6.2 x 2–2.5 cm; roots slender, fibrous, golden to black,

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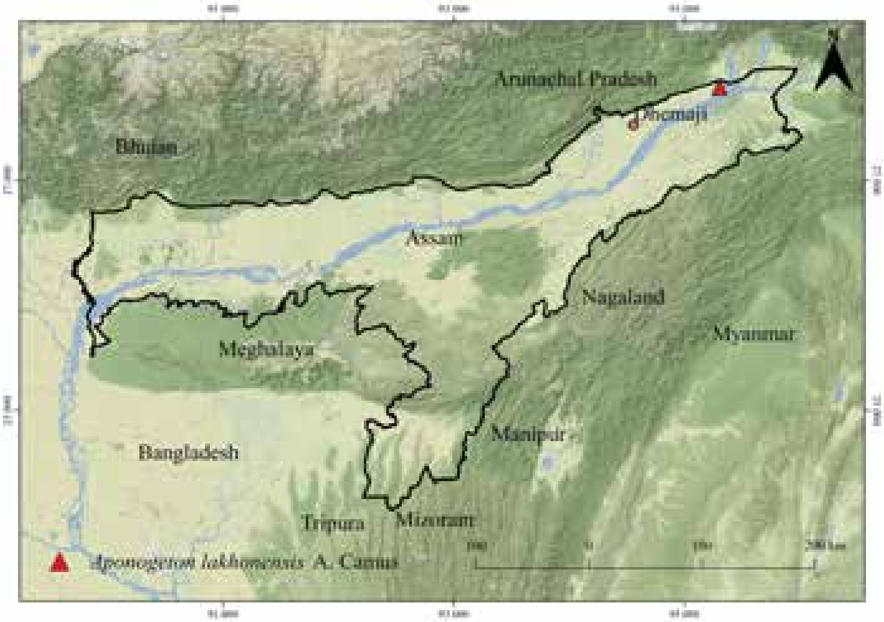

Figure 1. A map of northeastern India depicting the present collection site of *Aponogeton lakhonensis* (Map tiles by Stamen Design, under CC BY 3.0. Data by OpenStreetMap under ODbL).

Image 1. Habit of *Aponogeton lakhonensis*.

Image 2. Inflorescence of *Aponogeton lakhonensis* with floating leaves.

from top of tubers. Leaves both submerged and floating, petiolate. Submerged leaves brittle, petiolate; petioles 10–12 cm long, sheathing at base; lamina 9-22 x 4.3-5 cm, oblong-lanceolate, round at base, round to obtuse at apex, midrib prominent with 6–8 parallel nerves. Floating leaves slender, terete; petiolate; petioles 35–40 cm long; lamina 13.5–26 x 4.6–5.2 cm, oblong, cordate at base, narrow to round at apex, midrib prominent with 6–8 parallel nerves. Spathe c 2.2 cm long, membranous, caducous and acute. Peduncles 20–30 cm long, 0.4 cm in diameter, cylindrical, green, slightly thickening towards inflorescence. Spike simple, greenish-yellow, 8–9 cm long, flowers yellow, spirally arranged all around inflorescence, extending to 7–14 cm in infructescence. Tepals 2, equal, persistent, obovate, 0.1–0.2 x 0.07–0.15 cm long, rounded at the tip, yellow. Stamens 6, exserted, filaments c. 0.1–0.12 cm long, widened at base, anther 2–celled, pale yellow to grey, globose, dehiscing longitudinally; pollens 19–22 µm in diam. Carpels 3, rarely 4, yellow, stigma decurrent, style short, thick, ovules 7–10 per carpels. Follicles c. 0.4–0.6 x 0.2–0.3 cm, beaked. Seeds 0.35–0.4 x 0.1 cm, with a double testa, outer testa loose, ca 9 ridged, membranous, reticulately veined, inner testa smooth, greenish, closely fitting the embryo. Embryo cylindrical, 0.25–0.3 x 0.05–0.06 cm, minute, whitish, plumule not visible.

Flowering: March to October.

Specimen examined: India, Assam, 1836 (CAL499688,

Image 3. *Aponogeton lakhonensis*: A—Habit | B–E—Inflorescences in different stages (Scale 0.9 cm) | F—Enlarged portion of inflorescence (Scale 0.24 cm) | G—Enlarged portion of infructescence (Scale 0.6 cm) | H—Mature fruit (Scale 0.3 cm) | I—Seeds (Scale 0.2 cm) | J—Embryo with inner integument (Scale 0.3 cm) | K—Pollen grain (Scale 20 µm). © S.R. Yadav.

Image 4. *Aponogeton natans*: A—Habit | C & E—Inflorescence | G—Enlarged portion of infructescence | K—Mature fruit | L—L.S. of fruit showing seeds. *A. lakhonensis*: B—Habit | D & F—Inflorescence | H—Enlarged portion of infructescence | I—Mature fruit | J—L.S. of fruit showing seeds. © S.R. Yadav.

image!); Jaboka, Sivasagar district, Assam, 1898, M.A. Hock, CAL499690, image!; Poba Reserve Forest, Jonai, Dhemaji district, Assam, 132m, 13.iii.2021, 27.811N, 95.302E, D. Dey, DDM03 (GUBH!), (ASSAM!).

Distribution: India (Assam); Cambodia, China, Laos, Myanmar, Thailand, Indonesia, and Vietnam.

Population and habitat: A total of seven to eight individuals including three young plantlets were spotted blooming in a freshwater natural pond deep inside the Poba Reserve Forest of Dhemaji district, Assam. The plants were growing in association with other aquatic species like *Azolla pinnata* R.Br., *Lemna perpusilla* Torr., *Ceratophyllum demersum* L., and *Colocasia esculenta* (L.) Scott.

Discussion: On the basis of the existing literatures and herbarium specimens, it can be concluded that only two collections of *Aponogeton lakhonensis* have been made so far from India (viz. in 1836 and in 1898). The present sighting of *A. lakhonensis* is a rediscovery of the species from India after 123 years. The plant has been located from the Poba Reserve Forest of Dhemaji district, Assam making it a new report of occurrence apart from

Table 1. A comparative analysis between *Aponogeton lakhonensis* A. Camus and *A. natans* (L.) Engler & Krause (Image 4).

Attributes	*Aponogeton lakhonensis* A. Camus (Bruggen 1970, 1985; Yadav & Gaikwad 2003; present study).	*Aponogeton natans* (L.) Engler & Krause (Bruggen 1970, 1985; Yadav & Gaikwad 2003; present study)
Flower colour	Yellow.	White, pink to purple.
Tepals	Obovate, yellow.	Ligulate, white, pink, purple.
Stamens	Filaments 0.1–0.12 cm long, broad, anthers pale yellow.	Filaments 0.2–0.25 cm long, not broadened; anthers dark blue.
Style	Short, thick, yellow.	Long, thin, white to pink.
Ovules	7–10 per carpel.	4–8 per carpel.
Ovaries	Yellow.	White, pink to purple.
Fruits	Beak short.	Beak elongated.
Seeds	0.35–0.4 x 0.1 cm.	0.16–0.18x 0.08–0.09 cm.

the previous two localities in Assam. Pictures depicting its habit (Image 1,2) and a photo plate depicting the different parts of the plant (Image 3) along with a map (Figure 1) citing the present study location are provided to aid in its proper identification.

Voucher specimens (DDM03) have been deposited at the Gauhati University Botanical Herbarium (GUBH), Gauhati University, Guwahati and at the ASSAM Herbarium, Botanical Survey of India, Eastern Regional Centre, Shillong. *Aponogeton lakhonensis* A. Camus and *Aponogeton natans* (L.) Engler & Krause are very similar in appearance and sometimes misidentified. Therefore, a comparative analysis between both the species has been studied and enumerated in Table 1 along with a photographical presentation (Image 4).

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SHORT COMMUNICATION

Glyphochloa acuminata (Hack.) Clayton var. *laevis* (Poaceae): a new variety from central Western Ghats of Karnataka, India

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Abstract: This communication describes a new variety of *Glyphochloa acuminata* var. *laevis* from the lateritic plateau of central Western Ghats of Karnataka, southern India.

Keywords: Endemic grass, lateritic plateau, southern India.

The genus *Glyphochloa* is endemic to peninsular India and consists of 13 species and four varieties (Prasad et al. 2021). This genus is characterized by the presence of turbinate callus with knob at the center and ornamentation in the crustaceous lower glume of sessile spikelet. Bor (1960) reported five species under the genus *Manisuris* L., later Clayton (1981) transferred all *Manisuris* species to the new genus *Glyphochloa* W.D. Clayton. excluding *M. myuros* L. and *M. clarkei* (Hack.) Bor ex Sant (Fonseca & Janarthanam 2003). Fonseca (2003) clearly separated the varieties of *Glyphochloa acuminata* on the basis of transverse and vertical ridges on lower glume of sessile spikelets. In the varieties *acuminata* and *stocksii,* the ridges and furrows are prominent while in the variety *woodrowii* there are shallow depressions on the lower glumes of sessile spikelet and short awns. We compared our specimen with these varieties but no depressions or ridges on the lower glumes of sessile spikelets were observed and also length of the awns are not short it is up to 7mm long (Fonseca 2003). During the exploration of central Western Ghats of Karnataka the first author collected an interesting specimen close to *Glyphochloa acuminata* (Hack.) Clayton from the lateritic plateaus of Udupi and Uttara Kannada Districts. After critical examination of the specimens, types and literature (Bor 1960; Sreekumar & Nair 1991; Bhat & Nagendran 2001; Potdar et al. 2012) authors recognize it as a new variety of *G. acuminata*, *G. acuminata* var. *laevis*. A detailed description, photographs and illustration for the variety are provided.

Glyphochloa acuminata (Hack.) Clayton var. *laevis* Abhijit & Krishnamurthy var. nov.

(Image 1)

Type: India, Karnataka, Udupi district, Kamalshile pari (lateritic plateau), Abhijit & Krishnamurthy. 30.ix.2019, (Holotype, CAL0000033734 and isotype KUAB- 454)

Diagnosis: - *G. acuminata* var *laevis* differs from other verities of *G. acuminata* by the smooth lower glume of sessile spikelets without any ridges and furrows and long

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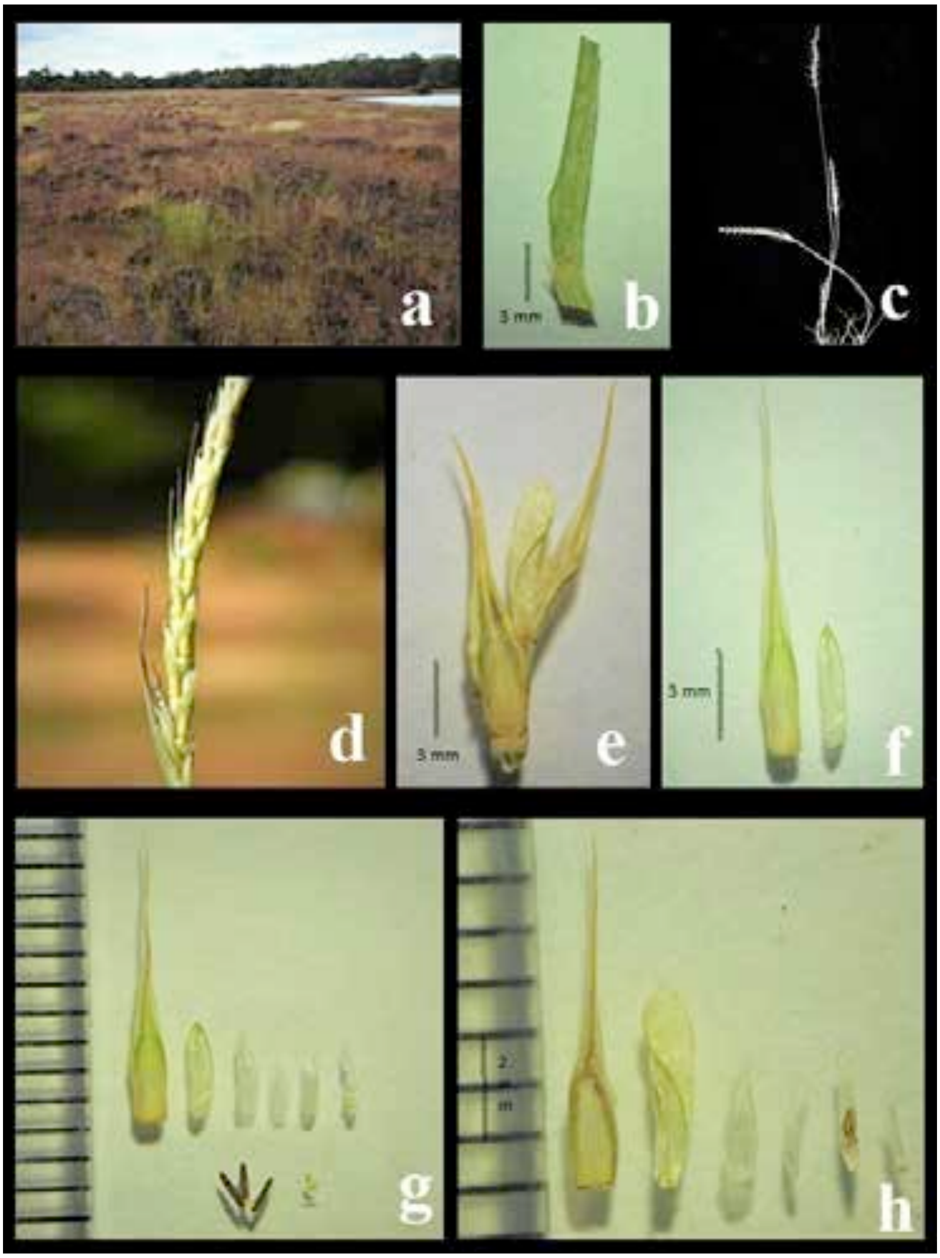

Image 1. *Glyphochloa acuminata* (Hack.) Clayton var. *laevis* Abhijit & Krishnamurthy, var. nov.: a—habitat | b—part of Leaf with ligule | c—habit | d—raceme | e—spikelet's | f—lower & upper glume of sessile spikelet | g—lower & upper glumes, lower lemma, upper lemma, palea, stamens & pistil of sessile spikelet | h—dissected pedicelled spikelet (lower & upper glumes, lower & upper lemma, paleas, respectively). © H.U. Abhijit.

pedicelled (Figure 1).

Annuals. Culms herbaceous, 25–30 cm long, erect with glabrous nodes. Leaf sheath slightly compressed; leaf blade linear-ovate, 4–6 × 0.3 cm; ligule membranous, 0.8–1 mm long. Racemes solitary, up to 6 cm long; joints and pedicels club- shaped, 0.2–0.3 cm long, spikelets are arranged in pairs. Sessile spikelets narrow, ovate, Bisexual, 1–1.2 × 0.15 cm (including awn), acuminate. Lower glume crustaceous, narrow, ovate 1.0 – 1.2 × 0.15 cm, 8–10 nerved, ridges absent, winged margins, apex awned. Upper glume smooth, 0.35 × 0.8 cm, 3-nerved, acute at apex. Lower florets are neuter and upper florets are bisexual. Lower lemma membranous, ovate, 0.3 cm long, apex acute. Palea ovate, hyaline, 0.2 cm long. Upper lemma hyaline, ovate, 0.2 × 0.6 cm. Palea hyaline, ovate, 0.15 cm long. Lodicule 2. Stamens 3; Anthers 0.12–0.16 cm long. Pistil 2 mm long. Caryopsis not seen. Pedicelled spikelets ovate, narrow, 0.65–0.7 cm long (including awn). Lower glume crustaceous, ovate, narrow 0.7 × 0.15 mm, keel-2, winged on margin,

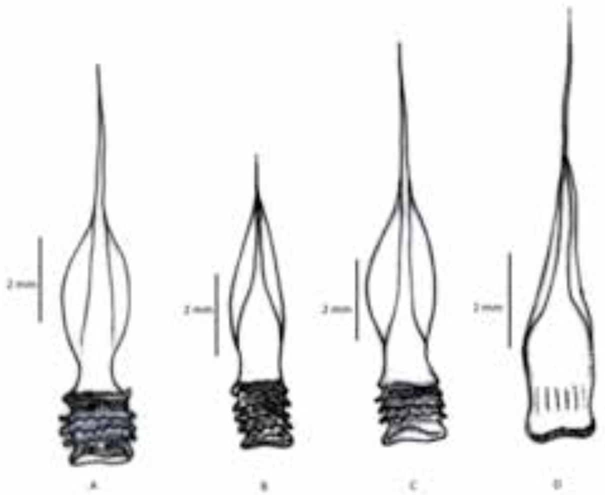

Figure 1. Morphology of lower glume of sessile spikelet in different varieties of *Glyphochloa acuminata*: A—*Glyphochloa acuminata* (Hack.) Clayton var. *acuminata* | B—*Glyphochloa acuminata* (Hack.) Clayton var. *woodrowii* (Bor) Clayton | C—*Glyphochloa acuminata* var. *stocksii* (Hook.f.) W.D. Clayton | D—*Glyphochloa acuminata* (Hack.) Clayton var. *laevis* Abhijit & Krishnamurthy. © H.U. Abhijit.

aristate at apex. Upper glume papery, boat shaped, 0.5 cm long, keel-1 with wavy wing on upper side, wing up to 0.3 cm long. Lower lemma membranous, ovate, 0.15 cm long. Palea hyaline, 0.15 cm long. Upper florets are male. Upper lemma hyaline, lanceolate, 0.15 cm long. Palea hyaline, ovate, 0.15 cm long, Lodicule 2. Stamens 3; anthers 0.12 cm long.

Etymology: The epithet '*laevis*' refers to its smooth ornamentation on the lower glume of sessile spikelet.

Distribution: The new variety grows in open areas of the lateritic plateaus of Kamalshile pari, Vate bachalu pari, Kamarapalu and its surroundings in Udupi district. The species is also found in Castle rock and its surroundings of Uttara Kannada district during monsoon to post monsoon season (Image 2).

Species distribution modeling of this grass variety is analyzed by using Maxent version 3. 4. 1. The color indicated in the Image 2 is help to explain the distribution of this variety in the Karnataka state. In the model, color towards green is more preference of species occurrence and towards red is the less preference of species occurrence in the particular area.

The Table 2 gives estimates of relative contributions of the environmental variables extracted from world claim data to the MaxEnt model version 3.4.1 (Philips et al 2004). To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. For

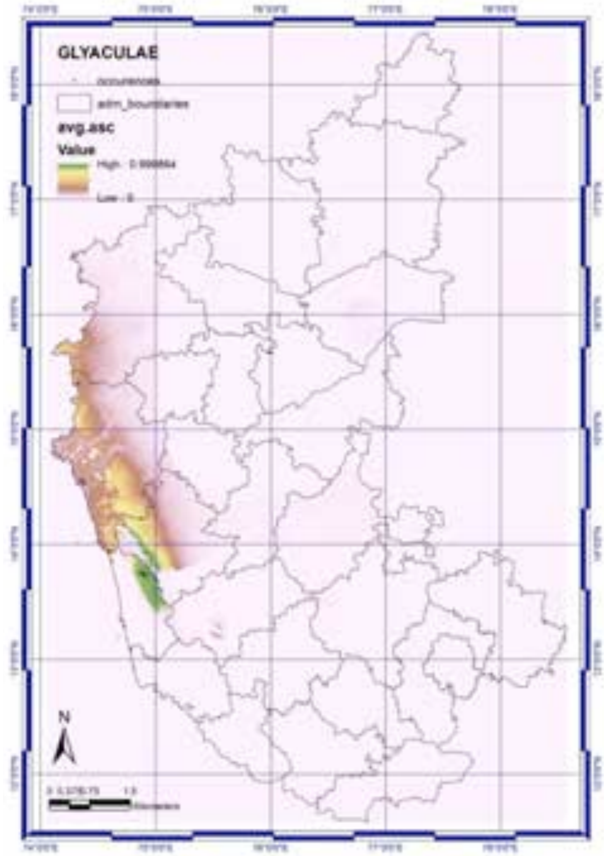

Image 2. Species Distribution model (SDM) of *Glyphochloa acuminata* (Hack.) Clayton var. *laevis* Abhijit & Krishnamurthy.

the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted. The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages. As with the variable jackknife, variable contributions should be interpreted with caution when the predictor variables are correlated. Values shown are averages over replicate runs.

Habitat and ecology: Lateritic rocky plateaus of open area and altitude about 150 m.

Flowering and fruiting: August to October

Specimens examined: 0000033734 (CAL). 30.ix.2019. 13.723N & 74.905E, 177m.

Kamalshile pari, Udupi district, Karnataka, India. Coll. H.U. Abhijit.

Conservation status: Data deficient but appears to be restricted to this particular region.

Field notes: Lower glume of sessile spikelet smooth, without ridges and furrows. The species is always associated with *Bhidea burnsiana* Bor. and *Danthonidium gammiei* (Bhide) C.E. Hubb. on lateritic rocks.

Table 1. Diagnostic morphological differences between varieties of species *Glyphochloa acuminata*.

Characters	*Glyphochloa acuminata* var. *acuminata*	*Glyphochloa acuminata* var. *woodrowii*	*Glyphochloa acuminata* var. *stocksii*	*Glyphochloa acuminata* var. *laevis*
Length of sessile spikelets (including awn)	0.8–1 cm	0.4–0.5 cm	0.7–1.2 cm	1–1.2 cm
Lower glume of Sessile spikelets	Coriaceous with ridges and furrows	Coriaceous with ridges and furrows	Coriaceous with ridges and furrows	Not coriaceous, without ridges and furrows
Length of pedicelled spikelets (excluding awn)	3–4 mm	3–4 mm	4.5–5 mm	5–5.5 mm

Keys to the varieties of *Glyphochloa acuminata* (Hack.) Clayton

1a. Pedicelled spikelets less than 0.4 cm long 2
1b. Pedicelled spikelets more than 0.4 cm long 3

2a. Sessile spikelet 0.8–1 cm long; lower glume awned and coriaceous .... *Glyphochloa acuminata* (Hack.) Clayton var. *acuminata*
2b. Sessile spikelet up to 0.5 cm long; lower glume shortly awned or awnless and coriaceous .... *Glyphochloa acuminata* (Hack.) Clayton var. *woodrowii* (Bor) Clayton

3a. Lower glume of sessile spikelet is coriaceous with ridges and furrows and pedicelled spikelet 0.5 cm long .... *Glyphochloa acuminata* (Hack.) Clayton var. *stocksii* (Hook. f.) Clayton
3b. Lower glume of sessile spikelet is not coriaceous without ridges and furrows and pedicelled spikelet 0.7cm long .... ***Glyphochloa acuminata* (Hack.) Clayton var. *laevis***

Table 2. Relative contribution of environmental variables.

Variable	Percent contribution	Permutation importance
karnataka_bio_30s_13	62.3	36.9
karnataka_bio_30s_14	22.1	56.7
karnataka_bio_30s_15	13.6	1.2
karnataka_bio_30s_3	1.3	1.8
karnataka_bio_30s_2	0.5	1.3
karnataka_bio_30s_17	0.2	2.3

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SHORT COMMUNICATION

A cytomorphological investigation of three species of the genus *Sonchus* L. (Asterales: Asteraceae) from Punjab, India

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Abstract: Three species of the genus *Sonchus* L. (*Sonchus asper*, *S. oleraceus* and *S. wightianus*) were collected from the Malwa region of Punjab during 2019 to 2020. These species were studied for cytomorphological variations. The species under investigation were identified based on their morphological descriptions. *Sonchus asper* (L.) Hill and *Sonchus wightianus* DC. possess the same number of chromosomes (2n=2x=18) whereas *Sonchus oleraceus* (L.) L. is tetraploid with 2n=4x=32 chromosomes. Chromosome number of *S. wightianus* (2n=2x=18) was worked out for the first time from the state of Punjab. *Sonchus olereceus* has larger pollens than *S. asper* and *S. wightianus*. This study will be useful for researchers, taxonomists and cytologists for accurate identification of these three species.

Keywords: Chromosome number, involucral bract, meiosis, palynology, *Sonchus*, taxonomy.

Sonchus L. is a member of the family Asteraceae with 95 species distributed throughout the world including western Morocco, Ethiopia, southern Sudan, South Africa, Canary Island, Europe, Iran, Iraq, Egypt, Afghanistan, and Turkistan (Boulos 1960; Cho et al. 2019). *Sonchus* species are annual to perennial herbs with a milky latex. The stem is clasping, toothed or pinnatifid, segmented leaves; terminal, umbellate, yellow, ligulate-homogamous heads; ovoid, ellipsoid, compressed, ribbed achenes with white hairy pappus which are the important features of the genus *Sonchus* L. (Quireshi et al. 2002; Rahman et al. 2008). Earlier four species of *Sonchus* (*S. asper* Vill., *S. arvensis* L., *S. oleraceus* L., & *S. maritimus* L.) were reported from British India (Hooker 1882) and undivided Punjab (Bamber 1916). Sharma (1990) enlisted *S. asper, S. oleraceus*, and *S. wightianus* from Punjab. Later on, Sidhu (1991) recorded *S. asper, S. arvensis*, and *S. oleraceus* from the state of Punjab. *Sonchus asper* and *S. oleraceus* were common in the previous studies whereas *S. wightianus* or *S. arvensis* were frequently misplaced under confusing species.

Morphological parameters have been used for the identifications of plant species for a long time. It is one of the basic, simple and cost effective tools. Morphological features such as leaf shape and color; flower color and type; number, position and nature of androecium and gynoecium; shape and type of fruit and seeds are used for identification of species (Singh & Dey 2005). Chromosome number is also important in the identification of species because species, genera and families have their own unique chromosome numbers in general and basic chromosome number in particular. Variations in chromosome numbers are useful in taxonomic studies (Raven 1975; Jones 1979).

The present study is an attempt to differentiate between previously reported two (*S. arvensis* and

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S. wightianus) species (Sharma 1990; Sidhu 1991). Therefore, it is important to look into the detailed morphology of the three species under investigation. Keeping this in view, the present study has been planned to characterize three species of *Sonchus* from the state of Punjab based on morphological and cytological observations.

Materials and Methods

Collection of study materials

The present study has been undertaken in the Malwa region of the state of Punjab, India. The study material of three species of *Sonchus* was collected during 2019 to 2020. The collected plant specimens were cleaned thoroughly, pressed, and dried at room temperature. After this, the plant specimens were pasted on herbarium sheets. Herbarium specimens were deposited in the Herbarium, Department of Botany, Punjab University Chandigarh (PAN-21994, 21996 and 21997).

Morphological study

Morphological features of a leaf (arrangement, shape, type, color), stem (glabrous, hairy), flower (colour, type, shape), androecium (number, shape, nature), gynoecium (shape, number, nature) were examined to establish the identity of each of the three *Sonchus* species. The available literature (Hooker 1882; Bamber 1916; Turner et al. 1961; Walter & Kutta 1971; Boulos 1972; Hsieh et al. 1972; Nair 1978; Mejias & Andres 2004; Cho et al. 2019) have been looked into to describe the *Sonchus* species in question. The Herbarium, Department of Botany, Panjab University Chandigarh and online Herbaria have also been consulted for identification.

Meiotic and pollen study

Meiotic analysis has been carried out in three *Sonchus* species to examine their chromosome numbers. Young flower buds were collected and fixed in the fixative (ethanol 3: glacial acetic acid 1) for 24 hours then shifted to 70% ethanol till further use. Anthers were excised from young flower bud on the glass slide having a drop of acetocarmine and crushed with the help of a glass rod. The material was covered with a micro cover-slip and pressed in two folds of filter paper after gentle heating. Slides were observed under the microscope. Photographs of the pollen mother cells containing countable chromosomes have been taken. For pollen study, mature anthers were taken on the slide and squashed in glycerol acetocarmine (1:1), covered with a cover-slip and observed under the microscope after 24 hours. Uniformly stained pollens (S.P.) were considered fertile whereas, poorly stained or unstained pollens as sterile. The percentage of pollen fertility was calculated using (Pollen fertility = S.P. / Total Pollens x 100) formula. Pollen size has been measured with the help of camera-lucida technique.

Results and Discussion

Three species of the genus *Sonchus*, i.e., *Sonchus asper*, *S. oleraceus*, and *S. wightianus* were collected from the Malwa region of Punjab during 2019 to 2020. All the three species are annual with erect habit. Leaves of *S. oleraceus* are smooth, glabrous, and light green whereas they are dark green in the case of *S. wightianus*. In *S. asper*, leaves are spined and bluish-green. Leaves are elliptic-oblong, half amplexicaul with round auricles in *S. asper* and *S. wightianus* but auricles are spreading in the case of *S. oleraceus* (Image 1,2). Similarly, leaf auricles were found to be round in *S. asper* and pointed to acute in *S. oleraceus* (Barber 1941; Quireshi et al. 2002; Cho et al. 2019). *S. asper* and *S. oleraceus* are very similar to each other in flower colour, i.e., pale yellow to dark yellow whereas the flower colour in *S. wightianus* is orange yellow. Involucral bracts are smooth in *S. oleraceus*, glandular hairy in *S. wightianus* and spiny-

Image 1. Habitat of *Sonchus* L. species (a–c): a—*Sonchus asper* | b—*Sonchus oleraceus* | c—*Sonchus wightianus*. © Rai Singh

Image 2. Morphological details of *Sonchus* species (a–d): a—leaf | b—leaf auricles | c—capitulum | d—involucral bracts. © Rai Singh

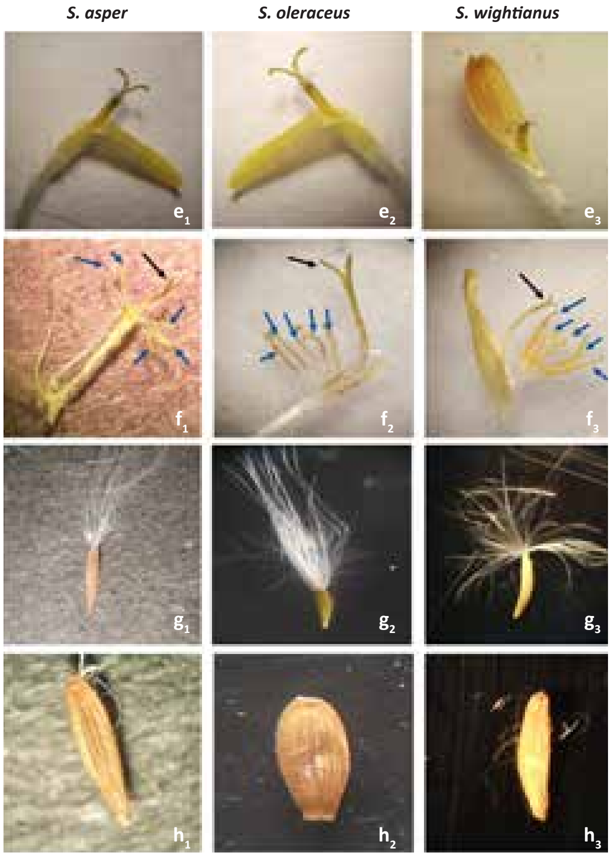

Image 3. Morphological details of Sonchus species (e–h): e—flower | f—flower (black arrow showing stigma and blue arrows showing stamens) | g—achene with pappus | h—achene. © Rai Singh

hairy in *S. asper* (Image 2). Rahman et al. (2008) also observed glandular and hairy involucral bracts in *S. wightianus* which supports the present study. This feature is important and useful for establishing the identity of *S. wightianus*. Achenes are wrinkled with ribs in *S. asper*, compressed in *S. oleraceus* and finely compressed in *S. wightianus* (Image 3).

Identification key (morphology)

1 (a) Leaf auricles acute........................ *S. oleraceus*
1 (b) Leaf auricles round... 2
2 (a) Involucral bracts with glandular hairs .... *S. wightianus*
2 (b) Involucral bracts with spiny hairs .... *S. asper*

Both *Sonchus asper* and *S. wightianus* are diploid and contain 2n=2x=18 chromosomes. Nine bivalents were observed at diakinesis and metaphase-I in *S. asper* and equal segregation of chromosomes (9-9) at anaphase-I in *S. wightianus* (Image 4.a,b,d). Razaq et al. (1994) also reported chromosome numbers 2n=18 in both *Sonchus asper* and *S. wightianus* and 2n= 32 in *S. oleraceus* from Pakistan.

Sonchus oleraceus is a tetraploid and has shown 16 bivalents at diakinesis stage (Image 4c). Present chromosome findings of *S. oleraceus* is in consonance with Ishikava (1911) who also reported 2n=4x=32 chromosome in this species. It has suggested the genetic stability of species even after more than 100 years. But a diploid form of *S. oleraceus* (2n= 16) and tetraploid (2n= 32) were previously reported by Marchal (1920) and Cooper & Mahony (1935), respectively. More studies had described *S. asper* as diploid (2n= 18) and *S. oleraceus* as tetraploid (2n= 32) (Turner et al. 1961; Walter & Kutta 1971; Boulos 1972; Hsieh et al. 1972; Gupta & Gill 1983; Sidhu et al. 2011; Kaur & Singhal 2015). The variation of chromosome number in *Sonchus* species points towards the incidence of aneuploidy that has happened over time in the genus *Sonchus*.

Pollen size of *S. oleraceus* is 36.25 x 32.5 µm–40 x 33.75 µm followed by *S. wightianus* (33.75 x 32.5 µm–36.25 x 33.75 µm) and *S. asper* (31.25 x 28.75 µm–35

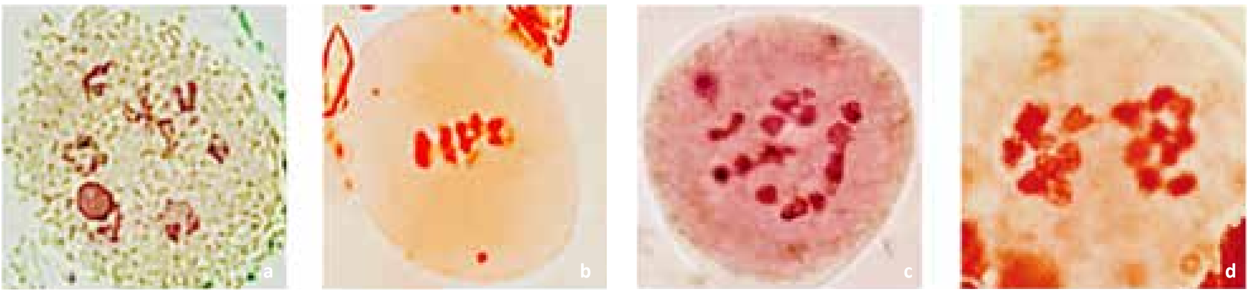

Image 4. Chromosome details of *Sonchus* L. species (a–d): a–b—*S. asper* (n= 9) | c—*S. oleraceus* (n= 16) | d—*S. wightianus* (n= 9). © Rai Singh

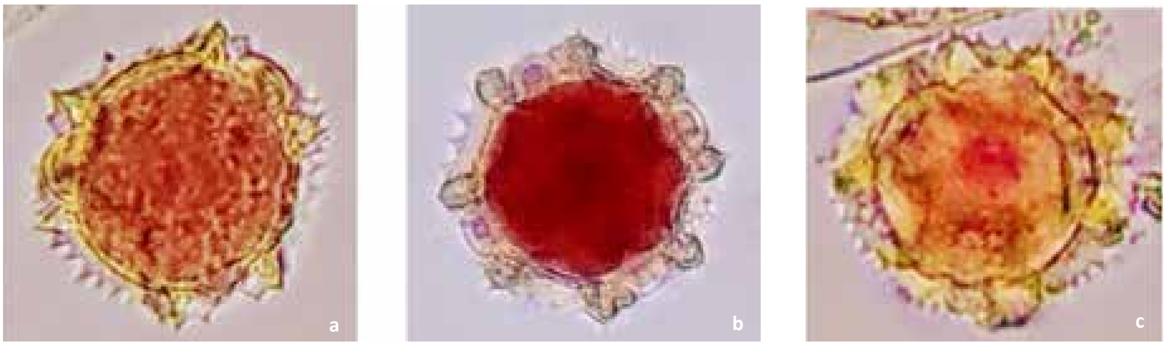

Image 5. Pollen grains of three *Sonchus* L. species (a–c): a—*S. asper* | b—*S. oleraceus* | c—*S. wightianus*. © Rai Singh

x 32.5 µm) (Image 5 a–c). Pollen size of *S. asper* and *S. wightianus* is almost similar which may be due to the same number of chromosomes (2n=2x=18). Pollens of *S. oleraceus* are larger than the other two species which may be because of its tetraploid (2n=4x=32) nature. Pollen fertility was maximum in *S. oleraceus* (94.33%), followed by *S. wightianus* (92.13%) and *S. asper* (88.88%). High pollen fertility in *S. oleraceus* suggested that it is an allotetraploid. These observations are in consonance with Poole (1932) who found that amphidiploids possess a greater degree of pollen fertility.

Earlier three species of *Sonchus* such *S. asper, S. oleraceus*, & *S. wightianus* (Sharma 1990) and *S. asper, S. oleraceus*, & *S. arvensis* (Sidhu 1991) were documented from the state of Punjab, India. But according to available literature (Shumovich & Montgomery 1955; Mamgain 1998) *S. arvensis* grows exclusively in Europe and is likely confused with *S. wightianus* in India. In literature, from the state of Punjab third species of *Sonchus* was considered as *S. arvensis* but it is actually a *S. wightianus*.

Cytological details of *Sonchus* species are also incomplete from the state of Punjab, India. Previously, Gupta & Gill (1983) had worked out chromosome numbers of three *Sonchus* species (*S. asper* (L.) Hill, *S. brachyotus* DC and *S. oleraceus* L.) from the state of Punjab. However, they have not worked out the chromosome of *S. wightianus.* Consequently, information about the chromosome number of *S. wightianus* is not known. Therefore, the present study has been carried out for cytomorphological characterization of *Sonchus* species from the state of Punjab India. The findings of the present study will be useful for researchers, cytologists, and taxonomists for correct identification of *Sonchus* species based on morphological, cytological, and palynological details.

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NOTE

Dryopteris lunanensis (Dryopteridaceae) - an addition to the pteridophytic diversity of India

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Abstract: The occurrence of the very rare and little-known fern, *Dryopteris lunanensis* (Christ) C.Chr., in India is reported for the first time. A detailed description and photographs of the species are provided along with notes on its distribution. A second-step lectotype has also been designated.

Keywords: Arunachal Pradesh, distribution, fern, Pteridophyta.

The genus *Dryopteris* Adans. (Dryopteridaceae) is one of the most widespread fern genera with approximately 350 species worldwide (Fraser-Jenkins 1986; POWO 2021) and has high species diversity in subtropical montane regions, though the genus extends northwards into boreal regions as well. The Sino-Himalayan and Sino-Japanese regions support the greatest numerical and morphological diversity, with secondary centres of diversity in Africa, Europe (including Macronesia), Hawai'I, and North America. *Dryopteris* in India is represented by 66 species and seven hybrids (Fraser-Jenkins 1989; Fraser-Jenkins et al. 2018), excluding the distinct Dryopteridaceous genera, *Peranema*, *Nothoperanema*, and *Dryopsis*, in contrast to a recent cladonomic oversimplification by Zhang (2012) and Zhang & Zhang (2012) artificially intended to avoid paraphyly. Many species have been discovered recently in the eastern Indo-Himalaya that were previously only known from the main centre of distribution in southeastern Tibet and southwestern China. Of these, *Dryopteris lunanensis* (Christ) C.Chr., a distinctive species in Sect. *Hirtipedes*, was detailed from a single collection in Bhutan by Fraser-Jenkins (1989), now augmented by a second Bhutanese collection, but was not previously collected in India.

A misidentification of supposed *D. lunanensis* from India was made by S.R. Ghosh concerning a specimen from Ukhrul, Manipur (R.D. Dixit 58874, 24.2.1987, CAL!), but the specimen was unequivocally reidentified by Fraser-Jenkins et al. (2018) as *D. scottii* Ching, a very different species.

The first author recently collected a specimen from Dibang Wildlife Sanctuary, Arunachal Pradesh. After critically observing its morphological characters, it was immediately identified as *D. lunanensis* by the second author from his familiarity with collections of the species in China and Bhutan. This is therefore the first authentic report of this species from India. Its taxonomy and distribution, along with photographs are provided here.

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A second-step lectotype is also designated in the present article in accordance with its lectotypification by Fraser-Jenkins (1989) and the ICN (Turland et al. 2018).

Methods and Materials: During the field-survey in Dibang Wildlife Sanctuary of Arunachal Pradesh, a few specimens of an unusual *Dryopteris* were collected. The collected specimens were not immediately able to be identified and after preparation as herbarium-specimens were photographed and the photographs were sent to the second author, who identified them as *Dryopteris lunanensis* (Christ) C.Chr. The collection showed the typical long, sparsely scaly stipe with darkish brown scales, deeply lobed pinnae (to just over half way to the rachis on each side) with slightly narrowed bases, slightly falcate-deflexed lowest pinnae and aristate and slightly flabellate teeth at the lobe-apices (Ching 1938; Fraser-Jenkins 1989). The specimen was deposited in ARUN herbarium, Itanagar.

Dryopteris lunanensis (Christ) C.Chr., *Index Filic.*: 276. 1905.

Basionym: *Aspidium lunanense* Christ, *Bull. Herb. Boissier* 6: 966. 1898.

Type: (Lectotype (Fraser-Jenkins 1989), second-step, here designated)**:** China, Yunnan, Lunan, A. Henry 10584, sin. date, P (P01514061 digital image!); Isolectotypes: BM (BM001066079 digital image!); K (K001080923 digital image!)

Synonyms: *Dryopteris paralunanensis* W.M.Chu ex S.G.Lu, *Guihaia* 11(3): 225. 1991.

Dryopteris semipinnata Ching, *Fl. Tsinling.* 2: 226. 1974.

Description: Plant up to 60 cm tall. Rhizome short, thick, erect, scaly at the apex. Fronds bipinnatifid, arching, stipe nearly as long as the lamina, 20–30 cm, brown at base, stramineous upwards, dorsally grooved, densely scaly at base with scales 8–15 × 0.5–1 mm, blackish-brown, basifixed, narrowly lanceolate, base broad, margin ciliate, apex attenuated, sparsely scaly, with shorter, narrower scales, upwards and on the rachis; rachis stramineous, ± sparsely scaly; lamina deltate-lanceolate, subcoriaceous or slightly crispaceous, 25–30 × 10–15 cm; pinnae pinnatifid, lobed up to 2/3 towards costa or more, lanceolate, alternate, sessile to sub-sessile, apex acute to acuminate, 12–15 × 2–2.5 cm, characteristically narrowed at their bases; costae stramineous, sparsely scaly with small fibrils or hair-like scales, dorsally grooved; pinna-lobes with entire margins and rounded, acutely dentate apices, the teeth abruptly narrowed to their apices and slightly flabellate; veins simple, free. Sori indusiate, round, median, in two rows, one on each side of the midvein; indusia reniform, c. 0.5 mm in diameter.

Habitat: A terrestrial species, occurring at approximately 1,900 m altitude, in forest on slopes by streams.

Distribution: India (Arunachal Pradesh); Bhutan, China (Yunnan, Kweichow, Szechuan, Hunan, Kansu), Tibet, Japan. Its long-known presence in Bhutan was mistakenly omitted by Wu et al. (2013) in the Flora of China.

Specimen examined: India, Arunachal Pradesh, Dibang Valley District, Dibang Wildlife Sanctuary, slope above streams in forest, c. 1900 m, C. Chanda 42060, 23.xi.2018, ARUN.

Conservation status: CR (Critically Endangered and known only from a single collection in India). Despite extensive collection by pteridologists in Arunachal Pradesh and elsewhere in northeastern India this distinctive and easily recognisable species has only been found as a single small group of a few individual plants in one locality.

Note: This species is rare and restricted in distribution throughout all parts of its range and is to be considered as globally threatened. It has only been collected twice before in the Indian subcontinent, both from west-central Bhutan (Punakha Dzongkhag, Tinlegang to Gon Chungnang, c. 1,700 m, H. Kanai, G. Murata, H. Ohashi, O. Tanaka & T. Yamazaki 14832, 5.v.1967 (BM, TI, KYO) and Wangdue Phodrang Dzongkhag, Pho Chu, north-east of Kewa Nang, evergreen Quercus forest on steep E.-facing rock slope, undisturbed, 2,350 m, *S. Miehe* & *D.B. Gurung* 00-459-12, 10.xii.2000 (UC), det. CRFJ) (Fraser-Jenkins 1989 and in prep., re Bhutan). The present collection from India was made from an isolated group of only three individuals in a small area.

Nomenclatural Notes: Christ (1898) described *Aspidium lunanense* Christ on the basis of a specimen collected from Lunan (the "stone forest"), in Yunnan Province, China, A. Henry 10584. Christ mentioned in the first part of his paper that it concerned the collections of Augustine Henry from the Meng-tse (or Mong Tseu., now Mengzi) semi-autonomous area in southeastern Yunnan Province, situated south of Kunming and east of central Myanmar, north of Vietnam.

Referring to website data-bases, we found three specimens in BM, K and P (1 in each) and Fraser-Jenkins (1989) had also found a second specimen in P with the same details as provided in the protologue of *A. lunanense*. The specimens in K and P are well preserved and exhibit all the characters required for identification, while the specimen housed in BM

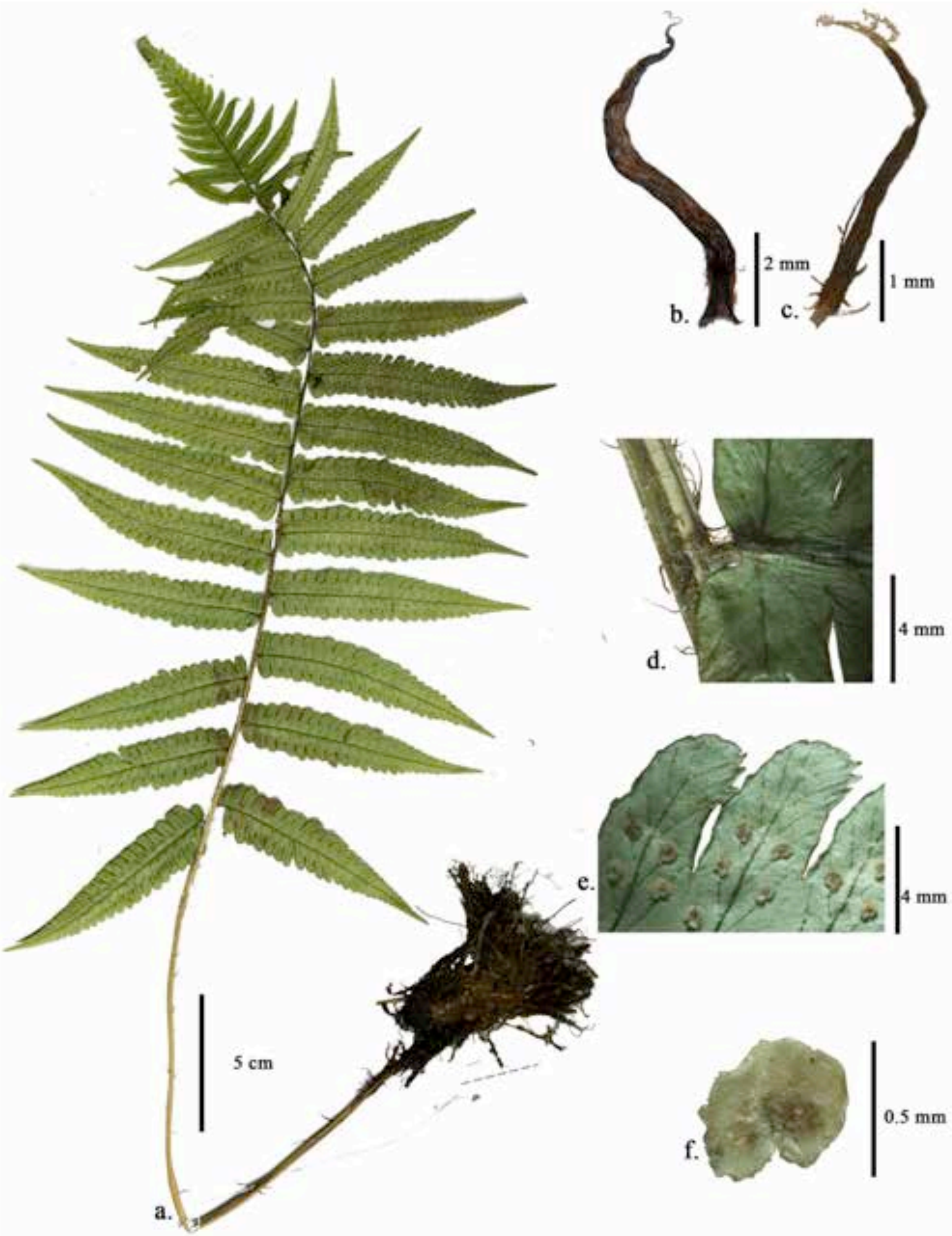

Image 1. Habit and different parts of *Dryopteris lunanensis* (Christ) C.Chr. (photographs prepared from C. Chanda 42060, ARUN): a—Habit of the plant | b—Rhizome scale | c—Rachial scale | d—Barching point showing rachial scales | e—Venation and sori arrangement | f—Indusium. © Chhandam Chanda.

has original circumscription copied and written by Christensen, but is only a single pinna taken by him from the Paris material and forming part of Christensen's comprehensive type-fragment herbarium. The sheet at P, barcoded as P01514061 (digital image!), bears original data by Henry and *"Aspidium lunanense* n. sp. [species nova]" in Christ's handwriting. We designate this sheet as a second-step lectotype.

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NOTE

First record of Spotted Linsang *Prionodon pardicolor* (Mammalia: Carnivora: Prionodontidae) with photographic evidence in Meghalaya, India

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Abbreviations: CITES—Convention on International Trade in Endangered Species of Wild Fauna and Flora (Appendix I, II and III) | IUCN—International Union for Conservation of Nature | RF—Reserved Forest | WS—Wildlife Sanctuary.

The Spotted Linsang *Prionodon pardicolor* is distributed from central Nepal, Bhutan, northeastern India, and southern China to the northern Sundaic region (Van Rompaey 1995; Jennings & Veron 2015; Duckworth et al. 2016). It is listed under Appendix I of CITES and as 'Least Concern' on the IUCN Red List of Threatened Species (Duckworth et al. 2016). In India, it is accorded the highest protection under Schedule I of the Indian Wild Life (Protection) Act, 1972.

Previously placed in the civet family (Viverridae), the Spotted Linsang is now under a new monogeneric family, Prionodontidae – a sister group of the family Felidae, from which it is estimated to have diverged about 33 million years ago (Gaubert & Veron 2003). Its size ranges between 31–45 cm and weight between 0.55–1.2 kg (Hunter 2020). It is characterized by a pointed muzzle, an elongated neck and head, a slender body, short limbs, and a tail that is as long as its head and body, between 30–40 cm. It also exhibits cat-like characteristics such as retractile claws. It has a fulvous coat, with large black spots on its dorsal side that extend from the shoulder to its posterior and decrease in size as they approach the ventral side. The long cylindrical tail is also covered by eight to ten broad dark rings, separated by paler rings (Hodgson 1847; Blanford 1888–91; Van Rompaey 1995).

In India, the current distribution of the Spotted Linsang is limited to the states of Arunachal Pradesh, Assam, Nagaland, Manipur, Sikkim, and northern Bengal (Duckworth et al. 2016). But few authors have also mentioned that there is a high probability of its distribution in Meghalaya (Choudhury 2013; Jennings & Veron 2014).

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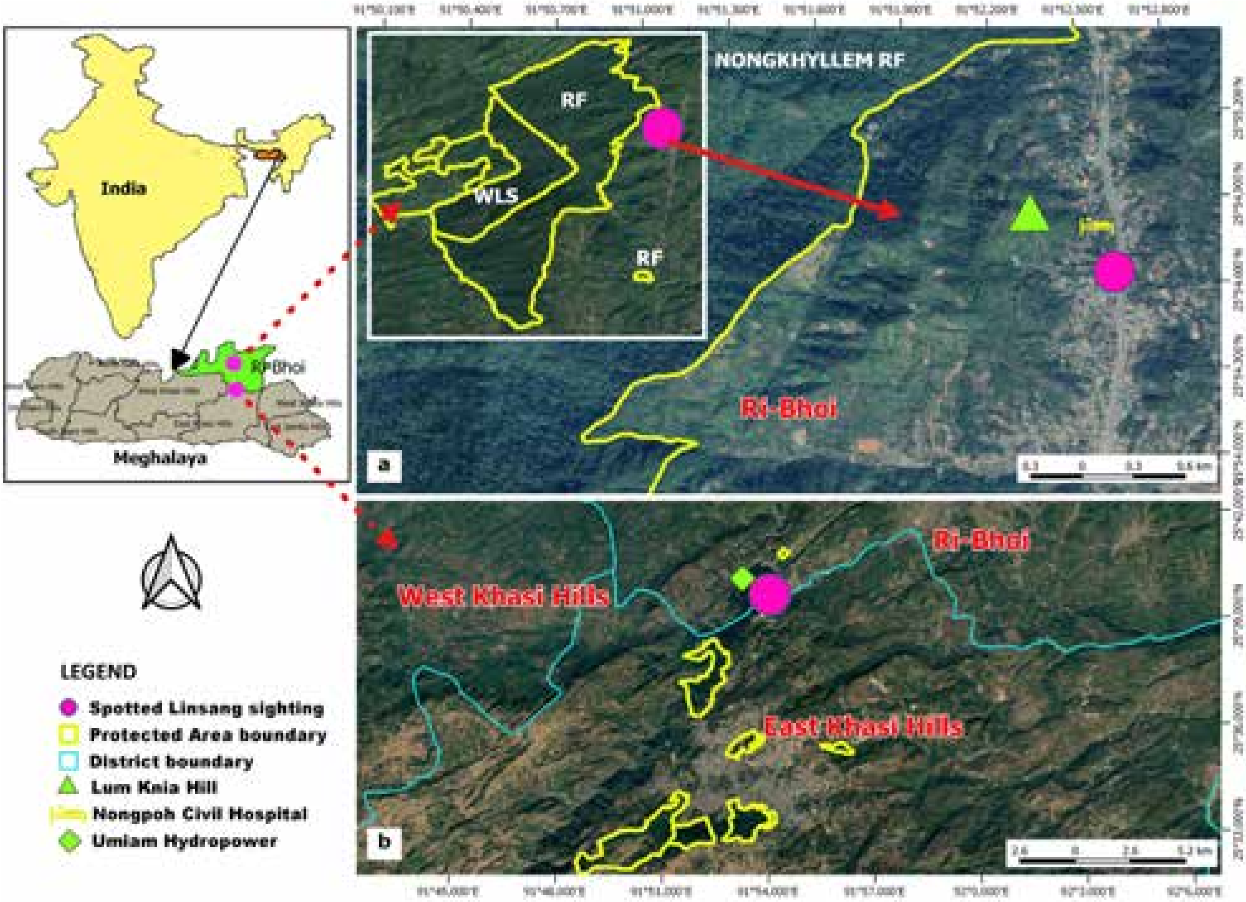

Figure 1. Map showing the two sighting locations of Spotted Linsang in Ri-Bhoi District.

In this paper, we report the first record of Spotted Linsang in the state of Meghalaya with photographic evidence, which extends the known distribution range of this species.

On 29 October 2019, at around 0400h, a Spotted Linsang (Image 1) was found by a hospital staff worker, Wanphai Lyngdoh straying inside the compound of Nongpoh Civil Hospital, Nongpoh Town, Ri-Bhoi district, Meghalaya, India (485m; 25.911^{0}N, 91.878^{0}E) (Figure 1a). It was rescued by the forest department later in the day and released back to Lailad Salt Lick area of Nongkhyllem Wildlife Sanctuary (located approx. 6 km from Nongpoh town; 250m; 26.037^{0}N, 91.867^{0}E) at 1700h. Again, on 4 November 2019, one more individual was rescued from Nongpoh Civil hospital compound around 1630h. It was released on the very same day in Nongkhyllem WS (Lailad Salt Lick area).

Furthermore, in the same area, one resident of Pahamsyiem village near Nongpoh town reported sighting of the Spotted Linsang on a number of occasions, around five years ago, in 'Lum Knia' hill. When shown the photo of the Spotted Linsang, Leopard Cat and Small Indian Civet, from "Mammals of India" (by Grewal & Chakravarty 2017), he insisted that it was the Spotted Linsang that he had sighted (Goson Sangma, pers. comm.).

This area which includes the wildlife sanctuary, Umsaw Reserved Forest, Nongkhyllem RF and patches of unclassed (community owned) forests are mostly characterized by tropical Moist Deciduous forest, with patches of tropical Semi-evergreen forest along rivers. There are also large bamboo patches in old Jhum areas and scattered grasses in depressions and plantations dominated by *Shorea robusta* and *Tectona grandis* (Choudhury 1998).

Another encounter in the state was in 1997, in Ri-Bhoi district, when a forest official sighted one Spotted Linsang near the Hydropower Dam of Umiam Lake (25.660^{0}N, 91.901^{0}E) crossing the National Highway 40 at dusk (P. Doonai, pers. comm. 2020) (Figure 1b). The highway intersects a patch of unclassed forests, which is contiguous with the Riat Khwan RF. The area experiences a subtropical climate. The vegetation of the Riat Khwan RF and the adjoining forests is mostly subtropical broadleaf hill forests, with the presence of Khasi Pine *Pinus kesiya*

Image 1. Spotted Linsang *Prionodon pardicolor* kept in a cage after being rescued from Nongpoh Civil Hospital, Nongpoh Town, Ri-Bhoi district, Meghalaya, India.

towards higher elevation (Lahkar 2002).

This current record of the Spotted Linsang is in a habitat similar to the habitat types where the species had previously been recorded (Pham-Chong-Ahn 1980; Sunquist 1982; Choudhury 2002; Borah 2010; Ghose et al. 2012; Naniwadekar et al. 2013).

Among the handful of records of the Spotted Linsang in India, it was never reported before from the state of Meghalaya (Lyngdoh et al. 2019). The only mention about the species in Meghalaya was from an unpublished social survey report in south Garo Hills where the respondent stated that the animal had caused damage to domestic livestock (Samrakshan Trust 2008).

The Spotted Linsang is mainly threatened by habitat loss caused by deforestation and conversion to agriculture, such as Jhum and terrace farming (Choudhury 2002; Jennings & Veron 2015).

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NOTE

First record of the Eastern Cat Snake *Boiga gocool* (Gray, 1835) (Squamata: Colubridae) from Tripura, India

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Northeastern India has a rich herpetofaunal diversity, with 102 species of snakes, represented by six families comprising 42 genera (Ahmed et al. 2009; Aengals et al. 2018) with some new snake genera and species recently discovered in, e.g., *Blythia hmuifang, Pareas modestus*, *Gongylosoma scriptum*, *Smithophis atemporalis, Hebius lacrima, Trimeresurus salazar, Trachischium aptei, Trimeresurus arunachalensis, Smithophis arunachalensis, Hebius pealii* (Vogel et al. 2017, 2020; Lalremsanga 2018; Bhosale et al. 2019; Captain 2019; Giri et al. 2019; Purkayastha & David 2019; Das et al. 2020; Mirza et al. 2020). Tripura is a landlocked, small, hilly state surrounded by Assam & Mizoram of India and Bangladesh on three sides (Image 1). So far, 21 species of snakes under 19 genera and six families have been reported from the state (Majumder 2012; Purkayastha et al. 2020). Earlier, only one species of the genus *Boiga*, *B. ochracea* was recorded from the state (Majumder et al. 2012; Purkayastha et al. 2020).

Boiga gocool (Gray, 1835) is a nocturnal, arboreal, mildly venomous snake that occurs in tropical semi-evergreen and degraded forests, tall grasslands, and tea gardens at lower elevations of 50–1,000 m (Das et al. 2010; Wallach et al. 2014). It feeds mainly on lizards but sometimes also on small birds and mammals. *Boiga gocool* is poorly known, has a narrow distribution, and is thus rarely reported in regional inventory reports with only a few preserved specimens in scientific collections (Das et al. 2010). This is a southern Asian species having definite distribution records from northern and eastern India, Bangladesh, and Bhutan (Ahsan et al. 2015; Das et al. 2016). Of late, a few records of this species were reported from many other places. In India, *B. gocool* is reported from Assam- Manas National Park, Guwahati (Purkayastha et al. 2011), Kaziranga National Park (Das et al. 2007), Arunachal Pradesh, Manipur, Meghalaya, Nagaland (Das et al. 2007; Bhupathy et al. 2013), Sikkim (Chettri et al. 2011), West Bengal (Das et al. 2007), northern Odisha (Mohalik et al. 2020), and Uttar Pradesh (Choure et al. 2020). It has been listed as Schedule IV species under the Indian Wildlife (Protection) Act, 1972 (Ahmed et al. 2009) whereas under IUCN Red List category, it stands as 'Not Evaluated'.

In this note, we report our sighting of *B. gocool* in Tripura state. The current survey site is situated within the Khowai district of Tripura (24.064N & 91.596E;

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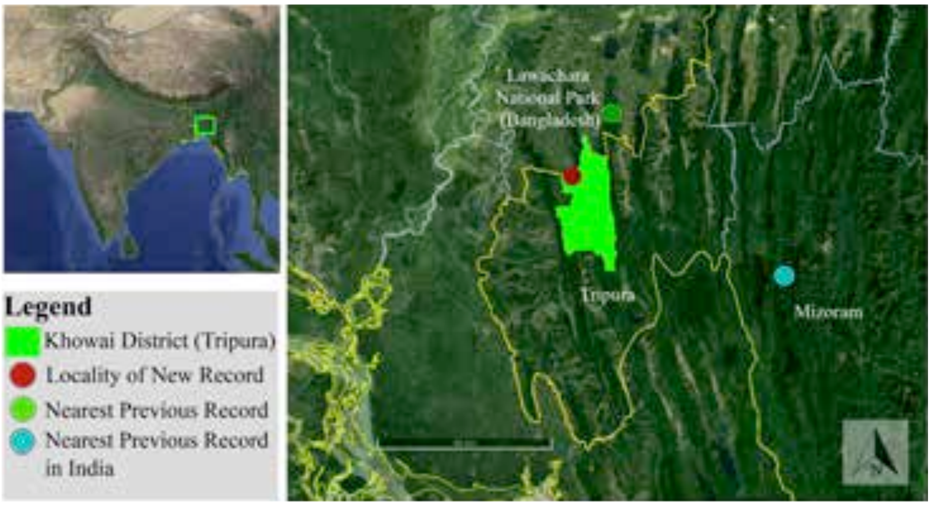

Image 1. Showing new locality record of *B. gocool* in India and its nearest previous records. © Google maps.

129m), the forest patch of the survey area was primarily mixed moist deciduous type (Choudhary et al. 2019) having tree species like *Tectona grandis*, *Shorea robusta*, *Dalbergia sissoo*, *Bombax ceiba*, *Phayllanthus emblica*, and *Mangifera indica* spread over an undulating terrain with moderate canopy cover.

The observation made by us was based on opportunistic sightings in the field. On 12 July 2020, during a field visit to Khowai, we noticed a snake passing by near the Khowai river bridge at evening 1539 h. The snake was restrained using a snake hook with utmost safety for making morphological observations and measurements. Photographs were taken using DSLR camera. The length of the individual from snout to vent (SVL) was measured by measuring tape. Gender was confirmed by observing everted hemipenis of the individual and subsequently, the snake was released where it was initially observed.

The recorded individual showed morphological characters as follows: triangular head, distinctly broader than the neck; dorso-laterally compressed body consisting of yellowish-brown dorsal colour with paired dorsolateral series of 45 black vertical Y-shaped markings on the either side which was separated from one another only by the light yellowish vertebral scale row; black markings edged with white; anterior-most six Y-shaped markings fused to form small black lines; markings broken down to small black spots posteriorly; tail with a few small irregular brownish spots, but without markings towards the tip; a large dark brownish arrow-shaped mark with darker edges begins at the posterior part of the inter-nasals, covering the top of the head; an arrow shaped mark followed by black, round spot on nape (Image 2a); a black postocular stripe extending from jaw angle to neck, ending at lower 3rd dorsal scale row; supra-labials and infra-labials white, with small black markings on sutures; pupil black with yellow iris; ventral yellowish-white with small black spots at the lateral edges (Image 2b). The gender of the individual was confirmed as male, by observing everted hemipenis. The length of the individual from snout to vent (SVL) measured 652 mm and tail length (TL) was 165 mm. Comparing the above data with the identification keys and descriptions specified in standard literature (Whitaker & Captain 2008; Ahmed et al. 2009; Das et al. 2010; Mohalik et al. 2020) the snake was positively identified as *Boiga gocool.*

Comparing the morphological characteristics between the known *Boiga* species in northeastern India, it is evident that the dorsolateral series of 45–50 dark brownish and whitish edged Y or T shaped marks, divided by distinct light vertebral scale row and a narrow black diamond or circular shaped nuchal dot, that never reaches to the sides of the body were major distinguishing characteristics of *B. gocool* (Table 1). In the past, much confusion existed regarding distinguishing between *B. gocool* and its closely related and one of the most widely distributed yet poorly studied congener in Indian subcontinent, *B. t. trigonata* (Das et al. 2010). Regardless, *B. gocool* has a lot in common with *B. t. trigonata* in terms of habits, body proportions, and skin colour, but *gocool* can be differentiated from *trigonata* by strongly enlarged vertebral scales and an entirely distinct head and dorsal body colour pattern, and dorsolateral series of 45–50 dark brownish and whitish edged Y-shaped marks which are prominently divided by a light vertebral scale row; whereas *B. trigonata* has yellow to whitish, dark edged, angular markings,

Table 1. Morphological comparisons of body (dorsal and ventral), head and tail morphology between *B. gocool* and other congeneric species from the Indo-Burma hotspot.

Species	Dorsal body	Ventral body	Head and tail	Distribution in Indo-Burma	References
gocool	Dorsal colour yellowish-brown; dorsolateral series of 45–50 dark brownish and whitish edged Y or T shaped marks.	Light yellowish- brown ventral colour with small dark brown margins or pattern less.	Head noticeably larger than neck; wide eye with vertical pupil, long tail.	Arunachal Pradesh, Assam, Nagaland, Manipur, Mizoram, Bhutan, and Bangladesh.	Das et al. 2010; Das et al. 2016; Lalremsanga & Lalronunga 2017; Whitaker & Captain 2008
cyanea	Dorsal colour uniform green or greyish- or bluish-green; black Interscale colour, same colour on the head and few dorsal scales.	Greenish- or yellowish-white belly; subcaudal scales are paired in a zig-zag pattern.	Head triangular with rounded tip, distinctly wider than body. Top of the head is normally same colour as the dorsal or has a brownish hue. Like other arboreal snakes, long thin tail with pointed tip.	Arunachal Pradesh, Assam, Meghalaya, Mizoram, Sikkim, Bangladesh, and Bhutan.	Das et al. 2010; Lalremsanga & Lalronunga 2017; Whitaker & Captain 2008
multifasciata	Dorsal pattern made up of narrow black irregular transverse bands separated by reddish-brown vertebral scale lines.	Ventral surface greyish- to reddish-brown.	Head wider than neck; large eye has vertical pupil. Long tail. Two black lines run across the top of the head; another runs down the neck, a black stripe runs behind the eye.	Arunachal Pradesh and Sikkim.	Tshewang, & Letro 2018; Das et al. 2010; Whitaker & Captain 2008
multomaculata	Dorsal colour is greyish-brown with dark brown markings, black edges, and brown; double series of conspicuous spots present.	Ventral colour is greyish-brown or impure white, marked with brown spots.	Head noticeably larger than neck; eye with vertical pupil; long tail.	Arunachal Pradesh, Assam, Nagaland, and Bangladesh.	Das et al. 2010; Whitaker & Captain 2008
ochracea	Dorsal body coral red, reddish- or yellowish-brown.	Scales on the anterior belly are yellow, while those on the mid-body and tail tip are light brown.	Head larger than neck; wide eye with vertical pupil; tail long and thin.	Sikkim, Assam, Tripura, Mizoram, Bhutan, and Bangladesh.	Das et al. 2010; Lalremsanga & Lalronunga 2017; Majumder et al. 2012; Whitaker & Captain 2008
quincunciata	Fine dark brown spots and a dark brown vertebral series make up the dorsal pattern.	Outer edges of the ventral surface are yellowish-white with white or brown spots	Three longitudinal stripes on the nape; head and neck distinct; body slender and elongated; eyes wide with vertical pupil.	Arunachal Pradesh, Assam, Mizoram, and Bhutan.	Chaida et al. 2020; Das et al. 2010; Lalremsanga & Lalronunga 2017
siamensis	Dorsal body yellowish-brown; many large black or dark brown oblique bands or V-shaped markings.	Ventral surface yellowish- or greyish-brown, with small dark brown spots present sometimes.	Head wider than neck; large eye has vertical pupil; tail long.	Arunachal Pradesh, Assam, Mizoram, Meghalaya, Sikkim, Nagaland, and Bangladesh.	Das et al. 2010; Lalremsanga & Lalronunga 2017; Whitaker & Captain 2008
trigonata	Dorsal colour brown or tan; darker zigzag markings that are possibly connected.	Underside of each belly scale white or tan, small black spots on the outer edges.	Head wider than neck; Large eye with vertical pupil; tail long; distinct pale Y-shaped mark appears on top of the head, which often black-edged.	Sikkim.	Das et al. 2010

with irregular branching across the vertebral scale row, often connected in a zigzag manner. The sole congener of *B. gocool* recorded from the state was *B. ochracea* (Majumder et al. 2012; Purkayastha et al. 2020) which can be readily distinguished without confusion from *B. gocool* by its patternless or indistinct dark transverse dorsolateral bands on coral red, reddish- or yellowish-brown dorsal body (Table 1).

With the centre of radiation of *B. gocool* lying in the plains and low hills of north and south of the Brahmaputra valley, Assam, (Das et al. 2010), recent records of *B. gocool* from Odisha (Mohalik et al. 2020) and Uttar Pradesh (Choure et al. 2020), extend its known distribution range further to the south and west, respectively. The current record of *B. gocool* from Tripura eventually fills the void in its northeastern Indian distribution. The present survey site is about 40 km north-east from Agartala, the state capital and about 35 km south to the

Image 2. *Boiga gocool* with identification marks: a—Black Y-shaped vertical markings with white edges on either side separated from one another only by pale yellowish vertebral scale row; anterior most Y-shaped markings fused to form small black lines; dark brownish arrow-shaped mark covering the top of the head followed by a black, somewhat round-shaped spot on the nape | b—Black postocular stripe; white supralabials and infralabials with small black markings on their sutures; black pupil with yellow coloured iris; yellowish-white ventral with small black spots at the outer lateral edges. (© Sumit Nath).

nearest previously recorded locality for the species from Lawachara National Park, Sylhet District, Bangladesh (Rahman et al. 2013). The nearest occurrence of *B. gocool* from the present survey site, within northeastern India, is that of Mizoram (Lalremsanga & Lalronunga 2017; Choure et al. 2020). Despite being situated in the Indo-Burma biodiversity hotspot, Tripura is rather poorly studied from the herpetofauna assessment viewpoint. Most of the herpetofaunal studies were limited to a few taxa and locations of the state (Majumder et al. 2012; Purkayastha et al. 2020). Before the current record, only one species of the genus *Boiga* (*B. ochracea*) was reported from Tripura, whereas eight representatives of the genus have been reported and found to be occurring in northeastern India, partly sympatric with *B. gocool* (Table 1). Hence, the first record of *B. gocool* from this state will contribute towards updating the checklist of the herpetofauna of Tripura. Future studies on the genus *Boiga* and other snake species sympatric with *B. gocool* throughout the state is much needed.

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First record of the genus *Tibetanja* (Lepidoptera: Eupterotidae: Janinae) from India

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The family Eupterotidae Swinhoe, 1892, is represented by 60 genera and 396 described species worldwide (Kitching et al. 2018) of which, only 12 genera and about 40 species are known from India (Hampson 1892; Nässig & Oberprieler 2008). Hampson (1892) remains the only comprehensive work on Indian Eupterotidae, having provided a key to 14 genera occurring in the Indian subcontinent, of which two genera *Gangarides* Moore and *Thaumetopoea* Hübner (= *Cnethocampa* Stephens) have since been transferred to Notodontidae (Grünberg 1912).

A new genus *Tibetanja* Naumann, Nässig, & Rougerie was described by Naumann et al. (2020) from Tibet. Although the affinities of this new genus were not clear, it was placed in the subfamily Janinae based on the morphological characters of the male genitalia. This genus currently comprises of the single species *T. tagoroides* which is known only from Tibet. In the present paper, we report this genus from India.

Moths were surveyed from 23–25 September 2014 and 5–7 September 2019 in two locations of Arunachal Pradesh, namely, the lower Dibang valley (28°764'N, 95°961'E) and Tale Valley Wildlife Sanctuary (27°328'N, 93°538'E), respectively. In the September 2014 survey, a mercury vapour lamp of 160W was hung in front of a white cloth for documenting moths and during September 2019, a LepiLED Maxi (Brehm 2017) supported by three 20,000-mAH Li-polymer power bank was used. No insects were collected, and individual moths were only photographed on the moth screen in both the surveys. The field images of live moths were taken using Nikon D3200 with an AF-S DX Nikkor 18–55mm f/3.5–5.6G VR II lens.

The images were sent by the second author to Mr. Peter Smetacek, Butterfly Research Centre, Bhimtal for identification and confirmed by Dr. Stefan Naumann, Berlin, Germany (pers. comm. 14 December 2020).

Genus *Tibetanja* Naumann, Nässig & Rougerie, 2020

(Naumann, Nässig & Rougerie, 2020; *Nachr. entomol. Ver. Apollo, N. F.*41 (3/4): 148)

Type species: *Tibetanja tagoroides* Naumann, Nässig & Rougerie, 2020

Type locality: Xizang Zizhiqu, Tibet, China.

Diagnostic characters: This genus is recognized by a typically broad and crenulate median line on both the

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wings and forewing margin rounded and ending in an acute tip, markedly pointed apex. Male genitalia with long, slender scoop-like uncus with two apical lateral teeth, gnathos with two long lateral processes. Valves rectangular with internal process emerging from the ventral margin and with two longer projections. Juxta small, rounded and phallus not fused with juxta as given by Naumann et al. (2020). Within Janinae, the genitalia of *Tibetanja* is somewhat close to *Hoplojana* Aurivillius, 1901 and also some '*Ganisa*-group' as discussed in Naumann et al. (2020) while describing this new genus.

Tibetanja tagoroides Naumann, Nässig & Rougerie, 2020

(Images 1 & 2)

Diagnostic characters: This species has been adequately described and illustrated by Naumann et al. (2020) can be easily identified by: the forewing with dark grey median line and zigzag postmedian line; a small black dot present in the basal-median area of both the wings; forewing with apex acute. *T. tagoroides* superficially resembles some species of the genus *Tagora* Walker, 1855 by having forewing with produced

Image 1 & 2. Records of *Tibetanja tagoroides*: 1—From lower Dibang Valley, Mishmi hills, 23–25.ix.2014, © © Alka Vaidya | 2—From Tale Valley Wildlife Sanctuary, 5–7.ix.2019, © Sankararaman. H.

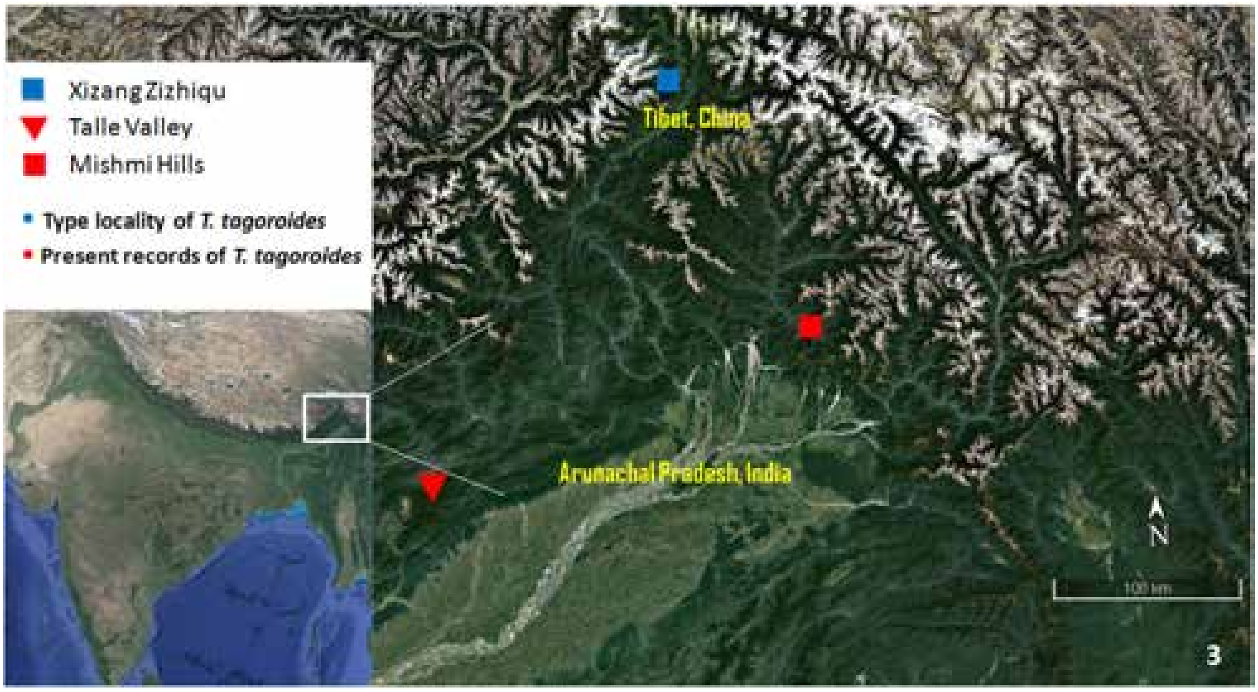

Image 3. Distribution of *Tibetanja tagoroides.*

apex. The immature stages and female of this species still remain unknown.

Distribution: India (Arunachal Pradesh – new record) and China (Tibet) [Naumann et al. (2020)].

Remarks: The present sightings of *Tibetanja tagoroides* from Tale valley and lower Dibang valley of Arunachal Pradesh form significant records and extend the known distributional range of this genus to northeastern parts of India, from its earlier reported distribution in Xizang Zizhiqu of southern Tibet, Chinese province (Image 3) and increases the known Indian Eupterotidae fauna to 41 species of 13 genera.

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NOTE

Austroborus cordillerae (Mollusca: Gastropoda) from central Argentina: a rare, little-known land snail

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To the north-west of Córdoba, in the central region of Argentina, there is an evolutionarily diverse land snail fauna dominated by endemic species. Such is the case of the two most abundant and diverse genera *Plagiodontes* and *Clessinia* (Pizá et al. 2006; Pizá & Cazzaniga 2010; Cuezzo et al. 2013, 2018).

This article concerns another land snail from the region, *Austroborus cordillerae*, which is a little-known species found infrequently (Klappenbach & Olazarri 1989; Gordillo et al. 2015). The lack of information on this species means that its state of conservation has not yet been categorized and it could be on the verge of extinction. This work therefore provides updated information on the records of this species by incorporating data collected in museums and new field findings.

Austroborus is recognized through three species with disjunct distribution: *Austroborus lutescens* (King), which lives in Uruguay (Scarabino 2004), *Austroborus dorbignyi* (Doering) from the south of Buenos Aires, Argentina (Delhey et al. 2005) and *Austroborus cordillerae* (Doering), from the north-west of Córdoba, Argentina (Gordillo et al. 2015). This genus is reduced in size (35 mm high) compared to other representatives of the Strophocheilidae family (i.e., *Megalobulimus*, 85 mm high). The species *A. cordillerae* is somewhat larger than the other two, and is characterized by the coloration of the peristome (intense orange) and the sculpture of the proto-shell with intersecting radial and axial ribs (like a lattice), with small globular thickenings standing out in the intersection areas (Image 1). Unfortunately, these structures are not always well-preserved due to natural erosion or wear. Our diagnostic references only use the shell, since very little is known about the soft parts, except for a short description of a section of the radula (maxilla) given by Klappenbach & Olazarri (1989). The paratype of *A. cordillerae* is housed in the Senckenberg Natural History Museum in Frankfurt (Zilch 1971).

The new records are 10 fossil (late Quaternary) shells from the Olaen pampa (Image 2; 1,100 m) and one modern specimen (shell) from Ongamira (Image 2; 1,160 m). In addition, 14 specimens that are part of museum collections or institutions were included (most of them

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Image 1. Apertural views of adult shells of *Austroborus cordillerae*: a—modern | b—recent specimen | c—details of the spire of specimen. © Sandra Gordillo.

are from archaeological sites), together with nine more modern specimens from different sources (specimens offered for sale via internet). When added to the previous 13 records summarized by Gordillo et al. (2015), these 34 new records considerably increase the number of specimens documented so far.

Based on all the information collected, it is interpreted that the development of the species would have reached its peak in the Olaen pampa, where it was recorded in late Quaternary sediments, probably of Pleistocene age. After that, *Austroborus* drastically decreased in number. This assumption is sustained through field observations in the provenance locations of the shells and previous studies carried out in the province of Córdoba to address climatic changes along the late Quaternary using different geological and biological proxies (Carignano 1999; Andreazzini et al. 2013; Córdoba et al. 2005; Giorgis et al. 2015; Gordillo & Boretto 2020).

However, despite its retraction in the Olaen pampa, we know that the species continued to live during the late Holocene, since it was found alive in the Achala pampa around 1885 and in the Ongamira valley in 1928 (Klappenbach & Olazarri 1989).

Thus, other factors would also have affected its retraction in the last millennium. In this sense, towards the end of the Holocene, the colder and drier climate, and practices associated with exotic livestock such as the burning of pastures, could have been the causes of their extinction in both the Achala and Olaen pampas. For the mountainous sector of Córdoba, including the high pampas, there is a history of four centuries of domestic grazing and man-made fires as a management practice, which have caused erosion, reduction of vegetation cover and shrinkage of forests (Díaz et al. 1994; Renison et al. 2006; Cingolani et al. 2008, 2013). Although there is no precise information on the effect of fire on mollusk species in the region, field observations in the Olaen pampa made it possible to verify the presence of a large number of burnt shells from different gastropod species (e.g., *Plagiodontes*, *Clessinia*, *Epiphragmophora*) as a result of the fires that raged in the region during the spring of 2020. Studies under controlled conditions by other authors with other species have also shown that, in addition to the death caused by forest fires, the altered habitat after a fire also affects the survival of snails (Ray & Berger 2015). Thus, bush burning over the years as an animal breeding practice must also be considered as a factor or threat to these and other species living today.

Finally, for Ongamira, a recent finding (March 2020) of a modern *Austroborus* shell, together with scattered data on specimens collected in the last 10 years (by collectors or for sale), suggests that there could be a relict population of this species. However, this information on 'collecting' should also lead us to reflect on the effects of these very practices and to consider them as an additional threat; one that could also severely affect some relict populations in this locality.

To conclude, it appears that a set of factors (climatic and anthropic) acting over time caused the retraction of this endemic snail.

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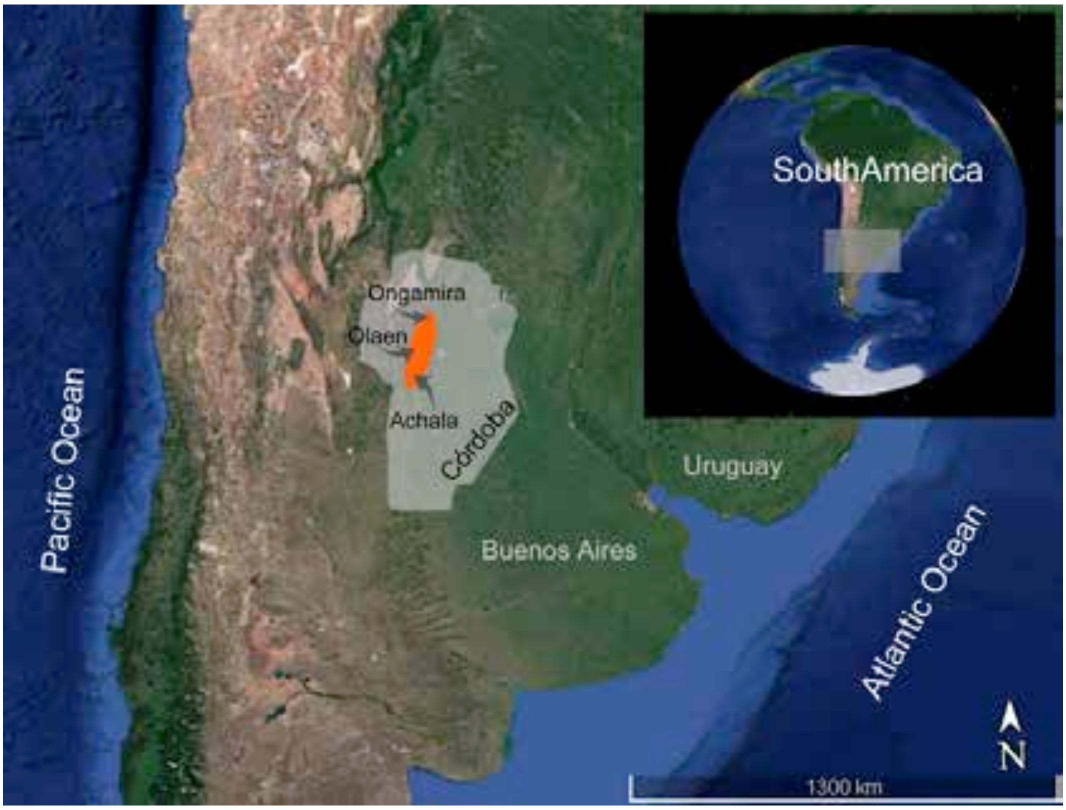

Image 2. Distribution area of *Austroborus cordillerae* (orange area) in central Argentina, South America.

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Intestinal coccidiosis (Apicomplexa: Eimeriidae) in a Himalayan Griffon Vulture *Gyps himalayensis*

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The Himalayan Griffon Vulture or Himalayan Vulture *Gyps himalayensis* is an Old World scavenger. It is closely related to the European Griffon Vulture G. *fulvus* and is found along the Himalaya and the adjoining Tibetan plateau. It is one of the largest, heaviest, and true raptors. Adults have a long and spiky ruff as pale brown with white streaks. They all have a large wingspan, which allows them to soar with little effort. The head is covered down with yellowish colour in adults and whitish in immature vultures. The under-wing coverts are quite pale brown or buff, being almost white in some specimens. The legs are covered with buffy feathers and the feet can vary from greenish-grey to white. The upper side is unstreaked, pale buff with the tail quills, outer greater coverts and wing quills being a contrasting dark brown. The inner-secondaries have paler tips.

Coccidiosis is an old protozoan parasitic disease, prevalent worldwide and has an inhibitory role in the growth of poultry production industries by disease complex, caused by different species of the parasite *Eimeria*. Coccidia affect both clinically and sub-clinically. The clinical form of the disease manifests through prominent signs of mortality, morbidity, diarrhoea or bloody faeces, and sub-clinical coccidiosis manifests mainly by poor weight gain and reduced efficiency (Williams 1999). The present paper highlights the hemorrhagic intestinal coccidiosis in the Himalayan Griffon and its importance in wildlife conservation.

A carcass of a free-ranging juvenile Himalayan Griffon from the Haldwani forest range division, Nainital, Uttarakhand was brought in for treatment. The fecal sample was placed in a 100 ml beaker and emulsified with 10–15 ml of water, strained, and centrifuged. A drop of sediment was examined under both low and high power objectives, microscopically (Soulsby 1982) for the presence/absence of parasitic *Eimeria* oocyst.

Microscopic examination of fecal sample from Himalayan Griffon carcass revealed the presence of parasitic *Eimeria* oocyst and confirmed based on the key points oocysts containing four sporocysts each with two sporozoites (Soulsby 1982; Urquhart et al. 1994).

If the oocysts from fecal samples are higher in number preferably coupled with typical clinical signs like bloody diarrhea, hemorrhages in the concerned birds, then the clinical approach should associate the usage of specific drugs like amprolium @ 3 ml of 9.6 per cent solution or potentiated sulphonamide drugs (Jayathangaraj et al. 2008).

Dolnik et al. (2010) reported that the prevalence of infection and intensity depended on the stratum, the gregariousness and the diet of the hosts. Aerial feeders had the lowest prevalence and intensity of infection, besides ground feeders the highest prevalence due to exposure by faeco-oral contamination. Coccidia were

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Image 1. Infected bird prior to death.

Image 2. Gross lesion showing severe intestinal hemorrhage.

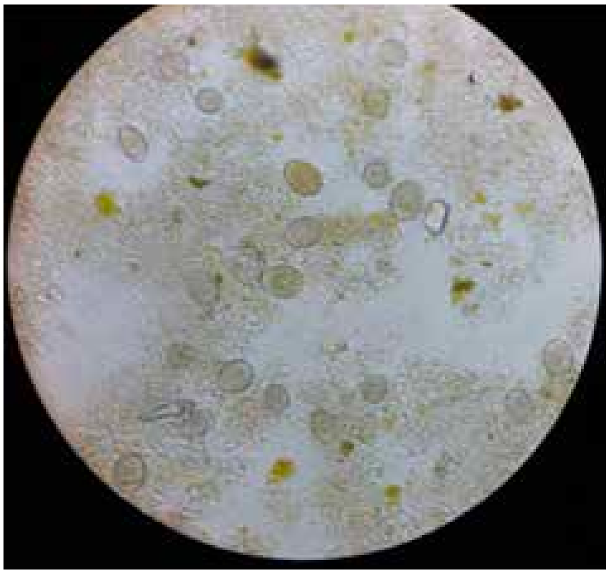

Image 3. Oocyst showing sporocyst.

very sensitive to direct sunlight and desiccation, when in shady and humid ground would provide the optimal habitat to survive and transmit infectious oocysts.

Coccidiosis is a serious and widespread disease of birds and needs periodical examination and continuous monitoring. Interestingly, the prevalence and presence of *Eimeria* sp. infection in Himalayan Griffon needs attention as it causes severe enteritis and mortality. However, the life cycle of coccidian parasites in free ranging wild birds and their disease transmission needs to be researched in detail.

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NOTE

Two new additions to the orchid flora of Assam, India

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Orchidaceae is one of the largest family and highly advanced monocotyledonous plants consisting of c. 28,000 species under 736 genera in the world (Chase et al. 2015; Christenhusz & Byng 2016). *Bulbophyllum* Thouars is one of the largest genera of Orchidaceae comprising c. 2000 species distributed in tropical and subtropical region of the world (Pearce & Cribb 2002; Pridgeon et al. 2014; Averyanov et al. 2018). In India it is represented by 134 species, including one subspecies, and two varieties (Singh et al. 2019). In northeastern India the genus is represented by 75 species and three varieties (Rao 2007). Assam contains 35 species and two varieties (Gogoi 2017).

During a floristic survey in Ultapani Forest of Chirang Reserve Forest, Kokrajhar under the Manas Biosphere Reserve, Assam, some specimens of *Bulbophyllum* were collected. To verify the identity of these specimens, we undertook morphological comparisons to earlier collections based on online available herbarium specimens at L, K, AMES, NY, P and consulting relevant literature (Averyanov & Averyanova 2003; Vermeulen & Byrne 2011; Wood et al. 2011; Averyanov 2013; Li et al. 2013; Vermeulen et al. 2015; Averyanov et al. 2016).

After critical examination these specimens were found to represent *B. tenuifolium* (Blume) Lindl. and *B. parviflorum* C.S.P. Parish & Rchb.f. which are hitherto unrecorded for Assam state (Bose & Bhattacharjee 1980; Sarkar 1995; Misra 2007; Rao 2007; Gogoi 2017; Mao & Deori 2018; Singh et al. 2019; Singh & Ranjan 2021) and are therefore reported here as new records to the flora of Assam. Of them, *B. tenuifolium was* earlier recorded from Andaman & Nicobar Islands by Kumar & Sreekumar (2002).

Representative specimens of the species are deposited in Herbarium of Botanical Survey of India (BSI), Andaman & Nicobar Regional Centre Herbarium (PBL) and Bodoland University Botanical Herbarium (BUBH), Kokrajhar, Assam. Field photographs of the species are provided for easy identification.

***Bulbophyllum tenuifolium* (Blume) Lindl. (Figure 1 & Image 1)**

Gen. Sp. Orchid. Pl.: 50 (1830); *Diphyes tenuifolia* Blume, Bijdr. Fl. Ned. Ind.: 316 (1825). *Phyllorkis tenuifolia* (Blume) Kuntze, Revis. Gen. Pl. 2: 678 (1891). *Bulbophyllum angulatum* J.J.Sm., Bull. Dép. Agric. Indes Néerl. 15: 19 (1908). *Bulbophyllum microstele*

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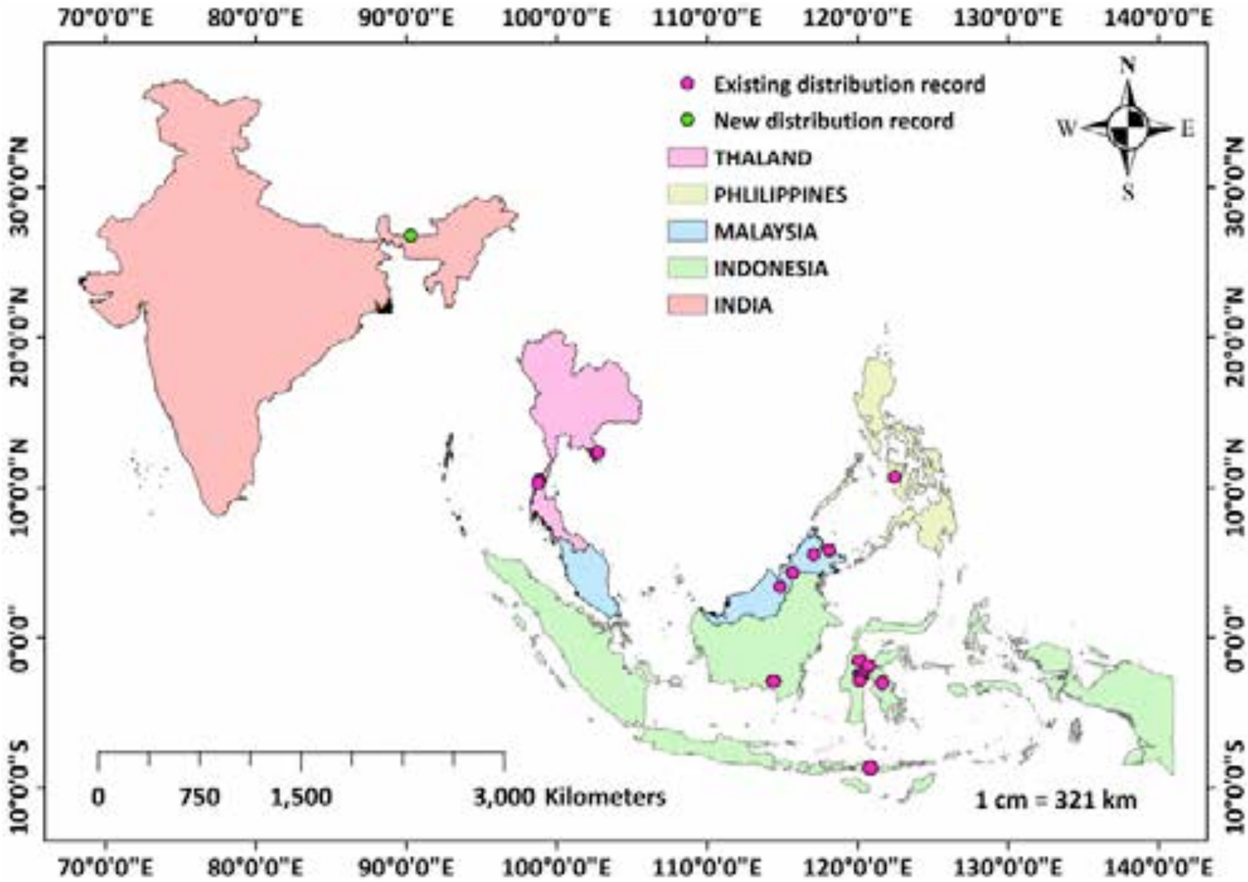

Figure 1. Distribution of *Bulbophyllum tenuifolium* (Blume) Lindl. across the world (Data shows as per GBIF).

Schltr., Repert. Spec. Nov. Regni Veg. 8: 569 (1910). *Cirrhopetalum chryseum* Kraenzl., Repert. Spec. Nov. Regni Veg. 8: 97 (1910); *Bulbophyllum chryseum* (Kraenzl.) Ames, Philipp. J. Sci., C 6: 54 (1911). *Bulbophyllum nigromaculatum* Holttum, Gard. Bull. Singapore 11: 276 (1947). *Bulbophyllum konstantinovii* Aver., Turczaninowia 16(4): 29 (2013).

Type: Indonesia: Java, Salak (?), coll. Blume 639 (L, holotype HLB 902.322479). Malaysia: Sarawak, Bei Kutching, 13.xii.1926, coll. Schlechter 15835 (K!, isotype [K000829845]).

Description: Dwarf creeping epiphyte, rhizome wiry, thin, greenish on young, later whitish-grey, 0.6–1 mm in diameter, pseudobulbs 0.7–2.2 cm apart from each other; green to yellowish-green, ovate, 5–10 mm tall, 2–6 mm in diameter, oblique in slightly bending to rhizome, longitudinally irregularly grooved with single apical leaf; leaves leathery, narrowly ovate, 1.5–5 × 0.4–1 cm, apex obtuse, petiole very short or subsessile; inflorescence arising from the base of pseudobulb, sometimes from the matured rhizome, 1.5–3 cm long, with single terminal flower, ascending, filiform, glabrous, light yellowish-green; stalk 1–2 cm long with small bract at the base; bracts 0.5–1 mm long, 0.2–0.3 mm in diameter; pedicel 6–10 mm long, filiform; flowers 1 cm across, with spreading lateral sepals; sepals light dull-yellowish with purple brown stripes, 4–6 × 1–2 mm, three distinct nerves, apex acute; median sepal elliptic with more darker stripes; lateral sepals narrowly ovate, spreading, slightly longer than the median sepals, slightly oblique at base; petals oblique ovate, 1.5–2 × 1–1.3 mm, bright-yellow, apex acute, margin with irregular dark purple spots; lip simple, elliptic 3–5 × 1–1.5 mm, yellow, base narrowing, forming bending neck, jointed with column foot apex; column erect, c. 0.8 × 0.5 mm, bright-yellow, apex with 2 straight, c. 0.6 mm long stelidia; column head broadening into cup-shaped, c. 1 × 1 mm, operculum concave, ovoid, c. 0.4 mm, yellow; pollinia 2, globose, yellow.

Flowering & fruiting: November–January.

Distribution: India (Andaman & Nicobar Islands, Assam), Borneo, Cambodia, Java, Lesser Sunda Island, Malaysia, Philippines, Sulawesi, Sumatra, Thailand.

Habitat & ecology: Epiphytic on small branches of

Image 1. *Bulbophyllum tenuifolium* (Blume) Lindl.: A & B—Habit | C & D—Flowers | E—Showing stelidia | F—Petals | G—Lip | H & I—Pollinia | J—Anther cap. © Sanswrang Basumatary.

trees in evergreen or semi-evergreen humid forest along a stream at elevations of 100–700 m.

Specimens examined: India: Assam, Chirang Reserve Forest, Ultapani, 197m, 18.i.2021, coll. Sanswrang Basumatary & Sanjib Baruah, 0268 (BUBH, acc. no. 0000411). Andaman & Nicobar Islands, Middle Andaman, Kadamtala Reserve Forest, 01.xi. 2012, coll. Lal Ji Singh, 29572 (PBL, acc. no. 38319); Little Andaman, Krishna Nallah, 13.x. 2015, coll. Lal Ji Singh, 29673 (PBL, acc. no. 38320). Philippines: Leyte, Panda, Dagami, 11.v.1913, coll. C.A. Wenzel, 93 (NY, 04012457), (AMES, 00000415).

Bulbophyllum parviflorum C.S.P. Parish & Rchb.f.
(Figure 2 & Image 2)

Trans. Linn. Soc. London 30: 152 (1874); *Phyllorkis parviflora* (C.S.P.Parish & Rchb.f.) Kuntze, Revis. Gen. Pl. 2: 677 (1891). *Phyllorkis thomsonii* (Hook.f.) Kuntze, Revis. Gen. Pl. 2: 677 (1891); *Bulbophyllum thomsonii* Hook.f., Fl. Brit. India 6: 764 (1894).

Type: Myanmar: Tenasserim, coll. Parish 305 (W, holotype Herb No. 2273; K!, isotype [K000829138]).

Description: Rhizomes branched, pseudobulb compressed globose, with apical point, 1–1.5 cm in diameter, 3.5–7.5 cm apart; petiole up to 2.5 cm long; inflorescence arising from the base of mature pseudobulb, up to 20 cm long, many flowered; flower c. 4 mm in diameter, pedicels 2–4 mm long, green; bracts (found on peduncle) c. 8 mm long, c. 3 mm diameter, encircled the peduncle, brown, apex acute; bracts (found at the base of pedicel) 2.5–4 mm long, ovate-lanceolate, apex acute-acuminate, glabrous; sepals pubescent at margin, c. 4 mm long, c. 1.5 mm at base, median sepal c. 2.5 mm long, c. 1 mm in diameter at base; petals c. 2 mm long, c. 1.5 mm in diameter, margin pubescent, white, lip c. 3 mm; anther cap c. 0.4 mm, brownish; pollinia 2, c. 0.3 mm, yellow.

Flowering & fruiting: November–January.

Distribution: India (Arunachal Pradesh, Assam, Manipur, Mizoram, Sikkim, West Bengal), Bhutan, Cambodia, China, Laos, Myanmar, Thailand, Vietnam.

Habitat & ecology: Epiphyte on branches of trees in semi-evergreen humid forest along a stream over tiny stones bedrock at elevations of 100–350 m.

Specimens examined: India: Assam: Chirang Reserve Forest, Ultapani, 215 m, 11.i.2021, coll. Sanswrang Basumatary & Sanjib Baruah 0268 (BUBH, acc.no. 0000405). Sikkim, 1850, coll. Thomson s.n. (K, K000829139). Sikkim, 3000 ft, ix.1898, coll. Pantling 245 (P, P00362005), (L, L. 1488763).

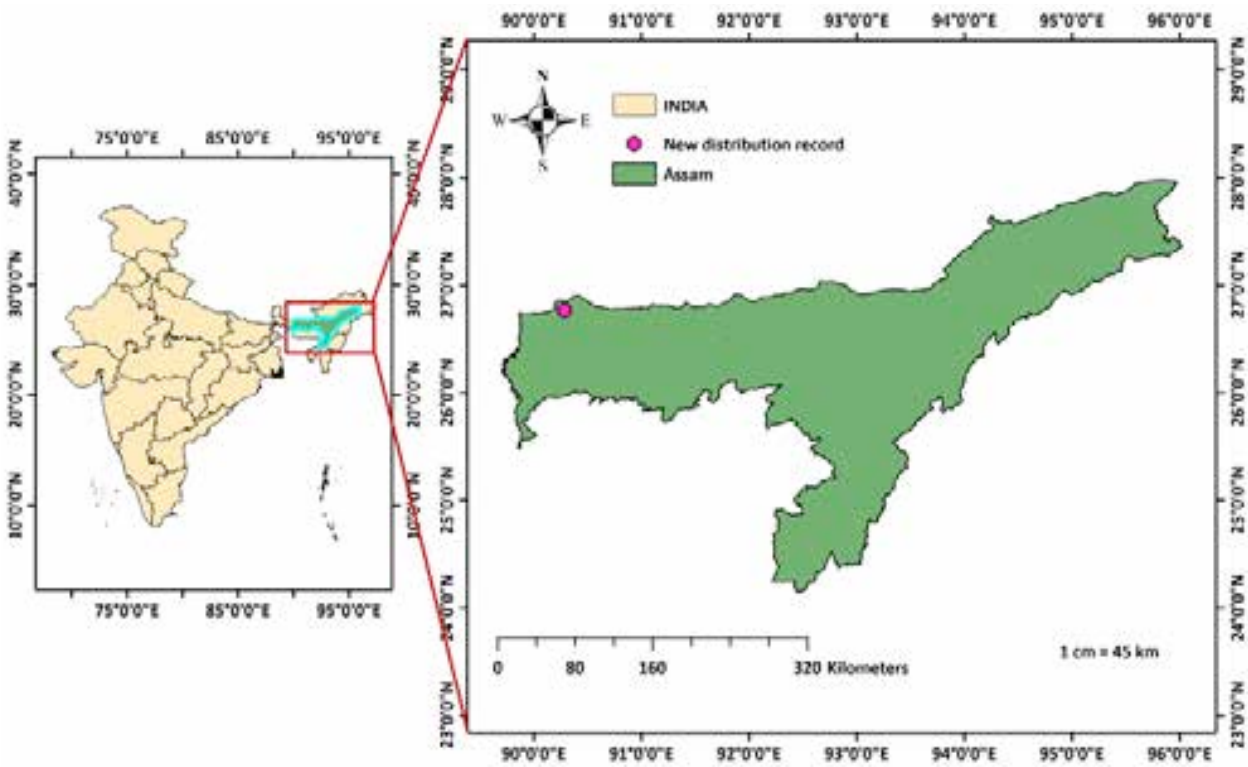

Figure 2. Distribution of *Bulbophyllum parviflorum* C.S.P. Parish & Rchb.f. in Assam.

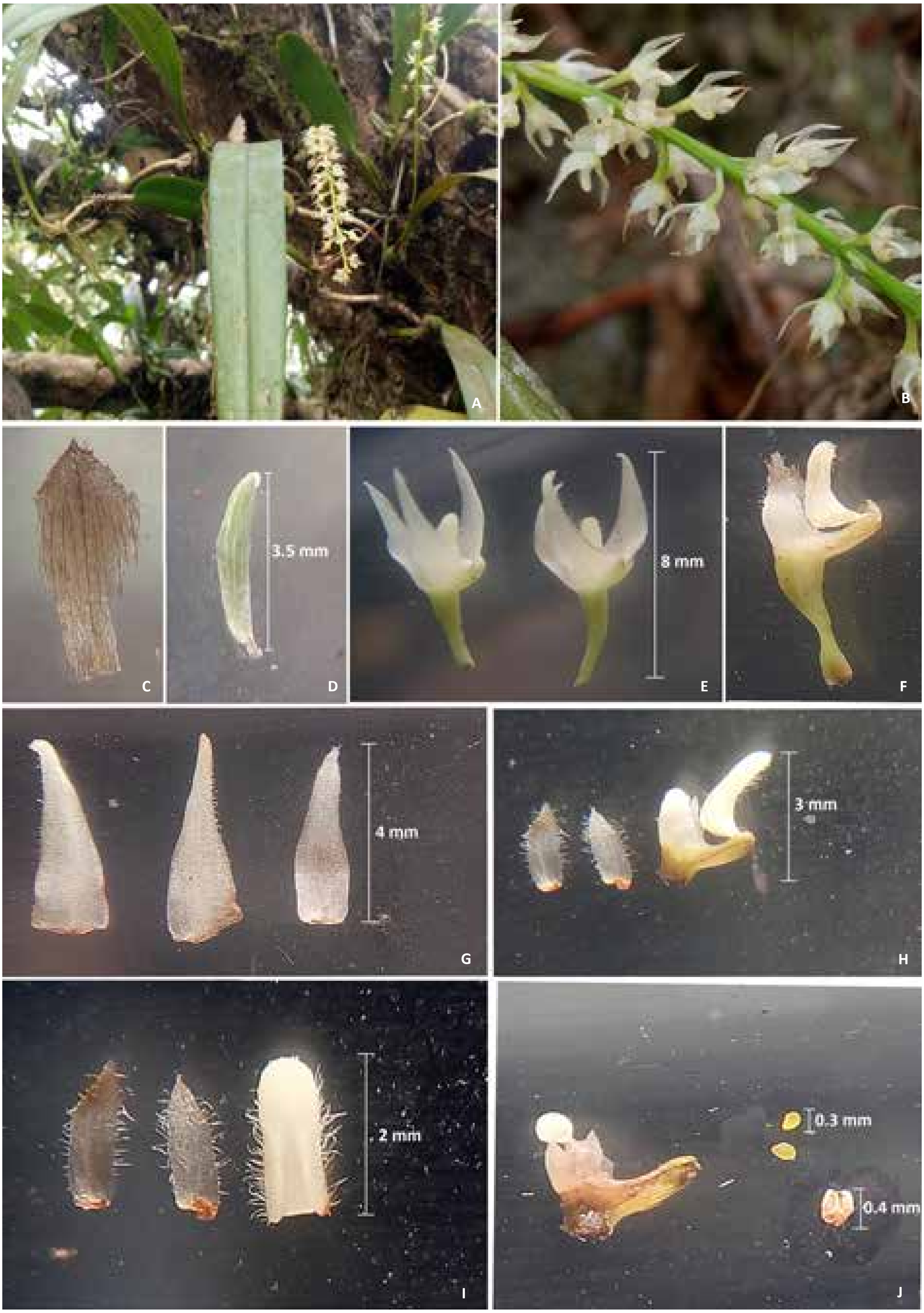

Image 2. *Bulbophyllum parviflorum* C.S.P. Parish & Rchb.f.: A—Habit | B —Inflorescence | C & D—Bracts | E—Flowers | F—Flower after removing sepals | G—Sepals | H & I—Petals and lip | J—Stelidia, Pollen and Anther cap. ©Sanswrang Basumatary.

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NOTE

Wildlife art and illustration – combining black and white ink drawings with colour: some experiments in Auroville, India

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Representing experiences concerning nature, with the variety of material and concepts at our disposal during present times, is a personal, and in our case, collective interpretation (Ramanujam & Brooks 2011). Huffington (1988), author of Pablo Picasso's biography mentions that he said, "nature has to exist so that we may rape it" But we are not here to judge anybody, and everyone is entitled to his / her own opinion, though one may vehemenantly disagree, mildly disagree or agree. In our opinion we are simply here to find new ways of expression, experiment and probably come up with something original and worthwhile, not to merely hold on to some ideology / media that has worked in the past. The 'eternal adventure' and thrill that comes from exploring new boundaries has most of us in its thrall and pushing beyond boundaries can often bring in a breath of fresh air that is a 'feeling' one cannot put into proper prose.

Here we deal with complete opposites: viz. a purist black and white medium (Ramanujam & Joss 2014) versus colour where we have made some headway in combining both media to express a fulfilling mode of expression.

There have been some artists who have used the technique of combining black and white pen and ink with paints which allows achieving a high level of control and detail in conjunction with aesthetic colour washes. One such artist has been Angus Fraser who works primarily with natural subjects and enjoys representing subjects in delicate but dynamic compositions. But unfortunately, not having a taxonomical background, his compositions tend to be stilted, especially his wildlife imagery. One such example can be seen in his rendering of a Wedge-tailed Eagle on its nest where he shows the step by step development of the final product <instructables-com/ Ink-Pen-Watercolour-Drawing>

Our experiments centre on scientific precision which combine pen and colour, especially watercolour pencils, though we have worked with both transparent and opaque washes at times. This work can be seen on the covers of *Journal of Threatened Taxa* for the year 2015. Our basic style of combining black ink with colour is that the colour is minimal, hence you may generally not see the entire animal in colour (though there have been exceptions), but only what we felt were the highlights – we allow the line work to speak for itself and allow black and white to emerge as the principal factor.

Our style of illustration concerning colour has often been said to be minimalistic, which it is. Minimalism is a comparatively recent art form. It began with the 'De stijal art movement' (also called Neoplasticism) which was in fashion in between 1917 to 1930. It pushed simple (and often abstract ideas) using lines, black and white, and simple colours to create new effects which

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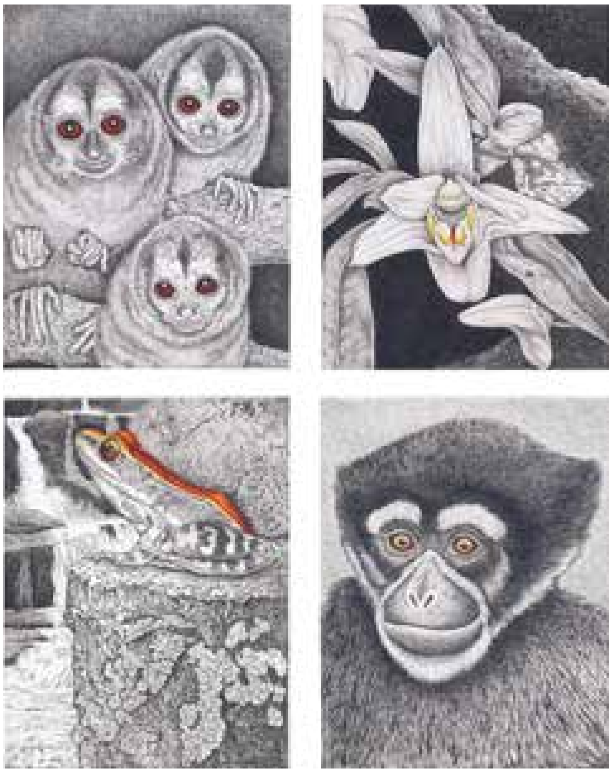

Image 1. It all started with JoTT's chief editor requesting the principal author of this article to create drawings with a difference for the journal cover in 2015. It was thought that it was a time to experiment, hence though we kept the onus on black and white we added poster colour to highlight salient features of the animals which could not be satisfactorily represented in monotone. Species depicted: Peruvian Night Monkey *Aotus micronax* (top left), Orchid *Conchidium braccatum* (top right), Fungoid Frog *Hydrophylax bahuvistara* (bottom left), and Eastern Hoolock Gibbon *Hoolock leuconedys* (bottom right).

Image 3. We next began drawing for projects we had undertaken. These images were executed during a biodiversity survey we had undertaken in the Kiliyur Falls area in Yercaud, Shevroy Hills in the Eastern Ghats of Tamil Nadu. Here we employed watercolour pencil and from that time it has remained our favourite mode as it prevents the ink running or smudging.
Species depicted: Crested Serpent Eagle *Spilornis cheela* (top left), and the Orange Minivet *Pericrocotus flammeus* and Kiliyur Falls at the bottom. On the top right is the Sheildtail *Uropeltis shorttii* - it had been assumed to be *Uropeltis ceylanicus* in the past, but it was found to be different (Ganesh et. al. 2014). The holotype (first recorded specimen to science) which our team from Pitchandikulam collected now rests with the Zoological Survey of India, Southern Regional Station.

Image 2. We also experimented with watercolour washes, but these showed very mild signs of smudging the ink. In this case the rendering of Denison's or Torpedo Barb *Sahyadria denisonii*. It is probably because we use Micron pens and could be avoided if we use technical pens with truly waterproof ink like Rotring, but it is very difficult to use these pens due to frequent clogging.

were very popular at the time. Though its popularity died out in just 13 years, it influenced many artists, architects, designers, etc and the effects are in vogue to this day. Today, wherever one turns another designer is releasing a project featuring a minimalistic design style <designshack.net/articles/layouts/minimalist-design-is-taking-over-heres-why/> Minimalistic design can be identified by its simple nature and use of only what the artist / illustrator feels is sufficient to communicate elements he / she feels are essential. What we see with minimalism is a distinct focus on one bit of content without competition from other elements. That is where our style differs. Our works essentially concentrate primarily on detailed taxonomic line work and colour is the only minimalistic element in our otherwise detailed drawings.

We are not at all insinuating that we are the first to come up with a new wildlife art form – Eric C. Watson comes to mind immediately and many of his renderings

Image 4. There have been applications for some of the artwork we do. One set of drawings was used to produce a table top calendar depicting 12 species of the snakes of Tamil Nadu.
Species depicted: Common Cat Snake *Boiga trigonata*, Bronzeback Tree Snake *Dendrelaphis tristis*, Green Vine Snake *Ahaetulla oxyrhyncha*, Ornate Flying Snake *Chrysopelia ornata*, Common Trinket Snake *Coelognathus helena helena*, Common Indian Rat Snake *Ptysas mucosa*, Checkered Keelback *Fowlea piscator*, Green Keelback (young) *Macropisthodon plumbicolor*, Indian or Spectacled Cobra *Naja naja*, Russell's Viper *Daboia ruselii*, Saw-scaled Viper *Echis carinatus*, and Bamboo Pit Viper *Trimeresurus gramineus*. The terminologies *oxyrhyncha* and *Fowlea* are recent changes (Purkayarsha et al. 2018; Mallik et al. 2020) - formerly the Green Vine Snake was *Ahaetulla nasuta* and the Checkered Keelback *Xenochrophis piscator*, which are available in field guides.

Image 5. Some specially commissioned works have been used to adorn walls. One such piece is this Tiger's eye, the property of Harry Marshall, CEO of ICON Films.

too use minimalistic colour <ericwatson.com>. There are quite a few more, but not many, as most monotone artists look upon black and white art as a purist art form stressing clarity of line which is not to be distracted by colour or any other media. In fact it was John Gould (1804–1881) who brought black and white together with colour. He brought bird illustration to fine bibliographical art using lithography, which enabled the artist to draw directly into stone giving a softer, more flexible line. The black and white prints would then be hand-coloured by teams of skilled colourists. He assembled a team of artists, including Edward Lear (1812–1888) and Joseph Wolf (1820–1899) <mallgalleries.org.uk/learning/resources/history-wildlife-art>

To the purist, combining black and white with colour may be considered to be 'rape' and the pontifical reality of puritanism does exist. The principal author too was a follower of that school until he discovered the joys of combining his forte with colour (the secondary author had a tough time trying to convince him for about a decade and a half to try his hand at combining colour with black and white). Combining black and white with colour may be heresy to the purist and be condemned, but we have enjoyed combining the two to give a

Image 6. We have experimented with the Lepidoptera (Butterflies and Moths) and results have been encouraging, though in most cases we had to show them in entire colour.
Species depicted: 1—Blue Pansy *Junonia orithya* | 2—Oleander Hawk Moth *Daphnis nerii* | 3—Common Rose *Pachliopta aristolochiae* | 4—Lime Butterfly *Papilio demoleus* | 5—Blue Mormon *Papilio polymnestor* | 6—Crimson Rose *Pachliopta hector* | 7—Atlas Moth *Atticus atlas*.

'different' effect.

Successful wildlife artists do use art to depict nature, and so do textile designers, interior designers, photographers, etc. But can this be constituted to be 'rape' will be the eternal question. If one takes inspiration from nature does it mean we are raping it? In our opinion, nature has a way of influencing the human body, mind and, if something like it exists, the soul. Their success is their selling value but many give it back – for example, David Shepherd <davidshepherd.org> and Robert Bateman <batemanfoundation.org/gallery-education>

How many amateur artists paint for the simple joy of just creating something inspired by nature with no thought of financial profit? Here lies the crux, and if Pablo Picasso was consumed by the salability value of his pieces when he said what he said, it is his prerogative – suffice is to say his personal conclusion does not impress us.

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