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Caption: Smooth-backed Gliding Gecko *Gekko lionotum* from Sangu Wildlife Sanctuary, Bandarban, Bangladesh. © Samiul Mohsanin

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ARTICLE

Status of Nahan's Partridge *Ptilopachus nahani* (Dubois, 1905) (Aves: Galliformes: Odontophoridae) in Uganda

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Abstract: We carried out a survey of Nahan's Partridge *Ptilopachus nahani* in the Ugandan forests of Mabira, Bugoma, and Budongo from December 2016 to December 2017, using a point count method employing a call playback technique. The aim was to establish the population status of this globally threatened species, which was last surveyed in 2003. Separate analyses of the number of groups per point and those involving use of the Distance Program yielded the same density estimates, indicating that either method reliably estimates the density of the species. The density estimates for the three reserves were 31.6, 25.2, and 13.3 groups per km^2 for Bugoma, Budongo, and Mabira forest reserves, respectively. In the last 14 years, it appears that the density of the species for Uganda has increased from 16.3 to 23.4 groups per km^2, which when extrapolated translates to 16,000 and 23,000 groups, respectively. This represents a 44% increase in density, or a group growth rate of 450 per year. The lowest density and population increment was registered in Mabira and we attribute this to the apparently high incidence of disturbance and degradation of this forest compared to the other two. Since Mabira, Bugoma, and Budongo are the only remaining large tropical rainforest reserves in Uganda, strengthening their conservation or upgrading their conservation status to national parks is required to save the species.

Keywords: Conservation, degradation, density, endangered species, ecotourism sites, hunting, nature reserve, playback, vulnerable.

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Competing interests: We declare that we have no significant competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

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Authors contribution: WO as director Nature and Livelihoods and ES (Galliform specialist) conceived the project; ES, SA, and UR collected the data; ES led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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INTRODUCTION

Nahan's Partridge *Ptilopachus nahani* is categorized as a globally Vulnerable species (BirdLife International 2019a), although between 2000 and 2018 it was categorized as Endangered. It is an enigmatic galliform known from a few localities in the eastern Democratic Republic of the Congo (DRC) from Yangambi eastwards, and in central and western Uganda (Dranzoa et al. 1999; McGowan 1994). Although Budongo, Bugoma, and Mabira forests are recognized as Important Bird Areas in Uganda (Byaruhanga et al. 2001) and are legally protected forest reserves, Mabira is under severe pressure from disturbance including logging and hunting. Nahan's Partridge is a strict forest specialist species (Bennun et al. 1996), inhabiting closed forest up to 1,400m (Dranzoa et al. 1999), but its tolerance of degraded and secondary habitats is not well known. In fact, until a study by Sande (2001), the species was listed as Data Deficient by IUCN (Collar et al. 1994; McGowan et al. 1995). Being one of the main sought-after species in Uganda for avi-tourism, its conservation through tourism would benefit the three forest reserves and their biodiversity. Nahan's Partridge was previously wrongly classified as a francolin. Now it is classified as a partridge, a sister species to another African endemic, the Stone Partridge *Ptilopachus petrosus*. It is most closely related to the New World quails (Odontophoridae) (Crowe et al. 2006; Cohen et al. 2012; BirdLife International 2016). Although the species was downgraded from Endangered to Vulnerable in 2019, its population in some parts of its range remains unknown and its global population size is believed to be decreasing (BirdLife International 2019a).

The population status of Nahan's Partridge is of particular concern because it is a forest specialist species occurring in only three forest reserves in Uganda (Mabira, Bugoma, and Budongo). Fuller et al. (2004) carried out a survey of the species in the three forest reserves in 2003 and estimated the Ugandan population to be 40,000 individuals. They recommended, among other actions, the survey to be repeated every 10 years. This is the first study to follow up those recommendations. Conservationists used the occurrence of this species as one of the arguments to reverse the 2007 government proposal to degazette 7,000ha of Mabira forest reserve for growing sugarcane. Fuller et al. (2004) estimated the density of the species in the naturally forested part of Mabira (204km^2), Bugoma (300km^2), and Budongo (428km^2) forest reserves (hereafter Mabira, Bugoma, and Budongo) as 8.3, 19, and 21 groups km^{-2}, respectively (Fuller et al. 2012). They attributed the relatively low density in Mabira to a high rate of logging and human disturbance compared to the other two forests. In their assessment of recreational values to promote sustainable use of Mabira, Olupot (2015) and Olupot & Isabirye-Basuta (2016) recommended the need for assessment of the status of the species in the entire Mabira to promote tourism and discourage the illegal human activities that threaten it. This study was conducted in part as a response to those recommendations.

The general aim of this study was to assess the population status of Nahan's Partridge in Uganda. Specific objectives were to:

1. Determine the population status of the species in Uganda after 14 years
2. Compare the population status of the species in the existing and proposed ecotourism sites (Olupot & Isabirye-Basuta 2016) in Mabira Forest Reserve.

METHODS

Study area

The study was conducted in the Ugandan forest reserves of Mabira, Budongo, and Bugoma (Figure 1).

Mabira Forest Reserve (Figure 2a) is the largest block of moist semi-deciduous forest remaining in central Uganda. It is estimated to be 303km^2 in total area (Howard 1991) but Westman et al. (1989) estimated the least degraded, high forest area to have fallen from 285.4km^2 in 1973 to 204.2km^2 in 1988. As Fuller et al. (2004) used the area estimate of 204.2km^2 for their study, we use the same for this study. The reserve lies in a gently undulating landscape, characterized by numerous flat-topped hills and wide, shallow valleys. The reserve is isolated from other protected areas by settled and agricultural land. The relative closeness of Mabira to Kampala (59km), and the presence of various ecotourism facilities, makes it a potentially popular site for visitors (BirdLife International 2019b).

Mabira Forest Reserve is divided into three management zones. The strict nature reserve covers 23% of the forest and no activities are legally permitted there except scientific research and law enforcement. Tourism activities are permitted only in the recreational and buffer zones which covers 22% of the reserve. The production zone which covers 54% of the reserve is allocated to sustainable supply of round wood for Uganda's plywood and veneer industry (Ministry of Water and Environment 2010). Despite having the designated zones, it is difficult to regulate the use of forest resources in the reserve because Mabira has 22

Figure 1. The three study sites: Budongo Forest (1.794^{0}N, 31.582^{0}E), Bugoma Forest (1.287^{0}N, 30.964^{0}E) and Mabira Forest (0.389^{0}N, 33.005^{0}E). These are the only sites for the Nahan's patridge in Uganda (Fuller et al. 2004).

legal enclaves (Howard 1991). The human population living in the forest enclaves was approximately 825,000 with a density of 200–230 people per km^2 in 2001 (Mrema et al. 2001). Mabira is considered an Important Bird and Biodiversity Area (IBA) because of the presence of the Nahan's Partridge (VU) and the Papyrus Gonolek *Laniarius mufumbiri* (NT) (BirdLife International 2019b). The reserve is home to 315 species of birds (Byaruhanga et al. 2001) and 30 species of mammals including the endemic Uganda Mangabey *Lophocebus albigena ugandae*. The survey was conducted in the following compartments: Wantuluntu, Namaganda (Nature Reserve), Namusa Hill, Kiwala, Lugala, Najjembe, Griffin, Bugoma, and Buwola (Mulberry forest) (Figure 2a). Some of these sites (Namaganda, Namusa Hill, Najjembe, and Buwola) were visited during previous studies and are relevant to both objectives of this study. Although not sampled during the early 2000s, we also sampled in Kiwala, Lugala, and Griffin sites with the primary purpose of fulfilling objective 2.

Bugoma Forest Reserve (Figure 2b) is situated on top of an escarpment east of and overlooking Lake Albert on the edge of the Western Rift Valley. It lies, approximately 10km south-west of Hoima and 10km east of Lake Albert. It sits on a gently sloping area, which drains towards lake Albert in the west. It comprises irregular blocks of high forest intersected by large patches of *Hyparrhenia, Pennisetum*, and *Cymbopogon* grasslands, which occupy approximately 18% of the reserve. About half of the forested portion is dominated by Iron Wood *Crynometra alexandri* and a further 38% is mixed Forest (BirdLife International (2019c). Bugoma is an IBA because of Nahan's Partridge (VU) and the Grey Parrot *Psittacus erithacus* (EN) (BirdLife International 2019c), and the forested area is 300km^2 (Howard 1991). The reserve is home to 225 species of birds (Byaruhanga et al. 2001) and 23 species of mammals including the globally endangered Chimpanzee *Pan troglodytes* (Humle et al. 2016). The survey was done in the nature reserve (Figure 2b) which is dominated by *Crynometra alexandri.*

Budongo Forest Reserve (Figure 2c), is one of the most important forest reserves in Uganda for biodiversity conservation. It lies on the escarpment north-east of lake Albert and covers 793km^2 of which 428 is forested. It consists of a medium-altitude moist semi-deciduous forest, with areas of savanna and woodland.

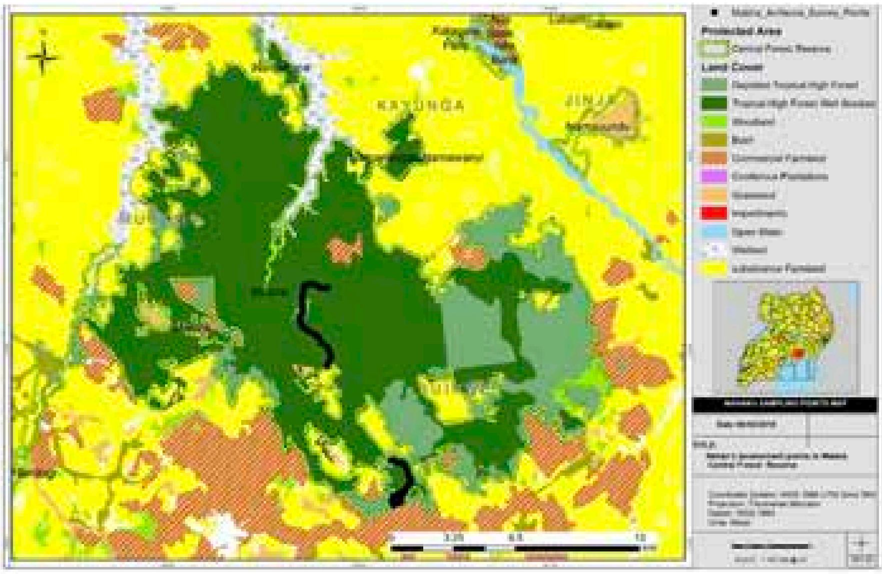

Figure 2a. Mabira Forest Reserve showing where the survey was done.

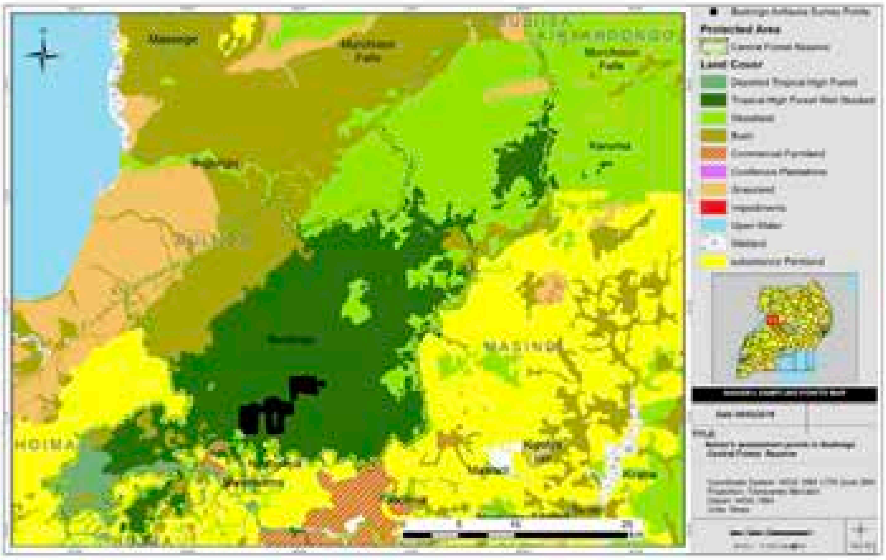

Figure 2b. Budongo Forest Reserve showing where the survey was done.

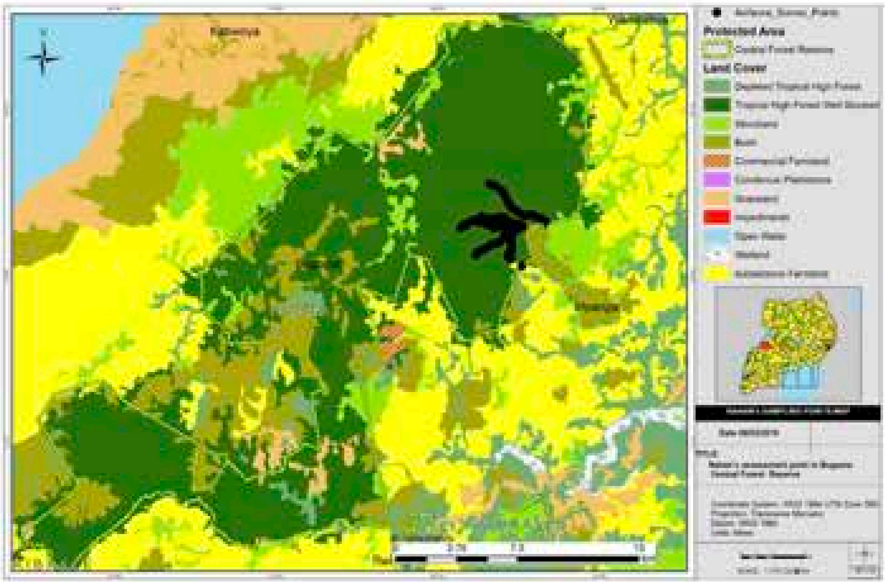

Figure 2c. Bugoma Forest Reserve showing where the survey was done.

The reserve occupies gently undulating terrain, with a general slope north-north-west towards the Rift Valley. Budongo has five main forest-types: colonizing, mixed, *Cynometra*, *Cynometra*-mixed and swamp-forest. The vegetation has also changed considerably following 60 years of selective logging and silvicultural treatment which favored the growth of valuable timber species, especially mahoganies. Today, the forest is the richest in Uganda for native timber production. The Budongo Conservation Field Station (BCFS) based at Sonso carries out research throughout the forest, mainly on primates and birds (BirdLife International 2019d). Budongo is an IBA because of the presence of the Nahan's Partridge (VU) and the Brown-cheeked Hornbill *Bycanistes cylindricus* (VU) (BirdLife International 2019d) with a forested area of 428km^2 (Howard 1991). The reserve is home to 360 species of birds (Byaruhanga et al*.* 2001) and 24 species of mammals including the globally endangered Chimpanzee *Pan troglodytes* (Humle et al. 2016). The survey was carried out in three compartments namely: N15 (66.7km^2; Nature Reserve), N3, (384.4km^2; logged in logged 1947–52) and W21 (24.5km^2; logged in logged in 1963-64 and 1996-97) (Figure 2c).

Survey techniques

The field survey was conducted on the following dates: 14–23 December 2016, 7–8 January 2017 and 2–3 December 2017 in Mabira; 11–19 November 2017 in Bugoma, and 15–24 December 2017 in Budongo. The point count method was used to survey the birds. At each point, locations of the birds were determined using a call playback technique at the points spaced evenly along line transects of varying lengths at distances of approximately 200m. Playback is the only method currently available for surveying the presence, absence, density and relative abundance of the species. Playback surveys have been used in the past to survey the species (Sande 2001; Sande et al. 2001; Fuller et al. 2004, 2012). In their verification of the methods used by Sande (2001), Fuller et al*.* (2012) noted that the playback method is now well developed, and recommended the use of the method for future surveys of the species. Elsewhere, playback surveys have been widely used to determine the presence of elusive birds (Glahn 1974; Marion et al. 1981; Gibbs & Melvin 1993).

The survey effort was 162, 231 and 397 points (covering 32.6, 46.4 and 79.6km) in Bugoma, Budongo, and Mabira forest reserves, respectively. The 200m interval between survey points was used because the investigator can hear the call within a radius of 100m (Sande et al. 2001; Fuller et al. 2004, 2012). At every point, we played the call for 20 seconds, three times at an interval of one minute. Fuller et al. (2004) on the other hand played for 10 seconds, waited for any ensuing response in 60 seconds and did this for two more playbacks. They, thus, estimated density from responses after three and a half minutes (70 seconds x3). Fuller et al. (2004) recommended that future surveys use a playback period of 20 seconds, play a total of three times, with a one-minute gap between each playback.

Fuller et al. (2012) demonstrate that movement of birds toward the sound stimulus during playback surveys can lead to significant overestimation of bird densities. They further showed that a higher number of groups responded to the third playback than the first two. This exacerbates the problem of overestimation, because some birds delayed several minutes before responding and were therefore likely to move a substantial distance toward the observer before being detected.

Sande (2001) found that 77% (n=525) of Nahan's Partridge responded to the playback within one minute and used only these records to estimate density in Budongo Forest in 1997–1999. Also for this study, only responses within one minute were used in the estimation of density. This minimized the risk of overestimating density arising from birds moving towards the observer before being detected as the response within the one minute meant that the birds would not have moved a substantial distance before they responded. This is confirmed by the fact that the population estimate by Sande (2001) for Budongo Forest reserve (6000–7000 groups) (using the responses within one minute) was comparable with the estimate by Fuller et al. 2012) (8000 groups) in 2003 using the adjusted response distance (based on the responses from three call backs taking into account the distance they could have moved before responding). Thus, either the population estimate based on only the responses within one minute of the playback (Sande 2001) or that based on adjusted response distance (Fuller et al. 2012) can be used to avoid overestimation of density.

For every survey point we recorded the GPS coordinates, and wherever we got a positive response we estimated the distance from the researcher to the responding birds (sighting distance) and the number of individuals in case they were seen. Playback surveys were conducted from around 07.30h to around 15.00h.

Data analysis

Two methods were used: the number of groups per point, and distance analysis**.** A requirement of the latter is at least 60–80 sightings for fitting the detection function (Buckland et al. 1993). Since this may not always be possible for rare or globally threatened species, there is need to test and recommend other methods that can be used to analyse data sets with fewer observations. This is important in conservation terms since threatened bird species require regular assessment to feed data into the Global Bird Species Program that is updated every four years.

Using the number of groups per point method, we obtained the mean response distance r from which the birds responded to the observer (which ranged from 10–200 m), the area of each point surveyed (πr^2 m^2), the number of points surveyed in each forest reserve (n) and the total area surveyed in the reserve (nπr^2 m^2). Thus, using the total number of groups (g) recorded in each forest reserve, the density of groups per m^2 was g/n$\pi r^2$and the number of groups per km^2 was calculated.

The Program DISTANCE as described by Buckland et al. (1993) and Laake et al. (1993) was used. For point counts, this program calculates the density of animals using the sighting/radial distances. According to Bibby et al. (1998), each point surveyed is regarded as a sample and the effort is the number of times the point was surveyed. Buckland et al. (1993) stated that often when distances are estimated, the observer tends to round to convenient values (heaping) and recommended that the analysis of such data can be improved by grouping the distance data taking the midpoints as the distance measurements for each observation. Following Buckland et al. (1993), we used midpoint distances as these also remove the zero distance in the unlikely event that a bird was observed on the point. The six bands (groupings) used were: 0–5, 6–15, 16–30, 31–50, 51–100, 101–200 m. Distance analysis using point count data requires sighting distance and the number of individuals for every group recorded. For groups whose individuals were not seen during our surveys, the mean group size for the forest in question was used. This technique (and the groupings) was used by Sande (2001).

RESULTS

Use of the number of groups per point and distance sampling analyses methods

The mean distance from the observer at which the birds responded was 73.14, 73.43 and 62.90m in Bugoma, Mabira, and Budongo, respectively. The density estimates using the number of groups per point and that using Distance sampling in each of the three forest reserves didn't differ (Z<1.96, P>0.05, Table 1). This shows that either method can be used to estimate density for the species and thus the number of groups per point method can be reliably be used to estimate density when the number of observation or sightings is less than 60. Therefore, the results presented in Tables 2, 3 and 4 were based on distance analysis method since the number of observations were more than 60. Results presented in Tables 5 and 6 however (comparisons among Mabira forest reserve's compartments) were based on the number of groups per point analysis method since the number of observations in study compartments were less than 60.

Density and relative abundance of Nahan's Partridge

The density estimates using Distance analysis for the three reserves were 31.6, 25.2 and 13.3 groups per km^2 for Bugoma, Budongo, and Mabira, respectively (Table 2). Results show an increase of density in Uganda from 16.3 in 2003 to 23.4 groups per km^2 in 2017. The mean group size in the three reserves was not significantly different (F=1.52, df=2, 124, P=0.21, One-way ANOVA). From 2002 to 2017, a period of 14 years, the total number of individuals of Nahan's Partridge in Uganda increased by 50% from about 40,000 to 60,000 (Table 3). Sande (2001) found that although the Nahan's Partridge breed throughout the year, the peaks of breeding were January to March, and then August to November. The survey by Fuller et al. (2004) was done from July to September while that for this study was done from November to January during the peak of the breeding season. Since our study was done in the breeding months, it is a good time to survey these birds. Call playback surveys are recommended as the most efficient survey method during the breeding season, especially for those species that are known to respond to call playback, occupy relatively large home ranges and/or are otherwise difficult to detect (Ministry of Environment, Lands & Parks (1999). The time when our study was done is therefore the best to get a good population estimate, and hence our results are reliable and not an over or under estimate.

Intra-reserve status analyses are required for monitoring of population changes within each reserve. Comparisons were done only for Budongo and Mabira where there was data from compartments with different management histories. In Budongo, the three compartments with different management histories (N15-Nature Reserve, N3-logged in logged 1947–52 and W21-logged in logged in 1963–64 and 1996–97) were surveyed in 1997 and 2017. In 2017, the mean group size from the three compartments was not

Table 1. Density estimation (95%CI) for Bugoma, Budongo, and Mabira using Distance sampling and groups per point analyses.

Forested area (km²)	Effort	n	MRD (+SE)	Grps/km²		Z value	Significance
				GPM	DSM		
Bugoma (300)	162	79	73.14 ±5.12	29.1 (20.6–33.6)	31.6 (19.3–51.7)	0.321	0.749
Budongo (428)	231	82	62.90±3.91	28.6 (25.3–32.5)	25.2 (13.4–47.5)	0.463	0.643
Mabira (204)	397	96	73.43 ±4.24	14.3 (12.9–16.3)	13.3 8.13–21.68)	0.190	0.849

MRD—Mean response Distance | GPM—Groups per point | DSM—Distance Sampling method.

Table 2. Density estimates for Bugoma, Budongo, and Mabira.

Forested area (km2)	Effort	n	Grps/ km² (95%CI) (2017)	Grps/ km² (2002)	Z value	Significance
Bugoma (300)	162	79	31.6 (19.3–51.7)	21.5	1.386	0.166
Budongo (428)	231	82	25.2 (13.4–47.5)	19.0	0.933	0.351
Mabira (204)	397	96	13.3 (8.13–21.68)	8.3	1.076	0.282
All the 3 reserves (Ugandan population)			23.4	16.3	1.127	0.260

Table 3. Total no. of groups of Nahan's Partridge (95%CI) in Bugoma, Budongo, and Mabira for 2002 and 2017.

Forested Area (km²)	Total no. of groups	Total no. of groups		Mean group size	Total no. of individuals	Total number of individuals	
		2002*	2017			2017	2002*
Bugoma (300)	9,480 (5790–15,510)	6,458	9,480	2.58±0.19	24,458 (14,938–40,015)	24,458	18,400
Budongo (428)	10,785 (5,735–20,330)	8,112	10,785	2.71±0.20	29,228 (15,541–55,094)	29,228	18,658
Mabira (204)	2,713 (1,658–4,422)	1,695	2,713	2.54±0.12	6,891 (4,211–11,231)	6,891	2,610
Total no. of groups in Uganda		16,265	22,978	Total no. of individuals in Uganda		60,577	39,668

* Fuller et al. 2012

significantly different (F=1.64, df=2, 17, P=0.43, One-way ANOVA). The density was, however, significantly higher between N15 and N3 (Z=2.74, P=0.006) and also significantly higher between W21 and N3 (Z=3.25, P=0.001). The density in N15 and W21 was the similar (Z=0.53, P=0.593) (Table 4). With the current estimate of 10,000 groups and 30,000 individuals for Budongo, (Tables 3), the population of Nahan's Partridge in the reserve increased by 33% groups and by 57% individuals within 20 years. In two decades, (1997 to 2017), the density did not change significantly in N3 (Z=0.195) but it doubled in N15 (Z=2.676) and almost doubled in W21 (Z=2.284) (Table 4).

Olupot & Isabirye-Basuta (2016) recommended among other things the assessment of the status of the Nahan's Partridge in the entire Mabira Forest Reserve and setting up of new tourism camps. We conducted our surveys in nine sites (Table 6). Using the number of groups per point method, the highest densities of Nahan's Partridge were recorded in Wantuluntu (39.3 groups/km²) and lowest in the forest adjacent to the Buwoola enclave (2.0 groups/km²), which is predominantly a Mulberry forest (Table 5). The density was significantly higher in Wantuluntu compared to other sites (Z>2.58, P<0.01). There were no significant difference in the densities between the existing and proposed ecotourism sites and between proposed ecotourism sites and the nature reserve (Z<1.96, P>0.05) (Table 6).

DISCUSSION

Status of Nahan's Partridge population in Uganda

The study has established that the density of the globally Vulnerable Nahan's Patridge in Uganda increased from 16.3 to 23.4 groups per km² in 14 years. Over the years, the total number of groups of Nahan's Partridge in Uganda grew from 16,000 to 23,000 (44%).

Table 4. Density (95%CI) and number of groups (abundance) (95%CI) of Nahan's Partridge in Budongo in 2017 compared to 1997.

	N15	N3	W21
Mean response Distance	59.1±5.9	67.5±10.4	62.3±5.6
No. of responses	32.0	16.0	34.0
Sampling Effort	84.0	73.0	71.0
Density (Gps/km²) (2017)	34.7 (28.7–42.9)	15.3 (21.4–11.5)	39.3 (33.1–47.4)
Density (Gps/km²) (1997)	15.7	16.4	22.1
Z Value (2017 Vs 1997 density	2.676 (P=0.007)	0.195 (P=0.845)	2.284 (P=0.022)
Total No. of groups (2017)	2,316 (1,915–2,859)	5,337 (4,007–7,458)	962 (810–1,162)
Total No. of groups (1997)*	751	6,051	450
Population change based on No. of groups	Tripled	No change	Doubled

*Sande (2001)

Table 5. Status of Nahans Partridge in the existing and proposed ecotourism sites of Mabira.

	Points surveyed	No. of groups	Groups/km²
Wantuluntu	6	**5**	**39.3**
Nature Reserve (Namaganda)	113	44	18.4
Namusa Hill**	15	5	15.7
Kiwala Hill**	17	5	13.9
Lugala**	9	2	10.5
Najjembe*	85	19	10.5
Griffin*	46	9	9.2
Bugoma	38	7	8.7
Buwola (Mulberry)	23	1	2.0

*—existing eco-tourism site | **—proposed eco-tourism site

The population growth is attributed to the fact that the species inhabits only three remaining largest forest reserves (Mabira, Budongo, and Bugoma) which are protected by law. There is sustainable utilization of forest resources in the three forest reserves and the other 503 central forest reserves in Uganda. Human activities in the species habitat are allowed but fairly regulated by the Uganda National Forestry Authority (NFA).

Mabira, Budongo, and Bugoma, the three major forest reserves in Uganda, happen to be the only reserves in the country that harbor Nahan's Partridge. They have been zoned into nature reserves (20% of the forest is strictly protected), protection ⁄buffer zone where low-impact uses are permitted (30%) and the production zone for controlled production of timber and other forest products (50%). Although these zones occur in theory, the situation on the ground is very different because the communities utilize the zones the way they want in some reserves due to ineffective enforcement by NFA. Current forest destruction within and outside protected areas in Uganda is alarming. According to NFA (2018), forest cover across the country declined sharply from 24% (4,933,271ha) of land area in 1990 to less than 9% (1,956,664ha) in 2018 (https://www.nfa.org.ug/index.php/12-nfa-news).

The lowest density in Mabira can be explained by less favourable management forest practices compared to the other reserves. Our study observed that at the time of the survey, logging was very severe in Mabira Forest Reserve in particular, although the intensity was not quantified. It often involves use of tools such as power saws to cut or damage large mature trees and trees with prominent buttresses such as *Ficus exasperata* and *Alstonia boonei* (Image 1a,b), which are vital for nesting and roosting of Nahan's Partridge. Loss of such trees reduces the breeding and roosting micro-habitats of the species. Sande (2001) found that 91% (n=58) of breeding females nested in buttresses. Another tree species that is intensively being harvested in Mabira forest reserve is the wild rubber tree *Funtumia elastic* (Image 2a,b). We were reliably informed by locals that this tree is highly desired for making face-boards in house construction and sofa set chairs. Other than the timber harvesting, we encountered many charcoal burning spots in Mabira Forest Reserve; some with stumps being collected for burning, some covered with soil ready for burning, and others after burning and charcoal taken (Image 3a–c). The fact that Mabira Forest Reserve has up to 22 enclaves (villages) legally settled within the reserve makes it a fertile ground for forest encroachers compared to Budongo and Bugoma, which do not

Image 1. a—Logged *Ficus exasperata* (Mabira) | b—Logged *Alstonia boonei* (Bugoma). © Eric Sande

Table 6. Pair-wise comparison of density between the different compartments.

Pairs	Value 1	Value 2	Z-Value	P-Value
Wantuluntu vs Nature Reserve	39.3	18.4	2.751	0.006
Wantuluntu vs Namusa	39.3	15.7	3.182	0.001
Wantuluntu vs Kiwala	39.3	13.9	3.482	0.000
Wantuluntu vs Lugala	39.3	10.5	4.081	0.000
Wantuluntu vs Bugoma	39.3	8.7	4.416	0.000
Wantuluntu vs Najjembe*	39.3	10.5	4.081	0.000
Wantuluntu vs Griffin	39.3	9.2	4.322	0.000
Nature Reserve vs Namusa	18.4	15.7	0.462	0.644
Nature Reserve vs Kiwala**	18.4	13.9	0.791	0.429
Nature Reserve vs Lugala**	18.4	10.5	1.469	0.142
Nature Reserve vs Bugoma	18.4	8.7	1.863	0.062
Nature Reserve vs Najjembe*	18.4	10.5	1.469	0.142
Nature Reserve vs Griffin	18.4	9.2	1.751	0.080
Nature Reserve vs Namusa**	15.7	18.4	-0.462	0.644
Namusa** vs Kiwala**	15.7	13.9	0.330	0.741
Namusa** vs Lugala**	15.7	10.5	1.015	0.310
Namusa** vs Bugoma	15.7	8.7	1.417	0.156
Namusa** vs Najjembe*	15.7	10.5	1.015	0.310
Namusa** vs Griffin*	15.7	9.2	1.302	0.193
Kiwala** vs Bugoma	13.9	8.7	1.093	0.274
Lugala** vs Bugoma	10.5	8.7	0.410	0.681
Lugala** vs Najjembe*	10.5	10.5	0	1.000
Lugala** vs Griffin*	10.5	9.2	0.292	0.770
Kiwala** vs Lugala**	13.9	10.5	0.688	0.491
Kiwala** vs Najjembe*	13.9	10.5	0.688	0.491
Kiwala** vs Griffin*	13.9	9.2	0.977	0.328
Bugoma vs Najjembe*	8.7	10.5	-0.410	0.682
Bugoma vs Griffin*	8.7	9.2	-0.118	0.906
Najjembe vs Griffin*	10.5	9.2	0.292	0.770

have such settlements within the reserves. According to BirdLife International (2019a), Nahan's partridge is currently categorized as globally Vulnerable because it's very small, severely fragmented global range is declining in the area of occupancy and in the extent and quality owing to deforestation and forest degradation. The high forest destruction of Mabira forest reserve is a significant contribution to this global decline of the species area of occupancy.

Fuller et al. (2004) indicated that around Mabira, Bugoma, and Budongo forest reserves, 54% and 30% of the respondents said that they hunt galliformes by hand and using nets, respectively. Netting is probably by far the more destructive of these two hunting techniques. Hunters string out nets and then drive ground animals towards them using dogs and by shouting and beating objects. During our survey on Bugoma Hill (Compartment 192 of Mabira), the informant (our local guide who himself also occasionally participates in hunting) informed us that forest management authorizes hunting in that compartment three days a week (Tuesdays, Thursdays and Saturdays), however, this is contradicted by NFA managers who insist that hunting is not authorized. Hunters can kill up to 30 duikers and six Nahan's Partridges in a single expedition. If this is true, extrapolating from the figures provided by the informant it would appear that one team of hunters can kill up to 18 Nahan's Partridge in a week. Such a level of off-take likely explains why the abundance of Nahan's Patridge in Mabira lower than in other reserves. Further detailed studies on the impact of hunting on the species need to be carried out in the three reserves.

Density and relative abundance of Nahan's Partridge in Budongo from 1997 to 2017

Sande (2001) and this study provide a good baseline assessment of the population status of the species after two decades and a prediction of the population of the species in the next 50 years if the conservation efforts currently being undertaken are maintained or improved. The tripling of the groups in 20 years in the Nature Reserve (N15) can be explained by two factors. Firstly, the relatively rapid population growth in the nature reserve is explained by the healthy breeding environment there. Our study has observed that Budongo's Nature Reserve (N15) still remains relatively intact. It is an Ironwood *Cynometra* forest which Eggeling (1947) suggested that this represents the climatic climax and a species poor forest type with *Cynometra alexandrii* dominating and forming 75% of the cover. *C. alexandrii* usually has extensive thin buttresses near the base that can be up to 8m long and several metres high. Sande (2001) found that 91% of the Nahan's Partridge nested in buttresses and nest survival and nest success were higher in the unlogged Nature reserve than in the logged habitat with *C. alexandrii* being the most commonly used tree species for nesting. So a microhabitat with many large buttresses provides a good breeding environment for the species.

The second factor could be that fewer researchers and research assistants spend less time in the nature reserve compared N3. There is therefore a high human-Nahan's Partridge encounter rate in N3 compared to N15 and W21. This is because most of the research in Budongo is done on primates, especially Chimpanzees. The habituated groups of Chimpanzees spend most of the time in N3 (where Sonso, the Budongo Conservation Field Station is located) because fruiting trees, especially figs, are abundant there. The number of researchers and field assistants, and the amount of time they generally spend, are much less in N15 and W21 than in N3. Nahan's Partridges being very shy birds, their daily activity patterns particularly nesting are affected by human disturbance. According to Sande (2001), the survey from March 1998 to January 2000 reported that 43% of the nests (n=58) were located 2m or less from the trail and 76% of these did not succeed probably due to disturbance. It is therefore probable that the relatively low research activity in N15 and W21 provides better nesting conditions for the birds. Thus the tripling of the number of groups in N15 can be explained by the buttress-rich environment provided by *C. alexandrii* and the less human-Nahan's encounter while only the latter explains the doubling of the population in W21. The high human-Nahan's encounter in N3 probably explains the no change over the years. The impact of researcher's activities on Nahan's Partridge's nest success and nest survival needs to however be further investigated.

Density of Nahan's Partridge in the proposed ecotourism sites

The highest density in Wantuluntu (39.3 groups per km^2) should be interpreted with caution because of the small sample size (five sightings). When this site is excluded, the density of Nahan's Partridge was generally the same in all the sites (11 groups per km^2). This was probably because of the high and increased incidence of human activities generally in all the sampling sites including what we noted in the strict nature reserve. Although sustainable utilization of natural resources is allowed in forest management in Uganda, areas gazzeted as strict nature reserves should be managed for

Image 2. Logged *Funtumia elastica* for face boards at Namaganda | a—and stumps freshly cut for making sofa sets at Kiwala | b—both from Mabira. © Eric Sande

Image 3. Charcoal burning: a—before covering with soil (Wantuluntu) | b—after covering with soil (Wantuluntu) | c—after burning (Kiwala) all from Mabira. © Eric Sande

Image 4. a—Good birding trails stretch in Kiwala near Nagojje ranger post (Mabira) | b—the Royal Mile (Budongo). © Eric Sande

the purpose they are set aside for particularly in Mabira. This will allow better assessments and predictions of the impact of forest disturbance and utilization on biodiveristy.

Compared to Watuluntu and Namaganda areas, Kiwala and Lugala (sites that Olupot & Isabirye-Basuta 2016 recommended for ecotourism development) did not do well in terms of Nahan's Partridge abundance. This was probably because of the high and increased incidence of human activities noted there, particularly

Image 5. Good birding trails along Namusa Hill: a—forest-grassland interface | b—swamp on Namusa Hill top. © Eric Sande

Image 6. a—Paper Mulbery forest in Mabira FR | b—understorey growth in the *Cynometra* (Bugoma). © Eric Sande

tree cutting for charcoal and fire wood. The two recommended sites are nonetheless good potential ecotourism sites that could be developed. Kiwala Hill Area was recommended because of a good landscape and camp site. In addition, it has an excellent hiking route (Image 4a) from the valley near Nagojje Ranger post to the sugarcane plantation that looks like the famous Royal mile of Budongo (Image 4b) which is believed to be one of the best places for forest bird watching in Uganda according Rossouw & Sacchi (1998). Lugala on the other hand has a good forest and high potential for hiking route and camp site. Our survey in Lugala found that in addition, an excellent 2–3 km long birding trail along the forest boundary where the visitors would enjoy watching the forest edge birds, e.g., turacos and hornbills.

Namusa Hill is the third potential ecotourism site which could be developed. Our study found that because it has a good landscape appeal, good birding trail of up to 5km, the hill top has a grassland meadow with a transitional grassland-forest interface (Image 5a) and a swamp at the top of the hill (Image 5b). The hill is therefore an excellent bird watching site where forest specialists, forest generalists, grassland birds and water birds can be seen.

Possible causes for the low abundance of Nahan's Partridge in *Brousonettia papyrifera* forest

Paper mulberry *Broussonetia papyrifera* is an exotic tree that has colonised a large degraded area in the eastern part of the forest. This is where the population of Nahan's Partridge was minimum. Fuller et al. (2004) also did not report occurrence of Nahan's Partridge in this habitat. As this is a monodominant *B. papyrifera* -dominated forest (Image 6a), the diversity of arthropods that are known to be one of the major food items for the species is low. The trees also do not have large buttresses that can provide nesting and roosting sites, probably reducing breeding success. We suspect these are the likely reasons why the population in that particular forest type is low because we know that the species prefers forest types that have trees with large buttresses and a lot of undergrowth (Image 6b) that presumably has lots of arthropods and insect larvae.

CONCLUSIONS

Results from this study show that the density of Nahan's Partridge (Image 7) increased by seven groups per km^2 in Uganda, while the total number of groups and total number of individuals increased by 44 and 50% respectively in the period of 14 years. The lowest density was noted in Mabira, where the level of forest disturbance and degradation was notably higher as the forest lies in the vicinity of highly-industrialized and populous Kampala City, Jinja, Lugazi, and Mukono municipalities, which are in dire need of forest products including bushmeat. The rampant exploitation is exacerbated by the apparent weak and limited law enforcement by NFA. There is, therefore, an urgent need to hasten conservation action in these only remaining forest reserves in Uganda that will save the 315, 225, 360 bird species and 30, 23, 24 mammal species in Mabira, Bugoma, and Budongo forests, respectively, many of which will undoubtedly disappear if the forests themselves disappear.

RECOMMENDATIONS

1. Carry out a detailed study on impacts and mechanisms through which forest, use including hunting, affect Nahan's Partridge populations in Uganda
2. Stop or at least discourage hunting, particularly with nets as they over exploit and do not discriminate forest floor fauna according to target and non-target species and age groups
3. Assess the impact of research intensity on the nesting success of Nahan's Partridge in Budongo Forest Reserve.
4. NFA should ensure that the strict nature reserves within these forests are better managed to ensure that they are visited strictly for research and law enforcement.
5. As threatened primates and other biodiversity occur in the three forest reserves, including globally endangered chimpanzee in Budongo and Bugoma and the endemic Uganda Mangabey *Lophocebus albigena ugandae,* every effort should be made to strengthen conservation of the three reserves, including the possibility of having them gazetted as national parks.

Image 7. A pair of Nahan's Partridge roosting between buttresses of a large Cynometra tree stand in Budongo Forest. © Eric Sande

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ARTICLE

Fish diversity in streams/rivers of Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu, India

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Abstract: This article describes fish diversity in streams and rivers of Kalakad-Mundanthurai Tiger Reserve (KMTR), Tamil Nadu. Fifty species of fishes belonging to 10 orders, 15 families, and 32 genera are recorded. Seven species, *Garra joshuai*, *G. kalakadensis*, *Haludaria kannikattiensis*, *Hypselobarbus tamiraparaniei* *Mesonemachilus tambraparniensis*, *Neolissochilus tamiraparaniensis*, and *Dawkinsia tambraparniei* are strictly endemic to this protected area. The minnows, *Devario aequipinnatus*, *Garra mullya*, and *G. kalakadensis* are widely distributed in KMTR streams. High species diversity (H'=2.81) was recorded in Gadana River, whereas low species diversity (H'=0.61) was registered in Poonkulam area. Bray-Curtis similarity analysis showed that sites along the headwater streams have similar faunal assemblage. Result of regression analysis revealed that there is a significant pattern explained between stream order and species richness (r^2=0.86; $p<0.05$). Among 50 species, four (*Garra kalakadensis*, *G. joshuai*, *Dawkinsia tambraparniei*, and *Tor malabaricus*) are listed in threatened categories of IUCN Red List. Important threats faced by endemic species and their management strategies are discussed.

Keywords: Agasthyamalai, Pisces, Poonkulam, Tamiraparani, Western Ghats.

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Author contribution: K. Kannan—involved in field sampling, data collection and data analysis; J.A. Johnson—involved in filed sampling, Supervision, data analysis, image preparation and manuscript drafting

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भारतीय वन्यजीव संस्थान
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INTRODUCTION

Kalakad-Mundanthurai Tiger Reserve (KMTR) is one of the important biodiversity rich areas in southern Western Ghats forming an important watershed for the perennial east flowing Tamiraparani River. Since this reserve has many perennial streams and rivers, this protected area is popularly known as River Sanctuary (Johnsingh & Viickram 1987). The watershed area has very rich fish fauna with notable endemic and globally threatened species. Information on fishes of this region emerged in 1950s with the description of two new species *Garra joshuai* and *Dawkinsia tambraparniei* (Silas 1953). Later, Johnsingh & Viickram (1987) provided the first comprehensive list of fishes (33 species) of the Mundanthurai Sanctuary with illustrations. This checklist covered the fishes from dams and associated rivers in Mundanthurai Sanctuary, and gave an insight into the ichthyological diversity of this region. Subsequently, four new species *Garra kalakadensis* (Remadevi 1992), and *Haludaria kannikattiensis* Arunachalam & Johnson 2002, *Hypselobarbus tamiraparaniei* Arunachalam et al. 2014 and *Neolissochilus tamiraparaniensis* Arunachalam et al. 2017 were described from this region. In addition to taxonomy, ecology and biology of fishes of this region have also been studied in recent years (Johnson & Arunachalam 2010, 2012; Kannan et al. 2013, 2014). Despite this, the diversity of fishes in KMTR is probably underestimated, because many streams/ rivers of KMTR had not been explored in the past. Further, comprehensive information on fish in KMTR is still in an emerging stage. Hence, the present paper is an attempt to provide an updated status of the fish diversity and assemblage structure associated with different streams/ rivers of KMTR.

MATERIALS AND METHODS

Study Area

Kalakad-Mundanthurai Tiger Reserve is located in the southern end of Western Ghats in Tirunelveli District, Tamil Nadu. This reserve comprises of four wildlife sanctuaries, namely, Kalakad, Mundanthurai, Nellai, and Kanyakumari, covering a total area of about 1,601km^2. It lies between 8.4166—8.8833 ^{0}N & 77.1666 —77.9166 ^{0}E with altitude ranging from 50m to 1,868 m at the highest point, Agasthyamalai Peak. This area represents diverse vegetation types and the core zone of the reserve is considered as one of the important rainforest areas in the country (Johnson & Kannan 2012). The rich and dense forest types are important watershed areas for many streams and rivers. The major perennial river, Tamiraparani originates from Poonkulam at the base of Agasthyamalai (Image 1) and flows through the core zone of the tiger reserve. Along its course, several major tributaries such as Servalar, Manimuthar, Pachiyar, Gowthalaiar, Gadana, and Ramanadhi rivers join delete the river Tamiraparani. In the present study, 25 streams covering different streams/ rivers within the KMTR were sampled for species diversity and the survey was carried out between January 2011 and March 2012. The location of sampling sites in KMTR is presented in Figure 1.

Fish sampling

Fish sampling was performed in different habitats such as pools, riffles, runs, and cascades within 100m reach based on the methods of Angermeier & Schlosser (1989) and Johnson & Arunachalam (2009). These reaches were selected based on regular pattern of morphology such as pools and riffles and also special scales covering different stream orders. Fishes were collected using monofilamentous gill nets of different mesh sizes (8 to 32 mm), drag and scoop nets. Sampled fishes were examined, counted, photographed and released back to the system. Gill nets were also set during night along the habitat to obtain nocturnal catfishes. In addition to netting, hooks and lines were also used for collecting Anguillid and Mastacembelid fishes. Few specimens of unidentified taxa were preserved in 10% formalin and the species were confirmed using standard taxonomic literature (Jayaram 2010). Current valid species names follow the Catalogue of Fishes (Fricke et al. 2020) and conservation status follow the IUCN Red

Image 1. Poonkulam – the origin of River Tamiraparani in Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu.

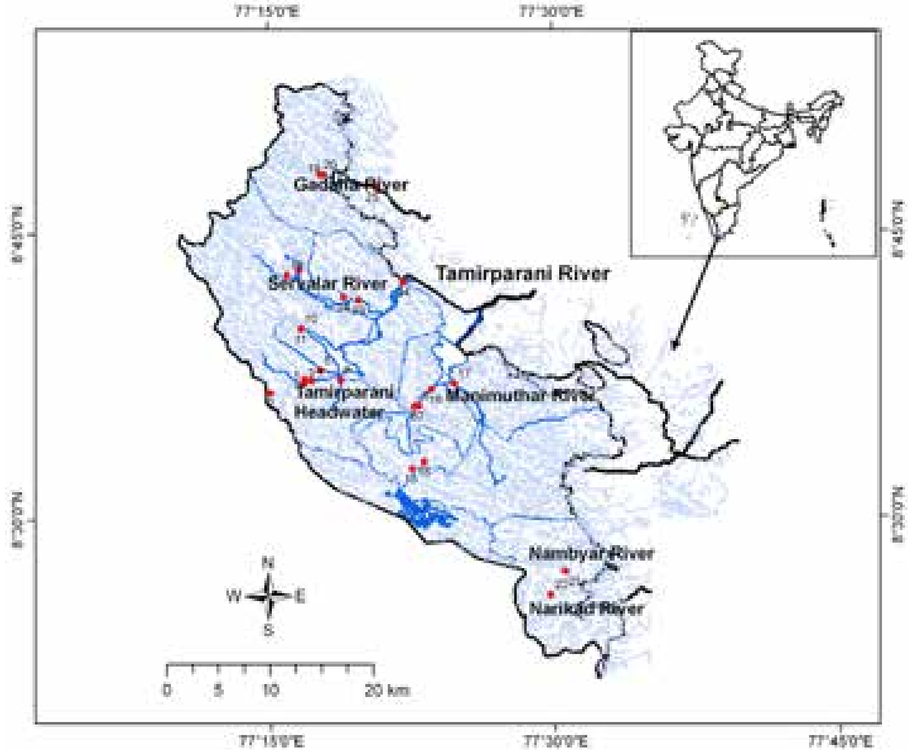

Figure 1. Sampling sites in Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu.

List of Threatened Species (2020). At each sampling location, altitude and GPS coordinates were recorded. In addition, stream order classification was obtained for all sampling reach based on Strahlar's method (Strahlar 1957).

Data Analysis

Information on fish diversity and their distribution pattern were extracted by adopting different univariate indices, Shannon diversity index and evenness index. Calculation of these indices followed the methods of Padhye et al. (2006). The indices were used to compare species distribution, richness, diversity, and equitability across the study streams. Quantitative data of species along with their abundance were used for construction of dendrogram to understand the similarity of fish assemblage structure between the streams. This was done using Bray-Curtis similarity index based on non-transformed species abundance data (Anderson 2001; Padhye et al. 2006) in PAST program. Further, the patterns of species distribution in KMTR streams was examined using simple linear regression model, where stream order and altitude were used as independent variables and species richness as dependant variable.

RESULTS

Diversity and assemblage structure

A total of 50 species of primary freshwater fishes belonging to 10 orders, 15 families, and 32 genera were recorded from the study area (Table 1 & Images 2–6). Among the species, *Devario aequipinnatus*, *Garra mullya*, *Garra kalakadensis, Garra joshuai*, and *Rasbora dandia* were commonly present across the study streams. The Malabar Mahseer *Tor malabaricus* was recorded from Myeelar, Pambanar, Gowthalyar, Vaalayar streams, and also in Ingikuli river. Of 50 species, seven species namely, *Garra kalakadensis*, *G. joshuai*, *Haludaria kannikattiensis*, *Hypselobarbus tamiraparaniei*, *Mesonemachilus tambraparniensis*, *Neolissochilus tamiraparaniensis*, and *Dawkinsia tambraparniei* are endemic to KMTR and Tamiraparani River basin. Among these endemic species, *Dawkinsia tambraparniei* is the only species with a wide distribution range in middle and lower reaches of Tamiraparani River basin and the rest are restricted to the headwaters of Tamiraparani (i.e., within KMTR). The exotic species *Oreochromis mossambicus* was recorded in the lower reach of Gadana and Tamiraparani rivers at Papanasam region.

Total number of species, Shannon diversity, and evenness index for each stream are given in Table 2.

Table 1. List of fish species recorded from streams/rivers of Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu.

Rivers/Streams Fish species	Aielar	Poonkulam	Sophar	Palavarathod	Ullar	Selampanodai	Elumbenodai	Myeelar	Pampanar	Gowthalyar	Karayar	Chinnapullar	Vaalayar	Thailar	Nalumukkuyar	Kakachiodai	Manimuthar	Thalayani	Kallar	Thooneyar	Naraikkad	Nambiyar	Servalar	Papanasm	Gadana
Cyprinodontiformes **Aplocheilidae** *Aplocheilus lineatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+
Cypriniformes **Cyprinidae** *Bangana dero*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Cirrhinus reba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Dawkinsia filamentosa	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-	-	+	+	+	-	-	-	+	+	+
Dawkinsia tambraparniei	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	+	+	+	+	+	-	+	+	+
Garra mullya	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-	+	-	-	+	+	+
Garra joshuai	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
Garra kalakadensis	+	-	-	+	+	+	+	+	-	+	+	+	+	+	+	+	-	-	-	-	+	+	-	-	-
Haludaria kannikattiensis	-	-	+	+	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypselobarbus tamiraparaniei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-
Labeo calbasu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Labeo fimbriatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Labeo rohita	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Labeo pangusia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Neolissochilus tamiraparaniensis	+	-	-	-	-	+	-	-	+	+	+	-	+	+	-	-	+	+	+	+	-	-	+	-	+
Pethia punctata	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	+	-	-	-	-	+	+	+
Puntius sophore	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+
Puntius amphibius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	+	+
Puntius bimaculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	-	-	+
Puntius chola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+
Puntius dorsalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	-	-	+
Puntius vittatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Systomus subnasutus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	-	+	+
Tor malabaricus	-	-	-	-	-	-	-	-	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Danionidae *Amblypharyngodon microlepis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+

Rivers/Streams **Fish species**	Aielar	Poonkulam	Sophar	Palavarathod	Ullar	Selampanodai	Elumbenodai	Myeelar	Pampanar	Gowthalyar	Karayar	Chinnapullar	Vaalayar	Thailar	Nalumukkuyar	Kakachiodai	Manimuthar	Thalayani	Kallar	Thooneyar	Naraikkad	Nambiyar	Servalar	Papanasm	Gadana
Devario aequipinnatus	+	-	+	+	+	+	+	+	+	+	+	-	-	+	+	-	+	+	+	+	+	+	-	-	-
Esomus thermoicos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Rasbora dandia	+	-	+	+	+	+	-	-	+	+	+	-	-	+	-	-	+	+	+	+	+	+	+	+	-
Rasbora caverii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+
Salmostoma balookee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	+
Salmostoma boopis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	+
Balitoridae *Bhavania annandalei*	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-	-
Nemacheilidae *Mesonoemacheilus tambaraparniensis*	-	-	-	-	+	-	-	-	-	+	+	-	-	-	-	-	-	-		+	+	+	-	-	-
Cobitidae *Lepidocephalichthys thermalis*	-	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	+	-	+	-	-	-	-
Siluriformes **Bagridae** *Mystus armatus*	+	-	+	+	-	-	-	-	+	+	+	-	-	-	-	-	+	+	+	+	-	-	-		-
Mystus montanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
Mystus seengtee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Mystus vittatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	+
Siluridae *Ompok bimaculatus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Ompok malabaricus	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-
Anguilliformes **Anguillidae** *Anguilla bengalensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
Synbranchiformes **Mastacembelidae** *Mastacembelus armatus*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Cichliformes **Cichlidae** *Etroplus suratensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	+
Pseudetroplus maculatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Oreochromis mossambicus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Gobiiformes **Gobiidae** *Glossogobius giuris*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+

Fish species	Rivers/Streams Aielar	Poonkulam	Sophar	Palavarathod	Ullar	Selampanodai	Elumbenodai	Myeelar	Pamparar	Gowthalyar	Karayar	Chinnapullar	Vaalayar	Thaliar	Nalumukkuyar	Kakachiodai	Manimuthar	Thalayani	Kallar	Thooneyar	Naraikkad	Nambiyar	Servalar	Papanasm	Gadana
Anabantiformes **Channidae** *Channa gachua*	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Channa striata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Perciforms **Ambassidae** *Chanda nama*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Beloniformes **Belonidae** *Xenentodon cancila*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+

Maximum number of species were recorded in Gadana River, (S=30), followed by Papanasam site (S=30), whereas low number of species were recorded in Poonkulam (Tamiraparani origin) in the upstream and Elumbenodai Stream (two species in each). In the entire study area, cyprinids were the dominant members of the assemblage structure, comprising 12 genera and 23 species. High values for the Shannon diversity index were registered in Gadana (H'=2.81), Papanasam (H'=2.78), and Servalar (H'=2.62), whereas low value was registered in Poonkulam (H'=0.61). The evenness index of species equitability was high in Nalumukkuyar (E=0.97) followed by Palavarathod and Aielar (E=0.96 in both) whereas the site Chinnapullar and Vaalyar had comparatively uneven distribution of species (0.74 and 0.77, respectively). Cluster analyses of species composition in KMTR showed that two distinct clusters and two separate lines were formed based on the Bray-Curtis similarity (Figure 2). The sites along the headwater streams had more similar faunal assemblage and they were grouped together in cluster 'A'. The sites in the middle reach of the river with rich diversity sites such as Papanasam, Gadana, Servalar, Naraikkad, and Nambiyar had more similar faunal assemblages and they were grouped in cluster 'C'. The streams namely Vaalayar and Poonkulam (headwater) had distinct species assemblage and they did not cluster with other sites (line 'B' & 'D' in Figure 2). The result of regression analysis revealed that there is a strong significant pattern explained between stream order and species richness ($r^2=0.86$; $p<0.05$). The study site with higher stream order had more species (Figure 3a). Similarly in the case of regression result on altitude vs. species richness a weak relationship explained between altitude and species richness ($r^2=0.19$; $p<0.05$). Sites located at lower elevation such as Gadana, Papanasam, and Servalar had more number of species than higher elevation sites (Figure 3b).

Threatened species

Current status of KMTR fishes were compared with IUCN Red List data (IUCN 2020) and of 50 species four species are listed under threatened categories (*Garra kalakadensis*, *G. joshuai*, *Dawkinsia tambraparniei*, and *Tor malabaricus*). Apart from those, two species namely *Labeo pangusia* and *Ompok bimaculatus* are listed in the Near Threatened category. Distributions of these threatened species in KMTR are presented in Table 3. These threatened species constitute about 8% of the species inhabiting KMTR region.

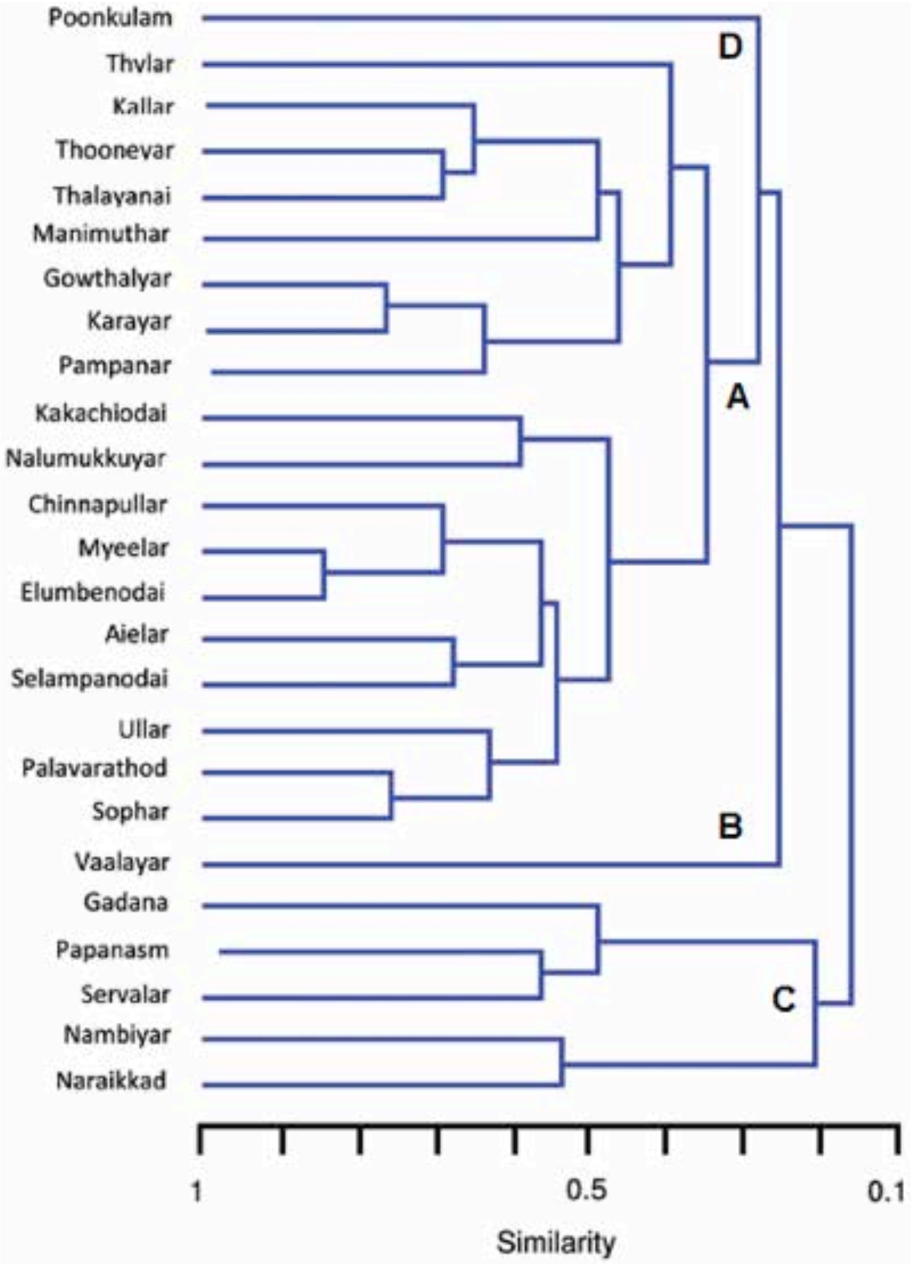

Figure 2. Dendrogram resulting from Bray-Curtis similarities of species abundance data of study streams.

DISCUSSION

Previous studies on ichthyofauna of this region covered different isolated patches. Silas (1953) listed nine species of fishes including two new species *Garra joshuai* and *Dawkinsia tambraparniei* from the headwaters of Tamiraparani. Johnsingh & Viickram (1987) listed 33 species of fishes from Mundanthurai Sanctuary, primarily from Papanasam lower & upper dam and Servalar & Manimuthar dams. Of the 33 species, four species, *Homaloptera brucei* (restricted to eastern Himalayan), *Garra lissorhynchus* (restricted to eastern Himalaya), *Barbodes carnaticus* (restricted to Cauvery River drainages), and *Nemachilus pulchellus* were misidentifications of *Bhavania annandalei*, *Garra mullya*, *Neolissochilus tamiraparaniensis*, and *Mesonemachilus tambraparniensis*, respectively. Later, Remadevi (1992) also listed 19 species from Kalakad Sanctuary and Arunachalam et al. (2000) listed 14 species from Nambiyar River. Thus, the present list of 50 species represents a complete updated account on fishes of KMTR.

Table 2. Geomorphological features, species richness, Shannon index and evenness index recorded in streams/rivers of Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu.

Sites	Stream order	Altitude (m)	Number of Species	Shannon index (H')	Evenness index (E)
Aielar	3	609	7	1.87	0.96
Poonkulam	2	609	2	0.61	0.88
Sophar	3	600	7	1.63	0.84
Palavarathod	3	630	7	1.87	0.96
Ullar	3	637	8	1.77	0.85
Selampanodai	3	258	6	1.71	0.95
Elumbenodai	2	252	4	1.24	0.90
Myeelar	3	248	4	1.28	0.93
Pampanar	3	291	9	1.96	0.89
Gowthalyar	4	300	13	2.42	0.92
Karayar	4	300	15	2.44	0.88
Chinnapullar	3	300	4	1.02	0.74
Vaalayar	3	405	6	1.39	0.77
Thailar	3	400	6	1.53	0.85
Nalumukkuyar	3	1250	4	1.34	0.97
Kakachiodai	3	1230	3	1.05	0.95
Manimuthar	4	300	8	1.95	0.94
Thalayani	4	300	15	2.16	0.82
Kallar	4	150	10	2.01	0.87
Thooneyar	4	165	7	1.81	0.93
Naraikkad	4	350	15	2.49	0.92
Nambiyar	4	350	13	2.37	0.92
Servalar	5	300	22	2.62	0.88
Papanasm	6	250	24	2.78	0.90
Gadana	6	150	30	2.81	0.84

Table 3. List of threatened species and their distribution range within Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu.

	Threatened species	IUCN status	Distribution within KMTR
1.	*Garra kalakadensis*	Endangered	Aielar, Sophar, Palavarathod, Ullar, Selampanodai, Elumbenodai, Myeelar, Pampanar, Gowthalyar, Karayar, Chinnapullar, Vaalayar, Thailar, Nalumukkuyar, Kakachiodai, Nambiyar
2.	*Garra joshuai*	Endangered	Aielar, Poonkulam, Sophar, Palavarathod, Ullar, Selampanodai, Elumbenodai, Myeelar, Pampanar, Gowthalyar, Karayar, Chinnapullar, Vaalayar, Thailar, Nalumukkuyar, Kakachiodai, Manimuthar
3.	*Dawkinsia tambraparniei*	Endangered	Gowthalyar, Karayar, Manimuthar, Thalayanai, Kallar, Thooneyar, Servalar, Papanasam, Gadana
4.	*Tor malabaricus*	Endangered	Pampanar, Gowthalyar, Karayar, Vaalayar

Interestingly, the record of a viable population of Malabar Mahseer in streams such as Pampanar, Gowthalaiar, Karayar, and Valayar in KMTR is additional information to this area. This mahseer was described by Jerdon (1849) as *Barbus malabaricus* from the mountain streams of Malabar regions of India. Menon (1992) synonymised this species with *Tor khudree* without any explanation. Indra (1993), however, considered this species as a valid subspecies as *Tor khudree malabaricus*. Recently, Silas et al. (2005) confirmed the validity of *T. malabaricus* as a separate species using molecular techniques. This species is reported from rivers Balamore in Kanyakumari District, Tamil Nadu and Kallada River in Kerala (Silas et al. 2005). Though, the presence of this species in Tamiraraparini River was reported by various workers under different names (as

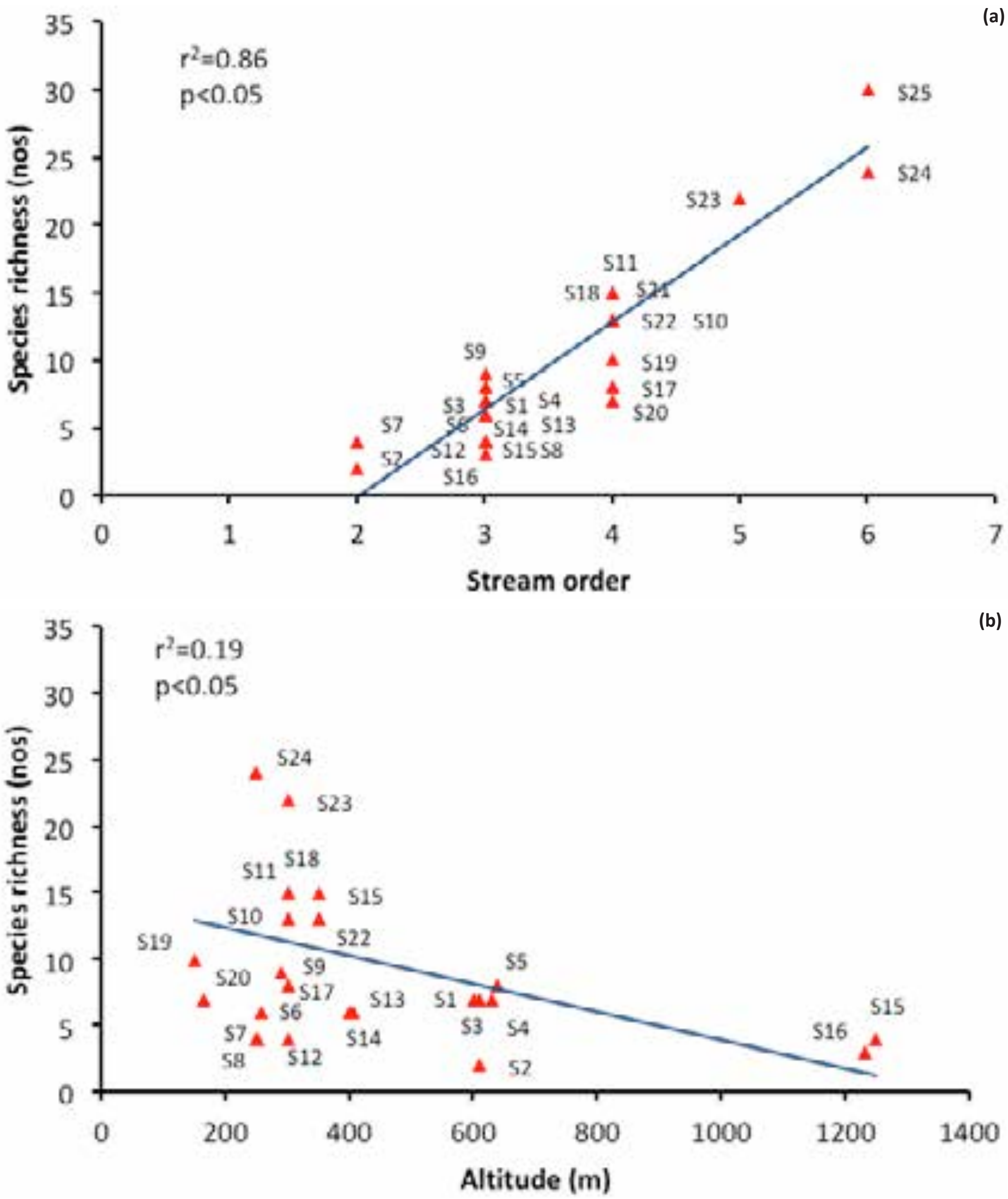

Figure 3. Regression plot of species richness vs stream order (a) and species vs altitude (b)—among sampling streams/ rivers in Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu [S1—Aielar | S2—Poonkulam | S3—Sophar | S4—Palavarathod | S5—Ullar | S6—Selampanodai | S7—Elumbenodai | S8—Myeelar | S9—Pampanar | S10—Gowthalyar | S11—Karayar | S12—Chinnapullar | S13—Vaalayar | S14—Thailar | S15—Nalumukkuyar | S16—Kakachiodai | S17—Manimuthar | S18—Thalayani | S19—Kallar | S20—Thooneyar | S21—Naraikkad | S22—Nambiyar | S23—Servalar | S24—Papanasam | S25—Gadana].

Barbus malabaricus by Johnsingh & Viickram 1987; as *Tor khudree malabaricus* by Johnson 1999; *Tor malabaricus* by Johnson & Arunachalam 2012), the distribution of *Tor malabaricus* in an east flowing river is questionable. In this context, a separate investigation on identity of this species using molecular techniques is in progress.

Moreover, recently the genus *Horalabiosa* was synonymised with genus *Garra* by Yang et al. (2012) based on molecular data without any discussion on *Horalabiosa's* morphological features. Other workers have also followed the same synonymy (Kottelat 2013; Bleher 2018). We, however, strongly suspect that the chance of sampling error as juvenile *Garra* are morphologically similar to *Horalabiosa* (Kottelat 2020). Further, combined molecular and morphological investigation on the validity of genera *Horalabiosa* and

Garra is necessary.

The patterns of diversity explained in the present study revealed that sites falling in the lower altitude with large stream size had high diversity of fish. The study sites Gadana, Papanasam, and Servalar are large size rivers (6th order streams) and located at the foot-hills of Western Ghats, which had high Shannon diversity index (H'=2.81; H'=2.78; H'=2.68, respectively) comparted to study sites located high elevation with small stream channel (2nd order stream). High diversity of fishes found in Gadana, Papanasam, and Servalar rivers are mainly due to the size of the channel and tributary effect (Horwitz 1978; Vannote et al. 1980; Minshall et al. 1985), as these are 6th order river channel with many tributaries in the upstream. In general, main river channel will have high species richness than head waters (Schlosser 1991; Pusey et al. 1993). Similar type of patterns have been reported in east flowing streams of Western Ghats (Johnson 1999; Johnson & Arunachalam 2010). Further, the regression plot fitted with species richness vs altitude suggest that altitude is covariate for temperature, which may be a key environmental variable associated with fish species distribution in the KMTR streams. Similar observations of longitudinal gradient in species diversity and assemblage structure have been reported from other mountainous regions (Horwitz 1978; Oberdorff et al. 1993, 1995; Godinho et al. 2000; Silvano et al. 2000; Ostrand & Wilde 2002; Grenouillet et al. 2004).

An exotic fish *Oreochromis mossambicus* was recorded from Gadana and Tamiranaparani rivers at Papanasam. This species was introduced in south Indian reservoirs in 1950s by fishery department (including reservoirs of KMTR) to improve reservoir fishery production (De Silva et al. 2004). Now it is well established in rivers, canals, irrigation tanks and downstream of Tamiraparani River, below the reservoirs. This species is not established in the upper reaches of KMTR (above reservoirs) due to presence of natural obstacles like high water falls and rocky cascades.

Although, the endemic fishes are present inside the protected area, there are few threats to these species. The important threats faced by these endemic species are: habitat degradation due to tea garden operation, entry of household waste from human settlements in some parts of KMTR and entry of chemical contaminations from tea garden. These activities may render the stream habitat not suitable for highly specialized fishes like *Garra joshuai* and *G. kalakadensis*, ultimately leading to reduction in endemic fish population. In order to conserve these threatened fishes, proper waste management mechanism should be placed in the tea garden areas. Further, the study on population status of endemic species is essential for conserving threatened species.

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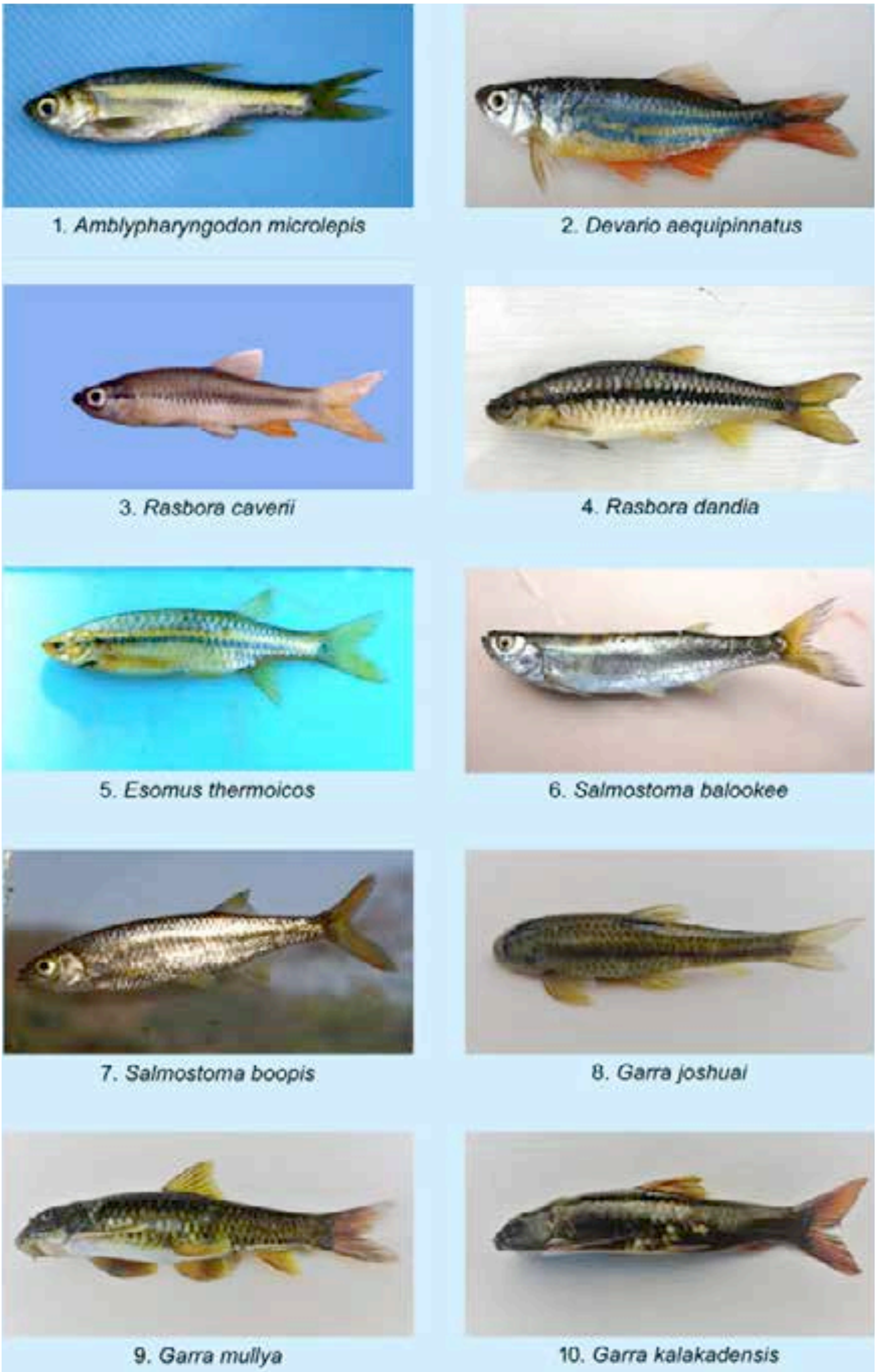

Image 2. Fishes of Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu. © J.A. Johnson & K. Kannan

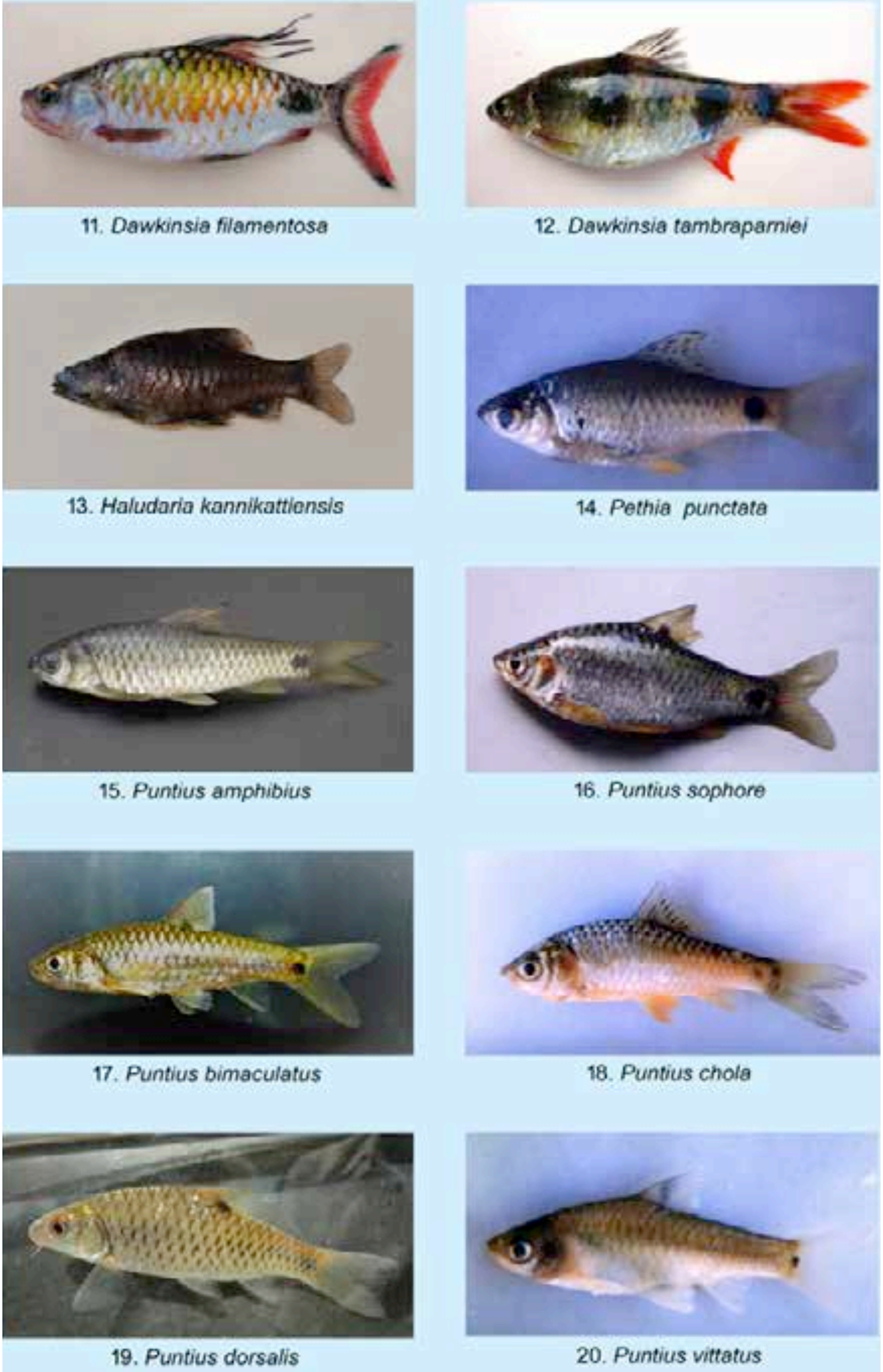

Image 3. Fishes of Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu. © J.A. Johnson, K. Kannan & K. Krishna Prasad

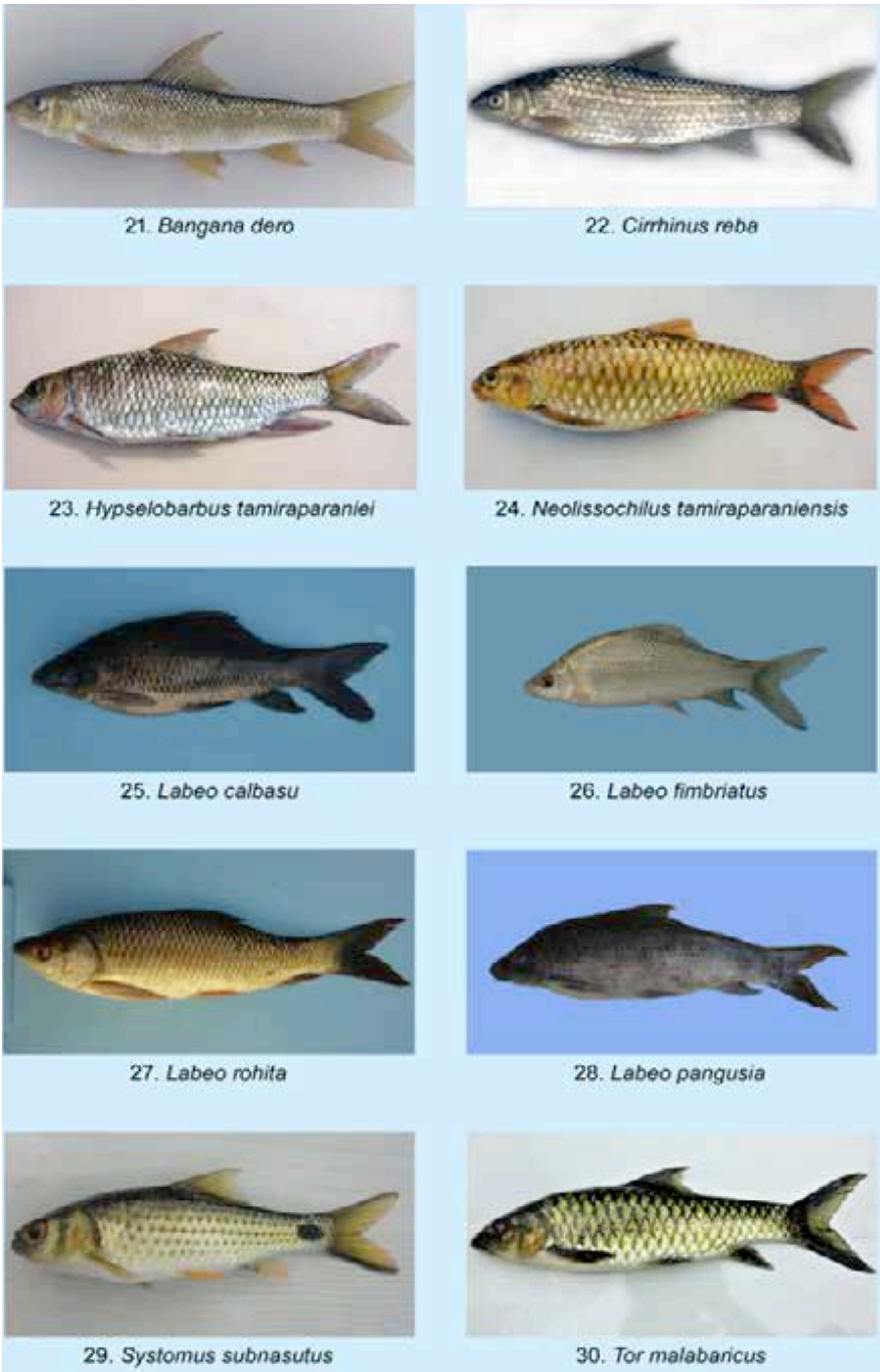

Image 4. Fishes of Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu. © J.A. Johnson & K. Kannan

Image 5. Fishes of Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu. © J.A. Johnson & K. Kannan

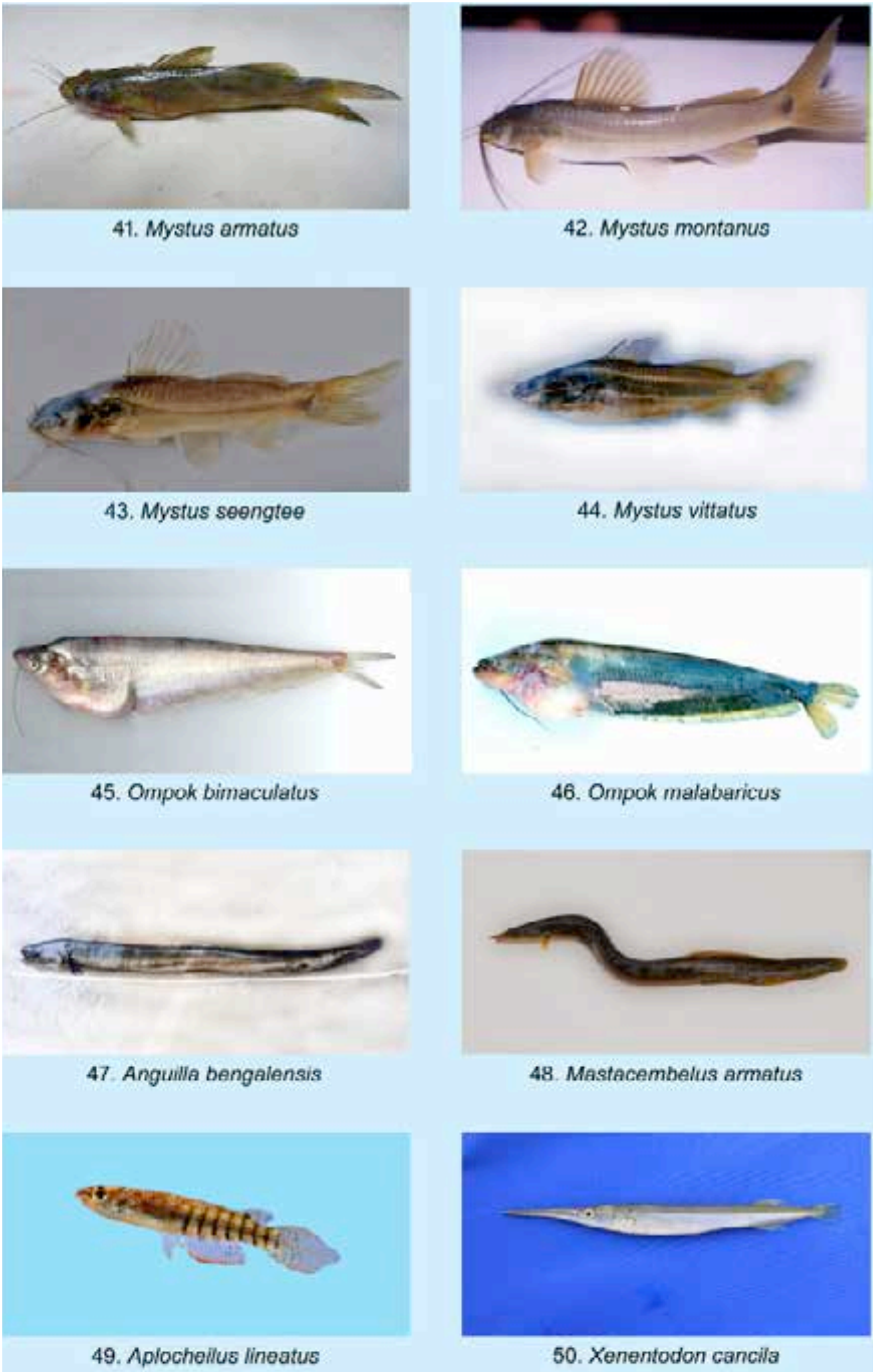

Image 6. Fishes of Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu. © J.A. Johnson & K. Kannan

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ARTICLE

Gastrointestinal helminth and protozoan infections of wild mammals in four major national parks in Sri Lanka

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Abstract: A cross-sectional, coprological survey of gastrointestinal (GI) parasites of wild mammals in four major National Parks in Sri Lanka: Wilpattu, Udawalawe, Wasgamuwa, and Horton Plains was carried out during November 2016 to August 2017. Fresh fecal samples were collected and analyzed using sedimentation technique, iodine & saline smears, and Sheather's sucrose flotation for morphological identification parasite eggs, cysts, and larvae. A modified salt flotation was carried out for egg counts. Seventy samples from 10 mammal species: Asian Elephant, Spotted Deer, Water Buffalo, Sambar, Indian Hare, Asian Palm Civet, Sloth Bear, Wild Boar, Grey Langur, Leopard, and four unknown mammals (two carnivores, one herbivore and one omnivore) were analyzed. Most were infected (94.3%) with more than one GI parasites. The highest prevalence of infection was recorded in Horton Plains (100%), followed by Wasgamuwa (92.8%), Wilpattu (90.4%) and Udawalawe (75.0%) with a significant difference among four parks (Chi square test; χ^2=35.435; df=3; p<0.001). Nineteen species of GI parasites were recorded, of which *Entamoeba*, *Isospora*, *Balantidium*, *Fasciola*, *Moniezia*, *Dipylidium*, strongyles, *Toxocara*, *Trichiurus* and hookworms were the most common. Strongyles (62.1%) and *Entamoeba* (80.3%) were the most prevalent helminth and protozoan infections, respectively. Overall, there was no difference in the prevalence of protozoans (84.3%) and helminths (87.1%; χ^2=1.0; df=1; p=0.317). In carnivores, *Entamoeba*, *Balantidium*, *Moniezia*, strongyles and *Strongyloides* were common and in herbivores, *Entamoeba*, strongyles, *Strongyloides* and *Toxocara* were common. The quantitative analysis showed strongyles (17.639 EPG) and *Isospora* (18,743 OPG) having the highest infection intensity among helminthes and protozoans, respectively. This study provides baseline information of GI parasites and their distribution in wild mammals in the four national parks. Although the prevalence of GI infections was high, their intensity shows that they could be incidental infections. When the prevalence of an infection is high but the intensity is low, it is unlikely to be a major health problem leading to the endangerment of a species. Parasitic diseases can not only affect conservation efforts, but they are also natural selection agents and drive biological diversification, through influencing host reproductive isolation and speciation.

Keywords: Cysts, gastrointestinal parasites, helminthes, identification, protozoans, wild mammals.

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Author contribution: CSS—carried out the field and laboratory work, analysed data and wrote the manuscript; RSR—designed the study protocols, supervised the field and laboratory work, edited the manuscript

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INTRODUCTION

National parks are established in many countries to protect and conserve nature while also serving for education, tourism and entertainment (Kaffashi et al. 2015). National parks in Sri Lanka were first established 100 years ago to conserve valuable natural environments (Dahlberg et al. 2010) and are distributed over three climatic zones; dry zone, wet zone and intermediate zone. Today, there are 35 national reserves consisting of three strict nature reserves, 26 national parks, five nature reserves, and one jungle corridor. In Sri Lanka, the Department of Wildlife Conservation (DWC) is the main government authority which has the legal power to control national reserves and natural forests. In these national reserves, a total of 95 species and subspecies of mammals have been described consisting of 21 endemic species and 12 introduced species (Weerakoon 2012).

Endoparasites are an important part of studying the disease ecology of wild animals as the abundance and diversity of parasites can determine the health of a particular ecosystem (Sallows 2007). Especially, in a natural ecosystem carnivores occur in lower densities than ruminants, therefore, parasitic infection of carnivores is a good indicator to understand the health of a specific national park (Stuart et al. 2017). Moreover, parasitic infections can vary between sexes, for example male ungulates are more susceptible to parasitic infections than the females (Dunn 1978; Apio et al. 2006). Environmental conditions like monsoon rains and soil moisture affect parasitic transmission and many parasitic diseases are acquired through contaminated soil and water (Marathe et al. 2002). When food and water are contaminated with infected feces it can easily spread the diseases among wild animals in the park (Coffey et al. 2007; Stuart et al. 2017). Parasites can affect the growth rate, mortality rate, population size and interaction between individuals such as sexual selection and social behaviors of wild mammals (Sinclair & Griffith 1979; Sumption & Flowerdew 1985; Freeland et al. 1986; Marathe et al. 2002).

Ecologists have recently begun to understand the importance of diseases and parasites in the dynamics of populations (Altizer et al. 2003). Diseases and parasites were probably responsible for some extinctions on islands but also on larger land masses, but the problem has only been identified retrospectively (reviewed in McCallum & Dobson 1995). On the other hand endemic pathogens and parasites might play a crucial role in maintaining the diversity of ecological communities and ecosystems (Karesh et al. 2012). When the hosts are keystone or dominant species with important functions in an ecosystem, the effects of diseases on ecological communities can be particularly pronounced (Preston & Johnson 2010). Patterns of disease emergence in wildlife and integration of parasitism into community ecology provide information for better understanding of the roles of parasites in nature. Among these, their role in food webs, competitive interactions, biodiversity patterns, and the regulation of keystone species, make it clear that parasites contribute to structuring ecological communities (Preston & Johnson 2010).

There is no current literature available on the GI parasites of wild animals in national parks in Sri Lanka. The present study was carried out to obtain baseline information of the types, prevalence and infection intensity of GI parasites in wild mammals in four major national parks located in three climatic zones of Sri Lanka.

MATERIALS AND METHODS

Study site and study animals

Four nature reserves were selected. Wilpattu National Park (8.433N & 80.000E), Wasgamuwa National Park (7.716N & 80.933E) and Udawalawe National Park (6.438N & 80.888E) are located in the dry zone with mean annual temperature of 27.2^{0}C, 27.0^{0}C, and 27.5^{0}C, respectively. Horton Plains National Park (6.800N & 80.000E), located in the wet zone has a mean annual temperature of 13.0^{0}C (Figure 1).

The number of wild mammal species varies among the four parks: 31 species of mammals in Wilpattu National Park, 43 in Udawalawe National Park, 23 in Wasgamuwa National Park and 24 in Horton Plains National Park (DWC, Sri Lanka).

Collection of samples

Fresh fecal samples from wild mammals in the four parks were collected during November 2016 to August 2017. Approximately, 10–15 g of fecal matter was collected from each animal that had defecated in the morning between 07.00 and 10.00 h while samples from those that defecate in the afternoon (e.g., Elephant and Wild Boar) were collected in the late afternoon between 16.00 and 18.00 h. A trained tracker from the DWC identified the fecal samples. Samples were taken to the laboratory in a cooler, stored in a refrigerator at 4^{0}C and were analyzed in the parasitology laboratory in the Department of Zoology at the University of Peradeniya.

Figure 1. The four national parks in Sri Lanka.

Sample analysis

Fecal samples were analyzed using four methods: (a) sedimentation technique, (b) direct iodine and saline smears, (c) Sheather's sucrose flotation, and (d) modified salt flotation. The eggs of different species were identified morphometrically under a microscope under 10X ocular lens and objective lens of 40X (total magnification 400x). The number of eggs, cysts/oocysts in 0.5ml were calculated as eggs per gram (EPG) in helminthes and cysts per gram (CPG) or oocysts per gram (OPG) in protozoans. The length and width of the eggs were measured under the same 400x magnification (10×40).

Sedimentation technique (Zajac & Conboy 2012; page 13)

Since the trematode eggs are relatively large and heavy they were qualitatively isolated using the sedimentation method. Approximately, 3g of feces was measured (for elephants 50g was measured due to the high fiber content in their feces) and mixed with 50ml distilled water. Then the suspension was poured into a test tube and allowed to settle for 5 min. The supernatant was removed and the pellet was re-suspended in 5ml of distilled water and then allowed to set for another 5 min. Finally, the supernatant was removed and the sediment layer collected in the bottom of the test tube was examined after adding one drop of Methylene Blue under 400x magnification.

Direct iodine and saline smears (Zajac & Conboy 2012; pages 12–13)

A drop of Lugol's iodine was placed on a microscopic slide and a small portion of fecal matter (~ size of head of a match) was picked up by using a cleaned toothpick and mixed thoroughly with iodine. Then a drop of saline (1% solution) was added to the smear, covered using cover slip and was observed under light microscope at 400x magnification.

Sheather's sucrose flotation technique (Zajac & Conboy 2012, pages 4–11)

This method was used to identify nematode and cestode eggs, coccidian oocysts and other protozoan cysts in the fecal sample. Approximately, 3g of fecal sample was measured (again 50g was used for elephant dung samples) and mixed with 50ml of freshly prepared Sheather's sucrose solution (SPG 1.2–1.25) to make a suspension. The suspension was filtered and poured into cleaned test tube and filled until a convex meniscus formed at the top of the tube. A cover slip was placed over the meniscus and left for 20 min. The cover slip was then placed on a slide and examined under the microscope at 400x magnification.

Modified salt flotation technique (Zajac & Conboy 2012; pages 4–11)

Modified salt flotation is a quantitative method to count eggs of nematodes, trematodes and cestodes and cysts of protozoa. Approximately, 3g of the sample was transferred into a 15ml clean centrifuge tube and 14ml of distilled water were added. For elephant dung samples, 50g was transferred into a 50ml centrifuge tube and 45ml of distilled water were added. Then the fecal solution was stirred well with using a glass rod, the tube was centrifuged at 3000G (N/kg)for 20 min. After that, the supernatant was removed, and the tube was filled again with 14ml (or 45ml) of distilled water and was centrifuged at 3000G for 20 min. This procedure was repeated until a clear solution of the supernatant was obtained. Then the supernatant was removed and salt solution was added to the butt of the centrifuge tube up to 14ml (or 45ml) level. Again, the tubes were centrifuged at 3000G for 20 min. Then the supernatant with the floating parasitic eggs was transferred into a 15ml clean centrifuge tube and distilled water was added up to the 15ml level and was centrifuged at 3000G for 10 min. Then the supernatant was removed and the sediment was pipetted out into microcentrifuge tubes (Eppendorf®). These tubes were then centrifuged at 3000G for 10 min. The supernatant was removed leaving about 0.5ml of solution. This was mixed thoroughly and about 0.1ml of the suspension was placed on and a microscopic slide. Five such smears were prepared from each sample and examined using a light microscope. Eggs of different species were identified and counted and the number of eggs per gram in each sample was calculated. Intensity of infections was calculated using CPG (cysts per gram), OPG (oocysts per gram) and EPG (eggs per gram) of feces.

RESULTS

Prevalence of parasites

A total of 70 mammals were examined (Wilpattu = 21, Udawalawe = 8, Wasgamuwa = 28 and Horton Plains = 13) of which 66 (94.3%) were infected with more than one GI parasite of protozoans, trematodes, nematodes and cestodes. Among the four parks, the highest prevalence of GI parasites was observed in the Horton Plains where all the mammals were infected (100%), followed by Wasgamuwa (92.8%) and the lowest was Udawalawe (75.0%) with a significant difference in the prevalence among parks (Chi square test; $\chi^2 = 35.435$; df = 3; p<0.001). Overall, there was no difference in the prevalence of protozoans (84.3%) and helminths (87.1%; $\chi^2 = 1.0$; df = 1; p = 0.317).The highest protozoan prevalence was observed in Horton Plains(100%), followed by Wasgamuwa (85.7%), Wilpattu (80.9%) and Udawalawe (62.5%). The highest helminth prevalence was observed from Horton Plains (92.3%), followed by Wasgamuwa (89.3%), Wilpattu (85.7%) and Udawalawe (75.0%).

Types of gastrointestinal parasites

Parasites belong to 19 genera were observed in mammals in the four national parks. Out of which 14 species were identified (Table 1; Figure 2). The most common protozoan was *Entamoeba* (80.3%) observed

Table 1. Prevalence of gastrointestinal parasites of wild mammals in four national parks in Sri Lanka.

Parasite	National Park			
	Wilpattu	Udawalawe	Wasgamuwa	Horton plains
Entamoeba	71.4%	83.3%	85.7%	92.3%
Isospora	52.4%	50%	35.7%	84.6%
Balantidium	14.3%	16.7%	-	-
Moniezia	19.0%	16.7%	39.3%	53.9%
Fasciola	38.1%	33.3%	39.3%	-
Schistosoma	4.8%	-	10.7%	-
Dipylidium	-	-	32.1%	-
Diphyllobothrium	-	-	14.3%	-
Ascaris	14.3%	-	32.1%	-
Strongylus	57.1%	83.3%	57.1%	61.5%
Strongyloide	-	33.3%	10.7%	-
Trichostrongylus	19.0%	16.7%	10.7%	-
Trichiurus	-	-	10.7%	15.4%
Toxocara	-	-	10.7%	-
Hook worm	-	50%	-	7.7%
Pin worm	23.8%	-	7.1%	-
Unknown sp 1	4.8%	-	-	3.8%
Unknown sp 2	-	-	-	15.4%
Unknown sp 3	-	-	3.6%	15.4%

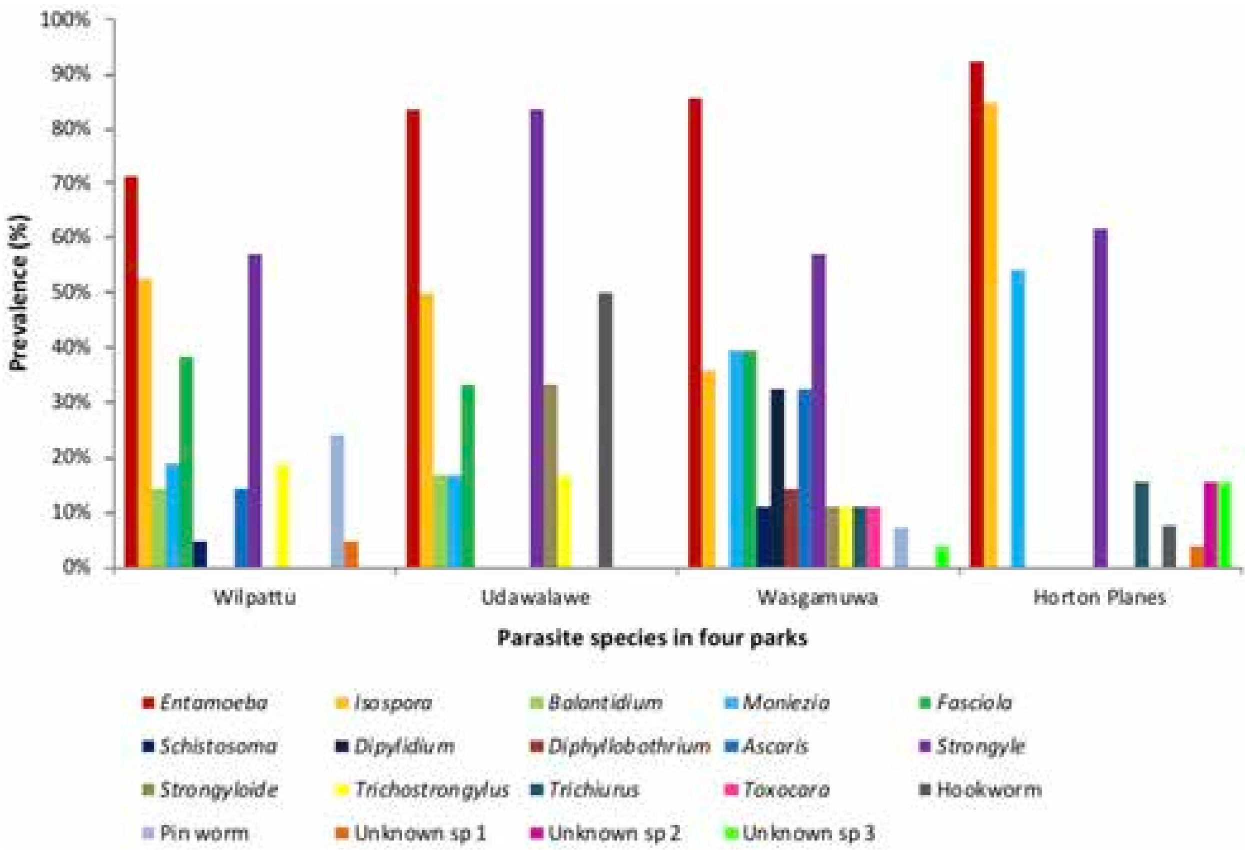

Figure 2. Percentage prevalence of gastrointestinal parasites in wild mammals of four national parks in Sri Lanka.

in the Asian Elephant, Water Buffalo, Spotted Deer, Asian Palm Civet, Indian Hare, Sloth Bear, Sambar, Wild Boar, and Grey langur. The most common helminth were strongyles (62.1%) observed in the Asian Elephant, Water Buffalo, Asian Palm Civet, Leopard, Sloth Bear, Sambar, Indian Hare, and Grey Langur. The least common parasite infections were pinworm, *Toxocara*, *Diphyllobothrium* and *Balantidium*.

Intensity of Infections

Overall, the intensity of infection was not high in any GI parasite observed in the four parks (Table 2). The highest protozoan infection was observed in the Horton Plains (23.811 CPG) and the highest helminth infection was observed in Wasgamuwa (18.743 EPG; Table 2).

DISCUSSION

Results show that the prevalence of GI infections in wild mammals in the four national parks was high (94.3%). High prevalence of GI infections are recorded in many national parks: Masai Mara National Reserve (100%) in Kenya (Engh et al. 2003), Kibale National Park (84%) in Uganda (Bezjian et al. 2008), Serengeti and the Ngorongoro Crater (97.3%) in Tanzania (Muller-Graf, 1995), Langtang National Park (88.9%) in Nepal (Achhami et al. 2016). There was a significant difference in the prevalence among the four parks. Udawalawe had the lowest prevalence GI infections while Horton Plains had the highest. This could be due to the period of sampling where it was carried in the dry period in Udawalawe and in the rainy season in Horton plains. During rainy periods, the transmission of parasitic infections is high. The environmental conditions such as rainfall patterns have a significant influence on the parasitic transmission in mammals and there is a strong relationship between the rainfall and the pathogenecity of GI infection (Marathe et al. 2002; Rosenthal 2010; Turner et al. 2012; Chattopadhyay & Bandyopadhyay 2013; Stuart et al. 2017). On the contrary, Wasgamuwa Park was also sampled during the dry season but had a higher prevalence of infection. Some studies, however, show that the prevalence of certain GI parasites is not correlated with rainfall pattern (Gillespie et al. 2004, 2005). For example, *Oesophagostomum* is a common infection in baboons in the dry season in Kibale National forest (Bezjian et al. 2008). The authors point out that this parasite may resist desiccation due to the lush habitat of the Kibale National Forest and the presence of the Dura River. It has also been noted that during the dry season, *Oesophagostomum* sp. larvae can avoid adverse weather conditions by arresting their development (Pettifer 1984). Nevertheless, the sample size in the Udawalawe Park was small (n = 8) and therefore comparing across parks and drawing conclusions cannot be done uncritically. The prevalence of infection did not show any marked seasonal variation among the four parks.

There was no difference in the prevalence of helminthes and protozoans in the four national parks. The two groups have developed different adaptive strategies for their survival. Protozoans release large number of cysts with feces, compared to helminthes. But helminth egg is resistant to various environmental conditions like high temperature, high rainfall, desiccation etc (e.g., *Toxocara*, *Trichiurus*) (Okulewicz et al. 2012) as they have a thick egg shell. Wilpattu and Udawalawe parks are located in the dry zone of the country that has high temperatures but the helminth eggs and protozoan cysts were able to survive those conditions. Some studies however, show high prevalence of helminthes than protozoans, have been reported in wild lions in Tanzania (Muller-Graf 1995) and spotted hyenas in Masai Mara Reserve, Kenya (Engh et al. 2003) whereas in captive conditions such as zoological gardens, the protozoan prevalence is higher than helminthes due to regular anthelmintic treatments (Dawet et al. 2013) but may not be the case always (Adeniyi et al. 2015; Aviruppola et al. 2016).

Prevalence of parasite infections can lead to evolution of tolerance or resistance in the host. Tolerance to parasites, or infection tolerance is the ability of a host to limit the health or fitness effect of a given infection intensity whereas resistance is the ability of the host reduce risk of infection. Both resistance and tolerance are host traits that have evolved to alleviate the health and fitness effects of infection, but they represent two fundamentally different strategies to deal with parasites. The main difference of the two is that resistance reduces the risk of infection and/or the replication rate of the parasite in the host, whereas tolerance does not. Tolerance and resistance lead to different ecological and evolutionary interactions between hosts and their parasites (Roy & Kirchner 2000; Rausher 2001; Best et al. 2014; Vale et al. 2014). Roy & Kirchner (2000) show that if hosts evolve resistance, this should reduce the prevalence of the parasite in the host population and if hosts evolve tolerance instead, this will have a positive effect on parasite prevalence.

Among the GI parasite species observed *Entamoeba*, *Isospora*, and *Balantidium* were the most common protozoans while *Moniezia*, *Fasciola*, *Schistosoma*, *Dipylidium*, *Diphyllobothrium*, *Ascaris*, strongyles, *Strongyloides*, *Trichostrongylus*, *Trichiurus*, *Toxocara*, hookworm, and pinworm infections were the common helminthes. The diversity of parasite species was highest in the Wasgamuwa Park and the lowest in the

Table 2. Prevalence and the intensity of parasites found in wild mammals in four national parks in Sri Lanka.

National Park	Mammal species (n)	Parasite	Prevalence	Intensity (CPG/EPG/OPG)
Wilpattu	Asian Elephant *Elephas maximus* (1)	*Entamoeba*	100%	0.020
		Fasciola	100%	0.060
		Strongyles	100%	0.300
	Water Buffalo *Bubalus arnee* (5)	*Entamoeba*	40%	0.334
		Balantidium	60%	0.734
		Isospora	60%	3.467
		Fasciola	40%	0.201
		Moniezia	20%	0.067
		Schistosoma	20%	0.067
		Strongyle	40%	0.400
	Spotted Deer *Axis axis* (4)	*Entamoeba*	50%	0.417
		Isospora	75%	0.084
		Moniezia	75%	0.084
		Ascaris	75%	0.084
		Trichostrongylus	50%	4.834
	Indian Palm Civet *Paradoxurus hermaphroditus* (1)	*Entamoeba*	100%	6.670
		Isospora	100%	1.334
		Strongyle	100%	0.334
	Sloth Bear *Melursus ursinus* (1)	*Entamoeba*	100%	0.334
		Isospora	100%	14.000
		Dipylidium	100%	10.000
		Strongyle	100%	14.668
	Indian Hare *Lepus nigricollis* (1)	*Entamoeba*	100%	1.334
		Moniezia	100%	0.334
	Sambar *Rusa unicolor* (3)	*Entamoeba*	100%	0.778
		Isospora	100%	1.222
		Fasciola	100%	2.889
		Ascaris	66.7%	0.222
		Strongyle	66.7%	0.778
		Trichiurus	33.4%	0.222
	Wild Boar *Sus scrofa* (4)	*Entamoeba*	50%	0.333
		Isospora	25%	0.416
		Fasciola	50%	0.416
		Moniezia	25%	0.084
		Dipylidium	25%	0.084
		Strongyles	75%	1.000
		Unknown sp1	100%	2.084
	Unknown omnivore (1)	*Isospora*	100%	1.000
		Dipylidium	100%	7.334
		Unknown sp 1	100%	4.334
		Unknown sp 2	100%	0.334

National Park	Mammal species (n)	Parasite	Prevalence	Intensity (CPG/EPG/OPG)
Udawalawe	Asian Elephant *Elephas maximus* (1)	*Fasciola*	100%	0.020
		Strongyle	100%	0.960
	Water Buffalo *Bubalus arnee* (1)	*Entamoeba*	100%	2.000
		Balantidium	100%	1.000
		Isospora	100%	4.667
		Strongyle	100%	1.334
	Grey Langur *Semnopithicus priam* (1)	*Entamoeba*	100%	1.000
		Isospora	100%	5.334
		Strongyle	100%	18.668
		Strongyloide	100%	7.334
		Hook worm	100%	0.334
	Unknown carnivore (1)	*Entamoeba*	100%	1.000
		Isospora	100%	1.667
		Strongyle	100%	8.334
		Strongyloide	100%	1.667
		Hook worm	100%	0.334
	Spotted Deer *Axis axis* (1)	*Entamoeba*	100%	2.000
		Fasciola	100%	0.334
		Hook worm	100%	0.334
		Trichostrongylus	100%	1.000
	Indian Hare *Lepus nigricollis* (1)	*Entamoeba*	100%	2.000
		Moniezia	100%	4.000
		Strongyle	100%	8.000
Wasgamuwa	Asian Elephant *Elephas maximus* (6)	*Entamoeba*	100%	2.667
		Isospora	25%	0.166
		Fasciola	50%	0.334
		Moniezia	100%	1.083
		Strongyle	50%	1.883
	Water Buffalo *Bubalus arnee* (6)	*Entamoeba*	100%	3.050
		Isospora	50%	0.555
		Moniezia	66.7%	0.611
		Schistosoma	50%	0.167
		Ascaris	83.3%	0.889
		Strongyle	66.7%	0.833
	Spotted Deer *Axis axis* (6)	*Entamoeba*	83.3%	0.833
		Isospora	83.3%	0.833
		Unknown sp3	16.7%	0.055
		Fasciola	66.7%	0.444
		Moniezia	50%	0.167
		Dypylidium	33.3%	0.222
		Diphyllobothrium	33.3%	0.166
		Ascaris	16.7%	0.167
		Trichostrongylus	50%	0.500

National Park	Mammal species (n)	Parasite	Prevalence	Intensity (CPG/EPG/OPG)
Wasgamuwa	Asian Palm Civet *Paradoxurus hermaphroditus* (7)	*Entamoeba*	100%	1.048
		Isospora	14.2%	0.528
		Fasciola	85.7%	3.667
		Dipylidium	71.4%	1.000
		Diphyllobothrium	28.5%	0.190
		Strongyle	100%	19.667
		Strongyloide	42.8%	1.381
		Trichiurus	42.8%	1.714
		Toxocara	28.5%	0.809
		Pinworm	14.2%	0.407
	Leopard *Panthera pardus kotiya* (1)	*Dipylidium*	100%	0.334
		Strongyle	100%	9.334
		Toxocara	100%	5.000
	Sloth Bear *Melursus ursinus* (1)	*Dipylidium*	100%	2.000
		Strongyle	100%	1.668
	Unknown herbivore (1)	*Entamoeba*	100%	2.000
		Ascaris	100%	0.667
		Strongyle	100%	0.667
Horton Plains	Indian Hare *Lepus nigricollis* (4)	*Entamoeba*	100%	15.755
		Isospora	100%	45.697
		Moniezia	75%	2.647
		Strongyle	75%	12.521
		Trichiurus	50%	3.014
		Unknown sp 3	25%	6.500
	Asian Palm Civet *Paradoxurus hermaphroditus* (1)	*Entamoeba*	100%	16.000
		Strongyle	100%	4.000
		Unknown sp 3	100%	2.000
	Wild Boar *Sus scrofa* (2)	*Entamoeba*	50%	0.333
		Isospora	100%	4.667
		Strongyle	100%	0.667
		Unknown sp 1	100%	2.000
	Sambar *Rusa unicolor* (5)	*Entamoeba*	100%	1.401
		Isospora	100%	0.734
		Moniezia	60%	0.200
		Strongyle	20%	0.067
		Hook worm	20%	0.067
	Unknown carnivore (1)	*Entamoeba*	100%	6.000
		Moniezia	100%	2.000
		Strongyle	100%	4.000

Horton Plains. Although the prevalence of infection was highest in the Horton Plains National Park, the diversity of infection was the lowest. The common GI parasites for both herbivores and carnivores were *Entamoeba* and strongyles. Fecal samples of herbivores such as the Asian Elephant *Elephas maximus*, Water Buffalo *Bubalus arnee*, Spotted Deer *Axis axis*, Sambar *Rusa unicolor*, Grey Langur *Semnopithecus priam*, and Indian Hare *Lepus nigricollis* were infected with *Entamoeba*, *Balantidium*, *Moniezia*, *Fasciola*, *Trichiurus*, strongyles, *Strongyloides*, and *Trichostrongylus*. Carnivorous such as Leopard *Panthera pardus kotiya* and other unknown carnivorous species were infected with *Entamoeba*, strongyles, *Strongyloides,Toxocara*, and hookworm.

Herbivores get the infections through contaminated food or water as most of these GI parasite eggs, cysts and larvae are associated with pasture. Digenetic trematodes like *Fasciola,* and *Pharamphistomum* have indirect life cycles where a snail (e.g., *Lymnea, Planorbis*, *Balinus, Oncomelaria*) acts as an intermediate host of parasite who associate with water bodies. Cercariae of these trematodes encyst on vegetation where herbivores feed. *Moniezia* is a common cestode of herbivores and it was recorded from all four parks. It was also recorded in an unknown carnivore in Horton Plains. A recent study on GI parasites of wild cats reported *Moniezia* in four leopards in Horton plains (Kobbekaduwa et al. 2017) and the authors attribute this as an accidental ingestion of oribatid mites, the intermediate host of *Moniezia* by the leopards. The mite lives on the pasture and enters the mammalian host while feeding. *Fasciola*, *Moniezia*, *Strongyloides*, and *Trichuris* obtained from herbivores in Bhutan (Tandon et al. 2005) and strongyles, *Strongyloides*, *Moniezia* observed from Musk Deer in Nepal (Achhami et al. 2016). *Balantidium* is also transmitted through fecal-oral route infection via contaminated pasture (Schuster & Ramirez-avila 2008). Carnivores get infected by GI parasites like *Toxocara* mainly by ingesting the intermediate host (Okulewicz et al. 2012) or by direct penetration like the hookworms. *Toxocara* is a common GI parasite of carnivores worldwide. Studies have shown Grey wolves in Riding mountain National Park of Canada (Sallows 2007; Stuart et al. 2017) wild Lions in Tanzania (Muller-Graf 1995), Wolves in northeastern Poland (Kloch et al. 2005) wild carnivores in Przybyszewskiego (Okulewicz et al. 2012), and Spotted Hyena samples in Masai Marai Reserve in Kenya (Engh et al. 2003) as few examples.

Although the prevalence of infection was high among the mammals, the intensity of most infections were not high enough to cause serious health problems in these mammals. Wild mammals have natural resistance against parasites or live mutually with them, unlike captive stressful conditions where the animals are more susceptible to parasitic infections (Borkovcova & Kopriva 2005; Singh et al. 2006a,b; Adeniyi et al. 2015). Free ranging animals can disperse the parasite throughout the environment, therefore the infections in wild mammals or free living ones occur in low intensities compared to captive or domestic mammals (Stuart et al. 2017). Because of constant stress of captivity makes animals more susceptible to parasitic infection as the immune system of these captive animals become weak (Gracenea et al. 2002; Cordon et al. 2008). Moreover, some infections in most captive and domestic mammals has both transplacental and transmammary transmission which can cause serious damage such as acute and ocular infections of *Toxocara* in cubs (Okulewicz et al. 2012). In some cases parasites can affect the cellulose digestion of host species, increase the rate of morbidity and mortality (e.g., *Oesophagostomum*; Muehlenbein 2005). This may depend on the intensity of infection, where some parasites become less pathogenic even with large number of eggs or cysts (>20,000), but some become high pathogenic with few eggs or cysts.

This study provides baseline information of GI parasites and their distribution in wild mammals in the four national parks. The prevalence of GI infections was high, nevertheless, their intensity shows that they could be incidental infections. When the prevalence of an infection is high but the intensity is low, it is unlikely to be a major health problem to endanger species. Mathematical models have shown that parasitic diseases affecting host mortality maintain equilibrium far below their disease free carrying capacity (Anderson 1979; McCallum & Dobson 1995). Highly pathogenic diseases also have minor effect on host populations. If a disease is detectable at high prevalence, it is probably mild and unlikely to be a major problem to an endangered species. Parasitic diseases can affect conservation efforts, acting as a contributing threat in the endangerment of wildlife hosts, and occasionally causing severe population declines (de Castro & Bolker 2005; Blehert et al. 2009). The maintenance of host-parasite relationships in managed wildlife populations can be ultimately beneficial, and points to a critical role for wildlife parasitologists in conservation efforts (Gomez & Nichols 2013). Parasites are also natural selection agents influencing a variety of host attributes, from phenotypic polymorphism and secondary sexual characters, to the maintenance of sexual reproduction (Wegner et al. 2003; Lively et al. 2004; Blanchet et al. 2009). These effects ultimately drive biological diversification, through influencing host reproductive isolation and speciation (Summers et al. 2003). Infections are fundamental to the ecological and evolutionary drivers of biological diversity and ecosystem organization (Marcogliese 2004). Wildlife parasites should be considered meaningful conservation targets as important as their hosts as they not only can affect conservation efforts, but they are also natural selection agents and drive biological diversification, through influencing host reproductive isolation and speciation.

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REVIEW

Appraising carnivore (Mammalia: Carnivora) studies in Bangladesh from 1971 to 2019 bibliographic retrieves: trends, biases, and opportunities

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Abstract: In contrast to <7% natural forest covers and >1,000 people living km^{-2}, Bangladesh, one of the smallest countries in Asia, shelters 28 carnivorous mammals. The species are of six families, nearly half of the entire carnivore diversity of the Indian Subcontinent. Carnivores of Bangladesh are little understood and they are disappearing fast despite receiving stern protection. Yet, there has been no assessment on the status of existing knowledge. A review was aimed to assess the existing knowledge and evaluate the research trends in country's mammalian carnivores. Peer-reviewed works published from 1971 to 2019 were skimmed and categorized systematically according to five traits: publication type, research topic, time of publication, region, and species of study. In a total of 95 works examined, substantial numbers were on tiger (n=45) and the Sundarbans (n=47). In imbalance to action plans procured for tiger conservation, 14 carnivores have never been exclusively studied in Bangladesh. Of the research topics, preference was evident for wildlife management and conflict analyses as there were 31 scientific papers out of 63 in these categories. Inventory compilation for books (18 of 24) comprised the next preferred subject. The assessment could identify gaps in related knowledge in different regions of the country. Eastern region has experienced a meagre amount of work, although its mixed evergreen forests have larger combined area than the Sundarbans, and is known for its higher richness of diversity. Exclusive works outside legally defined protected areas were also low. We found no works in northwestern and southern Bangladesh. In the last two decades, the temporal trajectory of research effort has been more, and the topics have started to diversify. In order to improve conservation practices, we stress that gaps in knowledge pertaining to region or subject may be bridged with contemporary study techniques. This is crucial to highlight the status of carnivore species that are otherwise 'elusive', 'apparently absent', or 'least-known'.

Keywords: Bibliography, conservation priorities, meta-analysis, review.

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Author contribution: MA conceived the research idea. MA and TZ designed the methodology. TZ collected necessary data and prepared the first draft. MA finalized the manuscript. Both authors reviewed and approved the manuscript.

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INTRODUCTION

Carnivora that constitute the fifth largest mammalian order faces taxon-wide existential crisis (Inskip & Zimmermann 2009; Ripple et al. 2014). According to IUCN (2019), 88 species are threatened with a trend of decreasing population. Conserving carnivores is now a major concern worldwide (Treves & Karanth 2003).

The concern is in recognition of the fact that for a stable and diverse community of wild animals, carnivorous mammals exert intangible influences. They can act as apex predators and their absence often leads to trophic cascades (Prug et al. 2009; Ripple et al. 2014; Suraci et al. 2017). As the ecosystem services of a carnivore can be of an umbrella or keystone to conserve an ecosystem in its entirety (Sergio et al. 2008; Baker & Leberg 2018), human intervention in wildlife management practices cannot supersede or bypass a carnivore's natural impact in the wild (Gittleman & Gompper 2005; Ripple et al. 2014).

Bangladesh is the world's 92nd largest country covering an area of 147,610km^2 and the 8th most populous with about 165.6 million people. Also, the country is rich in biodiversity and harbors 138 extant mammals; 28 of which are carnivores (IUCN Bangladesh 2015; Khan 2015, 2018).

Geographically, Bangladesh is traversed by the Tropic of Cancer, and there exists a transition zone between the Indo-Himalayan and the Indo-Chinese sub-regions of the Oriental realm, which are considered advantageous to form wildlife habitats (Corlett 2007; Feeroz 2013; Khan 2018). Historical anecdotes indicate about the rich presence of carnivores all over Bangladesh once. Many carnivore species have now become restricted to certain areas or are known only from sporadic encounters (Khan 2015).

The carnivores of Bangladesh are in six terrestrial families: Viverridae, Felidae, Herpestidae, Canidae, Ursidae, and Mustelidae. The Bengal Tiger *Panthera tigris* is the country's national animal. Three other large carnivores, the Indian Wolf *Canis lupus*, Striped Hyena *Hyaena hyaena*, and Sloth Bear *Melursus ursinus* are deemed to be extinct in Bangladesh (Khan 2018). If compared to more diverse carnivore assemblages of neighboring India (57 species), Nepal (47), and Bhutan (39) and their respective habitat diversity, the inventory of Bangladesh is still considerable given its <7% natural forest cover and >1000 people living km^{-2} (Wangchuk 2004; NFA 2007; Menon 2014; Amin et al. 2018).

Carnivores are still present in all the three major forest types of Bangladesh (IUCN Bangladesh 2015) (Fig. 1). The Sundarbans mangroves support the only stable Tiger population in the country. Wet deciduous forests which once swathed from central to north and northwest, is now extremely fragmented, but continue to be known for civets, mongooses, *Felis* and *Prionailurus* cats. Concentrations of mixed evergreen forests are in eastern regions typified by hills, streams, rugged terrain, and, in cases, tea-gardens on the periphery. Eastern forests are long credited for every native carnivore. Apart from the forests, homestead jungle and wetland vegetation support small mammals. Although protected under several formal definitions, here, threats to wildlife and wildlife habitats are surmounting because of encroachment, altercation, destruction, high-dependency on forest products, agro-industries, trafficking, persecution, and retaliatory killings, to name but a few (Khan 2015, 2018).

We find no comprehensive assessment of the status of existing knowledge on mammalian predators of Bangladesh. But on global or regional scales, extensive reviews tend to highlight species in critical research needs, and steer conservation interventions to new perspectives as exemplified by Dalerum et al. (2008), Inskip & Zimmermann (2009), Periago et al. (2014), Broto & Mortelliti (2018).

For instance, Broto & Mortelliti (2018) highlighted the pattern of researches on mammals of Sulawesi Island in Indonesia with high insular endemism. Similarly, Periago et al. (2014) assessed the pattern and consequence of losing mammalian herbivores and frugivores in savanna woodland of Central South America. On a larger scale, Inskip and Zimmerman (2009) evaluated the nature and level of conflict between human and each of the wild feline species. Whereas, Dalerum et al. (2008) reviewed the status and decline of carnivore guilds in continental perspective. All these reviews were systemic in assessing literary works. These have stressed on knowledge gap and research bias only to envisage better and bolder scheming of conservation pursuits.

In order to make an appraisal of the works on mammalian carnivores of Bangladesh, here we have proceeded with three objectives: (1) to construct a systematic compilation of peer-reviewed researches, (2) to identify taxonomic and knowledge bias in these studies, and (3) to assess their geographic trend within the country and the temporal trajectories.

MATERIALS AND METHODS

Extent of the review

Within a period of four months between April 2019 and July 2019, we carried out the literature search. In order to meet our objectives, we picked five traits for any work: publication type, research topic, region in Bangladesh, time (year of publication), and the studied species. We have investigated the pattern in publication types and research themes. We recognized the most-studied and the least-studied carnivores. We compared the relevance of research to threatened status of the species. We have examined the geographic distribution of works, their aforementioned traits, and consideration for protected areas. Similarly, we have examined plots over year bands to understand a temporal trend. On any pertinent bias and gap, we conjectured on the possible factors in discussion.

Consideration of literature

We restricted our search to the following types of publications: peer-reviewed scientific papers, peer-reviewed book/book chapters, conservation action plans, and doctoral theses completed from 1971 to 2019. We observed project reports within this period but excluded them from analyses. We did not consider conference abstracts, MS theses and non-scholarly articles.

We have considered only mammalian carnivores reportedly living within the geopolitical boundary of Bangladesh. To enlist the extant carnivores for consideration, we consulted Khan (2018, 2015), and Ahmed et al. (2009). To obtain insight to assessment of threat at the regional and global levels, respectively, we used IUCN Bangladesh (2015) and IUCN (2019).

Sourcing literature

Works were collected using three primary research databases, i.e., Google Scholar, BioMedCentral, and Web of Science. To intensify in-depth search, we followed preset keywords in English. Our search protocol was based on Pullin & Stewart (2006), and we included 'species name' (scientific or common) and 'Bangladesh' in every attempt. In addition to the pair of obligatory words we used the following keywords in combination: 'attitude', 'behavior', 'camera-trap', 'coexistence', 'conflict', 'depredation', 'distribution', 'diversity', 'ecology', 'mortality', 'new record', 'prey', and 'zoonotic disease'. We followed the search pattern for every extant carnivore species of the country. We also looked for key wildlife biologists of Bangladesh during searches to obtain maximum results.

Table 1. Terminologies applied for categorization of published studies on carnivore mammals of Bangladesh.

Research Topic	Scope of study
1. Inventory	Checklist of mammals of any study area.
2. Discovery and distribution update	Discovery, distribution update, new records, sighting documentations.
3. Ecology	Ecological study, breeding behavior, feeding behavior, territorial behavior, activity pattern, home range, habitat preference.
4. Wildlife management and conflict analysis	Ethno-zoological aspects, human-carnivore interactions, threat analysis, environmental impact, climatic impact, wildlife poaching and trade, anthropogenic effects and perceptions, conservation genetics, research in recovery strategies, conservation action plan.
5. Population dynamics	Population status, population size, population density.
6. Zoonotic and anthroponotic disease	Case studies on these diseases.
7. Consideration of protected area (PA)	
7.1. Inside PA	Researches that considered any protected area declared under international or regional definition, i.e., national park, wildlife sanctuary, reserve forest, ecologically critical area, eco-park, RAMSAR site as study site.
7.2. Outside PA	Researches that did not consider any of the above as study site.
7.3. Both	Researches that encompassed study area covering both protected and non-protected habitats.
8. Regions: As per Khan (2018)	
8.1. Central, 8.2. North, 8.3. South, 8.4. Northeast, 8.5. Northwest, 8.6. Southeast and 8.7. Southwest	

In addition to the three primary searches online, relevant books and journals were accessed from Professor Yousufzai Seminar Library repository of the Department of Zoology, University of Dhaka. This was carried out to acquire older works that could have missed digital indexing.

Categorization under pre-defined themes

We observed the respective aims and outcomes of the obtained works. Then, we categorized them under six pre-determined research themes. We construed the categorization after consulting verde Arregoitia (2016), Broto & Mortelliti (2018), and Inskip & Zimmermann (2009). The definition and scope for each category are given in Table 1.

Studies were examined to ascertain whether each of these dealt with a single species or multiple species or any particular group (taxa higher than genus). If multiple species names were specified in a single work, we added the work to tally count of each pertinent species, however, if any study approached a group (for example, a taxonomic family), we kept it to the mentioned group. For example, Islam et al. (2013) assessed bears of Bangladesh, we counted the work for the 'ursids' rather than each of the three bears of the country. We also considered the works that covered all wildlife or all mammals or all carnivores of Bangladesh and kept the count to 'wildlife', 'mammals', and 'carnivores', consecutively (Table 1; Appendices 1–2).

Spatial and temporal classification

We followed Khan (2018) where seven geographical regions have been defined to characterize wildlife distribution in Bangladesh and recreated the map for the review (Table 1). We put a particular work to a specific region, considering whether the respective work's study area fell within the geographic region. If multiple regions were specified in a single work, we added the work to tally count of each respective region, however, if any work considers the country, we accredited the count to 'Bangladesh'.

The works were also classified on their consideration of protected area (PA) and assorted into three groups: outside PA, inside PA or both (Table 1).

To assess the research trajectory in time, we considered two trends: year-wise pattern and a cumulative rate. We assigned a study to the year it was published. For tracking changes in publication types and research topics, works were classified into six time periods, each of a decade: 1971–1980, 1981–1990, 1991–2000, 2001–2010, 2011–2019. Time trajectory was initiated from 1971; this was when Bangladesh had gained independence.

Analyses

We summed the total number of works for each pertinent species, and, thus, identified the most-studied and the least-studied species. We summed the number of studies tallied for a research topic to check the bias among topics. In manner alike, to point out the geographic/temporal pattern, we considered the total number of works assigned to a region or a year.

RESULTS

A brief on the reviewed literature

We found 95 peer-reviewed works on carnivores of Bangladesh completed within the considered timeframe, i.e., 1971–2019. Of these, 63 (66.3%) were peer-reviewed scientific papers, six (6.3%) doctoral theses, 24 (25.3%) books. There were two action plans (2.1%) on Tiger. In addition, we came across seven project reports (Appendix 1) that were excluded from our analysis. All these 102 works we extracted through literature search are provided in Appendix 2.

Out of total 95 references used for analysis in the study, 'wildlife management and conflict analysis' (n=42, 44.2%) appeared to be the most prolific research topic among all types. Topics dedicated to other studies are: Ecology (n=15, 15.8%); discovery and distribution update (n=9, 9.5%), inventory (n=24, 25.3%), population dynamics (n=3, 3.1%), and investigation of zoonotic and anthroponotic diseases (n=2, 2.1%) (Fig. 1).

When we compared the research topics to publication types, Figure 1 also showed a preference for books in terms of inventory build-ups (n=18). Although a few books covered the topic of wildlife management and conflict analysis, we found no book on other topics. We came across only nine papers on discovery and distribution update whereas 14 papers were there on ecology.

Species-wise trend in studies

Of the 28 extant carnivores of Bangladesh, seven are Critically Endangered (CR), three Endangered (EN), six Vulnerable (VU), five Near Threatened (NT), four Least Concern (LC), and two are Data Deficient (DD) (IUCN Bangladesh 2015). Large-toothed Ferret Badger *Melogale personata* was recorded for the first time from northeastern Bangladesh in 2008 (Islam et al. 2008), although it is not assessed or included in the IUCN Bangladesh (2015).

After segregating the number of publications which targeted at threatened carnivores on both national and global assessments, we found that 14 species were without any dedicated work at all. Table 2 shows the comparison and the species without any research. On the other hand, 66 studies were found exclusively dedicated to 14 carnivore species. The studies covered six felids, four mustelids, two herpestids and one for each of a canid and a viverrid species. There are 29 studies which considered higher or multiple taxa: two for the felids, two for the ursids, one for all carnivore mammals of Bangladesh, six for all mammals, and 18

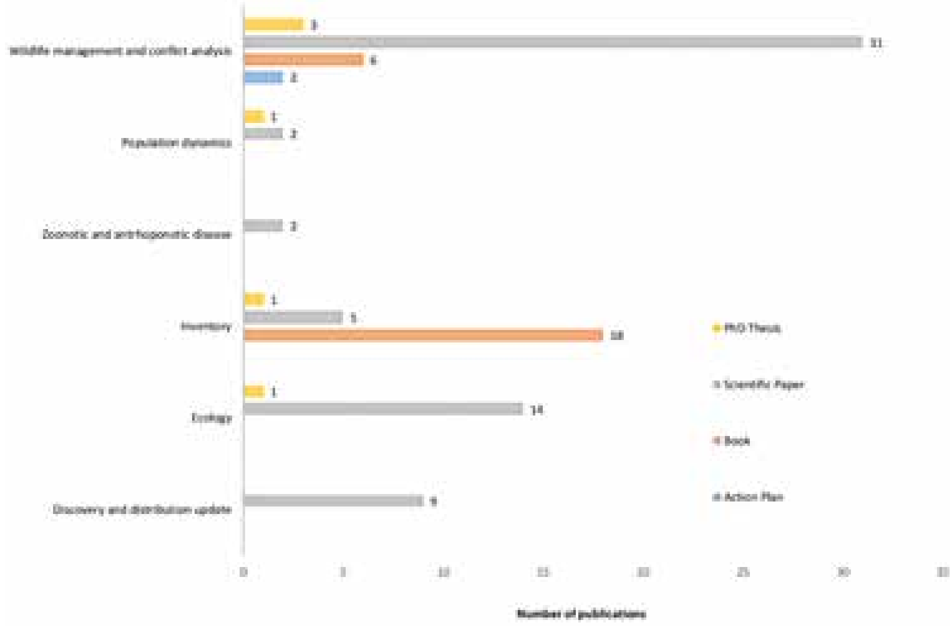

Figure 1. Characteristics of carnivore mammal studies in Bangladesh as the number of different publication types projected against different research topics. Appendices 1 and 2 detail out the works and the classification scheme used in these projections.

were inclusive of wildlife of Bangladesh (Appendix 1, Fig. 2, Table 2).

The most- and the least-studied species

The highest number of publications (n=45) was on Tiger. It experienced all types of publications. Considering the topic, wildlife management and conflict analysis were the most common subjects for studies on Tiger (Fig. 2). In Bangladesh, Tiger is the only carnivore with a conservation action plan that has been formulated twice (Ahmad et al. 2009; Aziz et al. 2018).

There were seven works on the Asian Golden Jackal *Canis aureus*, three on Fishing Cat *Prionailurus viverrinus*, two on Smooth-coated Otter *Lutrogale perspicillata*, one combined study on Masked Palm Civet *Paguma larvata,* and Small Indian Mongoose *Herpestes javanicus*. Only one study was found for each of the Asian Golden Cat *Catopuma temminckii*, Crab-eating Mongoose *Herpestes urva*, Yellow-throated Marten *Martes flavigula*, Large-toothed Ferret Badger, Leopard *Panthera pardus*, Leopard Cat *Prionailurus bengalensis*, Marbled Cat *Pardofelis marmorata* and Oriental Small-clawed Otter *Aonyx cinereus* (Fig. 2).

Region-wise trend in studies

A total of 47 studies were found in southwestern region, followed by 12 studies in southeast, 10 from northeast, and seven from central region (Table 3). Among all 95 references there are three studies accomplished by combining different regions in the works by Feeroz et al. (2011), Islam et al. (2013) and Al-Razi et al. (2014). Bangladesh is considered as the study site in 22 studies (Appendix 1). We projected the regions according to number of works and number of species exclusively targeted across regions (Fig. 3). Since 1971, there is no study from southern and northwestern regions (Fig. 3a). Figure 3b indicates the inadequacy in consideration of the number of species in different regions.

Of the 95 works considered for the analyses, 25 carried out the research in both protected and non-protected areas, and 57 of these exclusively considered the protected areas. Only 13 works took non-protected areas as study sites (Appendix 1).

Year-wise trend in studies

Only after the year 2000, the number of scientific publications has started to show a noticeable increase (Fig. 4). The highest number of publications were in 2008, 2013, and 2018 (n=7 for each year) (Fig. 4a). We could not find any particular reason behind these spikes; 10 publications on Tiger were found from these three years (n=4 in 2008, 4 in 2013, 2 in 2018). No scientific paper, however, was found until 1974, perhaps because it took some time for the conditions to become conducive for field research after the independence. It was the two recent decades (2001–2010 and 2011–2019) when carnivore studies in Bangladesh gained momentum. These periods were also a leap for conservation science and inventory compilation ventures. Only the current

Table 2. Comparison between number of threatened carnivore mammals of Bangladesh based on any exclusive study done unto them. CR—Critically Endangered | EN—Endangered | VU—Vulnerable | NT—Near Threatened | LC—Least Concerned | DD—Data Deficient | NE—Not Evaluated.

Table 2A. Number of species in different categories of status							
Not studied				Studied to different extents			
Global status	Number	Regional status	Number	Global status	Number	Regional status	Number
EN	1	CR	4	EN	1	CR	3
VU	5	EN	1	VU	4	EN	2
NT	1	VU	3	NT	2	VU	3
LC	7	NT	3	LC	7	NT	2
		LC	2			LC	2
		NE	1			DD	1
						NE	1

Table 2B. Status of carnivores with no exclusive study in Bangladesh		
Carnivores species	Global status	Regional status
Binturong *Arctictis binturong*	VU	VU
Small-toothed Palm Civet *Arctogalidia trivirgata*	LC	DD
Common Palm Civet *Paradoxurus hermaphroditus*	LC	LC
Large Indian Civet *Viverra zibetha*	LC	NT
Small Indian Civet *Viverricula indica*	LC	NT
Indian Grey Mongoose *Herpestes edwardsii*	LC	LC
Jungle Cat *Felis chaus*	LC	NT
Clouded Leopard *Neofelis nebulosa*	VU	CR
Dhole *Cuon alpinus*	EN	EN
Bengal Fox *Vulpes bengalensis*	LC	VU
Sun Bear *Helarctos malayanus*	VU	CR
Asiatic Black Bear *Ursus thibetanus*	VU	CR
Hog Badger *Arctonyx collaris*	VU	VU
Eurasian Otter *Lutra lutra*	NT	CR

Table 3. Comparison of works across regions of Bangladesh based on publication types and research topics of carnivore mammal studies.

Region	Publication type				Research topic					
	Book	Scientific Paper	Doctoral Thesis	Action Plan	Discovery and distribution update	Ecology	Inventory	Zoonotic and anthro-ponotic disease	Population dynamics	Wildlife manage-ment and conflict analysis
Central		7				4		2		1
Northeast	1	9			6	2	2			
North		1			1					
Southeast	5	6	1		3		8			1
Southwest	5	37	5			10			3	34
Whole Bangladesh	13	7		2	1	1	14			6

Figure 2. Species-wise preference in carnivore mammal studies in Bangladesh: a—based on different types of publication: action plan, book, scientific paper, and PhD Thesis | b—based on different research topics: discovery and distribution update, inventory, ecology, population dynamics, wildlife management and conflict analysis, and zoonotic & anthroponotic diseases. Appendices 1 and 2 detail out the works and the classification scheme used in these projections.

decade is the period in which we found all seven considered research topics (Fig. 4).

DISCUSSION

Severe discrepancies are evidently observed in research trends considering carnivore mammals of Bangladesh. Gaps and biases are present in every criterion that we considered. Species-wise preference, thematic trends, geographic distribution often leaned toward certain species or certain area, likely to have been influenced by conservation and management interests. Involvement in carnivore researches and interest in diverse species are on the rise. It is, however, worrisome that Bangladesh is at risk of losing more than half of its carnivore diversity, but, deployment of novel methodologies to study elusive and 'apparently absent' species is still very sketchy.

Highlighting the least-known and the least-understood species

Researches on Tiger, a flagship species of Bangladesh, make over half of all carnivore research counts. On the contrary, a single study was found on an occurrence record of leopard. The Indian Leopard *Panthera pardus* was thought to have been extirpated from Bangladesh. Among media reports, that may sometime form the beginning to a proper field research (Singh 2020), the term 'leopard' appears to be confused with that of Fishing Cat. In the last 12 years, based on verifiable media reports, however, there were instances of 16 Leopards appearing from northern and eastern corners of Bangladesh, each from different cases; six of which were killed as retaliatory responses (Akash et al. submitted). Bear is another charismatic carnivore yet got only one published scientific paper and one book chapter on status assessment (Sarker 2006; Islam et al. 2013; IUCN Bangladesh 2015). Some species are recorded in recent times (Binturong *Arctictis binturong*,

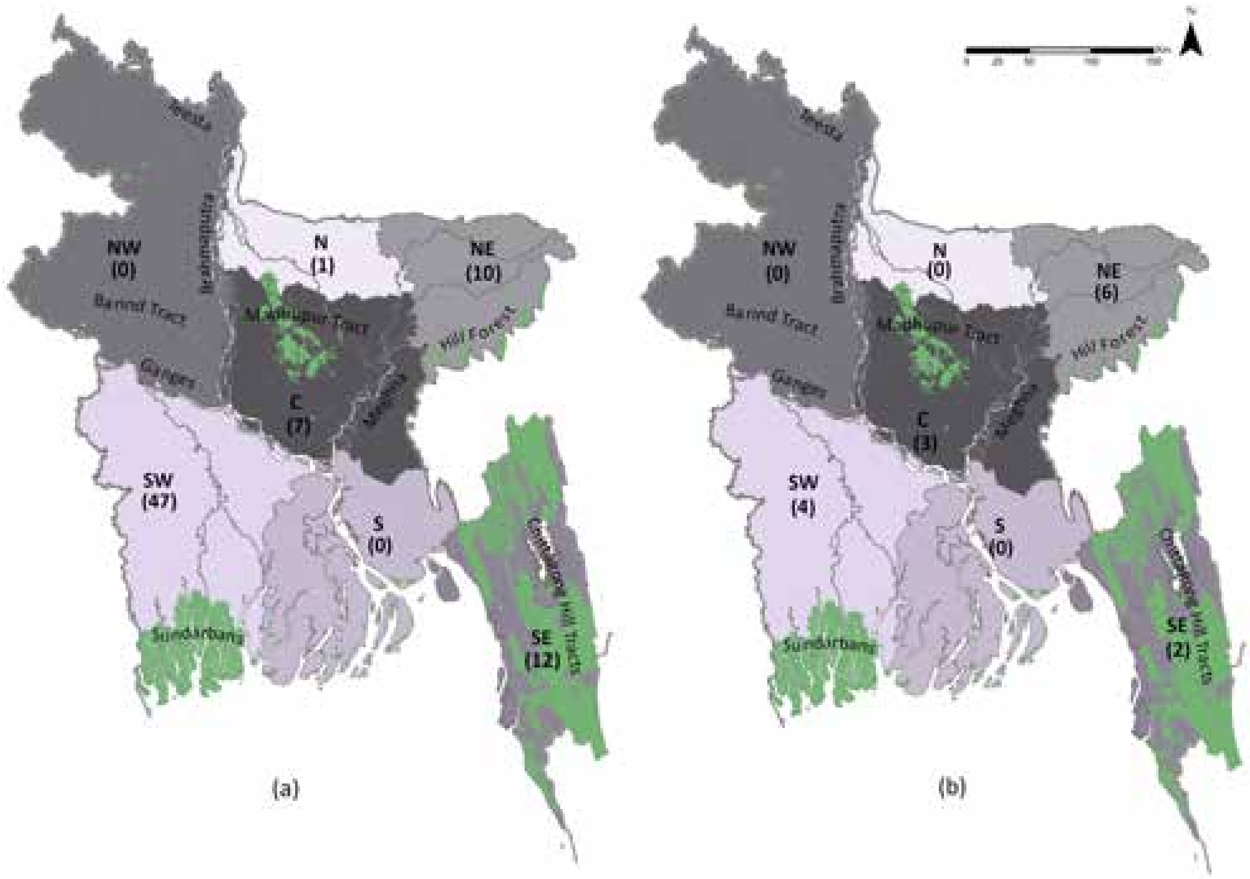

Figure 3. Spatial pattern of carnivore mammal studies in Bangladesh: a—based on different types of publication exclusively assignable to different regions | b—based on number of species exclusively considered and exclusively assignable to different regions. Regional classification is adopted from Khan (2018): N—North | NE—Northeast | NW—Northwest | C—Central | S—South | SE—Southeast | SW—Southwest. Number in parentheses indicates the number of works (in Fig. 3a) and the number of species (in Fig. 3b). Appendices 1 and 2 detail out the works and the classification scheme used in these projections.

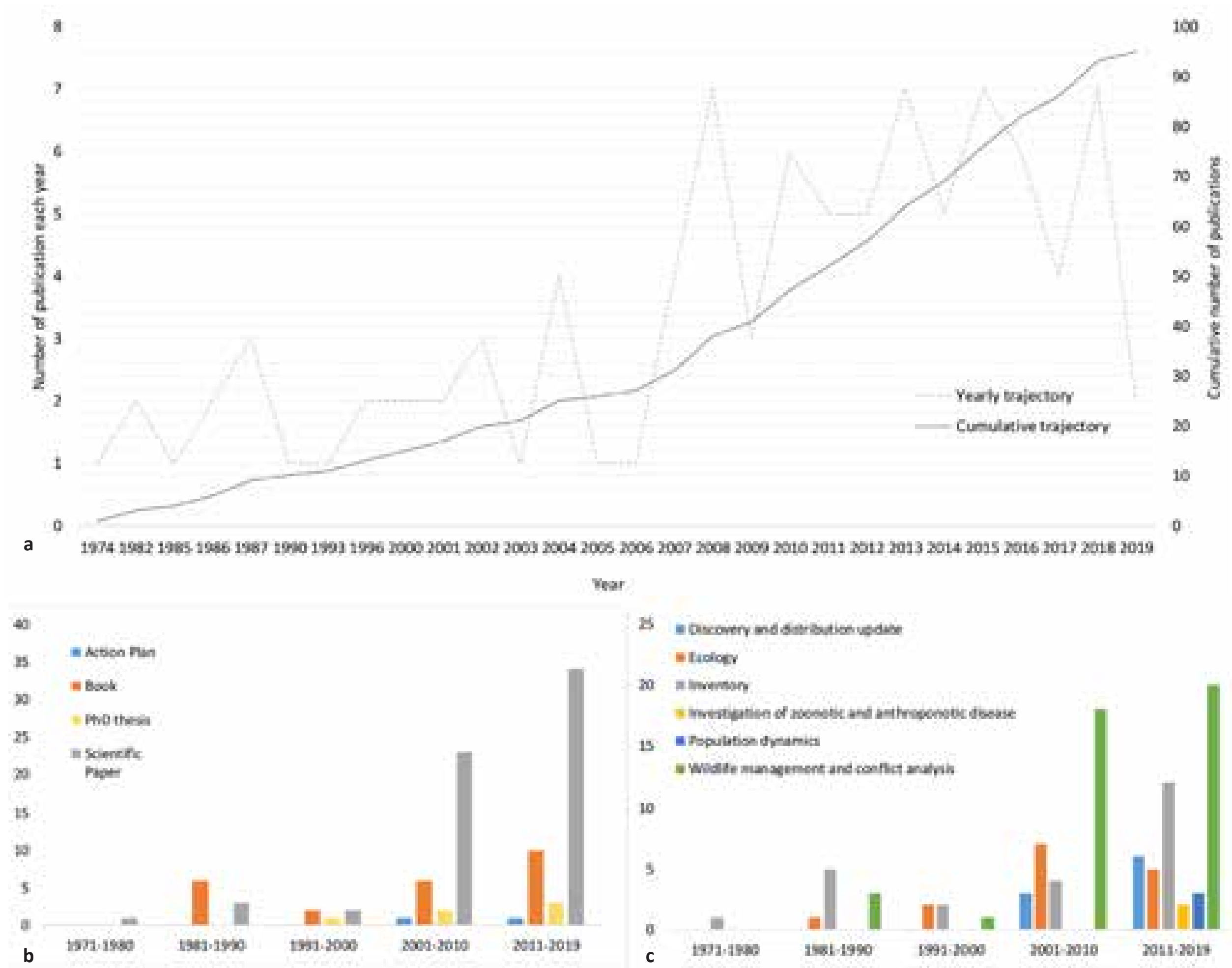

Figure 4. Temporal trajectories of carnivore mammal studies in Bangladesh from 1971 to 2019 showing a gradual increase: a—number of publications each year and their cumulative rate | b—number of different types of publication and | c—number of different research topics—both projected in five decadal periods. During the years 1971 through 1974, no publications of relevance could be accessed in this study. Appendices 1 and 2 detail out the works and the classification scheme used in these projections.

Crab-eating mongoose, Large-toothed Ferret Badger, Yellow-throated Marten, and Hog Badger *Arctonyx collaris*) or have only distant sightings (Small-toothed Palm Civet *Arctogalidia trivirgata*) but no further scientific investigations have been carried out. When the Tiger is the only carnivore to get its conservation action plan twice, 14 other extant carnivores of Bangladesh lack any sort of scientific documentation.

Approaching contemporary study techniques

Our review has highlighted the scattered and scarce data on 28 carnivores from 1971 to 2019 (Table 3, Fig. 4). It is also observed that IUCN Bangladesh (2015) assessed the country's carnivores mostly through sighting records or expert opinions. Of course, as implied in Singh (2020), all technical accounts may not follow from planned, long-term field research. Figures 3 and 4 clarify the clear lack in study effort. For example, although southeastern region is known for many carnivores, studies in this region have targeted only two species. Again, while there appears a preference for works like mitigation of conflicts and assessment of biodiversity, there is a certain deficit in species- or taxa-oriented ecological studies (Fig. 4). These can be attributed to challenges of encountering wild carnivores and the rugged terrain in certain areas. Non-invasive and novel technologies such as remote camera-trapping, radio-collaring, and systematic analytical approaches (species distribution modelling, density estimates) which can resolve these difficulties are limited to studies on the Tiger and, to a lesser extent, the jackal (Poche et al. 1987; Khan 2012; Aziz et al. 2018). It is true that, in many cases, the duration allowed and funds available determine the type of research work. Sometimes, these are opportunistic or out of convenience to fulfil a target.

Emphasizing the hypothetical 'empty forest'

We found that the majority of studies (n=47) carried out in the Sundarbans, exclusively focused on Tiger-related management and conflict issues (Table 3, Fig. 3a). Southeastern Bangladesh, though ranked the second, lagged far behind relative to the number of publications (n= 12), and performed mostly on the diversity and richness of certain protected areas (Feeroz et al. 2012; Feeroz 2013, 2014; Karim & Ahsan 2016; Khan et al. 2016; Kabir et al. 2017). Northeastern Bangladesh too (n=10) has received less than expected attention, having been investigated mostly for Fishing Cat (Giordano & Feeroz 2013; Rahman & McCarthy 2014). When compared to the mangroves, no other forest of the country has experienced likewise focus on carnivore research. In particular, the moist evergreen forests of Bangladesh are often ignored, deemed as 'empty forest' with no sustainable large carnivore population. On the contrary, eastern forests together stand larger than the Sundarbans. Furthermore, Khan (2012), Feeroz (2013, 2014), Chakma (2015), Khan (2015), and CCA (2016) showed the presence of apex predators and umbrella species from these areas. On further interesting note, in the recent years, Rahman (2017) and Zakir (2019), two unpublished MS theses, targeted least-known carnivores of northeastern Bangladesh, carried out camera-trap surveys, and showed some remarkable findings including the Asian Golden Cat and the Asian Wild Dog *Cuon alpinus*. Therefore, it is necessary to plan for large-scale structured camera-trapping, that could reveal the status of the carnivore fauna and their ecological associates in these hypothetical 'empty forests'.

Addressing newer research scopes

For northwestern, central, northern, and southern regions, Figure 3b depicted an extreme gap in knowledge. The regions support small carnivores, e.g., Bengal Fox *Vulpes bengalensis*, Fishing Cat, Jungle Cat *Felis chaus*, Leopard Cat, Large Indian Civet *Viverra zibetha*, Small Indian Civet *Viverricula indica*, and Common Palm Civet *Paradoxurus hermaphroditus* (Khan 2015; Khan 2018). The species are at risk, continuously persecuted across Bangladesh, at forest peripheries, fragmented patches and homestead jungles. Whereas Tiger in Bangladesh has been studied under broad spectra, their ecology, risk assessment, local perception and conflict management for these lesser species living outside protected areas have never been tried. Future research can put small carnivores as umbrella species for the fast disappearing village/peri-urban groves and wet deciduous forest.

Tiger is undoubtedly a flagship icon for Bangladesh, yet, the country harbors many other remarkable carnivores and unique habitats. Our knowledge on most of their ecology and management strategies are at a bare minimum. This paucity hinders adequate regional and global conservation attention and practices. Therefore, this assessment of the trend of research on mammalian carnivores highlights the gaps in research. Developing more comprehensive knowledge and researched data are expected to aid in future management across the regions where scientific investments have been traditionally low, the availability of data have been sparse and action for conservation is an exigency.

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Appendix 1. Reviewed literature with different categorization schemes.

Taxa/Species/Group	Theme	Region	Author
(A.) Peer-reviewed scientific papers			
Tiger	Ecology	Southwest	Reza et al. (2001a,b), Khan & Chivers (2007), Khan (2008a), Barlow et al. (2010, 2011)
	Population dynamics	Southwest	Khan (2012a), Aziz et al. (2017)
	Wildlife management and conflict analysis	Southwest	Gani (2002), Reza et al. (2002a,b), Azad et al. (2005), Islam et al. (2007), Muhammed et al. (2007), Barlow et al. (2008, 2010, 2013), Khan (2009), Loucks et al. (2010), Neumann-denzau & Denzau (2010), Aziz et al. (2013, 2017, 2018), Inskip et al. (2013, 2014, 2016), Mohsanin et al. (2013), Khanom & Buckley (2015), Rahim et al. (2015), Saif et al. (2016, 2018), Hossain et al. (2018), Mukul et al. (2019)
Leopard	Discovery and distribution update	Southeast	Kabir et al. (2017)
Asian Golden Cat	Wildlife management and conflict analysis	Southeast	Khan (2008b)
Marbled Cat	Discovery and distribution update	Northeast	Khan (2015)
Leopard Cat	Ecology	Southwest	Khan (2004a)
Fishing Cat	Discovery and distribution update	Northeast	Giordano & Feeroz (2013)
	Ecology	Northeast	Rahman & McCarthy (2014)
	Wildlife management and conflict analysis	Whole Bangladesh	Chowdhury et al. (2015)
Asiatic Golden Jackal	Ecology	Whole Bangladesh	Sarker & Ameen (1990)
		Central	Jaeger et al. (1996, 2007)
	Investigation of zoonotic and anthroponotic disease	Central	Khan et al. (2012), Yousuf et al. (2014)
	Wildlife management and conflict analysis	Whole Bangladesh	Brooks et al. (1993)
		Central	Pouche et al. (1987)
Oriental Small-clawed Otter	Ecology	Southwest	Aziz (2018)
Smooth-coated Otter	Ecology	Central, Southwest	Feeroz et al. (2011)
	Wildlife management and conflict analysis	Southwest	Feeroz et al. (2011)
Yellow-throated Marten	Discovery and distribution update	Northeast	Hasan et al. (2019)
Large-toothed Ferret Badger	Discovery and distribution update	Northeast	Islam et al. (2008)
Crab-eating Mongoose	Discovery and distribution update	Northeast	Hasan et al. (2018)
Small Indian Mongoose and Masked Palm Civet	Ecology	Central, Northeast	Al-Razi et al. (2014)
Felid	Discovery and distribution update	Whole Bangladesh	Khan (2004b)
Ursid	Discovery and distribution update	North, Northeast, Southeast	Islam et al. (2013)
Carnivore mammals	Wildlife management and conflict analysis	Whole Bangladesh	Rawshan et al. (2012)
All mammals	Inventory	Northeast	Aziz (2011)
		Southeast	Ahsan et al. (2008), Karim & Ahsan (2016)
All wildlife	Discovery and distribution update	Southeast	Khan (2012b)
	Inventory	Whole Bangladesh	Husain (1974), Gittins (1982)
(B.) Books/Book chapters			
Tiger	Wildlife management and conflict analysis	Southwest	Seidensticker (1986), Khan (1987a), Khan et al. (2003), Reza et al. (2004), Saif & MacMillan (2016)

Felid	Inventory	Whole Bangladesh	Khan (1986)
Ursid	Wildlife management and conflict analysis	Whole Bangladesh	Sarker (2006)
All mammals	Inventory	Whole Bangladesh	Khan (1985), Akonda et al. (2000)
All wildlife	Inventory	Northeast	Feeroz et al. (2011)
		Southeast	Feeroz et al. (2012), Feeroz (2013, 2014), Khan (2015), Khan et al. (2016)
		Whole Bangladesh	Khan (1982), Khan (1987b), Khan (1996), Ahmad et al. (2008), Khan (2010), IUCN Bangladesh (2015), IUCN Bangladesh (2010), Khan (2015), Khan (2018)
(C.) PhD theses			
Tiger	Ecology	Southwest	Reza (2000)
	Population dynamics	Southwest	Aziz (2017)
	Wildlife management and conflict analysis	Southwest	Khan (2004c), Barlow (2009), Saif (2016)
Mammals	Inventory	Southeast	Chakma (2015)
(D.) Conservation action plan			
Tiger	Wildlife management and conflict analysis	Whole Bangladesh	Aziz et al. (2018), Ahmad et al. (2009)
(E.) Project reports			
Tiger	Wildlife management and conflict analysis	Southwest	Rahman et al. (2009), Alam et al. (2011), Dey et al. (2015)
	Ecology	Southwest	Rahman et al. (2012)
	Population dynamics	Southwest	Hossain et al. (2012)
Ursid	Ecology	North, Northeast, Southeast	Islam et al. (2010)
All mammals	Discovery and distribution update	Southeast	CCA (2016)

Appendix 2. Publications on carnivores of Bangladesh in chronological order (1971–2019).

Scientific Papers	
1	**Husain K.Z. (1974).** An Introduction to the Wildlife of Bangladesh. Motijheel, Dhaka, Bangladesh.
2	**Gittins, S.P. & A.W. Akonda (1982).** What survives in Bangladesh? *Oryx* 16: 275–281. https://doi.org/10.1017/S003060530001752X
3	**Poche, R.M., S.J. Evans, P. Sultana, M. Haque, M.E, R. Sterner & M.A. Siddique (1987).** Notes on the golden jackal (*Canis aureus*) in Bangladesh. *Mammalia* 51: 259–270.
4	**Sarker, N.J. & M.N. Ameen (1990).** Food habits of jackals (*Canis aureus*). *Bangladesh Journal of Zoology* 18: 189–202.
5	**Brooks, J.E., M.E. Haque & S. Ahamad (1993).** Status of the golden jackal as an agricultural pest in Bangladesh. *Crop Protection* 12(8): 563–564. https://doi.org/10.1016/0261-2194(93)90118-3
6	**Jaeger, M.M., R.K. Pandit & E. Hawque (1996).** Seasonal differences in territorial behavior by golden jackals in Bangladesh: howling versus confrontation. *Journal of Mammalogy* 77(3): 768–775. https://doi.org/10.2307/1382682
7	**Reza, A.H.M.A., M.M. Feeroz & M.A. Islam (2001a).** Food habits of the Bengal tiger (*Panthera tigris tigris*) in the Sundarbans. *Bangladesh Journal of Zoology* 29(2): 173–180.
8	**Reza, A.H.M.A., M.M. Feeroz & M.A. Islam (2001b).** Habitat preference of the Bengal tiger, *Panthera tigris tigris* in the Sundarbans of Bangladesh. *Bangladesh Journal of Life Science* 13: 215–217.
9	**Gani, M.O. (2002).** A study on the loss of Bengal tiger (*Panthera tigris*) in five years (1996–2000) from Bangladesh Sundarbans. *Tigerpaper* 29: 7–12.
10	**Reza, A.H.M.A., M.M. Feeroz & M.A. Islam (2002a)**. Man-tiger interaction in the Bangladesh Sundarbans. *Bangladesh Journal of Life Sciences* 14(1–2): 75–82.
11	**Reza, A.H.M.A., M.M. Feeroz & M.A. Islam (2002b)**. Prey species density of Bengal Tiger in the Sundarbans. *Journal of Asiatic Society Bangladesh, Science* 28: 35–42.
12	**Khan, M.M.H. (2004a).** Food habit of the leopard cat *Prionailurus bengalensis* (Kerr, 1792) in the Sundarbans East wildlife sanctuary. Bangladesh. *Zoos' Print Journal* 19(5): 1475–1476.
13	**Khan, M.M.H. (2004b).** Status and distribution of wild cats in Bangladesh. *Bangladesh Journal of Life Sciences* 17(1): 69–74.
14	**Azad, M.A.K., M.A. Hashem & M.M. Hossain (2005).** Study on human Royal Bengal tiger Interaction of in situ and ex situ in Bangladesh. *Journal of Biological Sciences* 5(3): 250–252.
15	**Islam, M.W., M.S. Alam & M.M. Islam (2007).** Study of human casualties by Bengal tigers (*Panthera tigris tigris L.*) in the Sundarbans forest of Bangladesh. *Tiger Paper* 34: 11–15.

16	**Jaeger, M.M., E. Haque, P. Sultana & R.L. Bruggers (2007).** Daytime cover, diet and space-use of golden jackals (*Canis aureus*) in agro-ecosystems of Bangladesh. *Mammalia* 71(1–2): 1–10.
17	**Khan, M.M.H. & D.J. Chivers (2007).** Habitat preferences of tigers *Panthera tigris* in the Sundarbans East Wildlife Sanctuary, Bangladesh, and management recommendations. *Oryx* 41(4): 463–468. https://doi.org/10.1017/S0030605307012094
18	**Muhammed, N., M.T. Kamal, F. Haque, M.S.H. Chowdhury & M. Koike (2007).** A study on the Royal Bengal Tiger (*Panthera tigris tigris*) of the Sundarbans in Bangladesh with special reference to tiger–human conflict. *Journal of Social Research and Development* 4: 86–91.
19	**Ahsan, M.F. & M.W. Chowdhury (2008).** Mammals of the Chittagong University Campus, Chittagong. *Bangladesh Journal of Zoology* 36(2): 131–147.
20	**Barlow, A.C., M.I.U. Ahmed, M.M. Rahman, A. Howlader, A.C. Smith & J.L. Smith (2008).** Linking monitoring and intervention for improved management of tigers in the Sundarbans of Bangladesh. *Biological Conservation* 141(8): 2032–2040. https://doi.org/10.1016/j.biocon.2008.05.018
21	**Islam, M.A., G.W. Chowdhury & J.L. Belant (2008).** First record of the Large-toothed Ferret Badger *Melogale personata* in Bangladesh. *Small Carnivore Conservation* 39: 41–42.
22	**Khan, M.M.H. (2008a).** Prey selection by tigers (*Panthera tigris*) (Linnaeus 1758) in the Sundarbans East Wildlife Sanctuary of Bangladesh. *Journal of the Bombay Natural History Society* 105(3): 255–263.
23	**Khan, M.M.H. (2008b).** The neglected Asiatic golden cats of Bangladesh. *Cat News* 48: 20–21.
24	**Khan, M.M.H. (2009).** Can domestic dogs save humans from tigers *Panthera tigris*?. *Oryx* 43(1): 44–47. https://doi.org/10.1017/S0030605308002068
25	**Barlow, A.C., C.J. Greenwood, I.U. Ahmad & J.L. Smith (2010).** Use of an action-selection framework for human-carnivore conflict in the Bangladesh Sundarbans. *Conservation Biology* 24(5): 1338–1347. https://doi.org/10.1111/j.1523-1739.2010.01496.x
26	**Barlow, A.C.D, J. Mazak, I.U. Ahmad & J.L. Smith (2010).** A preliminary investigation of Sundarbans tiger morphology. *Mammalia* 74(3): 329–331. https://doi.org/10.1515/mamm.2010.040
27	**Loucks, C., S. Barber–Meyer, M.A.A. Hossain, A. Barlow & R.M. Chowdhury (2010).** Sea level rise and tigers: predicted impacts to Bangladesh's Sundarbans mangroves. *Climatic Change* 98(1-2): 291. https://doi.org/10.1007/s10584-009-9761-5
28	**Neumann-Denzau, G., & H. Denzau (2010).** Examining certain aspects of human-tiger conflict in the Sundarbans forest, Bangladesh. *Tiger paper* 37(3): 1–11.
29	**Aziz, M.A. (2011).** Notes on the status of mammalian fauna of the Lawachara National Park, Bangladesh. *Ecoprint* 18: 45–53. https://doi.org/10.3126/eco.v18i0.9398
30	**Barlow, A.C., J.L. Smith, I.U. Ahmad, A.N. Hossain, M. Rahman & A. Howlader (2011).** Female tiger *Panthera tigris* home range size in the Bangladesh Sundarbans: the value of this mangrove ecosystem for the species' conservation. *Oryx* 45(1): 125–128. https://doi.org/10.1017/S0030605310001456
31	**Feeroz, M.M., M.A. Aziz & P.K. Thanchanga (2011).** Breeding activities of *Lutra perspicillata* in Bangladesh. *IUCN Otter Specialist Group Bulletin* 28(A): 38–44.
32	**Feeroz, M.M., S. Begum & M.K. Hasan (2011).** Fishing with otters: a traditional conservation practice in Bangladesh. *IUCN Otter Specialist Group Bulletin* 28(A): 14–21.
33	**Khan, M.A.H.N.A., S.S. Khanm, J. Bashu, U.K. Rima, M. Pervin, M.Z. Hossain, M.A. Habib, G.A. Chowdhury & M.M. Hossain (2012).** Visceral leishmaniasis is endemic in golden jackals of Bangladesh agricultural university campus, a threat for expanding future zoonotic visceral leishmaniasis. *Bangladesh Journal of Veterinary Medicine* 10(1–2): 101–109. https://doi.org/10.3329/bjvm.v10i1-2.15655
34	**Khan, M.M.H. (2012a).** Population and prey of the Bengal tiger *Panthera tigris* tigris (Linnaeus, 1758) (Carnivora: Felidae) in the Sundarbans, Bangladesh. *Journal of Threatened Taxa* 4(2): 2370–2380. https://doi.org/10.11609/JoTT.o2666.2370-80
35	**Khan, M.M.H. (2012b).** New records of wildlife from the Chittagong Hill Tracts of Bangladesh. *Journal of Bombay Natural History Society* 109(3): 229–232.
36	**Rawshan, K., M.M. Feeroz & M.K. Hasan (2012).** Human-Carnivore Conflicts in Bangladesh. *Tiger Paper* 39: 17-21.
37	**Aziz, A., A.C.D. Barlow, C.G. Greenwood & A. Islam (2013).** Prioritizing threats to improve conservation strategy for the tiger *Panthera tigris* in the Sundarbans Reserve Forest of Bangladesh. *Oryx* 47(4): 510–518. https://doi.org/10.1017/S0030605311001682
38	**Barlow, A.C., I.U. Ahmad & J.L. Smith (2013).** Profiling tigers (*Panthera tigris*) to formulate management responses to human-killing in the Bangladesh Sundarbans. *Wildlife Biology in Practice* 9(2): 30–39. https://doi.org/10.2461/wbp.2013.9.6
39	**Giordano, A.J. & M. Feeroz (2013).** Albinism in the fishing cat (*Prionailurus viverrinus)* from the Haor Basin of Bangladesh. *Cat News* 58: 37–38.
40	**Inskip, C., M. Ridout, Z. Fahad, R. Tully, A. Barlow, C.G. Barlow, M.A. Islam, T. Roberts & D. MacMillan (2013).** Human–tiger conflict in context: risks to lives and livelihoods in the Bangladesh Sundarbans. *Human ecology* 41(2): 169–186. https://doi.org/10.1007/s10745-012-9556-6
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COMMUNICATION

Diversity of scorpions (Arachnida: Scorpiones) in Polonnaruwa Archaeological Reserve, Sri Lanka

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Abstract: Sri Lanka harbours 20 scorpion species belonging to four families, of which 15 are endemic. The distribution and ecology of scorpion fauna in Sri Lanka is poorly known. In this study, we surveyed the diversity of scorpions in the Polonnaruwa Archaeological Reserve in the dry zone of Sri Lanka. Microhabitats were thoroughly observed using the direct visual encounter method and UV lights from July to November 2018 for about seven hours (19.00–02.00 h) by two to three observers. Species, abundance, age/sex, and microhabitat features were recorded. Diversity indices, including α-diversity and β-diversity, were calculated. *Heterometrus swammerdami* was the most abundant species recorded, while *Isometrus thwaitesi* was the rarest. *Reddyanus loebli* and *R. besucheti* were common in both open and forest habitat types. *Charmus laneus* was recorded for the first time in Polonnaruwa. The highest Shannon Index and Margalef Diversity Index values were recorded in open habitats, but species evenness was low compared to forest habitats. Sørensen index values showed a 58% species similarity between two habitats. The results presented here contribute to the knowledge of the diversity of scorpions in these historically significant sites. This can serve as a basis for future research on the impact of habitat modification and fragmentation on populations, distribution and ecology of scorpions.

Keywords: Buthidae, diversity, dry zone, microhabitat, Scorpionidae.

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Author contribution: KBW did the field work and prepared the manuscript, LSW did the statistical analysis and prepared the manuscript and KBR prepared the manuscript.

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INTRODUCTION

Sri Lanka supports a high level of biodiversity, and hence Sri Lanka together with Western Ghats of India is considered a global biodiversity hotspot (Mayer 2000; Mittermeier et al. 2011). Most of the biodiversity research in Sri Lanka concerns charismatic, flagship fauna (Fernando et al. 2011; Nijman 2012; Kittle et al. 2017), paying less attention to small sized and enigmatic species. Invertebrates are among the poorly investigated taxa. A few published work available for butterflies (van der Poorten & van der Poorten 2016), bees (Karunaratne & Edirisinghe 2008), dragonflies (Bedjanič 2004), theraphosid spiders (Samarawckrama et al. 2005), land snails (Naggs et al. 2005) and freshwater crabs (Bahir et al. 2005) represent significant attempts to characterize little-known invertebrate fauna (Ranawana et al. 2013). Among invertebrate taxa, studies of scorpions have gained attention owing to their economic (Kularatne et al. 2015) and ecological importance. Recently, Kovařík et al. (2016, 2018, 2019) summarized 20 known scorpion species of Sri Lanka belonging to four families: Buthidae (13 species), Scorpionidae (five species) Hormuridae (one species), and Chaerilidae (one species), of which 15 species (75%) are endemic to the island.

The spatial distribution of scorpions is influenced by a range of climatic and environmental variables such as temperature, rainfall, elevation, slope, soil properties, vegetation type and land cover (Polis 1990; Prendini 2005). Sri Lanka has distinct types of habitats, including rain forest, dry mixed evergreen forest, montane forest, and shrub forest, which support scorpions (Ashton et al. 1997). Most scorpion species are distributed through the dry zone, and few are found in the wet zone of Sri Lanka (Kovařík et al. 2016). The objective of this study was to assess the diversity of scorpions in an archaeological reserve located in the ancient city of Polonnaruwa, in North-central Province, Sri Lanka, as a conservation initiative for scorpions. Additionally, the study aimed to provide important information on population structure (age/sex ratio), microhabitat preference, and community-level characteristics (species richness and diversity in two selected habitats). Since Polonnaruwa is a well-preserved historic site and tourist attraction, this study is relevant to the impact of tourism on the conservation of biological diversity.

MATERIALS AND METHOD

Study site

This study was carried out in the archaeological reserve in Polonnaruwa ancient city (7.9584N & 81.0027E) located in North-central Province, Sri Lanka, from early July to late November 2018. The selected study site with an area of 7.9km^2 was an isolated secondary forest patch consisting ancient monuments dating back to King Parakramabahu in the 12th Century, and surrounded by human settlements. We have divided the study area into two habitat types: open habitat and secondary forest (Image 1). Open habitat predominantly consists of ancient monuments maintained by the Central Cultural Fund, Sri Lanka, with scattered trees. Some parts of the open habitat encompass exposed bedrock with boulders, and the soil type is sand to gravel particle-sized soil with low/no leaf litter (Image 2a). Secondary forest habitat consists of a dry mixed evergreen forest dominating by *Cassia marginata* (Fabaceae), *Manilkara hexandra* (Sapotaceae), *Drypetes sepiaria* (Putranjivaceae), and *Ficus* sp. (Fabaceae), tree species (Abeynayake et al. 1993) and scattered amidst shrubs and herbs (Image 2b).

Survey

A pilot study was carried for two days in early July for habitat selection and species identification before the survey. All possible microhabitats, including both terrestrial and arboreal, were thoroughly observed using the direct visual encounter method with the aid of UV lights. Sampling was carried out by two to three observers and lasted for about seven hours (19.00–02.00 h). A total of 78 human hours were spent equally for open and forest habitats (39 human hours per each habitat). Abundance and age-sex classes were recorded as male, female, or juvenile. But burrowing scorpions were not classified into age/sex categories due to difficulties in excavating their burrows and habitat disruptions. Tree barks were observed up to 3m in height from the ground level. Tree heights were categorized into five height classes as 1: 0–60 cm, 2: 61–120 cm, 3: 121–180 cm, 4: 181–240 cm and 5: 241–300 cm. Tree diameter at breast height (DBH) was measured using a DBH tape. Tree DBH measures were categorized into five classes as 1: 0–120 cm, 2: 121–240 cm, 3: 241–360 cm, 4: 361–480 cm and 5: 481–600 cm. Photographs were taken using a Canon 750D camera with Canon EF 100mm f/2.8L Macro IS USM lens with an external flashlight. Identifications of the species were based on Kovařík et al. (2016).

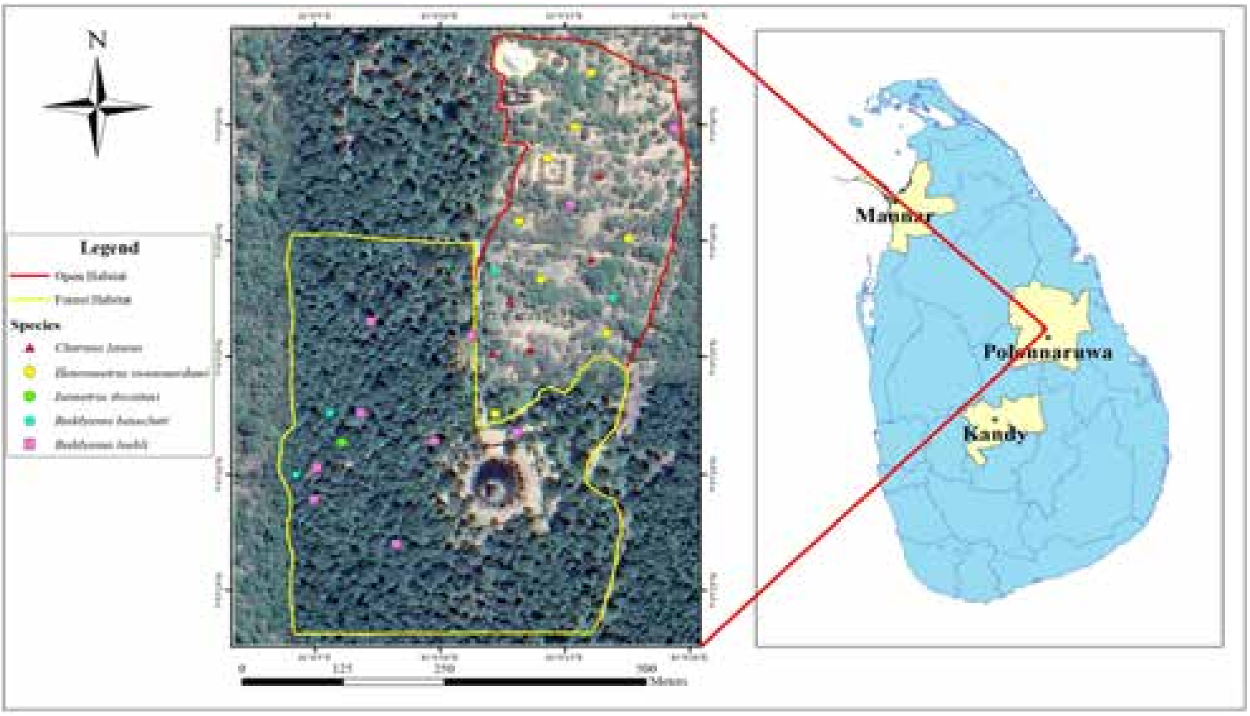

Image 1. Study site, Polonnaruwa Archaeological Reserve, Sri Lanka.

Image 2. Habitat types in Polonnaruwa Archaeological Reserve: a—open habitat | b—forest habitat. © Kumudu B WIjesooriya.

Statistical analysis

The α-diversity of scorpion species across open and forest habitat was calculated using the Shannon diversity index (H') separately for two habitats (Magurran 1988). Shannon evenness (E) was calculated to analyse the evenness of species across the forest and open habitats (Magurran 1988). Margalef's species richness index (D_{Mg}) was used to compare species richness across microhabitats (Magurran 1988). Bootstrap sampling using the means of each data set was carried out to assess 95% confidence intervals of Shannon Index (H'), Shannon Evenness (E) and Margalef Diversity Index (D_{Mg}) using R version 6.3.

The β-diversity, which represents unshared species, was measured by finding similarity or overlap between scorpion species composition across microhabitats, using Sørensen index. We employed chi-squared tests of independence to test the significant difference in the microhabitat preference (height and DBH) of scorpions between open and forest habitat types.

RESULTS

During the survey, five species of scorpions belonging to four genera in two families were recorded (Image 3). Of which, 28% of individuals belonged to family Buthidae, and 72% of individuals belonged to family Scorpionidae (Table 1). Observed four species of scorpions were terrestrial, and only one species, *Reddyanus loebli*, was arboreal. *Heterometrus swammerdami* (271 individuals) was abundant across the archaeological site, but its distribution was only confined to the open habitat. *Charmus laneus* was the second most abundant species (37 individuals) in open habitat. *Reddyanus loebli* (45 individuals) was the most abundant species in forest habitat. The least abundant species of the open and forest habitats were *Reddyanus besucheti* (nine individuals) and *Isometrus thwaitesi* (three individuals), respectively.

The highest number of individuals was recorded in open habitat (327 individuals) compared to forest habitat (52 individuals). Highest Shannon index (H') was recorded in open habitat but, species evenness was low compared to the forest habitat. Sørensen index was 0.5882 (or 58.82%), where *Reddyanus loebli* and *R. besucheti* were the common species recorded from both habitats (Table 2).

Tree height and DBH preference of arboreal *R. loebli* were varied. The highest occurrence height was recorded as 300 cm in a *Manilkara hexandra* tree, whereas the lowest occurrence height was 15 cm in a *Drypetes sepiaria* tree. Importantly, the highest number of individuals was recorded in height class 3, while the lowest number of individuals was recorded in height class 5 (Figure 1a). The average DBH was recorded as 330cm. The highest number of individuals was recorded in DBH class 4, whereas, at least was recorded in DBH class 2 (Figure 1b). However, there was no significant difference among tree height preference and habitats (χ^2= 2.947, DF = 4, p= 0.5667). Nevertheless, there was a significant difference in DBH preference and habitat type (χ^2= 18.041, DF = 4, p= 0.0012).

Table 1. Scorpion species found in Polonnaruwa Archaeological Reserve, Sri Lanka in 2018.

Family	Species
Buthidae (28%)	*Charmus laneus*
	Isometrus thwaitesi
	Reddyanus besucheti
	Reddyanus loebli
Scorpionidae (72%)	*Heterometrus swammerdami*

Table 2. Species diversity indices in Polonnaruwa Archaeological Reserve, Sri Lanka.

Diversity index	Open habitat	Forest habitat
No. of species (S)	4	3
Total number of individuals recorded (N)	327	52
Shannon Index (H')	0.6011	0.4869
Shannon Evenness (E)	0.4336	0.4432
Margalef Diversity Index (D_{Mg})	0.5181	0.5062
Sørensen index between open and forest habitat	0.5882	

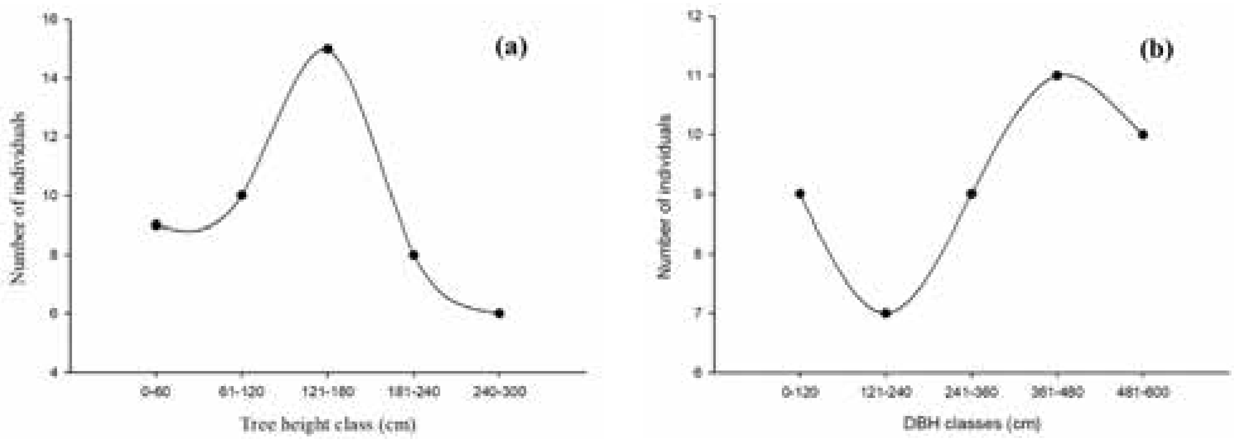

Figure 1. a—tree height preference of arboreal *Reddyanus loebli* | b—tree DBH preference of arboreal *Reddyanus loebli*.

DISCUSSION

The equatorial location of Sri Lanka and the complex topography of the island produce several distinct climatic zones and diversified habitats. The dry zone (60% of the island), intermediate zone (15%), and the wet zone (25%) are the major climatic zones. Though climatic and environmental factors and vegetation vary among these climatic zones, scorpion species are not confined to specific zones (Kovařík et al. 2016). Their distributions overlap, and only a few species are restricted to specific habitats, like *Hottentotta tamulus* from Jaffna peninsula, Sri Lanka (Ranawana et al. 2013). We recorded five species, of which four are endemic to Sri Lanka. In the present study, *Heterometrus swammerdami* was the most abundant species, whereas *Isometrus thwaitesi* was the rarest. *Reddyanus loebli* and *R. besucheti* are the only two species sharing both habitat types. Importantly, *Charmus laneus* was recorded for the first time in Polonnaruwa.

Heterometrus swammerdami was the only burrowing species in this study. They prefer to burrow in termite mounds, though they are not constructing burrows. They displayed sit and wait behaviour expecting possible prey with extended pedipalp and open chela. Most of the time, one adult can be seen in the opening of the termite mound burrow, and sometimes several juveniles can be observed with their mother. Due to their burrowing behaviour it is difficult to observe them closely to determine age and sex. Higher opportunities to access resources might account for their higher abundance. *Isometrus thwaitesi* is known as an arboreal species. Kovařík et al. (2016) found *I. thwaitesi* running on branches and trunks of trees, and also sitting on leaves 1–4 m in height. In this study, however, all three individuals were observed on the ground near a wood debris pile among leaf litter, and they were only observed in forest habitat. The presence of a higher stratum in the forest habitat compared to open habitat could be influencing scorpion abundance by providing better foraging areas where moonlight cannot reach easily (Nime et al. 2013).

Reddyanus loebli is a tree-dwelling species. Most dry zone trees have fissured barks as an adaptation for harsh weather conditions, and this gives a suitable microhabitat. They were mostly (93.2%) observed in *Manilkara hexandra*, *Drypetes sepiaria*, and *Ficus* sp. trees among and under the scales, within the cracks in the bark. Most of the observed individuals displayed sit and wait behaviour under the scales of the tree bark, with extended pedipalp and open chela, remaining 6.8% individuals observed in brick walls of ruins. All juvenile individuals were observed in forest habitat. Vegetation cover in the forest provides a safe habitat from predators for these tree-dwelling scorpions. *Reddyanus besucheti* is a terrestrial species that is also found in both habitats. In the forest habitat, 55.6% of individuals were observed on the leaf litter, whereas 44.4% were observed in open habitat on sand.

Charmus laneus was the second most abundant scorpion species observed only in the open habitat. Lourenço (2002) recorded this species from Mannar District and in Wilpattu National Park (Northwestern part of Sri Lanka) and Kovařík et al. (2016) recorded this species from Puttalam District and Eluwankulama (western part of Sri Lanka). Therefore, this is the first record of *C. laneus* from the Polonnaruwa District (eastern part of the island), which is about 200km away from Mannar District. Their distribution was confined to the surrounding of exposed bedrock in an open area. Unlike *H. swammerdami,* they were very active and observed running among small grasses near to exposed bedrock on open land. None of the individuals was observed in the open grassy plains or among leaf litter.

The total Shannon diversity index was calculated as 1.0880 for both open and forest habitat. Since the normal range of the Shannon index is 1.5–3.5 (Magurran 1988), this value for the entire site indicates shallow species diversity compared to other taxa. This low alpha diversity is common among predators like scorpions because they are well known for their restricted movement, cannibalism, predation by nocturnal predators, habitat specificity, food size specificity, extreme climate adaptability, and adaptive radiation (Newlands 1972; Polis 1990; Pande et al. 2004). Together with a longer life span than many invertebrates, these factors may act as constraining factors as far as species diversity is a concern (Pande et al. 2012). Since, the 95% confidence intervals of Shannon index values are not overlapped, the Shannon index value for open habitat is significantly different than the forest habitat (Figure 3a). This reflects open habitat has higher scorpion diversity compared to the forest habitat, because open habitat contains scattered boulders. Crevices under boulders are a preferred habitat for scorpions to spend the day time.

The number of species reflects the species richness. Species richness is strongly dependent on sampling size and effort (Help et al. 1998). The species abundance is often a more sensitive measure of a diversity parameter than species richness alone (Kempton 1979). To overcome this problem, the Margalef index was used. Since, the 95% confidence intervals for the Margalef

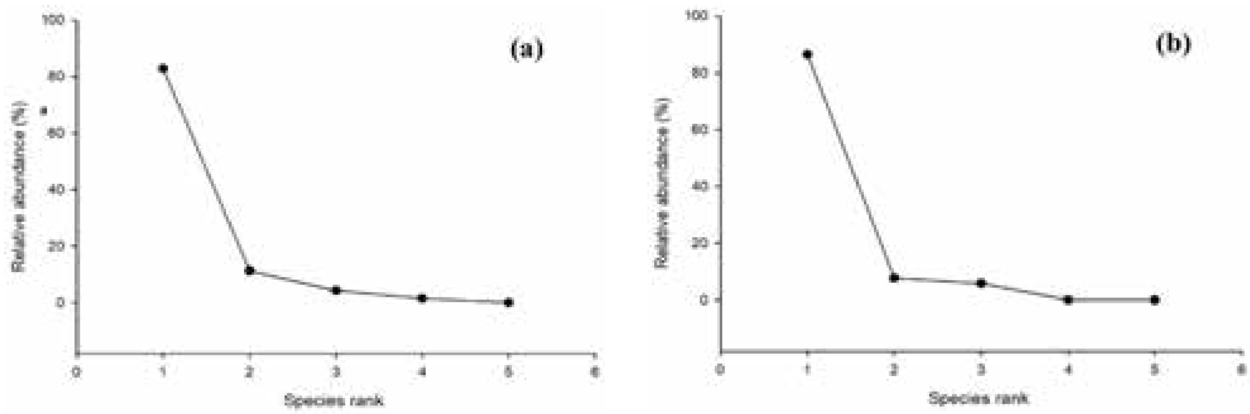

Figure 2. a—Whittaker plot for open habitat Rank 1: *H. swammerdami,* 2: *C. laneus,* 3: *R. loebli,* 4: *R. besucheti,* 5: *I. thwaitesi* | b—Whittaker plot for forest habitat Rank 1: *R. loebli,* 2: *R. besucheti,* 3: *I. thwaitesi,* 4/5: *C. laneus, H. swammerdami.*

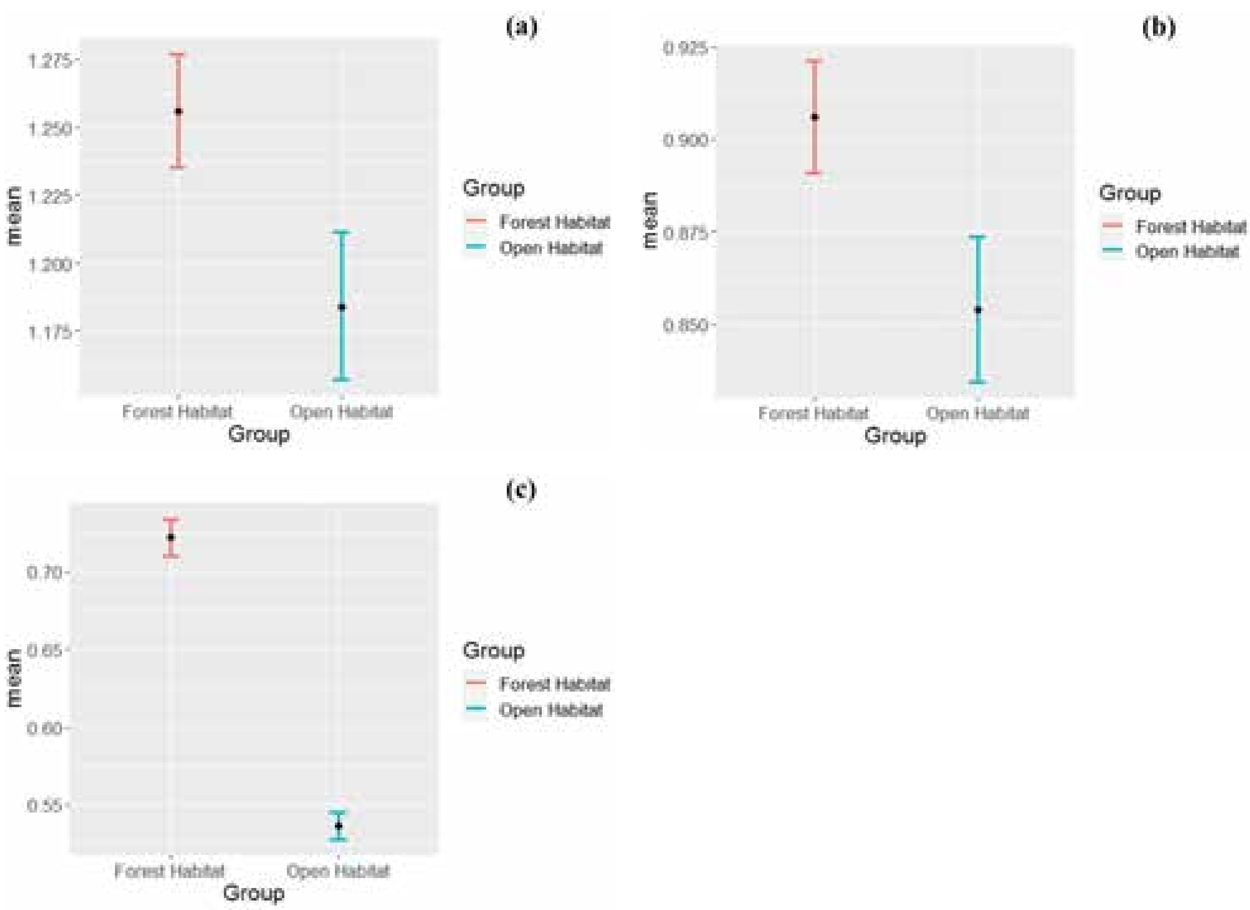

Figure 3. 95% confident intervals of a—Shannon index (H') | b—Shannon evenness (E) | c—Margalef diversity Index (D_{Mg}) for forest and open habitat.

index values in two habitats are not overlapped with each other, the Margalef index value for open habitat is significantly different from forest habitat (Figure 3.c). This index reflects two habitats have almost similar in species richness. Species evenness is a measure of how similar species are equally abundant (Lloyd & Ghelardi 1964; Magurran 2004). Evenness value range from 0.0-1.0. When the species are equally abundant, evenness value is greater. When the few species are dominant in the community, evenness is less (Magurran 2004). Since

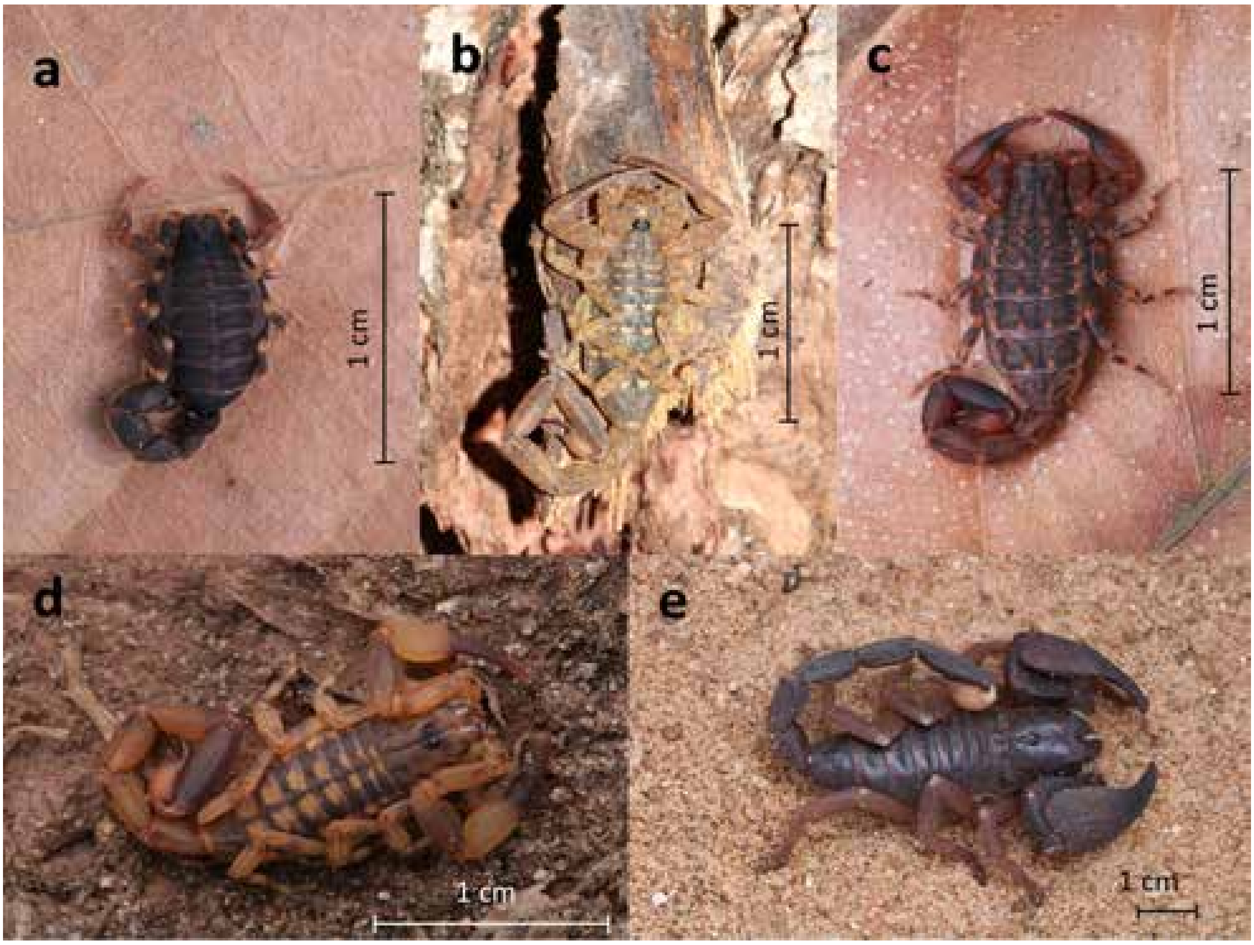

Image 3. Scorpion species found in Polonnaruwa Archaeological Reserve, Sri Lanka: a—*Charmus laneus* female | b—*Isometrus thwaitesi* female | c—*Reddyanus besucheti* female | d—*Reddyanus loebli* female | e—*Heterometrus swammerdami* female. © Kumudu B Wijesooriya

the 95% confidence intervals for the Shannon evenness values of two habitats are not overlapped, the Shannon evenness values are significantly different in the forest and open habitats (Figure 3b). The higher Shannon evenness value of forest habitat explains that scorpions found in forest habitat were more equally abundant than the open habitat due to the high dominance of *H. swammerdami* in open habitats (Figure 2a). Similarly, forest habitat has evenness value below 0.5, which is due to the high dominance of *R. loebli* in forest habitat (Figure 2b). Beta diversity of habitats compares the species similarity between the two habitats (Magurran 2004). To compare the similarity between two habitats, which was calculated as 0.5882 in Sørensen index in a way reflecting a more than 50% shared species between two habitats. Similar results were observed in previous studies as intra-specific and inter-specific coexistence in several species of scorpions (Kaltsas et al. 2009; Shehab et al. 2011; Lira et al. 2013). Thus, species might either co-occur in the same habitat or co-occur in the same shelter (Warburg 2000).

Arboreal scorpion *R. loebli* prefers to occupy around heights of 121–180 cm range. This might be mainly due to foraging opportunities and predator pressure. They are considered efficient predators of Isoptera, Hymenoptera, Diptera, Hemiptera, while civets, mongoose, land monitors, and lizards are the predators of them (personal observation). Thus, *R. loebli* might prefer to forage in this favourable height range without being consumed by another predator. On the other hand, *R. loebli* prefers to inhabit around DBH of 361–480 cm range, which is above the average DBH level. The diameter of a tree considered as contemplate of a niche area for an arboreal scorpion. Thus, they favour occupying a much larger niche for obtaining more resources like prey, sites to rest and hide from predators.

In conclusion, the five species reported in the Archaeological site of Polonnaruwa suggest high scorpion richness in this area. This highlights the importance of conservation of historic ruins and forest patches of the archaeological site to maintain scorpion fauna. Thus, the results presented here contribute to the knowledge of the diversity of scorpions in these historically significant sites that can serve as a basis for future research on the impact of habitat modification and fragmentation on the population, distribution, and ecology of scorpions.

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PLATINUM OPEN ACCESS

COMMUNICATION

A faunistic survey of tiger beetles (Coleoptera: Carabidae: Cicindelinae) in Chakrashila Wildlife Sanctuary and adjoining riverine ecosystem in Assam, India

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Abstract: A faunistic survey was made to assess the tiger beetle fauna from the Chakrashila Wildlife Sanctuary and adjacent rivers for the first time from the western part of Assam, India. A total of 15 species of tiger beetles (subfamily Cicindelinae) belonging to seven genera were recorded from forest, moist and dry riverine ecosystem using an occasional night trap. Eight species belonging to five genera were recorded from the riverine ecosystem. Two species, viz., *Cylindera spinolae* and *Calochroa assamensis*, were strictly restricted to the forest and *Cosmodela virgula* was recorded from both forest and riverine areas. *Cylindera (Eugrapha) minuta*, *Calochroa flavomaculata*, and *Lophyra (Spilodia) vittigera* were collected using a night trap from the forest area. The study revealed that habitat degradation due to human interference is the major threat to the tiger beetles in the study area.

Keywords: *Calochroa assamensis*, *Cylindera spinolae*, diversity, night trap, northeastern India, predatory insects, riverine, sandy, threats.

Abbreviations: BTAD—Bodoland Territorial Autonomous Districts | BTC—Bodoland Territorial Council | GPS—Global Positioning System | ZSI—Zoological Survey of India.

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Active contribution: KC conceptualised and supervised the study and also wrote the first draft. CD visited the field, collected the beetles and took images along with KC. ADS analysed the data, structured the manuscript and approved the final draft.

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INTRODUCTION

Tiger beetles are charismatic, fast running, and predatory insects under the subfamily Cicindelinae and family Carabidae. Cicindelinae is characterized by large compound eyes, filiform and 11-segmented antennae, long legs, and long sickle-shaped mandibles. The size of tiger beetles varies from 6–45 mm. They are adapted to different habitat types such as riverine sandy areas, stream and pond edges, hillsides, rocky areas near roads, trails, and forest openings. Though the tiger beetle is mainly distributed in the tropical region, it is also found in Greenland, Tasmania, and some small oceanic islands such as Hawaii (Pearson 1988; Cassola & Pearson 2000; Pearson & Vogler 2001).

All tiger beetles are highly habitat-specific (Knisley & Hill 1992; Adis et al. 1998; Cardoso & Vogler 2005; Pearson & Cassola 2007; Rafi et al. 2010). Each species prefer specific habitats such as riverine habitats (Ganeshaiah & Belavadi 1986; Satoh et al. 2006; Dangalle et al. 2011a,b), forests (Adis et al. 1998), agroecosystems (French et al. 2004; Sinu et al. 2006), parks, areas with human disturbances (Bhardwaj et al. 2008; Mosley 2009), open areas with sparse vegetation (Schiefer 2004) and grasslands (Acorn 2004). The association of tiger beetle species with habitat has been related to their preferences for mating and oviposition sites, food availability, seasonality, vegetation cover and physical, chemical and climatic qualities of the habitat (Pearson et al. 2006). Most of the tiger beetles are diurnal, some species are strictly nocturnal and many are cathemeral (Pearson 1988). Though several species living together is common, there is very little competition among them, particularly because of niche partitioning (Pearson & Carroll 1998).

There are around 2,300 species of tiger beetles recorded so far all over the world. India harbors 208 species of tiger beetles and ranks third among the countries inhabited by them. Of these, 51.9% species are endemic to India only (Cassola & Pearson 2000). Geographically, species richness of tiger beetles is comparatively high in the northeastern and southwestern parts of India (Pearson & Ghorpade 1989; Pearson & Juliano 1993). Since they are widespread, having specific habitat requirements and well-known taxonomy they serve as valuable indicators of the general state of the environment (Annemarie 1999; Cardoso & Vogler 2005; Satoh et al. 2006; Pearson & Cassola 2007). Besides, some species serve as important biological control agents in agroecosystems (Rodriguez et al. 1998).

Indian tiger beetles were first documented by Schaum (1863), Atkinson (1889), and Horn (1905a,b), though the first comprehensive list of all genera of tiger beetles of the Indian subcontinent was published by Fowler (1912). After independence, Pajni & Bedi (1973) reported a preliminary survey of the cicindelid fauna of Chandigarh. Pearson & Ghorpade (1987) studied the geographical distribution and ecological history of tiger beetles of the Siliguri-Darjeeling area of eastern India. Later, Bhargav & Uniyal (2008) studied tiger beetles in the Shivalik Landscape. In 2008, Werner & Wiesner first recorded *Neocollyris* (*Leptocollyris*) *parvula* (Chaudoir, 1848), *Calochroa bicolor haemorrhoidalis* (Wiedemann, 1823) and *Cylindera* (*Ifasina*) *severini* (Horn, 1892) from the state of Maharashtra, Rajasthan, and Madhya Pradesh. Bhardwaj et al. (2008) reported the occurrence of tiger beetles from Uttarakhand. Tiger beetles of Meghalaya were exclusively reported by Sawada & Wiesner in 1997. Recently, Harit (2013) studied the diversity of tiger beetles in Mizoram of northeastern India. Invertebrates are understudied overall, and for even some of the taxonomically better studied groups like tiger beetles (Cicindelidae), knowledge is scanty from this part of the land. Keeping these aspects in view, an investigation of the occurrences and preferences of habitats along with their present threats in Chakrashila Wildlife Sanctuary and the adjoining riverine ecosystem in western Assam of India was conducted.

MATERIALS AND METHODS

Study area

Chakrashila Wildlife Sanctuary (26.250–26.433 ^{0}N and 90.250–90.333 ^{0}E 4,500ha) is located in the districts of Kokrajhar and Dhubri in the state of Assam, India. The sanctuary is the only protected area for the Golden Langur *Trachypithecus geei* in India. The hilly terrain is covered with dense forest which is mostly semi-evergreen and moist deciduous, with patches of grassland and scattered bushes (scrubland). The dominant trees found are *Tectona grandis*, *Shoresa robusta*, *Eleocarpus* sp., *Oroxylum indicum*, *Castanopsis purpurea*, and *Dillenia pentagyna*. The forest type falls in the category 3C/C.1.a(ii) following Champion & Seth (1968).

There are several small streams, of which the major ones are Howhowi Jhora and Bamuni Jhora, which help maintain humidity of the environment. Two major wetlands, viz., Diplai and Dhir 'beel' (water bodies) are also adjacent to its boundary. The sanctuary harbours about 154 species of butterflies (Choudhury & Ghosh

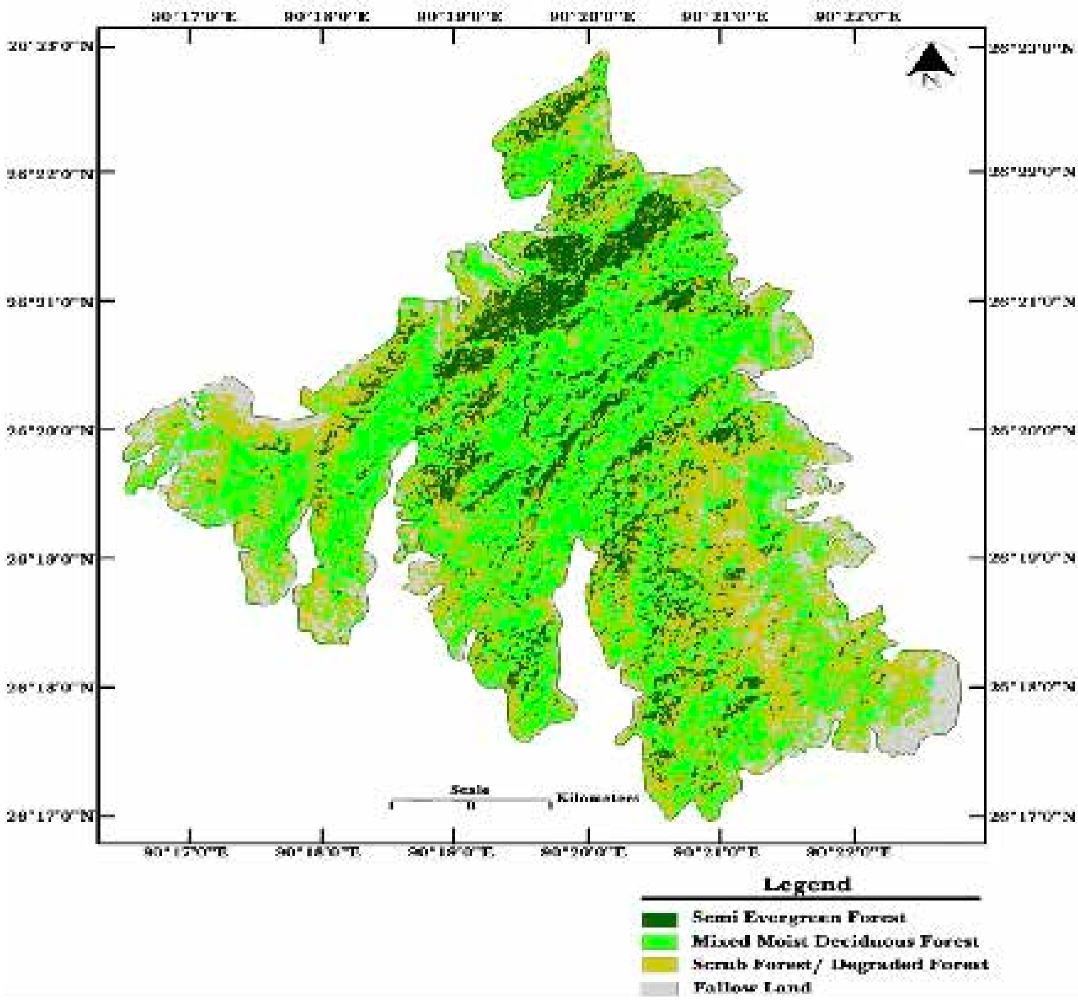

Figure 1. GIS image of Chakrashila Wildlife Sanctuary, western Assam, India.

2009) and the endemic Golden Langur (Gee 1961). Besides, a survey was also carried out along the river banks of Gaurang, Champawati, Saralbhanga, and Bahalpur, which are the major tributaries of the river Brahmaputra and originate from the Bhutan Himalayas.

The present study was conducted from October 2018 to October 2019. Surveys were carried out between 10.00 and 16.00 h on sunny days by walking on dry river beds and along the banks of the rivers Gaurang, Champawati, Saralbhanga, and Bahalpur. Visual encounter survey is the most effective method for tiger beetle study. Species recorded in moist sandy soils and dry sandy soils were recorded. For forest species, active search was made along all approachable areas of different habitats such as stream bank, grassland and forest trails of Chakrashila Wildlife Sanctuary. All the GPS locations were recorded with the help of Garmin GPS-60. Specimens were collected by hand picking and a standard-sized insect net. Besides, an opportunistic light trap was also carried along during the survey along the road side of the Chakrashila Wildlife Sanctuary to find out the alpha-diversity of tiger beetles. Collected specimens were preserved in 96% ethanol in the laboratory of P.G. Department of Zoology, Science College, Kokrajhar and Zoological Survey of India (ZSI), Kolkata for further reference. Identification was carried out following Fowler (1912) and with the assistance of an insect taxonomist.

RESULTS

A total of 15 species of tiger beetles belonging to seven genera were recorded in Chakrashila Wildlife Sanctuary and riverine ecosystem of Gaurang, Champawati, Saralbhanga, and Bahalpur during the sampling period (Table 1). Maximum number of species was recorded from the genus *Calomera* (27%)

Table 1. Tiger beetle fauna of Chakrashila Wildlife Sanctuary, and adjacent riverine ecosystems with their associated habitat.

	Genus	Species	Habitat
1	Calomera	*Calomera angulata* (Fabricius, 1798)	Moist sandy soil
2		*Calomera (Lophyridia) chloris* (Hope, 1831)	Moist sandy soil
3		*Calomera plumigera macrograptina* (Acciavatti & Pearson, 1989)	Moist sandy soil
4	*Myriochila*	*Myriochila undulata* (Dejean, 1825)	Moist sandy soil
5	*Cylindera*	*Cylindera (Eugrapha) minuta* (Olivier, 1790)	Moist sandy soil
6		*Cylindera (Eugrapha) venosa* (Kollar, 1836)	Moist sandy soil
7		*Cylindera spinolae* (Gestro, 1889)	Forest area
8		*Cylindera bigemina* (Klug, 1834)	Moist sandy soil
9	*Cosmodela*	*Cosmodela virgula* (Fleutiaux, 1893)	Moist sandy soil and forest area
10	*Chaetodera*	*Chaetodera albina* (Wiedemann, 1819)	Dry sandy soil
11	*Lophyra*	*Lophyra cancellata intemperata* (Dejen, 1825)	Moist sandy soil with sparse vegetation
12		*Lophyra (Spilodia) vittigera* (Dejean, 1825)	Forest area
13	*Calochroa*	*Calochroa octonotata* (Wiedemann, 1819)	Moist sandy soil
14		*Calochroa flavomaculata* (Fabricious, 1775)	Forest area
15		*Calochroa assamensis* (Parry, 1844)	Forest area

Table 2. Geographical locations of different survey areas during the study period.

Survey area	Latitude (N)	Longitude (E)	Altitude (m)
Gaurang River	26.713	90.444	57
	26.722	90.443	57
	26.426	90.262	57
	26.429	90.265	56
	26.713	90.444	56
	26.691	90.445	56
	26.710	90.459	56
	26.429	90.265	57
	26.417	90.271	57
	26.722	90.448	57
	26.710	90.459	57
	26.692	90.717	57
	26.724	90.429	57
	26.670	90.434	57
	26.667	90.430	57
	26.687	90.447	57
Champawati River	27.120	90.620	45
Bahalpur River	26.533	90.798	82
Saralbhanga River	26.568	90.211	82
Malbhog River	26.540	90.082	73

Image 1. Survival threats to tiger beetle: A—extraction of sand | B—extraction of gravel and boulder | C—forest fire. © K. Choudhury.

followed by *Calochroa* (20%) and *Cylindera* (20%). *Lophyra* presented 13% of the total species. The least number of species was recorded from the genus *Chaetodera* and *Cosmodela* (7%) (Figure 2A). In the study, maximum number of species was recorded from the moist riverine sandy soil (53%) which was followed by forest area (33%) while the least number of species was recorded from the dry, riverine sandy soil, while only 7% species share both forest and moist riverine sandy soil (Figure 2B). *Cylindera* (*Eugrapha*) *venosa* and *Myriochila undulata* were the most common species in moist riverine sandy soil while *Cylindera spinolae and Calochroa assamensis* were restricted to the forest area only. *Cosmodela virgula* was recorded from both the moist sandy soil and forest area. *Chaetodera albina* was the only species recorded from dry sandy soil during the study period (Table 1). Three species were encountered using a light trap of which *Cylindera (Eugrapha) minuta* and *Calochroa flavomaculata* occurred frequently but *Lophyra (Spilodia) vittigera* was rare. All the survey sites along with their GPS locations during the survey period are depicted in Table 2.

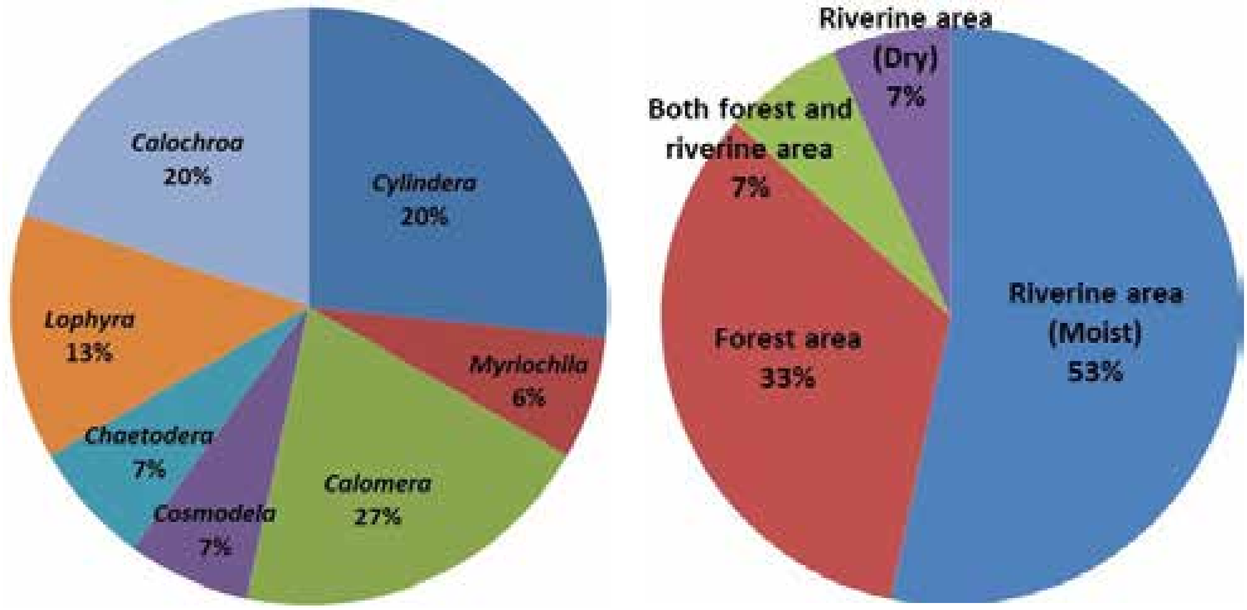

Figure 2. A—Different genera of tiger beetles in percentage recorded during the survey | B—Habitat utilization of tiger beetles in the study sites during the survey.

DISCUSSION

The sandy bank formed along the margin of the water level attracts many invertebrates due to accumulated organic matter and high food supply. Such riparian habitats are known to be preferred by tiger beetles not only because of adequate food resources but also due to safety from predators and low human disturbance (Bhargav & Uniyal 2008; Dangalle et al. 2012). Among the species, nine—*Calomera plumigera macrograptina, Cylindera bigemina*, *Lophyra cancellata intemperata, Myriochila undulata, Chaetodera albina, Calochroa octonotata, Cylindera* (*Eugrapha*) *venosa, Cylindera (Eugrapha) minuta*, and *Calomera chloris* (Image 3)—were recorded in moist riverine sandy areas of rivers Gaurang, Sarlbhanga, and Champawati. Tiger beetles usually prefer low moisture containing sandy soil with sparse vegetation where females' oviposition becomes easier (Ganeshaiah & Belavadi 1986; Hoback et al. 2000; Satoh et al. 2006; Dangalle et al. 2011a,b). Among the moist riverine sandy species, *Cylindera* (*Eugrapha*) *venosa* and *Myriochila undulata* were the most common species and dominated all other species in terms of occurrence. *Calochroa octonotata* is the largest tiger beetle in terms of body size and has a powerful flyer and usually occurs individually in the margin of the water level. When disturbed, it flies for long distances and perches in areas of sparse vegetation. Some species like *Cylindera* (*Eugrapha*) *venosa, Myriochila undulata, Cylindera (Eugrapha) minuta, Calomera plumigera macrograptina*, and *Lophyra cancellata intemperata* co-occurred but they could have the least competition amongst themselves probably due to niche separation (Pearson 1998). *Lophyra cancellata intemperata* was less abundant and prefers moist sandy area with sparse vegetation (Schiefer 2004). It has been noticed that this species, when disturbed or threatened, moves to sparse vegetation areas at once and obscures itself. They usually co-occurred with *Cylindera (Eugrapha) venosa* and *Myriochila undulata* but were found to be scanty in number. During the survey, *Chaetodera albina* was recorded only from a few locations of the river Gaurang specifically during hot sunny days when sand temperatures were about 45^{0}C (mid-day). It was recorded in a characteristic dry sandy soil (white) about 20m away from any water source. *Chaetodera albina* is a conspicuous species and is difficult to locate unless or until it moves. The expanded white maculations on the elytra may have functioned in lowering the body temperature making them able to forage longer without overheating (Dangalle et al. 2012). Besides, it is an apparent adaptation for remaining inconspicuous to natural enemies reliant on visual cues (Seago et al. 2009).

Likewise, three species namely *Cylindera spinolae, Calochroa assamensis*, and *Cosmodela virgula* were recorded from the forest of Chakrashila Wildlife Sanctuary. *Cylindera spinolae* and *Calochroa assamensis*

Image 2. Different habitats of tiger beetles: a—forest | b—moist sandy soil | c—dry sandy soil | d—moist soil. © K. Choudhury

are both forest dwellers and observed while perching on leaf surfaces. The presence of tiger beetles in forest and thick undergrowth vegetations were also reported by Pearson & Ghorpade (1987) and Adis et al. (1998). The black coloration of both the species seems to give them an advantage of not being easily recognized by predators as they seem to camouflage in the dark and shady environments and dark substrates. In general, tiger beetles' general coloration tends to match their substrate as a tool to evade and confuse predators (Morgan et al. 2000; Dangalle et al. 2014). On the other hand, *Cosmodela virgula* occurs in both river banks as well as forest paths. This indicates that this species is a habitat generalist. Among the forest dwellers, *Cosmodela virgula* is the most abundant species. During the study period, *Lophyra (Spilodia) vittigera* and *Calochroa flavomaculata* were collected by incidental catch by night trap near the Forest Bungalow of Chakrashila Wildlife Sanctuary. Among the night trap species, *Cylindera (Eugrapha) minuta* and *Calochroa flavomaculata* occurred frequently but *Lophyra (Spilodia) vittigera* was sighted only once. Harit (2013), however, recorded *Calochroa flavomaculata* and *Calomera chloris* from riverine sandy soil, while *Cylindera (Eugrapha) minuta* was reported to prefer riverine sandy soil as well as agricultural land in the Mizoram State of northeastern India.

The present study reveals that due to rapid urbanization, demand of sand and gravel has increased manifold. These materials are extracted legally or illegally in large and small scale from the river bed by traders as well as villagers from almost all the rivers. The extraction pressure however is comparatively more on the Champawati River than the others because of its good sand quality. The raw materials for rock crushing industries are also extracted from these rivers. Since, most tiger beetles are habitat specific, such activities definitely impact on their survival which may lead to their local extinction (Image 1). Presently, the unscientific use of fertilizers in the paddy fields around the vicinity of riverine sides may degrade the soil quality, which in turn hampers the development of the tiger beetles' larvae. Besides, illegal tree-felling, encroachment, silvicultural practices, conversion of cultivated land into tea gardens and illegal forest fire can cause the diversity of tiger beetles in the area to decline. The study indicates the presence of pristine habitat condition of tiger beetles in this region. Therefore, conservation of these local poorly known taxa is of utmost importance along with other flora and fauna of this region.

Image 3. Microphotographs of different species of tiger beetles: a—*Cylindera spinolae* | b—*Calochroa assamensis* | c—*Calochroa flavomaculata* | d—*Calomera plumigera macrograptina* | e—*Cylindera* (*Eugrapha*) *minuta* | f—*Calomera angulata* | g—*Lophyra cancellata intemperata* | h—*Lophyra (Spilodia) vittigera* | i—*Calomera (Lophyridia) chloris* | j—*Chaetodera albina* | k—*Cylindera (Eugrapha) venosa* | l—*Cosmodela virgula* | m—*Calochroa octonotata* | n—*Cylindera bigemina*. © K. Choudhury

CONCLUSION

The detection of 15 species of tiger beetle for the first time reflects the low survey effort and opportunistic nature of the collections. Therefore, a long-term survey covering maximum habitats over different seasons will be required at the earliest to explore and document the entomological wealth of the region. Though the species inventories are few in number, the present findings have high significance for understanding insect biodiversity in the region and provides a baseline data for further research programmes.

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Erratum

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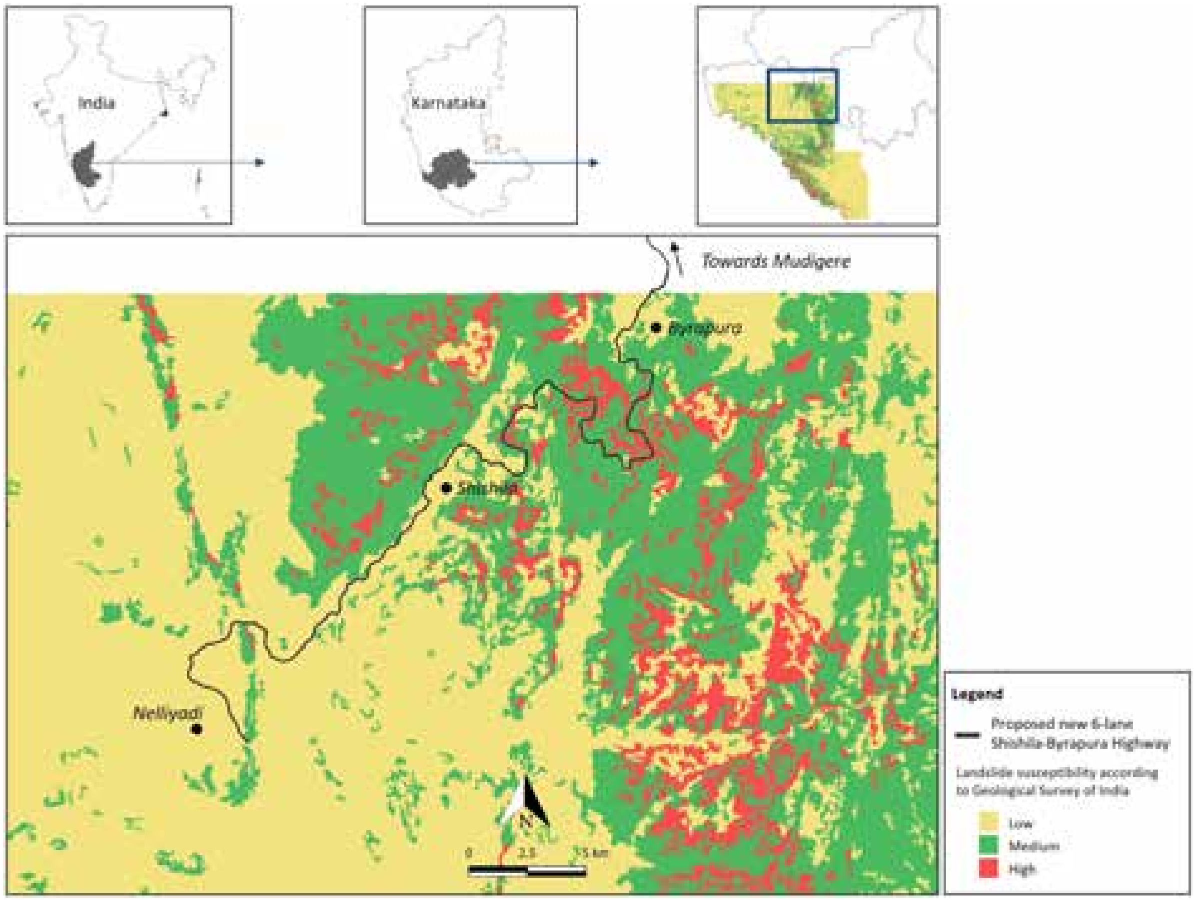
Legend for the Appendix 3 has been wrongly written within map, which could be problematic to the representation of the results. Legend should read as:



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PLATINUM OPEN ACCESS

COMMUNICATION

Occurrence of the *Aporrectodea caliginosa caliginosa* (Savigny, 1826) (Annelida: Clitellata: Haplotaxida) from Kashmir Valley, Jammu & Kashmir, India

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Abstract: The paper describes the earthworm *Aporrectodea caliginosa caliginosa* (Savigny, 1826) of class Clitellata, order Opisthopora and family Lumbricidae, from Kashmir Valley, Jammu & Kashmir, India. Previously the species was recorded from Himachal Pradesh, and in the present study the species is reported from Gulmarg forest within the geographical coordinates of (34.050^{0}N & 74.388^{0}E). During the study the seasonal variation of *A.c. caliginosa* in terms of density and biomass along with the soil physiochemical characteristics were reported. *A.c. caliginosa* showed significant variation in density (t=3.34, p<0.044) and biomass (t=3.40, p<0.042) among different seasons, with maximum density (129.6/m^2) and biomass (26.90g/m^2) during spring, and minimal values of 34.33/m^2 and 6.94g/m^2 during winter respectively. Soil physiochemical characteristics also varied significantly among seasons.

Keywords: Biomass, density, earthworm, Kashmir Valley, soil physiochemical.

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Author contribution: ABK and IAN conceptualized the study. IAN conducted the field work and analysis of samples with technical support by AH. All the three authors contribute to the synthesis of manuscript, however ABK supervised the overall study.

Competing interests: The authors declare no competing interests.

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INTRODUCTION

Human activities are causing major shifts in the community composition of biological systems by transporting species across biogeographic barriers (Wardle & Peltzer 2017). Invasion of exotic earthworms is increasing worldwide (Lee 1985; Fragoso et al. 1999), apparently facilitated by global commerce with the importation of soil-containing materials (agricultural and horticultural products) for commercial applications (waste management and land bioremediation). Invasive earthworms are also continuing their expansion into earthworm-free zones (Tiunov et al. 2006), where they may have large ecological impacts (Bohlen et al. 2004; Frelich et al. 2006).

Globally, 4,400 earthworm species are known (Sinha 2009), most having restricted ranges (Reynolds 1994). Julka et al. (2009), Blakemore (2008), and Julka (2014) reported more than 500 species of earthworms from India, belonging to 10 families and 69 genera (Dash 2012; Kathireswari 2016). In comparison to other Asian countries, earthworms are well studied in India (Bisht et al. 2003; Tripathi & Bhardwaj 2004; Sathianarayanan & Khan 2006; Karmegam & Daniel 2007; Chaudhuri et al. 2008; Goswami & Mondal 2015; Deepthi & Kathireswari 2016; Narayanan et al. 2017, 2019; Rajwar et al. 2018; Lone et al. 2020), while there is paucity of information on the earthworms of the Kashmir Valley aside from the important contributions of Stephenson (1922), Sharma & Kaul (1974), Paliwal & Julka (2005), Najar & Khan (2011a,b,c, 2014), and Mir & Najar (2016). Earthworms play a key role in the improvement of soil, making nutrients available to plants and thus enhancing crop yields (Najar & Khan 2013a,b; Najar 2017).

The first record of earthworms from the Indian subcontinent was provided by Templeton (1844). Subsequently followed by Michaelsen (1907), Stephenson (1923, 1924, 1925, 1926, 1931), Gates (1940, 1945a,b, 1972a), Julka (1976, 1978, 1981, 1993), Kale & Krishnamoorty (1978a,b), Julka & Senapati (1987), Bhadauria & Ramakrishnan (1989), Ismail et al. (1990), Bano & Kale (1991), Blanchart & Julka (1997), Chaudhuri & Bhattacharjee (1999), Bhadauria et al. (2000), Bisht et al. (2003), Srivastava et al. (2003), Tripathi & Bhardwaj (2004), Paliwal & Julka (2005), Sathianarayanan & Khan (2006), Karmegam & Daniel (2007), Chaudhuri et al. (2008), Joshi & Aga (2009), Chaudhuri & Bhattacharjee (2011), Chaudhuri & Nath (2011) Verma & Shweta (2011), Najar & Khan (2011a,b,c, 2014), Chaudhuri & Dey (2012), Siddaraju et al. (2013), Dey & Chaudhuri (2013, 2014).

Aporrectodea caliginosa caliginosa is a typical synanthropic species and thrives in pastures, gardens and forests of the temperate zone. Miller et al. (1955) stated its possibility in every type of substrate, even in the poorest sandy soil. In disturbed ecosystems it can displace populations of native worms in a short span of time. According to Bouche's (1977) ecological characterization, *A.c. caliginosa* belongs to the endogeic group, living and feeding in the mineral soil layer.

Gulmarg is located in the Pir Pinjal range of the Himalayan Mountains of Kashmir Valley (Jammu & Kashmir) India. It is at a distance of 52km from Srinagar, the capital of Jammu & Kashmir to its southwest, at an altitude of 2,450m (Fig. 1). It is famous for retaining several rare and endangered species with a rich and varied avifauna. The area holds a rich cover of vegetation, the dominant forest consisting of conifers, which account for over 90%. The principal species are *Cedrus Deodara*, *Abies Pindrow*, and *Pinus wallichaina*. The dominant tree species at the site is *P. wallichaina* with a rich ground cover comprising of *Leucanthemu vulgare*, *Cyanodon dectylon*, and *Trifolium repens*.

MATERIALS AND METHODS

Earthworm and soil sampling

Earthworm samples were collected by digging soil monolith (25 x 25 x 30 cm) and hand sorting. Worms were sorted into clitellates, non-clitellates (>4cm, without clitellum but have genital markings) and juveniles (<4cm, lack of genital marking, tumescences and clitellum) following Zorn et al. (2005), preserved in 4% formalin and sent to Zoological Survey of India (ZSI), Kolkata for taxonomic identification. The specimens were deposited in the Museum, Department of Ecology and Environmental Sciences, Pondicherry Central University, (DEES-A: 03/2009) housed in Kalapet, Puducherry, India.

Soil analysis

Composite soil samples comprising of three subsamples were analyzed using standard protocols. Soil temperature measured by soil thermometer and soil moisture by gravimetric method (Gupta 1999); pH, electrical conductivity (EC) and organic nitrogen (ON) by micro Kjeldahl method (Jackson 1973); soil texture by the international pipette method (Gee & Bauder 1986); organic carbon (OC) by Walkley & Black (1934).

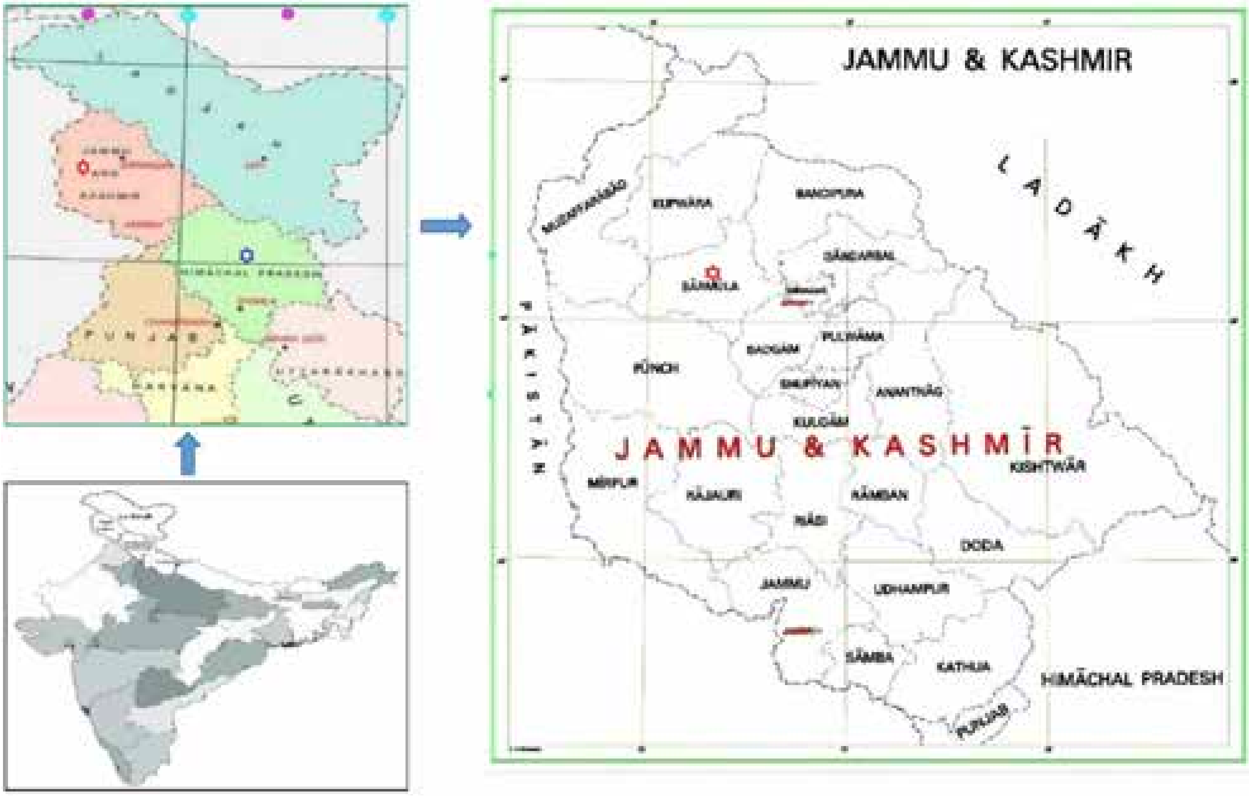

Figure 1. Distribution of *Aporrectodea caliginosa caliginosa*. Blue star - Himachal Pradesh (previous report) and red star - Jammu & Kashmir (new record).

Data analyses

Data sets were subjected to *t*-test in order to determine differences among the parameters. Statistical analyses and graphical presentations were performed using SPSS statistical software (Version 16) and PAST statistical software (Version 1.93).

RESULTS AND DISCUSSION

Aporrectodea caliginosa species complex includes three species, *A. caliginosa s.s.* (Savigny, 1826), *A. trapezoides* (Duges, 1828), and *A. nocturna* (Evans, 1946) and one subspecies, *A. c. tuberculata* (Eisen, 1874), although this view has been challenged several times. Because of their similarity, the taxonomic status of the taxa within *A. caliginosa* species complex is a matter of debate for more than a century. Based on morphological data, *A. caliginosa s.s.*, *A. trapezoides*, and *A. nocturna* were initially described as distinct species, whereas *A. tuberculata* was described as a subspecies of *A. caliginosa*. Michaelsen (1900) noticed that some of these taxa were closely related and included them in a species complex, but he suggested that they belong to a single species with two subspecies: *A. caliginosa caliginosa* and *A. c. trapezoides* and considered the other taxa as synonymous to *A. caliginosa*. Omodeo (1952) and Casellato (1987) considered *A. trapezoides* as the polyploidal variety of *A. caliginosa s.s.* Gates (1972b) disagreed with Michaelsen (1900) and separated them into four distinct species [*A. caliginosa s.s.* (namely, *A. turgida Eisen* 1874), *A. tuberculata*, *A. trapezoides*, and *A. nocturna*]. The same year, however, Bouche (1972) split them into two species and placed them into a different genus, *Nicodrilus caliginosus* (*A. caliginosa*) and *N. nocturnus* (*A. nocturna*), with the former species composed of three subspecies: *N. c. caliginosus* (*A. c. caliginosa*), *N. c. alternisetosus* (*A. tuberculata*) and *N. c. meridionalis* (*A. trapezoides*). Finally, almost a century after Michaelsen's study, Briones (1996) resurrected his initial proposal suggesting that the *A. caliginosa species complex* is composed of one species with two subspecies - *A. caliginosa caliginosa* and *A. c. trapezoides* (Pérez-Losada et al. 2009). Paliwal & Julka (2005) in the checklist of earthworms of western Himalaya reported *A. c. caliginosa* species from Himachal Pradesh.

Its diagnosis is summarized in Image 1 comprising: length 60–160 mm; diameter 4–6 mm. segments 104–

Image 1. *Aporrectodea caliginosa caliginosa*.

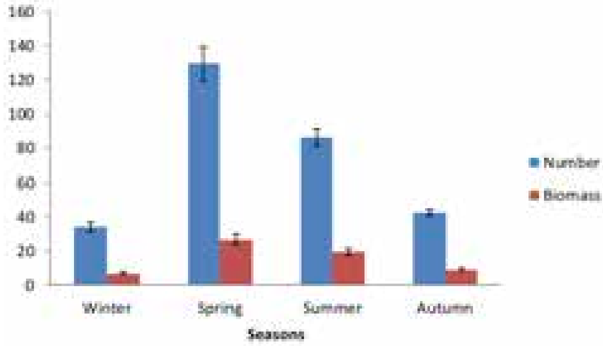

Figure 2. Density and biomass of *Aporrectodea caliginosa caliginosa* during different seasons.

248. Colour variable in life, grey, flesh-colour, brown, yellowish, slate-blue, but never purple. Prostomium epilobous 1/3, tongue cut off behind. Dorsal pores from 9/10 or less often 8/9. Setae closely paired, the lateral especially closely; aa greater than bc; dd=half the circumference or somewhat less. Clitellum saddle shaped, xxvi, xxvii, or xxviii to xxxiv or xxxv (= 7–10). Tubercles of puberty two pairs on xxxi and xxxiii. Male pores in transverse slits, on usually much elevated glandular areas, which take up xiv-xvi. Spermathecal pores two pairs, in 9/10 and 10/11, on cd. Setae ab of ix, x, and xi usually on broad papillae, transformed into genital setae, grooved, somewhat longer and thinner than the normal setae, slightly curved. Septa 5/6–9/10 thickened, 7/8 most so. Seminal vesicles of ix and x small (Stephensen 1923).

The natural rate of dispersal of an established earthworm population is relatively slow and is of rate of 5–10 m/year (Lee 1985; Marinissen & van den Bosch 1992; Dymond et al. 1997; Hale et al. 2005). Thus, anthrochorous dispersion has likely played a key role in the spreading of earthworm populations across different geographical regions. According to Hendrix (2006) there is mounting evidence that exotic earthworm invasions are increasing worldwide, sometimes with significant effects on soil processes and plant communities. At least 100 earthworm species have distributions beyond their places of origin (Lee 1985; Fragoso et al. 1999). Earthworm introductions to new geographical areas appear to be facilitated by global commerce, both inadvertently with the importation of soil-containing materials (agricultural and horticultural products) and intentionally for use in commercial applications (waste management and land bioremediation).

There are many theories regarding the dispersal of earthworms. Medium to long range dispersal is attributable to earthworms escaping to the soil surface after heavy rains, followed by wash-off of cocoons and earthworms, and eventual further transport by streams. Birds also import earthworm cocoons to new areas through mud on their feet (Eijsackers 2011). Lee (1985) and Schwert (1980) also attributed cocoon dispersal partly to avian phoresy. Earthworms have been recently introduced to the South Sea islands Gough and Marion, probably by birds, although human transport seems to have the greatest impact (Lee 1985; James & Hendrix 2004).

Humans play a dominant role in earthworm introduction and redistribution by transporting soil and plant materials (Eijsackers 2011). Plisko (2001) observed that the distribution of exotic species exhibited proximity to urban and agricultural areas, in addition to dispersal through plant material and adhering soil. Proulx (2003) and Hale & Host (2005) found a relationship between dispersal and an anthropogenic index. Holdsworth et al. (2007) found a relationship between earthworm distribution and distance to roads, whereas Cameron & Bayne (2009) correlated the distribution of exotic earthworm species with road age and reported transportation as the most important distribution factors.

According to Julka (1988), earthworms in India have been introduced to new areas by man and other agencies with the importation of soil-containing materials (plants, agricultural and horticultural products), and species colonize successfully due to their inherent ability to withstand disturbance and interference. Gonzalez et al. (2006) reported the reproductive biology of species as an important characteristic in successful establishment. Further, high fecundity, short incubation periods and high hatching success are also likely adaptive strategies that enable survival of drastic environmental changes (Bhattacharjee & Chaudhuri 2002). Environmental

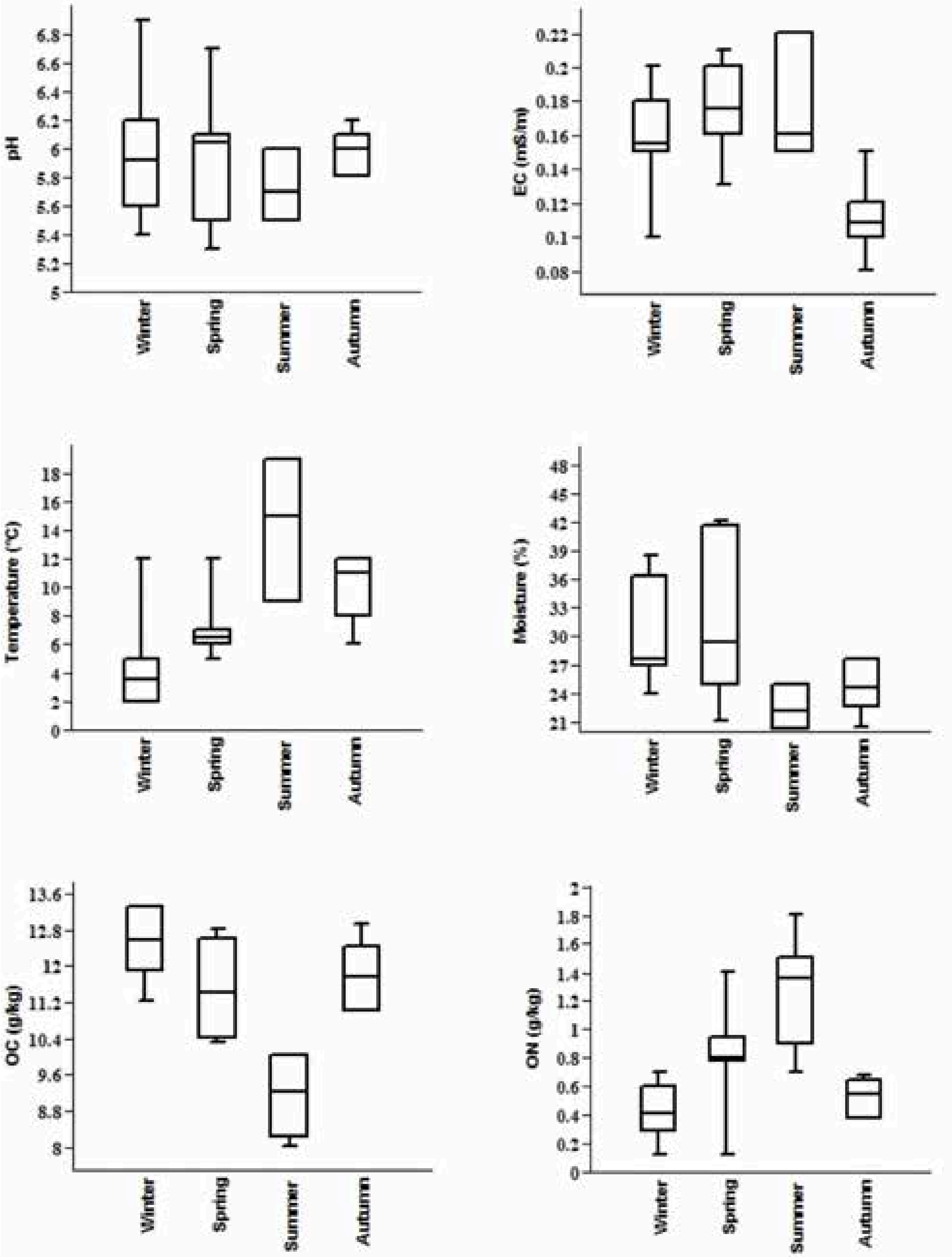

Figure 3. Soil physicochemical characteristics of the earthworm collection site.

plasticity and ability to aestivate appear to make some earthworms particularly successful as invaders (Fragoso et al. 1999; James & Hendrix 2004). According to Bengtson et al. (1979), the aestivation capability of *A. caliginosa* makes it a successful colonizer during adverse drought conditions and able to tolerate a wide range of soil moisture (35–65 %; Zorn et al. 2008) and pH (3.7–8.5). Further biological traits of *Aporrectodea* sp. such as tolerance to varying environmental conditions, rapid growth, and ability to live under a wide range of land uses and soils (Winsome et al. 2006), could give it a competitive advantage to successfully establish and dominate in different pedoecosystems.

The population size and species composition of earthworm communities is dependent upon soil texture, pH, moisture, and the palatability and quantity of litter (Lavelle 1997; Bohlen et al. 2004). *A. c. caliginosa* exhibited significant variation in population density (t=3.34, p<0.044) and biomass (t=3.40, p<0.042) among different seasons is shown in Figure 2. Population density varied from 34.33/m^2 to 129.6/m^2 during winter and spring respectively. The biomass also ranged from 6.94g/m^2 during winter to 26.90g/m^2 during spring. Population density was minimum during winter which is attributed to low temperature which causes delay in hatching of cocoons (Timmerman et al. 2006). Najar & Khan (2011a) also reported that earthworms were most abundant during spring and attributed it to the optimum moisture and temperature conditions. Complete cessation of cocoon production was observed by Nairw & Bennour (1998) during summer in *A. caliginosa* due to high temperature.

A variety of environmental factors such as soil texture, soil moisture, pH, temperature, organic content have been suggested as determinants for the distribution and abundance of earthworms (Bisht et al. 2003). Soil characteristics of the site are given in Figure 3. *A.c. caliginosa* was found within the pH range of 5.73 ± 0.09 to 5.99 ± 0.21. EC exhibited a value between 0.11 ± 0.01 to 0.17 ± 0.01 mS/m and varied significantly among the seasons (t = 10.40, p < 0.002). Moisture showed significant variation (t=12.64, p<0.001) among the seasons and ranged from 22.5±0.84 % to 31.4±3.52 %. Soil temperate was recorded 4.66±1.54 to 14.33±1.83 ^{0}C and exhibited significant variation (t=4.36, p<0.022) among the seasons during the study period. Organic nitrogen varied significantly (t=4.00, p<0.028) over the period and showed a range of 0.42 ± 0.08 to 1.26 ± 0.16 g/kg. Organic carbon significantly varied (t=15.72, p<0.001) with seasonal changes and ranged from 9.1±0.34 to 12.3±0.70 g/kg. The soil comprises 7.33% clay, 36.24% sand and 56.40% silt represented by silt loam class of soil texture Figure 4. According to Edwards, (2004) majority of the temperate earthworm species are found within the pH range 5.0 to 7.4 and *A. caliginosa* was reported at a pH range of 5.2 to 5.4 (Edwards & Lofty 1972). According to Nair & Bennour (1997) *A. caliginosa* can tolerate a wide range of temperature fluctuations and can be one of the reasons for its dominance in Benghazi soils (Libya). *A. caliginosa* is one of the most abundant earthworm species on agricultural lands in the temperate zone (Perez-Losada et al. 2009) and is found on all continents (except Antarctica) in agricultural and native ecosystems (Michaelsen 1903; Paoletti 1999; Baker et al. 2006; Hendrix et al. 2008; Blakemore 2009; Shekhovtsov et al. 2015). It is generally accepted that *A. caliginosa* is an European species that has been dispersed by means of human mediated transport to other parts of the world (Paoletti 1999) and in Russia, it is believed to displace native earthworms in some locations and to continue its eastward and northward expansion (Striganova & Porjadina 2005; Tiunov et al. 2006).

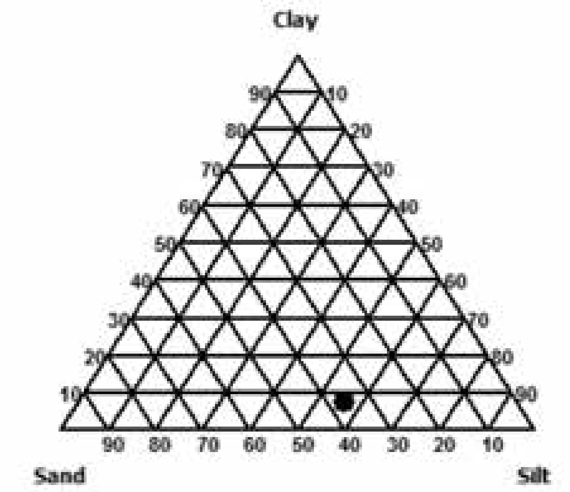

Figure 4. Ternary diagrams of soil texture.

Overall, the pattern of earthworm invasion closely resembles the ''jump dispersal'' model of Shigesada et al. (1995). There is a probability of colonization of distant localities which may be directly dependent on the availability of dispersal opportunities from the source and the time since initial colonization (MacIsaac et al. 2001).

CONCLUSION

A.c. caliginosa is an addition to the checklist of earthworms from Kashmir Valley, Jammu & Kashmir, India. It's biological characteristics and tolerance to varying environmental conditions helps them to encounter competitive challenges and make them successful to establish in new areas.

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SHORT COMMUNICATION

Avian congregation sites in the Gulf of Kachchh, Gujarat, India.

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Abstract: The present study deals with the congregation of avifauna at various locations in Gulf of Kachchh (GoK), Gujarat, India. The study was conducted between 2011 and 2014. A total of 14 sites were identified in Gulf of Kachchh which had regular and remarkable congregation of mono-species or multi-species of waterbirds. The observations were made through line transects and point count sampling methods. The largest congregation sites were Bhaidar and Pirotan Islands with more than 5,000 individuals of waterbirds. Khijadiya wetland was also recorded with a remarkable number of birds in the congregation, i.e., more than 4,000 individuals. The identified congregation sites were found to be distributed throughout the southern part of GoK. Such sites were intertidal areas, freshwater bodies, saltpans etc. The bird congregations comprised resident and migratory waterbirds and coastal birds.

Keywords: Bhaidar, congregation, Khijadiya, migratory, Pirotan, resident, sampling, waterbirds.

Many families of birds congregate either to breed or to feed during non-breeding period and sometimes, congregation protects them from natural predators as well. If degradation persists at the breeding colony for a long time, it may affect the population of those breeding birds and if similar site related threats perseveres at the non-breeding or wintering sites, the birds might have to look for other similar sites to sustain themselves (BirdLife International 2008). A majority of congregations are observed in families such as Pelecanidae, Ardeidae, Anatidae, Ciconiidae, Scolopacidae, and other shore-birds. Usually, congregation of birds comprise single or more than one species. And usually, waterbirds are congregational compared to terrestrial birds (Pandey & Teli 2005).

Gujarat is a maritime state in India having the longest coastline and rich in coastal biodiversity (Sengupta & Deshmukhe 2000). Out of the three gulfs in India, two gulfs, i.e., Gulf of Kachchh (GoK) and Gulf of Khambhat (GoKh) are in Gujarat State. GoK is one of the four major reefs of the country (Venkataraman et al. 2003;

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Parasharya & Padate 2014). Geographically, the GoK is endowed with islands, intertidal areas, offshore areas, and terrestrial habitats in shorelines that results in the existence of various habitats such as mangrove forests, coral reefs, Inter-tidal mudflats, reef vegetation, salt affected areas, and marine & terrestrial biodiversity (Sengupta & Deshmukhe 2000). Furthermore, from an avifaunal point of view, GoK is an ecologically significant place as two International flyways of migratory birds pass through GoK (MoEF 2005; Newton 2007; Kirby 2010; BirdLife International 2010) and some internationally known congregation sites have been identified as Important Bird Areas and potential Ramsar sites (Islam & Rahmani 2004). The large continental shelf of the southern part of the gulf harbors vast areas of mangrove and coral reefs that provide shelter to other benthos such as fishes, crabs and small invertebrates. Birds utilize these vast habitats as a wintering ground and attract enormous migratory birds in the state. Several studies have been carried out to make an inventory of avifauna of GoK such as Ali (1945); Ali (1962); Parasharya (1984); Naik et al. (1991); Bhuva & Soni (1998); Urfi (2002); Singh (2001); Singh et al. (2004); Panday & Teli (2005); Jani & Mishra (2007). Some of the observations with scattered information on congregation are also available, however, detailed information of the congregation sites is not available. The present study deals with the congregation sites of avifauna in GoK, Gujarat, India.

Study Area

The present study is confined to the GoK, the western-most part of the country that encompasses an area of around 7,350km^2 (ICMAM 2002). A cluster of nearly 42 islands exist in the southern part of the gulf. GoK is a shallow water body and the average depth is 30m ranging from 20m at the head to 60m at the mouth. In the southern part of the gulf, most of the intertidal areas have been notified as marine national park and sanctuary, which is also one of the IBA sites (Islam & Rahmani 2004). An area of 162.89km^{2}and 457.92km^2 have been declared as marine national park and marine sanctuary, respectively (Singh 1994; Jani & Mishra 2007). The study was conducted on islands, intertidal and coastal areas of the GoK. The area under the observation was mainly 500m landwards side and 200m seaward side from HTL. Along with this, 14 islands were also considered for making observations. Administratively, the southern part of GoK comprise seven talukas viz., Okhamandal, Kalyanpur, Khambhalia, Lalpur, Jamnagar, Jodiya, and Maliya. Likewise, the northern part of the GoK comprises six talukas, viz.: Bhachau, Gandhidham, Anjar, Mundra, Mandvi, and Abdasa.

Methods

The observations for congregation sites in the GoK were made through whole area search with opportunistic observation as well as through point sample observations from October 2011 to December 2014. Coastal areas of a total of 13 talukas and 14 islands of the GoK were surveyed thoroughly to search and identify bird congregations based on the number of waterbirds (as per Delaney & Scott 2006). In addition to the whole area search method, a total of 34 locations, mainly wetlands near the coastline, were also selected for point sampling observations for occurrence of bird congregations. The observations were made with a pair of binoculars (10X50), spotting scopes (16-48 X/ 20-60 X), GPS instrument and predesigned datasheet.

In order to recognise waterbird congregation sites worldwide, IBA has identified four main criteria (Islam & Rahmani 2004). Any large geographical area that justifies at least one of the four criteria can be considered as a congregation site. It is worth mentioning that islands and coastal areas of the GoK are too small to apply these criteria, however, to identify relatively important areas of the GoK from a congregation point of view, A4 (i) criterion (i.e., site known or thought to hold, on a regular basis, >1% of a biogeographic population of a congregational water-bird species) has been used as a reference. The count of water-birds throughout the GoK is known to be about 66,855 birds by Singh et al. (2004). Therefore, in the present study, the site has an occurrence of more than 600 water-birds (i.e., about 1% of 66,855 water-birds) those mentioned by Delaney & Scott (2006) were considered as congregation site of the Gulf of Kachchh. Each site, identified based on the criterion, might not fulfil the criteria for global recognition, but these can be considered as important congregation sites in GoK.

Results and Discussion

From the stretch of the GoK a total of 250 species of birds were recorded during the study. Of the total recorded species, a total of 145 (58%) were primarily terrestrial and 105 (42%) were primarily aquatic. Though primarily aquatic bird species were less than primarily terrestrial, the abundance of aquatic species was always higher. Moreover, many aquatic species have a tendency to congregate at a site for various purposes such as foraging, sheltering, roosting and protection.

Many places in GoK were observed with a congregation of water-birds (Images 1–3), however, a total of 14 locations were identified which had regular,

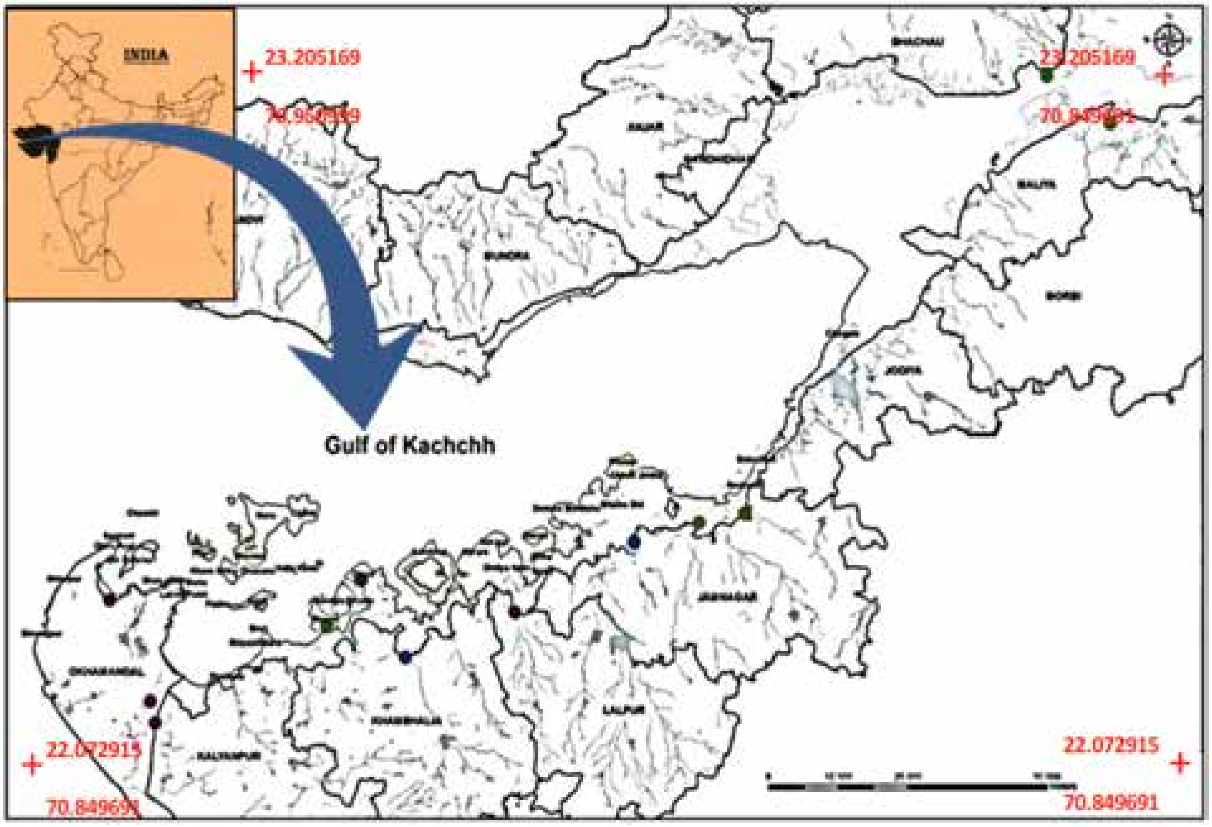

Figure 1. Study area - Gulf of Kachchh.

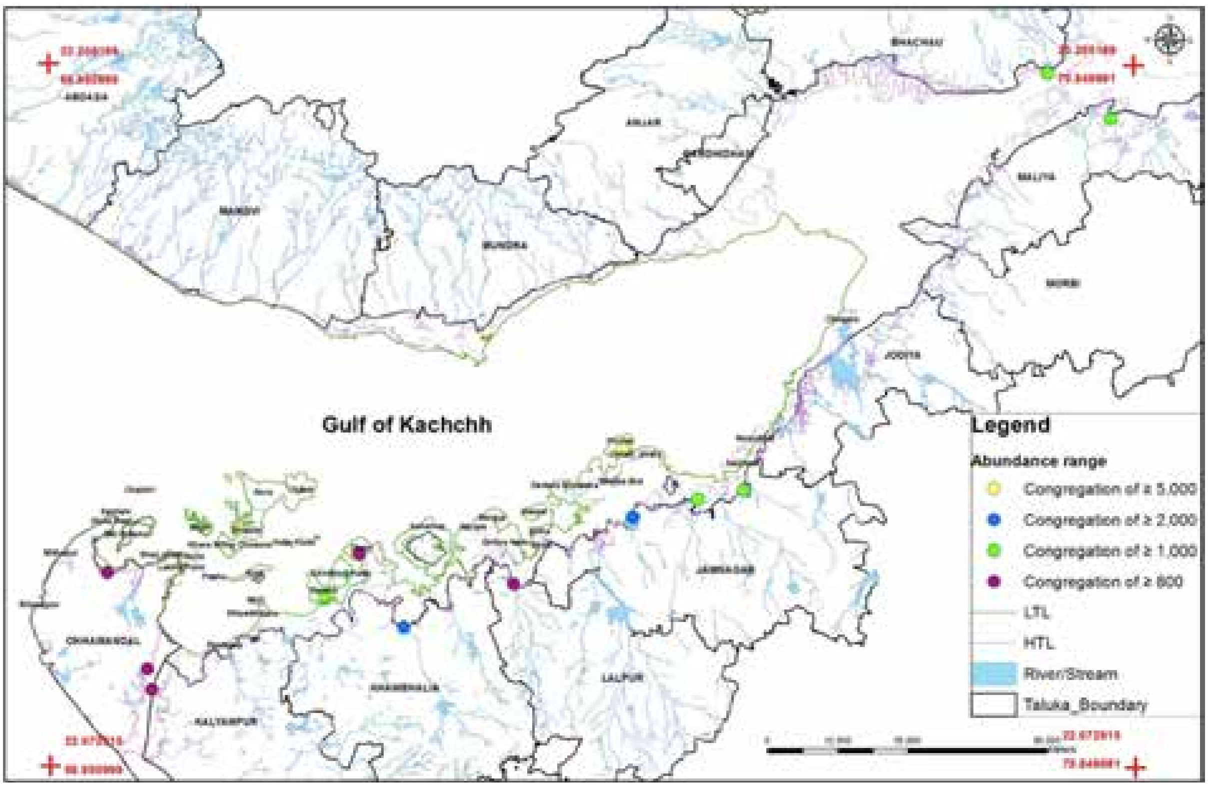

Figure 2. Congregation sites of avifauna in the Gulf of Kachchh.

Table 1. Congregation sites recorded from the Gulf of Kachchh (GoK) (2011–14).

Site no.	Site name	Geographical co-ordinates	Habitat types	No. of water-birds	No. of species	Season
1	Bhaidar	22.458^{0}N & 69.292^{0}E	Intertidal area with mudflat	>5000	28	Winter
2	Pirotan	22.597^{0}N & 69.962^{0}E	Intertidal area with mangrove cover and sand patches mangrove cover	>5000	13	Winter
3	Khijadiya	22.534^{0}N 70.171^{0}E	Fresh and saline water wetland	>4000	27	Summer
		22.520^{0}N & 70.133^{0}E	Fresh and saline water wetland	>1000	19	Winter
4	Khara-Beraja	22.472^{0}N & 69.978^{0}E	Freshwater wetland	>2000	16	Winter
		22.483^{0}N & 69.967^{0}E	Freshwater wetland	>2000	17	Summer
5	Salaya	22.303^{0}N & 69.591^{0}E	Wetland with saline mudflat	>2000	35	Winter
6	Panero	22.352^{0}N & 69.458^{0}E	Intertidal area with sand and mudflat	>1000	20	Winter
7	Tupani	22.233^{0}N & 69.238^{0}E	Saline area	>1000	21	Monsoon
		22.238^{0}N & 69.153^{0}E	Saline area	>800	17	Winter
8	Sikarpur	23.211^{0}N & 70.710^{0}E	Saltpan	>1000	16	Monsoon
9	Kajarda	23.114^{0}N & 70.833^{0}E	Creek	>1000	25	Winter
10	Nava nagna	22.532^{0}N & 70.106^{0}E	Saltpan	>1000	16	Winter
11	Charakla	22.199^{0}N & 69.137^{0}E	Saltpan	>800	15	Summer
12	Padli	22.383^{0}N & 69.035^{0}E	Freshwater wetland	>800	36	Winter
13	Parodiya	22.341^{0}N & 69.633^{0}E	Thorny & Scrub	>800	34	Winter
14	Dhani	22.433^{0}N & 69.508^{0}E	Intertidal area with thorny & scrub	>800	10	Winter

remarkably during winter, congregation of either mono-species or multi-species (Figure 2). Among selected sites for the observations, Bhaidar Island was identified to be the largest congregation site of water-birds. During each observation, especially in winters a minimum of 5,000 individuals of various species were recorded. Sometimes bird counts exceeded even 10,000 individuals. About 28 species were recorded to be congregating in Bhaidar island. Major congregating species were Little Ringed Plover *Charadrius dubius*, Kentish Plover *Charadrius alexandrinus*, Eurasian Curlew *Numenius arquata orientalis*. The extent of Bhaidar Islands is about 51.57km^2 with sand-dune, intertidal mudflats along with mangroves and shrub vegetation (Singh et al. 2004). Such habitat features attract enormously waders for feeding. The second largest congregation site was recognised to be Pirotan Island, with often more than 5,000 individuals. Similar to Bhaidar, water-birds count on Pirotan sometimes exceeded 7,000 birds. Interestingly, Crab Plover *Dromas ardeola* was a mono-species congregating bird on the Pirotan island and recorded throughout the years whereas the other 13 species of birds were found congregating on Pirotan island. The Pirotan island is characterized by exposed sand-patches during low tides and it is partially covered with mudflats and mangrove vegetation (Singh et al. 2004; Ramkumaran et al. 2017). Major congregating species at Pirotan Island were the Black-tailed Godwit *Limosa limosa*, Bar-tailed Godwit *Limosa lapponica*, Indian Skimmer *Rynchops albicollis*, Grey Plover *Pluvialis squatarola*, European Golden Plover *Pluvialis apricaria*, and Little stints *Calidris minuta*. Observations were made mostly at 22.597^{0}N & 69.962^{0}E , however, locations of the congregation varied due to various factors such as tidal amplitude, tide timing, and activity of fishermen. Another important congregation site was Khijadiya wetland that makes the site as one of the congregation sites of GoK. Though the number of birds in the entire sanctuary would be in the thousands, some of the places in the Khijadiya wetland and its surroundings had congregations of birds. It is important to mention that one of the congregation place in the Khijadiya was the congregation of migratory cranes (i.e., Common Crane *Grus grus* and Demoiselle Crane *Grus virgo*) which roost in part on wetland covered with shallow water. A congregation of about 27 species were recorded during

Image 1. Congregation of small waders at Bhaidar island during low-tide.

Image 2. Mono-species congregation (Crab Plover) at Pirotan island.

Image 3. Congregation of waders (multi-species) at Pirotan island during low-tide.

the study period. Khijadiya remains always an important area for birds as it has been declared an IBA site (Pandey & Teli 2005; Islam & Rahmani 2004). Congregations were also recorded in a saline area of Tupani Village of Okhamandal Taluka at 22.233^{0}N & 69.238^{0}E and a freshwater wetland of Khara-Beraja Village of Jamnagar Taluka during the study. So far, the sites were not listed as avian congregation sites in any literature. Apart from mentioned sites, there were many other sites recorded as avian congregation sites during the study (Table 1). Of the recorded sites, 11 sites were intertidal area, saline area, saltpans and creeks, whereas the other three sites were freshwater wetland habitats. The congregation was recorded mainly during the winter and monsoon seasons, however, a congregation was also recorded in summer at Charkala and Khijadiya. The likely reason for congregation in summer is water availability. It is interesting to note that no congregation site was recorded in northern GoK (Figure 1), as the area is devoid of large intertidal area as well as saline or freshwater wetlands. Occurrence of migratory species is more towards the southern coast of the GoK compared to the northern coast due to resource availability (Singh et al. 2004). The extensive mudflat areas (intertidal and high-tidal mudflats), channels, shoals, islands, sand bars, coral reefs and mangroves exist mainly in the southern part Saltpans are potential habitats for waders and storks, herons and egrets present at the innermost parts of the Gulf, i.e., eastward of Jamnagar which are mainly occupied with saltpans along the coast and mudflats (ICMAM 2002). In addition, the southern part of the GoK comprises islands that provide undisturbed habitats for roosting at night. Sparse mangrove, intertidal mudflats, the coast dominated by sand and silt with narrow beaches at the northern side of the GoK (ICMAM 2002), attracts a number of resident as well as migratory coastal birds, however, this area is not suitable for regular congregation of birds.

Conclusion

A total of 14 congregation sites were recorded from the GoK, of which the largest site was Bhaidar. Whereas Pirotan Island and Khijadiya wetland were also considerably large sites with a remarkable number of birds in congregation, however, GoK may have more than 14 congregation sites. The recorded congregation sites were found to be distributed throughout the southern part of GoK. The congregation sites are prone to damage by some of the anthropogenic activities such as direct effect of fishing activities and indirect effects of pollutions and alteration of habitats. Hence, the sites should receive serious attention for the conservations because, if the site get damaged, and population survival would be affected.

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SHORT COMMUNICATION

Checklist of brachyuran mangrove crabs of Kerala, India

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Abstract: Checklist of brachyuran mangrove crabs from Kerala, western coast of India is presented in this paper with re-validation of nomenclature since many of the crab species have been renamed so far, and no reports have been published from mangroves of Kerala. A total of 18 true mangrove crabs were identified from different mangroves associated with estuaries along the western coastline of Kerala State, of which four crab genera were renamed and revalidated and all species were photo-documented during the present study. The paper enlists the taxonomic account of the true mangrove crabs known so far from Kerala mangrove ecosystems.

Keywords: Brachyura, checklist, Kerala, mangrove crab, Crutsacea, Portunidae, Grapsidae, Sesarmidae, Ocypodidae.

Brachyurans are the most promising and prominent group of crabs, because of their great diversity; comprising of about 6,793 species, 1,721 genera, and 93 families recorded globally (Ng et al. 2008). Brachyuran crabs perform a significant role in the mangrove ecosystems and are commercially valuable with high culture and fattening potential (Tan & Ng 1994). Mangrove ecosystems warrant more attention as it is diminishing day by day, especially along Kerala coastline and its importance protecting the environment from natural catastrophes are increasing. Mangroves are fragile ecosystem having highly variable conditions of life style, which make them profusely rich in biodiversity (Kathiresan & Qasim 2005). The ecosystem value of mangroves overwhelms any other ecosystem as it gives very many services, including biodiversity richness. Distribution studies of brachyuran crabs, especially the mangrove crab in Indian mangroves are scanty (Joel et al. 1985) and the available literature discusses the distribution of both marine and estuarine/mangrove crabs together.

Literature regarding crabs of mangrove ecosystems of Kerala was comparatively meager apart from that of few individual report and citations of each crab species. Kathirvel (2008) reported 990 species of marine brachyuran crabs belonging to 281 genera and 36 families from Indian waters. Thirty-six brachyuran crab species were identified from Pichavaram mangroves by Soundarapandian et al. (2008). A study reveals that 33 mangrove crab species belonging to the family Grapsidae and Ocypodidae were available from the state of Tamil Nadu (Wilson & Ravichandran 2013). A comprehensive approach to document the diversity and abundance of true mangrove crabs were lacking especially from Kerala, which was considered to be one of the crab-rich states (Rajesh et al. 2017). The first publication in this respect was by Pillai (1951), who provided an account of the brachyuran crabs of Travancore. In a report on

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mangroves and their faunal associates, Radhakrishnan et al. (2006) provided a list of 25 species of crustaceans, including 20 species of brachyuran crabs associated with marine, estuarine and mangroves of Kerala. Devi et al. (2015) recorded 24 species of crabs belonging to 16 genera and eight families from the Cochin backwaters of Kerala. A preliminary study on true mangrove crabs reported 14 crabs from various mangrove habitats of Kerala (Apreshgi 2014) and Apreshgi & Abraham (2019) observed 12 species from Puthuvype mangrove belt at Ernakulam, Kerala. Recently Ng & Devi (2020) reported a new tree spider crab, *Leptarma biju* from mangrove area of Chithari River, Kasargode District, Kerala. The brachyuran diversity of Kerala coastline mangrove ecosystem has not been documented and the present study presents the check list of the brachyuran crabs and photo-documents the diversity along with revalidation of crab nomenclature.

Materials and Methods

A survey of crabs of different estuarine mangrove ecosystems along the western coastline of Kerala was carried out from June 2016 to May 2017. Crabs were collected live by handpicking, opening of burrows, bait trap and normal traditional trap kept overnight. Collected specimens were preserved in alcohol (70%) after anaesthetization and ice killing. Crab specimens were collected from a total of 14 mangrove locations from nine districts of Kerala State (Fig. 1). The collected specimens were washed thoroughly in situ and photo-documented without much disturbance to obtain natural colour and morphology. Specimens were brought to the laboratory for further identification and after specimen confirmation, specimens of three species (*Austruca annulipes*, *Austruca perplexa*, and *Parasesarma bengalense*) were submitted in the repositories of Department of Aquatic Biology and Fisheries, University of Kerala, Thiruvananthapuram, (Voucher numbers DABFUK-AR-BR-52,53; DABFUK-AR-BR-54,55; DABFUK/AR-BR-72, 73 respectively). Identification and classification were done using standard keys and publications (Pillai 1951; Sakai 1976; Sethuramalingam & Khan 1991; Roy & Das 2000; Roy 2008). Ng et al. (2008) was followed for classification and validity of the names of the brachyuran crabs were cross-checked with information from World Register of Marine Species (WoRMS 2020; http://www.marinespecies.org) and conservation status of each species was verified from the IUCN Red List of threatened species (IUCN 2017).

Results and Discussion

A total of 18 species of true mangrove crabs under four families (Portunidae, Grapsidae, Sesarmidae, and Ocypodidae) and 11 genera were identified and documented in the present study. Highest number species was recorded from the family Sesarmidae (seven species) followed by Portunidae and Ocypodidae with four species each and Grapsidae with three species (Table 1 & Images 1–18). *Scylla serrata*, *Scylla olivacea*, and *Thalamita crenata* were the economically valuable crab species. Among different species, *Parasesarma bengalense* was reported for the first time from the western coast of India and *Clistocoeloma lanatum* was reported for the first time from Kerala mangroves. *Pseudosesarma glabrum* was one of the rare species and was recently reported from Cochin in southwestern India (Ng et al. 2017). *Parasesarma plicatum* was the common crab species encountered throughout west coastline mangrove ecosystems of Kerala.

Pillai (1951) and Chhapgar (1957) reported the occurrence of crabs from mangrove habitats around Travancore and Bombay respectively without much of its taxonomic identity. After a long gap, Krishnamurthy & Jeyaseelan (1981) reported the presence of 20 species of crabs from Pichavaram mangroves, which includes true mangrove as well as estuarine crabs. There are several taxonomic works on the brachyuran crabs of estuarine and mangrove ecosystems of India (Chakraborty et al. 1986; Mandal & Nandi 1989; Chakraborty & Chaudhury 1992; Roy & Das 2000; Radhakrishnan et al. 2006). A total of 55 species of brachyuran crabs represented under 31 genera have been reported earlier from different mangrove habitats of India (Roy & Das 2000). But none of the above reports exclusively documented mangrove crabs, in fact they included estuarine, marine forms in addition to mangrove crabs. Eighteen species of brachyuran crabs under nine genera and four families were identified exclusively from Sunderban mangrove ecosystems (Chakraborty & Chaudhury 1992). Mangrove fauna of Andaman & Nicobar Islands (Das & Roy 1989) enlisted 31 species of crabs from Andaman mangals and briefly dealt with zonation and annual breeding pattern of some of the crabs.

Even though nomenclature of many crabs has been changed by different taxonomists, genus name of four crabs has been changed or revalidated recently; *Perisesarma bengalense* has been changed to *Parasesrma* (WoRMS 2020), genus *Uca* has been renamed as *Austruca* for *Uca annulipes* and *Uca perplexa* and for *Uca vocans* renamed as *Gelasimus vocans* (WoRMS 2020). Many taxa belonging to the

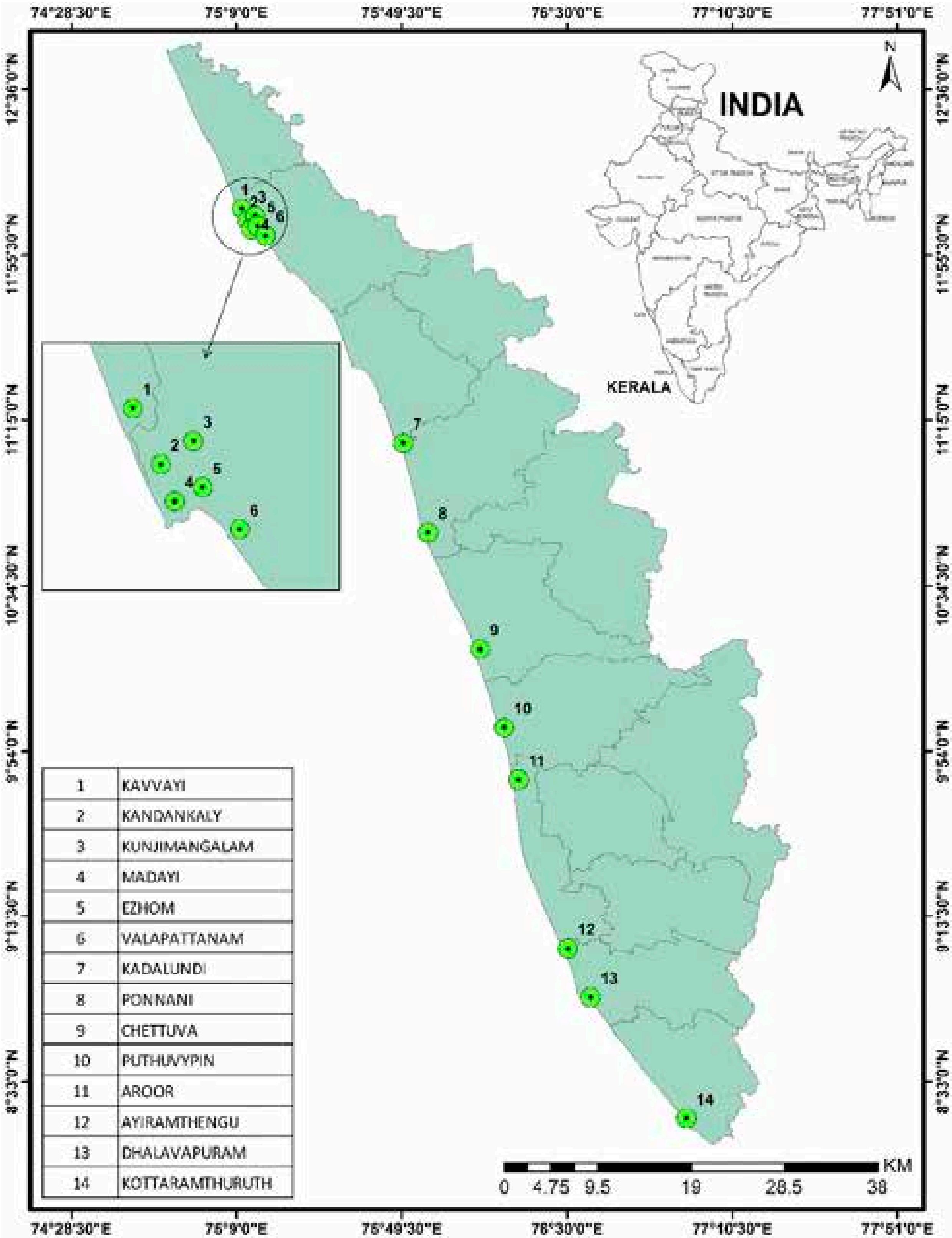

Figure 1. The sampling locations of mangrove crabs from Kerala.

Table 1. Checklist of mangrove brachyuran crabs from Kerala.

Family	Scientific name/Revalidated name	Original name/Synonym	Common name	Image no.
Portunidae	*Scylla olivacea* (Herbst, 1796)	*Cancer olivacea* Herbst, 1796	Orange Mud Crab	Image 1
	Scylla serrata (Forskål, 1775)	*Cancer serrata* Forskål, 1775	Green Mud Crab	Image 2
	Scylla tranquebarica (Fabricius, 1798)	*Cancer tranquearica* Fabricius, 1798	Mangrove Mud Crab	Image 3
	Thalamita crenata Ruppell, 1830	*Thalamita crenata* Ruppell, 1830	Crenate Swimming Crab	Image 4
Grapsidae	*Metopograpsus latifrons* (White, 1847)	*Grapsus latifrons* White, 1847	Purple-Claw Mudflat Crab	Image 5
	Metopograpsus messor (Forskal, 1775)	*Cancer messor* Forskal, 1775	Messor's Shore-Crab	Image 6
	Metopograpsus thukuhar (Owen, 1839)	*Grapsus thukuhar* Owen, 1839	Thukuhar Shore-Crab	Image 7
Sesarmidae	*Clistocoeloma lanatum* (Alcock, 1900)	*Sesarma lanatum* Alcock, 1900	Far Bodied Mudflat Crab	Image 8
	Neosarmatium malabaricum (Henderson, 1893)	*Sarmatium malabaricum* Henderson 1893	Violet Mudflat Crab	Image 9
	Parasesarma bengalense (Davie, 2003)*	*Perisesarma bangalense* Davie, 2003	Bengal Mangrove Crab	Image 10
	Parasesarma pictum (De Haan, 1835)	*Grapsus (Pachysoma) pictum* DeHaan, 1835	Mangrove Mudflat Crab	Image 11
	Parasesarma plicatum (Latreille, 1803)	*Ocypode plicatum* Latreille, 1803	Orange-claw Marsh Crab	Image 12
	Perisesarma dussumieri (Edwards, 1853)	*Sesarna dussumieri,* Edwards, 1853	Yellow-claw Mudflat Crab	Image 13
	Pseudosesarma glabrum Ng, 2017	*Pseudosesarma glabrum,* Ng, 2017	Glabrous Mangrove Crab	Image 14
Ocypodidae	*Austruca annulipes* (Edwards, 1837)*	*Gelasimus annulipes* Edwards, 1837	Ring-legged Fiddler Crab	Image 15
	Austruca perplexa (Edwards, 1852)*	*Gelasimus perplexa* H. Edwards, 1837	Perplexing Fiddler Crab	Image 16
	Gelasimus vocans (Linnaeus, 1758)*	*Cancer vocans* Linnaeus, 1758	Calling Fiddler Crab	Image 17
	Macrophthalmus (Mareotis) depressus (Ruppell, 1830)	*Macrophthalmus depressus,* Ruppell, 1830	Cream-claw Mud Crab	Image 18

genus *Perisesarma* have been changed to *Parasesarma* (Shahdadi & Schubart 2018), however, *Perisesarma dussumieri*, without any name changes is the type species of the genus *Perisesarma* owing to its original characters of the genus (Shahdadi & Schubart 2018). All the crabs documented in the present study were listed as 'Least Concern' status of IUCN Red list of the threatened species (IUCN 2017), which may be due to lack of baseline data about abundance and distribution the true mangrove crabs.

Conclusion

The present investigation revealed 18 true brachyuran mangrove crab species along estuarine mangroves of western coast of Kerala. Family Sesarmidae constitute the major diversity (seven species) followed by Portunidae (four species) and Ocypodidae (four species), and least in Grapsidae (three species) of mangrove crabs. Among the 18 brachyuran crabs, four crabs have been revalidated by change in genus or species name and provided in a checklist along with photo-documention of true mangrove crabs of Kerala estuarine systems.

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Image 1. *Scylla olivacea*

Image 2. *Scylla serrata*

Image 3. *Scylla tranquebarica*

Image 4. *Thalamita crenata*

Image 5. *Metopograpsus latifrons*

Image 6. *Metopograpsus messor*

Image 7. *Metopograpsus thukuhar*

Image 8. *Clistocoeloma lanatum*

Image 9. *Neosarmatium malabaricum*

Image 10. *Parasesarma bengalense*

Image 11. *Parasesarma pictum*

Image 12. *Parasesarma plicatum*

Image 13. *Perisesarma dussumieri*

Image 14. *Pseudosesarma glabrum*

Image 15. *Austruca annulipes*

Image 16. *Austruca perplexa*

Image 17. *Gelasimus vocans*

Image 18. *Macrophthalmus (Mareotis) depressus*

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A new country record of Smooth-backed Gliding Gecko *Gekko lionotum* (Annandale, 1905) (Squamata: Gekkonidae) from Bangladesh

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Gliding geckos are cryptic species distributed in the tropical forests of southeastern Asia, including southern China (Pawar & Biswas 2001). Among the 60 species of *Gekko*, four gliding geckos are placed under the subgenus *Ptychozoon* (Wood et al. 2020), restricted to India, Indonesia, Singapore, the Philippines, and the mainland southeastern Asian countries (Uetz et al. 2020). Although species of this subgenus have been recorded from northeastern India (Pawar & Biswas 2001) and Myanmar (Grismer et al. 2018), they have not been reported from Bangladesh. We present here a new country record of *Gekko lionotum* from Bangladesh (Figure 1).

Observed specimen: Padma Bridge Museum #2246, one adult individual, 4.iii.2020, Sangu Wildlife Sanctuary, Bandarban, Bangladesh, 22.689N & 92.166E, collected by Md. Rashedul Kabir Bhuiyan and his team.

We found a freshly dead specimen, later donated to Padma Bridge Museum, Dogachi, Sreenagar, Munshiganj. In the museum this specimen was identified as a Smooth-backed Gliding Gecko *Gekko lionotum* Annandale, 1905 based on the body features and other morphometric measurements. Considered a rare specimen and a valuable resource for future studies, the gecko was preserved in alcohol as a wet specimen. According to The Reptile Database (www.reptile-database.org/), this species is distributed in India (Mizoram), Myanmar (Rakhine and Bago), Laos, Malaysia, Cambodia, Vietnam, and Thailand.

We combined characters to identify the species after Brown et al. (1997), Brown (1999), and Grismer et al. (2018). The key characters were: snout-vent length 94.8mm; the absence of imbricated scales to support parachute, dorsal tubercles and postorbital stripe; the presence of predigital notch in preantebrachial expansion; 14–15 lamellae in 4th toe; five caudal lobes fused to form terminal lobe of the tail and denticulated laterally with expansion; absence of caudal tubercles in tail terminus; angling is slight between caudal lobes. We compared these characteristics with other species of the subgenus *Ptychozoon* (Table 1). The characteristics clearly show the present specimen is *G. lionotum*.

Morphometric data and coloration: We measured morphometric characteristics using regular slide calipers

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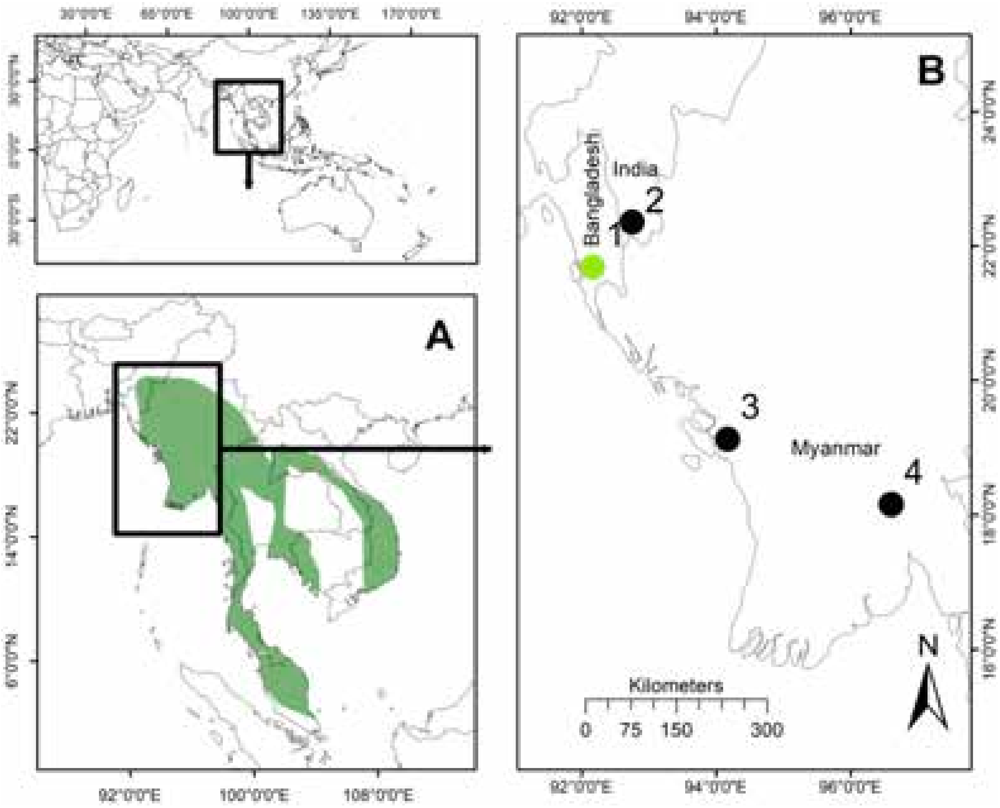

Figure 1. A—Global distribution of *Gecko lionotum* according to IUCN (2018) | B—Present record (1) of *Gecko lionotum* from Sangu Wildlife Sanctuary, Bandarban Bangladesh, along with nearest previous record from (2) Ngengpui Wildlife Sanctuary, Mizoram, India (3) Chin Minbyin Village, Rakhine State, Myanmar (4) Chaung Gwa Village, Bago Division, Myanmar

Table 1. Comparison of species under the subgenus *Ptychozoon* (after Brown et al. 1997, Brown 1999, and Grismer et al. 2018).

Characters	*P. lionotum*	*P. horsfieldii*	*P. kuhli*	*P. trinotaterra*
SVL (mm)	94.8	73.9	107.8	71.3
Dorsal tubercle	absent	absent	2-6 convex-shaped	0-1 flat-shaped
Parachute support scales	absent	present	present	present
Predigital notch	present	absent	absent	absent
4^{th} toe lamellae	14–15	11–13	12–16	12–14
Postorbital stripe	absent	present	absent	present
No. of caudal lobes fused	5	2/3	1–3	1/2

with an accuracy of 0.1mm (Table 2). We compared our morphometric data with the described specimen of Pawar & Biswas (2001). Our comparison matches the description given by Grismer et al. (2018) and the nearest specimen from Mizoram, India (Pawar & Biswas 2001). We also observed the color pattern and body shape of our specimen. The upper parts of the body are gray to dark gray and the underparts are yellowish with black spots (Image 1 & 2). The anterior ventral part is light grayish-yellow and the posterior is dark grayish-yellow. Ten transverse, distinct, wavy, blackish-gray bands present in the dorsal side (one in the head, four in inter-limb area, five in the tail). The head is triangular, with two dark gray-brown bands running from eye to ear opening and a deep gray-brown band present at the central region. The neck is narrow, small, and brownish color; thighs and arms are similar in color. The tail is slightly shorter than the snout-vent length, dark black at the tip, and both dorsal and ventral sides are covered with a dark gray-black band. The skin of limbs, toes, and fingers is extended and lamellae are yellowish-white in color. Coloration of the body can perfectly match with

Image 1. Dorsal view of *Gekko lionotum*

Image 2. Ventral view of *Gekko lionotum*

Table 2. Comparative morphometric data of the present specimen and literature records of *Gekko lionotum* (after Pawar & Biswas 2001; measurement in mm).

Parameters	Present Specimen (PBM Reg. #2246)	*Ptychozoon lionotum*
A. Morphometric characters		
Total Body Length (TBL)	184.6	168.7
Snout Vent Length (SVL)	94.8	
Body Width in the widest part (BW)	14.5	
Neck Width (NW)	11	11.9
Head Length (HL)	19.5	16.8
Head Width (HW)	20.4	16.8
Tail Length (TL)	89.8	93
Tail Width (TW)	7.5	7.6
Eye Diameter (ED)	5.2	4.8
Ear Opening (EO)	1.5	2.3
Distance between Eyes (DE)	9.1	10.3
Distance between Eye and Ear (DEE)	7.5	7.7
Distance between Eye and Nostril (DEN)	6.7	8.2
Distance between Nostrils (DN)	3.7	3.7
Total Forelimb Length (TFL)	32.5	27.8
Forearm Length (FL)	22.1	18.7
Total Hindlimb Length (THL)	42.3	39.6
Hindlimb (Femur) Length (HFL)	16.5	13.6
Hindlimb (Tibio-fibula) Length (HTL)	16.0	12.7
Inter-limb Distance (ILD)	47.6	47
Forelimb Digit (FD)	6.9+9.5+12.5+ 13.3+11.4	
Hindlimb Digit (HD)	9.5+13.5+14.4+ 14.8+11.3	
Mouth opening (MO)	17.2	
B. Scales and Digits		
Supralabials (Left/Right)	11/11	10/11
Infralabials (Left/Right)	9/9	9/9
Mental	01	
Post-mental	02	
Rostral	01	
Postrostral/Supranasal	02	
Femoral pores	02	
Forelimb lamellae	11+12+12 +15+13	11/10+11/13+12/ 16+15/15+14/14
Hindlimb lamellae	11+12+14 +14+12	11/11+12/12+16/ 15+14/14+14/14

woods and trees for camouflage.

Parachute length and width: Measurements are: Head to neck (length-width) 14.3-6.2; abdomen (length-width) 47.4-11; forelimb anterior (length-width) 17.5-5.1; forelimb posterior (length-width) 17-3.9; hindlimb anterior (length-width) 10.9-4.7; hindlimb posterior (length-width) 22.7-3.8; 21 lobes of parachute in tail, first segment (length-width) 5-3.4 and last segment (length-width) 14.6-3.7.

Located in the southeast of the country, Bandarban District is a global biodiversity hotspot of the Indo-Malayan region (Nishat et al. 2002), although the forest vegetation has been degraded by settlers, local inhabitants and others (IRG 2012). We believe that more new species can be found if proper effort is given, however, the richest biodiversity zone also attracts organized poachers to traffic wildlife resources, timber and illegal drugs. The discovery of the lizard species indicates the probability of getting more novel species in this area. We suggest more research work to expand our knowledge and strictly manage the diversity of the zone with the leadership of the Bangladesh Forest Department.

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Amblyomma gervaisi (Ixodida: Ixodidae: *Amblyomma*) infestation in a Rat Snake from northwestern Himalayan region: a case study

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Climate change, especially climate warming not only governs the density variation of arthropods, but also population preponderance of their hosts, changes in periods of activity and variations in geographical distribution (Moudgil & Singla 2013). Ticks (Acari: Ixodidae) act as vectors for the transmission of a wide range of pathogens including bacteria, virus, rickettsia and protozoa (de la Fuente et al. 2008). Along with vertebrates, ticks can also infest reptiles and transmit ehrlichiosis, anaplasmosis and rickettsiosis. The presence of novel spotted fever group rickettsiae, *Anaplasma* and *Ehrlichia* species prevalent in wild snakes has been demonstrated by molecular evidences (Kho et al. 2015). The ticks infesting snakes are also responsible for transmission of zoonotic pathogens *Coxiella burnetti* and *Rickettsia honei* to humans in India (Pandit et al. 2011). In the past, *Amblyomma* (*Aponomma*) species have been reported from pythons, cobra and rat snakes in southern India (Soundararajan et al. 2013; Catherine et al. 2017), Western Ghats (Pandit et al. 2011), and eastern parts of India (Patra et al. 2017). Ticks are also responsible for transmitting various pathogens, which result in pneumonia in snakes (Marcus 1971). Also, they are responsible for blood borne infections such as *Aeromonas* septicaemia, which had led to the deaths of snakes (Rosenthal 1997). The changes in climatic conditions especially climate warming have rendered many vectors including ticks to distribute in newer and naïve regions, i.e., species of tropical and subtropical regions become more vulnerable to expand their niche to temperate regions (Moudgil & Singla 2013). In case of arthropod vectors, along with abiotic environmental conditions, availability of hosts also plays an important role for preponderance. The present study thus reports the presence of *Amblyomma gervaisi* in the snakes of northwestern Himalayan region.

A Rat Snake *Ptyas mucosa* stuck into a basin pipe strainer was brought to the Teaching Veterinary Clinical Complex, Palampur (Himachal Pradesh), to get it released. On thorough examination, the snake was found infested with ticks. The ticks were collected carefully without damaging the body parts and were introduced to further processing for identification. The ticks were processed as per Jain & Jain (2011) and

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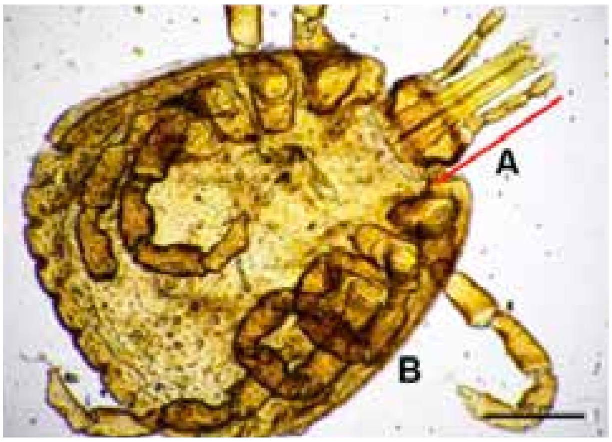

Image 1. Photomicrograph of male *Amblyomma gervaisi*, where A represents Gnathosoma and B represents rest of the body Idiosoma. © Moudgil, A.D.

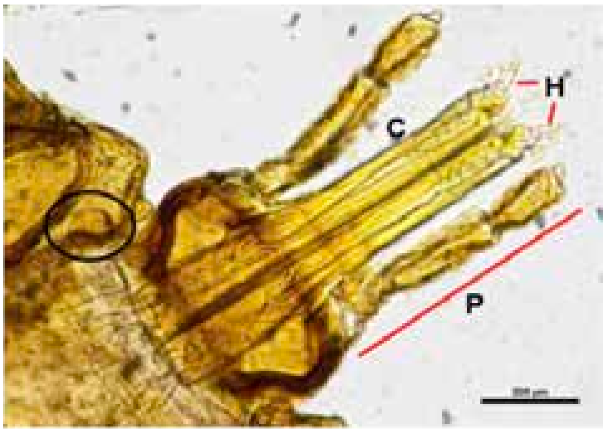

Image 2. Photomicrograph of basis capituli of *Amblyomma gervaisi*, along with comma shaped cervical grooves (encircled), pedipalps (P), chelicerae (C) and median hypostome (H). © Moudgil, A.D.

Image 3. Photomicrograph highlighting the oval spiracle (O) of *A. gervaisi*. © Moudgil, A.D.

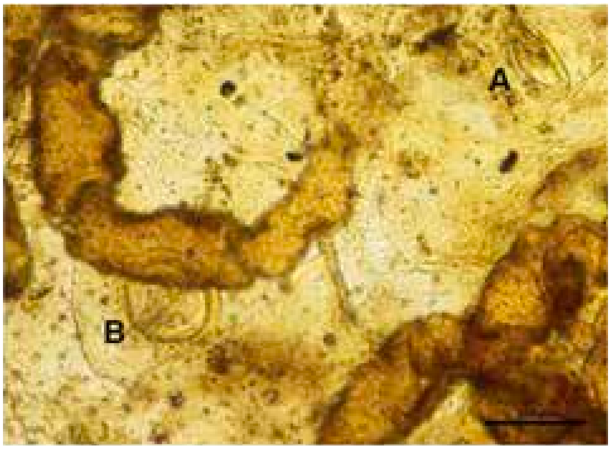

Image 4. Photomicrograph of genital orifice (A) and anus (B) of *A. gervaisi*. © Moudgil, A.D.

identified following the key of Georgi et al. (1990) and Barnard & Durden (2000). These were cleared in 10% potassium hydroxide, dehydrated in ascending grades of alcohol, again cleared in cedar wood oil, placed in xylene for one minute and then finally mounted in Canada balsam. The ticks were identified up to the species level based on the characters of whole male tick, basis capitulum, pedipalps, presence or absence of festoons, anal groove, and comma shaped cervical grooves.

Earlier, *Amblyomma gervaisi* was believed not to hold any zoonotic significance and Georgi et al. (1990) had suspected man, felids, canids, and domestic animals as its probable targets (Catherine et al. 2017). The tick was found responsible for transmission of zoonotic pathogens *Coxiella burnetti* and *Rickettsia honei* to humans in India (Pandit et al. 2011). The actual appearance of the male tick is like a tear drop (Image 1), as it is dorso-ventrally flattened and posterior extremity is wider than the anterior. Generally, the morphology of the ixodid ticks provides them protection from external odds of the environment (Ghosh & Misra 2012). The capitulum or basis capituli of the tick retrieved was dorso-ventrally rounded flask-shaped (Image 2), consisted of intact mouth parts bearing mandible, hypostome and a pair of pedipalps. The observations were in concordance with the findings of Ghosh & Misra (2012); whereas the shapes of the basis capituli of other *Amblyomma* species vary from rectangular to trapezoid (Barros-Battesti et al. 2005a,b). The mandible was the extension of the dorsal capitulum and hypostome lying ventrally juxta-positioned to the mandibular sheath. The sensory palps originated from the base of the hypostome consisting of four articles, where the first two articles were fused (Image 2). The third article was the longest of all and about double the size of the fourth article. There was presence of comma-shaped cervical grooves (Image

2). The spiracles were oval in appearance with a round anterior end and a pointed posterior end (Image 3). The genital orifice, oval in appearance was situated in a median line just behind the basis capituli (Image 4), in between the second pair of coxa. Anus was present at the posterior end behind the genital opening, consisting of a posterior anal groove (Image 4). The tick was festooned with 11 distinct festoons (Image 1). All the observations in the present study were in line with the findings of Ghosh & Misra (2012), delineating the ticks to be of the *Amblyomma gervaisi* species.

Although in the present study the ticks were recovered from under the scales of the snake, which was in concordance with the observations of Catherine et al. (2017); in the earlier study, Rosenthal (1997) recovered the ticks from the blood swollen abdomen also. The previous studies (Mader 1996; Catherine et al. 2017) also highlighted the skin infections including dermatitis, dysecdysis, and lumps associated with the tick infestation in snakes, but no such observation was recorded in the present study. The observation could be attributed to low ectoparasitic infestation in the present case. All the previous reports of the tick *A. gervaisi* are restricted to the southern, eastern and western parts of India (Alwar 1960; Pandit et al. 2011; Soundararajan et al. 2013; Catherine et al. 2017; Patra et al. 2017) and the present study claims to be the first documented report of the ticks from a rat snake of the northwestern Himalayan region. The preponderance of the ticks and other vectors in naïve areas could be considered as an aftermath of climate change, most importantly climate warming.

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NOTE

Parasitic enteritis in the free-ranging Common Myna *Acridotheres tristis* (Aves: Passeriformes: Sturnidae)

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The Common Myna *Acridotheres tristis*is is an opportunist omnivore and can be easily spotted near human localities or grazing pastures (Feare et al. 2016). The maintenance of a high level of infection in mynas is associated with their feeding habits. These birds often feed insects which are usually the intermediate hosts for many helminthic infections (Caughley & Sinclair 1994). The myna has also been found to carry protozoan parasites like *Haemoproteus* and *Plasmodium* spp. (Ishtiaq et al. 2006). Various reports of mynas spreading the zoonotic diseases to humans (bird flu and salmonellosis), asthma, dermatitis etc. are also recorded (Young 2000). This communication highlights the presence of the parasitic tapeworm, *Hymenolepis cantaniana,* in a free ranging bird, precipitating the potentiality of disease transmission to domesticated birds.

Two adult Common Myna (1 male and 1 female) were brought to the Department of Veterinary Pathology for necropsy examination from Rajot, Baijnath Tehsil, Himachal Pradesh. On detailed necropsy examination the entire small intestine was found to be stuffed with balled-up dull white coloured tapeworms along with catarrhal exudate (Image 4). The collected cestode parasites were thin thread-like having average lengths of 1.84±0.13 cm. The proglottids of the tapeworms were collected carefully from the intestines (mainly duodenum and jejunum) of the birds, which were dorso-ventrally compressed between two slides and fixed in 10% neutral buffered formalin. After complete overnight washing, the worms were dehydrated in ascending grades of alcohol. The specimen were stained in borax carmine and then transferred to a clearing agent (cedar wood oil) and finally mounted in dextrine plasticised xylene (DPX) (Meyer & Oslen 1975).

Tissue sections of the intestine with a thickness of 5mm were collected in 10% neutral buffered formalin for histopathological investigation. The formalin fixed tissues were processed, sectioned at 4–6 micron thickness and stained with Haematoxylin and Eosin (H&E) for microscopic evaluation as per the protocol described by Luna (1968).

A thorough external examination revealed emaciated carcasses with whitish to pale conjunctival mucus membranes. The morphological characteristics of the parasites recovered from the small intestine were studied in detail for identification of the genus of the cestode parasite. The detailed observation of the scolex,

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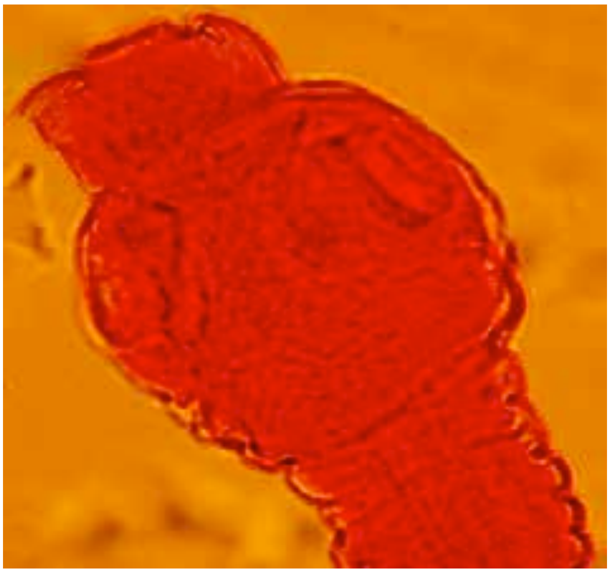

Image 1. Photomicrograph of scolex depicting armed rostellum (100X). © Moudgil, A.D.

Image 2. Photomicrograph of proglottids with unilateral genital pore (100X). © Moudgil, A.D.

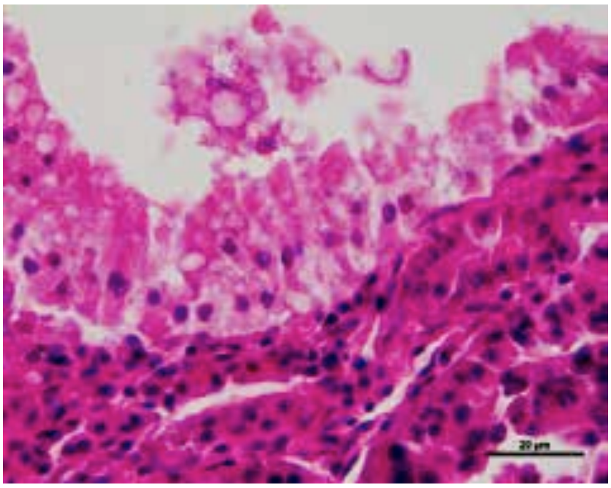

Image 3. Sloughed and necrosed enterocytes with eosinophilic catarrhal exudate in the intestine. H&E (100X). © Kumar, R.

Image 4. Incised intestine of Common Myna showing presence of tapeworm. © Kumar, R.

exhibited the presence of armed rostellum, i.e., presence of rostellar hooks (Image 1). The mean length of the cestode parasites was 1.84±0.13 cm (mean ± standard deviation) (n=10). The proglottids exhibited the presence of unilateral genital pores, slightly anterior to the middle of the proglottids (Image 2). The observations were depicting the parasite to be *Hymenolepis cantaniana* and were in concordance to the findings of Demis et al. (2015). In a similar study, Ponnudurai et al. (2009) recovered tapeworms from Myna, which were later on identified as *Railliettina* species.

The histopathological examination of the intestine revealed the presence of severe congestion, necrotic cellular debris in the intestinal lumen, pyknotic changes and eosinophilic catarrhal exudate along with goblet cell hyperplasia and a few polymorphonuclear cells (Image 3). The observations are in concordance with the findings of Omer et al. (2015).

As this avian species frequently wanders around the backyard or organized poultry farms, consequently, may act as a potential source for pathogen transmission to the domesticated poultry and other birds by contaminating the feed or water with their droppings. The gross and histopathological studies revealed that severe emaciation due to catarrhal enteritis caused by *H. cantaniana* tape worms was most probably the cause of death in the Common Myna.

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