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continued on the back inside cover

Caption: Diverse! Colourful! Almost Magical! Beetles are all around us from ancient cultures, art and entertainment to being considered pests, food, medicine, biodiversity indicators and even inspiration for technologies. This pencil and pen sketch by Priyanka Iyer, Zoo Outreach Organization is to celebrate Beetles.

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ARTICLE

The pattern of bird distribution along the elevation gradient of the Sutlej River basin, western Himalaya, India

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Abstract: We examined the species richness of birds along the elevation gradient of the Sutlej River basin in Himachal Pradesh in the western Himalaya of India. Birds were sampled at 318 sites categorized into 16 elevation bands ranging from 498 to 3700 m between June 2012 and April 2013. A total of 203 bird species were recorded. Species richness showed a monotonic decline with increasing elevation, with 27% of species recorded within a narrow elevation range. We tested the roles of explanatory variables such as environment (temperature, precipitation, area, & Mid-domain Effect (MDE) richness) and habitat (Normalized Differential Vegetation Index (NDVI): July, November & March) on the observed distribution pattern. The observed species richness pattern was strongly correlated with temperature, while three other variables—precipitation, area, and MDE richness—contributed negligibly to the observed pattern. The present study indicates that climatic conditions and vegetation are the major contributors for determining species richness along the Sutlej River basin. Thus, a customized approach is crucial for conservation of species in the elevation range.

Keywords: Bird distribution, elevation range size, hydro-electric projects, India, mid-domain, monotonic decline, Sutlej River basin, western Himalaya.

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INTRODUCTION

Understanding the spatial aspects of species diversity is a key challenge in ecology (Gaston 2000). One well-known pattern is global latitudinal diversity, where species richness peaks in the tropics and declines towards the poles (Rosenzweig 1992). Variation in species richness along latitudinal gradients is a well-documented pattern (Yu et al. 2013) and similar patterns have been observed along elevation gradients (Rahbek 1995) and across taxonomic groups (Stevens 1992) and continents (Cavarzere & Silveira 2012) to provide striking patterns in diversity (Sanders & Rahbek 2012). Distribution patterns along elevation gradients have been noted in invertebrates (Sanders 2002; Sanders et al. 2003; Khan et al. 2011; Levanoni et al. 2011; Bhardwaj et al. 2012; Yu et al. 2013; Carneiro et al. 2014; Acharya & Vijayan 2015), mammals (Patterson et al. 1996, 1998; Brown 2001; Nor 2001; Rickart 2001; McCain 2004b, 2005, 2006), birds (Terborgh 1977; Blake & Loiselle 2000; Lee et al. 2004; Raman et al. 2005; Franco et al. 2007; Das 2008; Jankowski et al. 2009; McCain 2009; Acharya et al. 2011; Naithani & Bhatt 2012; Wu et al. 2013; Joshi & Rautela 2014; Joshi & Bhatt 2015; Montano-Centellas & Garitano-Zavala 2015), and herpetofauna (Hofer et al. 1999; Naniwadekar & Vasudevan 2007; Chettri et al. 2010; Srinivas 2011). In general, species richness along elevation gradients follows one of three patterns: monotonic decline (decreasing with elevation), a hump-shaped pattern peaking at middle elevations (mid-domain), and that increasing with elevation (Stevens 1992; Rahbek 1995). Among these, the most widely-observed patterns are monotonic decline and mid-domain peak (Rahbek 1995; McCain 2009).

Comprehensive data sets for bird communities living along elevation gradients are available for many sites (Colwell et al. 2004; Boyle et al. 2015). Empirical studies have shown that bird species richness may decrease linearly with increasing elevation or may show a mid-elevation peak (McCain 2009; Wu et al. 2013). The decline in species richness with increasing elevation is widely accepted as a general pattern in different taxa (Stevens 1992; Rahbek 1995). Rahbek (1995), however, stated that this view of the relation between species richness and elevation is immature and that the compositional changes in bird communities along elevations are still not well understood (Terborgh 1971, 1977; Blake & Loiselle 2000; Jankowski et al. 2009; Acharya et al. 2011). Monotonic decline of species richness (Stevens 1992; Nor et al. 2001; Yu et al. 2013; Acharya & Vijayan 2015), mid-elevation peak (Rahbek 1995, 1997; Nor 2001; Rickart 2001; McCain 2004; Brehm et al. 2007; Das 2008; Acharya et al. 2011; Srinivas 2011; Joshi & Rautela 2014; Joshi & Bhatt 2015), monotonic increase in species richness (Sanders et al. 2003; Naniwadekar & Vasudevan 2007), and U-shaped pattern or mid-elevation depression (Raman et al. 2005) are widely observed patterns of species distribution along elevation gradients.

Understanding the association between species richness and elevation gradients is essential as it provides insights into the observed patterns and processes responsible for the relation, which in turn supports conservation efforts (Stevens 1992; Raman et al. 2005; Acharya et al. 2011). In view of this, the present study was carried out to document and describe the distribution pattern of bird communities along the elevation gradient in Sutlej River basin of Himachal Pradesh belonging to the western Himalayan part of India. The western part of Himalaya is an important area of regional endemism and is a priority region for conservation (Rahmani & Islam 2004). The study aims to provide comprehensive information on the species richness pattern from yet another important region of the western Himalaya, thereby contributing more information to the debatable topic of species distribution patterns along an elevation gradient.

METHODS

Study area

The Sutlej River basin in the western Himalayan mountain range (30.85–32.91^{0}N & 76.26–79.00^{0}E) is situated in the state of Himachal Pradesh (Fig. 1). The entire region is characterized by numerous mountain ranges, hills, rivers, and forests (Rahmani & Islam 2004; Sharma & Kumar 2012). The Sutlej River is one of the major physical features of Himachal Pradesh and flows in the southwesterly direction, bisecting the state. The Sutlej River basin covers wide-ranging variations in elevation (498–6685 m), climate (tropical to temperate), and vegetation types (tropical forest to alpine pastures). The temperature varies from a minimum of -3.8°C in February during winter to a maximum of 31.9°C in May during summer. The average annual rainfall (June–September) is 1,035.1mm (Indian Meteorological Department 2012) and precipitation in the form of snow is recorded during winter from December to February. We stratified the study area into 16 elevation bands of 200m interval. Within each band, point counts were fixed in proportion to the availability of the area. ASTER

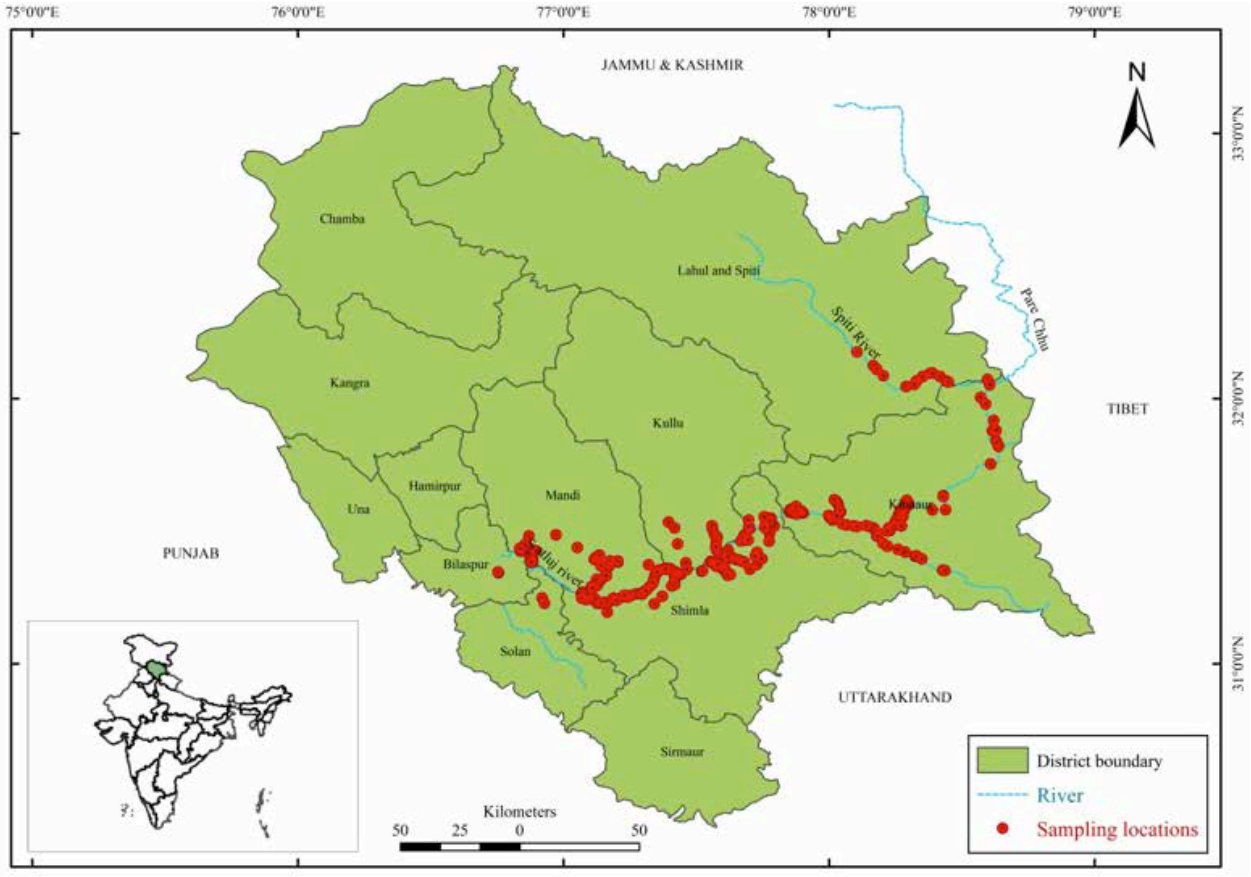

Figure 1. Map showing the sampling points at different elevations of Sutlej River basin, Himachal Pradesh

Global Digital Elevation Model (GDEM) was used to obtain the area available in each elevation band. A total of 318 sampling points were surveyed at different elevation bands (Table 1).

Bird sampling

The present study was conducted from June 2012 to April 2013. To assess the difference in the richness and abundance of birds along the elevation gradient, point count method (Gaston 1975) was followed. A minimum of 1km distance (calculated using QGIS 2.12.1) was maintained between the consecutive points. In each point count, a single observer recorded every bird seen inat 10min intervals (Ralph et al. 1995; Raman 2003) within the fixed distance of 50m radius. The number of individuals and species were recorded based on both visual and vocal estimation. The sampling was avoided in inaccessible areas and at point count stations with evidence of human settlement. The surveys were carried out 30min after dawn and 30min before sunset on days with suitable weather conditions. The point counts were conducted from 0600 to 1100 hr in the morning and 1500 to 1800 hr in the evening. The

Table 1. Area availability and sampling effort in Sutlej River basin

Elevation band	Area (km²)	Sampling points	Sampling replication
500-700	653.65	47	188
700-900	834.93	50	200
900-1100	652.74	22	87
1100-1300	566.20	34	136
1300-1500	549.23	20	80
1500-1700	506.60	36	144
1700-1900	479.71	22	88
1900-2100	426.88	20	80
2100-2300	371.42	11	43
2300-2500	333.42	11	44
2500-2700	340.98	3	12
2700-2900	316.68	13	50
2900-3100	309.35	9	33
3100-3300	338.79	6	18
3300-3500	387.30	11	26
3500-3700	483.80	3	10

probability of twice counts was minimized by excluding flocks that appeared in the same direction. To enhance the probability of detecting elusive or rare species, point counts varied between one to four replications in each season (summer, winter, & rainy season). Thus, a total of 1,239 point counts were conducted throughout the study. The average species richness of sampling replications has been used for analyses. The migratory status and taxonomic system used in this study followed Grimmett et al. (2011).

Habitat variables

We extracted temperature, precipitation, and other 19 bioclimatic variables from the WORLDCLIM database for the analysis. The database presents climatic data from 1950–2000 (50 years) at a spatial resolution of 1km (Hijmans et al. 2005). We used normalized differential vegetation index (NDVI) values from 2012 and 2013 to measure primary productivity, downloaded from Google Earth Engine (LANDSAT 7 with 32 days interval: https://earthengine.google.com/datasets/).

Analysis

We used non-parametric estimator (Chao 1) to calculate the estimated species richness using the statistical software program EstimateS 9.1 (Colwell & Coddington 1994; Colwell 2016). A precise estimate of observed and estimated species richness for a sampling interval was assumed if the species accumulation curve approached a plateau (Chao et al. 2005). Linear regression analysis (Sokal & Rohlf 1995) was performed against observed species richness with elevation to assess the species distribution pattern.

We performed Monte Carlo simulation using the software Mid-Domain Null model (McCain 2004) for testing geometric phenomena or mid-domain patterns of species ranges. The computed action simulates species richness curves based on empirical ranges or range midpoints within a bounded domain. It is based on the analytical–-stochastic models (Colwell & Hurtt 1994). The species ranges are randomly shuffled within a bounded geographical domain and resulting peak species richness at intermediate elevation (Colwell & Lees 2000). To test the geometric boundary constraints in relation to the distribution of species richness, 95% prediction curves were raised based on 50,000 simulations without replacement using empirical range sizes (with 200m elevation increases). Linear regression was applied between empirical species richness and the average of the predicted number of species to assess the model fit.

We used simple linear regression model to explore the effect of each explanatory variable that could support the bird species richness along an elevation gradient. The explanatory variables such as mean annual temperature, mean annual precipitation, area, NDVI for July, October, November, February, March & April, and MDE predicted richness were regressed with estimated species richness (Chao 1). Among the environmental variables, temperature, precipitation, and area were highly correlated, similar to the habitat variables NDVI for July, November, and March. These highly correlated variables were selected for stepwise multiple regression analysis to identify the best explanatory variables that predicted the estimated species richness along elevation. In the set of variables, we selected estimated species richness as dependent variable and others as independent variables. In each successive step, the model with significant results was dropped and tried with other variables to find the next significant one.

We examined the elevation range profile for each species occurring at all elevations, whether the species utilized all intermediate elevation or was stuck between elevation maximum and minimum limits (Patterson et al. 1998). We then performed Pearson correlation to test the relationship between the range size of each species against the lower and upper limits of its elevation ranges. Regression and correlation analysis were performed in statistics software package SPSS 17.0 (Chicago, IL, USA).

RESULTS

Species richness

A total of 203 bird species, including 147 residents and 56 non-residents, were recorded across 16 elevation bands during the study period. The number of species detected in each elevation band varied from 20 to 140. The bird species richness was highest at around 700m elevation in the Sutlej River basin. The species accumulation curves across all the bands almost reached an asymptote, except in the elevation gradient above 2100–2500 m and 3500–3700 m (Fig. 2). The observed species richness corresponded well with the estimated Chao 1 ($r = 0.99$, $p < 0.000$).

Mid-domain analysis

Mid-domain effect (MDE) predictions were not observed in Sutlej River basin ($F_{(1,14)} = 93.52$, $p < 0.0001$; $R^2 = 0.87$; Fig. 3). The observed species richness, however, significantly declined with increasing elevation along all elevation gradients. The species distribution

pattern in the Sutlej River basin showed a monotonic decrease in species richness with increasing elevation. A similar pattern was observed in the MDE, where the data revealed poor fit to the MDE predictions. The range size of resident bird species showed that only 12.5% of the empirical points occurred inside the predicted range of MDE null model (Fig. 4). The regression relationship between empirical species richness and the mean of the predicted richness is insignificant ($F_{(1.14)}$ = 0.026, p = 0.87, R^2 = 0.002). MDE for all the bird species was also insignificant ($F_{(1.14)}$ = 0.001; p = 0.97; R^2 = 0.0001) and 81% (13/16) of the empirical points fell out of the predicted limits (Fig. 5).

In simple linear regression, estimated species richness (Chao 1) was significantly correlated with mean temperature ($F_{(1.14)}$ = 79.10, p = 0.000, R^2 = 0.85). Other environment factors such as MDE predicted richness and habitat variables such as NDVI for October, February, and April were insignificant. In the stepwise regression first model, the annual mean temperature was significantly correlated with estimated richness (Table 2). After removing the temperature, the second model habitat variable, NDVI March, was significantly correlated and the third model precipitation and area together showed a significant correlation.

Variation in empirical species richness in different elevation bands matched closely with the observed species richness. Abrupt turndown in species richness at elevation ranges 900–1,100 m and 1,300–1,700 m, however, was closely associated with predicted range boundaries (Fig. 5). It shows that the deviation of MDE prediction between empirical and observed species richness slightly goes wrong in Sutlej River basin.

Elevation range profile

The elevation range profile for birds in Sutlej River basin recorded a higher number of species (72% of species) occurring below 2500m elevation gradients. A total of 55 bird species was restricted to very narrow elevation range size (200m), 10 species were restricted above 3,000m (Table 3), and 17 species were spread all over the gradients (Fig. 6). A total of 77 (38%) bird species were below 600m elevation range and 19 species occurred above 3,000m elevation range. The elevation range size of low elevation species, those occurring below 2,000m (upper limit: r = 0.825, p < 0.0001; lower limit: r = -0.383, p <0.0001), and high elevation species, those occurring above 2000m (upper limit: r = 0.282, p < 0.01; lower limit, r = -0.813, p < 0.0001), was positively correlated with upper limit and negatively correlated with lower limit. The range size of low elevation species, however, was inclined to decrease with elevation and that of high elevation species to increase with elevation.

DISCUSSION

In Sutlej River basin, we found a clear association between bird species richness and the factor (temperature) influencing the species distribution across the elevation bands. The MDE analysis also showed the decreasing trend of species richness along the alelevation gradients. In addition, species range size revealed that most of the species have a narrow elevation range within the sampled elevation gradients.

Species richness

Previous studies along Sutlej River basin examined a section of the elevation gradient for assessing the avian communities (Gaston 1993; Thakur et al. 2006; Mattu & Thakur 2006; Miller et al. 2008; Jayapal & Ramesh 2009; Kulkarni & Goswami 2012). This is the first study along an elevation gradient (498–3700 m) to document the distribution pattern of bird species along the Sutlej River basin. The species richness and abundance obtained from point count corresponded with Chao 1 estimate. The patterns of species richness across these elevation bands indicate that our sampling effort was fairly complete, although some new species were still recorded in few of the bands (2100–and2500 m & >3500m). This could be attributed to undersampling of the terrain in a few elevation bands due to inaccessibility and landscape degradation (Pandit & Grumbine 2012).

Table 2. Results of step-wise multiple regressions between estimated species richness (Chao 1) and explanatory variables to predict the most significant factor supporting the species distribution patterns

	Variables	Selected model	Part correlation	Adjusted R^2±SE	F	p
1	Temperature, precipitation, area, MDE predicted richness, NDVI (July, November & March)	Temperature	0.922	0.839±16.45	79.10	<0.000
2	Precipitation, area, MDE predicted richness, NDVI (July, November & March)	NDVI March	0.920	0.836±16.61	77.25	<0.000
3	Precipitation, area, MDE predicted richness, NDVI (July & November)	Precipitation area	0.406 0.341	0.909±12.39	75.52	<0.001

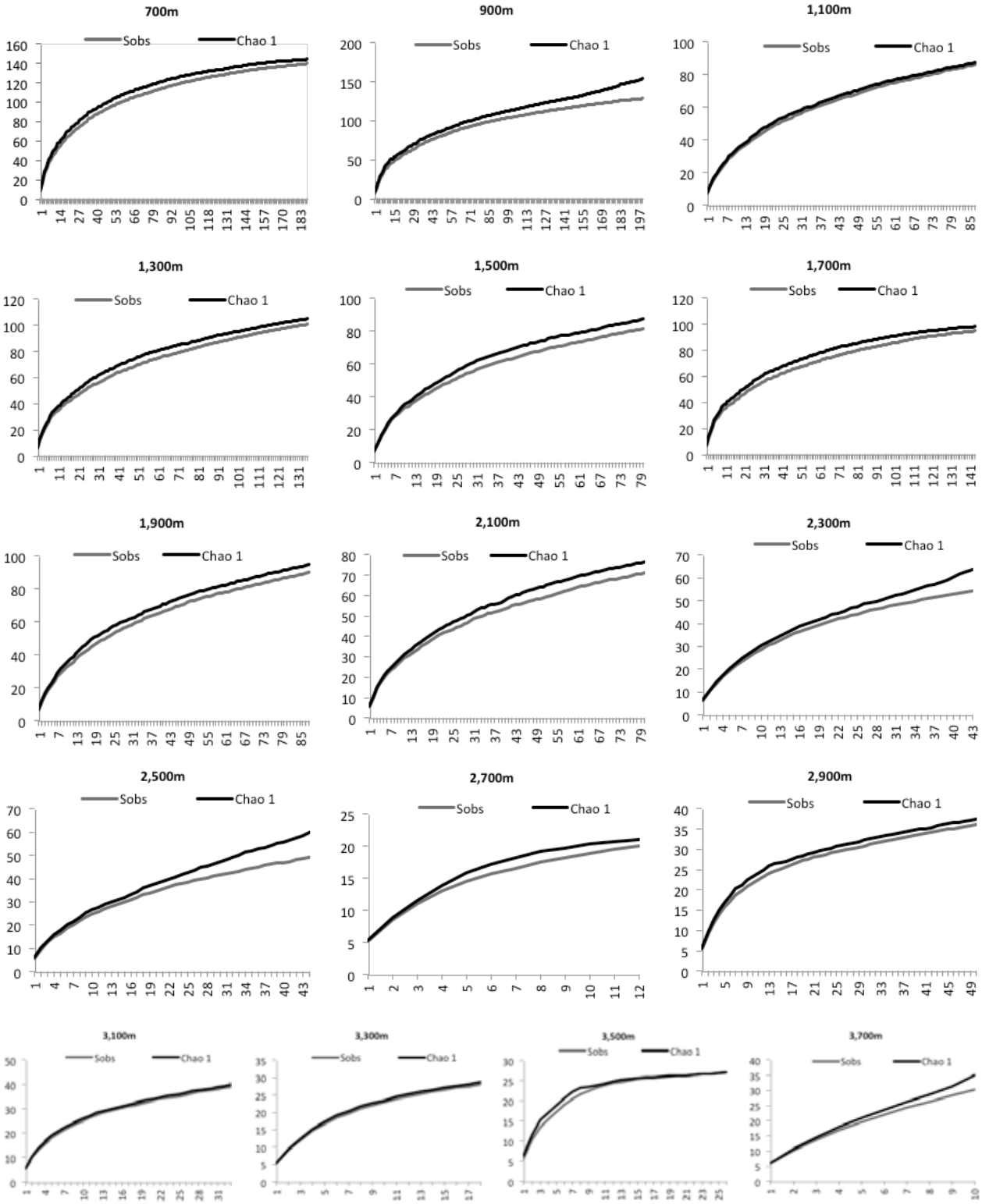

Figure 2. Estimates of species richness for birds - curves based on abundance detected in various elevation bands across Sutlej River basin, Himachal Pradesh
Horizontal axis - sampling effort, vertical axis - number of species, Sobs - species observed

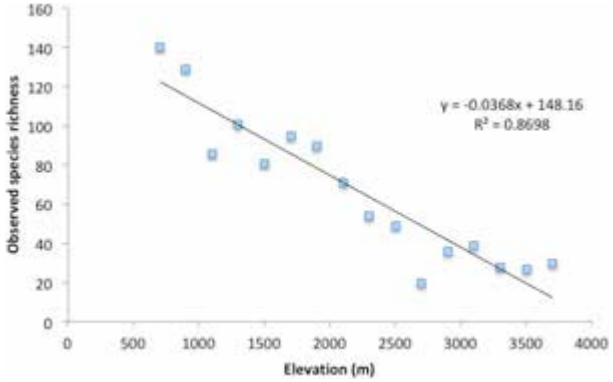

Figure 3. Elevation variation of observed bird species richness in Sutlej River basin

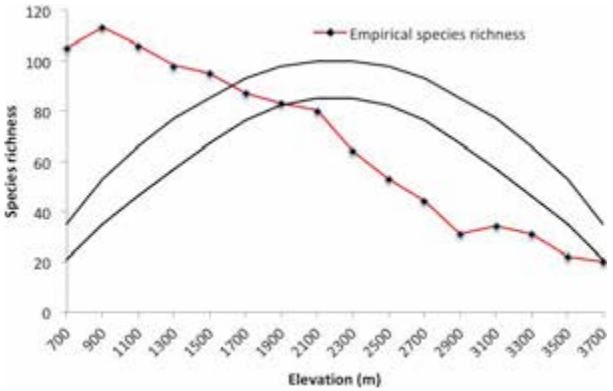

Figure 4. Mid-domain analysis for resident birds

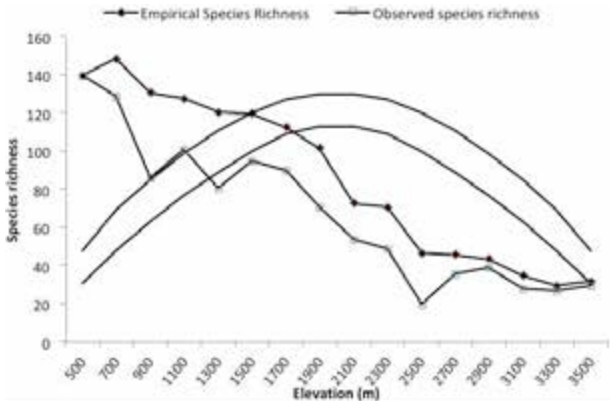

Figure 5. Mid-domain analysis for overall birds

Mid-domain analysis

The bird species richness along the elevation gradient was greater in three distinct peaks: 500–700 m, 1500–1700 m, and 3300–3500 m. This pattern reflects that the species richness of birds in Sutlej River basin is highly patchy. The present study, however, revealed that species richness of birds declined monotonically with increasing elevation. The monotonic decline in species richness along the elevation gradient has commonly been reported in various taxa and regions (Rahbek 1995, 2005; Patterson et al. 1998; Lessig 2008). In contrast, a few studies in the Himalaya observed high species richness at middle elevation than higher and lower elevations (Raza 2006; Acharya et al. 2011; Joshi et al. 2012; Joshi & Rautela 2014; Joshi & Bhatt 2015), although they found very little support for the MDE (Acharya et al. 2011). Lack of mid-elevation peak in species richness indicates that geometric constraints have a relatively low influence on the bird species richness pattern in the Sutlej River basin and western Himalaya.

The effect of climatic and productivity variables on the distribution pattern of birds in this river basin was tested. The monotonic decline in species richness was influenced by temperature as evidenced by the step-wise multiple regression model (Table 2). This observed result corresponds with Acharya et al. (2011) and Stevens (1992), where the species richness along the elevation gradient was influenced by climatic factors followed by habitat variables. In contrast, other studies in the Himalaya observed that the vegetation composition (Raza 2006; Joshi et al. 2012) and structure (Joshi & Rautela 2014; Joshi & Bhatt 2015) determined the species richness in a gradient, rather than the elevation and other climatic factors. These studies covered a part of the elevation range and did not consider a wide-elevation range as that followed in the present study and by Acharaya et al. (2011). This might be the reason for the absence of the influence of climatic variables on bird species distribution in other studies (Joshi et al. 2012).

In resident birds, 19% of observed species richness fells within 95% null model, which might be influenced by the geometric constraints than in other bands. For overall bird species, geometric constraints influenced between 1600 and 1800 m and >3500m elevation, whereas observed species richness fell between 900 and 1700 m and >3500m elevation of null model. The sudden decline in both resident and overall bird species richness above 2000m is in concurrence with increasing elevation and is due to sparse forest cover and harsh climatic conditions. These changes in climatic conditions could be a cause for the decline of species richness above the transition zone (>2000m) in Sutlej River basin.

Elevation range profile

Species richness of birds in Sutlej River basin was greater within 2000m elevation (116 species, 57%) and rest were found above 2000m. The elevation range limits of each species varied in this study area and

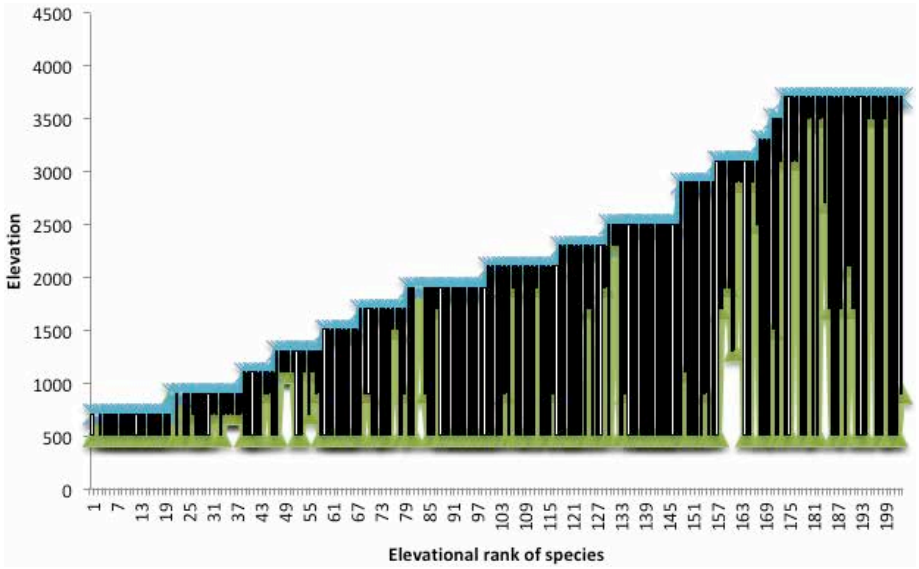

Figure 6. Elevation range profiles of birds in Sutlej River basin

showed very narrow ranges. Out of the 203 species, 17 species occurred in all sampled elevation bands while 55 species were found only in few elevation bands showing that their range sizes are narrow. Several factors such as habitat structure, inter-specific competition, and environmental tolerance (Jankowski et al. 2010; Laurance et al. 2011) would have driven the species into narrow elevation bands.

Species with broader elevation ranges were insectivorous or granivorous. The insectivorous birds such as Indian Roller *Coracias benghalensis*, Indian Pitta *Pitta brachyura*, Whiskered Yuhina *Yuhina flavicollis* & Red-billed Leiothrix *Leiothrix lutea* and granivorous birds such as Jungle Bush-quail *Perdicula asiatica*, Laughing Dove *Spilopelia senegalensis*, and Emerald Dove *Chalcophaps indica* were observed only at low elevation bands (<2000m). Stevens (1992) stated that the relationship between latitude and elevation differences experienced by the organisms along geographic gradients is due to the breadth of climatic conditions. Species that have narrow elevation ranges tend to have less climatic tolerance and thus are vulnerable to extinction due to global warming (Colwell et al. 2008; Laurance et al. 2011). For instance, broader elevation range species can migrate upward or downward in response to climatic change and could maintain their viable population sizes (Laurance et al. 2011).

This is the first study in the western Himalaya to assess the distribution pattern of birds along a broad elevation gradient (500–3500 m). Our observation revealed that the bird species richness was significantly greater at a lower elevation than at mid- and high elevation, showing a monotonic decline in species richness. This observed pattern is strongly correlated with the climatic variable, atmospheric temperature, in Sutlej River basin. A large proportion of resident birds occurs in a narrow elevation range, indicating the necessity of sustainable conservation efforts. One of the major threats to the birds in Sutlej River basin is the hydropower projects that are reducing the green cover of the mountains, which perhaps is driving away species from their native elevation ranges (especially 600–1600 m) (Pandit & Grumbine 2012). Hence, a highly customized approach is crucial for the conservation of this entire elevation range.

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Table 3. Narrow elevation range size of species and restricted species of birds in Sutlej River basin

Common name	Scientific name	Narrow elevation range size (200m)	Restricted (above 3000m)
Indian Peafowl	*Pavo cristatus*	+	
Jungle Bush-quail	*Perdicula asiatica*	+	
Cheer Pheasant [E, VU]	*Catreus wallichii*	+	
Common Pochard [VU]	*Aythya ferina*	+	
Little Grebe	*Tachybaptus ruficollis*	+	
Hill Pigeon	*Columba rupestris*		+
Snow Pigeon	*Columba leuconota*		+
Grey-capped Emerald Dove	*Chalcophaps indica*	+	
Pacific Swift	*Apus pacificus*	+	
Common Moorhen	*Gallinula chloropus*	+	
Indian Pond-heron	*Ardeola grayii*	+	
Cattle Egret	*Bubulcus ibis*	+	
Grey Heron	*Ardea cinerea*	+	
Great White Egret	*Ardea alba*	+	
Intermediate Egret	*Ardea intermedia*	+	
Little Egret	*Egretta garzetta*	+	
Little Cormorant	*Microcarbo niger*	+	
Black-winged Stilt	*Himantopus himantopus*	+	
Little Ringed Plover	*Charadrius dubius*	+	
Red-wattled Lapwing	*Vanellus indicus*	+	
Wood Sandpiper	*Tringa glareola*	+	+
Marsh Sandpiper	*Tringa stagnatilis*	+	
Spotted Owlet	*Athene brama*	+	
Red-headed Vulture [CR]	*Sarcogyps calvus*	+	
Black Eagle	*Ictinaetus malaiensis*	+	
Bonelli's Eagle	*Aquila fasciata*	+	
Hen Harrier	*Circus cyaneus*	+	
Indian Roller	*Coracias benghalensis*	+	
Common Kingfisher	*Alcedo atthis*	+	
Pied Kingfisher	*Ceryle rudis*	+	
Great Slaty Woodpecker [VU]	*Mulleripicus pulverulentus*	+	
Indian Pitta	*Pitta brachyura*	+	
Bay-backed Shrike	*Lanius vittatus*	+	
Grey-backed Shrike	*Lanius tephronotus*		+
Spotted Nutcracker	*Nucifraga caryocatactes*	+	
Black-lored Tit	*Parus xanthogenys*	+	
Fire-capped Tit	*Cephalopyrus flammiceps*	+	
Wire-tailed Swallow	*Hirundo smithii*	+	
Oriental Skylark	*Alauda gulgula*	+	
Zitting Cisticola	*Cisticola juncidis*	+	
Tickell's Leaf-warbler	*Phylloscopus affinis*	+	
Yellow-eyed Babbler	*Chrysomma sinense*	+	
Large Grey Babbler	*Turdoides malcolmi*	+	
Red-billed Leiothrix	*Leiothrix lutea*	+	
White-browed Shrike-babbler	*Pteruthius flaviscapis*	+	
Goldcrest	*Regulus regulus*	+	+
Chestnut-bellied Nuthatch	*Sitta castanea*	+	
Bank Myna	*Acridotheres ginginianus*	+	
Asian Pied Starling	*Sturnus contra*	+	
White-collared Blackbird	*Turdus albocinctus*	+	
Grey-winged Blackbird	*Turdus boulboul*	+	
Grandala	*Grandala coelicolor*	+	+
Blue Rock-thrush	*Monticola solitarius*	+	
Slaty-blue Flycatcher	*Ficedula tricolor*	+	+
Rufous-bellied Niltava	*Niltava sundara*	+	
White-throated Dipper	*Cinclus cinclus*	+	+
Crimson Sunbird	*Aethopyga siparaja*	+	
Robin Accentor	*Prunella rubeculoides*		+
Citrine Wagtail	*Motacilla citreola*	+	+

VU - Vulnerable, CR - Critically Endangered, E - Endemic; + Species presence

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Morphological variations in marine pufferfish and porcupinefish (Teleostei: Tetraodontiformes) from Tamil Nadu, southeastern coast of India

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Abstract: In the present study, morphological variations in 14 species of two families, Tetraodontidae and Diodontidae, were examined for individuals collected from five different centres in Tamil Nadu in the southeastern coast of India. Twenty-seven morphological measurements and four meristic characters were taken and used for multivariate analyses such as discriminant function analysis (DFA) & MANOVA. DFA revealed that the first two functions accounted for more than 75% variation between the species. Negative allometric values were observed on head length (HL), orbital length (OL), pupil diameter (PD), interorbital length (IOL), pectoral-fin length (PEL), caudal peduncle depth (CPD), dorsal to pectoral fin distance (DPFD), caudal peduncle length (CPL) and post-pectoral-fin length (POPFL) measurements. Also, MANOVA supported the DFA results. Additions, allometric relationships, and meristic variations were observed for most of these species. Moreover, this is the first attempt to describe a greater number of morphological features of the species belonging to the order Tetraodontiformes.

Keywords: Allometry, Diodontidae, discriminant function analysis, MANOVA, meristics, morphometric variation, porcupinefish, pufferfish, Tetradontidae, trash fish.

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Author Contribution: KK & RR conceived & designed the experiments and analyzed the data; KK performed the sample collections; PP & GA associated the experiments; PP, GA, KK & RR wrote the paper.

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INTRODUCTION

Geographic variation in morphometry has been used to discriminate local forms of fish for over a century (Cadrin 2000). Phenotypic diversities exist in morphological variations within and among populations (Jeffares et al. 2015) and they may be one of the ways to determine the origin of divergence and speciation (Kerschbaumer et al. 2014). Morphometric analysis reveals the differences in body shape between different individuals to discriminate populations of the same species (Hirsch et al. 2013), which can help for the conservation of biodiversity, management of fishery resources, and identification & discrimination of species.

Both pufferfish and porcupinefish belong to the order Tetraodontiformes. Tetraodontidae, the family to which pufferfish belong to which includes 27 genera with 184 species, and which is considered the most important family in this orderthat 27 (Matsuura 2015). Porcupinefish of the family Diodontidae includes 19 species of six genera (Nelson et al. 2016). Some members of the pufferfish and porcupinefish have commercial value in the food industry and in the aquarium trade (Fiedler 1991). The indeterminate consistency of body and loose skin are the great taxonomic features in genera such as *Arothron*, *Chelonodon*, *Lagocephalus*, *Takifugu*, and *Torquigener*. Many species have not been studied taxonomically in detail by using morphological and meristic characters to classify them into appropriate groups (Randall 1985). The detailed counts and measurements were provided for freshwater pufferfish of *Tetraodon* by Dekkers (1975), marine pufferfish of *Canthigaster* by Allen & Randall (1977), *Lagocephalus* by Matsuura (2010) & Matsuura et al. (2011), and *Torquigener* by Hardy (1982a,b, 1983a,b, 1984a,b).

Despite the value and availability of genetic, physiological, behavioral, and ecological data for such studies, systematic ichthyologists continue to depend heavily on morphology for taxonomic characters. Commonly, fish are classified based on the shapes, sizes, pigmentation patterns, disposition of fins, and other external features (Strauss & Bond 1990). Pufferfish have been fatally consumed mainly in Japan, China, and Taiwancausing death (Bragdeeswaran & Therasa 2010; Arakawa et al. 2010; Monaliza & Samsur 2011). A few members of pufferfish are considered as serious hazards to consumers since they contain strong marine toxins that can be lethal to humans. Therefore, misidentification of the species is a major issue in the trade market and clear identifications of pufferfish are a prime need to solve this problem.

Among the different fish products, fresh and dried pufferfish are an important source of animal protein in Tamil Nadu. The preservation process starts when it is harvested and becomes complete when it reaches the consumer's table. According to Immaculate et al. (2015), paralysis resulting from ingestion of pufferfish was reported from southeastern Asia. This kind of study, however, has not been carried out on the Indian species. The improper handling and misidentification of this species can be adverse to human health. Recently, increasing availability and utilization of pufferfish in Tamil Nadu coast has caused health problems to the consumers. The current study deals with understanding the morphological variations of pufferfish and porcupinefish.

MATERIALS AND METHODS

Study area description

The specimens of pufferfish and porcupinefish were collected from five major fish landing centres such as Royapuram (Station I) (13.124^{0}N & 80.297^{0}E), Cuddalore (Station II) (11.716^{0}N & 79.775^{0}E), Nagapattinam (Station III) (10.755^{0}N & 79.849^{0}E), Mandapam (Station IV) (9.276^{0}N & 79.151^{0}E), and Kanyakumari (Station V) (8.0781^{0}N & 77.551^{0}E) located along the Tamil Nadu coast of southeastern India (Fig. 1). The specimens were caught by large fishing boats and small fibre boats with gill nets and trawl nets gear; trawl nets were the main method for collecting pufferfish and porcupinefish.

Sample collection and preservation

The sample collections were carried out for a period of two years from August 2014 to July 2016 by regular visits to the landing centres at monthly intervals. Fourteen species belonging to the families Tetraodontidae and Diodontidae were collected from trash items at all fish landing centres (Image 1). Collected specimens were transported to the laboratory in fresh conditions and stored at -20^{o}C until further analysis. The collected specimens were then thawed at room temperature and weighed. The specimens were identified to species level by referring to standard fishery identification manuals and publications (Fraser-Brunner 1943; Allen & Randall 1977; Leis 1978, 1984; Fischer & Bianchi 1984; Hardy 1982a, b, 1983a, b, 1984a, b; Smith 1958, 1986; Smith & Heemstra 1986; Matsuura 1994, 2002, 2010, 2014; Matsuura et al. 2011; Allen & Erdmann 2012; Randall et al. 2012).

Morphometric features

Morphological measurements were made months

Figure 1. Sampling stations along Tamil Nadu, southeastern coast of India

after fixation in 10% formalin and were taken to the nearest 0.1mm with a dial caliper. In this study, 10 specimens were taken from each species for morphometric and meristic analyses (Table 1). Methods for morphological measurements and fin-ray counts primarily followed Dekkers (1975) and Hubbs & Lagler (1958) with some additional measurements (Fig. 2): standard length (SL), snout length (SNL), mouth gape length (MGL), head length (HL), orbital length (OL), pupil diameter (PD), interorbital length (IOL), pre-nasal length (PRNL), inter nasal length (INL), dorsal-fin base length (DFBL), dorsal-fin length (DFL), pectoral-fin base length (PFBL), pectoral-fin length (PEL), anal-fin base length (AFBL), anal-fin length (AFL), pre-dorsal-fin length (PRDFL), pre-pectoral fin length (PRPFL), pre-anal fin length (PRAFL), post-dorsal-fin length (PODFL), post-pectoral-fin length (POPFL), post-anal-fin length (POAFL), caudal peduncle length (CPL), caudal peduncle depth (CPD), snout to anus distance (SNAD), dorsal to pectoral fin distance (DPFD), dorsal to anus distance (DAD), and depth of body (LDB).

Data analysis

All statistical analyses were performed using the statistical software (SAS 2014). The allometric relationship of all the characters with standard length was estimated using linear regression model and the significance of the allometric coefficient (b) was fixed (b=1: isometry, b>1: negative allometry, b<1: positive allometry).

For multivariate analysis, to remove the effect of size from the data, all the morphometric measurements were transformed to size-independent shape variables using an allometric method as suggested by Reist (1985).

$$M_{trans} = \log M - \beta (\log SL - \log SL\ mean)$$

where M_{trans} is the truss measurement after transformation, M is the original truss measurement, SL is the overall mean standard length of a species, and β is the slope regressions of the log M against log SL. Correlation coefficients were observed between each pair of variables before and after the size effect removal;, the values of which were expected to decrease , after the size effect removal (Murta 2000). Multivariate analysis used in this study consisted of discriminant function analysis (DFA). DFA was run to test the effectiveness of variables in predicting different groups of species (Tomovic & Dzukic 2003; Loy et al. 2007). Finally, multivariate analysis of variance (MANOVA) was performed to see the significant differences between the species.

RESULTS

Morphometric data is provided for the 11 species from six genera (*Arothron*, *Lagocephalus*, *Takifugu*, *Canthigaster*, *Torquigener* & *Chelonodon*) of Tetraodontidae and three species from three genera (*Chilomycterus*, *Diodon* & *Cyclichthys*) of Diodontidae in Table 1 & Image 1. The meristic differences for all the species of both the families are represented in Table 2. The relationship between all morphometric characters and SL has been described and represented in Table 3a, b.

Morphometric data of *Arothron* & *Lagocephalus*

In the present study, four species of *Arothron*, *A. hispidus*, *A. immaculatus*, *A. reticularis* & *A. stellatus*, and three species of *Lagocephalus*, *L. guentheri*, *L. sceleratus* & *L. lunaris*, were investigated by multivariate analyses and exhibited species variation. The results of DFA indicate that the first two components cumulatively explained 85.4% of the total morphometric variation. Some of the morphometric variables (HL, OL, PD, PD, IOL, PEL, CPD & SNAD) loaded heavily on DF, which explained 67.7% of the entire differences and few variables from DF2 (DPFD, CPL, POPFL & PRAFL) with 17.7% (Table 4 & Fig. 3). Additionally, MANOVA analysis also supported and followed the taxonomic status of these species (Table 5). Lower morphometric differences were observed between *A. hispidus* & *A. stellatus* and high differences were noticed in *A. reticularis* to other species of *Arothron* group; *L. sceleratus* & *L. lunaris* showed less variation in *Lagocephalus* group (Fig. 3).

Table 1. Morphometric characters of marine Pufferfish & Porcupinefish from southeastern India.

	Pufferfish											Porcupinefish		
Code	*A. immaculatus*	*A. reticularis*	*A. hispidus*	*A. stellatus*	*L. guentheri*	*L. sceleratus*	*L. lunaris*	*T. oblongus*	*T. brevipinnis*	*C. patoca*	*C. solandri*	*D. holocanthus*	*C. orbicularis*	*C. reticulatus*
SL	14.81±5.49	11.38±8.79	17.71±4.88	25.65±5.18	19.34±1.57	10.85±1.56	10.68±1.96	16.57±4.94	8.15±2.10	12.57±3.04	7.68±2.79	13.57±1.60	14.00±2.29	31.00±9.66
SNL	2.10±0.69	2.03±1.53	3.09±0.85	3.34±0.80	3.18±2.11	1.67±0.47	1.65±0.65	2.19±0.57	1.33±0.48	2.16±0.56	1.28±0.61	1.47±0.35	1.33±0.21	5.23±1.79
MGL	1.79±0.60	1.88±0.81	1.58±0.57	3.46±0.68	1.99±0.98	1.05±0.34	1.05±0.47	1.85±0.62	0.51±0.18	1.79±0.51	0.52±0.22	1.30±0.70	1.73±0.81	3.37±1.10
HL	4.57±2.03	4.25±2.50	4.88±1.34	9.92±2.29	4.96±2.11	2.49±0.38	2.45±0.52	4.31±1.64	1.89±0.63	4.40±1.21	1.80±0.80	4.30±0.61	4.40±0.70	9.03±2.59
OL	1.07±0.37	0.97±0.22	0.88±0.32	2.02±0.46	1.90±0.55	1.44±0.40	1.43±0.54	0.97±0.19	0.89±0.40	1.09±0.30	0.88±0.51	1.37±0.45	1.17±0.25	2.17±0.81
PD	0.83±0.25	0.75±0.18	0.71±0.30	1.14±0.33	1.11±0.36	1.14±0.41	1.18±0.54	0.76±0.10	0.61±0.25	0.84±0.13	0.60±0.32	0.87±0.21	0.77±0.06	1.30±0.53
IOL	2.55±1.02	2.40±1.74	2.42±0.67	4.59±1.35	2.75±1.50	1.60±0.58	1.53±0.79	3.17±1.24	1.42±0.54	2.32±0.48	1.34±0.64	3.13±0.21	3.50±0.72	4.80±1.39
PRNL	1.73±0.65	1.48±0.82	2.11±0.78	3.02±0.69	2.06±1.50	1.38±0.46	1.35±0.65	1.70±0.77	3.59±1.02	2.08±0.49	3.34±1.38	1.33±0.21	1.43±0.35	3.87±1.03
INL	1.37±0.54	1.25±0.77	1.27±0.58	2.16±0.55	2.09±1.00	1.05±0.43	1.08±0.64	1.65±0.71	0.74±0.21	1.64±0.47	0.74±0.27	1.77±0.71	1.40±0.46	2.93±1.07
DFBL	1.23±0.64	1.22±0.88	1.20±0.57	2.78±0.93	1.95±1.22	1.12±0.52	1.13±0.75	1.69±0.65	0.51±0.18	1.05±0.22	0.50±0.21	1.37±0.40	1.17±0.15	3.37±1.31
DFL	2.42±0.85	1.35±1.23	2.73±0.64	3.54±0.90	2.98±1.76	1.97±0.65	1.90±0.88	2.86±0.87	1.58±0.44	1.62±0.51	1.50±0.57	2.03±0.23	2.07±0.29	4.90±1.85
PFBL	1.61±0.83	1.45±0.89	1.64±0.72	3.29±0.78	1.80±1.00	1.36±0.52	1.33±0.74	1.48±0.58	0.72±0.23	1.15±0.38	0.72±0.29	1.87±0.23	1.93±0.31	3.37±0.76
PEL	2.12±0.71	1.52±1.12	2.16±0.66	3.13±0.66	3.24±1.41	2.48±0.69	2.35±0.94	2.61±0.58	1.35±0.69	1.71±0.51	1.32±0.81	2.40±0.50	2.67±0.68	4.27±1.70
AFBL	0.99±0.58	1.12±0.84	1.16±0.68	2.18±0.49	1.70±0.80	0.98±0.51	1.03±0.79	1.71±0.38	0.69±0.42	0.97±0.32	0.54±0.22	1.50±0.66	1.17±0.40	2.53±0.55
AFL	2.09±0.90	1.32±0.93	2.12±0.72	3.34±0.82	3.29±1.80	1.43±0.49	1.45±0.72	2.69±0.50	1.17±0.54	1.60±0.41	1.14±0.65	2.07±0.31	2.03±0.25	4.37±1.87
PRDFL	21.32±5.57	6.98±0.98	13.33±3.62	17.42±2.62	13.29±6.99	8.49±1.59	8.45±2.19	12.51±2.85	5.14±2.96	10.82±2.17	5.78±3.03	11.00±0.95	11.50±1.35	21.20±5.94
PRPFL	4.78±1.15	5.40±1.21	6.47±1.92	6.84±2.33	6.53±4.41	4.61±0.82	4.60±1.22	5.90±1.36	3.08±0.63	5.35±1.62	2.96±0.82	5.47±0.55	5.47±0.55	10.43±4.83
PRAFL	10.45±3.45	7.31±2.04	14.46±3.59	17.95±3.59	13.26±7.63	7.89±1.57	8.00±2.35	12.86±3.04	5.38±2.29	10.98±2.43	5.76±2.68	12.07±0.97	12.80±1.75	21.53±4.80
PODFL	4.84±2.21	3.73±3.40	4.15±1.43	12.77±3.49	6.64±4.03	4.36±1.12	4.28±1.63	5.75±3.69	2.71±0.79	3.22±0.71	2.54±1.03	2.97±0.21	3.23±0.67	11.83±5.40
POPFL	10.21±4.06	5.260±7.75	12.61±4.55	22.99±4.53	13.03±6.98	8.55±2.10	8.50±2.92	13.55±4.20	5.37±1.40	9.94±2.24	5.04±1.87	8.50±0.89	8.50±0.89	23.30±5.48
POAFL	3.81±2.05	2.65±3.03	3.66±1.21	8.29±3.15	6.03±3.34	4.13±1.09	4.15±1.65	6.97±2.32	3.57±1.16	3.95±0.70	3.40±1.54	2.67±0.71	2.30±0.46	9.17±4.01
CPL	3.38±1.06	1.81±2.21	3.25±1.34	6.52±1.63	5.67±2.85	3.47±0.66	3.53±0.99	2.76±0.91	1.65±0.59	3.28±0.55	1.56±0.76	2.63±0.68	2.23±0.15	6.97±2.40
CPD	2.28±0.91	2.30±1.47	2.32±0.90	4.72±1.37	1.76±0.72	1.01±0.43	1.05±0.64	2.30±0.80	0.72±0.24	1.98±0.43	0.68±0.29	1.43±0.85	1.10±0.30	3.83±1.10
SNAD	11.41±2.31	7.729±2.39	14.63±1.92	21.91±2.84	12.24±6.27	7.08±1.46	7.10±2.02	12.49±4.02	6.04±1.14	10.24±2.03	5.64±1.52	11.20±0.80	11.63±1.10	21.93±4.72
DPFD	6.34±2.59	5.0±4.05	7.19±1.80	12.84±3.72	7.29±4.41	4.49±0.93	4.48±1.28	7.77±2.10	3.85±0.68	6.41±1.26	3.70±0.90	6.93±0.83	7.20±1.06	14.43±4.71
DAD	4.18±2.34	3.85±3.77	4.92±1.16	9.84±2.79	4.40±1.93	1.51±0.62	1.58±0.92	4.30±1.75	1.52±0.47	3.96±0.84	1.42±0.60	3.27±0.50	3.53±0.64	8.80±2.61
DB	5.40±2.72	5.02±3.15	6.41±0.92	11.92±2.55	5.53±2.60	3.06±0.97	3.08±1.35	5.30±2.06	2.11±0.54	4.94±0.85	1.98±0.72	4.93±0.25	5.37±0.99	11.07±3.20

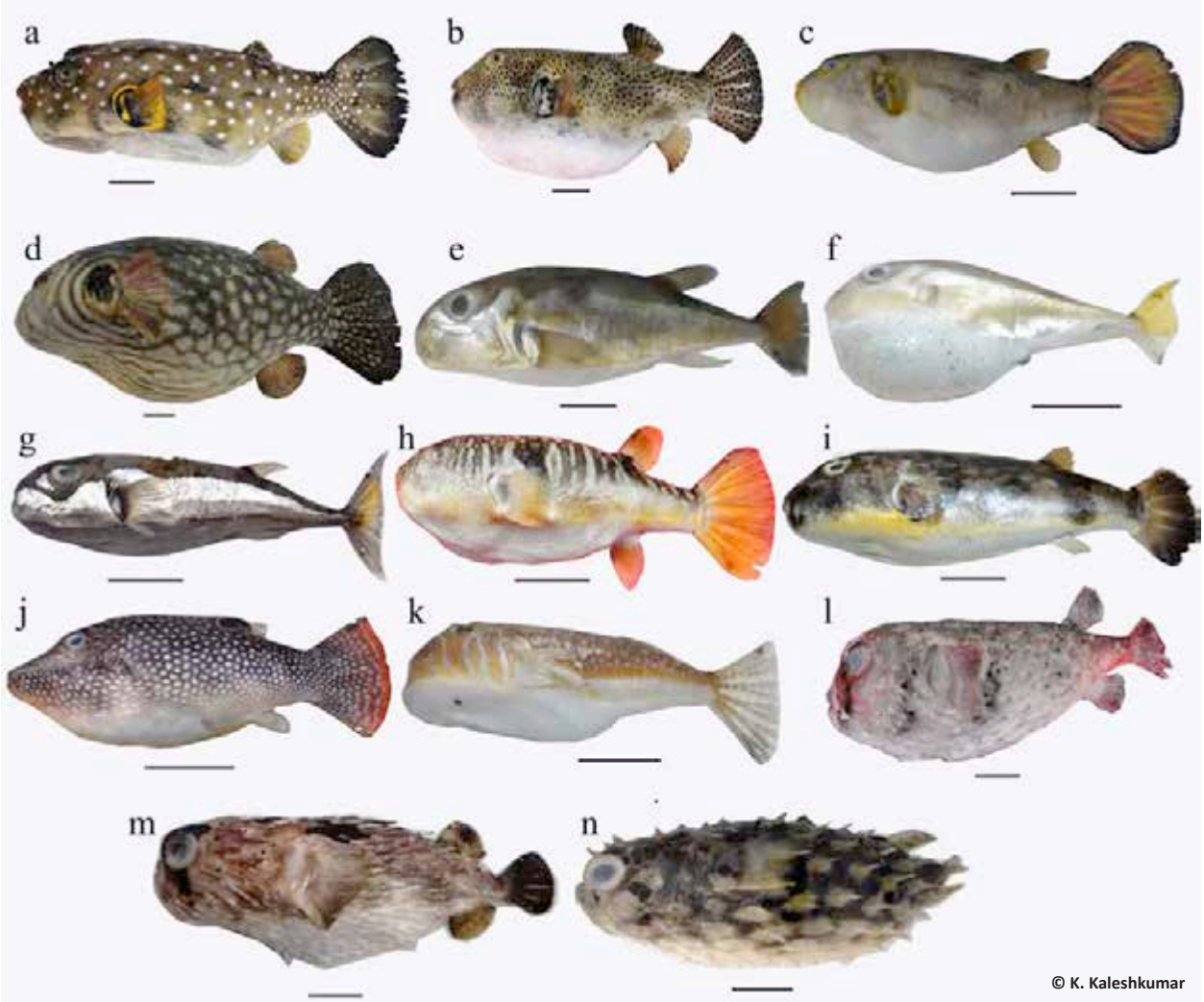

Image 1. List of identified marine Pufferfish & Porcupinefish from southeastern India.
Tetradontidae: a - *Arothron hispidus* (Linnaeus, 1758), b - *A. stellatus* (Anonymous, 1798), c - *A. immaculatus* (Bloch & Schneider, 1801), d - *A. reticularis* (Bloch & Schneider, 1801), e - *Logacephalus guentheri* (Miranda Riberio, 1915), f - *L. lunaris* (Bloch & Schneider, 1801), g - *L. sceleratus* (Gmelin, 1789), h - *Takifugu oblongus* (Bloch, 1786), i - *Chelonodon patoca* (Hamilton, 1822), j - *Canthigaster solandri* (Richardson, 1845) & k - *Torquigener brevipinnis* (Regan, 1903); Diodontidae: l - *Chilomycterus reticulatus* (Linnaeus, 1758), m - *Diodon holocanthus* (Linnaeus, 1758) & n - *Cylichthys orbicularis* (Bloch, 1785). Scale = 10mm.

Morphometric variations of Tetraodontidae & Diodontidae

The first two DF showed a cumulative value (77.7%) of the total morphological variations on the family of Tetraodontidae (Table 6). Moreover, all the loadings on DF1 (50.0 %) showed negative allometry. DF2 described 27.7% of the total variance with negative allometric growth and the characters MGL, HL, PRAFL, PRNL, CPD, SNAD, DPFD, DAD & DB were loaded heavily. Bivariate plot of DF1 and DF2 scores revealed the separation of *Lagocephalus* & *Canthigaster* and close relationship between *Arothron*, *Takifugu*, *Torquigener* & *Chelonodon* (Fig. 4). Also, significant results were observed in MANOVA too (Table 7 & Fig. 4).

Two DF were extracted from the family Diodontidae, exhibiting 95% of the total morphological variation. Probably all the characters show negative allometry and a few characters were noticed heavy loading on DF1 & DF2 (SNL, INL, DFBL, AFBL, POPFL, POAFL, LCPL, CPD & SNAD) (Table 8). Finally, the morphometric characters are showed the ability to discriminate the species in families of Tetraodontidae & Diodontidae. The detailed discriminate function was represented in Table 9 & Fig. 5.

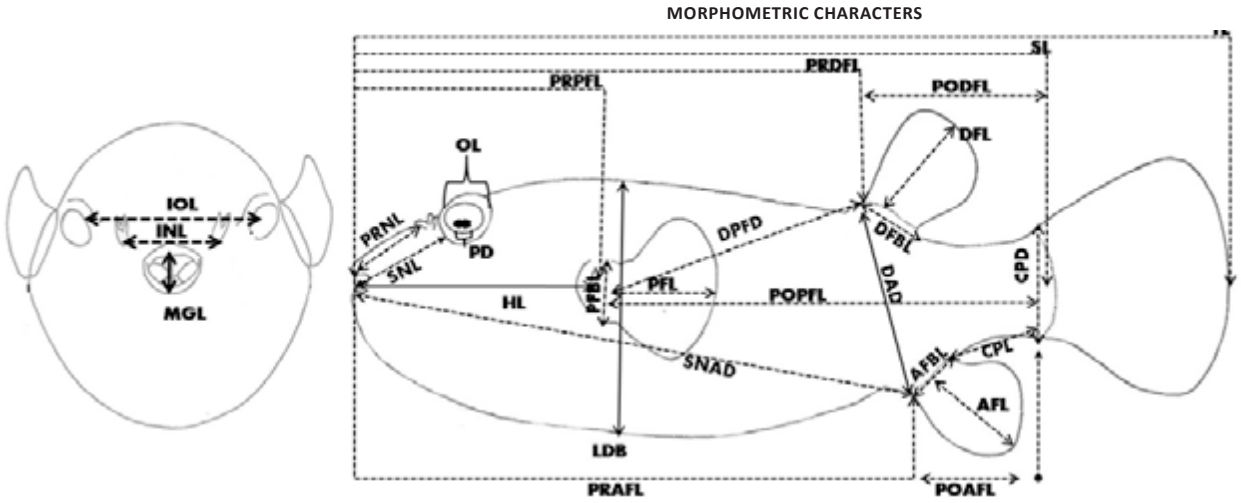

Figure 2. Typical Truss Morphometric Network (TMN) of marine Pufferfish & Porcupinefish.

Table 2. Meristic difference of marine Pufferfish & Porcupinefish from southeastern India.

Species	Meristic characters			
	PFR	DFR	CFR	AFR
Pufferfish (Family: Tetradontidae)				
Arothron immaculatus	21–22	13–14	14–15	12–13
A. reticularis	14–15	10–11	10–11	10–11
A. hispidus	16	11	9	8
A. stellatus	20	12	9	11
Lagocephalus guentheri	21–22	13–14	14–15	12–13
L. sceleratus	15–16	10	11–12	12
L. lunaris	15–16	10	11–12	12
Takifugu oblongus	16–17	12	12	11–12
Torquigenerbrevipinnis	17–18	9–10	7–8	7–8
Chelonodon patoca	15–16	10–11	10–11	10
Canthigaster solandri	17–18	9–10	7–9	7–9
Porcupinefish (Family: Diodontidae)				
Diodon holocanthus	21–22	9–11	8–9	13–14
Cyclichthys orbicularis	21–22	10	9–10	12
Chilomycterus reticulates	19–20	12–13	11	10–11

DISCUSSION

In the present study, the family Tetraodontidae (*Lagocephalus guentheri, L. sceleratus*, *L. lunaris*, *Arothron immaculatus*, *A. reticularis*, *A. hispidus*, *A. stellatus*, *Chelonodon patoca*, *Torquigener brevipinnis*, *Canthigaster solandri* & *Takifugu oblongus*) and Diodontidae (*Diodon holocanthus*, *Cyclichthys orbicularis* & *Chilomycterus reticulates*) were classified based on phenotypic appearance, and morphometric characters were adopted to identify the pufferfish and porcupinefish from the Indian coast. Also, those morphometric characters showed >70% of variation in the morphology. Similarly, Meng & Stocker (1984), Murta (2000) & Simon et al. (2010) noticed that the morphometric discriminant functions effectively classified individuals in fish species. Moreover, the same results were obtained by Mwita (2015). Additionally, these morphometric methods were more popular to reveal the stock differences in fisheries sectors.

The positive and negative values of allometric functions were able to show the taxonomic importance of the intra- and inter-species of the morphology (Meyer 1990; Mekkawy et al. 2002). Similarly, DF results confirmed that specific size and body shapes of various measurements are the determining taxonomic factors in morphometric identification. DF2 relating to the shape of the head regions of the fish separated the species of *Arothron* & *Lagocephalus* and genera of Tetraodontidae except for *Torquigener*. DF1 & DF2 more clearly separated *Cyclichthys* from *Chilomycterus*. The individuals of *Diodon* were not separated clearly, showing the close relationship to *Chilomycterus*. Also, *Torquigener* showed a close relationship to *Arothron* — these two members' results led us to reinvestigate the taxonomic status with molecular studies.

Previously, body shape and colouration characters were frequently used as distinguishing characters of these species. The present study has uncovered some morphological variation between the two closely related families, using multivariate techniques as reported in other marine fish (Pierce et al. 1994; Tudela 1999; Bolles & Begg 2000; Aktas et al. 2006; Mekkawy et al. 2011). This study demonstrates that Tetraodontidae from the southwestern

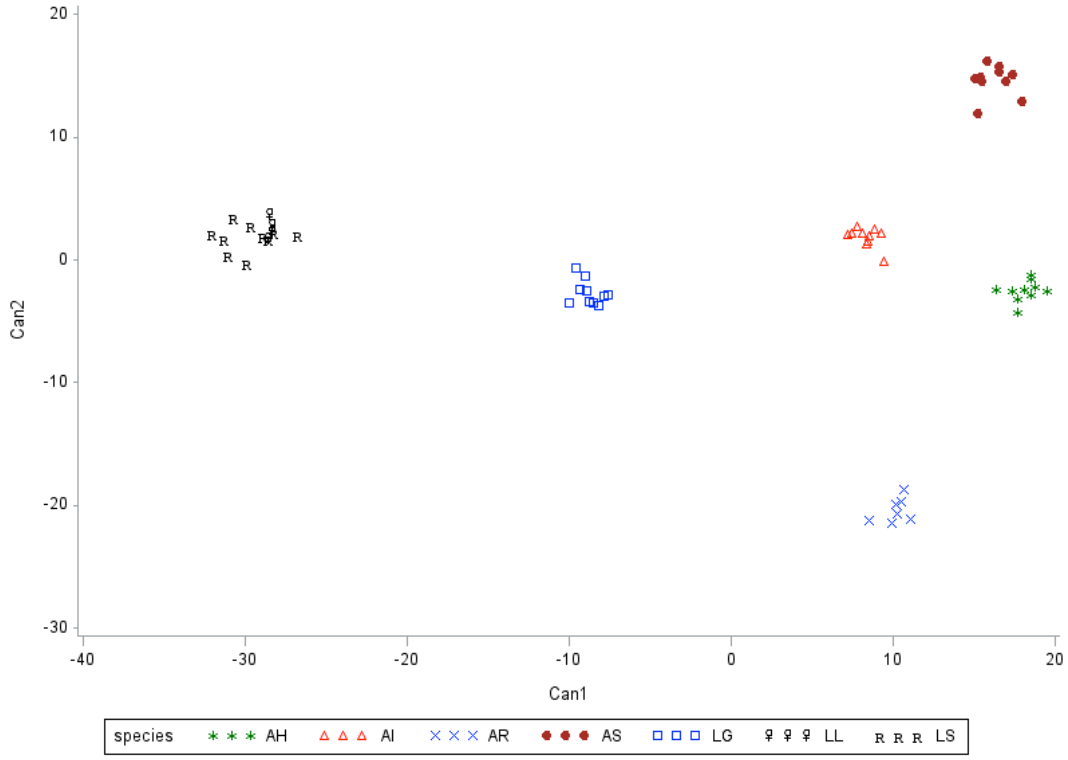

Figure 3. Scatter plot of first two factors from discriminant function analysis for *Arothron* & *Lagocephalus* from southeastern India (cumulative variations: 85%).

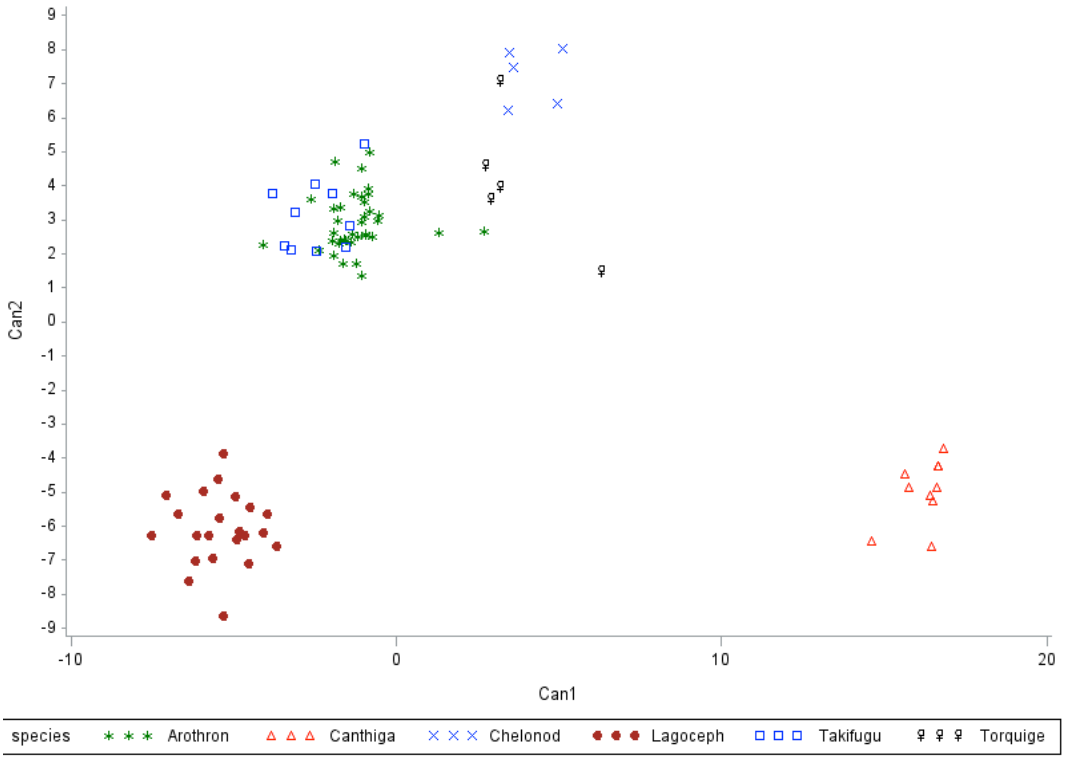

Figure 4. Scatter plot of first two factors from discriminant function analysis for Tetraodontidae from southeastern India (cumulative variations: 77%).

Table 3a. The relationship between all the characters and standard length of Tetradontidae from southeastern India, P<0.01.

Characters	*A. hispidus*			*A. immaculatus*			*A. reticulatus*			*A. stellatus*			*L. guentheri*			*L. sceleratus*		
	b	a	r^2	b	a	r^2	b	a	r^2	b	a	r^2	b	a	r^2	b	a	r^2
SNL	0.97	0.20	0.96	0.80	0.22	0.87	1.40	0.06	0.89	1.20	0.07	0.96	1.00	0.15	0.91	1.20	0.74	0.58
MGL	1.20	0.05	0.91	1.00	0.12	0.94	5.50	0.50	0.88	0.90	0.25	0.95	1.00	0.11	0.91	2.10	0.61	0.82
HL	0.94	0.33	0.96	0.90	0.37	0.90	0.80	0.55	0.99	1.10	0.27	0.95	0.74	0.61	0.84	0.90	0.27	0.85
OL	1.30	0.01	0.86	0.70	0.14	0.53	0.40	0.37	0.82	1.10	0.05	0.91	0.50	0.45	0.94	1.70	0.02	0.86
PD	1.50	0.01	0.81	0.80	0.10	0.84	0.40	0.27	0.80	1.10	0.02	0.02	0.50	0.27	0.78	1.50	0.03	0.56
IOL	1.00	0.15	0.97	1.00	0.15	0.90	0.90	0.25	0.98	1.40	0.04	0.87	1.00	0.15	0.93	2.60	0.00	0.91
PRNL	1.40	0.03	0.94	1.00	0.10	0.79	0.80	0.22	0.94	1.10	0.07	0.93	1.20	0.05	0.93	2.20	0.01	0.86
INL	1.80	0.01	0.89	1.20	0.05	0.79	0.90	0.14	0.91	1.20	0.03	0.91	0.72	0.25	0.91	2.40	0.00	0.71
DFBL	1.90	0.00	0.92	1.10	0.06	0.60	0.60	0.30	0.34	1.60	0.01	0.96	1.60	0.07	0.95	2.80	0.00	0.71
DFL	0.80	0.27	0.96	1.00	0.15	0.88	0.70	0.30	0.33	1.10	0.08	0.87	0.91	0.20	0.35	2.20	0.01	0.87
PFBL	1.80	0.01	0.87	1.40	0.04	0.93	0.80	0.18	0.98	1.10	0.07	0.09	1.03	0.09	0.94	2.60	0.00	0.70
PEL	1.00	0.11	0.94	0.70	0.33	0.66	0.90	0.33	0.96	1.00	0.10	0.97	0.69	0.45	0.91	1.90	0.03	0.86
AFBL	2.61	0.00	0.94	1.40	0.02	0.50	0.90	0.12	0.78	1.10	0.06	0.95	0.85	0.15	0.94	3.30	0.00	0.80
AFL	1.00	0.10	0.95	1.20	0.07	0.82	1.00	0.12	0.98	1.20	0.06	0.94	0.94	0.20	0.91	1.90	0.01	0.84
PRDFL	0.95	0.22	0.98	1.30	0.37	0.30	1.30	0.25	0.48	0.70	0.55	0.95	0.85	0.90	0.95	1.90	0.55	0.88
PRPFL	1.10	0.27	0.92	0.70	0.74	0.96	0.10	0.25	0.40	1.60	0.03	0.98	1.14	0.22	0.97	1.00	0.41	0.88
PRAFL	0.88	1.14	0.99	0.80	0.74	0.96	4.40	0.45	0.46	0.10	0.74	0.98	1.00	0.61	0.98	1.20	0.45	0.84
PODFL	1.30	0.09	0.96	1.10	0.22	0.89	1.10	0.27	0.57	1.30	0.15	0.98	1.04	0.31	0.89	1.70	0.07	0.90
POPFL	1.30	0.27	0.99	1.00	0.61	0.99	1.30	0.20	0.07	0.10	0.90	0.98	1.03	0.64	0.96	1.50	0.20	0.90
POAFL	1.20	0.09	0.94	1.30	0.11	0.85	1.00	0.22	0.50	1.90	0.02	0.99	0.89	0.42	0.84	1.60	0.08	0.95
CPL	1.50	0.03	0.96	0.80	0.41	0.98	1.20	0.10	0.94	1.10	0.15	0.96	0.92	0.37	0.83	1.00	0.30	0.95
CPD	1.20	0.06	0.96	1.00	0.14	0.97	0.90	0.27	0.90	1.40	0.05	0.97	0.71	0.25	0.62	2.60	0.00	0.82
SNAD	0.42	0.25	0.94	0.40	0.33	0.85	0.50	0.45	0.95	0.60	0.41	0.98	0.93	0.79	0.95	1.30	0.27	0.93
DPFD	0.82	2.61	0.91	0.80	0.74	0.83	0.90	0.50	0.89	1.40	0.14	0.98	0.95	0.50	0.95	1.30	0.27	0.92
DAD	0.80	0.50	0.96	1.10	0.18	0.93	1.10	0.25	0.98	1.40	0.09	0.93	0.81	0.43	0.83	2.40	0.00	0.83
DB	0.40	1.58	0.97	1.20	0.20	0.94	0.90	0.61	0.99	1.00	0.41	0.95	0.79	0.56	0.80	2.00	0.03	0.85

Table 3b. The relationship between all the characters and standard length of Tetradontidae from southeastern India, P<0.01.

Characters	*L. lunaris*			*T. oblongus*			*C. solandri*			*T. brevipinnis*			*C. patoca*		
	b	a	r^2	b	a	r^2	b	a	r^2	b	a	r^2	b	a	r^2
SNL	1.40	0.05	0.91	0.80	0.20	0.93	1.30	0.08	0.75	1.10	0.11	0.91	1.30	0.07	0.90
MGL	1.20	0.45	0.70	0.80	0.18	0.49	1.20	0.04	0.76	0.70	0.12	0.80	1.60	0.03	0.89
HL	0.80	0.33	0.88	1.20	0.14	0.91	1.20	0.15	0.95	1.40	0.30	0.96	0.70	0.67	0.92
OL	0.60	0.17	0.62	0.60	0.20	0.36	1.50	0.04	0.08	1.00	0.45	0.30	1.30	0.05	0.74
PD	0.60	0.74	0.71	0.40	0.27	0.67	0.90	0.08	0.25	0.50	0.07	0.93	0.80	0.11	0.95
IOL	0.50	0.74	0.78	1.30	0.07	0.97	1.30	0.08	0.90	0.50	0.25	0.93	1.30	0.07	0.93
PRNL	1.20	0.67	0.97	1.50	0.02	0.98	1.00	0.41	0.90	0.50	0.61	0.04	1.30	0.07	0.94
INL	0.40	0.15	0.63	1.30	0.04	0.95	0.70	0.15	0.67	1.10	0.50	0.44	1.70	0.02	0.89
DFBL	0.90	0.14	0.88	1.40	0.03	0.93	1.10	0.05	0.74	0.80	0.09	0.20	1.70	0.01	0.75
DFL	1.00	0.30	0.98	0.90	0.20	0.95	0.80	0.50	0.68	0.80	0.12	0.55	2.40	0.00	0.09
PFBL	0.70	0.33	0.98	1.20	0.04	0.95	0.70	0.14	0.55	0.90	0.45	0.99	2.00	0.01	0.87
PEL	0.70	0.22	0.85	0.70	0.33	0.93	1.90	0.02	0.08	0.90	0.14	0.99	1.80	0.02	0.89
AFBL	0.70	0.18	0.89	0.60	0.27	0.93	0.00	0.00	0.00	0.50	0.33	0.20	1.40	0.05	0.90
AFL	0.90	0.74	0.57	0.40	0.90	0.32	1.70	0.03	0.85	0.80	0.25	0.90	1.20	0.07	0.91
PRDFL	0.80	0.67	0.93	0.70	0.61	0.94	2.20	0.04	0.52	0.90	0.22	0.45	0.70	0.61	0.77
PRPFL	0.80	0.55	0.97	0.80	0.67	0.99	0.70	0.67	0.94	1.00	0.95	0.95	2.30	0.01	0.79
PRAFL	0.70	0.06	0.85	0.80	0.67	0.96	1.50	0.20	0.73	1.00	0.33	0.94	0.70	0.67	0.83
PODFL	1.50	0.50	0.97	2.10	0.01	0.90	1.10	0.25	0.95	0.70	0.67	0.90	1.40	0.50	0.89
POPFL	1.10	0.06	0.92	0.10	0.90	0.93	1.00	0.61	0.96	1.00	0.50	0.90	0.60	0.82	0.89
POAFL	1.40	0.12	0.94	1.10	0.30	0.98	1.30	0.20	0.96	0.50	0.61	0.53	0.50	0.94	0.88
CPL	1.20	0.07	0.92	0.10	0.14	0.97	1.30	0.09	0.96	0.60	0.97	0.92	0.80	0.45	0.95
CPD	1.20	0.09	0.95	1.10	0.09	0.96	0.50	0.20	0.14	0.80	0.25	0.97	1.30	0.07	0.86
SNAD	0.70	0.67	0.84	0.10	0.74	0.91	0.60	0.74	0.91	0.80	0.82	0.99	0.60	0.50	0.90
DPFD	0.90	0.67	0.93	0.80	0.74	0.93	0.60	0.99	0.95	0.80	0.74	0.84	0.70	0.82	0.86
DAD	0.90	0.20	0.92	1.30	0.11	0.97	1.20	0.12	0.94	0.80	0.50	0.93	1.20	0.18	0.80
DB	0.90	0.50	0.84	1.10	0.18	0.92	0.50	0.74	0.67	0.70	0.67	0.91	0.70	0.82	0.87

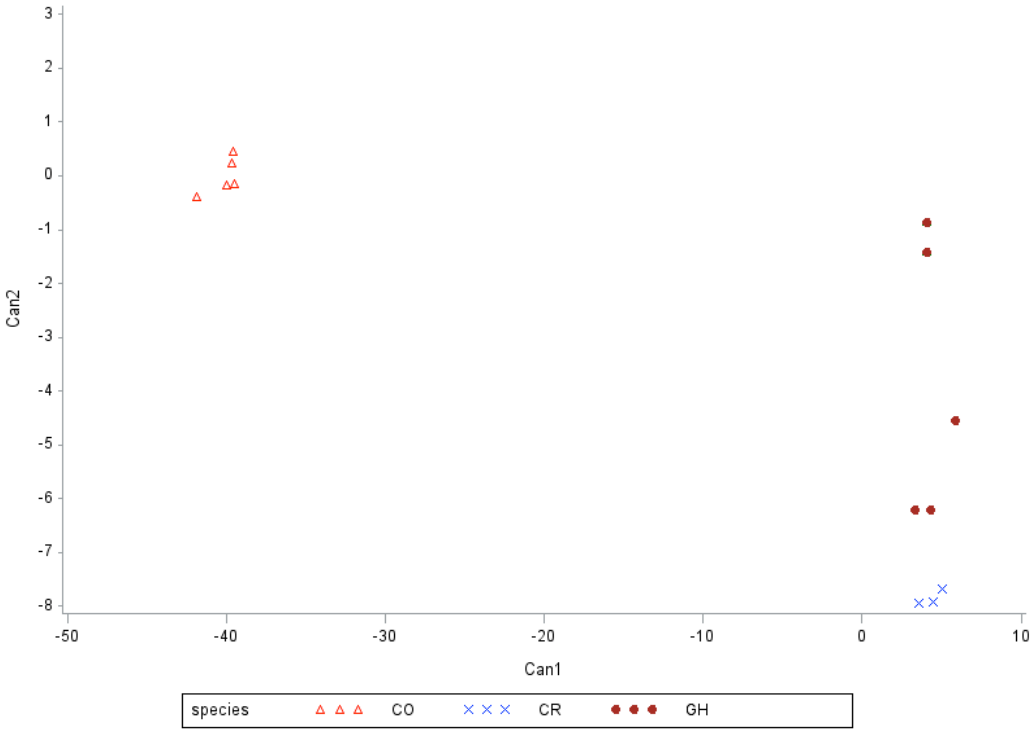

Figure 5. Scatter plot of first two factors from discriminant function analysis for Diodontidae from southeastern India.

Indian coastal waters are different from one another in morphometric characters. Statistical classifications using multivariate discriminant analyses were best for identification of the species of Tetraodontidae while morphometric characters provided comparatively less evidence of differentiation in Diodontidae.

Overall, morphological studies have been valid methods to identify the differences and to find out the relationship between different species and genera of pufferfish and porcupinefish. Also, these analyses will help to produce a better understanding of evolutionary studies with molecular markers.

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Table 4. Discriminant function analysis for *Arothron* & *Lagocephalus* — loading scores on the discriminant functions DF1 & DF2 and discriminatory power of morphometric characters Wilks' lambda (λ), F value & significance.

Variables	DF1	DF2	Wilks' lambda (λ)	F	Sig.
SNL	0.27767	-0.3457	0.577	6.604	0.005
MGL	0.51096	0.0186	0.718	3.527	0.000
HL	0.77027	0.19445	0.452	10.904	0.000
OL	-0.6579	0.19833	0.310	20.011	0.000
PD	-0.6266	-0.0158	0.489	9.403	0.032
IOL	0.48809	0.0053	0.781	2.522	0.000
PRNL	0.26549	0.12757	0.569	6.822	0.006
INL	-0.0079	-0.054	0.725	3.408	0.002
DFBL	0.05109	0.01338	0.684	4.155	0.001
DFL	0.03562	0.1024	0.679	4.262	0.017
PFBL	0.19747	0.16577	0.758	2.870	0.001
PEL	-0.7066	0.15675	0.666	4.515	0.009
AFBL	-0.0343	0.01229	0.738	3.195	0.004
AFL	0.10437	0.25586	0.710	3.679	0.000
PRDFL	0.09368	0.27503	0.600	5.993	0.014
PRPFL	-0.1662	-0.2831	0.751	2.984	0.217
PRAFL	0.38933	0.47538	0.862	1.439	0.000
PODFL	-0.0339	0.52274	0.518	8.373	0.000
POPFL	0.15219	0.66339	0.514	8.494	0.000
POAFL	-0.3403	0.41338	0.538	7.715	0.001
CPL	-0.4434	0.54312	0.653	4.791	0.000
CPD	0.74421	0.03476	0.577	6.607	0.000
SNAD	0.72037	0.52557	0.300	21.015	0.000
DPFD	0.50859	0.3704	0.295	21.483	0.000
DAD	0.83338	0.0651	0.489	9.387	0.000
DB	0.75468	0.16647	0.281	23.006	0.000

Table 5. MANOVA for Arothron & Lagocephalus from southeastern India.

	Multivariate Tests				
	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	4.944	4.846	174.000	180.000	.000
Wilks' lambda	.000	16.781	174.000	155.572	.000
Hotelling's trace	322.406	43.235	174.000	140.000	.000
Roy's largest root	196.515	203.291[a]	29.000	30.000	.000

Table 6. Discriminant function analysis for Tetraodontidae — loading scores on the discriminant functions DF1 & DF2 and discriminatory power of morphometric characters Wilks' lambda (λ), F value & significance.

Variables	DF1	DF2	Wilks' Lambda (λ)	F	Sig
SNL	-0.1301	0.19393	0.703	7.170	0.000
MGL	-0.4734	0.57841	0.773	4.982	0.000
HL	-0.2756	0.62793	0.489	17.800	0.000
OL	-0.1108	-0.5693	0.631	9.926	0.000
PD	-0.2476	-0.3415	0.818	3.778	0.004
IOL	-0.0282	0.486	0.744	5.851	0.000
PRNL	0.83839	-0.1381	0.717	6.697	0.000
INL	-0.1863	0.16984	0.743	5.889	0.000
DFBL	-0.4264	0.12681	0.799	4.276	0.002
DFL	-0.0065	-0.1592	0.720	6.619	0.000
PFBL	-0.366	0.14915	0.791	4.482	0.001
PEL	-0.4736	-0.3898	0.688	7.695	0.000
AFBL	-0.1924	-0.0013	0.699	7.326	0.000
AFL	-0.2902	0.04044	0.837	3.316	0.009
PRDFL	-0.3733	0.23676	0.775	4.924	0.001
PRPFL	-0.1618	0.09356	0.715	6.775	0.000
PRAFL	-0.3715	0.4519	0.757	5.465	0.000
PODFL	-0.2557	-0.1268	0.649	9.188	0.000
POPFL	-0.3095	0.25291	0.810	3.978	0.003
POAFL	0.06503	-0.2177	0.762	5.296	0.000
CPL	-0.4437	-0.2509	0.888	2.138	0.069
CPD	-0.3471	0.71149	0.708	7.027	0.000
SNAD	-0.1138	0.61576	0.776	4.919	0.001
DPFD	-0.0543	0.50741	0.614	10.699	0.000
DAD	-0.1211	0.70674	0.727	6.370	0.000
DB	-0.2455	0.6481	0.545	14.184	0.000

Table 7. MANOVA for Tetraodontidae from southeastern India.

	Multivariate tTests				
	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	7.394	5.870	290.000	600.000	.000
Wilks' lambda	.000	14.274	290.000	510.032	.000
Hotelling's trace	151.242	25.659	290.000	492.000	.000
Roy's largest root	44.754	92.595[a]	29.000	60.000	.000

Table 8. Discriminant function analysis for Diodontidae — loading scores on the discriminant functions DF1 & DF2 and discriminatory power of morphometric characters Wilks' lambda (λ), F value & significance.

Variables	DF1	DF2	Wilks' lambda (λ)	F	Sig..
SNL	-0.073	-0.483*	0.652	2.942	0.095
MGL	-.160*	-0.155	0.407	8.026	0.007
HL	-0.204	-0.340*	0.289	13.506	0.001
OL	-0.1	-0.331*	0.598	3.690	0.059
PD	-0.092	-0.275*	0.642	3.063	0.088
IOL	-.209*	-0.109	0.287	13.637	0.001
PRNL	-0.187	-0.392*	0.705	2.300	0.146
INL	-0.079	-0.479*	0.354	10.059	0.003
DFBL	-0.196	-0.509*	0.292	13.320	0.001
DFL	-0.164	-0.395*	0.553	4.443	0.039
PFBL	-0.194	-0.306*	0.221	19.356	0.000
PEL	-.194*	-0.13	0.512	5.249	0.025
AFBL	-0.145	-0.456*	0.337	10.813	0.003
AFL	-0.175	-0.290*	0.478	6.015	0.017
PRDFL	-0.147	-0.179*	0.527	4.940	0.029
PRPFL	-0.057	-0.366*	0.344	10.487	0.003
PRAFL	-0.183	-0.205*	0.386	8.751	0.005
PODFL	-0.298	-0.396*	0.654	2.910	0.097
POPFL	-0.195	-0.448*	0.432	7.235	0.010
POAFL	-0.167	-0.504*	0.779	1.565	0.252
CPL	-0.166	-0.511*	0.473	6.122	0.016
CPD	-0.362	-0.529*	0.454	6.618	0.013
SNAD	-0.239	-0.388*	0.268	15.011	0.001
DPFD	-0.273	-0.381*	0.327	11.317	0.002
DAD	-0.24	-0.356*	0.326	11.356	0.002
DB	-0.286	-0.323*	0.261	15.605	0.001

Table 9. MANOVA for Diodontidae from southeastern India.

	Multivariate tTests				
	Value	F	Hypothesis df	Error df	Sig..
Pillai's trace	1.670	1.013	20.000	4.000	.563
Wilks' lambda	.000	4.447[b]	20.000	2.000	.199
Hotelling's trace	679.540	.000	20.000	.000	.000
Roy's largest root	677.494	135.49[9]c	10.000	2.000	.007

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Tamil abstract:

தற்போதைய ஆய்வில், 14 வகையான மீனினங்கள், 2 குடும்பங்கள் (டெட்ராடொன்டைடே மற்றும் டியோடோண்டிடே) ஆகியவைகளை உடல் அளவியல் ஆய்வு செய்யப்பட்டன இதற்கான மாதிரிகளை இந்தியாவின் தென்கிழக்கு கடற்கரையில், தமிழ்நாட்டில் ஐந்து வெவ்வேறு மீன்பிடி மையங்களில் இருந்து சேகரிக்கப்பட்டன. இதற்கான மாதிரி சேகரிப்புகள் இரண்டு வருடங்கள் மேற்கொள்ளப்பட்டன. ஆகஸ்ட் 2014 முதல் ஜூலை 2016 வரை மாதாந்திர இடைவெளியில் அனைத்து மீன்பிடி மையங்களிருந்தும் எடுக்கப்பட்டன. இருபத்தி ஏழு உடல் அளவீடுகள் மற்றும் 4 மெரிஸ்டிக் எண்ணிக்கைகள் கொண்டு சேகரிக்கப்பட்ட மாதிரிகளில் அளவிடப்பட்டன. மேலும், கணிதவியல் ஆய்வுக்களான Discriminant Function Analysis (DFA) மற்றும் MANOVA பயன்படுத்தப்பட்டன. DFA ஆய்வின்படி, முதல் இரண்டு செயல்பாடுகள் மீனினங்களில் இடையே 75% க்கும் மேற்பட்ட வேறுபாடுகள் கண்டறியப்பட்டன. கூடுதலாக, DFA முடிவுகளை MANOVA ஆதரித்தது. மேலும், இது Tetraodontiformes-யை சேர்ந்த உயிரினங்களின் அதிக எண்ணிக்கையிலான உடற்கூறியல் அம்சங்களை விவரிப்பதற்கான முதல் முயற்சி ஆகும். குறிப்பாக, இந்த ஆய்வு டெட்ராடொன்டைடிடே (Tetraodontidae) மற்றும் டியோடோண்டிடே (Diodontidae) சார்ந்த மீனினங்களை கண்டறிய மிகவும் உறுதுணையாக இருக்கக்கூடும் என இந்த ஆய்வு பரிந்துரைக்கிறது.

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Possible range decline of Ganges River Dolphin *Platanista gangetica* (Mammalia: Cetartiodactyla: Platanistidae) in Indian Sundarban

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Abstract: Recent survey reports and observations from rivers in southern West Bengal (India) indicate the extirpation of Ganges River Dolphin (GRD) from the Indian Sundarbans. The present study undertaken during 2011–16 reviews the possible factors accountable for the disappearance of this obligatory freshwater cetacean from the major waterways of the Sundarbans, India and conclude that it is due to reasons of anthropogenic and geo-climatic origin. Sundarbans, the largest contiguous mangrove forest on earth encompassing almost 10,000km^2 of India and Bangladesh is located at the head of the Bay of Bengal within 21.533–22.666 ^{0}N and 88.083–89.850 ^{0}E, of which 62% lies within Bangladesh and 38% in India (Spalding et al. 2010). The landscape is a network of mudflats and islands at the deltaic mouth of the rivers Ganga, Brahmaputra and Meghna created by accumulated sediments carried by the snow-fed Himalayan rivers and their tributaries along with anastomosing tidal water channels. Historic reports reveal the occurrence of GRD in the Sundarbans waters of both India and Bangladesh (Anderson 1879). Current data, however, confirms the disappearance of *Platanista gangetica* but there is continued occurrence of *Orcaella brevirostris* in the Indian part of the estuary. Analysis of causative factors in light of existing evidence validates the potential extirpation of *Platanista* from the majority of the Sundarbans in India, except for its persistence in only the westernmost segment in the lower reaches of river Hooghly as confirmed by this study. The present study also records the habitat preferences and limiting factors affecting GRD distribution, and maps the decline of its range.

Keywords: Anthropogenic, freshwater, Hooghly, Irrawaddy, occurrence, river, Salinity.

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INTRODUCTION

The Ganges River Dolphin *Platanista gangetica gangetica* Lebeck, 1801 inhabits the river systems of the Ganga-Brahmaputra-Meghna and Karnaphuli-Sangu in Nepal, India and Bangladesh (Mohan 1995; Smith & Reeves 2000; Smith et al. 2001; Choudhary et al. 2006; Braulik & Smith 2017). Many river dolphin species are among the least known and endangered of all cetaceans (Hamilton et al. 2001).

Previous data on the status of Ganges River Dolphins in this unique estuarine water of the Indian Sundarbans is limited to historical reports (Anderson 1879; Jones 1982). In the past few decades, there has been no systematic and continuous survey of GRD in the Indian Sundarbans. The presence of GRD is doubtful in the Indian Sundarbans, as reported in the initial phase of a survey conducted by IUCN in 2014 (Wakid, A, 2017 pers comm). Mandal & Nandi (1989) reported the common occurrence of *Platanista* in estuarine waters of the Indian Sundarbans due to their entry from freshwater rivers. There was, however, no site specific data or any supporting image recorded. Surveys and observations carried out in the present study from West Bengal, India indicate that the current distribution of GRDs is confined to small pockets of habitat (Chowdhury et al. 2016). There has been no authentic record or observation of GRD in recent times especially in the central and eastern part of the Indian Sundarbans. Observations prior to this study were not clear about the range decline of Platanista in Indian Sundarbans, however, the present study confirms that GRD populations do not inhabit the waterways of central and eastern Sundarbans in India.

Nearly 9,630km^2 of area in the two districts of North and South 24 Parganas of West Bengal (Fig. 1) covering 1,692km^2 of core area, 2,233km^2 of buffer and 5,705km^2 of transition zone is presently known as the Sundarbans Biosphere Reserve (SBR). The extent of mangroves in the Indian Sundarbans has decreased over the past centuries, due to clearing of large tracts of forests and land reclamation for agricultural purposes. Currently the extent of the Sundarbans mangrove forest is limited to 4,264km^2 of SBR (Fig. 1) and the remaining landscape comprises of inhabited islands and human settlements in the adjacent mainland. Hydrological modifications like water diversion and commissioning of large barrages upstream has had a great impact on the salinity profile of the rivers downstream in central Sundarbans, which lose their freshwater supply for much of the year. The channels of the western segment (Hooghly and Muriganga) are hyposaline than in the 80s and 90s, primarily due to the increased amount of freshwater. Intrusion of marine phytoplankton species indicates the increased salinity profile in the central Sundarbans (Banerjee 2013). Surface water salinity has increased in central Sundarbans at a rate of 1.09 psu per year during 1984–2013 (Trivedi et al. 2016). According to Manna et al. (2010) salinity in the Sundarbans estuary ranges from 11–25 psu, being highest in the dry season and lowest in the wet season.

Recent work from the Bangladesh Sundarbans shows that the Ganges River Dolphins share their habitat with Irrawaddy Dolphins Orcaella brevirostris but that Irrawaddy Dolphin distribution extends further southwest and offshore into the saline coastal waters of the Bay of Bengal (Smith et al. 2006). The range of *Platanista* has declined since the 19th century when it was mapped by Anderson (1879) especially in the upstream reaches (Sinha et al. 2000; Smith et al. 2001). Sighting of Irrawaddy Dolphins is common in the Indian Sundarbans (Chakraborty & De 2007), however, there is no estimated count available so far.

The trans-boundary waters adjacent to Bangladesh Sundarbans is low in salinity (5–15 ppt) compared to other segments eastward in Bangladesh which are moderately saline (15–25 ppt) and hypersaline (25–30 ppt) as reported by the Centre for Environmental Geographic Information Services, Dhaka (CEGIS 2006; Hussain et al. 2013). Smith et al. (2009) recorded distribution of GRD is dependent on low salinity in the Sundarbans mangrove forests of Bangladesh. They reported the presence of GRD in waterways with a mean salinity of 0.00 ppt in the low water seasons (March) and around 6.00 ppt during the high water seasons (Sept/Oct).

In August 2010, a floating carcass of a Ganges River Dolphin was reported from the river Bidya flowing through the eastern part of the Indian Sundarbans and a similar incident was recorded earlier in June 2010 from Jhingakhali (Fig. 3). Bahuguna & Mallick (2010) reported the occurrence of GRD in river Ichchamati based on a previous survey undertaken in 2002. Sighting records of three Indo-Pacific Hump-backed Dolphins *Sousa chinensis* in the Gomor River close to Sajneakhali Wildlife Sanctuary (Saha & Palchowdhury 2008) and by B.D. Smith in 2002 on the Raimangal River on the Indo-Bangladesh border indicate the likely continued occurrence of these marine cetaceans in the eastern Indian Sundarbans. There is no consistent sighting record or evidence of the GRD population from the central and eastern segment of the Indian Sundarbans in the recent past. Occurrence has been recorded only in the water channels of the

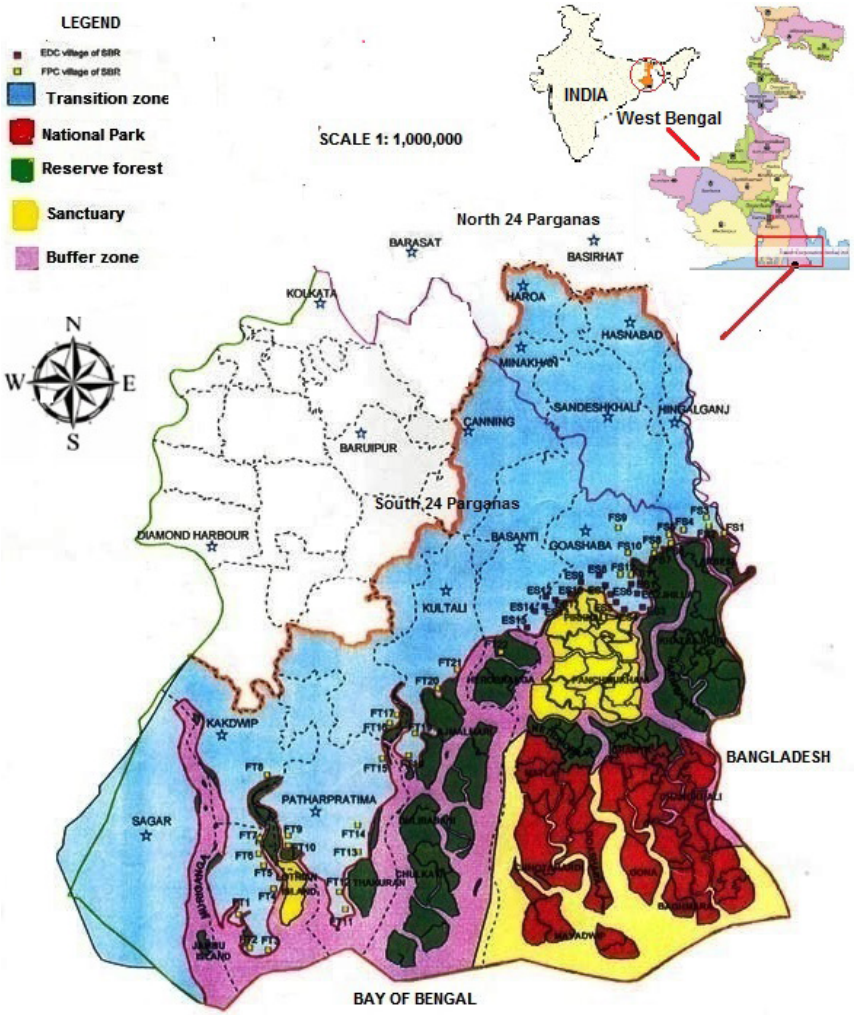

Figure 1. Map of Sundarban Biosphere Reserve

transition zones of SBR during 2015–2016.

Study Area

The present study was carried out in the river Hooghly, as the lower stretch is termed from the point where the Ganges meets with the river Jalangi at Nabadwip until it reaches the Bay of Bengal, eight tributaries of river Ganges upstream and also in the comparatively saline, estuarine creeks and channels of the Sundarbans in West Bengal, India (Fig. 2).

Selection of the river courses for survey was based on the secondary data collected from the literature review, interactions with communities presently residing along the river banks and primary data generated from direct observations and occurrence records of the Ganges River Dolphin in the last decade from the waterways flowing in this region. The coastline of southern West Bengal was avoided on the basis of less likelihood of sighting GRD and greater possibility of Irrawaddy Dolphins *Orcaella brevirostris* occurring in some channels and along the coast.

MATERIALS AND METHODS

Interviews

Secondary data, both on the occurrence and absence of GRD, was collected by conducting interviews with local boatmen and fishers who spend a considerable amount of time on the rivers during their day-to-day activities. A total of 251 respondents of all age groups including boatmen, fishermen, fish vendors from the local community, officials of the forest department, and tourists were interviewed about the frequency and seasonal pattern of dolphin sightings in last 10 years, recent and past records of entanglement in fishing nets, mortality records, availability of fish species, habitat preference, and human induced pressures, etc.

Figure 2. Location of Sundarban in the study area of West Bengal, India

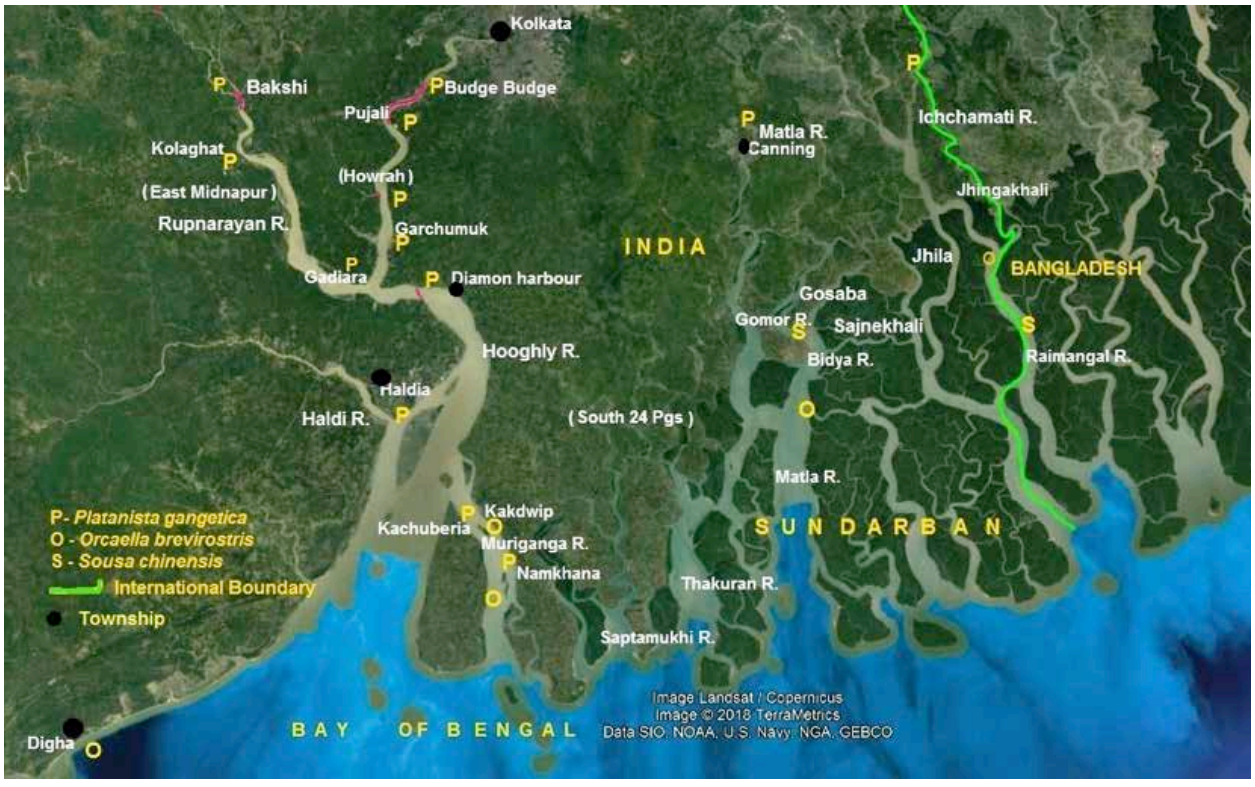

Figure 3. Occurrence records of *Platanista* (P) and *Orcaell* (O) from southern West Bengal

Boat-based surveys

A survey effort of a total stretch of 96.3km in rivers (Table 1) was utilized in selected channels of the Indian Sundarbans including visits to all segments in summer (March–June), monsoon (July–October) and winter (November–February) seasons during 2013–2016. The waterways were scanned in all the seasons to confirm the presence or absence of dolphins and to avoid any information gap due to seasonal differences. The observations following the method of Smith & Reeves (2000) were carried out by a team of 3–4 observers by sailing with the help of traditional country boats and mechanized boats as well, at a speed of a maximum of 5-8km/hr. Country boats of low height and comparatively higher mechanized boats with double decks were used. All encounters with dolphins and the respective geographical coordinates were recorded by a hand held GPS (GARMIN e-trex) and river depths measured by a hand held echo sounder. River width at specific locations was measured with the help of Google Earth imagery.

Land-based surveys

Point observations were made during 2012–2016 at different stretches of river Ganges, its tributaries and selected rivers and channels in the Sundarbans based on previous records of GRD. The observations were carried out by a team of 3–4 observers along the river banks or channels in summers, monsoons and winters. The observers watched the river courses from specific observation points on river banks for 7–9 hours, especially at confluences of rivers and stretches where there are regular sighting records of GRD. All land-based survey locations are shown in Fig. 1. All the sightings were confirmed by more than one observer. Photographs were captured in the areas with higher visibility of dolphins. River dolphins are extremely difficult to photograph, as the unpredictable surfacing of a solitary animal or two for a moment is difficult to capture. Wherever possible, images of surfacing GRD were captured and documented during the field observations to authenticate location, timing and records of the encounters. Digital photographs were taken using a DSLR camera Nikon D700, D300s with lenses of Nikkor 70-200 mm f/2.8 G ED VR II and Nikkor 24-70 mm f/2.8 G ED.

Monocular spotter (Bushnell) was used for better visibility in wider channels. Surface water salinity was obtained by using an optical refractometer and monitored every season in the study area at all focal points to understand the salinity preference of the GRD population in this region. Online Google Earth imagery was used for geo-referencing and plotting of the ground observation points recorded from the field.

Analysis

Platanista and *Orcaella* both inhabiting the Sundarbans waterways are often considered as a single species by the locals. Therefore the secondary information was verified and the taxonomic identity of both the species was confirmed by direct sighting, photographic records and official records obtained from the forest department. Sighting of dolphins in any channel for two consecutive years or more in different seasons during this study was considered to confirm their year round occurrence. Absence of records or direct observation of the live species in any season at any channel or river for a period of 10 years or more based on primary and secondary data has been considered as local extirpation. Salinity was recorded in low water and high water seasons to understand the minimum-maximum range and preference to specific salinity range was calculated based on the frequency of dolphins' occurrence in consecutive seasons.

RESULTS

Out of a total survey effort of 373.5km in different waterways of southern West Bengal, nearly 96.3km estuarine section in five channels of the western, central and eastern Sundarbans in India was studied every season during 2012–2016. This could not confirm the presence of GRD from the central and eastern segment.

The major congregations of GRD or sighting points in the lower stretch of the Hooghly and some of the confluences show a preference to a hyposaline (Table 2) environment. Sightings of GRD by boat and land-based surveys reflect that distribution of the species is affected by salinity.

Among the hydrological parameters recorded so far, surface water salinity was found to be a key factor influencing the distribution of GRD in the estuary. Encounter rate (sightings/hr) of GRD has been recorded at different salinity levels in a boat-based survey effort at the lower reaches of Hooghly. There has been no sighting record in the waterways wherever the salinity level crosses 10 ppt (Fig. 4).

The present study clearly indicates that the encounter rate of dolphins was consistent in all seasons mostly in hyposaline waters (<1 ppt) and in moderate salinity (1-10ppt) which occurs close to the estuarine mouth of Ganges. The absence of GRD at salinity >10

Table 1. Boat-based surveys in selected water channels in Sundarban

Section	River/ Channel	Survey length (km)	Sighting	Salinity range
Western	Hooghly	38	Y	<1.0–19 ppt
	Muriganga	14	Y	
Central	Matla	15	N	9.0–24.6 ppt
Eastern	Gomor	17	N	5.0–24 ppt
	Bidya	12.3	N	

Y - sighted, N - not sighted

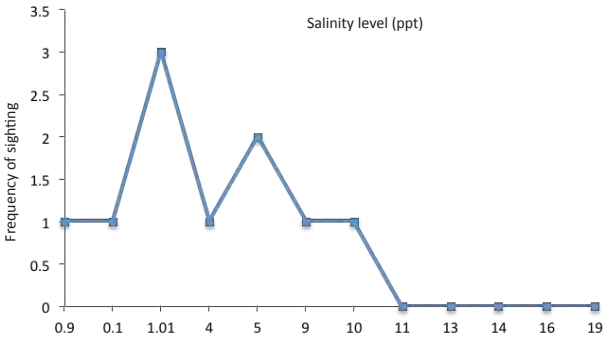

Figure 4. Encounter rate of GRD at different salinity levels from western Sundarban

Image 1. A pair of *Orcaella brevirostris* near eastern Sundarban, India

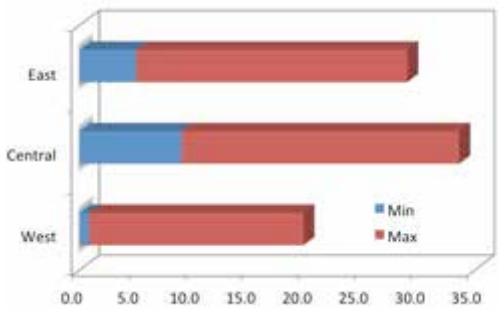

Figure 5. Average salinity range in different zones of Indian Sundarban

ppt, however, indicates that the dolphins do prefer lower salinities. Findings and sighting records in the present study shows a correlation between dolphin sightings and salinity which suggests that this is an important environmental factor influencing the distribution.

Significant increase in salinity levels were documented in the river Ganges in India after the commissioning of the Farakka Barrage. Five rivers namely the Saptamukhi, Thakuran, Matla, Gosaba, and Harinbhanga in central section (Fig: 2) of Indian Sundarban are also tidally fed and lost their upstream freshwater connectivity. Based on the current study, and historical records, there is no evidence that GRD occurs in the central section of the Sundarbans; however a group of Irrawaddy Dolphins (Fig: 4) was sighted in 2014 and also in 2016 in the central section (present study).

Salinity range varies on account of seasonal changes, fresh water flow and tidal influence (Fig. 5). The recorded salinity range from three zones in the Indian Sundarbans reflects a comparatively hypersaline central part, which is not preferred by the GRD. The eastern section is comparatively less saline upstream, however there is no sighting record in the present study.

The present study recorded the use of moderate to shallow depth (3.9–37 m) by GRD in the river Hooghly and its tributaries of southern West Bengal depending on seasonal flow in different channels having variable width from 88.39m - 4.3km.

DISCUSSION

The stretch selected in the present study so far is very limited compared to the span of this estuary. The likelihood of GRD occurring in the selected channels, however, was comparatively better than the other stretches downstream with higher salinity levels and no sighting records in the last decade. The GRD subpopulation occurring downstream of Farakka Barrage in the river Ganges and its tributaries in West Bengal was studied by Chowdhury et al. (2016). The present study confirmed the sightings of GRD in the western part of the Indian Sundarbans.

The study conducted so far indicates a possible decline in the range of *Platanista gangetica* in the Indian Sundarbans. Occurrence of the GRD in the river Hooghly, its tributaries and estuarine rivers depends on a combination of various factors. The geo-climatic

Table 2. Sightings of *Platanista gangetica* in lower reaches of river Hooghly and its tributaries

Land reference	District	River	Salinity (ppt)	Boat-based (B)/ land-based (L) Survey	Geographic Coordinates	Year
Budge budge river side	South 24 Paraganas	Hooghly	0	B, L	22.483^{0}N & 88.183^{0}E	2015
Bata nagar	South 24 Paraganas	Hooghly	0	L	22.500^{0}N & 88.200^{0}E	2015–16
Pujali	South 24 Paraganas	Hooghly	0	L	22.466^{0}N & 88.150^{0}E	2015
Millenium park	Kolkata	Hooghly	0	B	22.550^{0}N & 88.031^{0}E	2014–15
Diamond Harbour	South 24 Paraganas	Hooghly	0	B, L	22.160^{0}N & 88.017^{0}E	2015
Kachuberia	South 24 Paraganas	Muriganga	0	B, L	21.850^{0}N & 88.133^{0}E	2015–16
Namkhana	South 24 Paraganas	Confluence of River Muriganga and Hatania-Doania	1.01–9.0	B	21.750^{0}N & 88.210^{0}E	2015–16
Gadiara	Howrah	Confluence of Rupnarayan and Hooghly	0	B, L	22.216^{0}N & 88.033^{0}E	2012–15
Haldia	South 24 Paraganas	Confluence of Haldi and Hooghly	0	L	22.000^{0}N & 88.050^{0}E	2012
Garchumuk	Howrah	Confluence of Damodar and Hooghly	0	L	22.333^{0}N & 88.080^{0}E	2012–2015
Bakshi	Howrah	Confluence of Rupnarayan, Damodar and Mundeshwari	0	L	22.510^{0}N & 88.016^{0}E	2014–15
Kolaghat	East Midnapur	Rupnarayan	0	B, L	22.416^{0}N & 87.883^{0}E	2011–15
Belur	Howrah	Hooghly	0	L	22.616^{0}N & 88.350^{0}E	2015

Table 3. Recorded Salinity data and occurrence of *Platanista gangetica*

	Zone	Salinity Level	Occurrence of *Platanista*
1	River Ganga, Hooghly & tributaries	<1–1.014 ppt (present study)	Recorded in all the stretches (observation from nearly a total of 300km except the estuarine part in the present study)
2	Tidal lower reaches of Hooghly and Muriganga River	1–19 ppt (present study)	Occurrence in the salinity level up to 10 ppt (present study)
3	Rivers in Central and Eastern Sundarban	9–26.59 ppt (Mitra et al. 2010) 5–24.6ppt (present study)	Not recorded (present study)

factors gained prominence in all recent studies, more so because of climate change and the subsiding delta complex in the Ganga River Basin, which has a geotectonic evolutionary history. The decline of *Platanista* in the Indian Sundarbans, however, may be attributed to the combined effect of increased sedimentation, reduced freshwater discharge and increased salinity. It has been observed that the salinity level has a marked influence on the distribution of GRD in the Sundarbans. Salinity in this deltaic system is influenced by the combined action of the following factors:

1) Natural salinity level of the rivers is regulated by evaporation and recharge by rainwater as well as tidal flow downstream.

2) Both the glacial melting and sea level rise due to climate induced changes affect the salinity level.

3) Anthropogenic factors like reduced discharge from barrages, runoff from adjacent lands, and water abstraction for irrigation etc.

4) The estuarine channels in the Indian Sundarbans at present are mostly fed by tidal flow and have lost their freshwater connectivity.

Primary and secondary data on surface water salinity obtained from Sundarbans in West Bengal, India show three distinct salinity zones in the Indian Sundarbans (Trivedi et al. 2016).

Table 4. Recent sightings of *Orcaella brevirostris* in West Bengal (India)

Land reference	District	River/ coast	Geographic Coordinates	Year	Observation from	Source
Kakdwip (Steamer Ghat)	South 24 Paraganas	Hooghly	21.850^{0}N & 88.166^{0}E	2012–13	River bank	Present study
Namkhana-Narayanpur	South 24 Paraganas	Hatania-duania	21.750^{0}N & 88.216^{0}E	2012–13	Boat	Present study
Sundarban	South 24 Paraganas	Bidya	21.933^{0}N & 88.700^{0}E	2016	Boat	(pers. comm)
Digha coast	West Medinipur	Bay of Bengal	21.616^{0}N & 87.500^{0}E	2014	Land	Present study

Image 2. Incidental mortality due to river traffic in Kolkata

Image 3. Watercrafts in the movement route of dolphins on River Hooghly

In the present study, GRD has been recorded only in the hyposaline zone in western Sundarbans, which includes the flow of the river Ganges, Muriganga and Saptamukhi rivers (Figs. 2 & 3). The lower stretch of the Ganga in Southern West Bengal receives snow melt and monsoon fed river water from upstream but that is only the discharge allowed through the Farakka Barrage. Occurrence of *Platanista* was recorded in this section up to a maximum salinity of 10 ppt. Salinity recorded from this zone in the present study varied between <1.0–19 ppt depending on seasonal fluctuation.

Hypersaline zone in the central part lost the connectivity with upstream freshwater flow. Siltation and clogging of some channels in the late 15th century and thereafter completely deprived this central sector from freshwater flow (Choudhuri & Chaudhury 1994). Takhuran, Matla and Gosaba are the major waterways in this segment (Fig. 2). There has been no recent sighting record of GRD from this segment.

The eastern most part of the Indian Sundarbans having freshwater connectivity with river Padma of Bangladesh is moderately saline. The trans-boundary waters adjacent to Bangladesh Sundarbans are low in salinity (5–15 ppt), but it increases downstream and the southwest part of Bangladesh Sundarbans is hypersaline. There has been no sighting of *Platanista* reported in recent times or recorded in this study from this zone.

Biodiversity loss in the Sundarban waterways due to the cumulative effects of changing weather patterns, subsidence and reduced freshwater input due to dams and diversions have not been discussed much, however, these factors changed the salinity dynamics of the region (Raha et al. 2012). The reduced freshwater supply not only led to higher river water salinity, but the aquatic subsystem was significantly altered, resulting in a sharp decline in the fish varieties from the central tracts of the Sundarbans (Mitra et al. 2010). All of these may have certainly influenced an obligate freshwater species like *Platanista* and the present study recorded a similar finding. Smith & Braulik (2017) postulated that GRD are not commonly found in salinities greater

than 10 ppt. The findings from the present study conforms with the fact opined by Jensen et al. (2013) that distribution limits of GRD is related to its preference of low salinity in the water channel. The present study clearly indicates that the encounter rate of dolphins was consistent in all seasons mostly in hyposaline waters (<1 ppt) and sometimes in moderate salinity (1–10ppt) close to the estuarine mouth of the Ganges. However, the disappearance of GRD from channels due to increased salinity >10 ppt strongly confirms its preference to low salinity. Findings and sighting records in the present study reveal that distribution of GRD is directly influenced by the salinity level of the waterways.

At the northeastern edge of the mangrove forest in Bangladesh, there has been increase of salinity and decline in river flow of the Ganges. Increased sedimentation due to reduced discharges also contributed to the gradual drying up of tributaries (Smith et al. 2009). Smith et al. (2007) opined that the upstream range of Irrawaddy Dolphins in Bangladesh Sundarbans is more affected by interspecific competition with GRD than by any dependence on a particular salinity. Irrawaddy Dolphins also co-occur with *Platanista gangetica* in a relatively small portion of their range in the Sundarbans mangrove forest (Smith et al. 2006). In India, it needs further study to confirm if there is any interspecific competition or range overlap of both the species in this mangrove region. Present findings indicate the suitability of hyposaline stretches for GRD and areas with salinity level >5 ppt for Irrawaddy dolphins.

In a study by Choudhary et al. (2012) the minimum mid-channel depth requirements were estimated at 5.2m for dolphin adults and between 2.2m and 2.4m for mother-calf pairs. The channel depth and width recorded under the present study find that the channels and creeks of the Indian Sundarbans are suitable for Ganges River Dolphins.

Dolphins depend on freshwater fishes. River Hooghly and estuarine waters in the Sundarbans are intensive fishing zones. Around 94–95 % of the Hilsa, an iconic fish *Tenualosa ilisha* in this sub region are captured by drift gill nets in the lower stretch of the Hooghly estuarine system (De 2014). These nets have a direct or indirect impact on the availability of fish in the river. Fishermen have reported that dolphins target fisherman's nets under water in search of prey. It was reported that dolphins directly collect fishes from fishing nets and also damage the nets. However, entanglement in fishing nets was also recorded by local fishermen in Diamond Harbour, Garchumuk and Raghunathpur near Farakka. Fishing nets increase vulnerability of dolphins to entanglement, however the present study didn't have the scope to establish the relationship of overfishing and use of unsustainable fishing gear with the non-occurrence of GRD in comparatively low saline water stretches of eastern Sundarbans.

Choudhury & Mitra (2014) reported the unsustainable use of fishing gear in the river Hooghly and its tributaries contributing to the loss of many fish varieties, especially their breeding grounds. Fishing is a common livelihood for the communities living in the Sundarbans or elsewhere in southern West Bengal. Exploitative fishing practices in many channels and use of destructive fishing gear contribute to the decline of fishes and incidental mortality of dolphins due to entanglement of dolphins in fishing nets. The most abundant gear observed in a survey at the lower reaches of Hooghly was the bottom set bag net (behundi jal) which accounted for nearly 98% of all gears recorded. Other gears were drag net, cast net along with a small percentage of hook and line fishing. The bag net is made of mosquito net and is mainly used to collect shrimps and their larvae. These nets are set in series across the river in many places obstructing the movement of dolphins. Mansur et al. (2008) has also cited incidents of entanglement of *Platanista* in the fishing nets in Bangladesh Sundarban.

Decline in fish variety and reduced wild catch prompted the fisher folks to look for other alternatives to compensate the economic loss. Establishment of brick kilns (10–11 / km) along river banks and sand or soil collection from riverbeds (8–9 boats/ 2–3 km stretch of river) in prolific quantity are recent practices that damage the riverfront and directly interfere with the fluvial habitat of river dolphins. These are more prominent in the main course of the Hooghly and its tributaries. All of these potential anthropogenic threats have been discussed by Chowdhury et al. (2016). Almost 70% of the respondents were unable to differentiate between different cetacean species, which often generates a generalized idea about the existence of GRD in the Sundarbans. Only confirmed sightings, however, have been considered in this study.

Relationship of dolphins with the fisher folk and the effect of underwater noise from the motorized boats are not favourable for dolphins. An encounter rate of 0.35 dolphins/km was recorded from the western part of the Indian Sundarbans. This rate was proportionately higher by around 55% in stretches of the rivers with limited use of motorized boats, less river traffic and more use of country boats; however, Kelkar et al. (2010) in his study on the habitat use and distribution of the Ganges River

Dolphin, opined that the number of motorised boats and boat noise were not significantly correlated with dolphin encounter rates. Motorised boats in good number (10–25/hr) travel at an average speed of 6–10km/hr across the dolphin movement route in different segments of the major rivers in South Bengal and near the inhabited islands of the Sundarbans. It is likely that underwater noise does affect the behavior of dolphins, which rely on sound for sensing of the environment. In Mahakam River of Indonesia, Irrawaddy dolphins dive for longer periods and avoid river traffic (Kreb & Rahadi 2004). Their study also highlighted the risk of vessel collision and impact of underwater noise pollution.

It was beyond the scope of this study to conclude that unsustainable fishery practices and underwater noise have a direct impact on the GRD population of the Sundarbans; however, salinity profile in different parts of the Indian Sundarbans, continued disappearance of Ganges Dolphin there along with its occurrence in hyposaline western segment indicate that the present habitat in the Indian Sundarbans may not be preferable to Ganges River Dolphins and none of the recent evidences indicate the existence of a population of GRD in most of the waterways of this estuary. Chowdhury et al. (2016) reported the confinement of the species in isolated pockets. Braulik & Smith (2017) reported non availability of information on the status of Ganges River Dolphins in the Indian Sundarbans. All secondary information or records of historical evidence indicate the existence of dolphins in estuarine channels of the Indian Sundarbans similar to the presence of GRD in the Bangladesh Sundarbans. Unlike Bangladesh, however, there has been no systematic and continuous survey on GRD in the Indian Sundarbans. In this context, the distribution of GRD in the Indian Sundarbans has been reviewed and visual surveys in this study and contemporary survey/observations by other workers indicate a restricted distribution of GRD in the westernmost part of the estuary at present. The decline of GRD population in the Indian Sundarban needs to be substantiated with further study, however the reduced freshwater flow in the channels and gradual rise of salinity clearly suggest a habitat unsuitability for GRD in this estuary. The extent of the former range of the species in light of previous records has definitely changed, but that has happened over a considerable time period while the waterways/channels have been losing their freshwater connectivity and some others have been drying up. Intensive study and long term survey data on this species in the Indian Sundarbans could further substantiate the viewpoints presented here.

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COMMUNICATION

Retrospective study on epidemiology of snakebites in Sarpang District, southern Bhutan

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Abstract: Although snake bite envenomation is considered as a medical emergency with significant morbidity and mortality, accurate figures on snakebite envenomation remains scarce. We conducted a retrospective study to evaluate the snakebite epidemiology in Sarpang District located in the subtropical zone of southern Bhutan. In this study, 78 snakebite cases treated in Gelephu Referral Hospital over a period of three years from 2013 to 2015 were evaluated based on the statistical record maintained by the medical administration. Twenty-eight (35.89%) cases developed signs and symptoms of envenomation and the remaining 50 (64.01%) were found to be cases of non-venomous bites. Forty-four males and 34 females were found to be affected by snakebites within the period. While snakebites were observed in all age groups, the large majority (n=51, 65.38%) were in adults aged between 21 and 50 years. Most of the venomous bites (68%) occurred during the monsoon season, particularly between May and August. It was found that adults in the economically productive age group were the ones most affected by poisonous bites. There is an urgent need for development and adoption of snakebite management guidelines and awareness among the vulnerable sections of the population, improvement of medical facilities in referral hospitals and rural health centres, and reduction of the morbidity and mortality associated with snakebites.

Keywords: Bhutan, envenomation, epidemiology, Sarpang District, snakebite, venomous snakes, victims.

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Author Contribution: BKK - data collection, data analysis, and manuscript writing; JK - contributed in data collection, and data compilation; SS - data compilation, manuscript writing and editing.

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INTRODUCTION

Since the dawn of human civilization, snakes have appeared in many tales and myths as they are deeply rooted in man-human tradition and culture. Despite snakes having occupied an important place in ethnozoology, snakebite envenomation is an important and life-threatening medical emergency. Snakebite is one of the most neglected public health issues in poor rural communities living in the tropics (Alirol et al. 2010). Southern Asian, southeastern Asian, and sub-Saharan African countries are the regions with the highest number of snakebite cases (Kasturiratne et al. 2008). It has been estimated that 4,000,000 snakebites occur each year in Asia alone, of which approximately 50% are envenomed, resulting in 100,000 annual deaths (Chippaux 1998). The existing epidemiological data, however, remain limited and the actual impact of snakebites is very likely underestimated. The current literature on snakebite epidemiology highlights the inadequacy of the available data on this neglected tropical injury (Warrell 2010). Moreover, this is the first snakebite epidemiological study in Bhutan as the existing epidemiological data on snakebites in Bhutan remain limited. Fatal injuries from snakebites are principally caused by a relatively small group of snakes, most of which are adapted to human-modified landscapes or live in close proximity to human inhabitations.

Among the 3,509 extant species of snakes in the world (Pincheira-Donoso et al. 2013), around 300 are venomous and 200 are medically important (Warrell 2010). In Bhutan, a total of 69 species belonging to five families are known to occur, out of which venomous snakes are represented by 15 species belonging to two families, Elapidae and Viperidae (Wangyal & Gurung 2017). The most commonly found venomous snakes include two species of krait *Bungarus niger* & *B. fasciatus*, three species of cobra *Naja kaouthia*, *N. naja* & *Ophiophagus hannah*, four species of viper *Ovophis monticola*, *Protobothrops himalayanus*, *Trimeresurus erythrurus* & *T. albolabris*, and one species of coral snake *Sinomicrurus macclellandi*. Among all 15 venomous snakes reported from Bhutan (Wangyal & Gurung 2017), only five species that are capable of delivering fatal injuries were observed in the present study location: *B. niger*, *B. fasciatus*, *N. kaouthia*, *N. naja*, and *O. hannah*.

Although the episodes of human mortality caused by snake envenomation are frequently reported in national news media and heard from oral testimonies of local people, it is difficult to know the actual number of morbidity and mortality of snakebites as these incidences are not systematically documented and studied in Bhutan. Very often, instead of going to the nearest hospital, villagers approach traditional healers who are often quacks. Though it is known that snakebites occur frequently in Sarpang District in the subtropical belt of southern Bhutan, the incidences are not documented despite the fact that the condition is a recognized medical emergency. Therefore, this study aimed to evaluate the human health issues associated with snakebite in Sarpang District through hospital-based statistics.

MATERIALS AND METHODS

Much of Sarpang consists of environmentally protected areas. Its far western region encloses a part of the uninhabited Phibsoo Wildlife Sanctuary along the India border. Northern Sarpang is part of the Jigme Singye Wangchuck National Park and its eastern and southeastern regions lie within the Royal Manas National Park. The district is divided into 12 local administrative blocks (Fig. 1).

The vegetation types here are characterized by subtropical broad-leaved forests with thick undergrowth. While its southern region is more or less topographically dominated by plains, gentle slopes dominate its northern region. The altitude ranges from 180 to 600 m and the annual rainfall varies from 2,500 to 5,500 mm with an annual average temperature of 23.8°C (National Statistics Bureau 2016).

The study was done retrospectively in Gelephu Referral Hospital (GRH) in Sarpang district, covering a three-year period (2013–2015). This government-owned hospital is situated near Gelephu Town and not only caters to the people of Gelephu alone but also acts as a tertiary care hospital and referral centre for four other districts of southern Bhutan, namely, Tsirang, Dagana, Zhemgang, and Pemagatshel.

All patients treated for snakebites in GRH (78 patients) from 2013 to 2015 were included in the study. Basic data such as cause for admission and dates of admission and discharge for each case were obtained from the general records kept in the administrative and recordkeeping sections of the hospital. The information was used to trace the relevant case files in the archives from which the necessary data were collected. In extracting data from the case notes, special consideration was given to the time and season of biting, the occupation, age and sex of victims, the species involved, if identified by medical personnel or mentioned in the record, and the

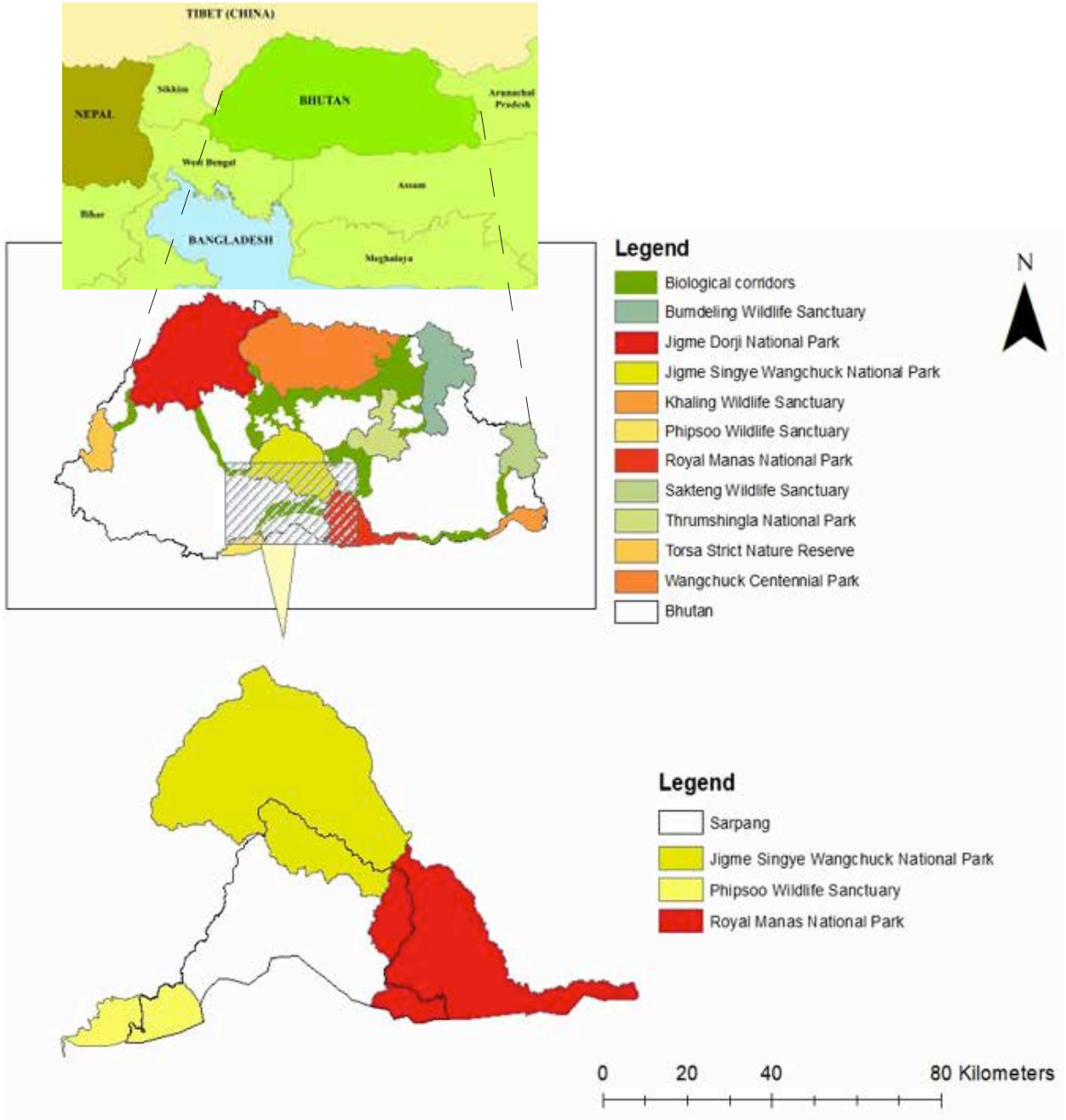

Figure 1. Map of the study area, Sarpang District in southern Bhutan

duration of stay in the hospital, if admitted. Information on clinical management of patients and types of anti-venoms administered were also recorded.

The overall data were classified into different categories: the number of victims under each specific age group, gender group, and outdoor and admitted patients. The age groups 1–20 and 61–70 years were classified as economically unproductive while the age -group 21–60 years was classified as economically productive based on the population structure of Bhutan.

Statistical analyses

Statistical tools such as the statistical package for the social sciences (SPSS) (version 16.0 For Windows) and Microsoft Excel 2010 were used to perform data analyses. An Independent sample t-test was performed to access the significance of the difference between both age and gender groups in relation to snakebites. A relative vulnerability with 95% confidence intervals was calculated for assessing the risk of snake bites by different characteristics of exposure.

RESULTS

In this retrospective study from June 2013 to July 2015, a total of 78 snakebite cases that were registered in GRH were analyzed (Table 1).

Out of the 78 cases registered, 28 (35.89%) developed signs and symptoms of envenomation and were admitted to the hospital for an extended period of time considering the magnitude of complication. The mean duration of the hospital stay was 3.85 days, ranging from two to 10 days. The remaining (n=50, 64.01%) patients received only outpatient treatment as the cases were not considered medical emergencies. While snakebite was observed in all age groups, the large majority of victims (n=51, 65.38%) were adults aged between 21 and 50 years (Fig. 2).

The outdoor patients (n=50) with minor snakebite injuries were kept under observation for a day or less to evaluate the manifestations of any clinical symptoms. Subsequently, the cases were verified, treated, and discharged.

Out of the 78 cases registered, 44 were of males and 34 were of females (Table 2). The results demonstrated that there was a slight difference between number of male and female victims (1.3:1, 56% vs 44%). An independent-samples t-test conducted to compare the vulnerability of gender groups to snakebites suggested that there was no significant difference between male (M=7.33, SD=2.80) and female (M=5.67, SD=3.93) victims; $t(10)=0.84$, $p>0.05$. On the other hand, statistical results suggest that there was a significant difference between the unproductive age group (M=0.94, SD=0.99) and the productive age group (M=2.54, SD= 0.97) in incidences of snakebites; $t(40)=-2.88$, $p<0.05$.

Out of the 28 cases of poisonous bites, the highest incidence (28.57%) of cases of envenomation occurred in the age range between 41 and 50 years while adults between 21 and 50 years accounted for 64.28% of the victims. Of the 28 hospitalized victims, two fatal cases were observed due to severe envenomation, which resulted in irreversible complications. The majority of snakes responsible for bites in the study were unidentified. The dvictims who succumbed to envenomation were suspected to be bitten either by kraits or cobras. Cobras and kraits are the two major groups of medically important species found in the study

Table 1. Age group and gender-wise distribution of snake bite cases (n=78) registered in Gelephu Referral Hospital, southern Bhutan

Year	2013		2014		2015		Total
Age- group	Male	Female	Male	Female	Male	Female	
1–-10	0	1	0	1	2	1	**5**
11–-20	3	2	1	2	0	2	**10**
21–-30	4	3	3	2	4	3	**19**
31–-40	3	2	5	2	3	2	**17**
41–-50	3	3	1	3	3	2	**15**
51–-60	2	1	2	1	4	1	**11**
61–-70	0	0	0	0	1	0	**1**

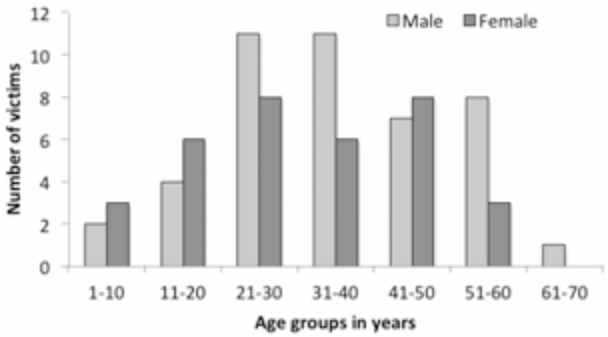

Figure 2. Age and sex distribution of the victims of snakebites in Gelephu Referral Hospital, southern Bhutan, during the study period

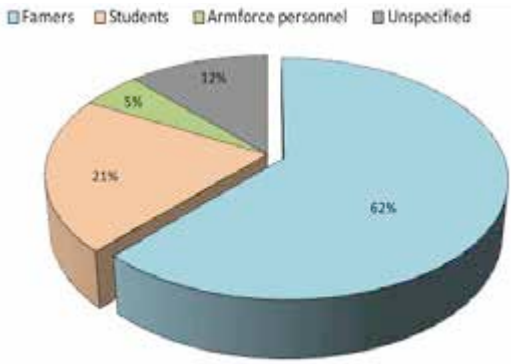

Figure 3. Distribution of snakebite cases based on occupation in Gelephu Referral Hospital, southern Bhutan, during the study period

Table 2. The ratio between male and female victims of snakebites registered in Gelephu Referral Hospital, southern Bhutan

Year	Male		Female	
	Individuals	%	Individuals	%
2013	15	19.23%	12	15.38%
2014	12	15. 38%	11	14.10%
2015	17	21.80%	11	14.10%
Total	**44**	**56.42%**	**34**	**44.58%**

area. A relatively low mortality rate (n=2, 0.02%) in 78 cases was observed during the three-year period in GRH, Sarpang.

Anti-snake venom (ASV) was administered to patients showing signs of systemic envenomation like clinically important coagulation abnormality or systemic affects such as ptosis or respiratory weakness caused by neurotoxicity. All patients were treated with recommended doses of ASV following the guideline of World Health Organization (W.H.O) (Warrell 2010); lyophilized, polyvalent enzyme refined equine immunoglobulin, supplied with 10ml sterile water for injections I.P., manufactured by Premium Serum and Vaccines Pvt. Ltd., Junnar Taluk, Pune District, Maharashtra 410504, India, is currently used as ASV in GRH. The timely administration of ASV remains the mainstay to reduce the morbidity and mortality associated with snakebites. Polyvalent ASV was the most important drug used to treat the patients and its administration showed excellent outcomes with only two cases of mortality out of the 28 envenomation cases enrolled. According to Pore et al. (2015), however, polyvalent ASV cannot be assumed to be uniformly effective for all poisonous snake bites as several factors affect region-specific observation of ASV use.

The present study also revealed that relatively large proportions of snakebite incidences are experienced by farmers when compared to other occupational groups. Combining both venomous and non-venomous snakebites, the farmer group accounted for 62% cases (n=48). This was followed by cases that involved students (n=16, 21%), unspecified (n=9, 12%), and armed force personnel (n=4, 5%) (Fig. 3).

Most of the venomous bites (68%) occurred in the monsoon season, particularly between May and August. The event of snakebites showed a sudden escalation in May while the maximum incidence occurred in June (21.42%); a decreasing trend of snakebite cases was observed towards late autumn and winter months. Cold season, particularly between November and February,

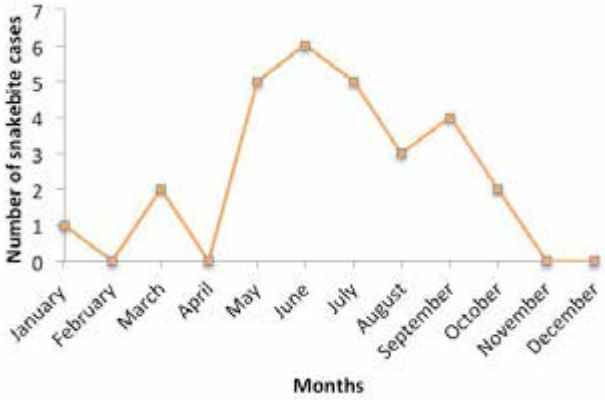

Figure 4. Monthly distributions of venomous bite cases (n=28) in Gelephu Referral Hospital, southern Bhutan, during the study period

represented the minimum incidences of snakebites (Fig. 4).

DISCUSSION

In this study, the majority of the snakebite victims were adults, which signified that an active population is at higher risk of snakebites. The high incidence of snakebites in the vulnerable age group of 21–50 years could be due to occupational exposure, being the economically productive age group. There was only a slight difference between number of male and female victims (1.3:1, 56% vs 44%), which suggests that both males and females are equally likely to be bitten by snakes. A similar finding was also reported by Pandey (2016) and Poudyal et al. (2016) from Nepal. This could be because of the equal exposure of both genders to outdoor activities, as the majority of the population in the study area is represented by an agrarian society.

The majority of victims (n=50, 64%) did not demonstrate signs and symptoms of envenomation. These patients were treated and discharged within a day or less. This finding suggests that a relatively large proportion of snakebite cases are attributed to non-venomous snakes. It is also likely that victims are exposed to dry bites. The relatively large proportion of incidences of non-venomous snakebites observed in this study agree with the general statement of Das (2012), who admitted that majority of the southeastern Asian snakes are non-venomous and, according to Holve (2007), out of the roughly 3,000 known species of snakes, only 15% are considered dangerous to humans.

The study found that more famers were bitten by snakes as compared to other occupational groups. This

could be due to the fact that people of this occupational category, especially in rural communities, have to engage in various outdoor activities such as collecting firewood and fodder from forest, herding cattle, and spending extended periods of time working in fields, which make them highly vulnerable to snakebites. The majority of people, however, were unable to identify the snakes that bit them, except the species that were very common and those belonging to the cobra family due to their distinctive characteristic of spreading the hood when provoked. This could be due to the occurrence of incidences at night, vanishing of the snake before the victim could see it, misleading descriptions provided by the victim, or inadequate knowledge of medical professionals in species identification.

Most of the venomous bites (around 68%) occurred during the months of May, June, July, and August, which corresponds to the early to peak monsoon season in Bhutan with average temperature and rainfall of 26.48^{0}C and 1,002.55mm, respectively. This season is characterized by increased humidity and temperature that introduce conducive climatic conditions for snakes to emerge out of their shelters in search of food and other ecological requirements. This findings agree with Pandey (2006) and Joshi (2010), who also observed the occurrence of such seasonal patterns in cases of snake envenomation. This is a peak season for agricultural activity, where the economically productive portion of the population spends considerable time in the fields, which also increases the probability of snakebites. The incidences of snakebites are higher during the rainy season and during periods of intense agricultural activity (Suleman et al. 1998; Ariaratnam et al. 2008).

CONCLUSION

Since this study is the first of its kind in the country, the true incidence of snakebites in rural Bhutan is largely unknown. The present available data are entirely based on hospital statistics that constitute a very small percentage of cases of snakebites. The present study, however, evidently revealed that snakebites were more common in rural areas and that, more importantly, people who were largely engaged in agricultural activities were those mostly affected by poisonous snakebites. The development and adoption of snakebite management guidelines, raising awareness among the vulnerable sections of the population, improvement of medical facilities in referral hospitals and rural health centers, and proper management and transfer of snakebite victims to hospitals are recommended in reducing the morbidity and mortality associated with snakebite incidences.

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Individual identification of *Duttaphrynus melanostictus* (Schneider, 1799) (Amphibia: Anura: Bufonidae) based on dorsal wart patterns

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Abstract: The dorsal surface of *Duttaphrynus melanostictus* is covered with keratinized warts of various sizes and shapes. Using combinations and patterns of cranial and mid dorsal warts, we attempted to identify individual toads from a natural population as a non-invasive alternative to existing marking techniques based on toe clipping, pit tagging, and subcutaneous elastomer injections to facilitate population estimates. An accuracy of 100% identification was achieved via this method, making it a potent tool for population studies in this species that is faster, cheaper and less disruptive than standard marking techniques.

Keywords: Capture-recapture, *Duttaphrynus melanostictus*, individual identity, population estimation.

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Author Contribution: UTB conducted the field study, undertook photography and analyzed the data. AD designed the study and supervised UTB.

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भारतीय वन्यजीव संस्थान
Wildlife Institute of India

INTRODUCTION

Accurate estimates of population size are essential for the effective management and conservation of species, and capture-recapture methods are frequently employed in an attempt to obtain rigorous population estimates (Begon 1979; Donnelly et al. 1994; Lettink 2012). The ability to recognize individuals within a population is fundamental to most capture-recapture methods. Individuals can potentially be recognized by artificial marks, or for species that exhibit sufficient phenotypic variation, by natural markings (Heyer et al. 1994; Sutherland 2006). Artificially marking animals usually involves capturing and handling, which can stress individuals and/or lead to injury (Bradfield 2004). Marking often creates a wound, which is a potential site of infection. In the case of amphibians, artificial marking usually involves tagging, toe-clipping, branding, tattooing, subcutaneous elastomer injections, or subcutaneous pit tags (Donnelly et al. 1994). Studies of the effects of these artificial marking techniques on behaviour and survival rates have reported conflicting results, indicating that it may be difficult to make broad generalisations about the effects of these techniques on amphibians (Donnelly et al. 1994; Bradfield 2004; Lettink 2012).

Negative effects of artificial marking techniques on amphibians have significant implications for population monitoring via capture-recapture methods. Altered behaviour and increased mortality resulting from marking violate an assumption that underlies most capture-recapture methods, namely that the probability of recapture is not affected by marking (Caughley et al. 1994) and does not jeopardise reproduction and growth. This is especially relevant to studies of threatened species.

The use of natural features or markings to identify individuals within a population is non-invasive, and therefore does not pose the same risk as invasive artificial marking techniques. Individuals or a particular region of their bodies can be either drawn or photographed, and the resulting images compared with the images for all previous captures (Bradfield 2004; Caorsi et al. 2012). The Common Asian Toad *Duttaphrynus melanostictus*, is a widespread amphibian species in the Indian sub-continent that exhibits a preference for human modified habitats and homesteads (Daniels 2005). Each *D. melanostictus* shows a distinct pattern of black, keratinized warts on the dorsal surface. These warts are typically paired except in toads less than 6 months old, and their patterns are not sexually dimorphic (Daniel 2002; Daniels 2005).

The objectives of this study were to determine whether photographic identification of naturally marked animals can be used to identify individual *Duttaphrynus melanostictus*. An earlier observation suggested that individual toads differed from one another in the pattern of dorsal warts, but no description of warts and methodology for identification was provided (Daniels 1994). Thus, we classified dorsal warts with respect to their position and combination and developed a simple method for efficient identification of individuals via visual analysis.

MATERIALS AND METHODS

Study site

The following study was conducted at the Chandrabani Forest Division (30.283^{0}E & 77.974^{0}N), Wildlife Institute of India campus, Dehradun (Fig. 1). The study area is ~3.44ha. The region is characterized with a sub-tropical climate, experiencing cold winters, warm springs, hot summers and a strong monsoon. The average annual rainfall received is usually around ~2073.3mm.

The vegetation is natural and semi-natural represented by a mosaic of natural scrub, woodland, various successional stages of *Shorea robusta* forest including stream bank vegetation and grassy banks. Thirty-three species of herpetofauna inhabit the campus; amphibians: 11 species belonging to four families (Bufonidae, Microhylidae, Rhacophoridae, Dicroglossidae), with two species of toads, and reptiles: 22 species belonging to nine families (Colubridae, Typhlophidae, Elapidae, Agamidae, Varanidae, Natricidae, Trionichydae, Geoemydidae, Scincidae) as listed on the campus database (www.wii.gov.in). All wildernesses are in close proximity to and in certain parts, interspersed with human habitation.

The study was conducted from mid March to the first week of May 2015. Dehradun, having already received its early showers at the end of February and early March, marked the onset of breeding activity of *Duttaphrynus melanostictus*. Tadpoles started appearing at the natal site by the end of March to early April.

Methods

During the study period (18 March 2015 – 28 April 2015), regular night surveys were conducted for 42 days. Usually a set of two digital images were generated for each captured animal, whereby the first image was in

Figure 1. Location of Wildlife Institute of India, Uttarakhand, India.

portrait mode and the second in landscape mode. This was done in order to obtain clear and properly focussed image sets for the dorsal side of each individual. This also helped in negating the problems in analysing the wart patterns due to discrepancies in the position of the animal when being photographed. If an animal exhibited certain distinct marks (such as deformity or scar), features or patterns on any part of the body, a third digital image was generated to showcase the distinctive features. The digital images generated were assigned unique identification codes, affixed with other data of the animal collected, and clear black and white photographs were obtained by printing a single photograph in the complete frame of an A4 sheet. The photographs were then subjected to visual analysis and manual scrutiny in order to determine the distinctive aspects of individuals.

For the purpose of this study the dorsal warts and associated structures were classified with respect to the position of their occurrence on toads as follows (Image 1; Table 1):

Snout warts: Keratinized small tubercles present in between cranial ridges in front of upper eyelids. The position and pattern of distribution with respect to the cranial ridges as well as arrangements of these warts are used as one character. It is a discontinuous character as toads may lack tubercles or warts in this region.

Crown warts: The region of the head from the point where the cranial ridge is notched along the eye to the anterior end of the parotoid glands is termed the crown

Table 1. Depicting the dorsal warts and their coding.

Character	Type	Code
Snout Warts	Discontinuous (not encountered in all individuals)	SW
Crown Warts	Discontinuous	CW
1st Primary Dorsal Wart Pair	Continuous (encountered in all individuals)	1PD
2nd Primary Dorsal Wart Pair	Continuous	2PD
3rd Primary Dorsal Wart Pair	Continuous	3PD
Parotoid Warts	Discontinuous	PW

(sensu stricto Daniel 2002), hence keratinized tubercles present in this region toad are referred to as crown warts. The position of these warts with respect to the cranial ridges, parotoid glands and the first primary dorsal wart pair exhibits great variation, as do their shapes and patterns of appearance. This is a discontinuous character, with some toads lacking crown warts.

Mid-dorsal groove: An associated structure aiding in the classification of dorsal warts and subsequent identification of individuals. A distinct dorsal groove is observed along the vertebral axis of the toad on the dorsal side. It becomes conspicuous along the plane of the anterior portion parotoid glands, just behind the crown, and runs all through the entire length of the body up to the vent. The mid-dorsal groove is usually smooth and usually lacks any tubercles or warts but a few keratinized tubercles might be found in the groove. The region shows distinct lateral undulations.

Primary dorsal wart pairs: Two series of large warts along the middle of the dorsal surface of the toad's body and exhibiting a certain degree of symmetry on either side of the distinct mid-dorsal groove. The primary dorsal warts are considerably enlarged and usually more keratinized in the adults. The primary dorsal warts appear to maintain a constant distance from the mid-dorsal groove. A certain wart of a pair may often be found associated in close proximity to a small secondary or satellite wart alongside it. They show great variability in their position and pattern of distribution. They are commonly found to be oval or spheroid in shape though some individuals do exhibit a conspicuous shape.

1st primary dorsal wart pair: It is the first large, distinct and keratinized wart encountered after the crown warts. It follows just behind the origin of the mid-dorsal groove, in the hind neck region, and is placed within one-third of the length of the parotoid glands from the anterior end. It often exhibits variability in shape and in the symmetry of its position on either side of the mid-dorsal groove. A satellite wart is found quite rarely. It is a continuous

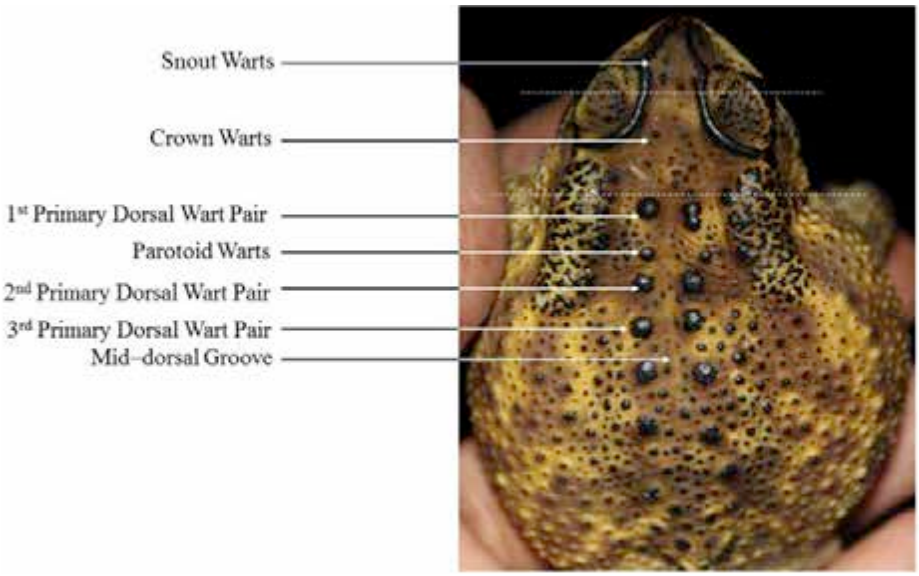

Image 1. Primary dorsal warts on *Duttaphrynus melanostictus*.

character being observed in all individuals.

2nd & 3rd primary dorsal wart pair: These are found closely associated to each other usually towards the distal end with respect to the plane of the parotoid glands. Variability in shape is less conspicuous and they usually are spheroid or ovate. Often found associated with a satellite wart. Varies with respect to position and pattern. It is a continuous character, being encountered in all individuals.

Parotoid warts: These warts are encountered along the parotoid glands on either side of the mid-dorsal groove and in the region between the 1st and 2nd primary dorsal wart pairs. They exhibit great variability with respect to their pattern, shape, position and distribution. It is a discontinuous character as certain toads don't bear these warts.

The above mentioned potential characters may be coded as shown in Table 1.

The photographs of the *Duttaphrynus melanostictus* individuals, obtained during the duration of the nocturnal surveys at the study site, were subjected to rigorous visual scrutiny, matching and analysis. We then attempted to segregate the individual toads based on the combinations of dorsal warts required to effectively distinguish and identify individuals. This allowed us to arrive at a pattern to be followed during visual analysis of photographs while sequestering individual toads to a sub-group.

RESULTS

The 1st primary dorsal wart pair was found to be the initial basis of analyzing the dorsal warts, owing to its apparent consistency in position and shape. The other dorsal wart characteristics were now used in combination to the 1st primary dorsal wart pair to distinguish and identify the individuals. Visual matching and analysis thus led to the development of a combination of dorsal wart characters based on which the individuals were subjected to effective individual identification and subsequent grouping as mentioned in Table 2.

The photographs of the *Duttaphrynus melanostictus* individuals, obtained during the duration of the nocturnal surveys at the study site, were subjected to rigorous visual scrutiny, matching and analysis (Appendix 2). We then attempted to segregate the individual toads based on the combinations of dorsal warts required to effectively distinguish and identify individuals. This allowed us to arrive at a pattern to be followed during visual analysis of photographs while sequestering individual toads to a sub-group.

DISCUSSION

In the wake of the rising concerns of global decline in amphibian populations (Stuart et al. 2004; Whittaker et al. 2013) the need of methods and protocols for sampling natural populations of amphibians has been greatly realized. It is here that mark-recapture techniques of

Table 2. Dorsal wart pattern combinations used for individual identification of toads.

Combination of dorsal wart characters	Combination code	Remarks
1st primary dorsal wart pair only	1PD	Based on variability of shape, size, pattern, satellite wart and symmetry.
1st primary dorsal wart pair + 2nd primary dorsal wart pair + 3rd primary dorsal wart pair	1PD + 2PD + 3PD	Based on variability of satellite warts, pattern and position.
1st primary dorsal wart pair + parotoid warts	1PD + PW	Based on variability of pattern, position and size.
1st primary dorsal wart pair + crown warts	1PD + CW	Based on variability of pattern, position and size.
1st primary dorsal wart pair + snout warts	1PD + SW	Based on variability of pattern and position.
1st primary dorsal wart pair + parotoid warts + 2nd primary dorsal wart pair	1PD + PW + 2PD	Based on variability of shape, size, pattern, satellite wart and symmetry.

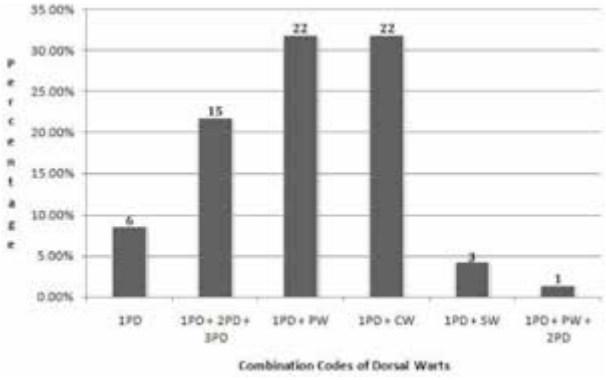

Figure 2. Graph showing the percentage of individuals identified based on the criteria of wart pattern combination used. The numerals atop the bars represent the number of individuals identified via the respective pattern combination. (Also refer Appendix II).

capturing, marking, releasing and recapturing animals have become an indispensable tool to monitor and estimate trends in populations. Mark-recapture techniques are advantageous, being statistically more accurate and robust than uncorrected counts of indices of relative abundance (Lettink 2012).

Visual image matching of natural markings is significantly more accurate than invasive techniques like toe-clipping and computer-assisted image matching, which though useful for large datasets are constrained by the position and posture of the animal, glare, shadows, lighting, background colour, equipment and cumbersome processing protocols to be followed, which can expose animals to prolonged durations of stress and handling (Caorsi et al. 2012; Sanchez et al. 2018). Invasive techniques like toe-clipping, especially for the first finger, might adversely affect amplexus in males owing to the loss of the nuptial callosities on phalanges. Thus there is a need for non-invasive identification techniques, as amphibians are most active during the breeding season (Sutherland 2006).

Dorsal warts were found to be a reliable and cheap way to ascertain and monitor populations in *Duttaphrynus melanostictus*. Thus, the technique may also be used in capture-recapture studies of this species. The study achieved an accuracy of 100%, whereby the digital image sets of the toads successfully distinguished and identified all 69 individuals (Appendix 1).

The results indicate that it should be possible to efficiently process photographs of unidentified captures in a full-scale monitoring programme by using the combination code key to identify and determine the identity of any given capture.

Analysis of photographs of 69 toads identified six combinations which resulted in optimal allocation of individuals into captures and recaptures. The decision as to which of these combinations to use in future studies shall depend on the clarity of the photographs of the dorsal side of the toad taken in the field. It is recommended that the 1st primary dorsal wart pair should be considered initially.

The 2nd primary dorsal wart pair was always found to be in symmetry, pattern and variation with the 3rd primary dorsal wart pair or the parotoid warts if present. Thus, establishment of individual identity was never made based on the 2nd and 3rd primary dorsal wart patterns alone, and thus were considered a separate combined character combination with the 1st primary dorsal wart pair.

It might also be mentioned that there were eight toads (~ 11.59%) that also exhibited certain distinct marks, patterns, wounds or infections. Preliminarily these could be used as a cue for individual identification, especially when in the field, complementing the dorsal wart patterns. But, it was seen that there was no constancy (wounds and infections heal, body marks might be lost during moulting and sloughing of skin etc.) of these characters, and thus they are unsuitable for application to individual identification in the long run.

This synchronized scientific method is simple to

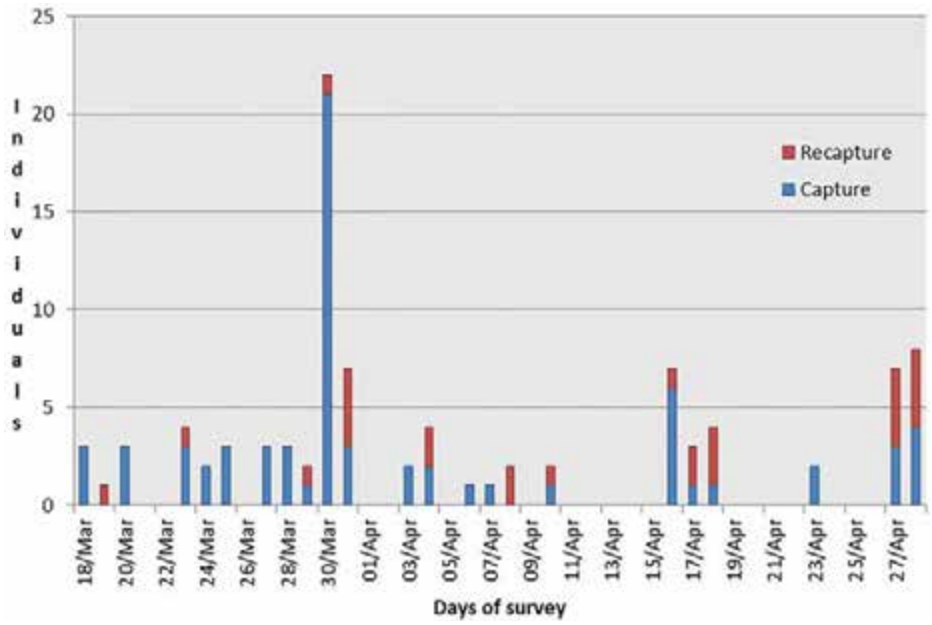

Figure 3. Graph showing the number of captures and recaptures of toads during each night survey of the study period.

follow and easy to implement, and thus can even be utilized by laymen in the field of biology to monitor toads in their backyards. The study also holds great value, both scientific and economic, in keeping tabs of toad populations threatened from road related mortality. It thus shows great potential to be successfully utilized and implemented in citizen science programmes aimed at studying amphibians.

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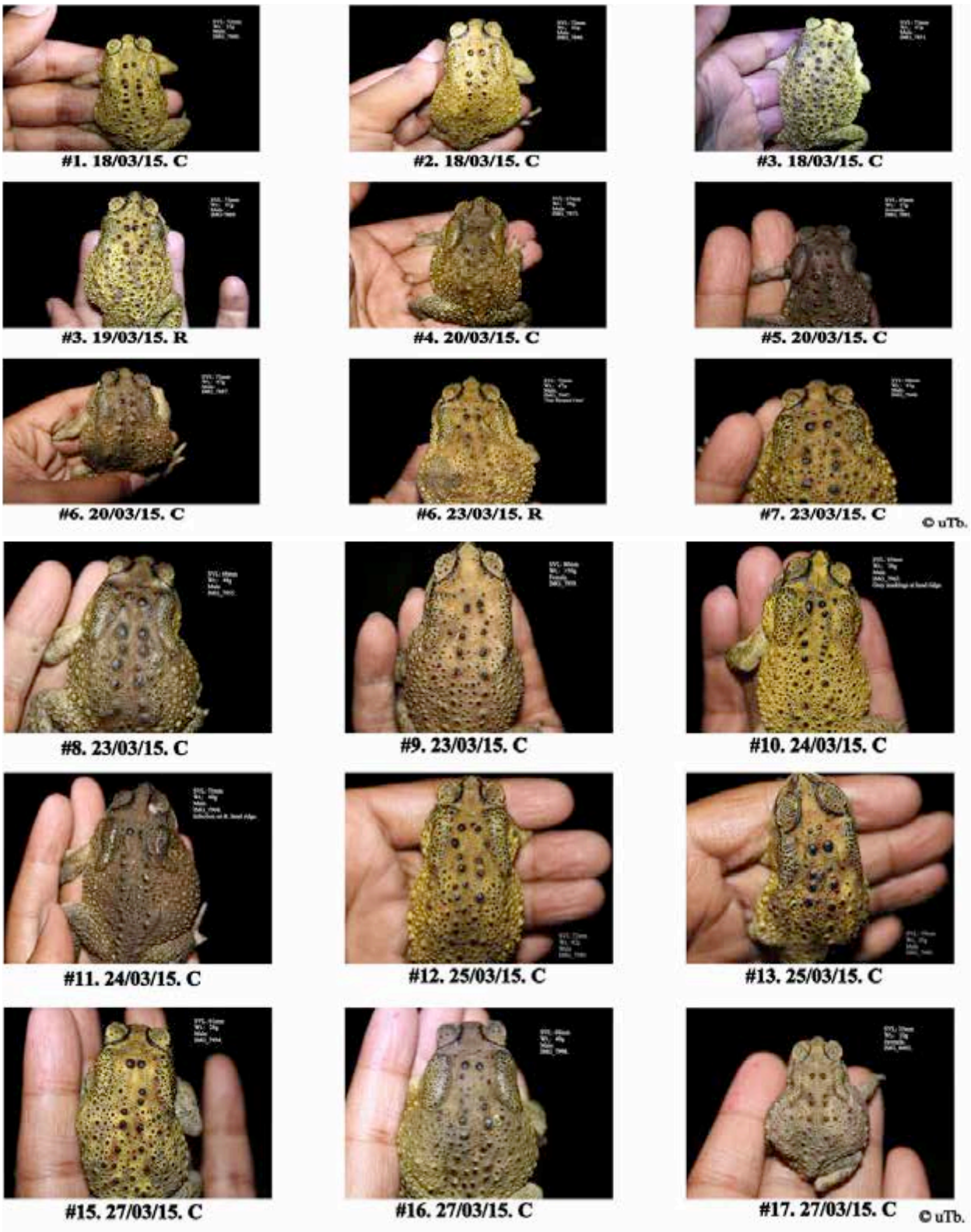
Appendix 1. Data sheet table, as prepared, for the creation of dorsal wart pattern combination codes and thus, distinctly identifying individuals of *D. melanostictus* from the Wildlife Institute of India campus, where '1' represents the character being used and '0' represents that the character wasn't utilized for identifying the individual:

Individual Id.	1 – PDW	2 – PDW	3 – PDW	SW	CW	PW
#1.	1	0	0	0	0	0
#2.	1	0	0	0	0	1
#3.	1	0	0	0	1	0
#4.	1	0	0	0	0	1
#5.	1	1	1	0	0	0
#6.	1	0	0	0	1	0
#7.	1	0	0	0	1	0
#8.	1	0	0	0	0	1
#9.	1	0	0	0	0	1
#10.	1	0	0	0	0	0
#11.	1	0	0	0	0	1
#12.	1	0	0	0	0	1
#13.	1	0	0	0	1	0
#14.	1	0	0	0	0	1
#15.	1	0	0	0	1	0
#16.	1	0	0	0	0	1
#17.	1	1	1	0	0	0
#18.	1	1	1	0	0	0
#19.	1	0	0	0	0	1
#20.	1	1	1	0	0	0
#21.	1	0	0	0	1	0
#22.	1	1	1	0	0	0
#23.	1	0	0	0	1	0
#24.	1	0	0	0	1	0
#25.	1	0	0	0	0	0
#26.	1	0	0	0	1	0
#27.	1	0	0	0	1	0
#28.	1	0	0	0	1	0
#29.	1	0	0	0	0	1
#30.	1	0	0	0	0	1
#31.	1	1	1	0	0	0
#32.	1	0	0	1	0	0
#33.	1	1	1	0	0	0
#34.	1	1	0	0	0	1
#35.	1	1	1	0	0	0
#36.	1	1	1	0	0	0
#37.	1	0	0	0	0	1
#38.	1	0	0	0	1	0
#39.	1	1	1	0	0	0
#40.	1	1	1	0	0	0
#41.	1	0	0	0	1	0
#42.	1	0	0	0	1	0
#43.	1	0	0	0	0	1

#44.	1	1	1	0	0	0
#45.	1	0	0	0	0	1
#46.	1	0	0	0	1	0
#47.	1	0	0	0	0	1
#48.	1	1	1	0	0	0
#49.	1	0	0	0	1	0
#50.	1	0	0	0	1	0
#51.	1	0	0	0	0	1
#52.	1	0	0	0	1	0
#53.	1	0	0	1	0	0
#54.	1	0	0	0	0	1
#55.	1	0	0	0	0	0
#56.	1	0	0	0	0	1
#57.	1	1	1	0	0	0
#58.	1	0	0	0	1	0
#59.	1	0	0	0	0	1
#60.	1	0	0	1	0	0
#61.	1	0	0	0	0	1
#62.	1	0	0	0	0	1
#63.	1	0	0	0	1	0
#64.	1	0	0	0	0	0
#65.	1	0	0	0	1	0
#66.	1	1	1	0	0	0
#67.	1	0	0	0	1	0
#68.	1	0	0	0	0	1
#69.	1	0	0	0	0	0

Appendix 2. Colour plates depicting the 69 individuals encountered during the study period, denoted as captures and recaptures with the date of encounter:




#18. 28/03/15. C


#19. 28/03/15. C


#20. 28/03/15. C


#13. 29/03/15. R


#21. 29/03/15. C


#22. 30/03/15. C


#23. 30/03/15. C


#24. 30/03/15. C


#25. 30/03/15. C


#26. 30/03/15. C


#27. 30/03/15. C


#28. 30/03/15. C


#29. 30/03/15. C


#30. 30/03/15. C


#31. 30/03/15. C


#32. 30/03/15. C


#33. 30/03/15. C


#34. 30/03/15. C


#35. 30/03/15. C


#36. 30/03/15. C


#17. 30/03/15. R


#37. 30/03/15. C


#38. 30/03/15. C


#39. 30/03/15. C


#40. 30/03/15. C


#41. 30/03/15. C


#42. 30/03/15. C


#43. 31/03/15. C


#34. 31/03/15. R


#35. 31/03/15. R


#32. 31/03/15. R


#13. 31/03/15. R


#44. 31/03/15. C


#45. 31/03/15. C


#46. 03/04/15. C


#47. 03/04/15. C


#35. 04/04/15. R


#34. 04/04/15. R


#48. 04/04/15. C


#49. 04/04/15. C


#50. 06/04/15. C


#51. 07/04/15. C


#48. 08/04/15. R


#34. 08/04/15. R


#52. 10/04/15. C


#34. 10/04/15. R


#53. 16/04/15. C


#54. 16/04/15. C


#55. 16/04/15. C

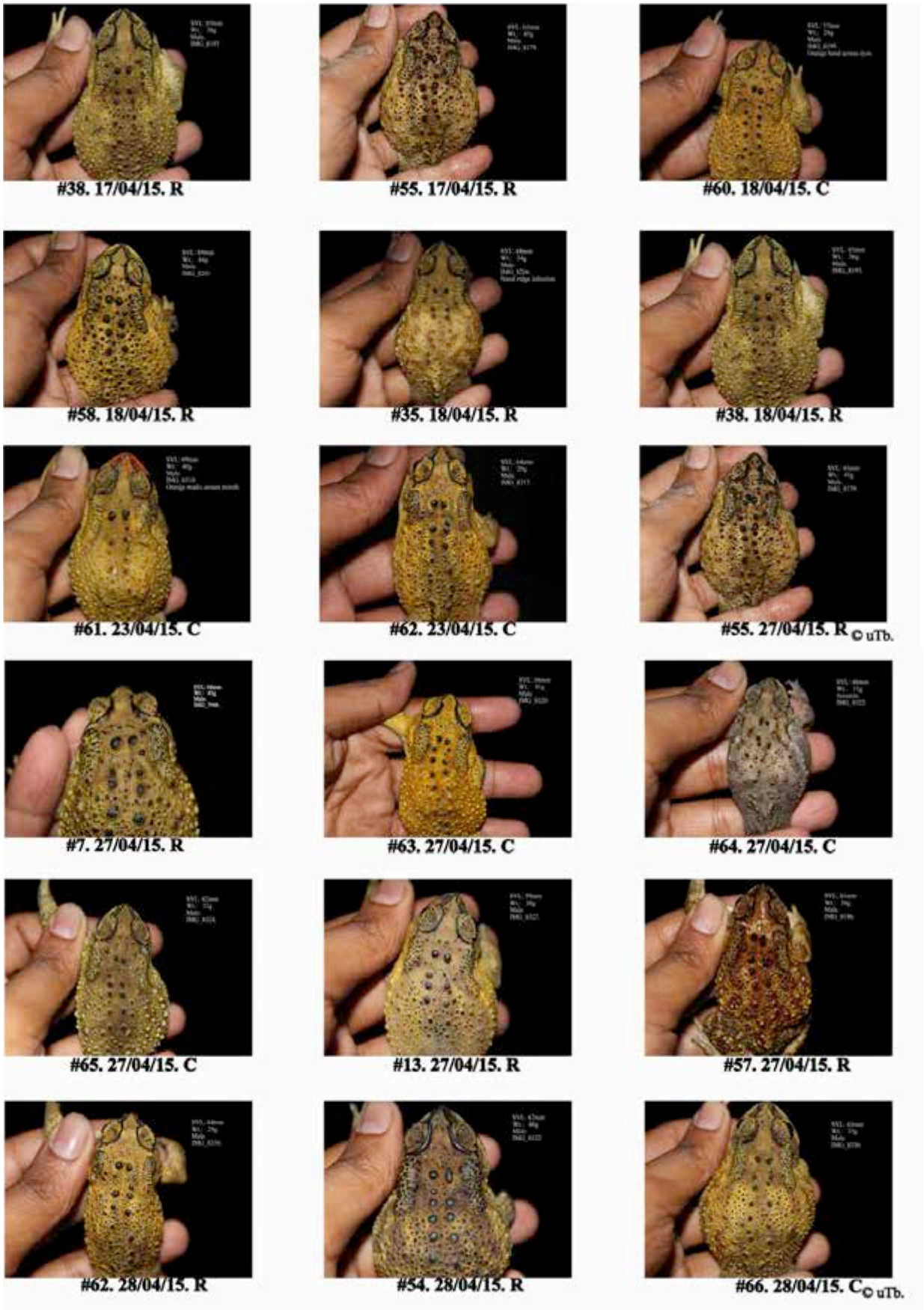

#56. 16/04/15. C


#57. 16/04/15. C


#58. 16/04/15. C


#21. 16/04/15. R


#59. 17/04/15. C


#38. 17/04/15. R
#55. 17/04/15. R
#60. 18/04/15. C
#58. 18/04/15. R
#35. 18/04/15. R
#38. 18/04/15. R
#61. 23/04/15. C
#62. 23/04/15. C
#55. 27/04/15. R
© uTb.
#7. 27/04/15. R
#63. 27/04/15. C
#64. 27/04/15. C
#65. 27/04/15. C
#13. 27/04/15. R
#57. 27/04/15. R
#62. 28/04/15. R
#54. 28/04/15. R
#66. 28/04/15. C
© uTb.

#67. 28/04/15. C

#68. 28/04/15. C

#69. 28/04/15. C

#56. 28/04/15. R

#6. 28/04/15. R

#14. 25/03/15. C

Key:
#Individual Identification Number. Date (dd/mm/yy). C or R
where, C: Capture and R: Recapture.

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COMMUNICATION

A preliminary checklist of butterflies from the northern Eastern Ghats with notes on new and significant species records including three new reports for peninsular India

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OPEN ACCESS

Abstract: The northern Eastern Ghats is an area with significant biodiversity value but remains poorly explored except for a few charismatic taxa such as birds, mammals and reptiles. Very few studies have looked at the invertebrate diversity of these hill ranges, particularly butterflies. We present the first peer-reviewed checklist of butterflies from the northern Eastern Ghats based on a rapid and intensive survey carried out at five sites over 16 days across the buffer area of Papikonda National Park and Araku Valley in 2015 and 2016. We report a total of 102 species of butterflies from six lepidopteran families. Seventeen significant records include numerous first reports: three new species reports for peninsular India, nine for Eastern Ghats and 14 for the northern Eastern Ghats. This checklist adds 17 species to the known butterfly fauna for the state of Andhra Pradesh. It is hoped that findings from the study will help to mobilise conservation research, action and attention for the northern Eastern Ghats forest habitats, which are currently threatened by large scale development, security threats due to the Naxalite insurgency and mesoscale exploitation of forest resources.

Keywords: Andhra Pradesh, Araku Valley, checklist, Lepidoptera, northern Eastern Ghats, Papikonda National Park.

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INTRODUCTION

The Eastern Ghats is a 1,750km long mountain range located along the eastern edge of the Indian peninsula. Even though studies and inventories carried out till date indicate its high diversity value, the Eastern Ghats remain one of the least explored natural landscapes of India. Its wide elevational range from almost sea level to 1,690m contains diverse vegetation types ranging from dry-scrub and dry deciduous to dry-evergreen, moist-deciduous and semi-evergreen that support diverse flora and fauna.

Unlike the Western Ghats, the Eastern Ghats is not a continuous mountain range. Instead they comprise of a series of patchy and isolated hill sections which are divided into three main zones based on their location: southern Eastern Ghats, central Eastern Ghats and northern Eastern Ghats (Rao 2000). Owing to the patchiness of the hills and variations in temperature, precipitation and elevation, each zone has its own unique floral and faunal assemblages. Variable intensities of forest-related activities such as shifting cultivation, hunting (by local communities), and plantations (usually by the state and/or policy-driven) has further led to an increase in the heterogeneity and diversity of the available land use and forest habitats (Beehler et al. 1987; Rawat 1997; Ganesh et al. 2015).

Among the three sections, the northern Eastern Ghats has the most diverse vegetation types including some of the most dense forests. Such diversity and abundance of forests is due to the relatively higher rainfall in the area, ranging from 900–1,700 mm annually, (Pattanaik et al. 2009b; Sreekar et al. 2010). The presence of perennial rivers such as the Godavari and the Mahanadi also contribute to creating conducive conditions for high forest density and diversity. In comparison, the central and the southern Eastern Ghats landscapes are drier with sparser vegetation due to lower elevation, lesser rainfall and higher annual temperatures.

Recent studies have shown that the northern Eastern Ghats region, owing to its proximity to the eastern Himalayan, the Indo-Malayan and the Western Ghats biodiversity hotspots, acts as a mixing and transition zone for these three distinct ecoregions. Therefore, elements of all these three hotspots has been observed in the northern Eastern Ghats, leading to higher diversity of plants and animals; for example, Stripe-necked Mongoose *Herpestes vitticollis*, recently discovered from the northern Eastern Ghats, was earlier recorded only from the Western Ghats (Balaji & Satyanarayana 2016). Similarly, birds such as the Ruby-cheeked Sunbird *Chalcoparia singalensis* and Pale-chinned Blue Flycatcher *Cyornis poliogenys*, earlier known as 'northeast birds' have been recorded from the northern Eastern Ghats (Prashanth 2016). Apart from sharing biological attributes with the proximate 'hotspots', the northern Eastern Ghats is home to several rare, endemic and threatened species of flora and fauna, including reptiles such as the Golden Gecko *Calodactylodes aureus* (Javed et al. 2007), Jeypore Ground Gecko *Geckoella jeyporensis* (Agarwal et al. 2012), a new species of caecilian *Gegeneophis orientalis* (Agarwal et al. 2013), birds like the Yellow-throated Bulbul *Pycnonotus xantholaemus* (Sreekar & Srinivasulu 2010) and the Critically Endangered Blewitt's Owl or Forest Owlet *Heteroglaux blewetti* (Azeez et al. 2008; Kumar et al. 2010).

Biodiversity inventories and studies carried out till date has focussed on a few taxa, such as aves (Price 1979; Ripley et al. 1986; Kumar et al. 2010), mammals (Aditya & Ganesh 2016; Balaji & Satyanarayana 2016) and reptiles (Chettri & Bhupathy 2010; Agarwal et al. 2013); however, the invertebrate taxa of the Eastern Ghats, particularly the northern Eastern Ghats, remain almost unexplored.

Among invertebrates, butterflies (order Lepidoptera, sub-order Rhopalocera) are among the most charismatic taxa. The beauty and ubiquitous nature of butterflies makes it the most effective invertebrate flagship which can be used to stimulate awareness, research and policy support for the conservation of invertebrate and overall biodiversity (Barua et al. 2012). India is very rich in butterfly taxa with over 1,300 species (Varshney & Smetacek 2015); however, they are not uniformly distributed and most of them (>1000 species) occur in the northeastern region (Varshney & Smetacek 2015). In recent times, there has been an exponential growth in biodiversity documentation in India, particularly during the last decade, owing to the rapid proliferation of digital and mobile photography. Birds and butterflies have received disproportional attention of the amateur naturalist and citizen scientists in this digital age, probably owing to their ubiquitous nature (Chandler et al. 2017). Yet, such coverage is not uniform across the geography of the country, even for well-surveyed taxa such as butterflies. Even today, there are many regions from where even basic information about species occurrences are lacking. The northern Eastern Ghats is one such region.

Apart from being ecologically rich, the northern Eastern Ghats is also one of the most threatened forested regions of the country owing to the presence of scarce and highly valuable natural resources such as

bauxite, iron, coal and water. The pressure to mine these resources, most of which overlap with dense forests, has already caused considerable loss of forest habitat and is triggering large scale land use change (Samata 2003; Oskarsson & Nielsen 2014). The lack of knowledge about the bare minimum attributes of biodiversity and ecology from the region hampers the ability of both the agencies and the civil society to take informed decisions about the impact of these projects on the ecology and biodiversity of the region.

The interactions of butterflies, as larvae and adults, with different sets of host plants and their sensitivity to micro-climate, moisture, topographic and light level changes makes them excellent ecological and environmental indicators (Murphy et al. 1990; Kremen 1992). Therefore, it is critical and urgent to document the butterfly diversity of these fragile, but biologically diverse and rich regions.

Most recent lists of butterflies from the Eastern Ghats have come from the central Eastern Ghats (Chandra et al. 2007) and southern Eastern Ghats (Harinath et al. 2014). We found numerous errors in identification and taxonomy of butterflies wherever they have provided images and therefore the quality of information in these studies is questionable. Earlier, Best (1954) had compiled a list of butterflies from Nagalapuram and Servarayan (anglicised as Shevaroy) Hills located in the southern Eastern Ghats in the present day Tamil Nadu. The Zoological Survey of India's Fauna of Andhra Pradesh series reported three new distribution records from Prakasam and Kadapa districts in 2007 (Majumdar 2007; Maulik 2007). Among the recent efforts to study the butterflies of the Eastern Ghats, the most significant has been the Eastern Ghats Insect Survey Project carried out by the Zoological Society of India's which resulted in a two volume edited report (Anonymous 1986a,b). These volumes had five chapters dedicated to butterfly fauna, the first two being list of collections from Javadi Hills, located in the Namakkal District of central Tamil Nadu (Khatri 1986d) and Kolli Hills, situated in the Vellore and Tiruvannamalai districts of Tamil Nadu (Khatri 1986a). The remaining two chapters describe the Nymphalid and Lycaenids of Eastern Ghats (Khatri 1986b,c). An additional chapter in volume 1 in the same report discusses some phenological and geographical variations in the butterflies from the Eastern Ghats (Khatri 1986e). Most of these surveys, however, have been focussed mostly in the Tamil Nadu sections of the Eastern Ghats, covering its southern parts. Very few studies have focussed on the butterfly fauna of the northern Eastern Ghats from Andhra Pradesh, and thus has remained comparatively under-explored, particularly in terms of its butterfly fauna.

In this paper, we present the first checklist of butterflies from the northern Eastern Ghats with notes on new and interesting records.

METHODS

Study area

The northern Eastern Ghats is spread over an area of 16,948.35km^2 in northern Andhra Pradesh covering the districts of Srikakulam, Vizianagaram, Visakhapatnam, East Godavari and West Godavari. The current study was conducted at two sites in the northern Eastern Ghats falling within Andhra Pradesh - the buffer area of Papikonda National Park (henceforth PNP) around Maredumilli and Araku Valley.

PNP (17.267–17.691 and 81.281–81.694) is located in the East and West Godavari districts of north, coastal Andhra Pradesh and is spread over an area of 1,012km^2. The dominant vegetation types in PNP are southern tropical mixed moist deciduous, along with some semi-evergreen and dry deciduous forest patches (Champion & Seth 1968). The topography is hilly and undulating with steep slopes with an elevation range of 20–850 m. Annual average precipitation is approximately 1,309mm with temperatures ranging from 15–45 ^{0}C.

About 200km north of PNP lies the Araku Valley (18.209–18.4420 and 82.700–83.115), a small hill station spread over an area of 36km^2, in the western part of Visakhapatnam District, Andhra Pradesh close to the border with Odisha. The elevation ranges from 930m in the Valley to 1,690m at Jindhagada Peak and is composed of a mosaic of semi-evergreen forests, coffee and pepper plantations and shifting cultivation plots, called 'podu' locally. The vegetation around the Valley is composed of moist deciduous forests with semi-evergreen patches with patches of degraded forest and scrubs (Champion & Seth 1968).

Survey sites

We opportunistically surveyed an area of approximately 100km^2 in the buffer area of PNP around Maredumilli between 21 July and 29 July 2015, and once again between 27 August and 29 August in 2016 (Table 1) at three specific localities—Jalatarangini, Kutravada and Maredumilli. Jalatarangini is located along the Rajahmundry-Jagdalpur highway (SH 41) at an elevation of 460m and forms the northeastern border of PNP. The habitat type is dense moist deciduous forest interspersed

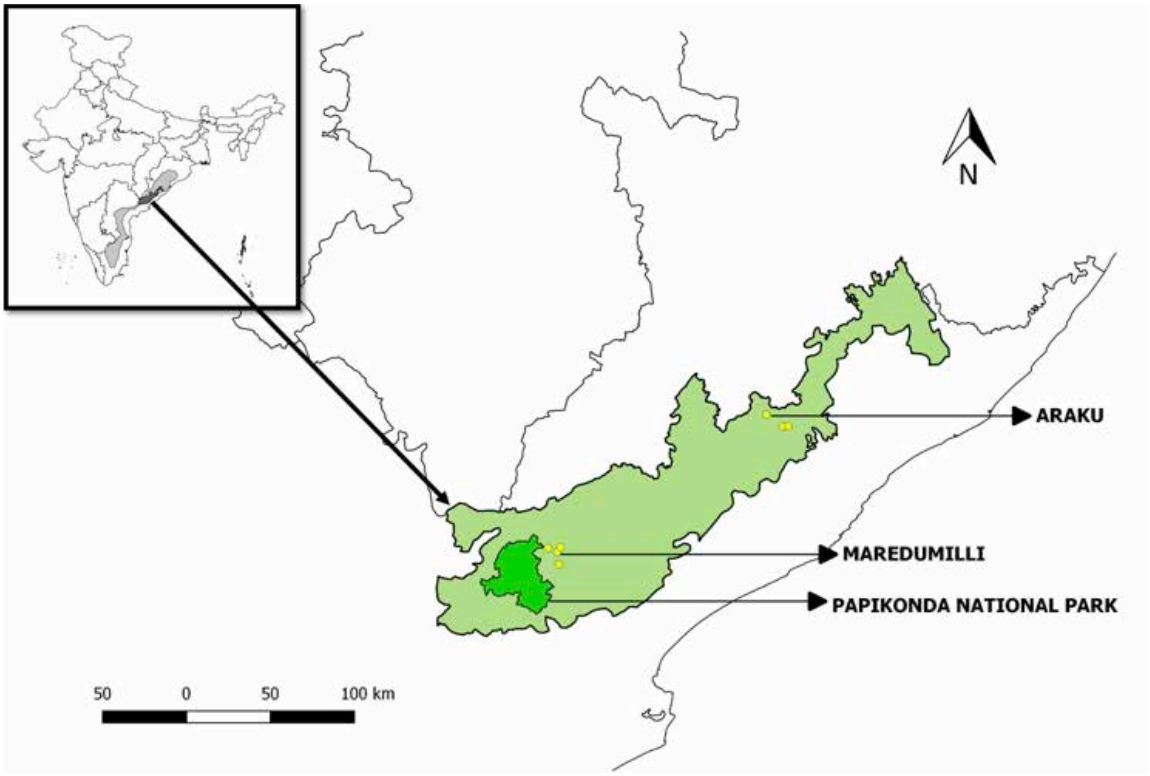

Figure 1. Study area map indicating the locations of the sites surveyed

with teak and coffee plantations. Kutravada is located about 7km northeast of Jalatarangini, at an elevation of 450m on the Maredumilli-Gurtedu Road. The locality is situated close to the Kutravada Village and is composed of moist deciduous forest and shifting cultivation plots, some of which has been planted with teak. Both of these localities are along the Pamuleru River, which forms the main drainage of PNP and is the second largest river within PNP after the Godavari. The third locality is close to Maredumilli Village surrounded by old teak plantations and secondary growth moist deciduous forests about 7km southeast of Maredumilli Village. It is located at an elevation of 400m along the Rajahmundry-Jagdalpur State Highway 41.

Table 1. Table showing the survey sites, localities, dates and number of days surveyed.

Sites	Localities	Survey dates	No of days surveyed
Buffer area of Papikonda National Park	Jalatarangini	21–29 July 2015, and 27–29 August 2016	12
	Kutravada		
	Maredumilli		
Araku Valley	Sunkarametta	30 July–2 August 2015	4
	Bisupuram		
Total Survey effort (in days)			**16**

In Araku Valley we surveyed two localities: Sunkarametta and Bisupuram from 30 July to 2 August 2015. Both are located close to the Visakhapatnam-Jeypore highway (Image 1). Sunkarametta is located about 15km from Araku at an elevation of 1,200m and is surrounded by coffee plantations interspersed with degraded moist deciduous forest patches. Bisupuram Village is located about 5km east of Sunkarametta at an elevation of 1,100m and is close to the Katiki waterfalls. The habitat is degraded moist deciduous forest interspersed with podus.

Data Collection

Intensive non-invasive butterfly surveys were carried out in the above mentioned six locations. The period of our survey coincided with the retreating south-west monsoons when the butterfly activity is known to peak. Owing to paucity of funds and limited time available, we decided to focus on the peak period for butterfly activity.

All possible habitat types in the survey areas were scanned for butterflies from 06.00hr to 18.00hr. Even though butterfly activity peaks during the late morning and noon, we surveyed during early mornings as well as late afternoons and evenings to include crepuscular species. The species which were difficult to identify in the field were photographed with good quality cameras

Image 1. Habitat of the surveyed sites: A - Araku, Sunkarametta Hills; B - Maredumilli, Jalatarangini waterfalls; C - Pamuleru River in the buffer area of Papikonda National Park; D - Maredumilli Teak Plantation

and later identified to species level wherever possible. We handled only those specimens which were found to be injured or dead.

Species were identified using Evans (1932), Wynter-Blyth (1957), and Kehimkar (2008, 2016). To confirm the various new records presented in this paper, ranging from the northern Eastern Ghats to peninsular India, we checked the known distribution of the species in question from three authoritative books by Evans (1932), Wynter-Blyth (1957), and Varshney & Smetacek (2015) . To further verify the new records for Eastern Ghats, we reviewed the published literature, namely, Best (1954), Khatri (1986a,b,c,d), Majumdar (2007), and Maulik (2007); while Majumdar (2007) and Maulik (2007) were scanned to cross-verify the new records for Andhra Pradesh. To check the unpublished photographic records, we scanned two expert-curated online portals-Butterflies of India (https://www.ifoundbutterflies.org) and India Biodiversity Portal (IBP, http://indiabiodiversity.org/). Both these portals allow users to access butterfly observations with information on the location and date of the records.

Finally, a checklist was prepared on the butterflies recorded from this region in which the species were arranged according to sub-families under each family. The names were listed alphabetically under each sub-family according to their genus and species.

RESULTS

We recorded a total of 102 species across six families. Nymphalidae was the most species-rich family with 38 species while only one species was recorded for Riodinidae (Table 2).

In the following text we provide notes on known distribution records of the new and significant butterfly records along with observation notes on their habit, habitat and commonness in the surveyed sites. Additionally, we provided detailed identification keys for cryptic species, particularly those which share similar morphological features with other species.

Family: Hesperiidae

Subfamily: Coeliadinae

***Bibasis sena* (Moore, [1866]) (Orange-tailed Awl)**

(Image 2(2))

This is the first report of this species from the Eastern Ghats. This species was encountered twice - inside a dense forest patch near Maredumilli early in the morning at 07:23hr on 18 July 2015 while a second individual was seen along the highway in a dense forest patch near Jalatarangini 06:39hr on 20 July 2015. So far from India, this species has been reported from the Western Ghats, central to eastern Himalaya and the northeast and is known to be rare throughout its range (Wynter-Blyth 1957). This species is listed within the Part II of Schedule II list of protected animals under the Indian Wildlife (Protection) Act (Anonymous 1972).

Table 2. Species richness across the six families of butterflies recorded during the survey

Family	No. of species
Nymphalidae	38
Lycaenidae	23
Hesperiidae	21
Pieridae	10
Papilionidae	9
Riodinidae	1

***Hasora badra* (Moore, [1858]) (Common Awl)**

This is the first record of this species from the Eastern Ghats. We observed this species nectaring near the small sluice gate dam on Pamuleru River near Kutravada, early in the morning on 29 August 2016. Previously, it was known to be distributed in the Western Ghats and northeastern India (Varshney & Smetacek 2015). This species was recorded from Bhitarkanika National Park, Kendrapara District, in Odisha which is not part of the Eastern Ghats (Kalesh et al. 2017).

***Hasora* sp. (An Awl sp.)** (Image 2(3)

This species was encountered frequently during our survey and we observed a total of eight individuals during our surveys of 2015 and 2016 in the area. Six individuals were recorded between 200–400 masl whereas two individuals (one male and one female) were seen at Araku Valley at 1,200m. The associated habitats ranged from semi-dense forests (deciduous) to small fragments of tree forests in coffee-plantation and meadows dominated landscape.

Earlier we suspected this species to be *Hasora leucospila* Mabille, 1891 based on the white band which extended slightly above the tornus in the hindwing and presence of purple sheen on its forewings. Moreover, its distribution was known from India: from the Andaman & Nicobar Islands and its recent report from Khurda District, Odisha in the northern Eastern Ghats (V. Sarkar pers. comm. 5 May 2017).

Both the main wing-based distinguishing character were clearly seen in the images of seven individuals we had photographed during the survey. In one of the images, we observed yellow hyaline spots in space two and three of the underside of forewings, indicating that it might be a female (Chiba 2009); however, when we tried to run the dichotomous identification key following Chiba (2009) to confirm species level identification, we found the presence of an apical white spot in the forewing of all the individuals that we had photographed during our survey. According to Chiba (2009) this characteristic goes against the morphological traits of *leucospila* species and in the absence of specimens, we couldn't conclusively run and complete the key. Therefore we retain this species as an unidentified *Hasora* sp.

***Hasora vitta* (Butler, 1870) (Plain Banded Awl)** (Image 2(4))

We recorded this species from a dense forest patch late in the evening on 20 July 2015, when it was feeding on trash deposited near the highway which passes through the PNP near Maredumilli. We also recorded this species at another location near Jalatarangini. This species is not common in its entire known range in India which includes the Western Ghats and adjoining areas from Maharashtra to Goa up to Kerala and northeast India (Evans 1932; Wynter-Blyth 1957; Varshney & Smetacek 2015). Apart from our record, the only other record from Eastern Ghats comes from an image of this species by Vivek Sarkar which is uploaded on IFB portal from Mundasaru in Kandhamal District of Odisha (Kunte 2017). So far, based on the existing reports, this species seems to be restricted to the northern parts of Eastern Ghats.

Family: Hesperiidae

Sub family: Hesperiinae

***Cupitha purreea* (Moore, 1877) (Wax Dart)**

(Image 2(6))

Our record of *Cupitha purreea* during this survey is the first report of this species from the Eastern Ghats. We observed only one individual of this species from an old regenerating 'podu' (local name for shifting agriculture) forest with lots of lianas, close to Pamuleru River near Maredumilli on 20 July 2015.

The known Indian distribution of this species is along the Western Ghats from Maharashtra to Kerala, eastern Himalaya, northeastern India and the Andaman Islands (Wynter-Blyth 1957; Varshney & Smetacek 2015). Globally, its range extends up to Sulawesi from Thailand, Laos, Langkawi, Malaysia, Borneo, Sumatra, Java, and the Philippines (Moore 1877, 1884; Piepers et al. 1910; Corbet & Pendlebury 1992; Vane-Wright & de Jong 2003). This species is not common throughout its range.

***Iambrix salsala* (Moore, [1866]) (Chestnut Bob)** (Image 3(1))

We recorded several individuals of this species on 18, 19 and 20 July 2017, from a riparian forest habitat flanked by shade coffee plantations near Maredumilli, in the northern Eastern Ghats. Apart from our record,

Image 2. Hersperiidae butterflies belonging to subfamilies Coeliadinae: 1. *Badamia exclamationis*, 2. *Bibasis sena*, 3. *Hasora* sp., 4. *Hasora vitta*; Hesperiinae: 5. *Oriens goloides*, 6. *Cupitha purreea*

the only other record of this species from the Eastern Ghats is that by Subramanium Kalluri (SK) from the same location in December 2010 (Kandoth 2018). The species is common in northeastern India where it can be seen in urban and semi-urban gardens as well as in the open areas, cultivations and plantation near forests and forest edges. All records of this species in India Biodiversity Portal, (IBP) (Goswami 2017) and Butterflies of India web portal (BOI) (Kandoth 2018), baring the one mentioned above, is restricted to the northeast, southern Bengal, the Western Ghats, eastern and central part of Karnataka and eastern Tamil Nadu. According to Varshney & Smetacek (2015) the species is distributed from Gujarat to Kerala and Uttarakhand to northeastern India.

***Matapa aria* (Moore, [1866]) (Common Redeye)** (Image 3(2))

In the northern Eastern Ghats, only one record of this species was obtained within the campus of the Forest Guest House at Maredumilli on 20 July 2015. This is the first record of this species from the Eastern Ghats. This species was earlier known from northern India (Uttarakhand, Delhi) and northeastern India, southern Bengal and southern India (Varshney & Smetacek 2015; Wynter-Blyth 1957). The species is common in its range in northeastern India and the Western Ghats.

***Potanthus* sp. (Dart)** (Image 3(4))

We recorded several individuals of *Potanthus* genus around Maredumilli beween 18 and 23 July 2015. There are no recent records of any species from the *Potanthus* genus from the Eastern Ghats or southern

Image 3. Hersperiidae butterflies belonging to subfamilies Hesperiinae: 1. *Iambrix salsala*, 2. *Matapa aria*, 3. *Notocrypta curvifascia*, 4. *Potanthus* sp., 5. *Suastus gremius*; Hesperiinae: 6. *Caprona ransonnettii*

Bengal. Specimens of this genus from Eastern Ghats needs to be collected and examined to determine species level distribution in the Eastern Ghats. Species level identification is difficult based on wing patterns and external morphological characteristics in this genus. Among the most abundant species of this genus, two species are known to occur in peninsular India and its hill ranges. *P. pseudomaesa* is known to be distributed from Jammu & Kashmir to northeastern India, Uttar Pradesh, Rajasthan, Madhya Pradesh and southwards down to Kerala (Varshney & Smetacek 2015). *P. palnia* is known from Karnataka and Kerala (Varshney & Smetacek 2015) while Wynter-Blyth (1957) recorded its distribution from the southern Indian hills.

Hersperiidae

Subfamily: Pyrginae

***Odontoptilum angulatum* (Felder, 1862) (Chestnut Angle)** (Image 4(1))

This is the first record of this species from the Eastern Ghats. We encountered only one individual of this species around the damp areas of moist deciduous forest during the survey on 20 July 2015 indicating that it might be rare in the Eastern Ghats. This butterfly is fairly common within its known range of the Western Ghats (Maharashtra to Kerala), western and central Himalaya, eastern Himalaya and the northeast (Wynter-Blyth 1957; Varshney & Smetacek 2015).

The known range of this species, which is closest to the Eastern Ghats, is from a record from Simlipal National Park in Odisha (Saji & Chandrashekharan 2017). Best (1954) did not record this from his survey

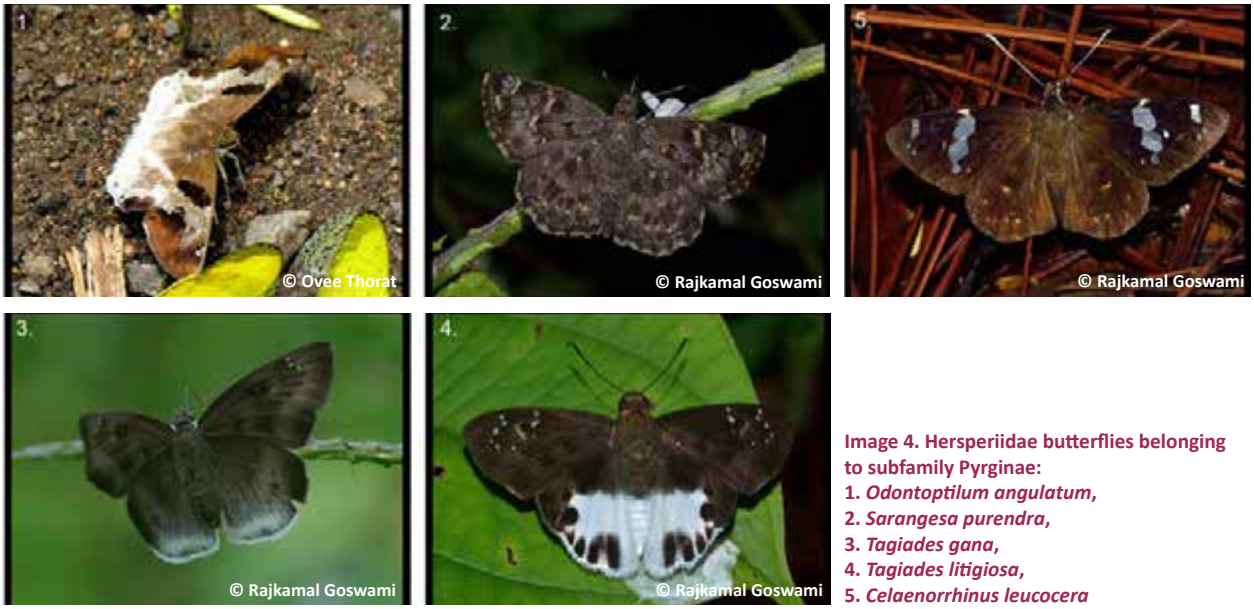

Image 4. Hersperiidae butterflies belonging to subfamily Pyrginae:
1. *Odontoptilum angulatum*,
2. *Sarangesa purendra*,
3. *Tagiades gana*,
4. *Tagiades litigiosa*,
5. *Celaenorrhinus leucocera*

of Nagalapuram Hills in southern Andhra Pradesh. The preferred habitat of this species is moist forests. In the Eastern Ghats, such forests mostly occur in the northern Eastern Ghats. Therefore, it is likely that the distribution of this species within the Eastern Ghats is probably restricted to the moist forests of northern Eastern Ghats.

***Sarangesa purendra* Moore, 1882 (Spotted Small Flat)** (Image 4(2))

Our observation of three individuals of this species on 18 July 2018 is the first report of this species from the Eastern Ghats. This species was sighted along the forest edges close to the Jalatarangini waterfall frequently during our July 2015 and August 2016 surveys in the area indicating that the species is locally common. The known distribution of this species is from northern Karnataka in the south till Maharashtra, Gujarat and Sindh region (Wynter-Blyth 1957). It has also been reported from Himachal Pradesh and Uttarakhand (Varshney & Smetacek 2015). It is not rare throughout its range.

Hersperiidae
Family: Lycaenidae
Subfamily: Polyommatinae
***Nacaduba berenice* (Herrich-Schäffer, 1869) (Rounded six-lineblue)** (Image 6(1))

Our observation of the species from Araku Valley near Katiki waterfall on 26 July is the first report of this species from the Eastern Ghats.

Two sub-species of *N. berenice* are reported from India. *N.b. nicobaricus* (Wood-Mason & de Niceville 1881) is distributed in the Andaman & Nicobar Islands while *N. b. plumbeomicans* (Wood-Mason & de Niceville 1881)'s distribution so far has been reported from Karnataka, Tamil Nadu, Kerala, Andaman & Nicobar Islands and northeastern India (Varshney & Smetacek 2015).

The species belongs to the six-lineblue group of butterflies which are difficult to identify in the field and without careful and technical diagnosis of its morphology can be easily misidentified as one of three very similar species with overlapping distributions - *N. kurava* Moore, 1858 (Transparent six-lineblue), *N. beroe* C. & R. Felder, 1865 (Opaque six-lineblue), and *N. calauria* C. Felder, 1860, (Dark Ceylon six-lineblue).

The main distinguishing features of *N. berenice* are rounded termen of fore and hindwings and the lack of zig-zagged lunules at the outer-discal region on the forewings (Wynter-Blyth 1957). Another identification key, which sets this species apart from the other two similar species, is the inner line of the discal area which joins the lower ends of the outer line of the cell-ending region (Evans 1932).

Lycaenidae
Subfamily: Theclinae
***Loxura atymnus* (Stoll, 1780) (Yamfly)** (Image 6(6))

Our report of *L. atymnus* from Maredumilli is its first record from the northern Eastern Ghats. Two individuals of this species were observed on 18 July 2018. This species is not uncommon throughout its range which

Image 5. Lycaenidae butterflies belonging to subfamily Polyommatini: 1. *Acytolepis puspa*, 2. *Caleta elna*, 3. *Castalius rosimon*, 4. *Chilades lajus*, 5. *Chilades pandava*, 6. *Euchrysops cnejus*

includes the Western Ghats from Maharashtra to Kerala, central India (Bihar, Jharkhand and Madhya Pradesh), and in northern India (Uttarakhand) to northeastern India, along with the Andaman & Nicobar Island (Evans 1932; Varshney & Smetacek 2015; Wynter-Blyth 1957). Wynter-Blyth (1957) has reported this species from the Servarayan Hills (anglicised as Shevaroy by Wynter-Blyth) which forms one of the southernmost parts of the Eastern Ghats and is part of Tamil Nadu.

Family: Nymphalidae

Subfamily: Cyrestinae

***Cyrestis cocles* (Fabricius, 1787) (Marbled Map)** (Image 8(1))

Our observation of this species on 20 July 2015 is its first record from Eastern Ghats. The species was observed mud-puddling at an elevation of 400m in a hill stream surrounded by dense forest patch near the Jalatarangini water fall. The location is frequently visited by tourists and is highly disturbed. This rare nymphalid is known from the northeast region of India including Sikkim along with southern part of Bihar and Odisha, which was its southernmost limit. So far, this is the southernmost limit of this species in India.

In the northeast too, this species has been recorded from areas with high human activity. This species is listed within the Part II of Schedule II list of protected animals under the Indian Wildlife (Protection) Act (Anonymous 1972).

Subfamily: Danainae

***Euploea sylvester* (Fabricius, 1793) (Double Branded Crow)** (Image 8(6))

This is the first record of this species from the

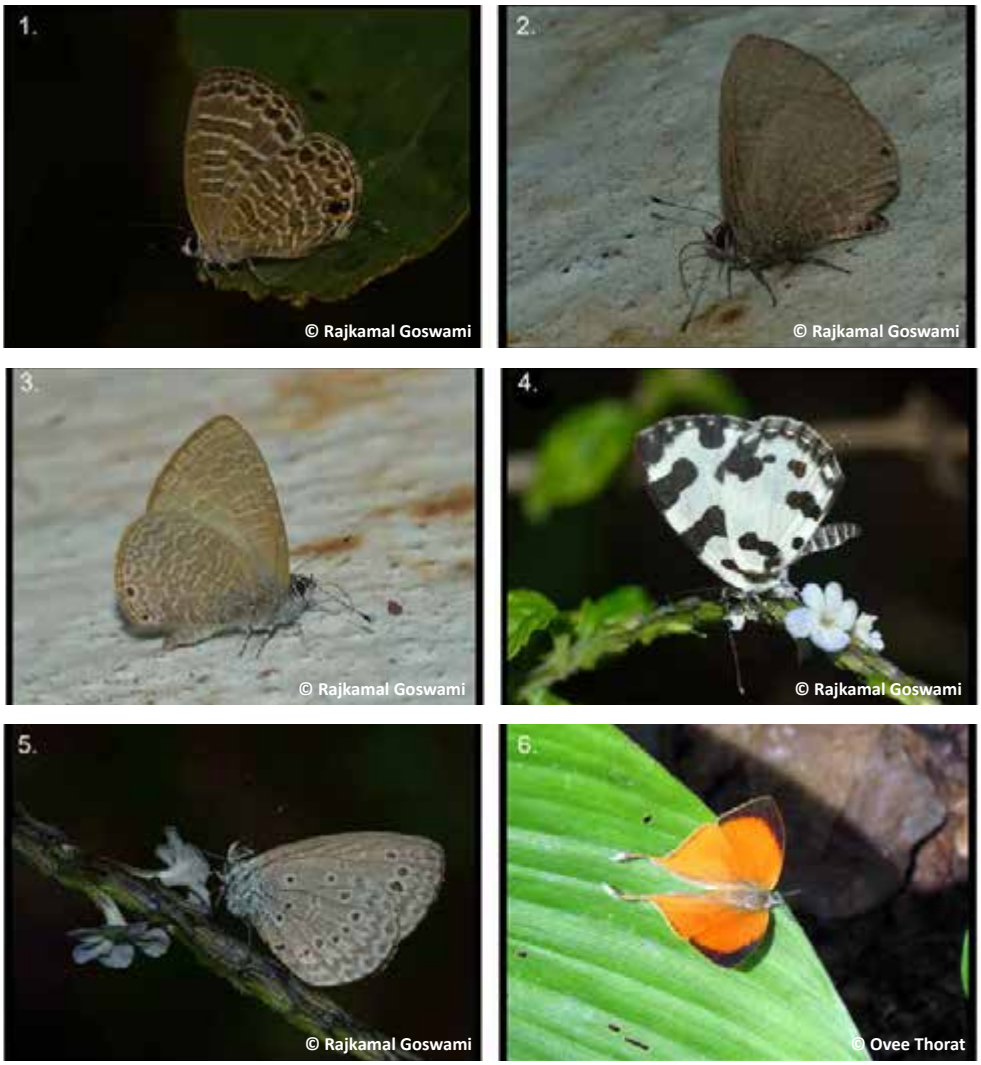

Image 6. Lycaenidae butterflies belonging to subfamilies Polyommatini: 1. *Nacaduba berenice*, 2. *Petrelaea dana*, 3. *Prosotas dubiosa*, 4. *Caleta decidia*, 5. *Zizeeria karsandra*; Theclinae: 6. *Loxura atymnus*

Image 7. Lycaenidae butterflies belonging to subfamily Theclinae 1. *Spindasis syama*, 2. *Spindasis vulcanus*, 3. *Zeltus amasa*

northern Eastern Ghats. We observed a dead specimen of this species on the 20 July 2015. The specimen was found on the tar road and was probably a case of roadkill. On examination, the specimen was found to be *E.s. coreta* as it had the two parallel long brands on the upper side of the forewings (Image 8(6)).

The subspecies *E.s. coreta* Godart, 1819 was found mud-puddling in damp patches on the side of the roads

Image 8. Nymphalidae butterflies belonging to subfamilies Cyrestinae: 1. *Cyrestis cocles*; Heliconiinae: 2. *Phalanta phalantha*; Charaxinae: 3. *Charaxes bharata*, 4. *Charaxes solon*; Danainae: 5. *Euploea mulciber*, 6. *Euploea sylvester*

along the denser part of the forest around Maredumilli. This species, although locally 'very common', particularly during the rainy and immediately after the rainy season throughout its range, hasn't been reported yet from the northern Eastern Ghats (Wynter-Blyth 1957), probably because the species is almost indistinguishable from *E. core* based on the underside wing-markings. Thus, it might have gone unreported.

Nymphalidae

Subfamily: Limenitidinae

***Neptis sappho* (Pallas, 1771) (Pallas' Sailer)**

(Image 10(1))

This is the first record of this species from Peninsular India. We observed several individuals during our surveys in July 2015 and August 2016. This species was encountered at about 1,100m in the highly degraded forest in Araku Valley near the Katiki Waterfall as well as at 400m in and around Maredumilli. The species is very similar to the Common Sailer (*N. hylas*) which we have also recorded from the northern Eastern Ghats; however the characteristics based on which *N. sappho* could be distinguished from *N. hylas*—(the veins in the UNH-under-hindwing is not blackened and in the forewing not blackened at least till cell) (Evans 1932)—could be photographed and therefore could be correctly identified. The species was found to be uncommon in the sites we recorded them from.

Our record of this species represents a significant range extension, adding a new species to the list of butterflies of peninsular India. From India, this species was so far known from western, central and eastern Himalaya and the northeastern region (Varshney & Smetacek 2015).

Image 9. Nymphalidae butterflies belonging to subfamilies Danainae: 1. *Parantica aglea*; Limenitidinae: 2. *Symphaedra nais*, 3. *Tanaecia lepidea*, 4. *Athyma nefte*, 5. *Athyma perius*, 6. *Athyma selenophora*

Nymphalidae
Subfamily: Satyrinae
***Lethe drypetis* (Hewitson, 1863) (Tamil Treebrown)**
(Image 11(2))

Our record of this species on the 28 August 2016 from Maredumilli and Jalatarangini water fall sites is the first record of this species from the Eastern Ghats. We observed four individuals during 2015 and another two during 2016 around the same locations in wet riparian vegetation. On both the days, rain had preceded our visit and the species was recorded resting in the shady understory. The species seemed to be locally common.

The subspecies *L.d. todara* Moore, 1881 is found in India and is distributed in the Western Ghats from Goa to Kerala and the states of Chhattisgarh and Odisha (Varshney & Smetacek 2015).

Papilionidae
Subfamily: Papilioninae
***Graphium eurypylus* (Linnaeus, 1758) (Great Jay)**
(Image 12(2))

Our observation of a single individual of *Graphium eurypylus* on 19 July 2015, mud puddling among yellows, papilionids and hedge blues in a damp teak plantation close to Maredumilli forest campus, is the first report of this species from peninsular India. Our record represents a significant range extension of the species from its current known range in the eastern Himalaya and the northeast of India (Varshney & Smetacek, 2015). The subspecies *G.e. macronius* Jordan, 1909 has been reported from the Andaman Islands.

Morphologically, in terms of wing markings and patterns, the species is similar to *Graphium evemon* (Boisduval, 1836) and *Graphium doson* (Felder & Felder,

Image 10. Nymphalidae butterflies belonging to subfamily Limenitidinae: 1. *Neptis sappho*, and Nymphalinae: 2. *Hypolimnas bolina*, 3. *Junonia iphita*, 4. *Junonia lemonias*, 5. *Kallima inachus*, 6. *Symbrenthia lilaea*

1864). The key characters in the underwing patterns, which distinguish it from the two similar species, could be detected from the images we shot. On the underside hindwing of this species, the costal bar is joined to the dark basal band across the cell and that the extreme end of the cell is red instead of brown (Evans 1932; Wynter-Blyth 1957). In very rare cases when the costal band in the UNH is not joined to the basal bar, then the basal margin of the silver band between them is notched (Evans 1932). This species is listed within the Part II of Schedule II list of protected animals under the Indian Wildlife (Protection) Act (Anonymous 1972).

***Papilio helenus* Linnaeus, 1758 (Red Helen)**

Our record of *P. helenus* from Maredumilli on 19 July 2015 is its first report from the northern Eastern Ghats. The species has not been recorded from Odisha or southern Bengal yet.

A relatively common butterfly of the forests, *P. helenus* is widely distributed across India. It has been reported from western and central Himalaya, eastern Himalaya and northeast and peninsular India (Evans 1932; Wynter-Blyth 1957; Varshney & Smetacek 2015). Within peninsular India, the butterfly so far has been reported from the Western Ghats, southern Eastern Ghats from the Servarayan Hills and Bangalore.

***Papilio polymnestor* (Cramer, 1775) (Blue Mormon)** (Image 12(6))

Our record of this species from multiple locations around Maredumilli, is its first report from the northern Eastern Ghats. We observed the species during morning and late afternoon nectaring around the forest edges close to streams and rivers on all days during our survey

Image 11. Nymphalidae butterflies belonging to subfamily Satyrini
1. *Melanitis leda*,
2. *Lethe drypetis*,
3. *Mycalesis mineus*,
4. *Ypthima huebneri*

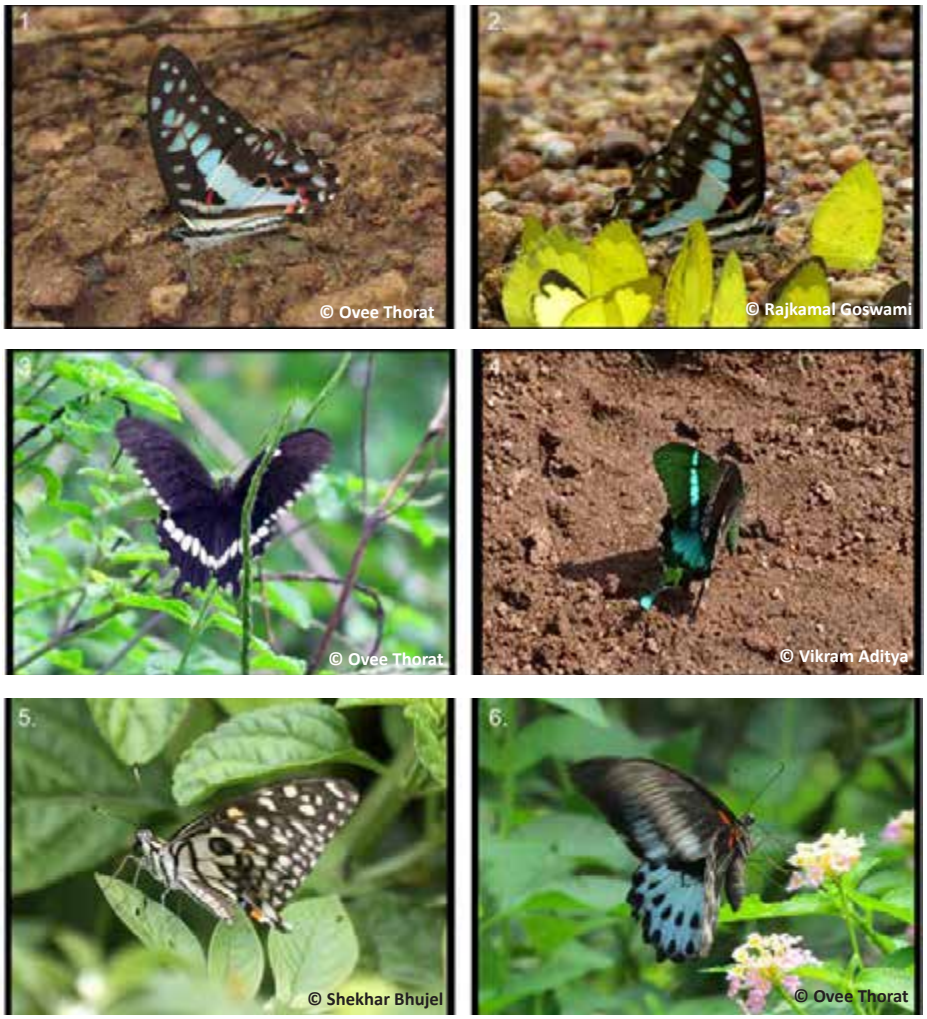

Image 12. Papilionidae butterflies belonging to subfamily Papilioninae
1. *Graphium doson*,
2. *Graphium eurypylus*,
3. *Papilio polytes*,
4. *Papilio crino*,
5. *Papilio demoleus*,
6. *Papilio polymnestor*

Image 13. Pieridae butterflies belonging to subfamily Coliadinae: 1. *Catopsilia pyranthe*, 2. *Eurema hecabe*, 3. *Eurema andersonii*, 4. *Eurema blanda*, 5. *Gandaca harina*, and a Riodinidae butterfly belonging to the subfamily Nemeobiina: 6. *Abisara bifasciata*

periods in 2015 and 2016.

P. polymnestor is a large common butterfly in peninsular India and found in urban, rural as well as edges of forested areas. Although the butterfly is believed to be endemic to peninsular India (Kunte & Gadgil 2000), its occurrence has been reported from as far as Sikkim, southern Bihar, West Bengal (Wynter-Blyth 1957) as well as neighbouring Bangladesh (Larsen 2004). RG has also recorded this species from Nongpoh located in the northern Khasi Hills, Meghalaya at 600m.

From the Eastern Ghats, there is only one previous record of this species by Best (1954) from the Nagalapuram Hills in southern Andhra Pradesh, close to the Tamil Nadu border.

Pieridae

Subfamily: *Coliadinae*

***Eurema andersonii* (Moore, 1886) (One-spot Grass Yellow)** (Image 13(3))

Our record of one specimen of *Eurema andersonii* on 18 July 2015, which lay injured on the SH 41 near Rampachodavaram probably after being hit by a vehicle, is its first report from northern Eastern Ghats. On both sides of the roads were teak plantations of variable age. This is the only record of this species we have got so far from our entire survey effort.

This butterfly's known distribution in India so far ranges from Uttarakhand, central Himalayan region, northeast, and the states of Karnataka, Kerala, Tamil Nadu in peninsular India and the South Andaman Islands (Varshney & Smetacek 2015; Sondhi & Kunte 2018).

Table 3. List of butterflies recorded during the survey along with their schedule according to the Wildlife Protection Act (1972). New species records for Peninsular India, Entire Eastern Ghats, northern Eastern Ghats and Andhra Pradesh are indicated with 'X' mark. WPA 1972=Wildlife Protection Act (1972). PI - Peninsular India; EEG - Entire Eastern Ghats; NEG - northern Eastern Ghats; AP - Andhra Pradesh

	Image number	Common name	Scientific name	Family	Subfamily	Tribe	New species record				Schedule Species -WPA, 1972
							PI	EEG	NEG	AP	
1	Image 2(1)	Brown Awl	*Badamia exclamationis* (Fabricius, 1775)	Hesperiidae	Coeliadinae						
2	Image 2(2)	Orange-tailed Awl	*Bibasis sena* (Moore, [1866])	Hesperiidae	Coeliadinae			X	X	X	Sch II (Part II)
3		Common Awl	*Hasora badra* (Moore, [1858])	Hesperiidae	Coeliadinae						
4		Common banded Awl	*Hasora chromus* (Cramer, 1780)	Hesperiidae	Coeliadinae						
5	Image 2(3)	Aw sp.	*Hasora sp.*	Hesperiidae	Coeliadinae						
6	Image 2(4)	Plain banded Awl	*Hasora vitta* (Butler, 1870)	Hesperiidae	Coeliadinae					X	Sch IV
7	Image 2(5)	Ceylon Dartlet	*Oriens goloides* (Moore, [1881])	Hesperiidae	Hesperiinae	Taractrocerini					
8	Image 2(6)	Wax Dart	*Cupitha purreea* (Moore, 1877)	Hesperiidae	Hesperiinae	Aeromachini		X	X	X	
9	Image 3(1)	Chestnut Bob	*Iambrix salsala* (Moore, [1866])	Hesperiidae	Hesperiinae	Aeromachini					
10	Image 3(2)	Common Redeye	*Matapa aria* (Moore, [1866])	Hesperiidae	Hesperiinae	Aeromachini		X	X	X	
11	Image 3(3)	Restricted Demon	*Notocrypta curvifascia* (Felder & Felder, 1862)	Hesperiidae	Hesperiinae	Aeromachini					
12	Image 3(4)	Dart sp.	*Potanthus* sp.	Hesperiidae	Hesperiinae	Aeromachini					
13	Image 3(5)	Indian Palm Bob	*Suastus gremius* (Fabricius, 1798)	Hesperiidae	Hesperiinae	Aeromachini					
14	Image 3(6)	Golden Angle	*Caprona ransonnettii* (Felder, 1868)	Hesperiidae	Pyrginae	Tagiadini					
15	Image 4(1)	Chestnut Angle	*Odontoptilum angulatum* (Felder& Felder, 1862)	Hesperiidae	Pyrginae	Tagiadini				X	
16		Common Small Flat	*Sarangesa dasahara* (Moore, [1866])	Hesperiidae	Pyrginae	Celaenorrhinini					
17	Image 4(2)	Spotted Small Flat	*Sarangesa purendra* Moore, 1882	Hesperiidae	Pyrginae	Celaenorrhinini		X	X	X	
18	Image 4(3)	Suffused Snow Flat	*Tagiades gana* (Moore, [1866])	Hesperiidae	Pyrginae	Tagiadini					
19		Common Snow Flat	*Tagiades japetus* (Stoll, [1781])	Hesperiidae	Pyrginae	Tagiadini					
20	Image 4(4)	Water Snow Flat	*Tagiades litigiosa* Möschler, 1878	Hesperiidae	Pyrginae	Tagiadini					
21	Image 4(5)	Common Spotted Flat	*Celaenorrhinus leucocera* (Kollar, [1844])	Hesperiidae	Pyrginae	Celaenorrhinini					
22	Image 5(1)	Common Hedge Blue	*Acytolepis puspa* (Horsfield, [1828])	Lycaenidae	Polyommatinae	Polyommatini					
23		Common Ciliate Blue	*Anthene emolus* (Godart, [1824])	Lycaenidae	Polyommatinae	Polyommatini					
24	Image 5(2)	Elbowed Pierrot	*Caleta elna* (Hewitson, 1876)	Lycaenidae	Polyommatinae	Polyommatini					
25	Image 5(3)	Common Pierrot	*Castalius rosimon* (Fabricius, 1775)	Lycaenidae	Polyommatinae	Polyommatini					
26	Image 5(4)	Lime Blue	*Chilades lajus* (Stoll, [1780])	Lycaenidae	Polyommatinae	Polyommatini					
27	Image 5(5)	Plains Cupid	*Chilades pandava* (Horsfield, [1829])	Lycaenidae	Polyommatinae	Polyommatini					
28	Image 5(6)	Gram Blue	*Euchrysops cnejus* (Fabricius, 1798)	Lycaenidae	Polyommatinae	Polyommatini					Sch II (Part II)
29		Metallic Cerulean	*Jamides alecto* (Felder, 1860)	Lycaenidae	Polyommatinae	Polyommatini					

	Image number	Common name	Scientific name	Family	Subfamily	Tribe	New species record				Schedule Species -WPA, 1972
							PI	EEG	NEG	AP	
30		Dark Cerulean	*Jamides bochus* (Stoll, [1782])	Lycaenidae	Polyommatinae	Polyommatini					
31		Common Cerulean	*Jamides celeno* (Cramer, [1775])	Lycaenidae	Polyommatinae	Polyommatini					
32	Image 6(1)	Rounded Six-Line Blue	*Nacaduba berenice* (Herrich-Schäffer, 1869)	Lycaenidae	Polyommatinae	Polyommatini		X	X	X	
33	Image 6(2)	Dingy Lineblue	*Petrelaea dana* (de Nicéville, [1884])	Lycaenidae	Polyommatinae	Polyommatini					
34	Image 6(3)	Tailless Lineblue	*Prosotas dubiosa* (Semper, [1879])	Lycaenidae	Polyommatinae	Polyommatini					
35		Common Lineblue	*Prosotas nora* (Felder, 1860)	Lycaenidae	Polyommatinae	Polyommatini					
36		Red Pierrot	*Talicada nyseus* (Guérin-Méneville, 1843)	Lycaenidae	Polyommatinae	Polyommatini					
37	Image 6(4)	Angled Pierrot	*Caleta decidia* (Hewitson, 1876)	Lycaenidae	Polyommatinae	Polyommatini					
38	Image 6(5)	Dark Grass Blue	*Zizeeria karsandra* (Moore, 1865)	Lycaenidae	Polyommatinae	Polyommatini					
39		Common Acacia Blue	*Surendra quercetorum* (Moore, [1858])	Lycaenidae	Theclinae	Arhopalini					
40		Purple Leafblue	*Amblypodia anita* Hewitson, 1862	Lycaenidae	Theclinae	Amblypodiini					
41	Image 6(6)	Yamfly	*Loxura atymnus* (Stoll, 1780)	Lycaenidae	Theclinae	Loxurini			X	X	
42	Image 7(1)	Club Silverline	*Spindasis syama* (Horsfield, 1829)	Lycaenidae	Theclinae	Aphnaeini					
43	Image 7(2)	Common Silverline	*Spindasis vulcanus* (Fabricius, 1775)	Lycaenidae	Theclinae	Aphnaeini					
44	Image 7(3)	Fluffy Tit	*Zeltus amasa* (Hewitson, 1865)	Lycaenidae	Theclinae	Hypolycaenini					
45		Angled Castor	*Ariadne ariadne* (Linnaeus, 1763)	Nymphalidae	Biblidinae	Biblidini					
46		Common Castor	*Ariadne merione* (Cramer, [1777])	Nymphalidae	Biblidinae	Biblidini					
47	Image 8(1)	Marbled Map	*Cyrestis cocles* Fabricius, 1787	Nymphalidae	Cyrestinae	Cyrestini				X	Sch II (Part II)
48		Tawny Coster	*Acraea terpsicore* (Linnaeus, 1758)	Nymphalidae	Heliconiinae	Acraeini					
49	Image 8(2)	Common Leopard	*Phalanta phalantha* (Drury, [1773])	Nymphalidae	Heliconiinae	Vagrantini					
50	Image 8(3)	Indian Nawab	*Charaxes bharata* (Felder & Felder, 1867)	Nymphalidae	Charaxinae	Charaxini					
51	Image 8(4)	Black Rajah	*Charaxes solon* (Fabricius, 1793)	Nymphalidae	Charaxinae	Charaxini					
52		Plain Tiger	*Danaus chrysippus* (Linnaeus, 1758)	Nymphalidae	Danainae	Danaini					
53		Striped Tiger	*Danaus genutia* (Cramer, [1779])	Nymphalidae	Danainae	Danaini					
54		Common Crow	*Euploea core* (Cramer, [1780])	Nymphalidae	Danainae	Danaini					
55	Image 8(5)	Striped Blue Crow	*Euploea mulciber* (Cramer, [1777])	Nymphalidae	Danainae	Danaini					Sch IV
56	Image 8(6)	Double branded Crow	*Euploea sylvester* (Fabricius, 1793)	Nymphalidae	Danainae	Danaini			X	X	
57	Image 9(1)	Glassy Tiger	*Parantica aglea* (Stoll, [1782])	Nymphalidae	Danainae	Danaini					
58		Blue Tiger	*Tirumala limniace* (Cramer, [1775])	Nymphalidae	Danainae	Danaini					
59		Dark Blue Tiger	*Tirumala septentrionis* (Butler, 1874)	Nymphalidae	Danainae	Danaini					
60		Large Yeoman	*Cirrochroa aoris* (Doubleday, [1847])	Nymphalidae	Heliconiinae	Vagrantini					

	Image number	Common name	Scientific name	Family	Subfamily	Tribe	New species record				Schedule Species -WPA, 1972
							PI	EEG	NEG	AP	
61	Image 9(2)	Baronet	*Symphaedra nais* (Forster, 1771)	Nymphalidae	Limenitidinae	Adoliadini					
62	Image 9(3)	Grey Count	*Tanaecia lepidea* (Butler, 1868)	Nymphalidae	Limenitidinae	Adoliadini					
63	Image 9(4)	Colour Sergeant	*Athyma nefte* (Westwood, 1850)	Nymphalidae	Limenitidinae	Limenitidini					
64	Image 9(5)	Common Sergeant	*Athyma perius* (Linnaeus, 1758)	Nymphalidae	Limenitidinae	Limenitidini					
65	Image 9(6)	Staff Sergeant	*Athyma selenophora* (Kollar, [1844])	Nymphalidae	Limenitidinae	Limenitidini					
66		Commander	*Moduza procris* (Cramer, [1777])	Nymphalidae	Limenitidinae	Limenitidini					
67	Image 10(1)	Pallas' Sailer	*Neptis sappho* (Pallas, 1771)	Nymphalidae	Limenitidinae	Limenitidini	X	X	X	X	
68		Common Sailer	*Neptis hylas* (Linnaeus, 1758)	Nymphalidae	Limenitidinae	Neptini					
69	Image 10(2)	Great Eggfly	*Hypolimnas bolina* (Linnaeus, 1758)	Nymphalidae	Nymphalinae	Junoniini					
70		Danaid Eggfly	*Hypolimnas misippus* (Linnaeus, 1764ŽŽ)	Nymphalidae	Nymphalinae	Junoniini					Sch II (Part II)
71		Grey Pansy	*Junonia atlites* (Linnaeus, 1763)	Nymphalidae	Nymphalinae	Junoniini					
72	Image 10(3)	Chocolate Pansy	*Junonia iphita* (Cramer, [1779])	Nymphalidae	Nymphalinae	Junoniini					
73	Image 10(4)	Lemon Pansy	*Junonia lemonias* (Linnaeus, 1758)	Nymphalidae	Nymphalinae	Junoniini					
74	Image 10(5)	Orange Oakleaf	*Kallima inachus* (Boisduval, 1846)	Nymphalidae	Nymphalinae	Kallimini					
75	Image 10(6)	Common Jester	*Symbrenthia lilaea* (Hewitson, 1864)	Nymphalidae	Nymphalinae	Nymphalini					
76		Common Palmfly	*Elymnias hypermnestra* (Linnaeus, 1763)	Nymphalidae	Satyrinae	Elymniini					
77	Image 11(1)	Common Evening-brown	*Melanitis leda* (Linnaeus, 1758)	Nymphalidae	Satyrinae	Melanitini					
78	Image 11(2)	Tamil Treebrown	*Lethe drypetis* (Hewitson, 1863)	Nymphalidae	Satyrinae	Satyrini		X	X	X	
79	Image 11(3)	Dark-brand Bushbrown	*Mycalesis mineus* (Linnaeus, 1758)	Nymphalidae	Satyrinae	Satyrini					
80		Common Bushbrown	*Mycalesis perseus* (Fabricius, 1775)	Nymphalidae	Satyrinae	Satyrini					
81	Image 11(4)	Common Four-ring	*Ypthima huebneri* Kirby, 1871	Nymphalidae	Satyrinae	Satyrini					
82		Common Lascar	*Pantoporia hordonia* (Stoll, [1790])	Nymphalidae							
83		Common Bluebottle	*Graphium sarpedon* (Linnaeus, 1758)	Papilionidae	Papilioninae	Leptocircini					
84	Image 12(2)	Great Jay	*Graphium eurypylus* (Linnaeus, 1758)	Papilionidae	Papilioninae	Leptocircini	X	X	X	X	
85	Image 12(1)	Common Jay	*Graphium doson* (Felder & Felder, 1864)	Papilionidae	Papilioninae	Leptocircini					
86		Red Helen	*Papilio helenus* Linnaeus, 1758	Papilionidae	Papilioninae	Papilionini			X	X	
87		Common Mime	*Papilio clytia* Linnaeus, 1758	Papilionidae	Papilioninae	Papilionini					
88	Image 12(3)	Common Mormon	*Papilio polytes* Linnaeus, 1758	Papilionidae	Papilioninae	Papilionini					
89	Image 12(4)	Common-banded Peacock	*Papilio crino* Fabricius, 1793	Papilionidae	Papilioninae	Papilionini					
90	Image 12(5)	Lime Swallowtail	*Papilio demoleus* Linnaeus, 1758	Papilionidae	Papilioninae	Papilionini					
91	Image 12(6)	Blue Mormon	*Papilio polymnestor* (Cramer, [1775])	Papilionidae	Papilioninae	Papilionini			X	X	
92		Common Emigrant	*Catopsilia pomona* (Fabricius, 1775)	Pieridae	Coliadinae	Coliadini					

	Image number	Common name	Scientific name	Family	Subfamily	Tribe	New species record				Schedule Species -WPA, 1972
							PI	EEG	NEG	AP	
93	Image 13(1)	Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus, 1758)	Pieridae	Coliadinae	Coliadini					
94	Image 13(2)	Common Grass Yellow	*Eurema hecabe* (Linnaeus, 1758)	Pieridae	Coliadinae	Euremini					
95	Image 13(3)	One-spot Grass Yellow	*Eurema andersonii* (Moore, 1886)	Pieridae	Coliadinae	Euremini			X	X	
96	Image 13(4)	Three-spot Grass Yellow	*Eurema blanda* (Boisduval, 1836)	Pieridae	Coliadinae	Euremini					
97	Image 13(5)	Tree Yellow	*Gandaca harina* (Horsfield, 1829)	Pieridae	Coliadinae	*Incertae sedis*	X	X	X	X	
98		Wanderer	*Pareronia hippia* (Fabricius, 1787)	Pieridae	Pierinae	Nepheroniini					
99		Common Albatross	*Appias albina* (Boisduval, 1836)	Pieridae	Pierinae	Pierini					
100		Common Jezebel	*Delias eucharis* (Drury, 1773)	Pieridae	Pierinae	Pierini					
101		Common Gull	*Cepora nerissa* (Fabricius, 1775)	Pieridae	Pierinae	Pierini					
102	Image 13(6)	Double-banded Judy	*Abisara bifasciata* Moore, 1877	Riodinidae	Nemeobiinae	Abisarini					

***Gandaca harina* (Horsfield, [1829]) (Tree Yellow)** (Image 13(4))

Our observation of *Gandaca harina* on 18 July 2015 from a shade coffee plantation edge close to Maredumilli, is the first report of this species from peninsular India.

Apart from this record, we observed this species only twice and believe that it might be rarely distributed in the northern Eastern Ghats within its preferred habitat of forest with dense forest canopy. The sub-species, *G. h. assamica* Moore, 1906, so far known to be occurring across the northeast and West Bengal (Varshney & Smetacek 2015) was recently reported from Kumaon by Sondhi (2017). Two other sub-species *G. h. andamana* Moore, 1906 and *G. h. nicobarica* Evans, 1932 has been reported from the Andaman and Nicobar Islands respectively.

DISCUSSION

A rapid and opportunistic but intensive survey of butterflies at a few sites within the northern Eastern Ghats resulted in recording 102 species of butterflies out of which 17 records were highly significant in nature. These included three new species records for peninsular India, nine new species records for the Eastern Ghats and 14 new species records for the northern Eastern Ghats. Nine of the species are accorded highest protection under the Indian Wildlife Act (Anonymous 1972) which include species such as the Orange-tailed Awl *Bibasis sena*, a new species for the Eastern Ghats and Great Jay *Graphium eurypylus*, a new species record for the Indian peninsular region. We add 17 new butterflies to the existing butterflies of the state of Andhra Pradesh.

Highest number of new species records (six) were obtained for members of the Herperiidae family, probably because most butterfly survey tends to take place once the day gets warmer, usually late morning, once the sun is fully out. Most of the Hesperiidae are shade loving and are usually crepuscular, i.e., they are most active during the early morning and evenings. Moreover, they are also fast moving and cryptic, therefore difficult to observe and capture images.

Among the other more camera-friendly and relatively more ubiquitous butterfly families, most new records were for species which are difficult to identify without handling them. Such as the Double-banded Crow *Euploea sylvester*. A few are impossible to identify conclusively without high quality images which manages to capture finer identifying morphological characteristics and wing-markings. For example, the Rounded Six-lineblue *Nacaduba berenice*, the Pallas' Sailer *Neptis sappho* and Great Jay *Graphium eurypylus*.

Thus, while the number of new records underlines how under explored the region has been till date, the high turnover of butterfly species within a short rapid survey underscores the importance of the northern Eastern Ghats as an area with significant butterfly diversity. During our survey, we recorded very high butterfly activity along the streams and roads with hundreds of lycaenids, pierids and papilionids seen to be mud puddling.

Numerous records of both Western Ghats, northeastern Indian and Himalayan butterfly species during our survey strengthens the theory that the Eastern Ghats is a transitional zone which facilitates species mixing and might have been crucial in the colonisation of peninsular India by the oriental fauna, which is known to comprise 78% of all butterflies known so far from the Western Ghats (Kunte 2016).

The Eastern Ghats, particularly the northern Eastern Ghats, is under severe developmental pressure today. Large areas, some of which include the sites we surveyed has been earmarked for many upcoming development and mining projects, including the Polavaram hydroelectric project, which will lead to the creation of one of the largest dams in India. The resulting reservoir is poised to submerge a substantial area comprised of primary forests. We feel that development at such high ecological costs has been allowed in the northern Eastern Ghats without much resistance, unlike other 'biodiversity hotspots', mainly because it has not received due attention from the conservation community.

The area is a goldmine for both the amateur natural historians and the conservation biologists seeking new avenues and area to study and conduct research. Higher engagement with this very poorly explored region will help to highlight its precarious status. For example, besides Polavaram, five other medium irrigation dams at Bhupathipalem, Musurumilli, Kovvadakalva, Jalleru and Surampalem have come up around PNP. Mining activities, particularly for bauxite in the mineral laden hilltops in Araku is a constant threat to these Ghats (Pattanaik et al. 2009a; Kumar et al. 2010; Samata 2003). Apart from such large scale threats, continuous use, extraction and disturbances of seemingly low intensities such as unruly and irresponsible tourism, high-demand for bamboo chicken, shifting cultivation, hunting and commercial plantations have been rendering many of these forest patches 'empty' by producing long term insidious impacts on the flora and fauna (Ganesh et al. 2015).

The high butterfly diversity recorded in the northern Eastern Ghats can be used to mobilise conservation attention to the ongoing damage to natural ecosystems. All the sites with high butterfly activity were very close to Maredumilli and can be easily accessed by foot. With an already existing range of accommodation options for tourists within the forest department campus, PNP has the potential to emerge as a popular butterfly tourism site, which can provide a much-needed profile boost to the region. Ecotourism is known to benefit conservation activities by enabling frequent monitoring of biodiversity and increasing the popularity of biodiversity rich area. Further, the eco-tourist tends to articulate strong and influential pro-conservation opinion during flashpoints of crises and threats. Therefore, we strongly recommend the development and implementation of a well-regulated butterfly tourism plan, within the framework of responsible and low-impact ecotourism, to attract amateur naturalists and nature lovers.

CONCLUSION

The survey showed that both the northern Eastern Ghats and the PNP are very important sites for butterfly diversity and conservation. Currently both face high conservation threats and the findings may be used to contain or reduce the extent of threat. The current findings although limited by time and funds, lay the foundation for more long-term, detailed and focussed butterfly surveys in the future. Diversity studies such as these will help to prioritise area for conservation and research, and designate no go areas for developmental and high intensity extraction/habitat transformation activities.

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Author Contribution: Rajkamal collected data in the field, compiled the checklist and wrote the manuscript. Ovee collected data in the field, contributed to the manuscript and prepared the image plates. Vikram facilitated logistics during field data collection, helped in data collection and contributed to the manuscript. Seena helped in data collection, contributed to the manuscript and worked on the taxonomy of the butterflies.

COMMUNICATION

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Aquatic and semi aquatic Hemiptera community of Sonebeel, the largest wetland of Assam, northeastern India

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Abstract: Aquatic and semiaquatic Hemiptera bugs play significant ecological roles, and they are important indicators and pest control agents. Little information is currently available concerning its populations in southern Assam. This study assessed hemipterans in four sites of Sonebeel, the largest wetland in Assam (3458.12 ha at full storage level), situated in Karimganj District. The major inflow and outflow of the wetland are the rivers Singla and Kachua, respectively (the Kachua drains into the Kushiyara River). Samples were trapped with pond nets and were seasonally recorded. This study recorded a total of 28 species of aquatic and semiaquatic hemipterans belonging to 20 genera under nine families. Population, geographical and environmental data (e.g., rainfall) were used to assess the relative abundance of species, species richness and different diversity indices, and species distribution.

Keywords: Distribution, diversity, Gerromorpha, Nepomorpha, relative abundance, richness, wetland.

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Author Contribution: AS has done the field work, laboratory work and preparation of the manuscript. SG has supervised the whole work and preparation of the manuscript.

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INTRODUCTION

Human disturbance can damage freshwater habitats and introduce biotic pressures including over-exploitation, water pollution, flow modification, degradation of habitat and invasion by exotic species (Dudgeon et al. 2006). These escalating threats have led to a global crisis in loss of freshwater biodiversity (Vorosmarty et al. 2010), which is especially serious in wetlands (Strayer & Dudgeon 2010). In India, for example, wetlands are under stress due to rapid urbanization, industrialization and agricultural intensification (Bassi et al. 2014) and freshwater systems are experiencing greater and more rapid declines in biodiversity compared to other terrestrial ecosystems (Sala et al. 2000).

Aquatic insects serve as ecological indicators of environmental change. Among aquatic insects, bugs of the order Hemiptera, suborder Heteroptera, occupy a prominent position, with approximately 4,000 known species (Dudgeon 1999) broadly classified into infraorders Nepomorpha and Gerromorpha (Bouchard 2009). These bugs play significant ecological roles as both predators and prey, and many are important biocontrol agents. Their varying tolerance to pollution and environmental change also makes them useful as indicator species. Studies of aquatic and semiaquatic Hemiptera in most regions of Assam are still at the exploratory stage (Tordoff et al. 2012). Against this backdrop we selected Sonebeel, the largest (3458.12ha at full storage level) wetland of Assam for studies of Hemiptera communities. Located in the Indo-Burma Biodiversity Hotspot, this wetland has an important role in conservation of local biodiversity as it provides habitats for many herbivores, carnivores and insectivores, including vulnerable and threatened avifauna. According to Chakravarty et al. (2015), Lesser Adjutant and Pallas's Fish Eagle (vulnerable) and Black-headed Ibis (threatened) were recorded in Sonebeel. This wetland also acts as the primary source of livelihood for local human inhabitants. This study provides an inventory of aquatic and semiaquatic Hemiptera communities in Sonebeel, and provides assessments of seasonal variations in species richness, diversity indices, relative abundance and dominance status.

METHODS

The Sonebeel (3458.12ha, 12.5km long and 3.9km wide with a shoreline of 35.4km) is situated in Karimganj District (Fig. 1). The catchment area of the wetland has ravines, slopes and hilly terrains. The soil type is loamy, sandy or gravelly in the plains and fine-grained sandstones in the hilly region. It is surrounded by hills on its west and east shorelines. The major inflow and outflow of this wetland are the rivers Singla and Kachua, respectively. For the current study four sites were selected, namely, Site 1 Debodwar (24.702^{0}N–92.453^{0}E), Site 2 Anandapur (24.682^{0}N–92.452^{0}E), Site 3 Chamala (24.676^{0}N–92.422^{0}E) and Site 4 Phakuagram (24.677^{0}N–92.424^{0}E). Data were recorded seasonally,

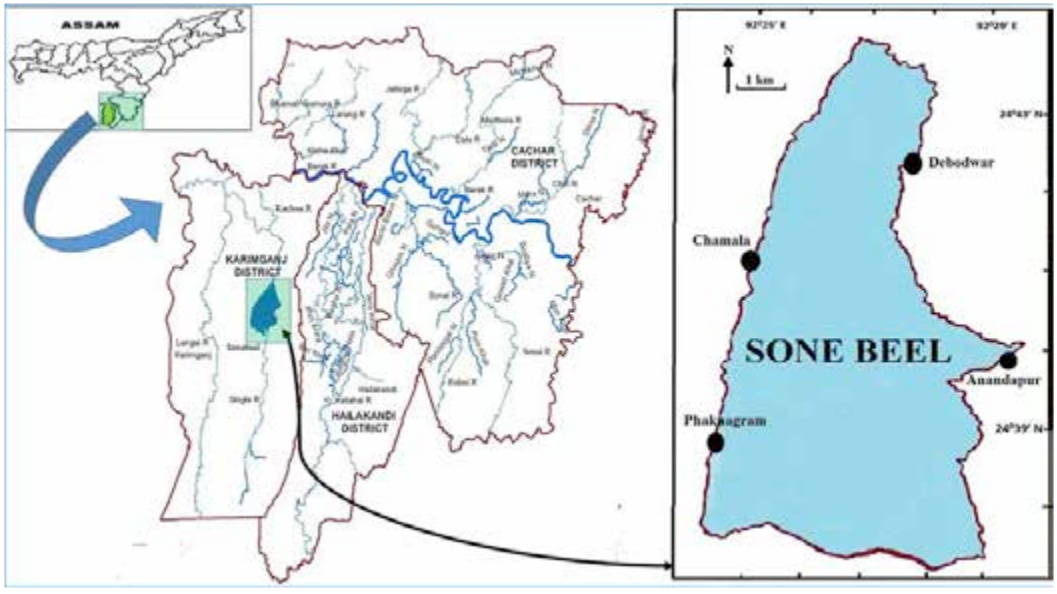

Figure 1. Map of Assam and Barak Valley showing Sonebeel and the four collection sites. (Map not up to scale)

viz, winter (W), premonsoon (PR), monsoon (M) and postmonsoon (PM) during 2012–2014. During collection hemipterans were sampled in triplicates using a bigger pond net (mesh opening: 500µm; diameter: 60cm; depth: 50cm) and a D-net with adjustable handle. Bigger pond net was dragged around the vegetation for one minute. Three such drags constituted a sample (Brittain 1974; Subramanian & Sivaramakrishnan 2007). Aquatic vegetation sampled for insects were searched vigorously for hemipterans. All out search method was employed to collect insects from the substratum when the lake becomes shallow. Samples were preserved in 70% ethanol (Subramanian & Sivaramakrishnan 2007). Identification was carried out by using standard keys (Bal & Basu 1994 a,b; Bouchard 2004; Nieser 2004; Nieser & Chen 2005; Thirumalai 1989, 1994, 1999, 2002; ZSI 2004). Various diversity indices like Shannon Weiner diversity index, Evenness index and Berger-Parker index of dominance were studied using Biodiversity Professional Version 2. Dominance status of the aquatic and semi aquatic Hemiptera were evaluated on the basis of relative abundance using Engelmann's scale (Engelmann 1978). The software Biodiversity Pro was also used to study the individual-based rarefaction curves, accumulation curve of the study sites. Community-level analysis of the four habitats using single linkage cluster analysis based on Bray-Curtis similarity was also performed using this package. Monthly Rainfall data were collected from the meteorological centre of Regional Agricultural Research Station (RARS), Akbarpur, Karimganj District, Assam.

RESULTS AND DISCUSSION

An inventory of the aquatic and semi aquatic Hemiptera of Sonebeel along with their relative abundance in the four sites is listed in Table 1. The study recorded a total of nine aquatic and semi aquatic Hemiptera families, 20 genera and 28 species belonging to infra-order Nepomorpha and Gerromorpha from the four sites of Sonebeel (Table 1; Appendix 1). Throughout the collection, Site 3 recorded with the highest number of 23 species. Among all seasons the highest number of species, genera and families of Hemiptera were recorded in monsoon 2014. Gerridae was represented by seven species followed by Corixidae and Notonectidae by nine species each. Highest number of species and genera was recorded during monsoon 2013 in Site 2, while the highest number of families was recorded during monsoon 2014 in Site 4 (Fig. 2). Das & Gupta (2012), recorded 14 species belonging to 11 genera and seven families of Hemiptera insect community in a temple pond of Silcoorie Tea Estate, Cachar, Assam. In a similar study at two ponds of Chatla floodplain of Cachar District, Purkayastha & Gupta (2012) recorded six species belonging to six genera and three families. Further Purkayastha & Gupta (2015) carried out a study at Monabeel, a part of Chatla floodplain ecosystem recorded two more species belonging to an additional family. Choudhury & Gupta (2015), carried out a study in Deeporbeel, the only Ramsar site of Assam, and recorded 17 species of Hemiptera belonging to 13 genera and eight families. Takhelmayum & Gupta (2011) recorded four species belonging to four genera and three families of order Hemiptera from the Phumdis (floating island) of Loktak Lake, Manipur. Further in the Keibul Lamjao National Park, which is a part of Loktak Lake, Takhelmayum & Gupta (2015) recorded two more species in addition to their previous study.

Micronecta scutellaris and *Trepobates* sp. were the eudominant species recorded in Site 1 and Site 3 respectively. Additionally, among the 18 recorded species in Site 1, *Micronecta siva* and *Micronecta ludibunda* were recorded dominant. In Site 2, among the 21 recorded species, *Micronecta scutellaris*, *Micronecta ludibunda* and *Anisops breddini* were the dominant species. In Site 3, *Micronecta scutellaris* was recorded dominant. In Site 4, among the 22 recorded species, *Micronecta siva*, *Micronecta scutellaris* and *Micronecta ludibunda* were recorded dominant (Table 1). Das & Gupta (2012) also reported Family Corixidae and Notonectidae as the eudominant in the temple pond whereas Purkayastha & Gupta (2012) reported family Gerridae to be the eudominant in the two ponds of Chatla floodplain, and Corixidae and Mesoveliidae as the eudominant families in Monabeel (Purkayastha & Gupta 2015). Takhelmayum & Gupta (2011, 2015), reported family Belostomatidae as eudominant in Loktak Lake and Keibul Lamjao National Park of Manipur.

Species ranking for both Whittekar plot and K-dominance plot is based on relative abundance (RA) of individual species. The species ranking sequence in the present study is *Micronecta scutellaris* (RA 30.35%) followed by *Micronecta ludibunda* (RA 21.87%). Next in the sequence are *Micronecta siva, Trepobates* sp*., Anisops breddini, Nychia Sappho* and *Micronecta haliploides.* The eudominant and dominant species recorded in the system were all semi-tolerant, belonging to the families Micronectidae, Notonectidae, and Gerridae. Thus, the Sonebeel is predicted to be disturbed to some extent.

The Whittaker plot (Magurran 2003) shows the

Table 1. Inventory of aquatic and semiaquatic Hemiptera along with their relative abundance (RA%) and dominance status (DS) (Engelmann's scale, 1978) in the four study sites of Sonebeel

Infraorder	Families	Species recorded	Site 1		Site 2		Site 3		Site 4	
			RA	DS	RA	DS	RA	DS	RA	DS
Nepomorpha	Micronectidae	*Micronecta siva* (Kirkaldy, 1897)	15.37	D	7.33	SD	3.44	SD	16.90	D
		Micronecta haliploides (Horvath, 1904)	3.55	SD	5.23	SD	1.08	R	2.46	R
		Micronecta scutellaris (Stål, 1858)	41.22	E	25.60	D	29.89	D	29.23	D
		Micronecta ludibunda (Breddin, 1905)	22.13	D	29.39	D	6.67	SD	13.38	D
		Synaptonecta issa (Distant, 1910)	0	-	0	-	0	-	4.23	SD
	Nepidae	*Ranatra varipes* (Stal, 1861)	3.38	SD	0.32	SR	0.22	SR	0.70	SR
		Ranatra gracilis (Dallas , 1850)	0.17	SR	0.08	SR	0.43	SR	0	-
		Ranatra longipes (Stal, 1861)	0	-	0	-	0.22	SR	0	-
	Notonectidae	*Anisops breddini* (Kirkaldy, 1901)	1.35	R	12.16	D	2.58	R	4.23	SD
		Anisops kuroiwae (Matsumura, 1915)	0	-	0	-	0	-	0.35	SR
		Nychia sappho (Kirkaldy, 1901)	2.53	R	6.20	SD	2.37	R	2.82	R
		Anisops niveus (Fabricius, 1775)	0.51	SR	2.42	R	1.51	R	2.82	R
		Enithares mandalayensis (Distant, 1910)	0	-	0	-	0.22	SR	0	-
	Belostomatidae	*Diplonychus molestus* (Dufour, 1863)	0.51	SR	0.48	SR	0	-	0	-
		Diplonychus rusticus (Fabricius, 1781)	0.51	SR	0.16	DR	0.65	SR	3.17	R
	Helotrephidae	*Tiphotrephes indicus* (Distant , 1910)	0	-	0.08	SR	0.22	SR	0	-
	Pleidae	*Paraplea frontalis* (Fieber , 1844)	0.51	SR	0	-	0.86	SR	0.70	SR
		Paraplea liturata (Fieber, 1844)	0	-	0.32	SR	1.08	R	2.46	R
Gerromorpha	Gerridae	*Trepobates* sp.	2.87	R	1.37	R	32.04	E	2.82	R
		Rhagadotarsus anomalus (Breedin, 1905)	0	-	0	-	1.51	R	0.35	SR
		Aquarius adelaidis (Dohrn, 1860)	0	-	2.98	R	4.73	SD	3.87	SD
		Gerris adelaidis (Dohrn, 1960)	2.70	R	3.78	SD	2.37	R	1.76	R
		Neboandelus sp. (Distant, 1910)	0	-	0	-	0	-	0.35	SR
		Limnogonous nitidus (Mayr, 1865)	0	-	0	-	4.52	SD	0	-
		Neogerris parvulus (Stal, 1859)	0	-	0.6	SR	0	-	1.41	R
	Mesoveliidae	*Mesovelia vittigera* (Horvath 1895)	1.69	R	1.0	R	2.15	R	3.17	R
	Veliidae	*Microvelia* sp.	0.51	SR	0.2	SR	1.08	R	1.06	R
		Pseudovelia lundbladi	0.34	SR	0.2	SR	0.22	SR	0	-
		Baptista sp.	0.17	SR	0.1	SR	0		1.76	R

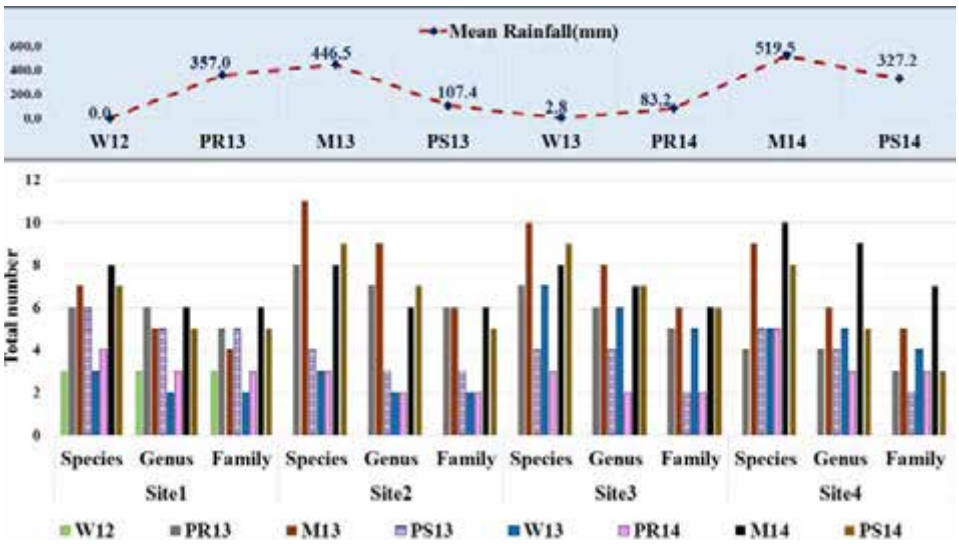

Figure 2. Temporal and spatial variations in total number of species, genera and families of Hemiptera in the four sites of Sonebeel. Seasonal variations in mean rainfall (mm) is represented graphically by line. (W12= winter2012; PR13= Premonsoon2013; M13= Monsoon2013; PS13= Postmonsoon2013; W13= Winter2013; PR14= Premonsoon2014; M14= Monsoon2014; PR14= Postmonsoon 2014)

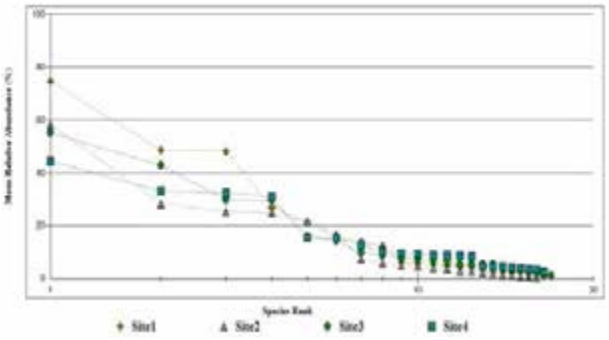

Figure 3. Whittaker plot showing the rank based abundance results of the aquatic and semiaquatic hemipterans in the four sites of Sonebeel

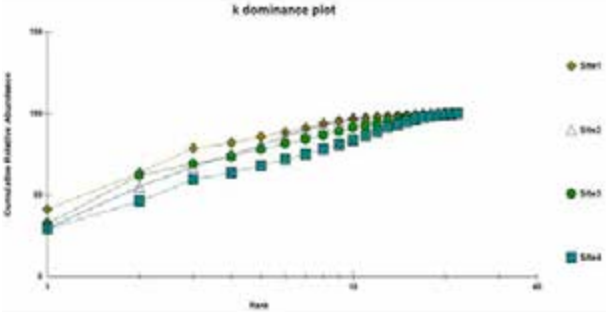

Figure 4. K-dominance graph showing cumulative relative abundance of the aquatic and semi aquatic hemipterans in the four sites of Sonebeel

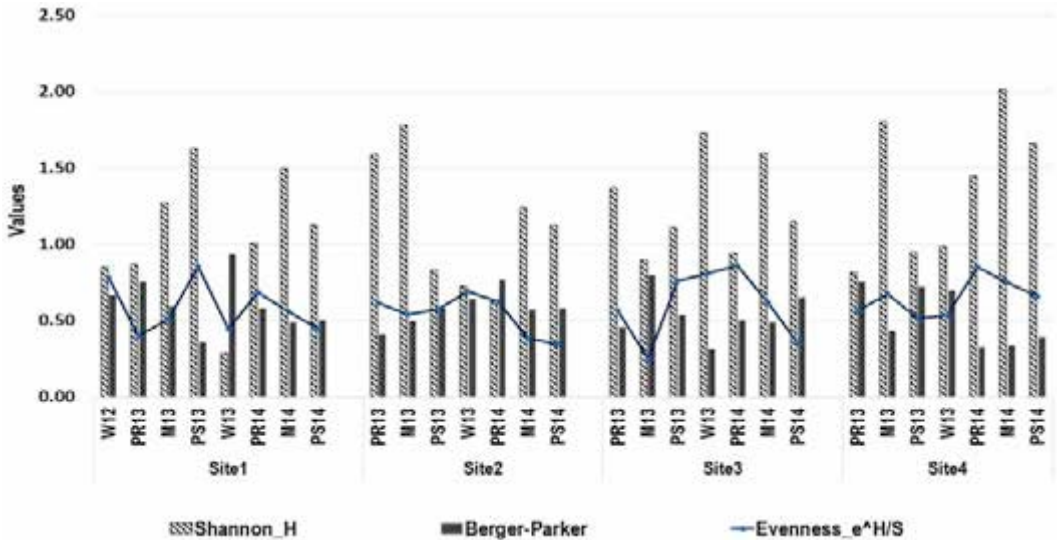

Figure 5. Spatial and temporal variation in Shannon Weiner diversity index, Evenness index, and Berger-Parker index of dominance in the four Sites of Sonebeel (W12 = winter2012; PR13 = Premonsoon2013; M13 = Monsoon2013; PS13 = Postmonsoon2013; W13 = Winter2013; PR14 = Premonsoon2014; M14 = Monsoon2014; PR14 = Postmonsoon 2014)

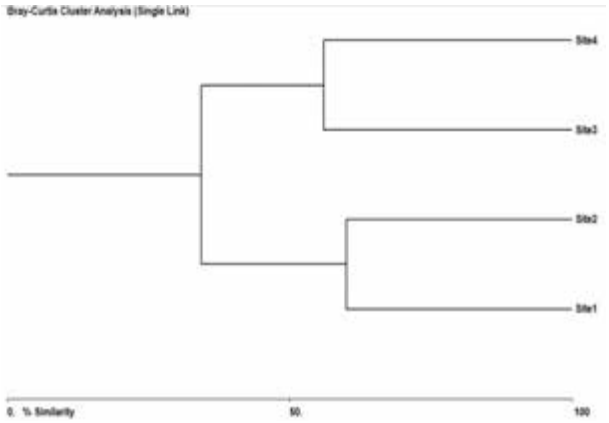

Figure 6. Bray-Curtis Single linkage cluster analysis of the four sites of Sonebeel

species abundance curve (Fig. 3) where species are plotted in sequence from most to least abundant along the horizontal axis with respect to their relative abundance on the vertical axis. This also facilitated comparison among the four sites of the wetland. The four sites showed similar shallower slopes inferring higher evenness of the aquatic and semi aquatic Hemiptera species. If imaginary straight line is considered passing through the first and last point of the respective graph, Site 1 shows the highest and Site 4 shows the lowest evenness. Site 2 and Site 3 also show similar result. The k-dominance plot (Fig. 4) shows cumulative relative abundance of the aquatic and semi aquatic hemipterans in the four sites in relation to species rank. The plot lines show similar pattern which is not much elevated inferring a diverse assemblage in the four study sites of

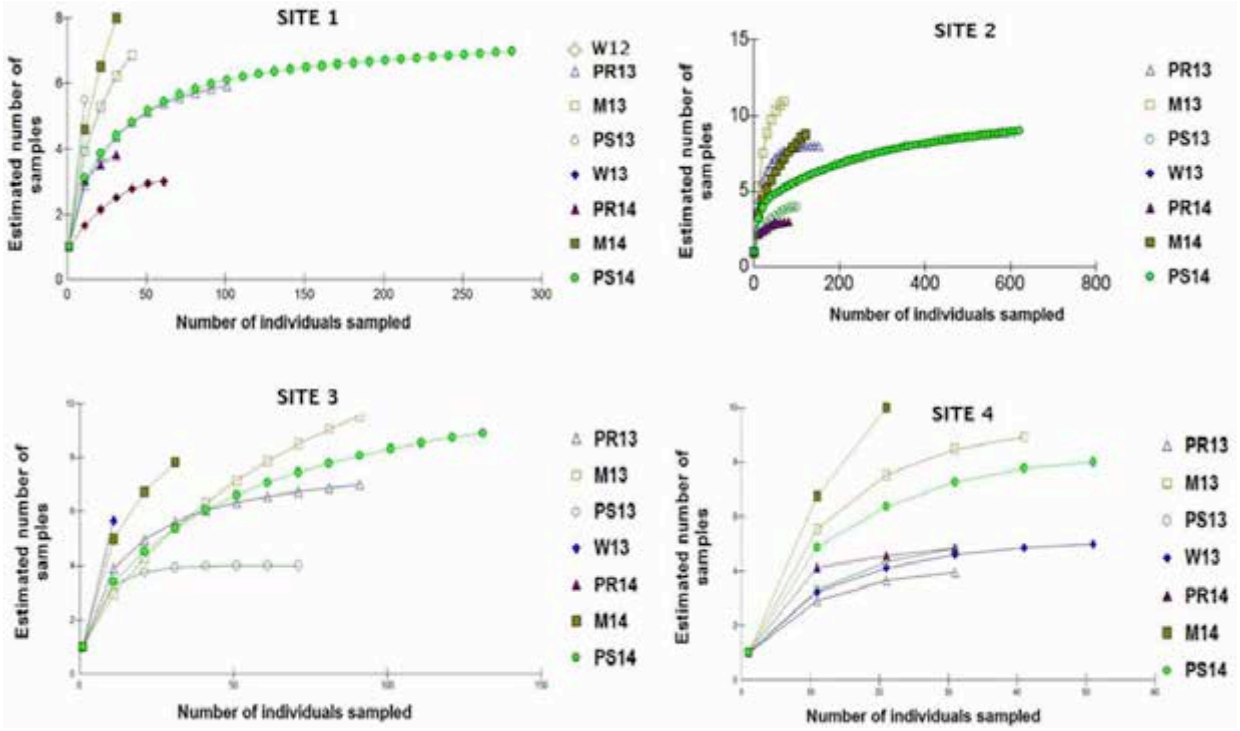

Figure 7. Sample based rarefaction curves in relation to sample size of four study sites during different seasons. (W12 = winter2012; PR13 = Premonsoon2013; M13 = Monsoon2013; PS13 = Postmonsoon2013; W13 = Winter2013; PR14 = Premonsoon2014; M14 = Monsoon2014; PR14 = Postmonsoon 2014)

the wetland (Magurran 2003).

The Shannon ($H^{/}$) values of the four sites ranged from 0.28 in Site 1 during winter 2013 to 2.02 in Site 4 during monsoon 2014 inferring poor to moderate water quality of the system in different sites in different seasons (Wilhm 1970) (Fig. 5). Evenness index in the four sites ranged from 0.25–0.86. Thus diversity is found higher in Site 4 with lower dominance.

Bray-Curtis similarity index (Fig. 6) based on different species and their population of each sites shows highest similarity of Site 1 and Site 2 (60%) forming a pair. Site 3 and Site 4 formed a separate pair with 56% of similarity. Highest similarity of Site 1 with Site 2 is due to the presence of common species in these two sites which might be attributed to the fact that the two sites are in the same direction of the lake.

Sample-based Rarefaction curves are shown (Fig. 7) in relation to the sample sizes of the four study sites of the wetland. Rarefaction is used to compare the estimated number of species in relation to the number of individuals sampled (Magurran 2003). The curves during winters were poorly produced and their confidence intervals were found overlapping other curves. During pre-monsoon 2013 and 2014 the curves were short but a gentle curve was formed where species diversity was less but number of individual was higher inferring complete sampling. In monsoon 2013 and 2014, the curve showed rapid rise inferring chances of getting more species. On the other hand, curves produced during post-monsoon of 2013 and 2014 showed different pattern. During post-monsoon 2013, curve of Site 1 inferred incomplete sampling while curves of rest of the sites inferred complete effort. In post-monsoon 2014, all the four sites produced most satisfied curves inferring the statistically highest richness of the aquatic and semi aquatic hemipterans in the system. This might be due to the fact that in this season the rainfall was optimum after the highest shower during monsoon 2014. The whole system retained sufficient water providing a uniform suitable condition for dispersion of insects during postmonsoon. Thus along with the increase in number of species their evenness in dispersion was also found higher contributing completeness in collection effort.

CONCLUSIONS

This is the first documentation of aquatic and semiaquatic Hemiptera species in Sonebeel, Assam,

where high population number and species variety has indicated good habitat suitability. The number of species, genera and families recorded were highest during wet seasons. Due to population pressure and various anthropogenic activities, this pristine system is under stress. Increase in land use for residences, agricultural practices, brick industry, siltation, and excessive fishing are well-known threats to the wetland. These impacts are reflected in this study, and there is an urgent need for conservation.

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Appendix 1. Species images from the study area: 1 - *Diplonychus rusticus*; 2 - *Mesovelia vittigera*; 3 - *Micronecta haliploides*; 4 - *Neogerris parvulus*; 5 - *Tiphotrephes indicus*

Short Communication

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First record of colour aberration in Basra Reed Warbler *Acrocephalus griseldis* (Hartlaub, 1891) (Passeriformes: Acrocephalidae) from Central Marshes of southern Iraq, with notes on its intraspecific/interspecific behavior

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Abstract: Pigment disorders such as albinism, leucism and progressive greying, which cause the absence of melanin pigments in all or parts of the plumage and bare parts, have been reported in many wild bird populations including *Acrocephalus* warblers. Basra Reed Warbler *Acrocephalus griseldis* (Hartlaub, 1891) is a restricted-range species confined to the extensive reed beds of Mesopotamian marshes. It is listed as Endangered due to breeding habitat degradation, water scarcity and climate change. In April 2018, a partly white plumaged Basra Reed Warbler was sighted in Central Marshes in southern Iraq. This is the first report of such a plumage aberration in this species. The nature of the aberration involved an intraspecific/interspecific behavior of the white plumaged Basra Reed Warbler are described.

Keywords: *Acrocephalus*, Central Marshes, colour aberrations, partial leucism, progressive greying, White Basra Reed Warbler.

Abnormal white feathers have been reported in many wild bird populations and can be caused by different aberrations. Leucism (Greek *Leukos* = white), for example, is a partial or total lack of melanin in feathers and skin (van Grouw 2012, 2013). The lack of melanin is due to the congenital and heritable absence of pigment cells from some or all of those skin areas where they would normally provide the growing feather with melanin pigment. In leucistic birds, the amount of white can vary from just a few feathers (= partial leucistic) to all-white individuals, which always possess colourless skin as well. Partially leucistic birds can have a normal-coloured bill and legs depending on where the colourless feathers occur, but the white pattern caused by partial leucism is normally patchy and bilaterally symmetrical—typical examples include a few white outer flight feathers on both wings and/or some white feathers in the face and on the belly. Leucistic birds always have pigmented eyes (van Grouw 2014). Leucism is caused by the expression of mutant alleles which affect the migration of melanoblasts (early melanin pigment cells) from the embryonic neural crest to the skin, resulting in un-pigmented (white) feathers

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and pink skin in those areas where melanoblasts are lacking (van Grouw 2014). Another more common cause for aberrant white feathers is progressive greying, a generic term for different aberrations which cause a progressive loss of melanin with successive moults. In the early stages of progressive greying the affected white feathers are usually spread randomly over the bird, which can eventually become white. Some forms of progressive greying are related solely to age while others are heritable, but more commonly the causes are unknown.

Progressive greying is the most common cause of white feathers in birds, and does not affect the eye colour (van Grouw 2012, 2013, 2018). Cases of aberrant white plumage in Acrocephalus warblers have been recorded (Holyoak, 1978; Bensch et al. 2000). Basra Reed Warbler *Acrocephalus griseldis* (Hartlaub, 1891) is a restricted-range species, a common breeding summer visitor confined to the extensive thickets/reedbeds of central and southern marshlands of Iraq and at one site in western Iraq (Fadhel 2007; Salim et al. 2012). It breeds in Israel and Kuwait; passage migrant in Saudi Arabia; vagrant in Syria and Cyprus (Yésou et al. 2007; Perlman & Shanni 2008; Porter & Aspinal 2010). Basra Reed Warbler is a long distant migrant to the subtropical or tropical zones of eastern Africa. It winters in Sudan, Ethiopia, southern Somalia, southeastern Kenya, eastern Tanzania, southern Malawi and Mozambique (Baker 1997; Urban et al. 1997; Kennerley & Pearson 2010). It listed as Endangered due to rapid decrease of its breeding habitats, water scarcity and management, and climate change (Birdlife International 2018).

Material and Methods

On 29 April 2018, a singing adult Basra Reed Warbler with distinctive partial white plumage was sighted at Ishan Al Ghubbah-Central Marshes (31.059^{0}N 47.018^{0}E; elvation 1m above sea level) in Al-Chebaeish district of ThiQar Province in southern Iraq. The local ecological landscape is an aquatic habitat of dense and extensive *Typha*/*Phragmites* sp. vegetation mixed with a few terrestrial muddy embankments. The White Basra Reed Warbler was loudly singing/displaying near its probable foraging/nesting territory; it was carefully observed for two hours from an elevated vantage point (c. 5–15 m in distance). The field observations/remarks were made using Swarovski EL 8x32 binocular; photographic documentation was made by Canon EOS Kiss X6i with a 400mm telephoto lens (Image 1a,c,e). On 30 April 2018, the bird was trapped using a 30mm mesh mist net in order to obtain further morphological notes. Trapping and handling wild animals for scientific research was permitted by the letter No. 141 issued from the College of Sciences /University of Baghdad on 15 January 2018. The bird was gently extracted from the net, carefully handled, the plumage was examined, and photographed using Nikon SLR D5200 with 18x55mm lens for about (5–10) minutes (Image 1b,d,f). In order to reduce stress on the bird caused from trapping/handling, no morphometric measurements were taken. The bird was released at the same trapping/capturing area and its behavioral reflexes were carefully monitored for about 30 minutes. It showed normal behavioral and active territorial performance afterward. The species' descriptive field identification remarks were noted following Kennerley & Pearson (2010). The naming of the white plumage followed the identification key for colour aberrations described by Mahabal et al. (2016).

Results

This is the first documentation of a Basra Reed Warbler in the marshes of southern Iraq with aberrant white feathers. The white bird showed distinctive features of Basra Reed Warbler, including the proportionately longer bill than other *Acrocephalus* allies. The body lacks the distinctive cold olive-brown coloration and the buffy-brown suffusion of the breast sides and flanks, long prominent supercilium on head. The visual hand examination showed white feathers covering 70–80 % of the body. The bare parts (eyes, bill, and legs) were of normal coloration. The body feathers with normal olive-brown coloration were unevenly distributed mainly in nape, ear-coverts, neck-side, throat, scapular, rump, uppertail-coverts, and lower flanks. The bill was long, slim, with concave sides and narrow tip. It had normal coloration of dark grey upper mandible, fleshy-pinkish lower mandible with dusky sides near the tip, and bright-orange commisure. The eyes were normal coloured with dark chestnut-brown iris with dark pupil and pale eye-ring (Image 1f). The tarsi are pale-grey with dark toes. The wing was long and pointed reaching behind the longest uppertail-coverts. The wing point was formed by the emarginated primary feather p3. First primary was minute and much shorter than primary coverts (pc). Wings had extensive white feathers in primaries, secondaries, primary coverts, median covets, and lesser coverts. The tail was rounded but shorter than Great Reed Warbler *Acrocephalus arundinaceus* (Temminck & Schlegel 1847), and also had white tail feathers (t) except for t2, t4, and t12 which were normal coloured. The distribution of white feathers especially in the wing seemed to follow a symmetrical pattern. The left

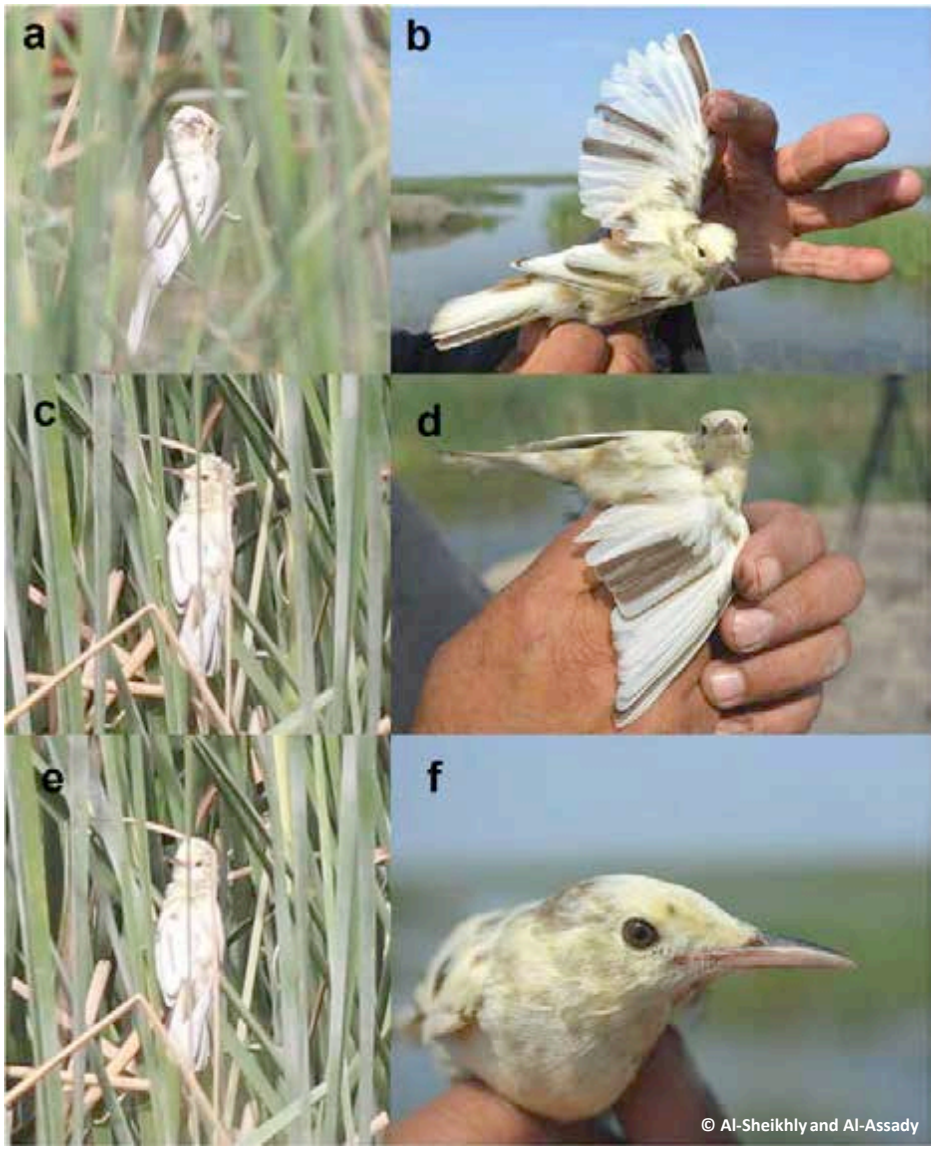

Image 1. (a, c, e) adult Basra Reed Warbler with white (advanced progressive greying) plumage, Ishan Al Ghubbah-Central Marshes, Southern Iraq; hand examination showing (b) left wing; (d) right wings; (e) head.

Table 1. wing and tail formula of white-plumage Basra Reed Warbler *Acrocephalus griseldis*: RW: right wing; LW: left wing; p: primary feather (shaft, inner/outer webs); s: secondary feather; te: tertials feather; t: tail feather; o: white feather; ●: normal- feather; *: moulted.

	Primaries									Secondaries						Tertials				Tail (left to right orientation)										
	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10	s1	s2	s3	s4	s5	s6	te1	te2	te3	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	t11	t12
RW	o	o	o	●	o	o	o	o	o	o	●	o	●	●	●	o	o	o	●	o	●	o	●	o	o	o	o	o	o	o	●
LW	o	o	o	●	o	o	o	o	o	o*	●	o	●	o	o	o	o	o	●												

and right wing showed normal coloration in p4, s1, s3, and te3 feathers while the rest were white. S4 and s5 feathers were normally coloured only in the right wing (Image 1b,d). The wing and tail formulae are shown in Table (1).

Breeding behavior: The white Basra Reed Warbler was observed loudly singing and actively displaying in dense reed beds, which suggests an adult male (Image

1c,e) that our field observations indicated was paired with a normal-coloured bird, possibly an adult female, which we observed leaping/flying around the same probable foraging/breeding territory. Both birds were observed carrying nesting materials (*Typha*/*Phragmites* dry roots) and entering into a specific location inside dense reedbeds, occupying a certain nesting territory, and performing normal displaying/territorial behavior. We did not observe interference from other normal coloured conspecific individuals or other sympatric species such as Great Reed Warbler, Indian Reed Warbler *Acrocephalus* (*Stentoreus*) *brunnescens* (Jerdon, 1839), and Common Reed Warbler *Acrocephalus scirpaceus* (Hermann, 1804), or from natural predators such as raptors and small mammals.

Discussion

There are no previous reports of white-plumage aberrations in *Acrocephalus* warblers from the Iraqi marshes, particularly in Basra Reed Warbler. As this bird still had normal coloured feathers in its plumage and normal coloured eyes and skin, we could exclude albinism (Mahabal et al. 2016). Based on the amount and distribution of white feathers, compared with the characteristics of partial leucism and progressive greying mentioned in the 'introduction', we believe the aberrant plumage of this individual is most likely the result of a form of progressive greying. The normal coloured body feathers were randomly distributed but the white wing feathers distribution was in a more or less symmetrical pattern. This, however, can be explained by the fact that birds moult their feathers in a symmetrical way and when these still coloured feathers did grow, the loss of pigment may not have yet fully set in. The white pattern in partial leucism is already present in juvenile plumage and does not change with age (van Grouw 2013; 2014). However, the white Basra Reed Warbler was a breeding adult so we do not have information regarding its juvenile plumage. The amount and distribution of the white feathers, however, suggests almost certainly an advanced stage of progressive greying. The occurrence of white plumaged birds in the wild is not uncommon; birds with white feathers in natural populations rarely exceed 1% (Sage 1963; Santos 1981). Bensch et al. (2000) reported an increased frequency of individuals with white feathers in recently founded inbred populations of Great Reed Warbler in Sweden. Aberrant white feathers in birds may have consequences, it may cause a special challenge in the wild (Nogueira & Alves 2011). It is believed to reduce the species ability to camouflage and make them vulnerable to predation (Santos 1981; Pomarede 1991; Alaja & Mikkola 1997; Ellegren et al. 1997; Collins 2003), but yet, in many species no evidence has been obtained (van Grouw pers. comm. 2018). In our case, these statements were noted. In general, Basra Reed Warbler has cryptic and enigmatic behavior (Fadhel 2007). The white Basra Reed Warbler was observed in a monotonic landscape (dense reed beds) where other conspecific individuals and/or sympatric species may interfere. Its breeding behavior was apparently not affected; however, the species intraspecific/interspecific competition in the Iraqi marshes is still obscure. In certain cases, birds with plumage aberrations reproduced successfully and survived several years in the wild (Alaja & Mikkola 1997; Forrest & Naveen 2000). This may explain the survival and normal breeding behavior of the white Basra Reed Warbler throughout the ecoregion of the Iraqi marshes and possibly elsewhere within its wintering range. The current observation was rather surprising; since there are no previous records on such plumage condition in Basra Reed Warbler. In Henderson Island Reed-Warbler *Acrocephalus taiti* (Ogilvie-Grant 1913) and Pitcairn Island Reed-Warbler *Acrocephalus vaughani* (Sharpe 1900); however, Progressive greying, probably an inheritable form, occurs very frequently in these populations and does not seem to affect their behavior (van Grouw pers. comm. 2018). Further monitoring for white-plumaged Basra Reed Warbler individuals in wintering grounds and ringing stations across the species geographical range is required for a more comprehensive evaluation of the aberration involved.

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SHORT COMMUNICATION

Avian fauna of Amboli Ghat, Sindhudurg District, Maharashtra State, India

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Abstract: The present report puts forth a systematic checklist of bird species observed at Amboli Ghat in Maharashtra from 2009 to 2012, along with information on their status. A total of 208 species were recorded, which is around 15% of bird species of the Indian subcontinent. A family-wise analysis showed that the families Accipitridae and Muscicapidae (14 species each) followed by Ardeidae dominated the avifauna of the region. The study also revealed that the area consisted of 11 species of birds that are classified under Near Threatened category and two under Vulnerable category of IUCN. This study highlights the urgent need to conserve the biodiversity-rich area of Amboli Ghat with long-term plans.

Keywords: Amboli, avian fauna, diversity, endemic, Western Ghats.

The Western Ghats along the western coast of peninsular India is one of the most ecologically significant biological regions of the world. These hill ranges are recognized as a unique biogeographic province (Mani 1974), a global biodiversity hotspot (Myers et al. 2000), and as one of the 200 most important eco-regions of the world (Olson & Dinerstein 1998). Amboli Ghat lies in the Sahyadri Hills of the Western Ghats in the Sindhudurg District of Maharashtra State, India. It is located at 15.962^{0}N–73.997^{0}E and has an average altitude of approximately 690m. The highest point is 1,100m and the lowest point is 166m. The terrain is undulating with steep escarpments and dense forests. There are three well-defined seasons in Amboli: the monsoon spanning from June to around mid-November, the winter from mid-November to February, and the summer, from March to May. It is the wettest place in Maharashtra State with an average annual precipitation of 7500mm. The plant life in Amboli is extremely rich since the climatic conditions give rise to a wide range of habitats. The habitats range from the tropical semi-evergreen forests, tropical moist deciduous forests, subtropical broadleaf hill forests, tropical dry deciduous forests, tropical thorn vegetation, grasslands, and agricultural lands to wetlands. The wetlands are mainly formed by the collection of water from streams in abandoned agricultural lands. In general, the vegetation turns drier as one moves from west to east (into the rain shadow region) across the hills. Lower elevations on the eastern region receive less than 1,200mm of annual rainfall and contain tropical dry deciduous and thorny forests, with tropical moist deciduous forests in more well-watered

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areas (Champion & Seth 1968). With an increase in elevation, tropical semi-evergreen rainforests appear along the higher slopes and ridges. The western region of the hills tends to have mostly tropical moist deciduous forests with wet evergreen forests at lower elevations. The former gives way to the latter type as one climbs higher. The forest is mainly fragmented and the semi-evergreen forest patches occur in isolated pockets.

In less than five years, four new faunal species were described and reported from Amboli. A species of toad, *Xanthophryne tigerinus*, was recently described as endemic to Amboli (Biju et al. 2009). Amboli was reported as one of the type localities of a species of frog *Pseudophilautes amboli* (Biju & Bossuyt 2009), a new species of coral snake *Calliophis castoe* (Smith et al. 2012), and a new species of colubrid *Dendrelaphis girii* (Vogel & Rooijen 2011) . Other snakes like Ornate Flying Snake and Brown Vine Snake were also sighted in this region.

Birds are considered as useful biological indicators because they are ecologically versatile and live in all kinds of habitats. Extensive documentation of avian fauna of various regions of the Western Ghats and Maharashtra are available. Prasad (2003) listed about 450 bird species from western Maharashtra, Abdulali (1981) listed 540 bird species from Maharashtra, and Gole (1998) studied bird species of Sahyadri,; documentation can also be found in Ranjit et al. (1990), Lainer (2004), Padhye et al. (2007), Lawate & Mule (2008), and Kachare et al. (2011). A systematic study on the avian fauna of Amboli Ghat is wanting. The aim of our study was to explore the nature of bird assemblage in various macrohabitat types in and around Amboli Ghat. The finding of this study can provide baseline data for intensive studies in the future. The study also highlights the ecological significance of this highly biodiverse spot in the Western Ghats of India.

Methods

Study area

An area of around 54km^2 covering locations like Amboli Town, Papdi, Malai, Chaukul, Mahadevgarh, Parpoli, and adjoining areas (Fig. 1), was explored for the study since each zone varies in its landscape type. In addition to the slope of the valley of Amboli Ghat, this study also included areas of lower hilly terrains, as the valley is surrounded by hills on almost all sides. The present study explores areas used for agriculture and human settlements as well as natural habitats such as forest patches, grasslands, streambanks, and scrublands. Locations around the collection of large wetlands near Papdi were also investigated. Habitat details of the above-mentioned locations are as follows:

1) Papdi (15.888^{0}N & 74.0372^{0}E) – a mostly flat terrain with a slightly undulating land, agricultural fields, and streams present with temporary marshes during monsoon and early winter.

2) Malai Forest (15.941^{0}N & 74.001^{0}E) - dense evergreen forest.

3) Chaukul Road (15.943^{0}N & 74.031^{0}E) – a flat terrain covered with vegetation during monsoon and dry scrub in late winter and summer.

4) Amboli Town (15.966^{0}N & 74.004^{0}E) - human settlements near Amboli reserve forest.

5) Mahadevgarh Road (15.967^{0}N & 73.990^{0}E) - evergreen forest cover with sporadic open grassland patches.

6) Amboli Ghat (15.934^{0}N & 73.990^{0}E) - steep escarpments with moist deciduous and evergreen forests.

7) Parpoli (15.950^{0}N & 73.975^{0}E) - foothills of Amboli receiving maximum rainfall in the study area. The short grown vegetation remains submerged under water till early winter. The remaining area is covered by evergreen forests.

Bimonthly surveys were carried out in the selected areas of various habitats from March 2009 to March 2012. The areas were surveyed using binoculars and digital cameras for documenting bird species. Direct observations and noting of species sighted were made by walking on the roads and village tracks and through grasslands and agriculture areas. Monitoring of areas was done in the morning from 6:00 to 10:00 hr as well as in the evening from 15:00 to 19:00 hr. Visits were also made in the afternoons and late evenings to check the activities of the avian fauna at different times. Birds were identified using widely accepted field guides like Ali & Ripley (1983) and Grimmett et al. (1998,2011). For taxonomy, species sequence, and nomenclature, we followed Praveen et al. (2016).

The status of birds was assigned based on the following criteria:

1) Resident - if a bird was seen all throughout the year (not necessarily nesting).

2) Winter visitor - if a bird was seen only during the period from December to February.

3) Summer visitor - if a bird was seen only during the period from March to May.

The birds were assigned strictly with reference to the study area on the basis of presence or absence method. The birds that showed irregular trends of sighting and population fluctuations (non-seasonal) were placed under uncertain status. Current status of threatened

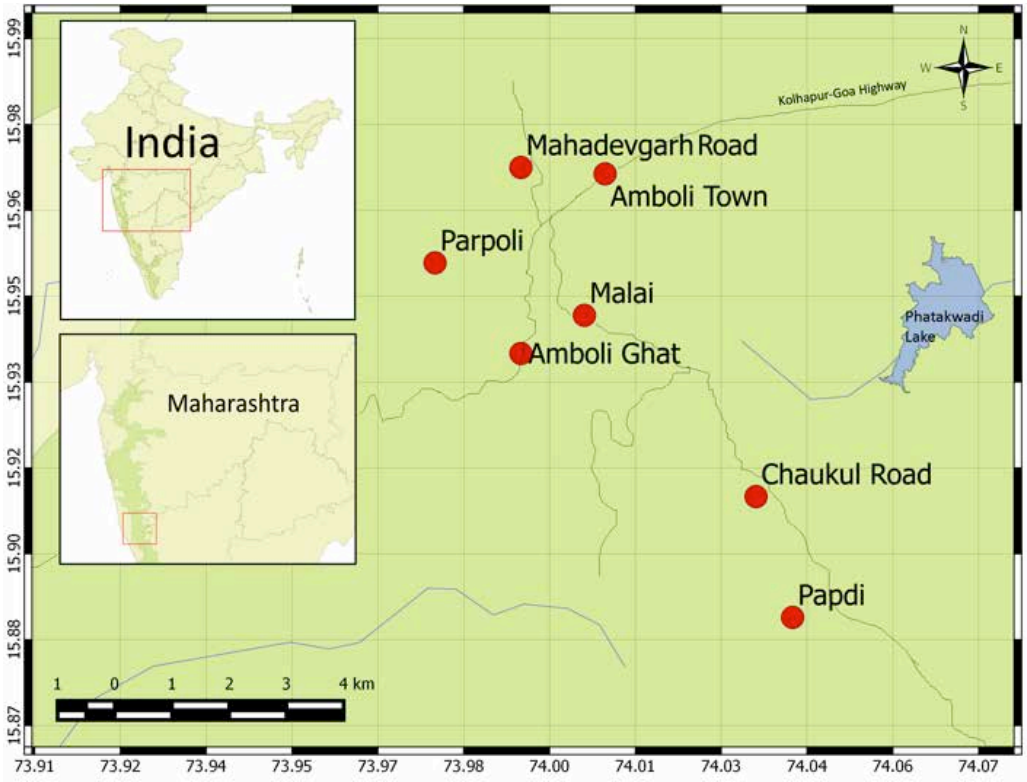

Figure 1. Map showing different locations in the study area in Amboli Ghat, Maharashtra State, India (Quantum GIS Development Team 2016).

categories was adopted from IUCN Red list (IUCN 2016).

Results

A total of 208 species was recorded during the study (Table 1), constituting around 15% of the total species listed in the Indian subcontinent by Grimmett et al. (2011). Birds from 64 families were recorded. Family-wise analysis showed that the families Accipitridae and Muscicapidae (14 species each) followed by Ardeidae (10 species) dominated the avian fauna, indicating a healthy bird diversity in the region. Out of the total species encountered, analysis of data revealed that 165 species were residents, 38 species were winter visitors, two species were summer visitors, and the remaining species have an uncertain status. The status of three species, European Roller *Coracias garrulus*, Asian Pied Starling *Gracupica contra*, and Green Avadavat *Amandava formosa*, was considered uncertain as they showed irregular trends of sighting and population fluctuations (non-seasonal). Since there are no habitats appropriate for Green Avadavat in the study area, the individuals sighted could be those escaped from cages.A comparative graph was prepared to see the differences in avian faunal diversity in the locations in the study area which revealed Parpoli region with maximum number of species (181 species of birds) (Figs. 2 & 3). A few bird species like Pompadour Green Pigeon *Treron pompadora,* Grey-bellied Cuckoo *Cacomantis passerinus*, Drongo Cuckoo *Surniculus lugubris*, Blue-faced Malkoha *Phaenicophaeus viridirostris*, Lesser Golden-backed Woodpecker *Dinopium benghalense*, Yellow-fronted Pied Woodpecker *Dendrocopos mahrattensis*, White-naped Woodpecker *Chrysocolaptes festivus*, Heart-spotted Woodpecker *Hemicircus canente* and Little Spiderhunter *Arachnothera longirostra* (Table 1) were sighted only at the low-lying well-wooded region of Parpoli in the study area. Studies show that habitats with structurally complex matrices have greater potential for supporting the populations of forest birds than open areas such as pastures (Raman 2006). Sixty-one species of birds are recognized as endemic to India (Praveen et al. 2016), of which 13 were sighted in the study area. A few birds that showed local seasonal migration due to heavy rainfall in the higher altitude areas of Amboli.

Based on the present study, it can be concluded that there are 11 species of birds in the study area that are struggling for their existence throughout their distributional range and therefore can be placed under threat categories as identified by IUCN (2016). These species are the Vulnerable Woolly-necked Stork *Ciconia*

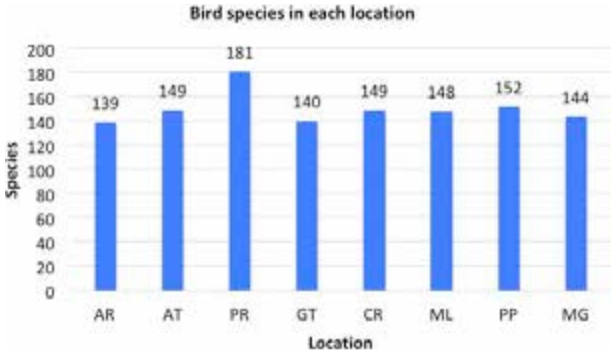

Figure 2. Number of bird species sighted in the different locations in Amboli Ghat
Key to locations: AR-All Regions, AT-Amboli Town, PR-Parpoli, GT-Amboli Ghat, CR-Chaukul Road, ML-Malai Forest, PP-Papdi, MG-Mahadevgarh Road

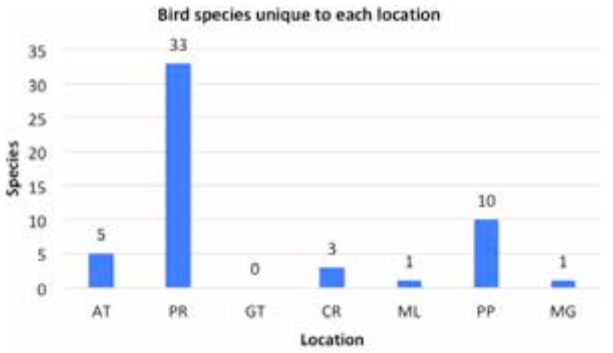

Figure 3. Number of bird unique species unique to different locations in Amboli Ghat
AT - Amboli Town, PR - Parpoli, GT - Amboli Ghat, CR - Chaukul Road, ML - Malai Forest, PP - Papdi, MG - Mahadevgarh Road

episcopus, Nilgiri Wood Pigeon *Columba elphinstonii* (observed roosting), and Green Avadavat (observed roosting) and the Near Threatened Black-necked Stork *Ephippiorhynchus asiaticus*, Black-headed Ibis *Threskiornis melanocephalus*, Oriental Darter *Anhinga melanogaster*, Pallid Harrier *Circus macrourus*, River Tern *Sterna aurantia,* Great Hornbill *Buceros bicornis*, Malabar Pied Hornbill *Anthracoceros coronatus*, and Grey-headed Bulbul *Brachypodius priocephalus* (observed feeding and roosting). Of these, Grey-headed Bulbul and Nilgiri Wood Pigeon are endemic to the Western Ghats. Vultures were not encountered in the present study.

Discussion

A list with authentic records reflects the true natural diversity of the avian fauna of any region. For taxa that are widespread or migrating, records in such lists form an essential part of the information that can be used to map their global distribution and seasonal movements. The Amboli Ghat area still provides some potential habitats for the declining population of many bird species. During the breeding season, Grey-headed Bulbuls were observed foraging in areas of Amboli Ghat dominated by sub-canopy trees bearing fruits. Fruit availability is also an important factor that decides the breeding season of this species (Balakrishnan 2011). The occurrence of Malabar Grey Hornbill can be attributed to the retention of fruits in the canopy, which provides food for the species (Raman & Mudappa 2003). Open areas are of utmost importance for bird populations as these areas provide better visibility for vigilance against predators and free movement for food procurement (Desai & Shanbhag 2012). It is the need of the hour to monitor these areas systematically in the rapidly changing environment with a focused study on the status, distribution, and conservation of the avian fauna of the region, which can be achieved only through strengthening public participation species.

One of the problems faced by Amboli Ghat in the recent years is the disturbance caused by humans along with deforestation for plantation, development, and mining. Changes in vegetation components could affect the availability of food resources and microclimatic conditions, which could then affect the richness and abundance of bird species (Johns 1991).

Animals in protected areas may face interference in their daily activities due to tourists and their associated activities. Tourism in protected areas can have negative influences on animal populations, as tourists often seek out rare or spectacular species during sensitive times such as breeding or nesting (Knight & Cole 1995). Where human traffic is frequent, species withdraw, change behaviour, or become habituated to human presence (Griffiths & van Schaik 1993). During the current study, Blue-capped Rock Thrush *Monticola cinclorhynchus*, Yellow-browed Bulbul *Acritillas indica*, and Quaker Tit Babbler *Alcippe poioicephala* were found feeding on garbage left by tourists.

Amboli Ghat is visited extensively by tourists and most of the tourist activities are concentrated around the Amboli Waterfall on State Highway 121 on the outskirts of Amboli Town. Good connectivity by roads to Karnataka, Goa, and the rest of Maharashtra State results in about 15,000 tourists visiting Amboli during weekends between July and September. During this period, the roadsides are littered without care. During the study period, it was revealed that around 20,000 vehicles pass through the study area, mainly Amboli Town on State Highway 121, which results in a number of roadkills and affects the feeding and nesting of birds.

Table 1. A systematic checklist of bird species of Amboli Ghat, Maharashtra State, India

	Family	Scientific name	Common name	Status	Sighting location
1	Anatidae	*Anas poecilorhynca*	Indian Spot-billed Duck	R	AR
2	Phasianidae	*Pavo cristatus*	Indian Peafowl	R	AR
3		*Perdicula asiatica*	Jungle Bush Quail	R	AR
4		*Gallus sonneratii*	Grey Junglefowl	R, EI	AR
5		*Galloperdix spadicea*	Red Spurfowl	R, EI	AR
6	Podicipedidae	*Tachybaptus ruficollis*	Little Grebe	R	PP
7	Columbidae	*Columba livia*	Rock Pigeon	R	AR
8		*C. elphinstonii*	Nilgiri Wood Pigeon	R, EI	AT
9		*Streptopelia orientalis*	Oriental Turtle Dove	R	AR
10		*S. chinensis*	Spotted Dove	R	AR
11		*Treron pompadora*	Pompadour Green Pigeon	R	PR
12		*T. phoenicoptera*	Yellow-legged Green Pigeon	R	AR
13		*Chalcophaps indica*	Emerald Dove	R	AR
14	Podargidae	*Batrachostomus moniliger*	Sri Lankan Frogmouth	R	CR, ML, MG
15	Caprimulgidae	*Caprimulgus indicus*	Grey Nightjar	R	AR
16		*C. atripennis*	Jerdon's Nightjar	R	CR
17		*C. affinis*	Savanna Nightjar	R	AT, CR
18	Apodidae	*Hemiprocne coronata*	Crested Treeswift	R	PR
19		*Apus pacificus*	Fork-tailed Swift	W	AR
20		*A. affinis*	Indian House Swift	R	AR
21	Cuculidae	*Centropus sinensis*	Greater Coucal	R	AR
22		*Phaenicophaeus viridirostris*	Blue-faced Malkoha	R	PR
23		*Clamator jacobinus*	Pied Cuckoo	S	AR
24		*Eudynamys scolopaceus*	Asian Koel	R	AR
25		*Cacomantis passerinus*	Grey-bellied Cuckoo	R	PR
26		*Surniculus lugubris*	Drongo Cuckoo	R	PR
27		*Hierococcyx varius*	Common Hawk Cuckoo	R	AR
28		*Cuculus canorus*	Eurasian Cuckoo	W	AR
29	Rallidae	*Rallina eurizonoides*	Slaty-legged Crake	R	CR
30		*Zapornia pusilla*	Ballion's Crake	W	PP
31		*Amaurornis phoenicurus*	White-breasted Waterhen	R	AR
32	Ciconiidae	*Ciconia episcopus*	Woolly-necked Stork	R	PP
33		*Ephippiorhynchus asiaticus*	Black-necked Stork	R	PP
34	Ardeidae	*Ixobrychus cinnamoneus*	Cinnamon Bittern	R	PP, AT
35		*Nycticorax nycticorax*	Black-crowned Night Heron	R	AR
36		*Butorides striata*	Striated Heron	R	PP
37		*Ardeola grayii*	Indian Pond Heron	R	AR
38		*Bubulcus ibis*	Cattle Egret	R	AR
39		*Ardea cinerea*	Grey Heron	W	PP, AT
40		*A. purpurea*	Purple Heron	R	PP
41		*A. alba*	Greater Egret	R	AR
42		*A. intermedia*	Median Egret	R	AR
43		*Egretta garzetta*	Little Egret	R	AR
44	Threskiornithidae	*Threskiornis melanocephalus*	Black-headed Ibis	R	PP
45	Phalacrocoracidae	*Microcarbo niger*	Little Cormorant	R	AR
46	Anhingidae	*Anhinga melanogaster*	Oriental Darter	R	PP

	Family	Scientific name	Common name	Status	Sighting location
47	Charadriidae	*Vanellus malabaricus*	Yellow-wattled Lapwing	W	AT
48		*V. indicus*	Red-wattled Lapwing	R	AR
49	Scolopacidae	*Actitis hypoleucos*	Common Sandpiper	W	AR
50		*Tringa totanus*	Common Redshank	W	PP
51		*T. glareola*	Wood Sandpiper	W	AR
52	Turnicidae	*Turnix suscitator*	Barred Buttonquail	R	AR
53	Laridae	*Sterna aurantia*	River Tern	R	AR
54	Accipitridae	*Elanus caeruleus*	Black-winged Kite	R	AR
55		*Pernis ptilorhynchus*	Oriental Honey Buzzard	R	AR
56		*Spilornis cheela*	Crested Serpent Eagle	R	AR
57		*Circaetus gallicus*	Short-toed Snake Eagle	R	AR
58		*Ictinaetus malaiensis*	Black Eagle	R	AR
59		*Aquila rapax*	Tawny Eagle	R	AT
60		*A. fasciata*	Bonelli's Eagle	R	AR
61		*Hieraaetus pennatus*	Booted Eagle	W	AR
62		*Circus macrourus*	Pallid Harrier	W	AR
63		*C. pygargus*	Montagu's Harrier	W	CR, PP
64		*Accipiter badius*	Shikra	R	AR
65		*Haliastur indus*	Brahminy Kite	R	AR
66		*Milvus migrans*	Black Kite	R	AR
67		*Butastur teesa*	White-eyed Buzzard	R	AR
68	Tytonidae	*Tyto alba*	Common Barn Owl	R	AR
69	Strigidae	*Athene brama*	Spotted Owlet	R	AR
70		*Strix leptogrammica*	Brown Wood Owl	R	AR
71		*Bubo bengalensis*	Indian Eagle Owl	R	AR
72		*Ketupa zeylonensis*	Brown Fish Owl	R	AR
73	Bucerotidae	*Buceros bicornis*	Great Hornbill	R	AR
74		*Anthracoceros coronatus*	Malabar Pied Hornbill	R	AR
75		*Ocyceros griseus*	Malabar Grey Hornbill	R, EI	AR
76		*O. birostris*	Indian Grey Hornbill	R	AR
77	Upupidae	*Upupa epops*	Common Hoopoe	R	AR
78	Picidae	*Picumnus innominatus*	Speckled Piculet	R	ML
79		*Hemicircus canente*	Heart-spotted Woodpecker	R	PR
80		*Dinopium benghalense*	Lesser Golden-backed Woodpecker	R	PR, ML
81		*Micropternus brachyurus*	Rufous Woodpecker	R	PR
82		*Chrysocolaptes festivus*	White-naped Woodpecker	R	PR
83		*Dendrocopos mahrattensis*	Yellow-fronted Pied Woodpecker	R	PR
84	Ramphastidae	*Psilopogon zeylanica*	Brown-headed Barbet	R	PR
85		*P. viridis*	White-cheeked Barbet	R, EI	AR
86	Meropidae	*Merops orientalis*	Green Bee-eater	R	AR
87		*M. leschenaulti*	Chestnut-headed Bee-eater	R	AR
88	Coraciidae	*Coracias benghalensis*	Indian Roller	R	AR
89		*C. garrulus*	European Roller	UC	CR
90	Alcedinidae	*Ceyx erithaca*	Oriental Dwarf Kingfisher	R	AT, CR, ML
91		*Alcedo meninting*	Blue-eared Kingfisher	R	PR, AT
92		*A. atthis*	Common Kingfisher	R	AR
93		*Ceryle rudis*	Pied Kingfisher	R	AR

	Family	Scientific name	Common name	Status	Sighting location
94		*Pelargopis capensis*	Stork-billed Kingfisher	R	AR
95		*Halcyon smyrnensis*	White-throated Kingfisher	R	AR
96		*H. pileata*	Black-capped Kingfisher	R	PP
97	Falconidae	*Falco tinnunculus*	Common Kestrel	W	AR
98		*F. peregrinus*	Peregrine Falcon	R	AR
99	Psittaculidae	*Psittacula cyanocephala*	Plum-headed Parakeet	R	AR
100		*P. krameri*	Rose-ringed Parakeet	R	AR
101		*Loriculus vernalis*	Vernal Hanging Parrot	R	AR
102	Pittidae	*Pitta brachyura*	Indian Pitta	W	AR
103	Campephagidae	*Pericrocotus cinnamomeus*	Small Minivet	R	PR
104		*P. flammeus*	Scarlet Minivet	R	AR
105		*Lalage melanoptera*	Black-headed Cuckooshrike	R	PR
106	Oriolidae	*Oriolus xanthornus*	Black-hooded Oriole	R	PR
107		*O. kundoo*	Indian Golden Oriole	W	AR
108	Artamidae	*Artamus fuscus*	Ashy Woodswallow	R	PR
109	Vangidae	*Hemipus picatus*	Bar-winged Flycatcher Shrike	R	PR
110		*Tephrodornis virgatus*	Large Woodshrike	R	MG, PR
111		*T. pondicerianus*	Common Woodshrike	R	PR
112	Aegithinidae	*Aegithina tiphia*	Common Iora	R	AR
113	Dicruridae	*Dicrurus macrocercus*	Black Drongo	R	AR
114		*D. leucophaeus*	Ashy Drongo	R	AR
115		*D. caerulescens*	White-bellied Drongo	R	PR
116		*D. paradiseus*	Greater Racket-tailed Drongo	R	PR
117	Rhipiduridae	*Rhipidura aureola*	White-browed Fantail	R	PR
118		*R. albicollis*	White-throated Fantail	R	PR
119	Laniidae	*Lanius schach*	Long-tailed Shrike	R	AR
120		*L. vittatus*	Bay-backed Shrike	R	AR
121	Corvidae	*Dendrocitta vagabunda*	Rufous Treepie	R	PR
122		*Corvus splendens*	House Crow	R	AR
123		*C. macrorhynchos*	Large-billed Crow	R	AR
124	Monarchidae	*Hypothymis azurea*	Black-naped Monarch	R	AR
125		*Terpsiphone paradisi*	Indian Paradise-flycatcher	R	AR
126	Dicaeidae	*Dicaeum agile*	Thick-billed Flowerpecker	R	AR
127		*D. erythrorhynchos*	Pale-billed Flowerpecker	R	AR
128		*D. concolor*	Plain Flowerpecker	R	AR
129	Nectariniidae	*Arachnothera longirostra*	Little Spiderhunter	R	PR
130		*Leptocoma zeylonica*	Purple-rumped Sunbird	R	AR
131		*L. minima*	Crimson-backed Sunbird	R, EI	AR
132		*Cinnyris asiaticus*	Purple Sunbird	R	AR
133		*Aethopyga vigorsii*	Vigors's Sunbird	R, EI	AR
134	Irenidae	*Irena puella*	Asian Fairy Bluebird	R	PR
135		*Chloropsis aurifrons*	Golden-fronted Leafbird	R	AR
136	Ploceidae	*Ploceus philippinus*	Baya Weaver	R	AR
137	Estrildidae	*Amandava formosa*	Green Avadavat*	UC, EI	AT
138		*Euodice malabarica*	Indian Silverbill	R	PR
139		*Lonchura striata*	White-rumped Munia	R	AR
140		*L. punctulata*	Scaly-breasted Munia	R	AR

	Family	Scientific name	Common name	Status	Sighting location
141		*L. malacca*	Black-headed Munia	R	AR
142	Passeridae	*Passer domesticus*	House Sparrow	R	AR
143		*Gymnoris xanthocollis*	Yellow-throated Sparrow	R	PR
144	Motacillidae	*Dendronanthus indicus*	Forest Wagtail	W	ML, MG, CR
145		*Anthus rufulus*	Paddyfield Pipit	R	AR
146		*Motacilla cinerea*	Grey Wagtail	W	AR
147		*M. citreola*	Citrine Wagtail	W	AR
148		*M. maderaspatensis*	White-browed Wagtail	W	AR
149		*M. alba*	White Wagtail	W	AR
150	Fringillidae	*Erythrina erythrina*	Common Rosefinch	W	AR
151	Paridae	*Parus cinereus*	Cinereous Tit	R	PR
152		*P. xanthogenys*	Black-lored Tit	R	AR
153	Alaudidae	*Galerida malabarica*	Malabar Lark	R, EI	AR
154	Cisticolidae	*Prinia hodgsonii*	Grey-breasted Prinia	R	PR
155		*P. socialis*	Ashy Prinia	R	AR
156		*P. inornata*	Plain Prinia	R	AR
157		*Orthotomus sutorius*	Common Tailorbird	R	AR
158	Acrocephalidae	*Acrocephalus dumetorum*	Blyth's Reed Warbler	W	AR
159		*A. agricola*	Paddyfield Warbler	W	AR
160	Hirundinidae	*Cecropis daurica*	Red-rumped Swallow	R	AR
161		*Hirundo smithii*	Wire-tailed Swallow	R	AR
162		*H. rustica*	Barn Swallow	R	AR
163		*Ptyonoprogne concolor*	Dusky Crag Martin	R	AR
164	Pycnonotidae	*Hypsipetes leucocephalus*	Black Bulbul	R	AR
165		*Pycnonotus melanicterus*	Flame-throated Bulbul	R	PR, GT
166		*P. jocosus*	Red-whiskered Bulbul	R	AR
167		*P. cafer*	Red-vented Bulbul	R	AR
168		*Brachypodius priocephalus*	Grey-headed Bulbul	R, EI	AR
169		*Acritillas indica*	Yellow-browed Bulbul	R	AR
170	Phylloscopidae	*Phylloscopus collybita*	Common Chiffchaff	W	AR
171		*P. tytleri*	Tytler's Leaf Warbler	W	PR
172		*P. affinis*	Tickell's Leaf Warbler	W	PR, ML
173		*Seicercus nitidus*	Green Leaf Warbler	W	AR
174		*S. trochiloides*	Greenish Leaf Warbler	W	AR
175	Sylviidae	*Curruca crassirostris*	Eastern Orphean Warbler	W	PR
176		*C. curruca*	Lesser Whitethroat	W	PR
177		*Chrysomma sinense*	Yellow-eyed Babbler	R	PR
178	Zosteropidae	*Zosterops palpebrosus*	Oriental White-eye	R	PR
179	Timaliidae	*Pomatorhinus horsfieldii*	Indian Scimitar Babbler	R	AR
180		*Dumetia hyperythra*	Tawny-bellied Babbler	R	AR
181		*Rhopocichla atriceps*	Dark-fronted Babbler	R	PR
182	Pellorneidae	*Pellorneum ruficeps*	Puff-throated Babbler	R	AR
183	Leiothrichidae	*Alcippe poioicephala*	Quaker Tit Babbler	R	AR
184		*Argya malcolmi*	Large Grey Babbler	R	AT
185		*A. subrufa*	Rufous Babbler	R, EI	AR
186		*Turdoides striata*	Jungle Babbler	R	AR

	Family	Scientific name	Common name	Status	Sighting location
187	Sturnidae	*Pastor roseus*	Rosy Starling	W	AR
188		*Gracupica contra*	Asian Pied Starling	UC	AR
189		*Sturnia pagodarum*	Brahminy Starling	R	AR
190		*Acridotheres tristis*	Common Myna	R	AR
191		*A. fuscus*	Jungle Myna	R	AR
192		*Gracula religiosa*	Hill Myna	R	AR
193	Muscicapidae	*Copsychus saularis*	Oriental Magpie Robin	R	AR
194		*Kittacincla malabaricus*	White-rumped Shama	R	AR
195		*Muscicapa dauurica*	Asian Brown Flycatcher	W	AR
196		*Cyornis pallidipes*	White-bellied Blue Flycatcher	R, EI	CR, ML, PR, MG
197		*C. tickelliae*	Tickell's Blue Flycatcher	R	AR
198		*C. rubeculoides*	Blue-throated Flycatcher	W	MG
199		*Eumyias thalassinus*	Verditer Flycatcher	W	AR
200		*Larvivora brunnea*	Indian Blue Robin	W	AR
201		*Myophonus horsfieldii*	Malabar Whistling Thrush	R, EI	AR
202		*Ficedula parva*	Red-breasted Flycatcher	W	ML, PR
203		*Monticola cinclorhynchus*	Blue-capped Rock Thrush	W	ML, PR
204		*M. solitarius*	Blue Rock Thrush	W	AR
205		*Saxicola maurus*	Siberian Stonechat	W	CR, PR
206		*S. caprata*	Pied Bushchat	R	AR
207	Turdidae	*Geokichla citrina*	Orange-headed Thrush	R	AR
208		*Turdus simillimus*	Indian Blackbird	S	AR

Key: S - summer visitor, W - winter visitor, R - resident, UC - uncertain
EI - endemic to India (from Praveen et al. 2016), * - sighted once
Abbreviations for location: PR - Parpoli region, GT - Ghat region, AT - Amboli Town, CR - Chaukul Road, ML - Malai region, PP - Papdi region, MG - Mahadevgarh region, AR - all regions

It was found that species like Oriental Dwarf Kingfisher *Ceyx erithaca* at Amboli are vehemently sought after by photographers and their enthusiasm has disturbed some of their favourite nesting sites. There are three main motorable roads in Amboli Ghat area. During monsoon, an average of around 24 roadkills of animals, mainly composing of reptiles and amphibians, are recorded per day. Most of these reptile and amphibian species were from the Endangered category of the IUCN Red Data Book (IUCN 2016) and were observed on all the motorable roads each day during the study period. The strategy of biodiversity conservation is based on applying methods of protection in a specified area. Tourism development must be carefully managed to avoid turning Amboli Ghat into yet another tourist town where bottles, wrappers, plastics, and billboards dominate the landscape. Though ecotourism is capable of generating high revenue for natural areas that need protection, planning and development of infrastructure pertaining to tourism, its marketing should focus on conservation of nature, minimizing negative visitor impact, and involvement and employment of local populations in all aspects of business operations. Commercialization programs should have policies to meet higher social and environmental goals like building ecolodges powered by alternative energy resources and allowing travellers to stay in relative comfort while having magnificent wildlife-viewing from their doorsteps, which minimally impacts the local environment.

The following management strategies can be implemented at Amboli Ghat (Wood 2002):

1) Provide adequate budget to conserve popular tourist areas and earmark tourism fees for conservation.

2) Tourism businesses should pay impact fees that should fund infrastructure for solid waste treatment, sewage treatment, electricity, water and tourists must receive clear incentives for conserving water and electricity.

3) Environmental impact monitoring programs should

be regularly implemented.

4) Well-managed trails and camping areas should be clearly marked with rules for low-impact use.

5) Restrictions should be in place for the type of vehicles permitted in specific zones, speed limits, dumping of waste, and off-road driving.

6) Training programs should be initiated at local levels to provide local inhabitants with the opportunity to run their own businesses.

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Image 1. Blue-capped Rock Thrush *Monticola cinclorhynchus*

Image 2. Indian Blue Robin *Larvivora brunnea*

Image 3. Yellow-browed Bulbul *Acritillas indica*

Image 4. Forest Wagtail *Dendronanthus indicus*

Image 5. Short-toed Snake Eagle *Circaetus gallicus*

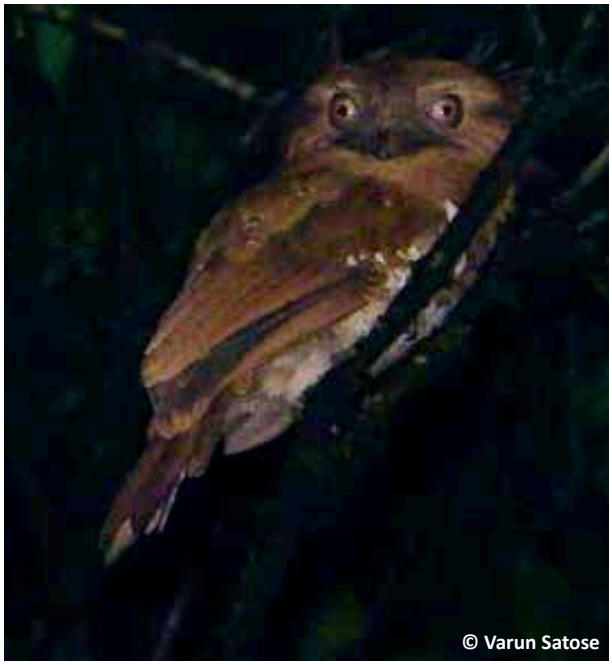

Image 6. Sri Lankan Frogmouth *Batrachostomus moniliger*

Image 7. Slaty-legged Crake *Rallina eurizonoides*

Image 8. Malabar Pied Hornbill *Anthracoceros coronatus*

Image 9. Malabar Grey Hornbill *Ocyceros griseus*

Image 10. Great Hornbill *Buceros bicornis*

Image 11. Plain Flowerpecker *Dicaeum concolor*

Image 12. Oriental Darter *Anhinga melanogaster*

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SHORT COMMUNICATION

DNA barcoding and morphological characterization of moth *Antoculeora ornatissima* (Walker, 1858) (Lepidoptera: Noctuidae), a new range record from western Himalayan region of India

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OPEN ACCESS

Abstract: DNA barcoding of *Antoculeora ornatissima* (Walker, 1858) was done for the first time from India. Redescriptions of genitalia and diagnoses of genus and species are presented with images and illustrations.

Keywords: *Antoculeora ornatissima*, DNA barcoding, Lepidoptera, morphology, new range record, Noctuidae, Plusiinae, western Himalaya.

Noctuidae is one of the largest families of moths with more than 35,000 known species documented in the world. The subfamily Plusiinae (Lepidoptera: Noctuidae) is represented by approximately 500 species worldwide (Ronkay et al. 2008) of which 59 are reported in India (Shashank & Longjam 2014), which were grouped in three tribes, Abrostolini Eichlin & Cunningham, 1978, Argyrogrammatini Eichlin & Cunningham, 1978, and Plusiini Boisduval, 1928. Abrostolini is represented by two species, Argyrogrammatini by 33 species, and Plusiini by 24 species. Under the subfamily Plusiinae, the genus *Antoculeora* is represented by three species, namely, *A. yoshimotoi* (Ronkay, 1997), *A. locuples* (Oberthür, 1880), and *A. ornatissima* (Walker, 1858). Walker (1858) described *Plusia ornatissima* on a single female specimen from the southern Himalayan region (northern Hindustan). Later, *Antoculeora* was erected as a subgenus of *Erythroplusia* Ichinose, 1962 (Ichinose, 1973) and raised to a full genus by Chou & Lu (1979). Further, Oberthür (1880) described *P. locuples* for the island of Askold located in the Bay of Vladivostok, Russia. These two taxa were treated as synonyms by Staudinger & Rebel (1901), whose opinion was accepted by Hampson (1913) and Warren (1913), followed by all subsequent authors till Ronkay (1997). Kitching (1987) expressed his opinion that *A. ornatissima* might be a complex of closely related taxa but may also be a single species. A detailed history of generic classification and species changes was provided by Kitching (1987), Ronkay (1997), and Ronkay et al. (2008).

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Due to large intraspecific variation in this species and to resolve a few ambiguities of the species complex, a need for molecular work was suggested by Ronkay (1997) and Ronkay et al. (2008). This is the first effort to study the occurrence and DNA barcode of *A. ornatissima* from India.

Material and Methods

Sampling

For the present study, 12 specimens were collected from Chamoli and Katrain, two different localities of northern India. The collection of specimens were carried out by hand collection of larvae, which were reared to the adult stage in the Lepidoptera Laboratory, National Pusa Collection, Indian Agricultural Research Institute, New Delhi (NPC-IARI). Light traps using hanging cloth method were also used for collection of adult moths. Further, collected materials were processed by pinning, spreading, proper labelling, and preparation of wings and genitalia slides. All the specimens are preserved in NPC-IARI.

Morphology of adult moths

Genitalia of both male and female specimens were prepared and images were taken with a Leica DFC425C digital camera mounted on a Leica M205FA stereozoom microscope. The terminology used for male and female genitalia follows Klots (1970). Forewing length was measured from the outer edge of the tegula to the outer most edge of the apex.

DNA isolation, PCR amplification, and sequencing

The DNA easy blood and tissue kit (Quiagen GmbH, Germany) method was used to extract DNA from one to three legs of each adult. The DNA extraction method provided by Fukova et al. (2009) was followed. For mitochondrial cytochrome c oxidase subunit I gene analysis was used on the voucher specimens. The genomic DNA was visualized using 0.8% agarose gel and quantified by fluorometer using standard procedures. Depending upon the concentration, the DNA samples were diluted with molecular gradient water to get a working solution of 10–30 ng/µL. A portion of the total DNA was preserved in glycerol (10%) in -80°C for future reference purposes. The universal barcode primer described by Folmer et al. (1994) (LCO-5'-GGT CAA CAA ATC ATA AAG ATA TTG G-3'; HCO-5'-TAA ACT TCA GGG TGA CCA AAA AAT CA-3') specific to mitochondrial cytochrome c oxidase subunit I gene (COI) was used in the present study. The optimized PCR conditions (per 25µL) using Taq DNA polymerase (Fermentas Inc., USA) were 2.5µL of 10 X PCR buffer with 2µL of 25mM $MgCl_2$, 0.5µL of 10mM dNTPs, 0.5µL each of forward and reverse primer, 1U of Taq, and 17µL of UltraPure water (Invitrogen). Thermocycler conditions were as follows: initial denaturation for 5min at 94°C followed by 35 cycles of denaturing for 30s at 94°C, annealing for 40s at 54°C and an extension time of 40s at 72°C, with a final extension for 5min at 72°C. PCR products were visualized on agarose gel after electrophoresis. Single bands were purified using a QIAquick PCR purification kit (Quiagen GmbH, Germany). Purified PCR products were sequenced directly in both directions using an automated sequencer (ABI prism® 3730 XL DNA Analyzer; Applied Biosystems, USA) at SciGenom Lab, Cochin, India. COI sequences in FASTA format were processed and submitted to NCBI for GenBank accessions as per Shashank et al. (2014). Accession numbers for the five specimens are KY886404, KY886405, KY886406, KY886407, and KY886408.

Results

Redescription of *Antoculeora ornatissima* (Walker, 1858)

Systematic accounts

Family: Noctuidae Latreille, 1809

Subfamily: Plusiinae Boisduval, 1828

Genus: *Antoculeora* Ichinose, 1973

Genus: *Antoculeora* Ichinose, 1973

Type species: *Plusia ornatissima*.

The genus *Antoculeora* is characterized by its large size of 30–42 mm, with broader, acutely pointed forewings. Head and collar lateritius. Forewing with metallic sheen present, gamma mark larger and divided into two oval spots. Male genitalia with longer uncus, juxta sclerotised. Asymmetrical valvae with saccular extensions. Female genitalia with longer sacculiform corpus bursae with strongly ribbed appendix bursae. Ovipositor rather medium sized, weakly sclerotised, papillae anales rounded.

***Antoculeora ornatissima* (Walker, 1858)** (Images 1A,B)

Plusia ornatissima Walker, 1858: 1786. Type locality: northern Hindostan.

Cerviplusia wukongensis Chou & Lu, 1974: 73. Type locality: China.

Antoculeora ornatissima Goater, Ronkay & Fibiger, 2003.

Redescription: Forewing length of adults 36–40 mm. Spherical rounded medium-sized compound eyes. Frons and vertex copper-bronze coloured. Frons distinctly exceeding the eyes. Labial palpi upturned, third segment is pointed and small. Second segment of labial palpi is densely covered with reddish scales. Antennae of male and female filiform in shape. Metathoracic tuft

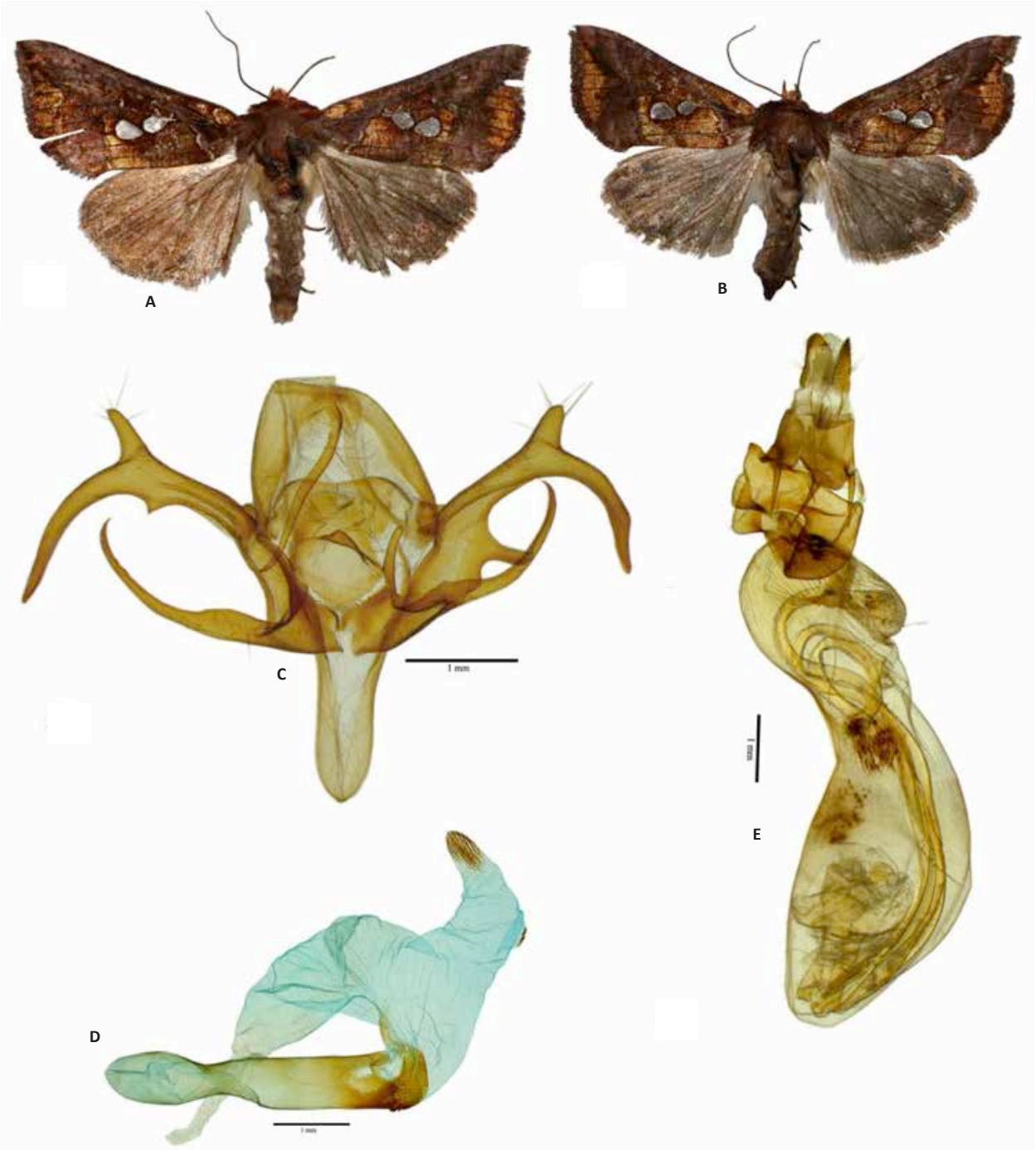

Image 1. *Antoculeora ornatissima* (Walker, 1858): A - adult male, B - adult female, C - male genitalia, D - aedeagus, E - female genitalia

well developed, looks like a pair of horns and generally reddish-orange coloured. Meso- and metathorax densely covered with hairs. Foreleg, midleg, and hindleg are similar in both males and females. Femur and tibia of foreleg covered with brownish-orange hairs. Tarsi full of spines. Two pairs of spurs present on hind leg. Abdomen light brown coloured. Abdominal tuft well developed. Two prominent crest present on abdomen. Anal tuft present. Orange coloured scales present on the back portion of the entire abdomen. Forewing triangular, subfalcate and metallic shimmering present on the termen region and post-medial region. Antemedial line golden coloured and ends at the stigma. Stigma mark is like two large oval spots with silver colour filled into it. Comma-like structure present above the gamma mark, the best identification feature of this species. Hindwing

aeneous brown coloured. Forewing with 12 veins, vein SC and R1 are free. RS2+RS3 joined by a short vein to discal cell. Vein M2 present near the middle of the discal cell. Veins RS1 and RS2 connected with short vein to form an areole. Anal vein separately present. Hindwing with nine veins present. RS1 joined with M1 (RS1+M1). M2, M3, and CuA1 originate from the same base stalk. Two anal veins A1 and A2 freely present.

Male genitalia (Image 1C,D): Male genitalia robust. Valvae with longer projections outwards. Fultura inferior rather low, apical part more or less broadly triangular. Tegumen arms are extremely swollen anteriorly and, in dorsal view, diverge at 180°. The valvae have projections that can interlock itself when valvae are closed. Vinculum U-shaped, clavus longer in shape. Aedeagus with carina terminated in a broadly half-moon-shaped plate covered with short but strong teeth at base (and sometimes in medial third); basal part of vesica with two diverticula bearing bundles of short, spiniform cornuti, one of them usually long and tubular, second much smaller, often without spinules; distal part of vesica with scobinate walls but without spinulose field.

Female genitalia (Image 1E): Corpus bursae lobular. Proximal third of corpus bursae a large, spacious sac, covered partly with fine, short, hair-like spiculi. Medial third of corpus bursae only slightly wrinkled. Ductus bursae smaller and twisted. Diverticule of corpus bursae sclerotised, proximal papillae anales asymmetrical. Ostium bursae form a heavily sclerotized, double complex. Posterior part smaller, flattened, more or less rectangular with deeply incised proximal margin; anterior part huge, axe-head-shaped with pointed postero-lateral tip. Cervix bursae elongated, folded.

Material examined: 1901–1904, 19.v.2015, 2 males, 2 females, Chamoli, Uttarakhand, India, 30.242^{0}N & 79.614^{0}E, coll. Shashank; 1905, 04.vi.2014, 1 male, Palampur, Himachal Pradesh, India, 32.129^{0}N & 76.538^{0}E, coll. Pathania; 1906–1908, 05.ix.2007, 2 males, 1 female, Srinagar, Jammu & Kashmir, India, 34.117^{0}N & 74.776^{0}E, coll. Rajesh; 1909–1912, 21.ix.2016, 2 males, 2 females, Katrain, Himachal Pradesh, India, 32.097^{0}N & 77.135^{0}E, Shashank.

Global distribution: India (Uttarakhand, Himachal Pradesh, Jammu & Kashmir, and Sikkim), Pakistan, China, Japan, and Russia.

Conclusions

Our study highlights the occurrence of species *A. ornatissima* from India. Molecular evidence along with morphology confirm the presence of this species. There was no molecular data available for this species from India, which is also its type locality. DNA barcodes provided in this study will help in the accurate diagnosis of this species from India.

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SHORT COMMUNICATION

ODONATA OF EASTERN BANGLADESH WITH THREE NEW RECORDS FOR THE COUNTRY

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Abstract: A study was conducted in the eastern region of Bangladesh to contribute to the knowledge of the country's Odonata fauna. A total of 75 species belonging to nine families was recorded during the study period from April 2014 to July 2016. Two zygopteran species, *Calicnemia imitans* and *Prodasineura autumnalis*, and one anisopteran species, *Megalogomphus smithii*, are new records for the country. The *Megalogomphus* genus is recorded for the first time from Bangladesh.

Keywords: Distribution, diversity, Indo-Burma biodiversity hotspot, Odonata.

Bangladesh, situated in southern Asia, possesses an enormous area of wetlands including ponds, rivers, freshwater lakes, marshes, and extensive mangrove swamps. The hilly areas of the northeastern and southeastern regions receive precipitation throughout the year and are rich in waterfalls and streams. In addition, during monsoon, many paddy fields and irrigation channels hold water for more than three months and generate numerous temporary water reservoirs. These diverse range of water resources offers ambient microhabitats for many Odonata species (Chowdhury & Mohiuddin 1994). Till date, 105 species of odonates are recorded from Bangladesh (Begum et al. 1977; Chowdhury & Akhteruzzaman 1983; Chowdhury & Mia 1989; Chowdhury & Mohiuddin 1993; Noruma & Alam 1995; Chowdhury & Mohiuddin 2011; Khan 2015a,b). Among these, 76 species from seven families are reported from the northeastern region (Khan 2015b). On the other hand, 90 species are reported from the southeastern region (Chowdhury & Mohiuddin 2011). The checklist of the eastern region, however, is not comprehensive and many prospective habitats are yet to be explored.

The eastern region of Bangladesh is situated in the Indo-Burma biodiversity hotspot and is rich with diverse floral and faunal communities. This region has a few semi-evergreen forests and wildlife sanctuaries enriched with numerous streams and waterfalls. In addition to that, there are many marshes and lakes that provide ambient habitats for odonates. Despite being a suitable habitat for Odonata fauna, there is a lack of studies annotating the order of the eastern region to date. Moreover, the previous research initiatives left many potential habitats to survey. The current study is a comprehensive approach for the documentation of the Odonata diversity of the eastern region of Bangladesh.

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Materials and Methods

Study area

The odonates were surveyed from the entire Sylhet Division and five districts of Chittagong Division, namely, Bandarban, Cox's Bazar, Chittagong, Khagrachari, and Rangamati, of Bangladesh (Fig. 1). In the northeastern region that is administratively under Sylhet Division, odonates were surveyed in Khadimnagar National Park, Tilagar Eco Park, Shahjalal University of Science and Technology campus, Satchari National Park, Lawachara National Park, and Madhobpur Lake. On the other hand, in the southeastern region that is administratively under Chittagong Division, odonates were surveyed in the Chittagong University campus, Kaptai National Park, Bariadhala National Park, and many streams and waterfalls in the areas associated with Chittagong, Khagrachari, and Bandarban districts.

Specimen collection and identification

During the survey, potential habitats like marshes, ponds, streams, streams associated with forest patches, and temporary watersheds created during the monsoon were scanned thoroughly from 09.00hr to 16.00hr. In the field, the species were photographed using a Canon 600 DSLR camera fitted with a 55–250 mm telephoto zoom lens. The specimens were captured using an insect-sweeping net and brought into the Department of Biochemistry and Molecular Biology, Shahjalal University of Science and Technology, Sylhet, Bangladesh, for further identification and deposition. In the laboratory, the specimens were examined under the microscope and identified based on the available identification keys provided by Fraser (1933, 1934, 1936) and Asahina (1993). The odonates were classified according to Dijkstra et al. (2013). The collected specimens are stored in my personal collection in the department of Biochemistry and Molecular Biology department in the Shahjalal University of Science and Technology, Bangladesh.

Results

A total of 75 species from nine families belonging to 45 genera were recorded from the eastern region of Bangladesh (Table 1, Fig. 2). Among the documented odonates, 45.33% (34 species) of 18 genera belong to the Zygoptera suborder while 54.66% (41 species) of 27 genera belong to the Anisoptera suborder (Table 1). Libellulidae was the predominant Anisoptera family with 35 species from 22 genera (Table 1, Fig. 2). On the other hand, Coenagrionidae was the best represented Zygoptera family with 18 species from six genera (Table 1, Fig. 2). Three species, *Calicnemia imitans*, *Prodasineura autumnalis*, and *Megalogomphus smithii*, were recorded for the first time from Bangladesh.

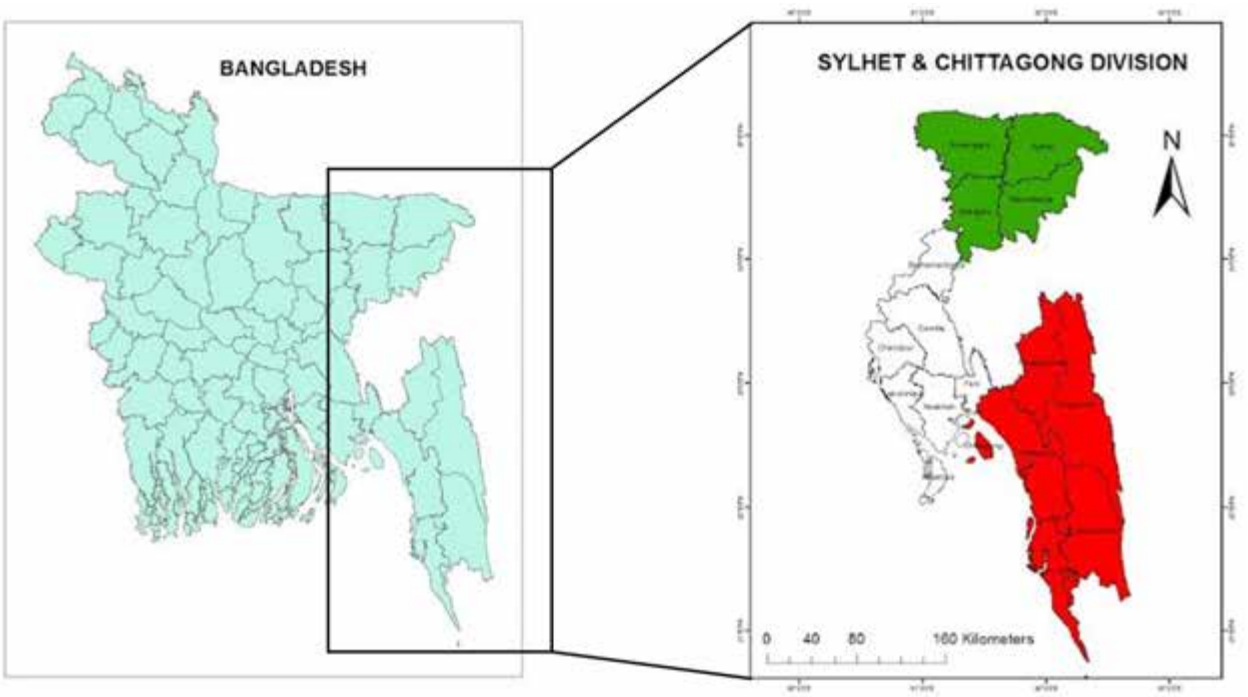

Figure 1. A reference map of the eastern region of Bangladesh. The northeastern region is administratively under Sylhet Division and the southeastern region is under Chittagong Division. The red and green colours represent the area covered during the study period.

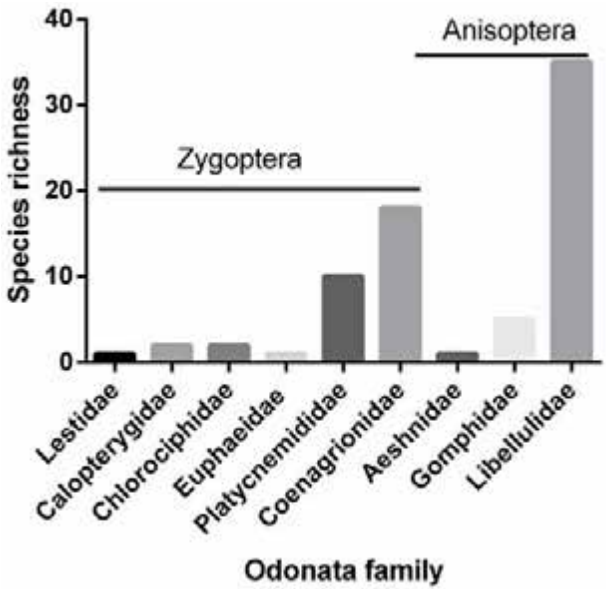

Figure 2. Number of Odonata species and their corresponding families recorded from the eastern region of Bangladesh in the present study

A total of 65 species belonging to eight families were recorded from the northeastern region. On the other hand, 52 species belonging to seven families were documented from the southeastern region. Among the 75 recorded species, 41 species were commonly recorded from the northeastern and southeastern regions. Twenty-three and 11 species were uniquely recorded from the northeastern and southeastern regions, respectively. Coenagrionidae and Libelluidae were the best-represented zygopteran and anisopteran families with 15 and 33 species, respectively. Similarly, in the southeastern region, Coenagrionidae and Libelluidae were the best-represented zygopteran and anisopteran families with 11 and 27 species, respectively.

Newly recorded odonates for Bangladesh

***Calicnemia imitans* Lieftinck, 1948 (Image 1A,B)**

Calicnemia imitans is one of the most abundant species of odonates in the southeastern hilly streams of Bangladesh. They prefer streams associated with shady bushes for perching. This is the third recorded species of this genus from Bangladesh after *C. eximia* and *C. pulverulans*. I recorded this species based on the two male specimens collected from the Alutila Cave, Khagrachari, Chittagong (23.085^{0}N & 91.956^{0}E, elevation 281m), on 02 June 2015 (specimen registration number ODO-008 and ODO-009). The length of the male abdomen is 29–31 mm and that of the hindwing is 20–22mm. This species can be distinguished by its body colouration and anal appendages. The ground colour of male is black; orange and red colours are absent in the thorax; narrow straight blue ante-humeral stripe present, inferior is two third of the superior, tip of the superior is wide apart. This species was previously known from India, Laos, Myanmar, Thailand, and Vietnam (Fraser 1933; Hamalainen & Pinratana 1999; Cuong & Hoa 2007)

***Prodasineura autumnalis* (Fraser, 1922) (Image 1C,D)**

I recorded this species based on two males and one female collected from the Kaptai National Park, Rangamati, Chittagong (22.497^{0}N & 92.184^{0}E, 51.4m), on 17 October 2014 (ODO-010, ODO-011 and ODO-012). I resighted this species later on 2 June 2015 from Richang Waterfalls, Khagrachari, Chittagong (23.110^{0}N & 92.002^{0}E, 78m), and on 04 June 2015 from Debota Pond, Khagrachari, Chittagong (23.085^{0}N & 91.971^{0}E, 52m). The length of the abdomen and hindwing of the males are 30–31 mm and 18–20 mm, respectively. *Prodasineura autumnalis* is superficially similar to *P. verticalis* and *P. sita*; however, they can be distinguished by the unmarked black thorax and the white-tipped inferior anal appendages (Image 1C). The females are found close to males and can be distinguished by their blue ante-humeral stripe (Image 1D). The species was previously known from China, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, Singapore, Thailand, and Vietnam (Fraser 1933; Vick 1989; Hamalainen & Pinratana 1999; Wilson & Reels 2003; Orr 2005; Cuong & Hoa 2007; Wilson 2005; Tang et al. 2010). The present record extends its distribution to Bangladesh.

***Megalogomphus smithii* (Selys, 1854) (Image 1E)**

Megalogomphus smithii was previously known from Assam, India, which is adjacent to the northeastern region of Bangladesh. Considering the similarity of habitats, this species was predicted to be present in Bangladesh too (Fraser 1934). I recorded this species based on one male collected from the Khadimnagar National Park, Sylhet, Bangladesh (24.951^{0}N & 91.918^{0}E, 56m), on 10 April 2015 (ODO-013). The lengths of the abdomen and hindwing in males are 53–55 mm and 42–44 mm, respectively. This species has a prominent M-shape marking in the thorax and can be easily distinguished from the other members of the genus by its yellow-marked black legs.

Discussion

In the current study, the Odonata fauna of the eastern region of Bangladesh was documented. A total of 75 species from 45 genera was recorded. Among them, three species and one genus were recorded

Table 1. A list of the Anisoptera and Zygoptera species recorded in the current study from eastern Bangladesh. The species newly discovered from Bangladesh are indicated with asterisks (*). The species present in a particular area are shown by tick sign (√) and the species absent are shown by cross mark (X).

	Species	Recorded from the north-eastern region	Recorded from the south-eastern region	Habitat feature
	Lestidae			
01	*Lestes praemorsus* Hagen in Selys, 1862	√	X	Paddy field, pond
	Calopterygidae			
02	*Neurobasis chinensis* (Linnaeus, 1758)	X	√	Stream, waterfalls
03	*Vestalis gracilis* (Rambur, 1842)	√	√	Forest, stream
	Chlorociphidae			
04	*Aristocypha quadrimaculata* (Selys, 1853)	√	√	Stream, waterfalls
05	*Libellago lineata* (Burmeister, 1839)	√	√	Stream
	Euphaeidae			
06	*Euphaea ochracea* Selys,1859	X	√	Stream
	Platycnemididae			
07	*Calicnemia imitans* Lieftinck, 1948*	X	√	Stream
08	*Coeliccia bimaculata* Laidlaw, 1914	√	X	Forest
09	*C. didyma* (Selys, 1863)	X	√	Forest, stream
10	*Prodasineura autumnalis* (Fraser, 1922)*	X	√	Stream
11	*P. laidlawii* (Förster in Laidlaw, 1907)	√	X	Stream, forest
12	*P. verticalis* (Selys, 1860)	X	√	Stream
13	*Onychargia atrocyana* Selys, 1865	√	X	Lake, forest
14	*Copera marginipes* (Rambur, 1842)	√	√	Stream, forest
15	*C. vittata* (Selys, 1863)	√	X	Stream
16	*Pseudocopera ciliata* (Selys, 1863)	√	√	Lake, marsh, pond
	Coenagrionidae			
17	*Agriocnemis clauseni* Fraser, 1922	√	X	Forest stream
18	*A. femina* (Brauer, 1868)	√	√	Marsh, pond
19	*A. kalinga* Nair & Subramanian, 2014	√	X	Lake, marsh, pond
20	*A. lacteola* Selys, 1877	√	√	Marsh, pond, paddy field
21	*A. pieris* Selys, 1877	X	√	Marsh, pond
22	*A. pygmaea* (Rambur, 1842)	√	√	Marsh, pond
23	*Ceriagrion cerinorubellum* (Brauer, 1865)	√	√	Lake, marsh, pond
24	*C. coromandelianum* (Fabricius, 1798)	√	√	Lake, marsh, pond
25	*C. olivaceum* Laidlaw, 1914	X	√	Forest
26	*Ischnura aurora* (Brauer, 1865)	√	√	Marsh, paddy field
27	*I. rufostigma* Selys, 1876	√	X	Pond, marsh, paddy field
28	*I. senegalensis* (Rambur, 1842)	√	√	Lake, marsh, pond
29	*Mortonagrion aborense* (Laidlaw, 1914)	√	X	Ditch, pond
30	*Paracercion calamorum*_ (Ris, 1916)_	√	X	Lake
31	*P. malayanum* (Selys, 1876)	√	X	Lake
32	*Pseudagrion microcephalum* (Rambur, 1842)	√	√	Lake, pond
33	*P. rubriceps* Selys, 1876	√	√	Lake, marsh, pond, stream
34	*P. spencei* Fraser, 1922	√	X	Lake
	Aeshnidae			
35	*Anax indicus* Lieftinck, 1942	√	X	Lake, pond
	Gomphidae			
36	*Ictinogomphus rapax* (Rambur, 1842)	√	√	Lake, pond
37	*Macrogomphus montanus* Selys, 1869	X	√	Hilly lake
38	*M. robustus* (Selys, 1854)	√	X	Forest stream
39	*Megalogomphus smithii* (Selys, 1854)*	√	X	Forest stream
40	*Paragomphus lineatus* (Selys, 1850)	√	√	Forest edge, stream
	Libellulidae			
41	*Acisoma panorpoides* Rambur, 1842	√	√	Marsh, paddy field
42	*Aethriamanta brevipennis* (Rambur, 1842)	√	√	Forest edge, lake
43	*Brachydiplax chalybea* Brauer, 1868	√	√	Ditch, lake, pond
44	*B. farinosa* Kruger, 1902	√	√	Ditch, lake, pond
45	*B. sobrina* (Rambur, 1842)	√	√	Ditch, lake, pond
46	*Brachythemis contaminata* (Fabricius, 1793)	√	√	Ditch, lake, pond
47	*Cratilla lineata* (Brauer, 1878)	√	√	Forest
48	*Crocothemis servilia* (Drury, 1770)	√	√	Pond, lake, stream
49	*Diplacodes nebulosa* (Fabricius, 1793)	√	X	Marsh, paddy field
50	*D. trivialis* (Rambur, 1842)	√	√	Marsh, paddy field
51	*Hydrobasileus croceus* (Brauer, 1867)	√	X	Forest
52	*Lathrecista asiatica* (Fabricius, 1798)	√	X	Forest
53	*Neurothemis fulvia* (Drury, 1773)	√	√	Forest, lake
54	*N. intermedia* (Rambur, 1842)	√	√	Forest, marsh

	Species	Recorded from the north-eastern region	Recorded from the south-eastern region	Habitat feature
55	*N. tullia* (Drury, 1773)	√	√	Marsh, paddy field, pond
56	*Orthetrum chrysis* (Selys, 1891)	√	√	Forest
57	*O. glaucum* (Brauer, 1865)	X	√	Forest, stream
58	*O. luzonicum* (Brauer, 1868)	√	X	Forest
59	*O. pruinosum* (Burmeister, 1839)	√	√	Marsh, lake, pond, stream
60	*O. sabina* (Drury, 1770)	√	√	Marsh, lake, pond, stream
61	*O. triangulare* (Selys, 1878)	√	√	Forest, stream
62	*Palpopleura sexmaculata* (Fabricius, 1787)	√	√	Forest edge, Lake
63	*Pantala flavescens* (Fabricius, 1798)	√	√	Marsh, pond, paddy field
64	*Potamarcha congener* (Rambur, 1842)	√	√	Lake, pond
65	*Rhodothemis rufa* (Rambur, 1842)	√	√	Lake, pond
66	*Rhyothemis variegata* (Linnaeus, 1763)	√	√	Marsh, paddy field
67	*Tetrathemis platyptera* Selys, 1878	√	X	Forest
68	*Tholymis tillarga* (Fabricius, 1798)	√	X	Lake, pond
69	*Tramea basilaris* (Palisot de Beauvois, 1805)	√	√	Forest edge
70	*T. virginia* (Rambur, 1842)	√	X	Lake
71	*Trithemis aurora* (Burmeister, 1839)	√	√	Hilly stream
72	*T. festiva* (Rambur, 1842)	√	√	Stream
73	*T. pallidinervis* (Kirby, 1889)	√	√	Marsh, lake, stream
74	*Urothemis signata* (Rambur, 1842)	√	√	Marsh, lake, pond
75	*Zyxomma petiolatum* Rambur, 1842	√	X	Forest

for the first time from Bangladesh. With the addition of those three species, the current checklist of the Odonata fauna of Bangladesh is raised to 108 species. The new record is an indication that the Odonata fauna in Bangladesh is poorly understood and demands more studies. Moreover, considering the habitat and Odonata fauna known from adjacent states of India, i.e., Assam, Meghalaya & West Bengal, and Myanmar, it can be predicted that more Odonata species are present in Bangladesh.

Regional checklists are indicators of the diversity, distribution range, and population fragmentation of a particular faunal community. Hence, updating regional checklists on a regular basis is a good practice to understand the conservation status of a species. In the current study, three species, *Agriocnemis clauseni, Pseudagrion spencei*, and *Tramea Virginia*, are newly added to the odonata fauna of the northeastern region of Bangladesh. In addition to that, the current study extended the distribution range of a few previously recorded species. The distribution range extension and new habitat allocation are particularly important to assess the global and national status of species. In the current study, the distribution range of two globally data deficient species is extended. Among them, *Macrogomphus robustus* was previously recorded from Lawachara National Park, Maulavibazar (Chowdhury & Mohiuddin 2011). The present record extends its distribution further north to the Khadimnagar National Park, Sylhet. The other data deficient species, *Megalogomphus smithii*, was previously known from China, India, and Indonesia. The present study reported this species for the first time within the geographical area of Bangladesh. The individual number of this two data deficient species recorded from the current study is very low and thus long-term studies are essential to assess their population trends and distribution range.

In conclusion, the diverse Odonata fauna and newly recorded species of the eastern region indicate that the area may accommodate hitherto unknown species. Moreover, the current study suggests that more long-term surveys are required to annotate the Odonata fauna of Bangladesh to estimate their current status and to determine their conservation needs.

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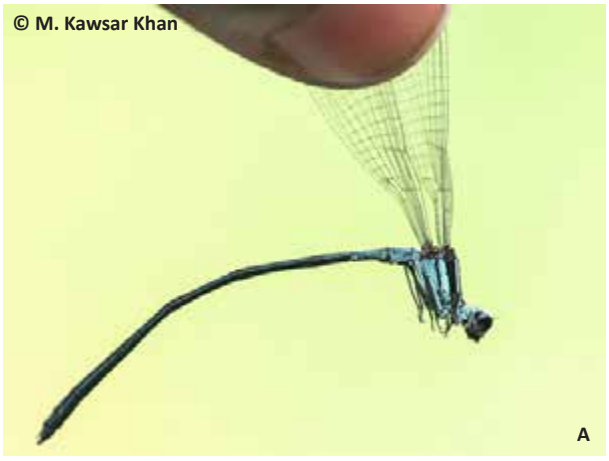

Image 1. Zygoptera and Anisoptera species newly recorded from Bangladesh in the present study.
A - *Calicnemia imitans* (male), B - *C. imitans* (female), C - *Prodasineura autumnalis* (male), D - *P. autumnalis* (male & female in tandem position), E - *Megalogomphus smithii* (male)

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Short Communication

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Two new species of phytoseid mites *Euseius* (Acari: Phytoseiidae) from Kerala, India

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Abstract: Two new species of phytoseiid mites, *Euseius pariyarensis* sp. nov. and *E. curcasae* sp. nov., collected from the medicinal plants *Saraca indica* L. and *Jatropha curcas* L. respectively, are described from the Kerala State of India. The morphological features of the two species are described with appropriate illustrations.

Keywords: *Euseius curcasae, Euseius pariyarensis,* Mesostigmata, Phytoseiidae.

Abbreviations: Z- Posterior mediolateral setae; S-Posterior lateral setae; JV-Ventrocentral setae; ZV-Mediolateral ventral setae

Phytoseiid mites have received considerable attention in pest management programs with respect to their potential for biological control of various phytophagous mites and agricultural and horticultural pests in greenhouses, on strawberries, and on deciduous fruits (McMurtry 1982; Helle & Sabelis 1985). The genus *Euseius* was first described by Wainstein (1962) under the subfamily Amblyseiinae based on the possession of an oval body, short, simple setae with Z_5 being the longest and well separated from Z_4, setae S_2 and S_4 present on ventrianal shield, setae JV_1 on its anterior margin and usually aligned with setae JV_2 and ZV_2.

The first version of the world phytoseiid catalogue was published by Moraes et al. (1986), which included about 1,500 species under 79 genera. The first version of an electronic database of Phytoseiidae prepared by Demite et al. (2014) included 2,436 valid species under 91 genera, of which the genus *Euseius* contains 219 valid species. Gupta & Karmakar (2015) prepared an updated checklist of Indian phytoseiid mites, which included 211 species. The present paper deals with the description of two new species under the genus *Euseius*, inhabiting the medicinal plants growing in northern Kerala, India.

Methods

The specimens included in the study were collected from mite-infested leaves of two species of medicinal plants namely, *Saraca indica* L. and *Jatropha curcas* L. The collected leaves were examined under a stereo zoom microscope (Magnus - MSZ-TR Trinocular Microscope). The mites wandering on the leaf surface were picked up with a camel hair brush and directly mounted on microscopic slides in Hoyer's medium (Haderson 2001). Systematic position of the species was identified following Gupta (2003) and Chant & McMurtry (2007) and by seeking expert opinion. The setal nomenclature

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followed Rowel et al. (1978) and Chant & Yoshida-Shaul (1989, 1991). All measurements are given in microns.

All the type specimens are kept in the P.G. & Research Department of Zoology, Malabar Christian College, Calicut and will be deposited in the National Zoological Collections of Zoological Survey of India, Kolkata, India.

Results

Euseius pariyarensis sp. nov.

(Fig. 1)

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Material examined: Holotype: No. D 75/1, female, 18.xii.2015, India, Kerala, Botanical Garden, Ayurveda College Pariyaram, Kannur District, 12.07^{0}N, 75.29^{0}E, xiiex: *Saraca indica* L., coll. P.P. Santhosh.

Paratype: No. D 75/2, 75/3, 75/4, three slides with three females, collection details same as holotype.

Female: Dorsum: Dorsal shield 320µm (300–325 µm) long, 202µm (200–208 µm) wide with 17 pairs of setae. Measurements of setae: j_1 37µm (35–42 µm), j_3 20µm (18–22 µm), j_4, j_5 & j_6 8µm (6–9 µm) each, J_2 9µm (8–10 µm), z_2 & z_4 – 6µm (5–7 µm) each. z_5 4µm (3–5 µm), Z_1 12µm (10–15 µm), Z_4 15µm (13–16 µm), Z_5 50µm (48–52 µm), s_4 8µm (6–9 µm), S_2 8µm (6–9 µm), S_4 9µm (8–10 µm), S_5 9µm (8–10 µm), r_3 8µm (6–9 µm), R_1 15µm (12–17 µm). Peritreme terminates anteriorly between legs I & II (Z_2 & Z_4).

Venter: Sternal shield 73µm (70–75 µm) long and 68µm wide with ST_1 22µm, ST_2 & ST_3 20µm long, ST_4 on metasternal shield 12µm long. Genital shield 50µm long and 65µm wide with ST_5 20µm long. Ventrianal shield slightly pentagonal in shape, 88µm long and 53µm wide. ZV_1 12µm, ZV_2 & ZV_3 14µm each, JV_1 15µm, JV_2 8µm, JV_4 12µm, JV_5 30µm long. A thick fold present between genital and ventrianal shields.

Chelicera: 24.5µm long, three teeth on fixed digit and none on movable digit.

Metapodal plate: Primary 13µm long, 4µm wide, accessory 5µm long.

Spermatheca: With tubular cervix 20µm long and with bifid atrium.

Macroseta on leg IV: Genu 37µm (34–39 µm) with pointed tips, tibia30µm (28–32 µm) with broadened tips, basitarsus 48µm (45–52 µm) with broadened tips.

Leg chaetotaxy:

$$\text{genu II } 2\frac{2}{0}\frac{2}{0}1 \qquad \text{tibia II } 1\frac{1}{1}\frac{2}{1}1$$

$$\text{genu III } 1\frac{2}{0}\frac{2}{1}1 \qquad \text{tibia III } 1\frac{1}{1}\frac{2}{1}1$$

Male: Unknown

Habitat: *Saraca indica* L.

Remarks: This new species closely resembles *E. ovalis* (Evans 1953) in dorsal chaetotaxy but differs in the structure of spermatheca and by the possession of the following features:

1. In the new species, the length of seta j_1 is 37µm (35–40 µm) whereas in *E. ovalis,* it is 31µm long.
2. The ventri-anal shield of the new species is slightly pentagonal, measuring 88µm (86–100 µm) in length and 53µm (51–55 µm) in width whereas it is oval and 84–90 µm long and 72–78 µm wide in *E. ovalis*.
3. The chelicera of the new species is with three teeth on the fixed digit and none on the movable digit whereas in *E. ovalis*, the fixed digit has two teeth and the movable digit has a small tooth.
4. In the new species, the spermatheca has a long tubular cervix (20µm) with funnel-shaped atrium whereas in *E. ovalis*, the cervix is funnel-shaped.
5. The new species possesses a thick fold between the genital and ventri-anal shields, which is absent in *E. ovalis.*

The new species also resembles *E. sacchari* (Ghai & Menon 1967) in the structure of chelicerae and spermatheca but differs by the possession of the following features:

1. The dorsal shield is smaller in size (320µm long & 202µm wide) in the new species when compared to that of *E. sacchari* (350µm long & 230µm wide).
2. The number of teeth on the fixed digit is three in the new species instead of two in *E. sacchari.*
3. The ventri-anal shield is 88µm long and 53µm wide in the new species, whereas in *E. sacchari*, it is 90–100 µm long and 70–80 µm wide.
4. In the new species, the macrosetae on leg IV basitarsus have broadened tip, whereas in *E. sacchari*, the tip of all macrosetae are pointed.
5. In the new species, the peritreme terminates between z_2 and z_4, whereas in *E. sacchari*, peritreme terminates anteriorly between j_3 and z_2.

Etymology: The nomenclature of this new species is based on the place from where the specimens were collected.

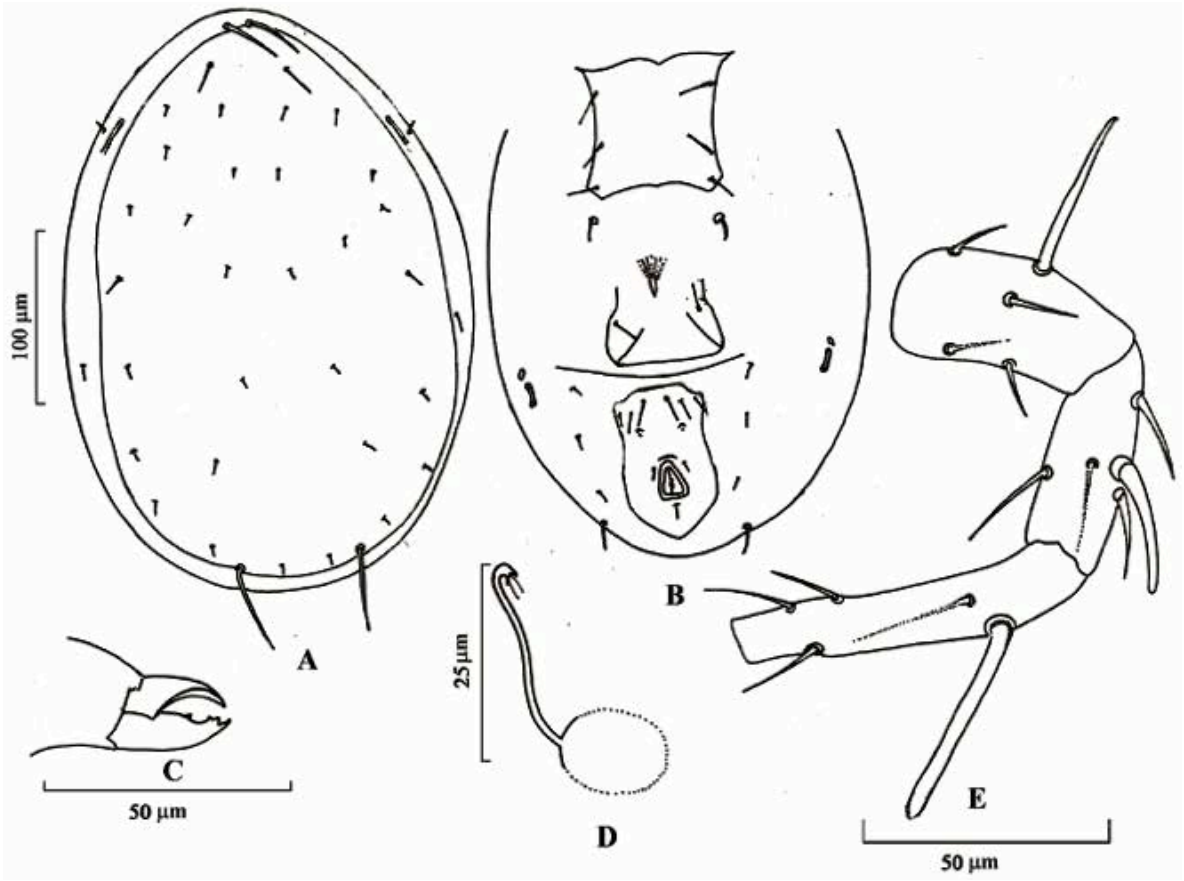

Figure 1. ***Euseius pariyarensis*** **sp. nov. (female). A - dorsal view, B - ventral view, C - chelicerae, D - spermatheca, E - leg IV**

Euseius curcasae sp. nov.
(Fig. 2)

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Material examined: Holotype: No. C 15/1, female, 15.v.2014, India, Kerala, University of Calicut, Malappuram District, 11.13^{0}N, 75.89^{0}E, ex: *Jatropha curcas* L., coll. P.P. Santhosh.

Paratype - Nos. C 15/2, 15/3, two females from the same habitat as holotype. Nos. C 15/4, 15/5, 20.vi.2015, two females, Chelembra, Malappuram District, 11.16^{0}N, 75.87^{0}E, ex: *Bauhinia acuminata* (L.), coll. P.P. Santhosh.

Female: Dorsum: Dorsal shield slightly reticulated along the lateral margin, 368µm (365–380 µm) long, 270µm (260–278 µm) wide with 17 pairs of simple setae. Measurements of setae: j_1 30µm (29–31 µm), j_4 9 µm (8–10 µm), j_5 & j_6 8µm (7–9 µm) each, J_2 11µm (10–12 µm), J_5 8µm (7–9 µm), j_3 13µm (12–14 µm), z_2 11µm (10–12 µm), z_4 11µm (10–12 µm), s_4 12µm (11–13 µm), Z_1 15µm (14–16 µm), S_2 11µm (10–12 µm), S_4 15µm (14–16 µm), S_5 11µm (10–12 µm), Z_5 44µm (43–45 µm) smooth, z_5 8µm (7–9 µm), Z_4 15µm (14–16 µm), r_3 11µm (10–12 µm), R_1 8µm (7–9 µm).

Venter: Sternal shield 75µm (73–78 µm) long and 73µm (70–75 µm) wide with three pairs of sternal setae, ST_1 & ST_2 measure 22µm each, ST_3 measures 18µm (16–20 µm). ST_4 lies on the metasternal plate, measuring 20µm (19–21 µm). Genital shield 75µm long, 93µm (90–95 µm) wide with ST_5 20µm (18–22 µm) long. Ventrianal shield vase-shaped, slightly concave laterally, 124µm (120–126 µm) long and 65µm (63–67 µm) wide with three pairs of preanal setae and four pairs of setae around. Setae ZV_1 & ZV_2 15µm (14–16 µm) each, ZV_3 12µm (11–13 µm), JV_1 & JV_2 15µm (14–16 µm) each, JV_4 12µm (11–13 µm), JV_5 25µm (23–26 µm) long. Two pairs of metapodal plates present, primary 17µm long and 5µm wide and accessory one 10µm long.

Spermatheca: Long tubular cervix (33µm) bent anteriorly with nodular atrium.

Peritreme: Terminates anteriorly between j_1 and j_3.

Chelicera: Fixed digit 22µm long with two apical teeth and movable digit with no tooth. Macrosetae on leg IV: genu 37µm (34–38 µm), tibia 35µm (36–37 µm), basitarsus 49µm (47–45 µm).

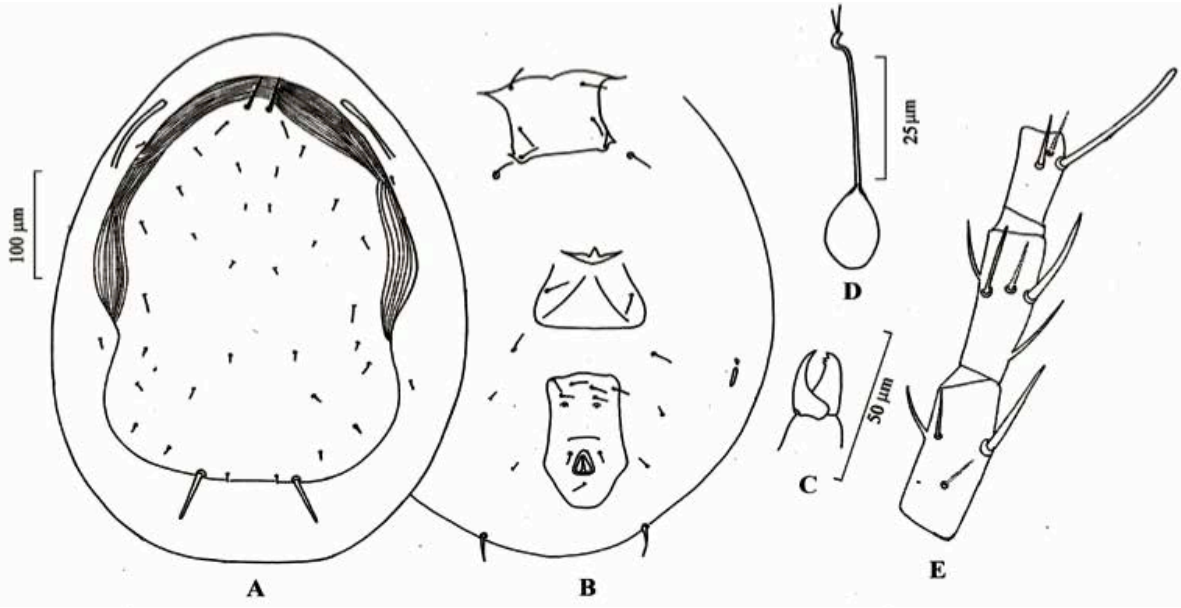

Figure 2. ***Euseius curcasae*** **sp. nov. (female). A - dorsal view, B - ventral view, C - chelicerae, D - spermatheca, E - leg IV**

Leg chaetotaxy:

genu II $2\frac{2}{0}\frac{2}{0}1$ tibia II $1\frac{1}{1}\frac{2}{1}1$

genu III $1\frac{2}{0}\frac{2}{1}1$ tibia III $1\frac{1}{1}\frac{2}{1}1$

Male: Unknown

Habitat: *Jatropha curcas* L., *Bauhinia acuminata* L.

Remarks: The specimen studied resembles *E. alstoniae* described by Gupta (1975) in dorsal chaetotaxy, structure of spermatheca, and length of macrosetae but differs in the following characters:

1. Dorsal shield longer and wider (368µm, 270µm) than that of *E. alstoniae* (325µm, 204µm).
2. Dorsal shield slightly reticulated on lateral margin of the anterior half, whereas it is smooth anteriorly and rugose posteriorly in *E. alstoniae*.
3. In the new species, seta S_2 shorter than Z_1, while in *E. alstoniae*, S_2 noticeably longer than Z_1.
4. In the new species, j_1 30µm (29–31 µm) and j_3 13µm (12–14 µm) long, whereas in *E. alstoniae*, j_1 almost equal (25–28 µm) in length and j_3 double the length than that of the new species (28–34 µm).
5. Seta JV_5 25µm long in the new species, whereas in *E. alstoniae*, JV_5 is 44µm.
6. The number of teeth on the fixed digit of chelicerae is three in the new species, whereas it is two in *E. alstoniae*.
7. In the new species, the shape of the ventrianal shield is pentagonal and measures 124µm long and 65µm wide, whereas in *E. alstoniae*, lateral margin of ventrianal shield slightly concave and differs in size (90–100 µm long, 70–80 µm wide).
8. Peritreme terminates anteriorly between j_1 and j_3 in the new species, whereas in *E. alstoniae*, it terminates between j_3 and z_2

This new species resembles *E. bambusae* described by Ghai & Menon (1967) also in the dorsal chaetotaxy but differs in the following characters:

1. Dorsal shield slightly reticulated along the lateral margin in the new species, whereas in *E. bambusae*, the entire dorsal shield is gently reticulate.
2. In the new species, seta JV_5 22µm long, whereas in *E. bambusae* it is 38µm long.
3. Macrosetae on leg IV genu 37µm (35–39 µm), tibia 35µm (33–37 µm), and tarsus 49µm (47–50 µm) long in the new species, whereas in *E. bambusae*, genu 52–56 µm, tibia 44—45 µm, and basitarsus 68–72 µm long.
4. In the new species, peritreme terminates between j_1 and j_3, whereas in *E. bambusae*, peritreme terminates anteriorly between j_3 and z_2.
5. Fixed digit of chelicerae with three apical teeth and movable digit with no tooth in the new species, whereas in *E. bambusae*, 3–4 apical teeth and one tooth on movable digit.

Etymology: The nomenclature of this new species is

based on one of the host plants, *Jatropha curcas* L., from which the specimens were collected.

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First photographic record of tiger presence at higher elevations of the Mishmi Hills in the Eastern Himalayan Biodiversity Hotspot, Arunachal Pradesh, India

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The Tiger *Panthera tigris* is a large and wide-ranging cat that occupies a variety of habitats, where it generally serves as the top predator. The tiger is also a flagship species (Dinerstein et al. 2007), and attention to protecting tiger populations and their habitats in Asian eco-regions has increased over the past few decades. India harbors more than 70% of the total global wild tiger population in five major areas containing habitats ranging from dry to moist deciduous forest, evergreen to mangrove forests, and Terai grasslands to mixed conifer-broadleaf forests (Jhala et al. 2015). Literature suggests that the ranges of the Royal Bengal Tiger *Panthera tigris tigris* and the Northern Indochinese Tiger *Panthera tigris corbetti* may overlap in northeast India and Myanmar (Luo et al. 2004). Limited ecological information exists on tiger ecology from the temperate forests of the Eastern Himalayan Biodiversity Hotspot (Jhala et al. 2011), which is located at the confluence of the Palearctic and Indo-China realms (Chatterjee et al. 2006). Biological surveys in the region, particularly in Arunachal Pradesh, have been hampered by the rugged and largely inaccessible landscape. Thus faunal diversity has remained poorly surveyed, and large areas remain unstudied.

Study Area: The Dibang Wildlife Sanctuary (DWS) (95°17'–96° 38'E and 28°38'–29°27' N latitudes) located in the Dibang Valley District of Arunachal Pradesh, India covers an area of 4,149km^2. It partially falls within the Dihang-Dibang Biosphere Reserve, and mostly extends over the Mishmi Hills. The northern and eastern parts of DWS are surrounded by China. The altitude ranges from 1,800–5,000 m, and the area receives an annual rainfall of 2,500mm from occasional rains and the southeast and northeast monsoons. The vegetation is broadly classified as temperate broad-leaved forest dominated by *Michelis* spp., *Quercus* spp., *Coptis teeta* and *Magnolia* spp., temperate conifer forest dominated by *Rhododendron arboretum, Taxus baccata* & *Pinus wallichiana,* and alpine forest dominated by *Saussurea* spp., *Sedum* spp. & *Saxifraga* spp.

Camera trapping: A three-year long study was recently carried out in the Dibang Wildlife Sanctuary and the Mishmi Hill range to strengthen the ecological baseline information on tiger, co-predators and prey ecology. As a part of this study, camera traps were laid to monitor wildlife in and outside DWS. To cover maximum area of DWS and its adjoining landscapes, a

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single-sided camera trap was deployed for every 3km^2 grid for three years (2015–2017). A total of 108 camera traps were deployed in 336km^2 with 13,761 trap nights inside and outside the protected area.

A total of 42 left sided photographs (Image 1) of tigers were recorded. With further image processing we were able to identify 11 unique individual tigers including two cubs. Two male tigers were captured in the Mishmi Hills at 3,246m on 29 May 2017 (Image 2a) and 14 January 2017 (Image 2b). One of the males (Image 2b) was recaptured at 3,630m on 07 June 2017 (Image 2c) in an area with different vegetation type: the higher elevation is sub-alpine forest comprising mainly of *Abies densa* and dwarf *Rhododendron* spp. While the lower elevation has mixed vegetation dominated by *Rhododendron arboreum*, Bamboo and Pine.

Our study provides photographic evidence for the presence of tiger in the Eastern Himalaya at 3,630m, within the biodiversity hotspot. Tiger tracks have been reported in winter snow in Indian Himalaya at 3,050m (Prater 1980), and pugmarks were reported from Temengor Forest Reserve, Malaysia at 1,700–1,945 m (Mohamad et al. 2013). In Bhutan, Jigme & Tharchen (2012) found photographic evidence of tigers up to an altitude of 4,200m. This information and our findings indicate that tigers may utilize high altitude habitats close to the tree line, where shrubs and grasses dominate and provide cover for prey and predators alike.

Captain F.M. Bailey of the Indian Army mentioned the occurrence of tigers in the high altitude forests of the Mishmi Hills (*Bailey 1912*). Aiyadurai (2007, 2014) provided information from the Idu Mishmi tribe that suggested the presence of tigers in Dibang. In December 2012, two tiger cubs were rescued from Angrim Valley of Anini Tehsil, located at 1968m in Dibang Wildlife Sanctuary (CMS ENVIS 2012). Thereafter, a preliminary rapid survey was carried out by the Wildlife Institute of India (WII) in collaboration with National Tiger Conservation Authority (NTCA) and Department of Environment and Forests, Arunachal Pradesh. The survey report (Gopi et al. 2014) mentions about the image of an adult tiger captured at an altitude of 1,765m at the Chelo Pani camp (page 12 and 18), and pugmark and scat evidence of Tiger at 2,065m in the Ange Pani

Image 1. Forty-two left sided photographs obtained from 108 camera traps deployed in 336km^2 with 13,761 trap nights inside and outside Dibang Wildlife Sanctuary, Arunachal Pradesh. Nine adults and two cubs were identified from the images.

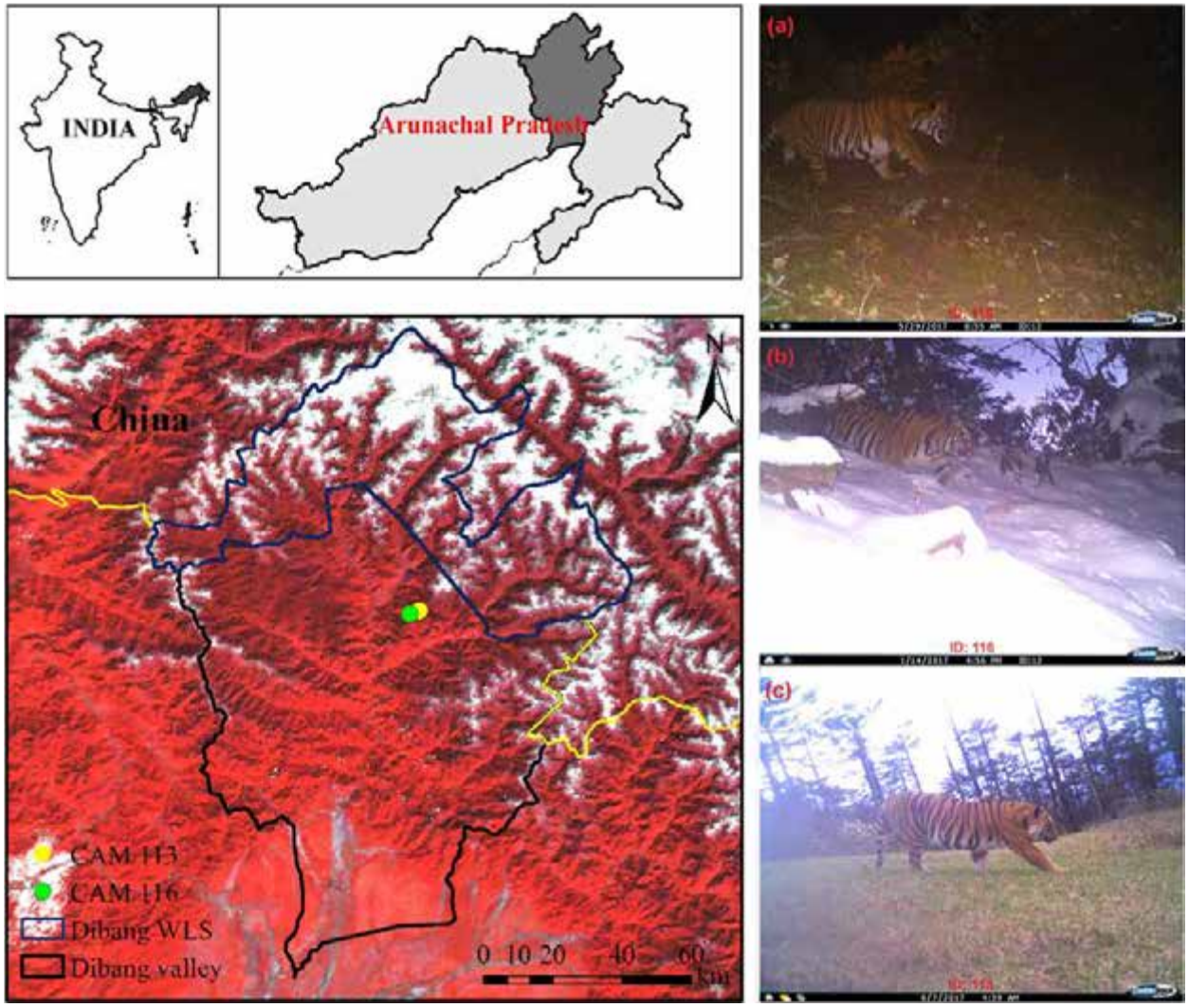

Image 2. Map showing the high altitude location where tigers were photographed; (a & b) Two different individuals captured at 3,246m; Tiger in (b) was recaptured at 3,630m (c).

area (pages 15 and 18). The team concluded that Dibang Wildlife Sanctuary holds the highest range for the tigers in India.

The all India tiger population estimation in 2006, which used camera traps for the first time, estimated a population of 84–118 tigers in the North Eastern Hills and Brahmaputra plains. The number increased to 118–178 in the 2010 estimate, and Jhala et al. (2011) suggested that these numbers are likely underestimates since the surveys did not systematically cover the entire landscape. In 2014, 201 tigers were reported for the North Eastern Hills and Brahmaputra plains. From Arunachal Pradesh 18 individual tigers were identified, and genetic analysis of scats indicated that five Tigers were from Dibang DWS (Jhala et al. 2015). After the launch of Project Tiger in 1973, monitoring systems evolved from traditional methods using pugmarks until camera trapping was introduced in 2006. Project Tiger highlights the conservation issues in a wide array of habitats in India. Knowledge of tiger ecology at higher elevations of the Himalayan region is currently inadequate, but is expected to improve in the future.

The Global Tiger Recovery Plan was initiated in 2010 by the 13 tiger range countries to double the number of wild tigers by 2022, popularly known as "TX2". Confirmed tiger presence in high altitude montane habitats in the Himalaya presents opportunities and challenges for the conservation of tigers and their habitats. The Mishmi Hill ranges are now documented to have more tigers than other designated tiger reserves in Arunachal Pradesh, including Pakke (9 Tigers), Namdapha (4 Tigers from scat genetic analysis) and Kamlang (not assessed) (Jhala et al. 2015). The immediate priority must be to ensure that the newly-discovered populations are protected

and monitored to identify potential genetic uniqueness. Other promising areas should also be surveyed to identify possible tiger presence. There is an urgent need for monitoring the tiger metapopulation in the northeastern hills range by assessing the functionality of corridors connecting local populations.

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An old collection reveals an additional distribution record of the Greater Long-tongued Fruit Bat *Macroglossus sobrinus* K. Anderson, 1911 (Chiroptera: Pteropodidae) from southern West Bengal, India

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The genus *Macroglossus* includes two species, *M. minimus* and *M. sobrinus*, with a geographical range that extends from India to Thailand, Indonesia, Philippines, New Guinea, and northern Australia. The Greater Long-tongued Fruit Bat *Macroglossus sobrinus* K. Andersen, 1911 is restricted to southern and southeastern Asia (Lekagul & McNeely 1977; Koopman 1993; Simmons 2005). It is a small and specialized nectar-feeding fruit bat. It inhabits low lands and montane forests, roosts in palm trees, roofs of jungle dwellings, in banana plants, and under branches, and feeds on nectar and some soft fruits (Bates & Harrison 1997). In India, this species was reported from northern West Bengal (Dobson 1878; Agrawal et al. 1992), Sikkim (Blanford 1888), Arunachal Pradesh (Saha 1985), Meghalaya and Tripura (Das et al. 1995), and Mizoram (Bates & Harrison 1997).

On 20 December 1995, a single female specimen of this bat species was caught in a mist net by a survey team of Zoological Survey of India (ZSI) from Narendrapur (22.439°N & 88.396°E, altitude 82m; Fig. 1) in South 24 Parganas District of West Bengal. The wet preserved specimen was deposited in the National Zoological Collections of ZSI, Kolkata (# 28014). We examined the specimen in detail to confirm its identity and report an additional location of the species in West Bengal. Based on the character matrix provided by Bates & Harrison (1997), the specimen was identified as *M. sobrinus*.

External characters: This specimen of *M. sobrinus* has a forearm length of 46.24mm (Table 1). The muzzle is elongated and tongue protrusible (Image 1c). According to Bates & Harrison (1997), the tail is rudimentary or absent, but the specimen we examine lacks tail. The index finger has a claw (Image 1d) and the thumb, including the claw, measures 17.48mm. The plagiopatagium (wing-membrane) is attached to the first phalanx of the fourth toe of the hind foot (Image 1e).

Craniodental characters (Image 2a–c; Table 1): The skull is very delicate and rostrum is long, the greatest length of the skull is 28.58mm, condylobasal length is 26.94mm, the skull has a low occipital crest and weakly developed postorbital processes, the braincase is deflected downwards, the length of the mandible is 22.44mm. All teeth are well-spaced along the tooth row, upper tooth length (C–M^2) is 9.51mm. The upper incisors (i2 and i3) are small. There is a wide gap between

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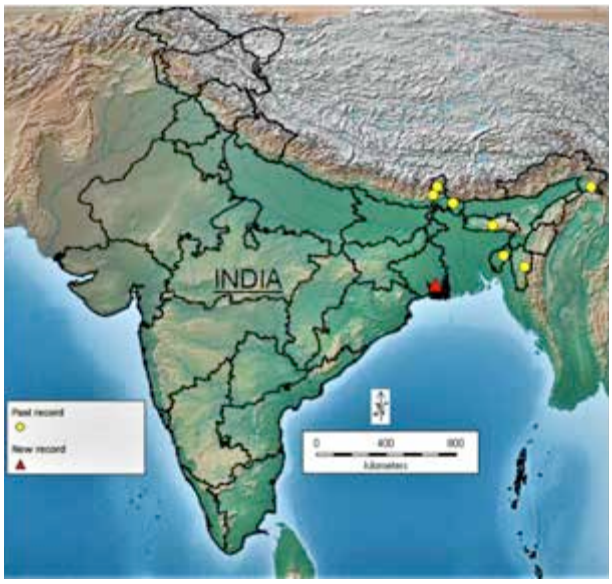

Figure 1. Distribution map of the Greater Long-tongued Fruit Bat *Macroglossus sobrinus* in India showing previous recorded localities (in yellow) and new record (in red) from southern West Bengal

the inner pair of incisors.

The first record of *M. sobrinus* in West Bengal was from Darjeeling and Cooch Behar areas of northern West Bengal (Dobson 1878). Thereafter it was reported from neighbouring Sikkim State and northeastern India (Anderson 1912; Blanford 1888; Saha 1985; Das et al. 1995; Bates & Harrison 1997). The present locality record of this species at Narendrapur, South 24 Parganas District, is more than 600km south of Darjeeling and significantly extends the distribution range of this species in West Bengal.

Table 1. Morphological and craniodental measurements (in mm) of the Greater Long-tongued Fruit Bat *Macroglossus sobrinus* specimen from West Bengal (Reg. No. 28014)

External characters	Measurements (in mm)
Sex	Female
Forearm length	46.24
Head-body length	66.24
Tail length	4.15
Thumb with claw	17.48
Hindfoot length	10.12
Tibia length	18.78
Ear length	15.83
3rd Metacarpal length	33.98
4th Metacarpal length	34.43
5th Metacarpal length	34.71
1st ph3rd mt	23.58
2nd ph3rd mt	27.95
1st ph4th mt	18.78
2nd ph4th mt	18.61
Craniodental characters	
Greatest length of skull (GTL)	28.58
Condylobasal length (CBL)	26.94
Condylocanine length (CCL)	25.37
Zygomatic breadth (ZB)	15.09
Breadth of braincase (BB)	11.90
Anterior palatal width (C1–C1)	5.37
Maxillary tooth length (C–M2)	9.51
Posterior palatal width (M2–M2)	6.47
Mandibular tooth length (C–M3)	10.41
Mandibular length (M)	22.44
Dental formula	Incisor 2/2, canine 1/1, premolar 3/3, molar 2/3: =34

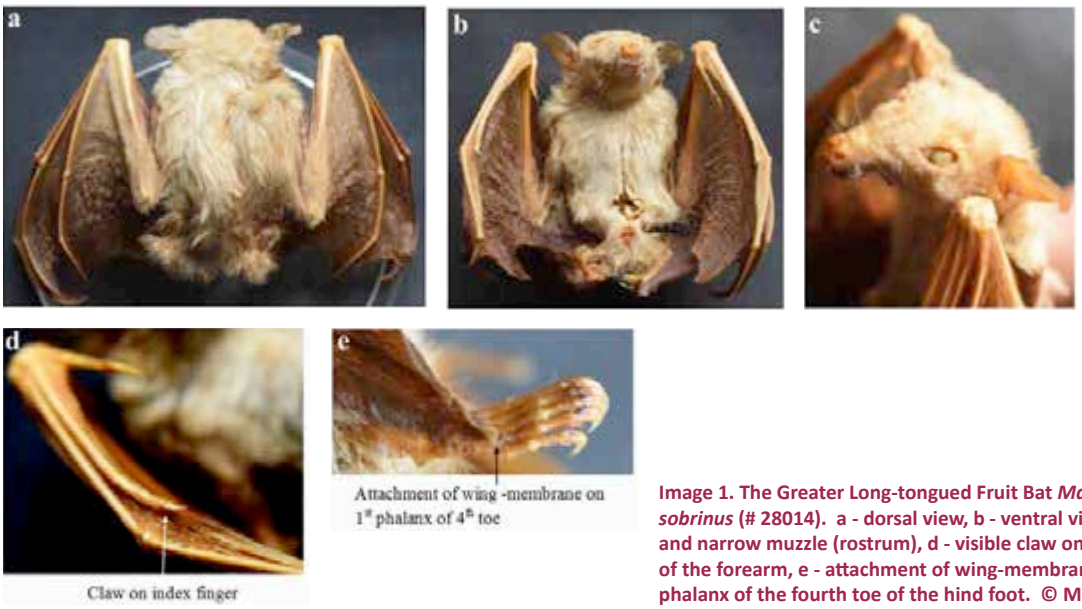

Image 1. The Greater Long-tongued Fruit Bat *Macroglossus sobrinus* (# 28014). a - dorsal view, b - ventral view, c - elongated and narrow muzzle (rostrum), d - visible claw on the index finger of the forearm, e - attachment of wing-membrane on the first phalanx of the fourth toe of the hind foot. © M. Kamalakannan

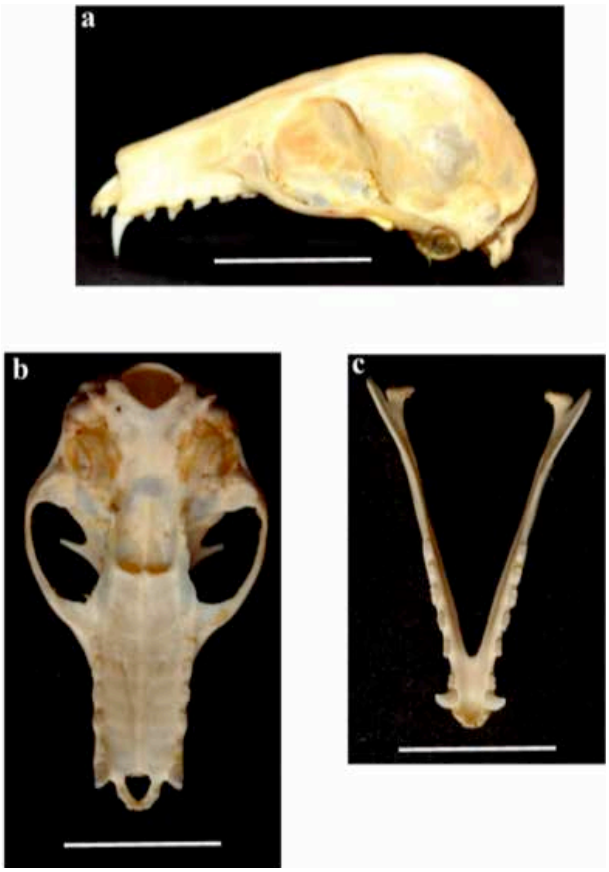

Image 2. Skull and mandible of the Greater Long-tongued Fruit Bat *Macroglossus sobrinus* (# 28014, scale = 1cm). a - lateral view of maxilla, b - ventral view of maxilla, c - ventral view of mandible. © M. Kamalakannan

Although listed as Least Concern in the IUCN Red List of Threatened Species (Hutson et al. 2008), the present status of *M. sobrinus* in West Bengal is unknown. Further studies on the ecology and distribution of the species will help in understanding the status of this species in West Bengal.

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Breeding reports and conservation implications of the Endangered Black-bellied Tern *Sterna acuticauda* J.E. Gray, 1831 (Aves: Charadriiformes: Laridae) in Odisha, eastern India

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The Black-bellied Tern *Sterna acuticauda* J.E. Gray, 1831 (Image 1) is one of the 23 species of terns occurring in the Indian subcontinent (Ali & Ripley 1983) and is categorized as Endangered in the IUCN Red List of Threatened Species (BirdLife International 2017). It is native to Bangladesh, Cambodia, India, Laos, Myanmar, Nepal, Pakistan, Thailand, and Vietnam and also occurs in some parts of southern China with an estimated global population of 6,700–17,000 mature individuals (BirdLife International 2017). The Black-bellied Tern inhabits large rivers and marshes and prefers to breed in isolated sandy islands in large rivers, which are often under deterioration from rapid and ongoing threats like Industrial pollution, dam construction, extraction of sand and gravel, over-harvesting of wetland products, and human disturbances (Sykes 2010; Rahmani 2012; BirdLife International 2017). Besides that, the collection of its eggs for food, destruction of its nests from flooding, and predation of eggs and chicks by stray animals have direct impacts on the breeding success of the bird (Goes et al. 2010; Rahmani & Nair 2012; BirdLife International 2017). As a result, Black-bellied Terns are becoming rarer and their population is declining worldwide (Li et al. 2009; Mundkur et al. 2017); it is presumed to be locally extinct in Cambodia, China, Laos, Thailand, and Vietnam (Goes et al. 2010; Sykes 2010; BirdLife International 2017). The recently compiled Asian Waterbird Census Report (Mundkur et al. 2017) recorded only 72 individual birds (57 from India, seven from Myanmar, and eight from Nepal) in 2015. Therefore, documentation and protection of the breeding sites of this globally threatened species deserve high priority for its long-term conservation.

In India, the Black-bellied Tern is widely distributed and comparatively common in the large rivers throughout the country in Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Delhi, Goa, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal excepting the far western, northern, and northeastern regions (Rahmani 2012; Fig. 1). Hardly any quantitative information, however, is available on its breeding sites. In Odisha, it is a resident bird and was reported from Bhitarkanika National Park (Gopi & Pandav 2007),

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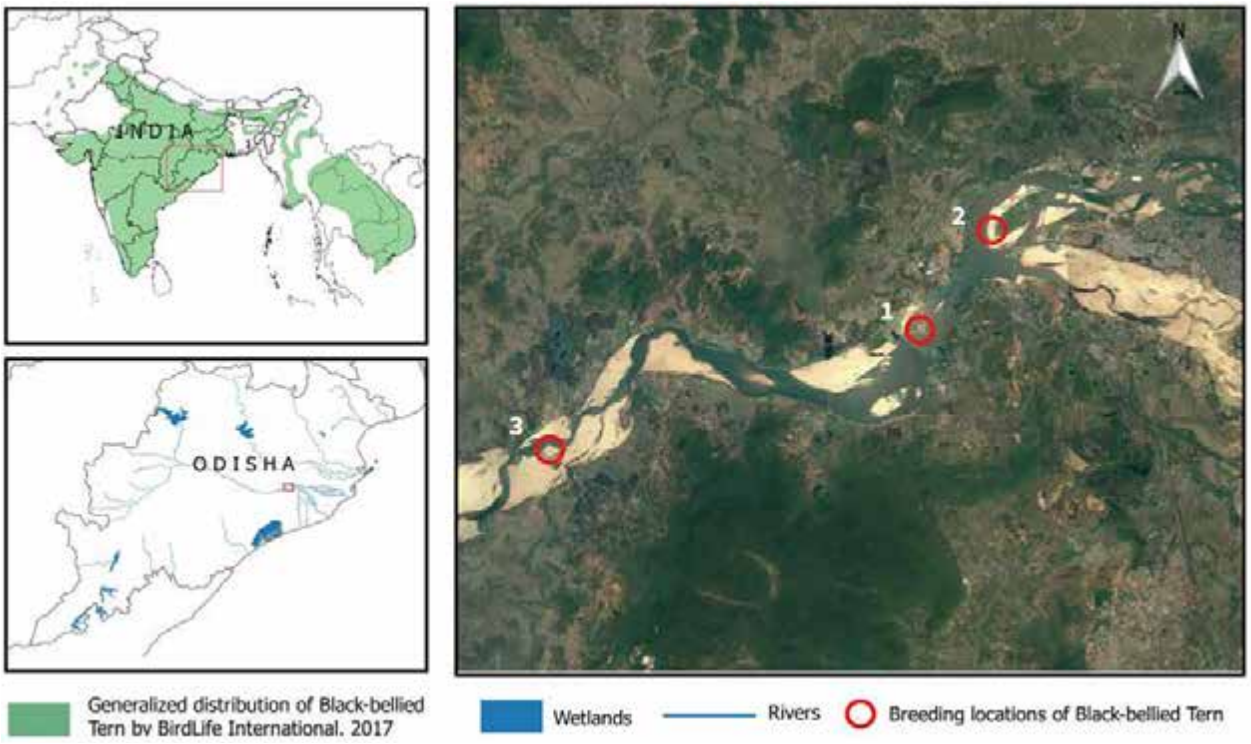

Figure 1. Map showing the distribution and breeding locations of Black-bellied Tern along the Mahanadi River in Odisha, eastern India. 1 - Mundali, 2 - Kakhadi, 3 - Jatamundia

Dhamra Estuary (Dutta 2007), Chilika Lake (Balachandran et al. 2009), Chandaka Wildlife Sanctuary (Tiwari et al. 2002), Rengali Reservoir (Rahmani & Nair 2012), Hirakud Reservoir, Satakosia Gorge Wildlife Sanctuary & Mundali barrage along the Mahanadi River, and Samal Reservoir in the Brahmani River (Palei & Mohapatra 2011; Palei 2015). Breeding activities of Black-bellied Tern in Odisha were reported by Rahmani & Nair (2012) and Dev (2013) from Chilika Lake and Mahanadi River, respectively. In this note, we further report breeding activities of this species in Odisha from three different localities along the Mahanadi River.

In February 2018, while surveying for the Indian Skimmer *Rynchops albicollis* Swainson, 1838 along the Mahanadi River (Fig. 1), we regularly sighted Black-bellied Terns in breeding plumage from different localities (Image 1) and predicted possible breeding activities. The number of individual birds recorded from different localities during the study period is given in Table 1. During 23–27 February 2018, we also recorded seven simple scrape nests having one to three greyish eggs with dark brown spots in each nest from three temporary sandy islands along the Mahanadi River (Image 2). These sites were Mundali (20.434^{0}N & 85.734^{0}E), Kakhadi (20.490^{0}N & 85.771^{0}E) situated around 8km north of Mundali along the downstream, and Jatamundia (20.417^{0}N & 85.585^{0}E), situated around 18km west of Mundali along the upstream (Fig. 1). For confirmation of the nests, we later monitored them on a boat from a safe distance using a pair of binoculars and observed the Black-bellied Terns incubating the eggs (Image 3). Earlier, Black-bellied Tern was known to breed in Kaziranga National Park in Assam (Barua & Sharma 1999), Bharathapuzha in Kerala (Neelakantan et al. 1993; Eldos et al. 2002), Hidkal Dam in Karnataka (Rahmani 2012), and Chilika Lake and the Mahanadi River in Odisha (Rahmani & Nair 2012) in India. The breeding habitat and nesting season of Black-bellied Tern observed in this study resemble its general behaviour throughout its distribution range (Rahmani 2012; BirdLife International 2017). Our informal discussions with the local fishermen revealed that all these islands appear only during summer and confirmed that the Black-bellied Terns regularly use these sites for nesting. We found that the clutch size of the nests varied from a single egg to three eggs, indicating that the nesting and egg laying activities may continue further.

As the population of Black-bellied Tern is declining rapidly throughout its range (Li et al. 2009; Mundkur et al. 2017), protection of the breeding sites should be given

Table 1. Number of individual Black-bellied Terns, nests, and eggs recorded during 5–27 February 2018 from different localities along the Mahanadi River in Odisha, eastern India

Survey dates	Mundali			Kakhadi			Jatamundia		
	No. of birds	No. of nests	No. of eggs	No. of birds	No. of nests	No. of eggs	No. of birds	No. of nests	No. of eggs
05.ii.2018	7			2					
09.ii.2018	3			5					
12.ii.2018	8								
13.ii.2018	3			4					
17.ii.2018	4			5					
23.ii.2018	9	1	3						
24.ii.2018	2			5	2	2+3			
25.ii.2018	7	2	1+1						
26.ii.2018	5						6	1	3
27.ii.2018	5			6	1	3			

priority for the breeding success and survival of this bird. These sites were also documented as breeding sites for the Vulnerable Indian Skimmer (Debata et al. 2017). Therefore, these sites can be ideal for the conservation of these globally threatened species with adequate management interventions. Unfortunately, all these nesting sites are situated within high anthropogenic zones outside protected areas. The communities residing in nearby areas are primarily fishermen who rely on the river for year-round fishing activities. Sand mining is also a regular activity along the riverbed near the nesting sites during the summer season (Image 3). Apart from that, the nesting islands are also prone to flooding due to improper management of check gates at the barrage, which imposes a direct threat on the survival of the nests (Images 4a,b).

For the protection of the nesting sites and long-term conservation of the Black-bellied Tern, regular community awareness activities should be carried out to seek local support to minimize disturbances in the area during the breeding season. Coordination with the water resource department and the revenue department will be helpful in managing the water level and controlling sand mining activities, respectively, during the breeding season. Apart from that, in agreement with the recommendation given by Rahmani (2012), Rahmani & Nair (2012), and BirdLife International (2017), further targeted surveys, particularly during the breeding season, along the entire length of the Mahanadi River and other large rivers are essential to understanding the status of the Black-bellied Tern in Odisha. The results of these will be helpful in reassessing the global status of the species and formulating conservation plans for the future.

Image 1. An adult Black-bellied Tern in breeding plumage on an island in the Mahanadi River near Kakhadi in Odisha, eastern India

Image 2. Black-bellied Tern nest with eggs on an island in the Mahanadi River near Mundali in Odisha, eastern India

Image 3. A Black-bellied Tern incubating its eggs on an island in the Mahanadi River in Odisha, eastern India. Sand mining is a regular activity near these breeding and nesting sites at Mundali.

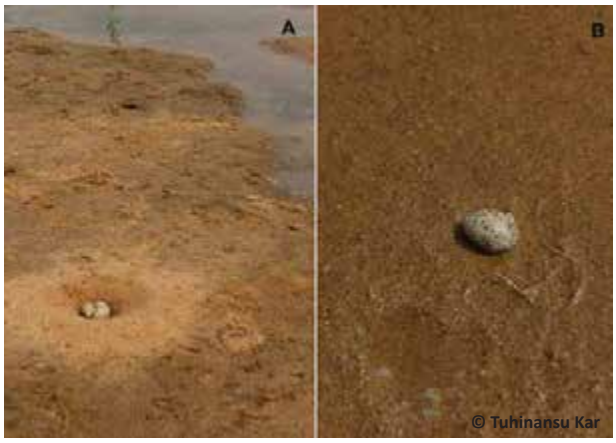

Image 4. Flooded nest (A) and egg (B) of the Black-bellied Tern due to the rise in water level along the Mahanadi River near Mundali in Odisha, eastern India

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A first record of the Redbelly Yellowtail Fusilier *Caesio cuning* (Bloch, 1791) (Teleostei: Caesionidae) from Visakhapatnam coastal waters, India

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Caesio cuning (Bloch 1791), commonly known as the Redbelly Yellowtail Fusilier, belongs to the family Caesionidae (order Perciformes) which contains 23 species and four genera. This species is a non-migratory reef associated fish and distributed in the Indo-West Pacific region, from Sri Lanka to Vanuatu and from southern Japan to northern Australia (Carpenter 1988; Froese & Pauly 2016). The species of Caesionidae are characterized by a slender, fusiform and elongated body, unique jaw morphology, and highly protrusible upper jaw with reduced dentition (Carpenter 1987). The genus *Caesio* contains six species throughout the world, *Caesio caerulaurea* (Lacepede, 1801), *C. cuning* (Bloch, 1791), *C. lunaris* (Cuvier, 1830), *C. teres* (Seale, 1906), *C. varilineata* (Carpenter, 1987), and *C. xanthonota* (Bleeker, 1853), and the former three species occur in Indian waters (Froese & Pauly 2016). From Indian waters Day (1958), Silas & Pillai (1982), Talwar & Kacker (1984), Padate et al. (2010), and Rao (2004) reported the occurrence of this species *Caesio cuning*; however, no occurrence of the genus *Caesio* has been reported from Visakhapatnam coastal waters, India. This paper reports the occurrence of *Caesio cuning* for the first time from the coastal waters of Visakhapatnam, Andhra Pradesh.

Material and Methods: A single specimen of *C. cuning* was collected from the Visakhapatnam coastal waters, India, on 22 June 2015. The material was fixed in 10% formalin and preserved in 70% ethanol. Identification was based on standard taxonomic keys of Carpenter (1987) and Froese & Pauly (2016). Counts and measurements were made according to Allen (1985). The specimen was deposited at the Department of Marine Living Resources, Andhra University (DMLRAU52/2015).

Results and Discussion

Genus *Caesio* Lacepecle, 1801
Caesio cuning (Bloch, 1791) (Image 1)
Telugu name: Dundava

Caesio Lacepede, 1801, pp. 85 (type species: *Caesio caerulaurea* Lacepede, 1801, by subsequent designation (Bleeker, 1876).

Body moderately deep, dorsal profile of head high, interorbital space strongly convex, profile of snout relatively short and pointed; mouth small, oblique; the lower jaw slightly projecting, the posterior end of maxilla reaching to above front edge of orbit. Preoperbital

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Table 1. Comparison of morphometric and meristic characters of *Caesio cuning*

	Dorsal	Anal	Pectoral	Ventral	Caudal	GR	Lateral line scales	Lateral transverse scales
Day 1875	X,15	III,11	20	I,5	17	-	-	-
Carptenter 1987	X,15	III,11	-	-	-	-	47-52	-
Rao 2004	X,15	III,11	18-19	I,5	-	-	45-51	-
Padate et al. 2010	X, 15	III,11	17	I,5	-z	-	48-51	-
Froese & Pauly 2016	X,14-16	III,10-12	17-20	I,5	-	35-40	45-51	7-9/15-18
Current specimen	X,15	III,12	17	I,5	17	-	54	8/16

Image 1. *Caesio cuning* (Bloch, 1791) 240mm, TL; Visakhapatnam coast, Andhra Pradesh, India

bone narrow and less than the eye diameter; eyes are relatively large in size. Villiform teeth in jaws; tongue without tooth; minute teeth in a triangular shaped patch of vomer and a narrow band on palatines. Preopercular flap slightly pointed. Head covered with ctenoid scales; originating from nape region and extending upto the base of the first dorsal spine. Transverse scale rows on cheek four.

Origin of dorsal and pelvic fin on the same line where as the origin of pectoral fin slightly anterior; dorsal fin continuous with ten spines and sixteen soft rays; fourth dorsal spine longest and succeeding spines decreasing length posteriorly. Dorsal fin rounded in shape slightly angular in shape posteriorly; anal fin with three spines; first anal spine shorter than second and second anal spine stouter and longer than third; pectoral pointed, it reaches up to the anterior margin of anus. Pelvic fin angular in shape; caudal fin forked. Body covered with ctenoid scales. Dorsal and anal fin with scaly sheath; lateral line runs parallel to dorsal profile; supra-temporal band of scales confluent at dorsal midline.

Upper body bluish superiorly yellow, lower sides and the belly portion reddish in colour; dorsal fin posteriorly yellow, pectoral fin rays pinkish, pelvic and anal fins reddish in color; axil of pectoral fin black; caudal fin yellowish and iris red.

Remarks: Cuvier (1830) reconciled the colour differences between *C. erythrogaster* and the figure of Bloch's *cuning* as due to Bloch's incomplete information of the original colour (Carpenter 1987). When compared with the original description of previous authors (Bloch, 1791 and Carpenter, 1987). The meristic, morphometric and colouration were well in agreement with the present specimen (Tables 1 and 2) except lateral line scales. According to Carpenter (1987), Rao (2004), Padate et al. (2010), and Froese & Pauly (2016) lateral line scales are 47–52; 45–51; 48–51 and 45–51 respectively where as in the present study the lateral line scales are observed to be 54 only.

Table 2. Morphometrics of *Caesio cuning* [DMLRAU52/2015] collected from Visakhapatnam, India

	C. cuning, n = 1
Percentage of standard length	
Total Length	136.6mm
Body depth	48.88
Head length	30.00
Pre dorsal distance	42.22
Pre pectoral distance	27.77
Pre pelvic distance	29.44
Pre anal distance	65.55
Dorsal fin base	58.33
Pectoral fin base	6.66
Anal fin base	45.00
Depth of caudal peduncle	11.11
1st Dorsal spine height	5.00
2nd Dorsal spine height	12.77
3rd Dorsal spine height	16.11
1st dorsal ray length	11.66
2nd dorsal ray length	12.22
1st anal spine height	2.77
2nd anal spine height	11.11
3rd anal spine height	9.44
1st soft anal ray length	10.00
4th soft anal ray length	8.33
Last soft anal ray length	13.00
Pectoral length	33.88
Pelvic spine height	11.66
Soft pelvic length	19.44
Body width	20.00
Head width	31.00
% of head length	
Head depth	65.00
Head width	57.40
Eye diameter	25.92
Pre orbital distance	14.81
Post orbital distance	51.85
Inter orbital distance	29.62
Upper jaw length	33.33
Lower jaw length	22.22
Maxillary width	11.11
Snout length	20.37

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NOTE

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A record after 92 years, and a first report of the moth *Mecodina metagrapta* Hampson, 1926 (Lepidoptera: Erebidae: Aganainae) from the Western Ghats' part of Maharashtra, India

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One single specimen of *Mecodina metagrapta* was collected from Lonavala by light trapping. The specimen was identified as per Hampson (1926). The placement of *Mecodina* in the family Erebidae and subfamily Aganainae in the present study is as per Zahiri (2012) and Kononenko & Pinratana (2013). The genus *Mecodina* was first described by Guenée in 1852 on the type species *M. lanceola* from Sylhet. Hampson (1895) in his third volume on Moths in the Fauna of British India mentioned 12 species of *Mecodina* i.e., *M. cineracea* (Butler, 1879), *M. analis* Swinhoe, 1890, *M. placida* (Moore, 1879), *M. umbrosa* (Hampson, 1891), *M. subviolacea* (Butler, 1881), *M. agrestis* (Swinhoe, 1890), *M. odontophora* Swinhoe, 1895, *M. albodentata* (Swinhoe, 1895), *M. hepatica* Moore, 1879, *M. oxydata* Swinhoe, 1895, *M. praecipua* (Walker, 1865), and *M. ruficeps* Hampson, 1895 from India. Later in 1926, Hampson described two species of this genus, i.e., *M. aequilinea* Hampson, 1926, and *M. metagrapta* Hampson, 1926 from India. After Hampson (1926), there is no record of this species and in his original literature he described this species from Belgaum, Karnataka. Thus, the present paper represents the rediscovery of this moth after a very long gap of 92 years and also reports the first record of this genus and species from Maharashtra.

Material and Methods

One female specimen was collected by the author in the northern Western Ghats at Lonavala Village, Pune District, Maharashtra, India using a light trap at night. The collected specimen was further processed in the laboratory and identified as per Hampson (1926). The specimen was studied under a Leica EZ 4 E stereozoom microscope and the images were processed with Adobe Photoshop CS Version 8. The identified specimen was labeled, registered and deposited at National Zoological Collection, Zoological Survey of India, Western Regional Centre, Pune, Maharashtra, India (ZSI-WRC). The terminology used for describing morphological features is as per Hampson (1926). The distributional records have been verified from Hampson (1895, 1926). The standard procedure given by Robinson (1976) and Zimmerman (1978) are followed to study the genitalia. The survey locality is given under material examined and also shown in Fig. 1. The map of the survey locality was prepared using the open-free access QGIS software.

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Results and Discussion

Superfamily Noctuoidea Latreille, 1809
Family Erebidae Leach, [1815]
Subfamily Aganainae Boisduval, 1833
Genus *Mecodina* Guenée, 1852
Mecodina metagrapta Hampson, 1926
Descr. Gen. Spec. Noctuinae : 491.

Material examined: ZSI-WRC-L-1808, 23.viii.2017, 01 female, Lonavala, Pune, coll. A.S. Kalawate & party (18.61^{0}N & 73.41^{0}E, elevation 780m).

Description: (Image 1 A) Body reddish-brown tinged with grey; palpi darker red-brown. Fore wing reddish-brown tinged with grey; a slight brown subbasal line from costa to submedian fold; waved brown antemedial line; small whitish discoidal reniform lunule surrounded by dark brown band, with an oblique brown bar from costa; an indistinct waved brown postmedial line, curved outward to vein 4, then curved inward; a dark brown patch from postmedial part of costa to vein 6; a series of dark brown points and fine white line at base of cilia.

Image 1. *M. metagrapta* A-B - habitus; A - dorsal view, B - ventral view, C - female genitalia. © Aparna S. Kalawate

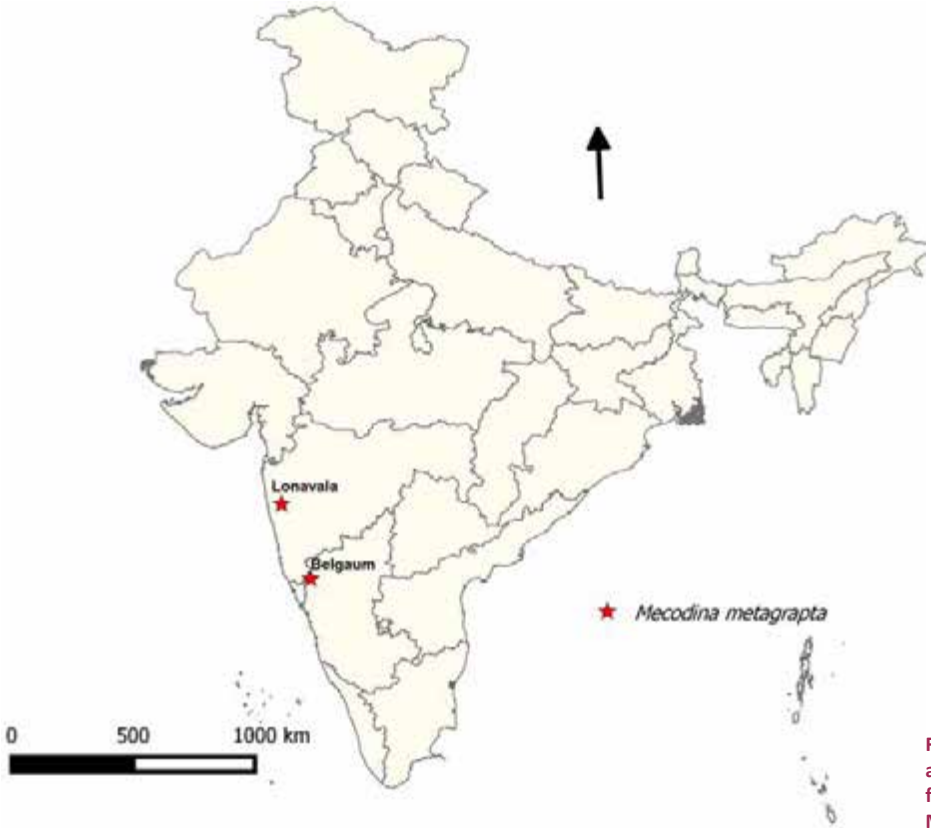

Figure 1. New collection locality and first record of *M. metagrapta* from the Western Ghats' part of Maharashtra.

Hind wing reddish-brown tinged with grey; faint brown medial line and of a postmedial line curved outward to vein 4; a faint whitish subterminal line, curved outward to vein 2, with dark blackish-brown bar on its inner side; base of cilia surrounded by a faint waved brown terminal line and a prominent whitish line. Underside (Image 1B) brown some places tinged with white; whitish discoidal reniform lunule and brown postmedial line on both wings.

Fore wing length: 28mm.

Female genitalia: (Image 1C) Ductus slightly funnel shaped, unsclerotised; corpus bursae elongate, membranous; apophyses longer.

Known distribution until this study: India (Belgaum) (Hampson 1926), Bali, Singapore (Hampson 1926), Java, Sulawesi (Holloway 2005).

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A new record of the Malay Cardamom *Amomum aculeatum* Roxb. (Zingiberaceae) for mainland India

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Zingiberaceae, with 53 genera and 1,377 species (Kong et al. 2010) is widely distributed in tropical areas. *Amomum* Roxb., the second largest genus of the family with ca. 150 species has its distribution along tropical Asia to Australia (Mabberley 2008). In India, the members of the genus are mainly restricted to northeastern India, peninsular India, and the Andaman & Nicobar Islands (Thomas & Sabu 2012). Hooker (1894) listed 48 species in the Flora of British India. Thomas et al. (2010) reported ca. 22 species from India. Sabu (2006) reported six species for southern India. Recent exploration by V.P. Thomas (2009–2018), M. Sabu (1990–2018) and V.S. Hareesh VS (2013–2018) has added 11 species and one variety to Indian flora, which takes the total count to 33 species and one variety of *Amomum* in India.

During a recent floristic exploration along the Western Ghats of Karnataka, the first author collected specimens belonging to the genus *Amomum* Roxb. After critical study and scrutiny of literature and herbarium materials, the collected specimen was identified as *Amomum aculeatum*. The species was first described by Roxburgh in 1810 from the Malay Archipelago. Later, Kurz collected the species in 1866 from the South Andaman Islands during his voyages to Southeast Asia. In recent times N.G. Nair recollected the species in 1976 from the South Andaman Islands and N. Bhargava from the Little Andaman Islands (Balakrishnan & Nair 1979; Pandey & Diwakar 2008). Hence, the present collection of the species from Pushpagiri Wildlife Sanctuary, Kodagu, Karnataka (12.633^{0}N & 75.654^{0}E); stands as a new record of this species in the wild for mainland India (southern Western Ghats) (Fig. 1). A brief description and photographs along with distribution are provided here.

Amomum aculeatum
(Image 1)

Roxb. in Asiat. Res. 11: 344, t.6.1810 & Fl. Ind., Carey & Wall. Ed. 1: 40. 1820; Baker in Hook. f., Fl. Brit. India 6: 243. 1892; Holtt. in Gard. Bull. Sing. 13: 212. 1950; Baker & Bakh. f., Fl. Java 3: 54. 1968; N.P. Balakr. & N.G. Nair in J. Bombay Nat. Hist. Soc. 76: 196. 1979; Vasudeva Rao in J. Econ. Taxon Bot. 8: 151. 1986; Karthik. & al. Fl. Ind. Enum. Monocot. 290. 1989. *A. aculeatum* var. *gymnocarpum* Valeton in Nova Guinea 8: 926. 1913. *A. aculeatum* var. *macrocarpum* Valeton in Nova Guinea 8: 927. 1913. *A. aurantiacum* Ridl. in J. Fed. Malay States Mus. 10: 153. 1920. *A. ciliatum* Blume in Enum. Pl. Javae 49. 1827. *A. flavum* Ridl. in J. Straits Branch Roy. Asiat. Soc. 32: 133. 1899.

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Competing interests: The authors declare no competing interests.

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Herbs, 2.5-3.5 m high; rhizome branched, yellowish-brown within; pseudo-stems 2.5–3.5 cm thick, reddish at base. Leaves distichous, 40–60 x 7–12 cm, elliptic or lanceolate, cuneate at base, acuminate at apex, glabrous; petioles short; ligules ca. 1cm long, bifid. Inflorescence many; peduncles 12–22 cm long; sterile bracts 4–5 x 2.5–3.5 cm, spirally arranged, ovate, cuspidate, red; spikes 7.5 x 4–7 cm, oblong; floral bracts 4.5–5.5 x 2–2.5 cm, ovate, slightly notched at apex, reddish-purple; bracteolate 1.2–1.4 cm long, tubular, pinkish-purple; pedicels 2–3 x 4–5 mm. Calyx 2.5–3 cm long, tabular, 3-keeled, puberulous on keels towards apex, red; limb bilobed, ca. 5mm long, ovate. Corolla 4.1–4.6 cm long, trilobed, white; lateral lobes 2.5–2.8 x 1–1.2 cm, elliptic-oblong, obtuse to subacute; median lobe 2.5–3 x 2.5–3 cm, obovate, obtuse, boat shaped. Labellum 3.5–4 x 3.8–4.2 cm, wedge-shaped, undulate-crispate at margin, white with thick yellow red-striated median band, trilobed at apex; lateral lobes ca. 1.5 x 2 cm, rounded, hyaline; median lobe 6–8 x 8–10 mm, triangular, obtuse, subacute, sometimes bilobed, hyaline, white with two thick yellow spots at middle. Staminodes 2, 4–5 mm long, linear-subulate, attached at the base of lip. Anthers 1–1.3 x 0.5–0.6 cm, puberulous; crest 0.5–0.6 x 1.5–1.7 cm, trilobed, white; lateral lobes orbicular; median lobe truncate, rounded or irregularly crenate at apex; filament 1.2–1.4 x 0.3–0.4 cm, linear, flat, glabrous. Ovary 0.4–0.5 x 0.3–0.4 cm, puberulous, pink; ovules numerous; style 4.2–4.5 cm long, puberulous; stigma 0.1 x 0.2 cm, cup-shaped, dorso-ventrally compressed, puberulous. Stylodes 2–3 mm long, fleshy, cream colored, many lobed.

Flowering & Fruiting: April–June.

Habitat: Primary forests at an elevation up to 800m.

Distribution: India [Andaman Is. (Kurz, Nair, Bhargava) and Karnataka (present study)], Myanmar, Thailand, Vietnam, Malaysia, Indonesia and, New Guinea.

Specimens examined: (K, CAL), s.n., 23.ix.1867, India,

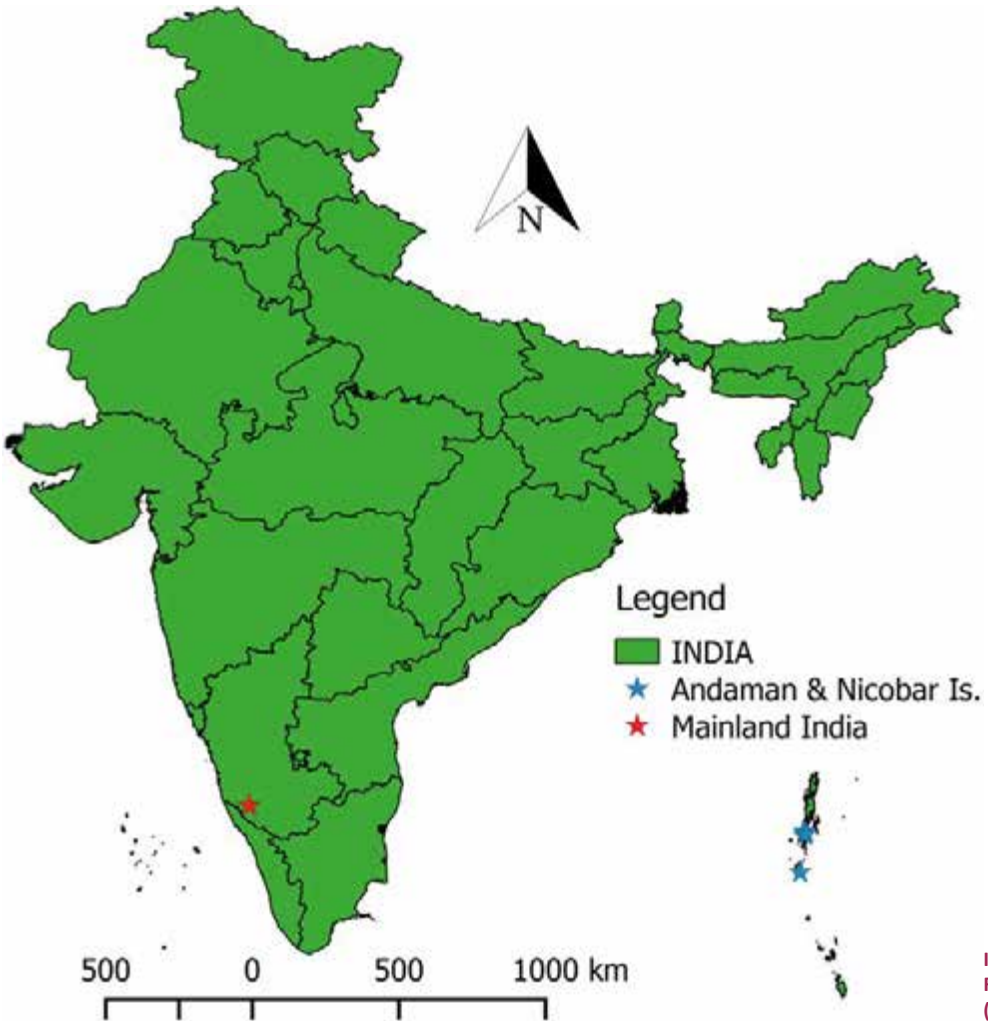

Image 1. *Amomum aculeatum* Roxb.: distribution map (georeferenced)

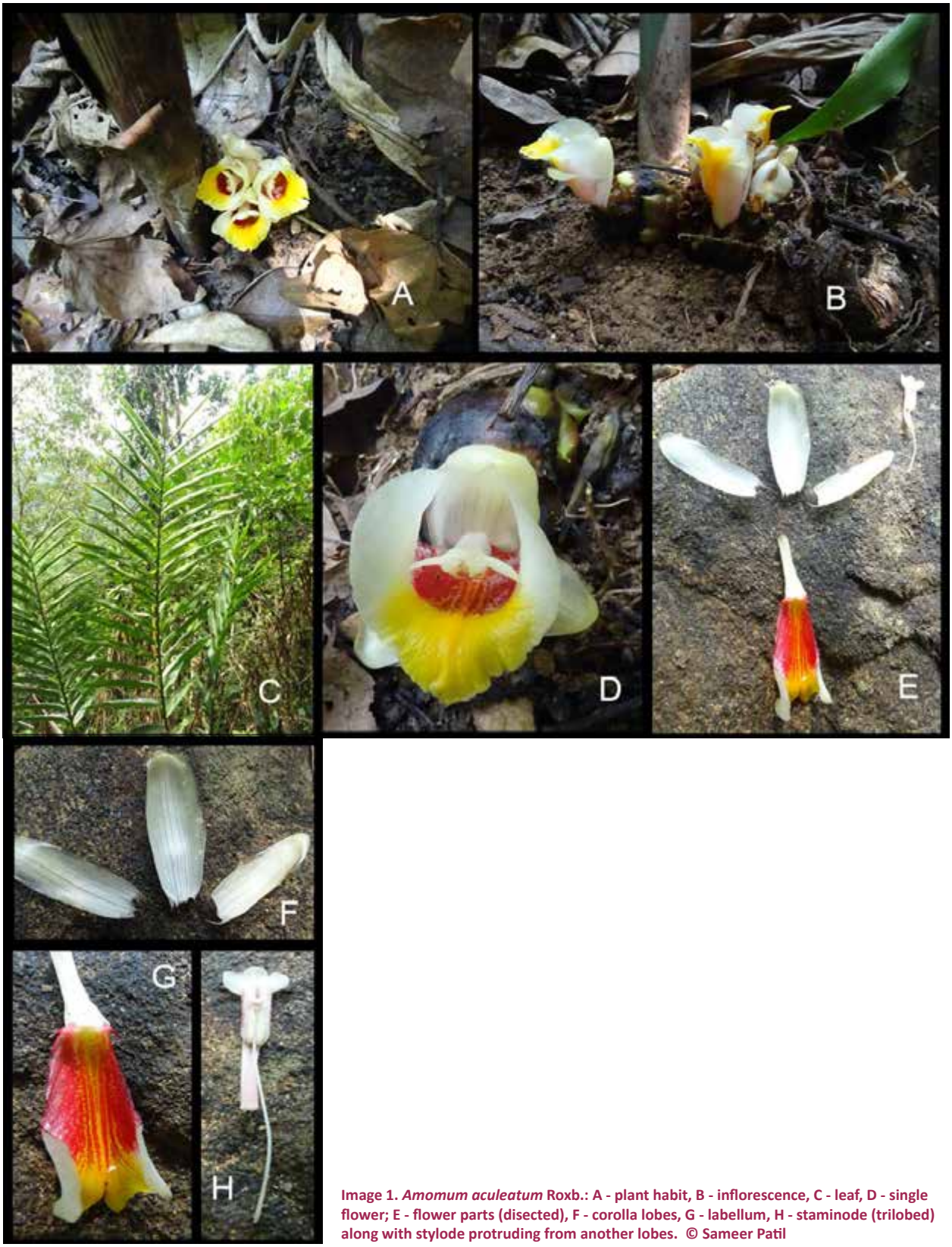

Image 1. ***Amomum aculeatum*** **Roxb.: A - plant habit, B - inflorescence, C - leaf, D - single flower; E - flower parts (disected), F - corolla lobes, G - labellum, H - staminode (trilobed) along with stylode protruding from another lobes. © Sameer Patil**

Andaman & Nicobar Islands, South Andaman Island, coll. S. Kurz; 119, 06.iii.1903, Andamans, C.G. Rogers (CAL); 3751, 15.v.1976, Ferrargunj, N.G. Nair (CAL) & 3752, 15.v.1976, Ferrargunj, N.G. Nair (CAL, PBL); 4133, 14.viii.1976, way to forest nursery, Little Andaman, N. Bhargava (PBL); 206709, 04.iv.2017, towards waterhole Marigundi, Pushpagiri Wildlife Sanctuary, Kodagu, Karnataka, 12.633^{0}N & 75.654^{0}E, c. 270m, coll. Sameer Patil (BSI - Botanical Survey of India, Western Regional Centre, Pune).

Notes: The Andaman aborigines use plants of *A. aculeatum* for tranquilizing the giant rock bees *Apis dorsata* and harvest honey from their hives without protective apparels, while the bees remain docile.

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New distribution records of the leopard plants *Ligularia amplexicaulis* DC. and *Ligularia sibirica* (L.) Cass. (Asteraceae) in the Indian Himalaya

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Asteraceae (Compositae) is a large family in the order Asterales, consisting of about 32,913 species belonging to 1,911 genera distributed worldwide (TPL 2013) and 999 species under 193 genera reported from India (Karthikeyan et al. 2009). According to Mabberley (2008), the genus *Ligularia* Cass. (Tribe: Senecioneae) is represented by 125 species in temperate Eurasia (China mostly). Generally well-known as a rhizomatous perennial herb, this genus has great medicinal value because of the presence of eremophilane sesquiterpenoids, which has cytotoxic properties (Xie et al. 2010). Most of the species under this genus are reported to have antibiotic, antiphlogistic, and antitumor properties, and have been used as folk medicine to treat asthma, bronchitis, hemoptysis, and tuberculosis (Wu et al. 2016).

In India, 18 species, one subspecies, and three varieties (Karthikeyan et al. 2009) are currently recognized under the genus *Ligularia.* These taxa are distinguished by several morphological characteristics such as rootlet shape, leaf shape, inflorescence type, capitula type, ray floret, pappus, and achene size (Nordenstam & Illarionova 2005; Flora of China Editorial Committee 2011).

During extensive field surveys for biodiversity inventory in Jammu & Kashmir State located in the northern-most part of Indian Himalaya, the author collected and came across specimens of two interesting perennial taxa that were characterized by having aromatic roots, irregularly toothed orbicular to cordate leaves, radiate capitula, and pale brown achene with hairy pappus. After examining the various flora, comparing drawing/illustration (http://www.plantillustrations.org) and vouchers housed in various herbaria (RRLH - Regional Research Laboratory Herbarium, Jammu; DD - Herbarium of the Forest Research Institute, Dehradun; JU - Herbarium of Jammu University, Jammu; CAL - Central National Herbarium, Howrah), and consulting relevant published literature (Hooker 1875, Sharma & Kachroo 1981–1983, Dhar & Kachroo 1983, Kachroo et al. 1997), the specimens were identified as *Ligularia amplexicaulis* DC. and *L. sibirica* (L.) Cass. The studies also include the critical examination of the habit, habitat, community structure, vegetation composition, associated allied taxa, dissection of flower parts, and taxonomic key of

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Competing interests: The authors declare no competing interests.

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both the species. Scrutiny of the literature reveals that *L. sibirica* and *L. amplexicaulis* have not been reported from Bandipora District of the Kashmir Himalaya.

Ligularia amplexicaulis described is a new record for the district of Bandipora of the Kashmir Himalaya. This species was previously recorded between the altitudinal range of 2,700m and 4,800m from Himachal Pradesh, West Bengal and Sikkim in India. *Ligularia sibirica* is reported in this study for the first time from the Kashmir Himalaya; this extends its recorded distribution in and around the southeastern Asian regions. The specimens from Bandipora extend the known *L. amplexicaulis* distribution from Paddar Valley of district Kishtwar to the extreme northern range of the western Himalaya and the specimens from Lidder Valley represent the first record of *L. sibirica* from the Kashmir Himalaya and extend its distribution range from Europe, Russia, and China to northern India.

The study area is located in the northern-most part of the Indian Himalaya along the upper reaches of the Kishanganga River, where temperate coniferous forests represent the most common landscape (Fig. 1). Meher-Homji (1971) classified the climate of the Kashmir Himalaya as Mediterranean type. The mean temperature in summer of the study area ranges from 14°C to 25°C and fluctuates in winter from minus –20°C to 6°C. The average annual temperature recorded was 13°C and the average annual rainfall was 650mm. January is the coldest month with the temperature much below the freezing point and maximum humidity, which ranged between 85% and 90%.

Plant materials were collected in August 2015 from the hilltop of the Bandipora District around the Razdhan Pass (34.553^{0}N & 74.641'^{0}E, elevation 3,492m). Techniques for collecting plants included square quadrat method of sampling herbs by 1x1 m size. The specimens were collected and processed as per herbarium techniques (Jain & Rao 1977).

The present communication deals with the taxonomic description, phenology, habitat and ecology, associated vegetation composition, distribution, and species discovery history of *L. sibirica* and *L. amplexicaulis*. The

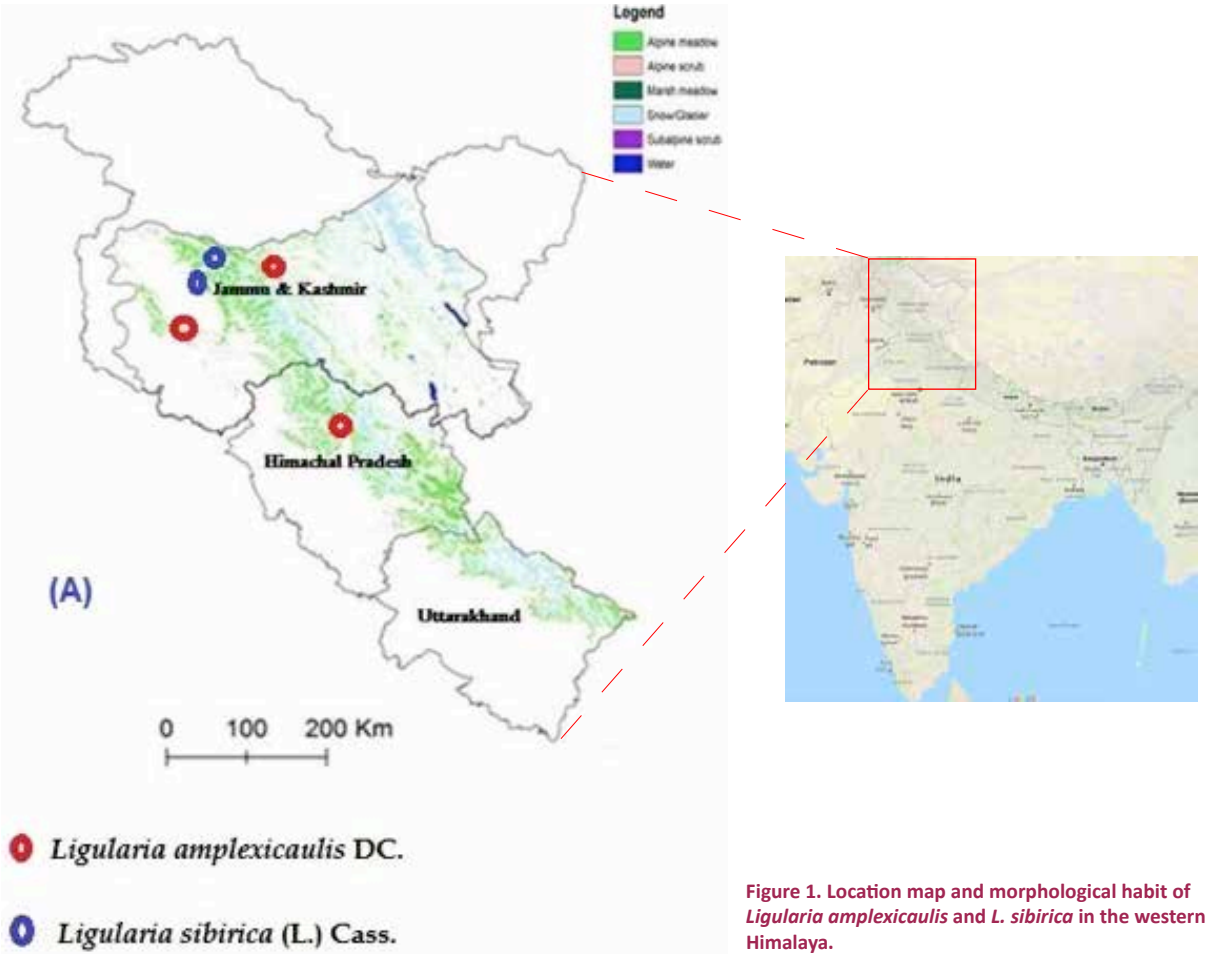

Figure 1. Location map and morphological habit of *Ligularia amplexicaulis* and *L. sibirica* in the western Himalaya.

identified and authenticated materials were deposited at the Council of Scientific and Industrial Research, Janaki Ammal Herbarium (RRLH), CSIR-IIIM, Jammu (J&K State).

Enumeration

1. *Ligularia amplexicaulis* DC., Prodr. 6: 314. 1838 (1837); R. Mathur in Hajra et al., Fl. India 13: 229. 1995; Grierson & Spring. in Grierson & D.G. Long, Fl. Bhutan (Ed. Spring.) 2 (3): 1574. 2001; Karthik. et al., Flow. Pl. India Dicot. 1: 248. 2009. *Senecio amplexicaulis* (DC.) C.B.Clarke, Compos. Ind.: 204. 1876 non Kunth, 1820; Hook.f., Fl. Brit. India 3: 348. 1881. *Senecio yakla* C.B. Clarke, Compos. Ind.: 204. 1876; W.W. Sm., Rec. Bot. Surv. India 4 (7): 384. 1913.

Perennial herbs, robust, 30–70 cm tall; stems slightly erect, 2–5 m in diameter depending on habit, young ones light green, old dark brown, slightly grooved, glabrous at base, slightly pubescent near flowering inflorescence; rootstocks fibrous; fresh rhizomes aromatic. Leaves orbicular to reniform, 8–15x7–12 cm, base cordate, margins irregularly toothed, apex acute, glabrous on both the sides; sinus 1/3–1/4 or as long as leaf blades; veins raised, prominent, reticulate; petioles 8–20 cm long, slightly pubescent and interruptedly winged. Bracts leaf-like, ovate-lanceolate, 5–6x2–3 mm, margins entire, rarely dentate, connate below. Inflorescences radiate, corymbose, 3–8x0.6–1.7 cm; involucres campanulate, distantly pubescent; phyllaries 6–10 in rows, lanceolate, 5–7 mm long. Ray florets linear, 1–1.5 cm long; rays oblanceolate, 4–6 mm long, apex obtuse; tubes 4–8 mm long. Disc florets numerous, 4–7 mm long; limb 1–3 mm long, 5-lobed; tube 3–4 mm long. Achenes slightly pale brown, oblong, minute, 1–2 mm long, slightly ribbed. Pappus pale brown, 5–6 mm long, pubescent.

Phenology: The plant flowers between July and October. Fruiting starts in September and matured fruits can be seen till the end of October in Kashmir, Ladakh,

Image 1. Herbarium voucher and wild habit of *L. amplexicaulis*

and Himachal Pradesh.

Habitat and ecology: The plant prefers temperate meadows and rocky ledges. It grows well in open areas or sometimes along mountain slopes on forest margins at altitudes between 1,200m and 2,000m. Usually, flowers are hermaphrodite and insects are the main pollinators. Soils are characterized as sandy and loamy and plants prefer moist soil environment.

Associated taxa: Species of the genus *Ranunculus* L., *Fragaria* L., *Potentilla* L., *Nepeta* L., and *Caltha* L. and some subtropical and temperate grasses such as *Carex* L. and *Eragrostis* Wolf. were found growing along with *L. amplexicaulis* in the study area.

Distribution: Bhutan and India (Paddar Valley, Kishtwar and Razdhan Pass in Jammu & Kashmir, Uttar Pradesh, Sikkim, and West Bengal).

Specimen examined: 53138 (RRLH!), 26.viii.2015, India, western Himalaya, Jammu & Kashmir State, Bandipora District, Razdhan Pass, 34.553^{0}N & 74.641^{0}E', 3,492m, coll. B. Singh (Image 1).

Economic importance: Leaves are used as fodder for goats and sheep. Stems, leaves, and flowers are used in the Tibetan system of medicine to treat vomiting caused by indigestion.

2. *Ligularia sibirica* (L.) Cass. in F. Cuvier's Dict. Sci. Nat. Ed. 2.26: 402. 1823; M.A. Rau, High Alt. Fl. Pl. W. Himal.: 134. 1975; Karthik. et al., Flow. Pl. India Dicot. 1: 250. 2009. *Othonna sibirica* L., Sp. Pl. 2: 924. 1753. *Cineraria sibirica* (L.) L., Sp. Pl. Ed.2.: 1242. 1763. *Senecio ligularia* Hook.f., Fl. Brit. India 3: 349. 1881. *Ligularia fischeri sensu* R. Mathur in Hajra et al., Fl. India 13: 230. 1995, p.p. non (Ledeb.) Turcz. 1838.

Perennial herbs, 50–150 cm tall; stems erect, 3–8 mm in diameter at base, glabrous, yellowish brown, pubescent; rootstocks fibrous; rhizomes aromatic with minute root hairs. Leaves basal; petioles 14–39 cm long, glabrous, base sheathed; leaf blades ovate-cordate or broadly cordate, 3.5–32x4.5–29 cm, base cordate, margins regularly dentate, apex rounded or obtuse, glabrous; veins raised, prominent; sinus 1/3–1/4 as

Image 2. Wild habit and herbarium voucher of *L. sibirica*

long as leaf blade, basal lobes sub-orbicular; petioles of cauline leaves slightly pubescent when young, 3–14 cm long; sheaths enlarged, 3–6 cm long. Bracts leaf-like, ovate-lanceolate, 2–3x1–2 mm broad, margins entire or denticulate, herbaceous. Inflorescence racemose, 10–30 cm long; involucre purplish red, broadly campanulate or campanulate-turbinate, 0.7–1x0.6–1 cm, base rounded; phyllaries 7–12, in two rows, lanceolate or oblong, 0.7–1 cm long, margins membranous, apex acute. Ray florets numerous, usually 5–9, yellow; lamina oblanceolate or oblong, 1–2.2x0.3–0.5 cm, apex obtuse; tube 5–8 mm in diameter. Disc florets numerous, 0.6–1.2 cm long; tubes 4–5 mm in diameter. Achenes brown, cylindric, 4–6x2–3 mm. Pappus yellow, 4–8 mm long, pubescent.

Phenology: The flowering starts in May and can be seen till the first week of September. Fruits start appearing in the middle of September, usually maturing in October. Dried fruits attached with inflorescence can be noticed till November in temperate belts of the Himalaya.

Habitat and ecology: The plant prefers marshy habitat. It grows well in sparse temperate forests or along slope side of forest margins at altitudes of 1800–3500 m. Single inflorescence arise at the tip of the plant and all flowers are usually hermaphrodite, i.e., both male and female organs are present on each flower. As observed in the field, insects are the main pollinators. Soils are characterized as sandy to loamy and the plant prefers moist soil environment.

Associated taxa: Species of the genus *Iris* L., *Ranunculus* L., *Aconitum* L., *Nepeta* L., *Primula* L., *Caltha* L., and some temperate grasses were found to be growing in the meadows along with *L. sibirica* in the western Himalaya.

Distribution: China, Tibet Province, Europe, India (Aru in Jammu & Kashmir State), Mongolia, Russia, and Siberia.

Specimen examined: 16241 (RRLH!), 29.vii.1977, India, western Himalaya, Jammu & Kashmir State, District Ladakh, Aru Valley, 34.554^{0}N & 74.641^{0}E, 2,400m, coll. B.M. Sharma. (Image 2)

Conclusion

The detailed field survey and morphological observations of Asteraceae and their taxa, comparison and matching with herbarium vouchers kept at RRLH, DD, JU & CAL, and consultation of literature proved that the recently collected species of *Ligularia* from the western Himalaya represent the centre of origin of the genus from the Himalaya. The study also provided new distribution records of *L. sibirica* and *L. amplexicaulis* for India and an extension of the distribution records of other globally known *Ligularia* species in the Indian Himalayan regions.

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National Biodiversity Authority

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Operational Guidelines to the State Biodiversity Boards for Processing of Applications for Access to Biological Resources received under section 7 of the Biological Diversity Act, 2002

Source: http://nbaindia.org/uploaded/pdf/Guidelines_for_Processing_ABSapplications_SBBs.pdf

Operational Guidelines to the State Biodiversity Boards for Processing of Applications for Access to Biological Resources received under section 7 of the Biological Diversity Act, 2002

1. Preamble and Scope

a) The objectives of the Biological Diversity Act (BD Act), 2002 are to provide for conservation of biological diversity, sustainable use of its components and fair and equitable sharing of the benefits arising out of the use of biological resources and associated knowledge. Under Section 7 of the BD Act, the State Biodiversity Board (SBB) is the competent authority for granting approvals to Indian citizens (other than NRIs)/ entities (body corporate, association or organization incorporated or registered in India under any law for the time being in force which has no non-Indian participation in its share capital or management) who give prior intimation to the SBB for obtaining biological resources for commercial utilisation or bio-survey and bio-utilisation for commercial utilisation.

b) The SBBs are also mandated to advise the State Government on matters relating to biological diversity. The operational guidelines in the following sections act as an aiding tool for SBBs in processing of access and benefit sharing (ABS) applications received by them under Section 7 of the BD Act.

c) The operational guidelines aim to ensure that the regulatory activities of SBBs are compliant with the provisions of the BD Act and the Biological Diversity Rules (BD Rules), 2004.

d) These guidelines provide clarity with respect to examination and processing of the applications submitted by the Indian citizens/ entities who fall under section 7 of the BD Act, in the Form prescribed in the relevant State Biodiversity Rules, seeking approval to access biological resources for specific purposes. The set of guidelines shall also provide a framework to ensure uniform procedure to be adopted by the SBBs in processing the applications.

2. Procedure for scrutiny of applications by the officer or person concerned:

2.1 Receipt of application

On receipt of the completed application form,

a) The officer or person concerned shall allot a reference number to the application.

b) See whether the requisite application fee has been received and if so arrange for depositing the same in the State Biodiversity Fund.

c) Generate a receipt for the application fee and forward the same to the applicant.

2.2 Status of the applicant

The officer or person concerned shall *prima facie* satisfy that the applicant is covered under Section 7 of the BD Act. This shall be done by examining the identity proof and address proof of the applicant furnished along with the Form. If the applicant is an entity (company / institution/ organization), the share holding pattern of the entity needs to be examined or a declaration on status of nationality/entity shall be obtained from the applicant. A copy of the format is appended as **Annex-01**.

Provided, if the applicant falls under Section 3(2) of the BD Act, he should apply to NBA in Form-I seeking approval to access the biological resources. Hence, the SBB shall return the application to the applicant with the intimation that the NBA is the competent authority to grant approval under Section 3 of the BD Act.

2.3 Screening of application

a) On receipt of the application, the officer or person concerned shall ensure that the applicant has filled in the respective columns appropriately and all the requisite documents (Address proof and identity proof of the applicant, authorisation letter for representative/ agents (if any), copies of board resolutions, declaration of nationality, etc.) are duly attached with the application form. If the application is complete in all respects and the requisite application fee has also been paid, then the application can be taken up for further processing.

Provided, if the application lacks vital information such as details of biological resources, geographical locations, purpose, without signature in the application, etc., the same may be returned to the applicant along with the fee.

b) If the application form is incomplete and needs certain minor details or clarification, the applicant may be addressed to provide the same by giving reasonable time. If there is no response, two reminders ought to be given after a gap of one month between the two reminders. In the event of non-response within the time limit specified or receipt of ambiguous replies, such applications may be treated as closed with the approval of the competent authority and the applicant informed accordingly without returning the application fee.

2.4 Purpose of access

a) The officer or person concerned shall verify whether the applicant has mentioned the exact purpose of accessing biological resources i.e, for commercial utilisation or for bio-survey and bio-utilisation for commercial utilisation.

b) It should be noted that no application should be entertained by SBBs if the purpose is for

- Research on a biological resource or associated knowledge.
- Obtaining Intellectual Property Rights for inventions based on any research or information on a biological resource obtained from India,
- Transfer of results of research related to biological resources occurring in, or obtained from India, to any non-Indian/ non-Indian entity, as defined u/s 3(2) of the BD Act
- Transfer of biological resource and/ or associated knowledge to any non-Indian/ non-Indian entity.

2.5 Biological resources

a) The officer or person concerned shall verify whether the biological resources to be accessed are clearly specified in the application along with common and scientific names, their parts and quantity.

b) The officer or person concerned shall also verify if the biological resource to be accessed is from wild (forest area) or cultivated or sourced from traders or communities or Joint Forest Management Committee. In case of any discrepancy or lack of information, the same shall be got clarified from the applicant.

2.6 Geographical location

a) The SBB is expected to entertain an application for access to biological resources only if the biological resources specified occur within the territorial jurisdiction of the State concerned. The officer or person concerned needs to verify the exact geographical location like name of the village, panchayat, block, taluk and district is within the State from where the particular biological resource is proposed to be accessed.

b) If the biological resource is proposed to be bought from a trader or from local market, institution or communities, etc. the officer or person concerned needs to verify that the complete details (Name, complete address, contact details, etc.) of such sources are also provided by the applicant. This is important while sharing benefits to the concerned.

c) In case a person other than the applicant is authorised for collecting the biological resources, the name and contact details of the person so authorised have to be verified. The authorisation letter in favour of the person so authorised, needs to be obtained. A format of authorization letter is appended as **Annex-02**

2.7 Quantity of biological resources

a) The officer or person concerned shall verify the exact quantity of biological resources and their parts proposed to be collected from each geographical location. This exercise may also involve a judicious assessment of the availability of some of the biological resources depending on their particular parts to be gathered in the light of sustainable harvesting.

b) The officer or person concerned shall verify whether the applicant furnished the proposed period / duration for collection of biological resources. If the applicant is proposed to collect the biological resources in different time interval, SBB may call for reasons/ justification for the same from the applicant.

c) If the applicant is intending to access of biological resources in a large quantity/ number of biological resources, SBB may call for reasons/ justification for the same from the applicant.

2.8 Threatened species

The officer or person concerned shall verify the threat (Rare, endangered and threatened) status of the biological resources sought to be accessed and evaluate whether obtaining the particular biological resources from their natural habitat is detrimental or contrary to the objectives of conservation and sustainable use of biodiversity. The officer or person concerned shall also check the relevant notifications related to the threat status of the species under question before processing the application further.

2.9 Exemptions under the BD Act

While examining the applications received for access to biological resources, the examiner shall note that certain activities, as indicated below are exempted from the purview of the BD Act:

a) Human genetic material is excluded from the definition of biological resources.

b) Indian citizens or entities accessing biological resources occurring in or obtained from India, for the purposes of research or bio-survey and bio-utilization for research in India;

[Explanatory note: Indian citizens or entities need to obtain prior approval of NBA when they intend to obtain IPR on the results of research related to accessed biological resources and/ or associated knowledge obtained from India.]

c) Accessing value added products, which are products containing portions or extracts of plants and animals in unrecognizable and physically inseparable form;

d) Accessing biological resources, normally traded as commodities as and when notified by the Central Government under section 40 of the BD Act. *(for the specific purposes as indicated in the Notification)*

[Explanatory note: As per MoEFCC notification dated 7th April, 2016 & 07th November, 2017, a list of 421 items of biological resources are exempted from the purview of the BD Act when normally traded as commodities. The products that are derived from these listed items and traded as a matter of common practice are also to be treated as NTACs. However, the provisions of the BD Act shall apply to these items if there is an intention to use them for any other purpose.]

e) The local peoples and communities of the area including growers and cultivators of biological resource and *vaids* and *hakims* who have been practicing indigenous medicines, except for obtaining intellectual property rights.

f) Accessing biological resources for conventional breeding or traditional practices in use in any agriculture, horticulture, poultry, dairy farming, animal husbandry or bee keeping, in India.

3. Consultation with Biodiversity Management Committees (BMCs)

a) In the event of accessing biological resources from wild or cultivated or from communities or traders, the SBB may consult the BMC, as outlined in the State-specific Rules. Wherever no BMC is constituted, the SBB may consult the respective local body.

Provided, if the biological resources are proposed to be collected from the ex-situ collection like ZSI, BSI, ICAR, CSIR, NBPGR, IARI institutes, etc., the process of consultation may be dispensed with.

[Explanatory note: The biological resources in the ex-situ collections are having no threat to conservation. Hence, the BMC consultation may be waived off.]

b) After consulting the BMC or the local body, the SBB may decide the application in consultation with the expert committee, wherever necessary.

4. Consultation with an Expert Committee

The SBB may form a committee having experts drawn from various fields for conclusive examination of the applications, determination of benefit sharing and advising the SBB on the techno-legal issues. The officer or person concerned may prepare an agenda on the application along with remarks of the SBB and place the same before the expert committee for its consideration. Nevertheless, the Board of

the SBB (Governing Body) is the competent authority to decide either to accept or reject the recommendations of the EC.

5. Determination of benefit sharing

a) With regard to the determination of benefit sharing, the SBB shall follow the broad principles outlined in the Guidelines on Access to Biological Resources and Associated Knowledge and Benefits Sharing Regulations, 2014.

b) When the biological resources are sourced from the jurisdiction of two or more BMCs, the total amount of the accrued benefits shall be shared among them in proportion as decided by the Governing body of SBB with due diligence.

c) When a particular biological resource is of high economic value, the benefit sharing may include an upfront payment as decided by the SBB on a case by case basis. The guidelines developed by the NBA for upfront payment (hosted in the NBA's website) may be followed (**Annex-03)**. This clause will not be applicable in case of commercial utilization, where ABS under regulation (3) and (4) are applicable.

d) In the event of IPR holder, who obtained approval from the NBA under Section 6 of the BD Act, applying to SBB for access to biological resources for commercial utilization, the SBB shall not fix benefit sharing as the applicant is already under obligation to NBA for sharing the benefits.

[Explanatory note: The person who falls under Section 3(2) or Section 7 needs to obtain prior approval of NBA before applying for IP rights in or outside India, as required under section 6 of the BD Act. Accordingly, if a person falls under section 7 applied to NBA seeking approval to obtain IP rights, the NBA while granting approval will fix benefit sharing on the commercial sale of the product using biological resources. Here, the approval granted by NBA is only to obtain IP rights from the Patent office. However, the applicant while accessing the biological resources for commercial production on the IP rights, he needs to obtain approval from the SBB. The above clause (d) explains that the SBB need not fix benefit sharing while granting approval to the applicant as the benefit sharing component has already been determined by the NBA.]

6. Grant of approval

a) The approval for accessing the biological resources shall be in the form of an agreement executed between the applicant and the competent authority of the SBB as per Regulation 2 (2) of the ABS Guidelines of 2014.

b) Upon approval of the Board, the SBB shall send a draft agreement to the applicant with a request to send two copies of the duly signed agreement (on a

non-judicial stamp paper of the value in vogue in the respective State) with witnesses' signatures to the SBB for execution. Once the Competent Authority of the SBB signed the agreement, one copy of the agreement shall be sent to the applicant which will be construed as the approval of SBB to the intimation of access to the biological resources for the purpose requested.

c) If a final decision is reached to the effect that no approval can be granted on an application, for any reason, such an application may be rejected, by recording he reasons for non-consideration of the application. However, the applicants shall be given an opportunity to be heard before such rejection.

7. Sharing of benefits and monitoring mechanism

a) SBBs may retain a share not exceeding 5% of the benefits realized towards administrative charges and the remaining 95% share of the benefits shall be passed on to the BMC concerned or to the benefit claimers, if identified.

b) Where benefit claimers are not identified, such funds shall be deposited in the State Biodiversity Fund and it may be applied to support conservation and sustainable use of biological resources and to promote livelihoods of the local people from where the biological resources are accessed as per sub- section (2) of section 32 of the BD Act.

c) SBB may obtain periodical reports from the applicant about the activities carried out on the accessed biological resources. After the Agreement is executed, proper monitoring of the commercialization shall be carried out by obtaining annual reports from the applicant which may contain the quantity of the biological resources accessed and the products developed, gross sales, etc. Annually a certificate of sales attested by a Chartered Accountant shall be obtained from the applicant.

d) Fees, if levied by the BMC for accessing or collecting any biological resources for commercial purposes from areas falling within its territorial jurisdiction shall be in addition to the benefit sharing payable to the SBB.

e) The SBB shall maintain a Register (both in hard and soft) of Benefit Sharing, wherein the details of the Application, approval granted, benefit sharing component fixed and received and the ultimate defraying of the amount realized shall be entered.

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