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Caption: Yellow Flax *Reinwardtia indica* from Chamba in Himachal Pradesh, India. Image by Sanjay Molur.

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ARTICLE

Cats, canines, and coexistence: dietary differentiation between the sympatric Snow Leopard and Grey Wolf in the western landscape of Nepal Himalaya

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Abstract: Understanding the dietary habits of sympatric apex carnivores advances our knowledge of ecological processes and aids their conservation. We compared the diets of the sympatric Snow Leopard *Panthera uncia* and Grey Wolf *Canis lupus* using standard micro-histological analyses of scats collected from the western complex of Nepal Himalaya. Our study revealed one of the highest recorded contributions of livestock to the diet of top predators (55% for Grey Wolf and 39% for Snow Leopard) and high dietary overlap (0.82) indicating potential exploitative or interference competition. Their diet composition, however, varied significantly based on their consumption of wild and domestic prey. Limitation in data precludes predicting direction and outcome of inter-specific interactions between these predators. Our findings suggest a high rate of negative interaction with humans in the region and plausibly retaliatory killings of these imperilled predators. To ensure the sustained survival of these two apex carnivores, conservation measures should enhance populations of their wild prey species while reducing livestock losses of the local community through preventive and mitigative interventions.

Keywords: *Canis lupus*, dietary pattern, dietary overlap, livestock, Naur, negative interaction, *Panthera uncia*, scat analysis, sympatry.

Nepali abstract: सार: एकै भौगोलिक क्षेत्रमा बस्ने खाद्य श्रृङ्खलामा शीर्ष स्थानमा रहेका मांसाहारीको आहारका बारेमा हाम्रो बुझाई राम्रो भएमा उनीहरुको पारिस्थितिकिय प्रक्रियाका बारेमा थप जानकारी हासिल गर्न सकिनेका साथै संरक्षणमा पनि टेवा पुग्दछ। हामीले नेपालको हिमाली भेगको पश्चिमी क्षेत्रबाट संकलित हिम चितुवा तथा ब्वाँसो को दिसाको माइक्रो-हिस्टोलोजिकल प्रविधिबाट विश्लेषण गरी यिनीहरुले खाने आहार प्रजातिको तुलना गरेका थियौं। हाम्रो अध्ययनबाट यी वन्यजन्तुले खाने आहारामा घरपालुवा जनावरहरुको हिस्सा धेरै मात्रामा रहेको (ब्वाँसो र हिम चितुवाका लागि क्रमश: ५५% र ३९%) तथा खाने आहार प्रजाति एकैखाले सुचकाङ्क ठूलो (०.८२) देखिएको छ जसबाट शोषणकारी वा हस्तक्षेपकारी प्रतिस्पर्धा हुने संकेत देखिन्छ। तथापी, यिनीहरुबीच आहार संरचनाको आधारमा घरेलु वा जंगली जनावरको सिकार गरी खाने तथ्याङ्कमा निकै नै फरक रहेको पाइयो। तथ्याङ्कको सीमितताले गर्दा यी वन्यजन्तुबीचको पारस्परिक अन्तरक्रियाको दिशा तथा परिणामको पूर्वानुमान गर्न मुश्किल पर्ने देखिन्छ। हाम्रो अध्ययनले उक्त क्षेत्रमा मानवसँग यी जनावरहरुको नकारात्मक अन्तरक्रियाको दर उच्च रहन सक्ने तथा यी दुर्लभ जनावरहरु सिकारीको प्रतिसोधमा मारिने पक्का-पक्की देखिन्छ। यी दुई शीर्ष मांसाहारी वन्यजन्तुको दिगो अस्तित्व सुनिश्चित गर्नका लागि संरक्षणका विभिन्न उपायहरु मार्फत यिनीहरुको संख्या बढाउनुका साथ-साथै स्थानीय समुदायको पशुधन हानी कम गर्ने रोकथाम तथा न्यूनीकरणका कार्यक्रमहरु अघि सार्नपर्ने आवश्यकता देखिन्छ।

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INTRODUCTION

Dietary habits of sympatric apex carnivores advance our understanding on ecological processes and regulation of the ecosystem functions, aiding their conservation (Macdonald 1983). In Nepal Himalaya, inter-specific interactions between apex predators have consequences for predator-prey relationships, habitat, and the entire ecosystem; this can also have a spillover effect on their relation to humans, through livestock depredation and retaliatory killing (Chetri et al. 2017). Information on dietary overlap and interactions of sympatric carnivores, however, is limited in these mountainous landscapes and nonexistent from the western complex of Nepal Himalaya.

With this background, we studied the dietary habits of the Snow Leopard *Panthera uncia* and Grey Wolf *Canis lupus* (hereafter referred to as 'Wolf') which live sympatrically in the western complex of Nepal Himalaya. Snow Leopards are twice the body size of Wolves (Jnawali et al. 2011) and are solitary hunters with a stalking ambush hunting behaviour (Jackson & Hunter 1996). In contrast, Wolves are coordinating cursorial pack-hunters (Viripaev & Vorobiev 1983).

We specifically investigated (a) the dietary pattern and relative importance of prey types for the sympatric Snow Leopard and Wolf, and (b) their dietary overlap in the western complex of Nepal Himalaya.

MATERIALS AND METHODS

Study area

Our study was carried out in the western landscape of Nepal Himalaya (83.281–28.493 in the east to 80.586–29.542 in the west) across the potential habitat of the Snow Leopard and the Wolf (Fig. 1). This covers an area of over 38,312km^2 with an altitude range of 3,000–5,500 m. Of the total study area, barren area (22%) is the most dominant land cover, followed by rugged and broken snow-capped mountains and glaciers (17%), alpine rolling grasslands (17%), and agriculture and settlement (12%) (ICIMOD 2010). The total potential habitat within the western landscape covers an area of 11,261km^2. The western landscape is one of three priority landscapes identified by The Global Snow Leopard and Ecosystem Protection Program (GLSLEP) (DNPWC 2017).

Wild prey species recorded in the study area included Bharal/ Blue Sheep/ Naur *Pseudois nayaur*, Himalayan Tahr *Hemitragus jemlahicus*, Kiang *Equus kiang*, Tibetan Argali *Ovis ammon*, Alpine Musk Deer *Moschus chrysogaster*, Tibetan Gazelle *Procapra picticaudata,* pika *Ochotona* spp., marmot *Marmota* spp., and Woolly Hare *Lepus oiostolus*.

With pastoralism as the main occupation of the local community, this region harbours a high density of livestock (73 head per km^2), including domestic yak *Bos grunniens*, cow *Bos* spp. and hybrid, horse *Equus ferus caballus*, goat *Capra hircus*, sheep *Ovis aries*, and pig *Sus scrofa domesticus* (CBS 2011).

Scat survey

We systematically collected putative Snow Leopard and Wolf scat samples from each of the 56 grids measuring 16km^2 (4km x 4km; effective sample area ~896km^2; Fig. 1) spread across 11,261km^2 following standard protocol (Thapa 2007) during the late spring season (April–May) in 2014. Within each grid, at least two transects (0.4–2.8 km) were laid 1.0–1.5 km apart (Jackson & Hunter 1996) and surveyed. Upon encounter of fresh scat samples, a few grams were collected and stored in 15ml tubes containing silica desiccant for micro-histological studies; the remaining scat was left in the field to avoid disturbing the regular movements and territorial marking of the predators (Lovari et al. 2009). All putative scat samples (n=265) were screened for species identification through molecular scatology (Kelly et al. 2012).

DNA extraction

DNA was extracted from scat samples using commercially available DNA stool kit (QIAGEN Inc.) following manufacturer instructions. We kept one negative control (water) in each batch of samples to monitor contamination during DNA extraction.

Species identification

All the samples were screened for PCR-based species identification using mitochondrial DNA (mtDNA) cytochrome-b segment Snow Leopard-specific primers (Janecka et al. 2008, 2011). All Snow Leopard-negative samples were further screened using D-Loop section of mtDNA (MIT forward/ reverse) with Wolf specific primers (Parra et al. 2008; Pilot et al. 2010). All PCR reactions for both Snow Leopard and Wolf were performed in duplicate for confirmation. Similar results in duplicate PCR runs were considered (Snow Leopard/ Wolf) positive samples. Non-conformity and/or discrepancy in two PCR runs were verified with a third run for confirmation.

Diet analysis

Species-positive scat samples for Snow Leopard and

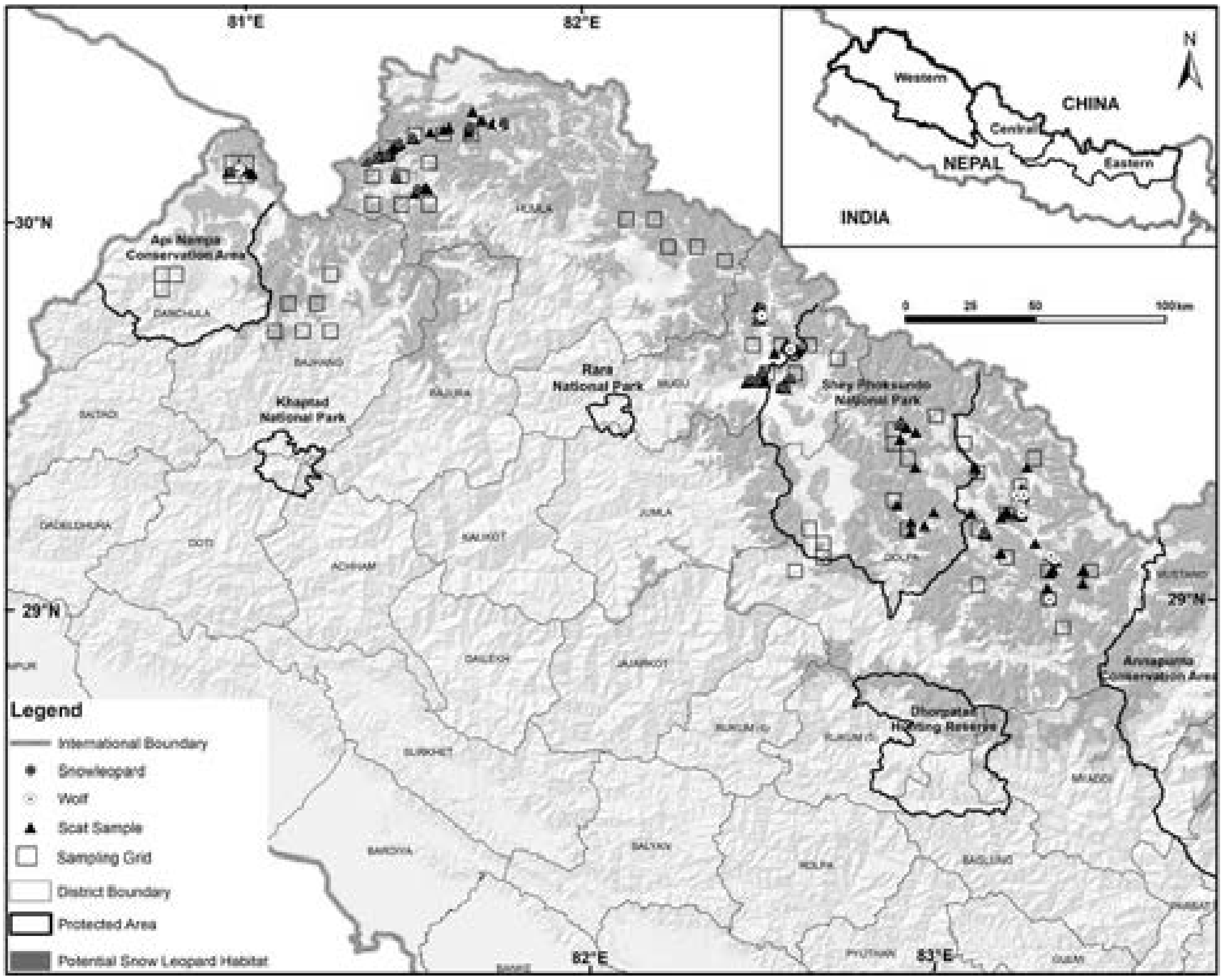

Figure 1. Study area and spatial location of sampling grids (n=56; 4km x 4km) covering an area of 896km² for opportunistic survey of scat samples and locations of Snow Leopard and Grey Wolf positive samples across the potential habitat in the western landscape of Nepal Himalaya.

Wolf were analyzed using a standard micro-histological study method (Oli et al. 1993; Devkota et al. 2013). Prey species were identified by comparing hair samples collected from these species-positive scat samples with reference to hair samples of all potential prey species (Oli et al.1994; Wegge et al. 2012).

We calculated and compared relative frequencies of occurrence of each prey species:

$$\left[\left(\frac{\text{No. of occurrences of each food item when present}}{\text{Total no. of occurrences of all food items}}\right) \times 100\right]$$

(Lucherini & Crema 1995) for all mammalian prey items, which were identified to species level. To investigate the relative importance of prey type, we used χ^2 analysis to compare differences in frequencies of occurrence of prey items between the diet of the Snow Leopard and Wolf in terms of wild versus domestic prey (Azevedo et al. 2006).

We also calculated Pianka's index to measure the dietary overlap between Snow Leopard and Wolf (Pianka & Pianka 1970):

$$DO = \frac{\sum PijPik}{\sqrt{\sum P^{\wedge}2ijP^{\wedge}2ik}}$$

where, DO is dietary overlap and P_{ij} and P_{ik} are the respective proportions of prey category i in the diet of the two predators 'j' and 'k'. The value ranges from zero to one, indicating no dietary overlap (DO=0) to complete overlap (DO=1), respectively.

RESULTS

Diet composition of carnivores

Of the 265 putative scat samples collected and genetically screened, 35 (13%) belonged to Snow Leopards and 24 (9%) to Wolves; the rest (78%) belonged to other species. Five wild prey species—Bharal, hare, pika, marmot, and Musk Deer—were identified in both Snow Leopard and Wolf scat samples. Of the domestic prey species identified, Snow Leopard scat was found to have goat, sheep, domestic yak, cow, dog, and horse, while Wolf scat had five of these, excluding horse. Spatial distribution of genetically screened scat samples as Snow Leopard, Wolf, and negative is shown in Fig. 1.

Snow Leopard diet

The Snow Leopard diet was dominated by wild prey comprising about 61%, followed by domestic livestock making up for 39% of the total identified species (Fig. 2). Bharal was the most significant prey of Snow Leopard, contributing 29%, followed by goat (21%), hare (15%), pika (5%), domestic yak (5%), domestic cow (4%), and others (Fig. 3). About 54% of the confirmed Snow Leopard scats comprised a single prey species, followed by 32% with two species and 14% with three species.

Wolf diet

Domestic livestock contributed more than half (55%) of the Wolf's diet while wild prey comprised only 45% (Fig. 2). Wolf diet was dominated by Bharal (28%), followed by domestic cow (15%), sheep (15%), goat (10%), dog (8%), domestic yak (8%), marmot (7%), and others (Fig. 3). About 46% of the confirmed Wolf scat comprised of a single prey species, followed by 29% comprising two species and 25% with three species.

Diet overlap between Snow Leopard and Wolf

High diet overlap (DO=0.82) was found between the sympatric Snow Leopard and Wolf. The diet composition (wild prey vs. domestic prey) of Snow Leopard and Wolf, however, varied significantly (X^2=5.13, d.f.=1, P<0.023).

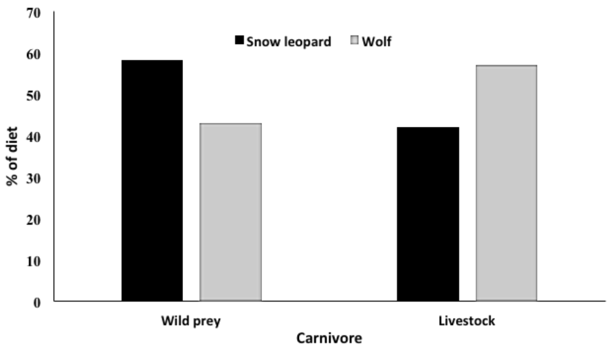

Figure 2. Diet comparison between Snow Leopard and Grey Wolf based on wild prey and livestock expressed as relative frequency of occurrence (%).

DISCUSSION

This appears to be the first study on Snow Leopard (Image 1) and Grey Wolf (Image 2) dietary pattern in western Nepal Himalaya applying standard micro-histological analysis of genetically confirmed scats. We compared our results specifically with similar studies that employed genetic screening to avoid biases (Weiskopf et al. 2016).

Our results showed that the diet of the Snow Leopard in the western landscape of Nepal Himalaya was dominated by wild herbivores (61%), with majority contributed by one principle prey species, i.e., Bharal, followed by livestock. This is consistent with the dietary

Figure 3. Prey species proportion in the diet of Snow Leopard and Grey Wolf expressed as relative frequency of occurrence (%).

Image 1. Snow Leopard *Panthera uncia*. © DNPWC/WWF Nepal.

Image 2. Grey Wolf *Canis lupus*. © DNPWC/WWF Nepal.

pattern of the Snow Leopard in the central landscape of Nepal Himalaya (Wegge et al. 2012; Aryal et al. 2014). Similar trends were also recorded in other Snow Leopard range states, except that the principal prey species was not Bharal (Jumabay-Uulu et al. 2014; Weiskopf et al. 2016). The proportion of livestock (39%) and small mammals (30%) in Snow Leopard diet, however, was found to be higher in the present study as compared to other similar studies (Shehzad et al. 2012; Lovari et al. 2013; Aryal et al. 2014; Jumabay-Uulu et al. 2014; Weiskopf et al. 2016; Chetri et al. 2017).

As a whole, more than half of the Wolf's diet (55%) was dominated by domestic livestock, but the single-most frequently encountered species was wild prey—Bharal (28%). Our findings confirm the preference of large prey by pack-living Wolves (Chetri et al. 2017) but differ in the proportion contributed to their diet by the cliff-dwelling primary wild prey, Bharal. Further detailed studies are needed to understand the underlying reason for this observation. As compared to other studies, the contributions of livestock to Wolf diet recorded here were among the highest (Jumabay-Uulu et al. 2014; Wang et al. 2014; Chetri et al. 2017). Interestingly, the contribution of wild prey and small mammals to Wolf diet was less in our study as compared to other studies (Jumabay-Uulu et al. 2014; Chetri et al. 2017). These findings may be an outcome of local circumstances; further research will be needed to verify the causes and effects of these findings.

Our study revealed a very high dietary overlap (0.82) between these sympatric predators. This differs significantly from a recent study carried out in the central landscape of Nepal Himalaya wherein a dietary overlap of 0.44 was recorded (Chetri et al. 2017).

High dietary overlap along with their dependence on one primary wild prey species, Bharal (contributing one-third of their diet), may warrant higher potential exploitative or interference competition between Snow Leopards and Wolves in the western landscape.

Interestingly, the finer scale dietary pattern showed a higher contribution of wild prey to the diet of Snow Leopard as compared to that of the Wolf; domestic livestock was dominant in the diet of the latter. The direction and outcome of the interaction between these two predators, however, are difficult to predict from our current study due to our limited sample size, restricted collection season (limited to spring), and lack of information on the population density of the prey species.

Nevertheless, in our study area, the relative contribution of livestock to the diet of both top predators (55% for Wolves and 39% for Snow Leopards) was higher as compared to other studies (Chetri et al. 2017). Further exploration would be necessary to establish if seasonality and local herding practices had a role in bringing this about.

Additionally, prime habitats of these species in the study area see very high anthropogenic activity in the form of Caterpillar Fungus *Ophiocordyceps* spp. ('yarsagumba') collection during the latter part of the scat collection season (April–May). This may also have had direct or indirect impacts on wild and domestic prey availability or accessibility, leading to greater livestock in the predator diet.

Increased dependence of both apex carnivores on livestock may lead to further escalation of human-carnivore negative interactions in the long run. This may trigger retaliatory killings of Snow Leopard and Wolf, as was reported from the region, thereby affecting the abundance of these predators in the region. Conservation measures focusing on preventive and mitigative measures that aid in securing people's livelihoods can potentially reduce retaliation against the predators. We recommend further detailed research on population trends of both predators and their principal prey species in the region to determine the degree of their interaction and ramification on livestock depredation in the area.

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Author contribution: KaT (Kamal Thapa), MD and GJT designed the study. KaT, AS and BPD contributed to the sample collection. BPD analyzed the hair samples. AS and KT analyzed the data and discussed the results. AS and KT wrote manuscript. SAS, MD, BPD, GJT, SS, SM and KaT participated in the manuscript editing.

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Genetic diversity among the endemic barb *Barbodes tumba* (Teleostei: Cyprinidae) populations from Mindanao, Philippines

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Abstract: *Barbodes tumba* is an important fishery resource in Lake Lanao and nearby areas in Mindanao, Philippines. It is one of only two remaining endemic cyprinids out of 20 endemic species originally reported in the lake. In this study, specimens were obtained from fishermen and fish vendors from the lake and from three other sites in Mindanao, namely, Nunungan Lake in Lanao del Norte, Dagoyanan Lake in Lanao del Sur, and Pulangi River in Bukidnon. Eighty-seven haplotypes were recovered from the 122 complete mitochondrial DNA control region sequences analysed. All four populations showed high levels of haplotype (0.662–0.976) and nucleotide (0.552–2.736 %) diversities. Pairwise F_{ST} values showed high genetic divergence between populations. Maximum likelihood tree and median-joining network showed geographic separation of Bukidnon population from the three other populations. Lanao Lake specimens also formed a distinct group, which clustered with nine specimens from Dagoyanan Lake. All the other specimens from Dagoyanan clustered with specimens from Nunungan Lake. Despite the high intra- and inter-population genetic variation found in the species, its populations need to be protected and managed so that it will not suffer the same fate as that of the other endemic cyprinids which are now reported to be extinct.

Keywords: Control region, cyprinid, Lanao Lake, mitochondrial D-loop, population genetics.

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Author contribution: OPA-L was responsible for collection of samples, laboratory work, data analysis, and preparation of the manuscript. JPQ was involved in designing the study, directing and supervising laboratory work and data analysis, and preparation of the manuscript.

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INTRODUCTION

Barbodes tumba is a popular food fish among the natives in communities living along Lake Lanao, the second largest lake in the Philippines. It is one of the two remaining endemic cyprinids of Lake Lanao. The other remaining endemic cyprinid is *B. lindog* (Ismail et al. 2014), which is now rarely caught from the lake and is believed to be on the brink extinction because of overfishing and introduction of non-native species in the lake. *Barbodes tumba* and *B. lindog* were described by Herre (1924) along with 11 other endemic cyprinids in the lake. Seven additional endemic cyprinid species were reported in the lake by Herre (1926, 1932), Fowler (1933), and Wood (1966). These Lanao endemic cyprinids have captured the attention of evolutionary biologists in the past because they were instrumental in the development of species flock concept in fishes and were cited as examples of explosive evolution (Myers 1960; Greenwood 1984; Kornfield & Carpenter 1984).

Barbodes tumba has been recorded in Lake Lanao in the different fish surveys reported by Villaluz (1966), Sanguila et al. (1975), Kornfield (1982), Escudero (1994), and Ismail et al. (2014). In 1996, the fish was classified as Vulnerable in the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (World Conservation Monitoring Centre 1996). Ismail et al. (2014) reported that the population of *B. tumba* in Agus River, the outlet of Lake Lanao, is stable, but the volume of fish caught from the lake in 2008 was only a small fraction (about 0.05%) of the volume recorded in 1990–1991. Ismail & Escudero (2011) assessed *B. tumba* as one of the threatened fishes of the world.

Brooks (1950), Herre (1924, 1953), and Kornfield & Carpenter (1984) reported that *B. tumba* was widely distributed in the Lanao plateau where Lanao Lake, Lake Dapao, Lake Uyaan, Lake Butig, Lake Nunungan and Sigawat River are located. Over the years, the population of *B. tumba* in Lake Lanao has seen a continuous decline. The fish is believed to be locally extinct in some of its original distribution and in Lake Dapao (Kornfield 1982) and Lake Uyaan according to locals living in communities surrounding the lakes.

Other than fish catch statistics from various market surveys, there are no published studies on life history, reproductive biology, and genetics of *B. tumba*. Population genetic studies are important to gather information on the levels of genetic diversity of the species that can be used for the management and conservation of extant populations of the species. This study aimed to determine intra- and inter-population genetic diversity of *B. tumba*. Specifically, this study aimed to characterize the genetic structure of the different populations of *B. tumba* in Lake Lanao, Dagoyanan Lake, Nunungan Lake and Pulangi River in Bukidnon, in the island of Mindanao, Philippines using the mitochondrial control region.

MATERIALS AND METHODS

Description of study areas

Thirty (30) to 32 specimens (Image 1) were obtained from fishermen and fish vendors from each of four sites in Mindanao, namely: (1) Lake Lanao; (2) Nunungan Lake; (3) Dagoyanan Lake; and, (4) Pulangi River in Bukidnon province (Fig. 1). Lake Lanao is located in the province of Lanao del Sur, Autonomous Region in Muslim Mindanao (ARMM) with a latitude of 8.000^{0}N, longitude of 124.288^{0}E, and elevation of 702m above sea level (Frey 1969). It is the second largest freshwater lake in the Philippines and covers an area of 35,250ha and has a maximum depth of 112m and a mean depth of 60.2m (Frey 1969). The lake has four large main river tributaries that are located in the municipalities of Ramain, Taraka, Gata, and Masiu; the only outlet of the lake is the Agus River which drains into Iligan Bay. Samples were collected near the source of Agus River in Marawi City. Lake Nunungan, also known as Gadongan, is located in Mount Inayawan Range, Nunungan, Lanao del Norte, Region X with a latitude of 7.819^{0}N, longitude of 123.950^{0}E, and elevation of 830m above sea level. The lake has a surface area of 153ha. The lake outlet drains into the municipalities of Sapad and Lala, Lanao del Norte and then into Panguil Bay. Lake Nunungan is about 6 hours of land travel from Lake Lanao in Marawi City, Lanao del Sur to Barangay Poblacion in the Municipality of Nunungan in Lanao del Norte (about 60km distance from Marawi City). From Barangay Poblacion, one has to walk for 30 minutes to reach lake Nunungan as the road is inaccessible to vehicles. An alternative route is to travel south from Marawi City to the Municipality of Ganasi in Lanao del Sur for 1 hour by land (a distance of about 47km) and then walk up a mountain (Mt. Inayawan) for 4 to 6 hours via the Municipality of Madamba to get to Lake Nunungan. Lake Dagoyanan, also known as Dagianan, is located in the forested area of the municipality of Madalum, Lanao del Sur. It is a small lake that has a surface area of about 3ha. From Marawi City, one can go to the Municipality of Madamba by land transportation for 30 minutes and

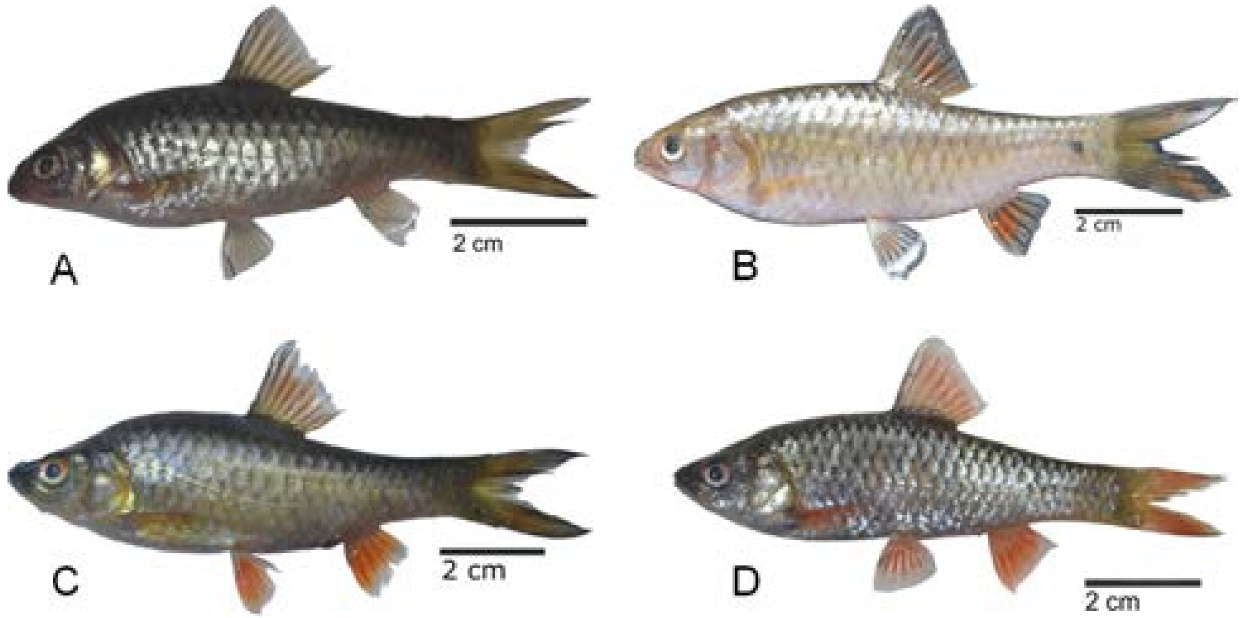

Image 1. Representative specimen from each of the four sites: A - Lake Lanao | B - Bukidnon | C - Dagoyanan Lake | D - Nunungan Lake.

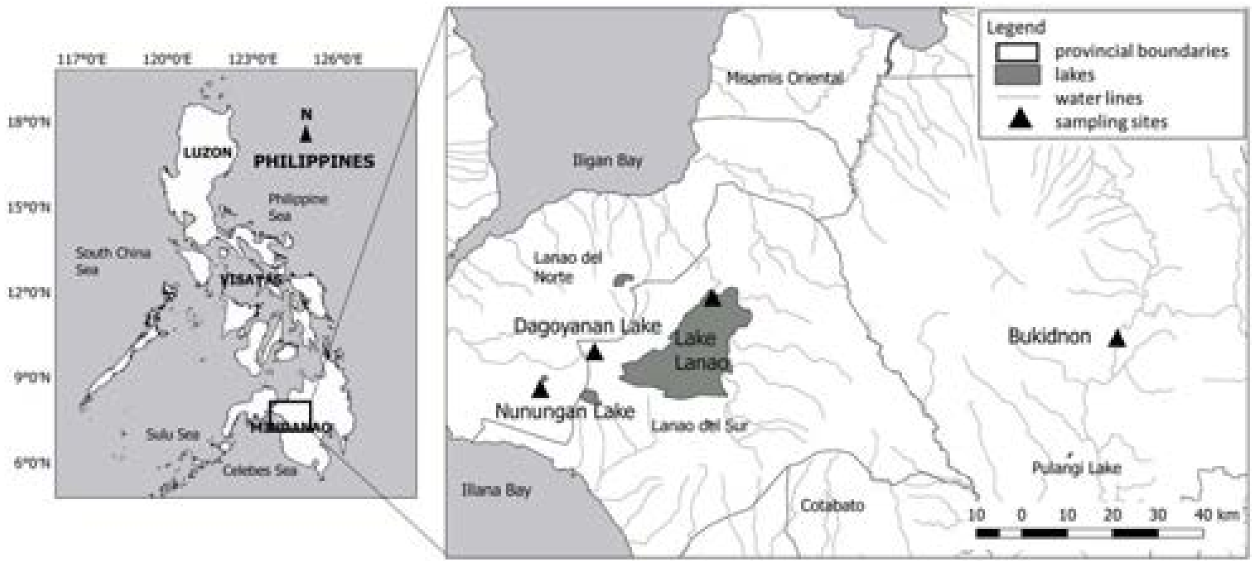

Figure 1. Location of sampling sites (shown in black triangles): Lake Lanao, Lanao del Sur; Dagoyanan Lake, Lanao del Sur; Nunungan Lake, Lanao del Norte; Pulangi River, Poblacion 1, Valencia City, Bukidnon.

then walk for another 30 minutes to Lake Dagoyanan (distance of 36km from Marawi City). The distance between Lake Dagoyanan to the nearest shore of Lake Lanao, which is located in the Municipality of Madalum, is only about 5–6 km. Lake Dagoyanan does not have any outlet. From Lake Dagoyanan, one can walk to the Municipality of Madamba for 30 minutes and then walk up Mt. Inayawan for 4–6 hours to get to Lake Nunungan. On the other hand, Pulangi River is one of the tributary rivers of Rio Grande de Mindanao river system in Bukidnon province, Region X. It is the longest river in Bukidnon with a total length of 320km and transverses majority of the cities of Bukidnon province. The site where the *B. tumba* samples were collected is the part of Pulangi River that transverses Poblacion 1, Valencia City, Bukidnon. The Rio Grande de Mindanao river system drains into the Illana Bay. Although Bukidnon and Lanao del Sur are adjacent provinces, the distance between Pulangi River in Bukidnon and Lake Lanao in Lanao del Sur is about 100km. There is also a mountain (Mt. Piyagayongan) between the two provinces so that one has to get around this mountain and travel by land transportation for about six hours to get from Lake Lanao to Pulangi River.

DNA extraction, primer design, and PCR amplification

A small piece of white muscle tissue, 1.5cm x 0.75cm x 0.5 cm, from the upper right side of the body was excised from each specimen, placed in a microcentifuge tube containing 100% ethanol, and stored in the freezer until further use. About 20mg of muscle tissue was subjected to DNA extraction using one of the following: (1) DNeasy Blood and Tissue (QIAGEN, Hilden, Germany) kit; (2) Promega Wizard Genomic DNA Purification (Promega Inc., Madison, WI) kit; (3) InstaGene Matrix (Bio-Rad Laboratories, USA) following the protocol of Hoff-Olsen et al. (1999) with modification; and, (4) simple salting out procedure by Miller et al. (1988) with minor modification. DNA yield was quantified using NanoDrop™ 2000/2000c Spectrophotometer.

The following pair of primers designed using Primer3plus program (Untergasser et al. 2012) were used to amplify the mitochondrial DNA control region of *B. tumba*: forward primer (LPTCR02: 5'-CCCAAAGCCAGAATTCTA-3') and reverse primer (PTCR01H:5'-GCATCTTCAGTGCTATGCTT-3'). Polymerase chain reactions (PCR) were done in 50-µl volumes. The PCR mix consisted of 1.0µl of dNTP (0.05 mM), 2.5µl of each primer (0.1 mM), 5.0µl of PCR buffer, 0.5µl of (1.25 U) Taq polymerase (Roche Taq dNTPack or Vivantis), 34.5 µl of ultrapure water and 4.0µl of DNA template (4–100 ng/ul). The PCR conditions (Tan et al. 2016) were as follows: initiation for 2min at 95^{0}C followed by 37 cycles of denaturation for 45s at 94^{0}C, primer annealing for 1min at 54^{0}C, and primer extension for 1min at 72^{o}C. A final extension step at 72^{0}C for 10min completed the reaction. PCR products were analysed by electrophoresis using 1% agarose gel with ethidium bromide. Approximately 1,037 bp-sized bands were excised from the gel and purified using QIAquick Gel Extraction Kit (QIAGEN, Hilden, Germany) or NucleoSpin® Gel and PCR Clean-up (Machere-Negel, Germany) following the manufacturer's protocol. Purified DNA products with concentration of 15ng/µl or higher were sent to 1st BASE Laboratories Sdn Bhd, Selangur, Malaysia for bidirectional sequencing.

DNA sequence analysis

Consensus sequences of each specimen were assembled, edited and trimmed using Staden Package4 (Staden et al. 2000). The resulting consensus sequences were checked if they were the DNA sequences of interest using the online National Center for Biotechnology Information (NCBI) BLASTn program (Altschul et al. 1990). The consensus sequences were submitted to GenBank and were assigned accession numbers MG663328 through MG663449. ClustalW (Thompson et al. 1994) implemented in MEGA 7 software (Kumar et al. 2016) was used to align the 122 sequences.

Nucleotide diversity (π) and haplotype diversity (h) were computed using DNA Sequence Polymorphism version 5 (DNAsp5; Librado & Rozas 2009). To estimate molecular variances within and among populations of *B. tumba*, F_{ST} values and analysis of molecular variance (AMOVA) were performed using Arlequin version 3.5 (Excoffier & Lischer 2010). Tajima's D and Fu's Fs tests for neutrality were conducted using Arlequin version 3.5 (Excoffier & Lischer 2010). Maximum likelihood tree was constructed using the model chosen by jModelTest 2.1.9 v20160115 (Darriba et al. 2012). A median-joining network (Bandelt et al. 1999) was constructed using PopArt (Leigh & Bryant 2015) to visualize clustering, connectivity and haplotype history.

RESULTS

One hundred twenty-two (122) sequences of the mitochondrial DNA control region were generated from four populations of *B. tumba*. Sequence length ranged from 907 bp to 918 bp. The final alignment length that was used for the analysis was 933 including 42 indels. Of the 933 sites, 191 were variable. The composition of each nucleotide is as follows: C, 17.7%; G, 12.2%; T, 33.2%; and, A, 36.9%. Of the 122 sequences, 87 distinct haplotypes were detected (Table 1). Of the 87 haplotypes, two haplotypes (Hap59 and Hap60) were common to Dagoyanan Lake and Nunungan Lake. There were 28 unique haplotypes found in Lake Lanao population, 28 in Bukidnon population, 15 in Dagoyanan Lake, and 14 in Nunungan Lake. There were no haplotypes shared between specimens from Lake Lanao and those from the other sites. Similarly, no haplotypes were shared between specimens from Bukidnon and those from the three lakes. Overall haplotype diversity and nucleotide diversity values were 0.947 and 3.407%, respectively (Table 1). Haplotype diversity and nucleotide diversity values in each population were also high

Table 1. Measures of genetic diversity in four populations of *Barbodes tumba* in Mindanao, Philippines.

Population	n	Number of haplotypes	No. of unique haplotypes	Haplotype Diversity	Nucleotide Diversity (%)
Lake Lanao	30	28	28	0.995	1.075
Bukidnon	32	28	28	0.976	0.552
Dagoyanan Lake	30	17	15	0.864	2.736
Nunungan Lake	30	16	14	0.662	1.248
Overall	122	87	-	0.947	3.407

Table 2. Analysis of Molecular Variance (AMOVA) within and between the four populations of *Barbodes tumba* in Mindanao, Philippines based on mitochondrial DNA control region.

Source of variation	d.f.	Sum of squares	Variance components	Percentage of variation
Among populations	3	1500.274	16.137*	66.70
Within populations	118	950.440	8.055*	33.31
Fixation Index F_{ST}: 0.667				

*p-value < 0.0001

Table 3. Pairwise F_{ST} values (below diagonal) and p-values (above diagonal) for four populations of *Barbodes tumba* in Mindanao, Philippines.

	Lake Lanao	Bukidnon	Dagoyanan Lake	Nunungan Lake
Lake Lanao	-	0.000	0.000	0.000
Bukidnon	0.832	-	0.000	0.000
Dagoyanan Lake	0.487	0.650	-	0.001
Nunungan Lake	0.760	0.822	0.146	-

(0.662–0.976 and 0.552–2.736 %, respectively, Table 1). Results of AMOVA (Table 2) showed that variation among populations (66.70%) was higher compared to variation within populations (33.31%); these results are significant (P < 0.01). Both chi-square (X^2: 334.009, *df* = 258, P = 0.0010) and overall F_{ST} (0.62718) results showed that genetic differentiation was seen among the four populations. Based on pairwise F_{ST} values (Table 3), there is a significantly high (P < 0.01) genetic differentiation between populations. Populations from lakes Nunungan and Dagoyanan are the least genetically diverged, whereas those from Bukidnon and Lanao Lake are the most genetically diverged.

jModelTest 2 (Darriba et al. 2012) indicated that the Hasegawa-Kishino-Yano model (Hasegawa et al. 1985) with gamma distribution (HKY85+Γ) was the optimal model to use for constructing maximum-likelihood tree. The ML tree (Fig. 2) separated the 87 haplotypes into two major clusters. The first major cluster (Cluster A) consists of specimens from Bukidnon, Lake Lanao and Dagoyanan Lake. The second major cluster (Cluster B) consists of specimens from Dagoyanan and Nunungan lakes. Cluster A is further subdivided into two groups: one group consisting of all the specimens from Bukidnon and the other group consisting of all the specimens from Lake Lanao and nine specimens from Dagoyanan. All the specimens from Lake Lanao formed a separate subgroup from the nine specimens from Dagoyanan. All the specimens from Nunungan Lake clustered with 21 specimens from Dagoyanan. This grouping is consistent with the results from Median-joining network analysis as shown in Fig. 3.

Tajima's D and Fu's Fs tests were done to infer the demographic history of each population. The results of Tajima's D and Fu's Fs tests including associated p-values are shown in Table 4. Tajima's D values were negative for Lake Lanao and Bukidnon populations, indicating an excess of rare nucleotide site variants compared to what would be expected under a neutral model of evolution. The results of Fu's Fs test, which is based on the distribution of haplotypes, showed negative values for Lake Lanao and Bukidnon populations, indicating an excess of rare haplotypes over what would be expected under neutrality. The hypothesis of neutral evolution was rejected for Lake Lanao and Bukidnon populations. Dagoyanan and Nunungan lake populations had neutral mutations.

Mismatch distribution analyses were performed to infer historical demographic expansions (Rogers & Harpending 1992; Ray et al. 2003). The results revealed that the mismatch distribution plot of Lake Lanao population has unimodal and ragged shape, Bukidnon population has bimodal and smooth shape plot, while Dagoyanan and Nunungan populations exhibited multimodal and ragged shape plots (Fig. 4).

Sum of squared deviations (SSD) (Schneider &

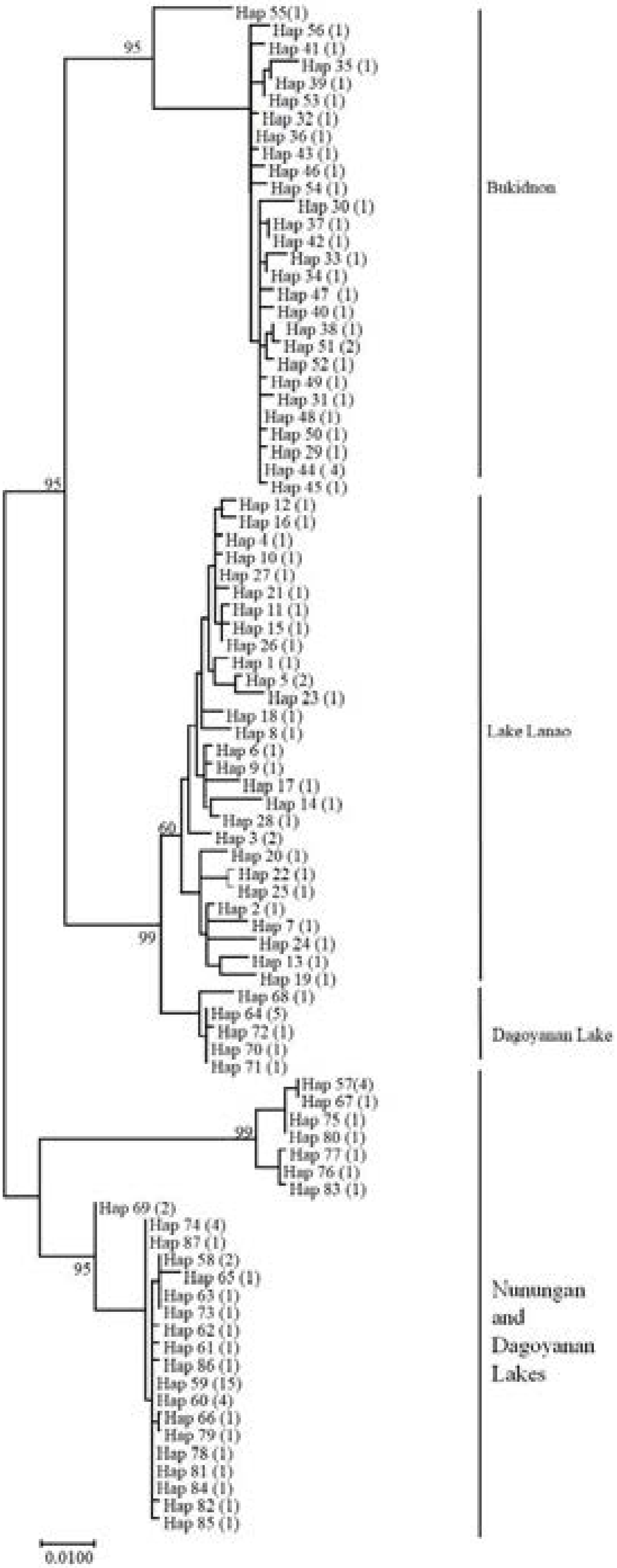

Figure 2. Unrooted HKY + Γ distance maximum-likelihood tree of 87 haplotypes of *Barbodes tumba* from four localities in Mindanao. Number in parenthesis indicates the number of specimens in each haplotype. Values on the nodes represent bootstrap support (1000 replicates). Bootstrap support less than 50% are not shown. The scale bar represents 1 substitutional change per 100 nucleotide positions.

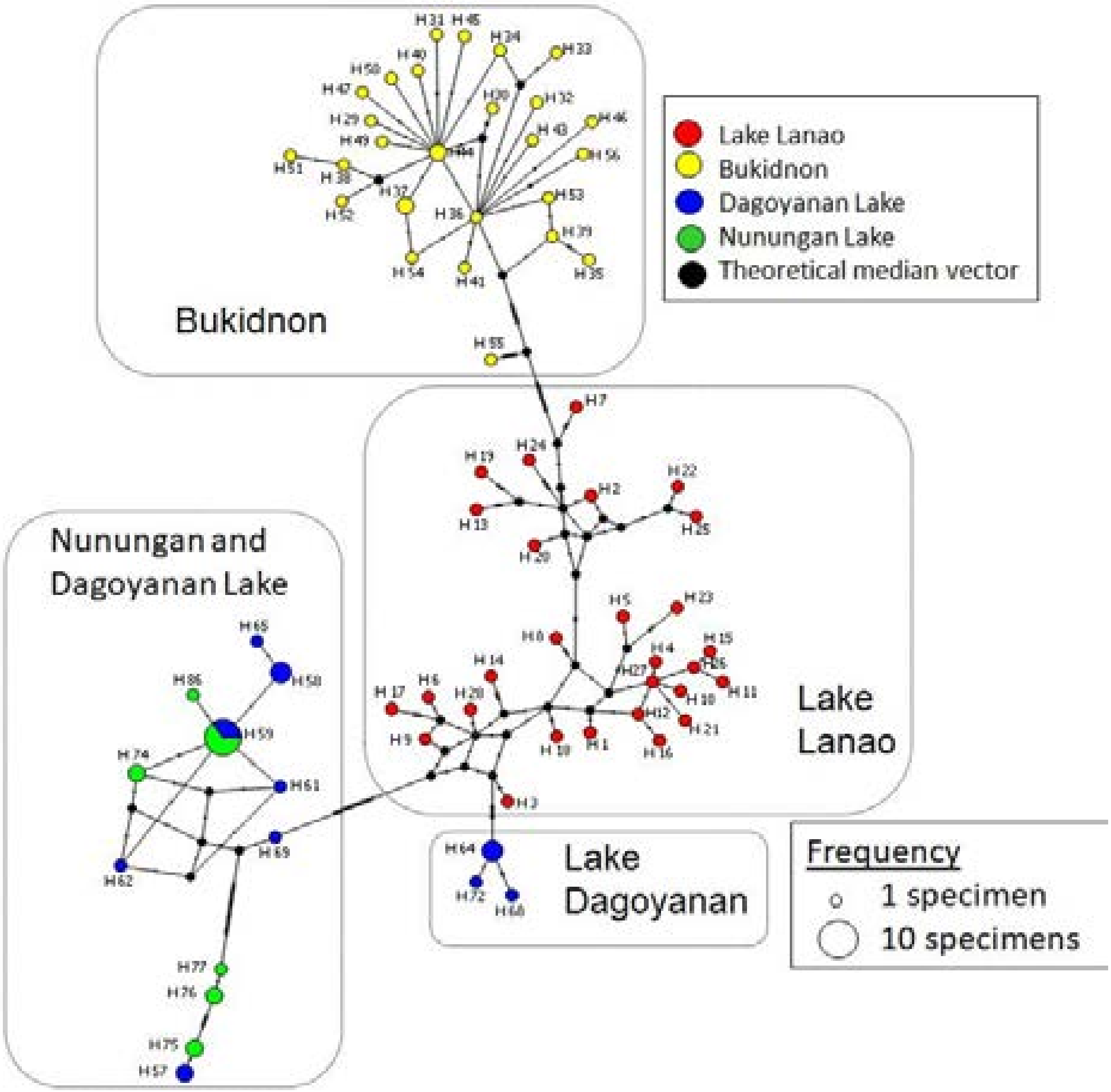

Figure 3. Median-joining haplotype network of four populations of *Barbodes tumba* in Mindanao, Philippines. Hatch marks on the branches represent the number of nucleotide changes. Each circle represents a haplotype, and the sizes of haplotype circles are proportional to the haplotype frequencies. The black dots represent theoretical median vectors introduced by the network software.

Excoffier 1999) and the raggedness index (r) (Harpending 1994) under both demographic and spatial expansion models were also calculated for each population. All populations had nonsignificant SSD and raggedness index, except for the SSD of Nunungan and Dagoyanan Lakes under sudden expansion model, which indicates that the dataset has relatively good fit to a model of population expansion (Harpending 1994; Table 4).

DISCUSSION

High values for haplotype and nucleotide diversities were observed in all populations of *B. tumba*. This can be interpreted as stable populations with long evolutionary history or secondary contact between differentiated lineages (Grant & Bowen 1998). High haplotype and high nucleotides diversities were also observed in other freshwater fishes such as *Channa striata* in a river basin in Central Thailand (Boonkusol & Tongbai 2016) and *Acrossocheilus paradoxus* in Taiwan (Wang et al. 2000). Populations that exhibit both high haplotype and nucleotide diversities may be due to the combination

Table 4. Neutrality tests and mismatch distribution analysis for four populations of *Barbodes tumba* in Mindanao, Philippines.

Population	Tajima's D		Fu's Fs		Sudden expansion model				Spatial expansion model			
	D	p-value	F	p-value	SSD	p-value	r	p-value	SSD	p-value	r	p-value
Lake Lanao	-1.767	0.016	-15.327	0.000	0.003	0.700	0.009	0.529	0.004	0.524	0.009	0.400
Bukidnon	-2.317	0.000	-23.023	0.000	0.002	0.489	0.017	0.636	0.002	0.550	0.017	0.679
Dagoyanan Lake	1.825	0.974	4.038	0.926	0.025	0.027	0.018	0.053	0.016	0.833	0.018	0.848
Nunungan Lake	0.112	0.600	0.560	0.603	0.228	0.005	0.033	0.999	0.029	0.582	0.033	0.905

SSD, sum of squared deviations; r, raggedness index

of high mutational rate and large population size of the species as in the case of *A. paradoxus* (Wang et al. 2000), or to gene flow between regional populations due to fish dispersal by flood, aquaculture (Boonkusol & Tongbai 2016), and anthropogenic transportation. In the case of *B. tumba,* high haplotype and nucleotide diversities may be due to large effective population sizes as a result of their reproductive characteristics. Cyprinids were reported to have high fecundity (500–5,500 eggs per female; Ismail & Escudero 2011), mature in a short period of time of about 112 days to one year (Cek et al. 2001), breed all year round (Ismail & Escudero 2011), and the interval between successive spawning is about 20 to 40 days (Targonska & Kuchaczyk 2012). Despite the reported drastic drop in fish catch for *B. tumba* in Lake Lanao in a survey conducted from 1990 to 1991 (Ismail et al. 2014), genetic diversity of population of *B. tumba* in the lake remains high.

The chi-square test for genetic differentiation, AMOVA, pairwise and overall F_{ST} values indicate that there is genetic differentiation in the four populations of *B. tumba* in Mindanao. Genetic divergence is expected among the different populations of *B. tumba* for being freshwater fishes that thrive in geographically isolated bodies of water compounded by their limited dispersal capacity (Wang et al. 2000).

The maximum-likelihood tree and median-joining network separated the 87 haplotypes into two major clusters and subgroups within each cluster. The first major cluster consists of specimens from Bukidnon, Lanao and Dagoyanan lakes. The second major cluster consists of specimens from Dagoyanan and Nunungan lakes. Within the first cluster, *B. tumba* specimens from Bukidnon formed a distinct group, which separated from the group formed by the specimens from Lanao and Dagoyanan lakes. The tree shows that *B. tumba* population from Lake Lanao is distinct from the Nunungan Lake population. Some haplotypes from Dagoyanan Lake clustered with either Lake Lanao or Nunungan Lake. No haplotypes were shared between Bukidnon population and the other populations from the three lakes. These findings are supported by the F_{ST} values. The separation of the Bukidnon population may be explained by the geographic distance and barrier (Mt. Piyagayongan) between Bukidnon and Lanao provinces. While the relative lower genetic differentiation among the Lanao del Norte and Lanao del Sur populations (i.e., specimens from Lanao, Dagoyanan and Nunungan lakes) may be attributed to a secondary contact between the populations due to the close proximity of their distances. Secondary contact among the three Lanao populations

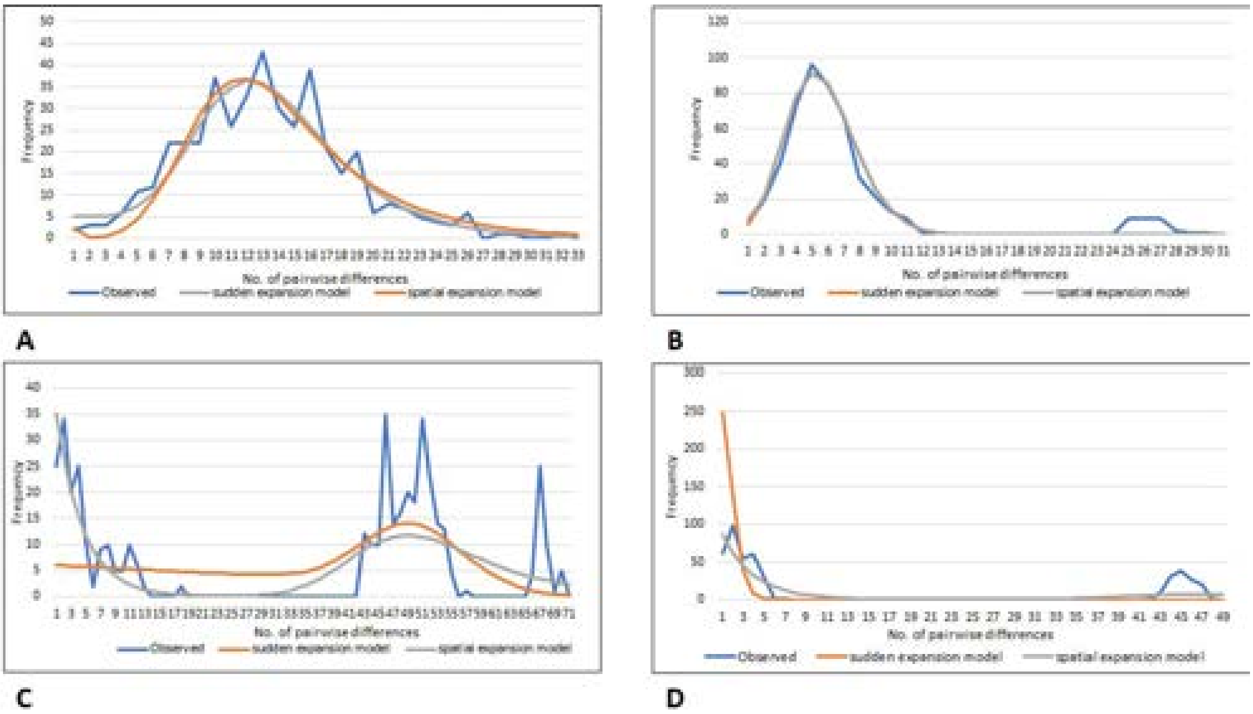

Figure 4. Mismatch analysis plots for four populations of *Barbodes tumba* based on the mitochondrial control region: A - Lake Lanao | B - Bukidnon | C - Dagoyanan Lake | D - Nunungan Lake.

can be brought about by flooding and human-mediated translocation either intentionally or unintentionally. This could explain why two haplotypes were shared between populations from Nunungan and Dagoyanan lakes and why they are the least genetically diverged based on F_{ST} values. Mixing between populations from these two lakes could have taken place in the past, which could have been brought about by human-mediated translocation since one can just walk from one lake to another for 5 to 7 hours. Lake Lanao population does not share any of its 28 unique haplotypes with any other population. These 28 haplotypes formed a single group which in turn clustered with five haplotypes from Lake Dagoyanan (Fig. 2). Lake Lanao and Lake Dagoyanan are the closest to each other based on geographic distance and because of this there may have been secondary contact between populations from these two lakes in the past.

Nunungan Lake and Dagoyanan Lake populations were found to have neutral mutations based on Tajima's D test and Fu's Fs values (Table 4). As such, these two populations were at demographic equilibrium with no selection pressure acting on them. *Barbodes tumba* in Nunungan and Dagoyanan lakes face no pressure as of now from overexploitation by humans, predation by introduced species, or habitat destruction. People in Nunungan and Dagoyanan do not prefer *B. tumba* for food because of the availability of larger fishes (such as tilapia, common carp, mudfish and catfish). In addition, there are only a few households that live in the vicinities of the two lakes. Predatory fishes such as *Glossogobius* spp. and *Giuris margaritaceus*, which were blamed for the extinction of other cyprinid species in Lake Lanao basin, are absent in these lakes. *Barbodes tumba* populations from Bukidnon and Lanao Lake showed significant negative Tajima's D and Fu's Fs values (Table 4), a signature of population expansion after a recent bottleneck. According to Fu (1997), however, natural selection is only one of potentially many possible causes of significantly negative Tajima's D and Fu Fs values. Negative value can also be seen in a population undergoing recent growth (Fu 1997).

Historical demographic expansions can be interpreted as follows: Unimodal mismatch distribution indicates a range expansion in populations with high deme size and gene flow (Ray et al. 2003) or past demographic expansion (Rogers & Harpending 1992), while a multimodal (including bimodal) mismatch distribution indicates recent demographic expansion after the population size diminished due to fragmentation (Ray et al. 2003). Smooth with peak mismatch distribution suggests that population has been growing, while a ragged and erratic mismatch distribution suggests that the population has been stationary for a long time or in equilibrium (Rogers & Harpending 1992; Harpending 1994). Ragged mismatch distributions can also result from fragmentation of the population's habitat that leads to contraction of their effective size (Ray et al. 2003). Non-significant values for SSD and raggedness index signify that the data do not deviate from that expected under the model of expansion.

Mismatch distribution analysis on the Lake Lanao population revealed a unimodal distribution that conformed to both demographic and spatial expansions (Fig. 4A and Table 4). In 1996, *B. tumba* was classified as vulnerable to extinction by International Union for Conservation of Nature due to decline in abundance in Lake Lanao (World Conservation Monitoring Centre 1996). This population decline, however, did not result in low genetic diversity. Mismatch analyses of populations from Bukidnon, Dagoyanan and Nunungan lakes showed multimodal distributions (Fig. 4B) with non-significant SSD and r values (Table 4), except the SSD values for Nunungan and Dagoyanan populations under sudden expansion model. These suggest that Bukidnon population has undergone spatial expansion, fragmented and then followed by demographic expansion. *Barbodes tumba* populations in Dagoyanan and Nunungan lakes, on the other hand, are expanding as they conform to the spatial expansion model.

In summary, there is high genetic diversity in each of the four populations of *B. tumba* in Mindanao and high genetic divergence between populations. Despite the reported drastic decline in fish catch for this species in Lake Lanao in the early 1990s, this did not result in low genetic diversity. Although the genetic diversity is high in each of the four populations, the species still merits management and conservation plan because of its limited distribution or endemism (limited to Mindanao region in the Philippines), its vulnerability to predation, and its utility as food species. In addition, Bukidnon population should be managed separately because it is distinct from the three other populations from the Lanao provinces. Local government units in areas where this endemic species is found should enact measures to prevent overfishing of the species, the introduction of exotic species that can prey on this endemic cyprinid and destruction of their habitat.

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ARTICLE

The importance of conserving fragmented forest patches with high diversity of flowering plants in the northern Western Ghats: an example from Maharashtra, India

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Abstract: The northern Western Ghats (NWG) comprises of a patchy continuum of forests that have been severely fragmented mainly due to anthropogenic activities. We documented tree diversity within a representative fragmented forest patch of the NWG to study the effects of fragmentation on forest structure and composition. The floristic survey was conducted by replicated strip transect sampling method leading to a total sampling area of 0.3ha. A total of 444 individual trees (Girth>10cm) were sampled, which represented 49 tree species belonging to 42 genera and 23 families. Species richness per unit area and tree density were higher than previously reported values from similar forest type in various regions of NWG. These variations, however, could have resulted due to differences in the sampling area, sampling method, and girth classes used across different studies. Nevertheless, various diversity parameters such as N/S ratio, Simpson's index, Shannon's index, and Fisher's α index were comparable with those reported in previous studies in the Western Ghats. The observed species richness was close to species richness estimates such as abundance-based coverage estimate, Chao-1, and Jackknife estimators. The present study also enumerates 108 species of understory flowering plants, which is provided as a checklist. While access restrictions are imposed in protected areas having high conservation priority, such restrictions are not imposed in non-protected areas, which make them much more vulnerable to anthropogenic activities. Hence, this study recommends that owing to their high diversity, the fragmented forest patches of NWG should also be given high conservation priority.

Keywords: Conservation, forest fragmentation, plant diversity.

Abbreviations: APG - Angiosperm phylogeny group; GPS - Global positioning system; NP- National park; NWG - Northern Western Ghats; WG - Western Ghats; WS - Wildlife sanctuary.

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INTRODUCTION

Biodiversity hotspots have been defined as the areas featuring exceptionally high concentrations of endemic species as well as those experiencing exceptional loss of habitat mainly due to anthropogenic activities (Myers et al. 2000). Currently, 34 biodiversity hotspots have been defined in the world (Mittermeier et al. 2005) and two of these biodiversity hotspots, the Western Ghats/Sri Lanka (WG/SL) and Indo-Burma regions, belong to the Indian subcontinent. The WG/SL is considered one of the eight "hottest hotspots" of biological diversity identified in the world (Gunawardene et al. 2007). WG/SL hotspot, however, is experiencing a rapid loss of habitat and, out of the 190,037km^2 of primary vegetation, only 6.3% area has presently remained as natural intact vegetation (Sloan et al. 2014).

The Western Ghats (WG) refers to a hill chain or escarpment of ~1500km that runs almost parallel to the western coast of the Indian peninsula from the river Tapi (or Tapti) in Gujarat down south to just short of Kanyakumari (Fig. 1). WG covers about 130,500km^2 area (Rodgers et al. 2000); however, the exact area under WG varies from report to report (129,037–164,280 km^2) due to the lack of well-defined boundaries (Reddy et al. 2016). WG, also listed as a world heritage site, is surrounded by one of the most densely populated areas of the world, creating huge anthropogenic pressure on the biodiversity hotspot (Cincotta et al. 2000; Williams 2013). As a result, WG is undergoing severe biodiversity loss, which began with the British colonization era (Chandran 1997) and intensified in the last two decades. In 1920, 95,446km^2 (73.1%) area of WG was under forest cover, of which an estimated 33,579km^2 (35.3%) of forest cover was lost during the period 1920–2013 (Reddy et al. 2016).

WG forms a barrier to the clouds of the southwestern monsoon leading to heavy rainfall up to 7,000mm on the western slopes; due to the rain shadow effect, the eastern slopes are comparatively drier. Similarly, the rainfall is heavier towards the south and extends over eight to nine months a year, while it is lower and restricted to four months of southwestern monsoon in the northern parts of the WG (Gadgil 1996). Most of the rivers of peninsular India originate in the WG and thus it constitutes the 'water tower' of the region (Viviroli et al. 2007). Due to this rainfall regime, WG has a cover of evergreen forest in its western slopes which gradually changes to moist and dry deciduous type forests moving eastwards. Together, these forests host one of the most diverse plant communities with a reported 5,588 native species of flowering plants (Nayar et al. 2014). Plant diversity is higher towards the south and the seasonality, or rather the duration of the raining season, is one of the factors determining the distribution of plant diversity in the WG (Davidar et al. 2005).

Based on the geology of the WG, Pascal (1988) considered three major regions as 'landscape elements' within WG, namely, the northern, central, and southern regions. The northern Western Ghats (NWG) comprises the ~600km stretch of Surat-Goa region of WG (Fig. 1). NWG is homogenous in terms of geology and vegetation compared to the central and southern WG. The vegetation of NWG is considered to be the least resilient among the WG flora, due to a longer dry season and increased anthropogenic activities (Daniels 2011). NWG in Maharashtra State had ~13,500km^2 of forest cover remaining by 2005, comprising dense forest (38.22%), open forest (31.39%), and scrubland (30.39%). Within the period from 1985–1987 to 2005, the overall forest cover of NWG remained more or less unchanged; however, loss of the dense forest cover (~10%) with increased fragmentation has been observed (Kale et al. 2010; Panigrahy et al. 2010).

Habitat loss typically leads to fragmentation, the process of division of large, continuous habitats into smaller, more isolated habitat fragments separated by a matrix of human transformed land cover (Haddad et al. 2015). The loss of habitat area, increase in isolation, and increased edge area initiate long-term changes to the composition, richness, and structure of communities of the remaining fragments (Wilson et al. 2016). Effects of fragmentation depend on the size, shape, and distribution of fragments among the landscape as well as the total amount of habitat and nature of non-habitat matrix (Ibanez et al. 2017). Species respond differently to fragmentation based on their population size and the order of succession; thus, late successional species are severely affected while the stress-tolerant pioneer species proliferate (Laurance et al. 2006).

Hence, fragmented forest patches often exhibit a high percentage of pioneer species while retaining the remnants of mature forest communities. As a result, the cumulative species richness of the fragmented patches can be comparable with mature forest communities and represents a significant portion of the overall biodiversity of the region (Arroyo-Rodriguez et al. 2009). This implies that conservation of fragmented forest patches is important to protect the gene pool, prevent species extinction, maintain biodiversity; it would also help in ecological restoration as well as in protecting soil and water resources. Also, the conservation of fragmented patches can establish a network of small conservation areas with flexible structure creating more efficient corridors within intact habitat and conservation network (Kale et al. 2010; Farah et al. 2017). Small-scale inventories in fragmented forest patches are useful to explore the plant community structure and composition as well as to create a baseline for eventual restoration (Castillo-Campos et al. 2008). Hence, the objective of the present study was to systematically document the floristic diversity in one of the representative fragmented forest patches in NWG to understand the actual floristic composition therein and to contribute to its usefulness for biodiversity conservation in the region.

MATERIALS AND METHODS

Study site

The study site was one of the fragmented forest patches of NWG located at 18^{0}32'204"N and 73^{0}25'107"E (Fig. 1), near the village Barpe in Mulshi Taluka, about 45km west of Pune, Maharashtra, India. The study site was roughly a crescent-shaped forested hill slope comprising of ~20ha area with an average elevation of 700m while the hilltop has an elevation of 1,000m. The vegetation of the area is described as a semi-evergreen forest of *Memecylon-Syzygium-Actinodaphne* (*M-S-A*) series (Pascal 1988). The study site is part of a reserved

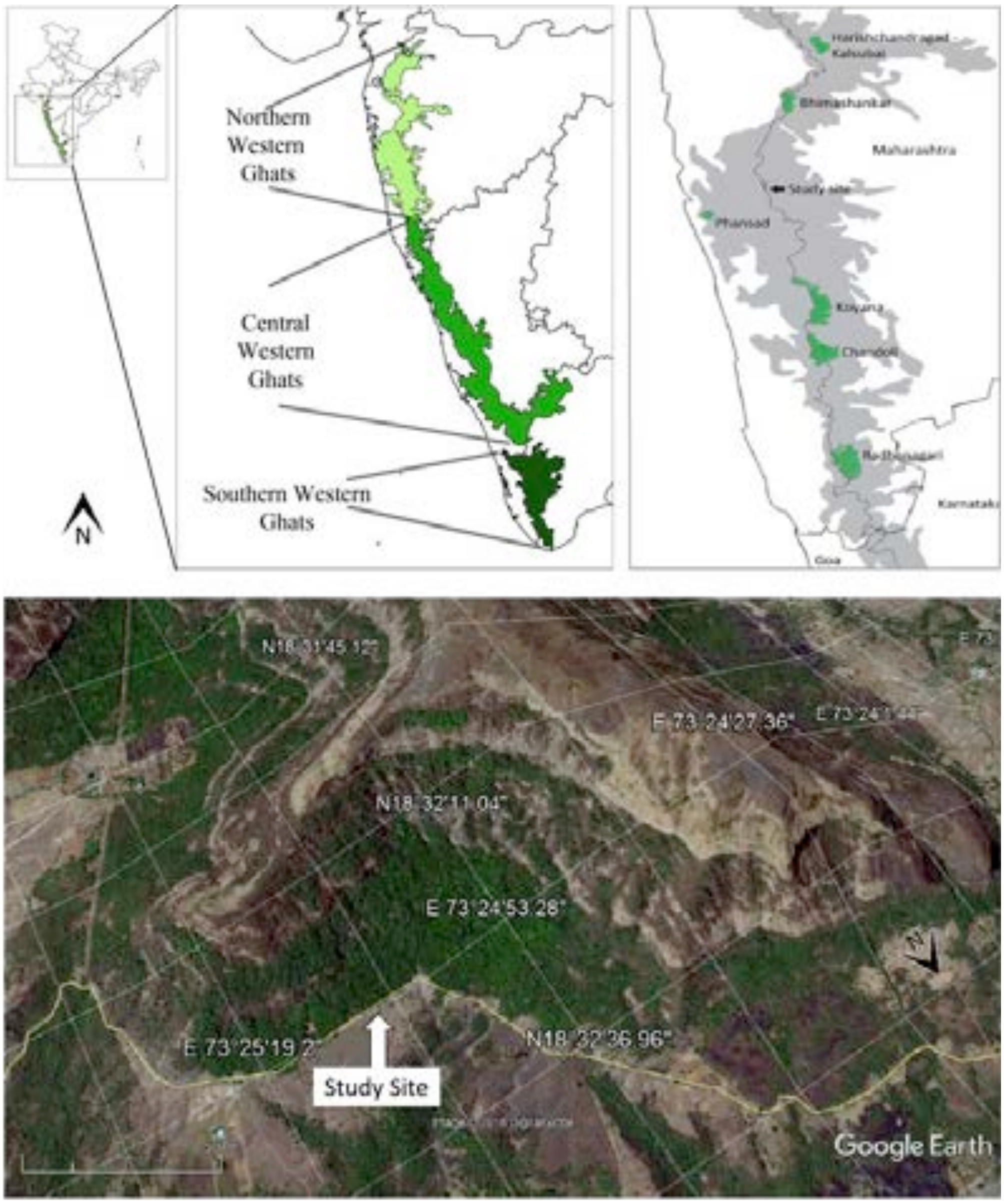

Figure 1. Study site in the northern Western Ghats, India.

forest as designated in the state forest surveys (PCCF 2013). Certain regions along the edge of the reserved forest, however, have a history of man-made disturbance as observed during the surveys as well as revealed during discussions with the locals.

The study site has a slightly acidic red soil and sandy loam texture. The area receives heavy rainfall (~6,500mm) in monsoon (June–September) followed by a dry spell of eight months including a cool, dry winter (October–February) and a warm moist summer (March–May). The average relative humidity is about 95% in the rainy season (monsoon), but varies from 30% to 70% during the rest of the year; the temperature is reported to vary from a minimum of 4°C in winter to a maximum of 41°C in summer (Watve et al. 2003). Faunal elements like Hanuman Langur *Semnopithecus hypoleucos* and Indian Muntjack *Muntiacus muntjack aureus* are native to the study area and were commonly observed during the study (ZSI 2012).

METHODS

For the present study, several floristic inventories were performed by strip transect sampling in the study site between March 2013 and May 2015, covering all months of the year. Three non-contiguous strip transects of 167m × 06m, spanning from edge to interior were demarcated within the selected forest patch according to Gordon & Newton (2006) and Buckland et al. (2007), and coordinates were recorded using a handheld GPS device (Oregon 550, Garmin, USA) (Fig. 1). Thus, the sampling area was 0.1ha at each strip transect, and the total sampling area was 0.3ha. Tree diversity and abundance encountered within the fixed area of strip transects were documented. Trees with Girth<10cm were excluded while understory plants such as lianas, climbers, shrubs, herbs, and epiphytes were documented. All the specimens were identified using local or regional floras (Sharma et al. 1996; Singh et al. 2001; Yadav & Sardesai 2002) and confirmed by expert taxonomists. Representative plant specimens were identified by comparison with herbarium accessions at the herbarium of the Botanical Survey of India (BSI), Pune, India. The APG IV classification system was followed at the family-level (Chase et al. 2016).

Alpha diversity of the study site was measured as species richness (number of species), species richness indices such as Margalef's index and diversity indices such as Simpson's dominance index, Simpson's reciprocal index, Shannon's index, evenness, equitability, Fisher's alpha index, and Berger-Parker dominance (Magurran 2003) and were calculated using the PAST software (v. 3.11) (Hammer et al. 2001). Species accumulation curve was plotted where X-axis represented the cumulative number of individuals and the Y-axis represented the cumulative number of species (Gotelli & Colwell 2011). Species richness estimates appropriate for abundance data such as Chao-1, abundance-based coverage estimate (ACE), and Jackknife estimators were calculated using EstimateS v. 9.1.0 (Colwell 2013). N/S (ratio of number of individuals (N) to the number of species (S)), a simple parameter to represent species diversity, was also calculated (Watve et al. 2003; Kanade et al. 2008).

RESULTS

Floristic inventories in the study area covering all months of the year resulted in the identification of 157 plant species (including 49 tree species and 108 understory plant species) representing 137 genera and 59 families (Table 1; Images 1–5). The most species-rich family was Fabaceae represented by 12 species, followed by Poaceae (N=11), Apocynaceae (N=9), Asteraceae (N=9), and Acanthaceae (N=8); 31 families were monospecific, i.e., represented by a single species each. Tree diversity of the study area comprised 49 tree species representing 42 genera and 23 families. The number of tree species varied from 33 to 39 among the three strip transects (0.1ha each), and 444 individuals stems (G>10cm) were recorded from the total sampling area of 0.3ha (Table 2).

Memecylon umbellatum Burm.f. (Melastomaceae) (N=77) was the most abundant evergreen tree species followed by *Olea dioica* Roxb. (Oleaceae) (N=32), *Nothapodytes nimmoniana* (J. Grah.) Mabb. (Icacinaceae) (N=31), *Garcinia talboti* Raiz ex Sant (Clusiaceae) (N=23), and *Ixora brachiata* Roxb. (Rubiaceae) (N=19). Members of the genus *Actinodaphne* and *Syzygium* were less abundant than the typical *M-S-A* series forest, suggesting a different community composition. Among the 49 tree species, similar numbers of evergreen (N=23) and deciduous (N=26) species were recorded; however, most individuals were evergreen (N=316, ~71%) while the rest (N=128, ~29%) were deciduous.

The N/S ratio for the total sampling area of 0.3ha was 9.06 while it varied from 3.50 to 4.79 for each strip transect of 0.1ha. Margalef's species richness index for the study site was 7.87, varying from 6.32 to 7.56 per transect. Dominance index (D) of the study site was 0.057, while Simpson's reciprocal index (1/D) was

Image 1 . Plant species observed in the study area: A - *Abrus precatorius* L. | B - *Careya arborea* Roxb. | C - *Dillenia pentagyna* Roxb. | D - *Erythrina stricta* Roxb. | E - *Garcinia talboti* Raiz. ex Sant. | F - *Kydia calycina* Roxb. | G - *Nothapodytes nimmoniana* (J. Grah.) Mabb. | H - *Pinda concanensis* (Dalz.) P. Mukh. & Constance. © Rani Bhagat.

Table 1. Plant species recorded in the study area, with their families, habits, and foliar habits (in case of trees). The species endemic to the Western Ghats are indicated by a '*'.

	Family	Species	Habit	Foliar habit
	Gymnosperms			
1	Gnetaceae	*Gnetum ula* Brongn.	Liana	
	Angiosperms			
2	Acanthaceae	*Cynarospermum asperrimum* (Nees) Vollesen	Herb	
3	Acanthaceae	*Eranthemum roseum* (Vahl) R. Br.	Shrub	
4	Acanthaceae	*Haplanthodes verticillata* (Roxb.) R.B. Majumdar	Herb	
5	Acanthaceae	*Hemigraphis latebrosa* (Heyne ex Roth) Nees var. latebrosa	Herb	
6	Acanthaceae	*Justicia diffusa* Willd.	Herb	
7	Acanthaceae	*Lepidagathis cuspidata* Nees	Shrub	
8	Acanthaceae	*Rungia repens* (L.) Nees	Herb	
9	Acanthaceae	*Strobilanthes callosa* Nees	Shrub	
10	Amaranthaceae	*Achyranthes aspera* L. var. aspera	Herb	
11	Anacardiaceae	*Holigarna arnottiana* (Wt.) Kurz*	Tree	Evergreen
12	Anacardiaceae	*Mangifera indica* L.	Tree	Evergreen
13	Apiaceae	*Pinda concanense* (Dalz.) P.K. Mukh. & Constance*	Herb	
14	Apocynaceae	*Anodendron paniculatum* A. DC.	Climber	
15	Apocynaceae	*Carissa congesta* Wight	Shrub	
16	Apocynaceae	*Cryptolepis buchanani* Roem. & Schult.	Shrub	
17	Apocynaceae	*Hemidesmus indicus* (L.) Schult.	Shrub	
18	Apocynaceae	*Hoya wightii* Hook. f.	Climber	
19	Apocynaceae	*Pergularia daemia* (Forssk.) Choiv.	Shrub	
20	Apocynaceae	*Tylophora dalzellii* Hook. f.	Liana	
21	Apocynaceae	*T. indica* (Burm. f.) Merr.	Liana	
22	Apocynaceae	*Wrightia tinctoria* R. Br.	Tree	Deciduous
23	Asparagaceae	*Asparagus racemosus* Willd.	Herb	
24	Asteraceae	*Ageratum conyzoides* L.	Herb	
25	Asteraceae	*Blumea eriantha* DC.	Herb	
26	Asteraceae	*B. lacera* (Burm. f.) DC.	Herb	
27	Asteraceae	*B. laciniata* (Roxb.) DC.	Herb	
28	Asteraceae	*Cyathocline purpurea* (Buch.-Ham. ex D. Don) O. Kuntze*	Herb	
29	Asteraceae	*Laphangium luteoalbum* (L.) Tzvelev	Herb	
30	Asteraceae	*Phyllocephalum scabridum* (DC) Kirkman	Herb	
31	Asteraceae	*Senecio bombayensis* Balakr.	Herb	
32	Asteraceae	*Cyanthillium cinereum* (L.) H. Rob.	Herb	
33	Bignoniaceae	*Heterophragma quadriloculare* (Roxb.) K. Schum.	Tree	Deciduous
34	Boranginaceae	*Cynoglossum zeylanicum* (Vahl ex Hornem.) Thunb. ex Lehm.	Herb	
35	Celastraceae	*Maytenus rothiana* (Walp.) Lobreau-Collen	Shrub	
36	Clusiaceae	*Garcinia indica* (Thou.) Choisy*	Tree	Evergreen
37	Clusiaceae	*G. talbotii* Raizada ex Santapau*	Tree	Evergreen
38	Clusiaceae	*Mammea suriga* (Buch.–Ham. ex Roxb.) Kosterm.	Tree	Evergreen
39	Colchicaceae	*Iphigenia magnifica* Ansari & R.S. Rao	Herb	
40	Combretaceae	*Calycopteris floribunda* (Roxb.) Poir.	Shrub	
41	Combretaceae	*Terminalia chebula* Retz.	Tree	Deciduous
42	Commelinaceae	*Murdannia pauciflora* (G.Brückn.) G.Brückn.	Herb	
43	Convolvulaceae	*Argyreia sericea* Dalz. & Gibs.	Climber	

	Family	Species	Habit	Foliar habit
44	Convolvulaceae	*A. elliptica* (Roth) Choisy	Climber	
45	Convolvulaceae	*Strictocardia campanulata* (L.) Merr.	Climber	
46	Cucurbitaceae	*Solena amplexicaulis* (Lam.) Gandhi	Climber	
47	Cucurbitaceae	*Trichosanthes tricuspidata* Lour.	Climber	
48	Cyperaceae	*Cyperus rotundus* L.	Herb	
49	Cyperaceae	*Eleocharis atropurpurea* (Retz.) J. Presl & C. Presl	Herb	
50	Dilleniaceae	*Dillenia pentagyna* Roxb.	Tree	Deciduous
51	Dioscoreaceae	*Dioscorea belophylla* (Prain) Voigt ex Haines	Climber	
52	Dioscoreaceae	*D. bulbifera* L.	Climber	
53	Ebenaceae	*Diospyros montana* Roxb.	Tree	Deciduous
54	Elaeagnaceae	*Elaeagnus conferta* Roxb	Shrub	
55	Eriocaulaceae	*Eriocaulon* sp.	Herb	
56	Euphorbiaceae	*Breynia nivosa* (Bull.) Small	Shrub	
57	Euphorbiaceae	*Euphorbia antiquorum* L.	Shrub	
58	Euphorbiaceae	*Falconeria insignis* Royle	Tree	Deciduous
59	Euphorbiaceae	*Macaranga peltata* (Roxb.) Muell.-Arg.	Tree	Evergreen
60	Euphorbiaceae	*Mallotus philippensis* (Lam.) Muell.-Arg.	Tree	Evergreen
61	Euphorbiaceae	*Securinega leucopyrus* (Willd.) Muell.-Arg.	Shrub	
62	Fabaceae	*Abrus precatorius* L.	Climbers	
63	Fabaceae	*Albizia odoratissima* (L. f.) Bth.	Tree	Deciduous
64	Fabaceae	*Cassia fistula* L.	Tree	Deciduous
65	Fabaceae	*Crotalaria filipes* Benth.	Herb	
66	Fabaceae	*C. hirsuta* Willd.	Herb	
67	Fabaceae	*Dalbergia horrida* (Dennst.) Mabb.	Climbing shrub	
68	Fabaceae	*Entada rheedei* Spreng.	Liana	
69	Fabaceae	*Erythrina stricta* Roxb.	Tree	Deciduous
70	Fabaceae	*Geissaspis cristata* Wight & Arn.	Herb	
71	Fabaceae	*G. tenella* Benth.	Herb	
72	Fabaceae	*Mucuna pruriens* (L.) DC.	Climbing shrub	
73	Fabaceae	*Smithia bigemina* Dalz.	Herb	
74	Gentianaceae	*Canscora diffusa* (Vahl) R. Br. ex Roem. & Schult.	Herb	
75	Icacinaceae	*Nothapodytes nimmoniana* (J. Grah.) Mabb.	Tree	Evergreen
76	Lamiaceae	*Colebrookea oppositifolia* Sm.	Shrub	
77	Lamiaceae	*Leucas ciliata* Benth.	Herb	
78	Lamiaceae	*Pogostemon benghalensis* (Burm. f.) O. Ktze.	Herb	
79	Lamiaceae	*P. heyneanus* Benth.	Herb	
80	Lauraceae	*Actinodaphne angustifolia* Nees*	Tree	Evergreen
81	Lauraceae	*Litsea* sp.	Tree	Evergreen
82	Lecythidaceae	*Careya arborea* Roxb.	Tree	Deciduous
83	Lentibulariaceae	*Utricularia* sp.	Herb	
84	Lythraceae	*Lagerstroemia microcarpa* Wight	Tree	Deciduous
85	Lythraceae	*Woodfordia frutiosa* (L.) Kurz	Shrub	
86	Malvaceae	*Bombax ceiba* L.	Tree	Deciduous
87	Malvaceae	*Ceiba pentandra* (L.) Gaertn.	Tree	Deciduous
88	Malvaceae	*Firmiana colorata* (Roxb.) R. Br.	Tree	Deciduous
89	Malvaceae	*Grewia tiliifolia* Vahl	Tree	Deciduous
90	Malvaceae	*Kydia calycina* Roxb.	Tree	Deciduous
91	Malvaceae	*Sterculia foetida* L.	Tree	Deciduous

	Family	Species	Habit	Foliar habit
92	Malvaceae	*Triumfetta rhomboidea* Jacq.	Shrub	
93	Melastomataceae	*Memecylon umbellatum* Burm. f.	Tree	Evergreen
94	Meliaceae	*Turraea villosa* Benn.	Shrub	
95	Menispermaceae	*Anamirta cocculus* (L.) Wight & Arn.	Liana	
96	Menispermaceae	*Diploclisia glaucescens* (Bl.) Diels	Climbing shrub	
97	Menispermaceae	*Tinospora sinensis* (Lour.) Merr.	Climbing shrub	
98	Molluginaceae	*Glinus oppositifolius* (L.) A. DC.	Herb	
99	Molluginaceae	*Mollugo pentaphylla* L.	Herb	
100	Moraceae	*Ficus amplissima* J.E. Sm.	Tree	Deciduous
101	Moraceae	*F. arnottiana* (Miq.) Miq.	Tree	Deciduous
102	Moraceae	*F. microcarpa* L.f.	Tree	Evergreen
103	Moraceae	*F. nervosa* B. Heyne ex Roth	Tree	Evergreen
104	Moraceae	*F. racemosa* L.	Tree	Deciduous
105	Moraceae	*F. talbotii* King	Tree	Evergreen
106	Moraceae	*F. virens* Ait. var. *virens*	Tree	Deciduous
107	Musaceae	*Ensete superbum* (Roxb.) Cheesm.	Herb	
108	Myrtaceae	*Syzygium* sp.	Tree	Evergreen
109	Oleaceae	*Jasminum malabaricum* Wight	Climbing shrub	
110	Oleaceae	*Olea dioica* Roxb.	Tree	Evergreen
111	Orchidaceae	*Aerides maculosa* Lindl.	Epiphyte	
112	Orchidaceae	*Dendrobium barbatulum* Lindl.	Epiphyte	
113	Orchidaceae	*Oberonia recurva* Lindl.	Epiphyte	
114	Piperaceae	*Piper* sp.	Climbing shrub	
115	Plantaginaceae	*Mecardonia procumbens* (Mill.) Small	Herb	
116	Poaceae	*Arundinella pumila* (Hochst. ex A. Rich.) Steud	Herb	
117	Poaceae	*Arundinella spicata* Dalz.	Herb	
118	Poaceae	*Bambusa bambos* (L.) Voss	Herb	
119	Poaceae	*Eragrostiella bifaria* (Vahl.) Bor	Herb	
120	Poaceae	*Eragrostis cilianensis* (All.) Vignolo-Lutati ex F.T. Hubb.	Herb	
121	Poaceae	*Heteropogon contortus* (L.) P.Beauv. ex. R. & S.	Herb	
122	Poaceae	*Isachne globosa* (Thunb.) O.Ktze. var. *globosa*	Herb	
123	Poaceae	*Ischaemum tumidum* Stapf ex Bor	Herb	
124	Poaceae	*Jansenella griffithiana* (C. Muell.)Bor	Herb	
125	Poaceae	*Oplismenus burmannii* (Retz.) P. Beauv.	Herb	
126	Poaceae	*Themeda triandra* Forssk.	Herb	
127	Primulaceae	*Maesa indica* (Roxb.) A. DC.	Shrub	
128	Ranunculaceae	*Clematis heynei* M.A. Rau	Climber	
129	Rubiaceae	*Catunaregam spinosa* (Thunb.) Tirveng.	Tree	Deciduous
130	Rubiaceae	*Hymenodictyon obovatum* Wall.	Tree	Deciduous
131	Rubiaceae	*Ixora brachiata* Roxb.	Tree	Evergreen
132	Rubiaceae	*Ixora nigricans* R. Br. ex Wight & Arn.	Shrub	
133	Rubiaceae	*Pavetta indica* Andr.	Shrub	
134	Rubiaceae	*Psydrax dicoccos* Gaertn.	Tree	Evergreen
135	Rutaceae	*Atalantia racemosa* Wight	Shrub	
136	Rutaceae	*Glycosmis pentaphylla* (Retz.) DC.	Shrub	
137	Rutaceae	*Murraya koenigii* (L.) Spr.	Tree	Evergreen
138	Rutaceae	*M. paniculata* (L.) Jack	Tree	Evergreen
139	Rutaceae	*Paramignya monophylla* Wight	Liana	

	Family	Species	Habit	Foliar habit
140	Rutaceae	*Zanthoxylum rhetsa* (Roxb.) DC.	Tree	Deciduous
141	Santalaceae	*Osyris quadripartita* Salz. ex Decne.	Shrub	
142	Sapindaceae	*Allophylus cobbe* (L.) Raeusch.	Tree	Deciduous
143	Sapindaceae	*Dimocarpus longan* Lour.	Tree	Evergreen
144	Sapindaceae	*Sapindus laurifolius* Vahl	Tree	Deciduous
145	Sapotaceae	*Xantolis tomentosa* (Roxb.) Raf.	Tree	Evergreen
146	Scrophulariaceae	*Rhamphicarpa fistulosa* (Hochst.) Benth.	Herb	
147	Scrophulariaceae	*Striga gesnerioides* (Willd.) Vatke	Herb	
148	Smilacaceae	*Smilax zeylanica* L.	Climber	
149	Solanaceae	*Solanum anguivi* Lam.	Shrub	
150	Thymelaeaceae	*Gnidia glauca* (Fresen.) Gilg.	Shrub	
151	Ulmaceae	*Celtis cinnamomum* Lindl. ex Planch	Tree	Evergreen
152	Urticaceae	*Boehmeria macrophylla* Hornem.	Shrub	
153	Urticaceae	*Girardinia diversifolia* (Link) Friis	Herb	
154	Vitaceae	*Cissus elongata* Roxb.	Climber	
155	Vitaceae	*C. repens* Lamk	Climber	
156	Vitaceae	*Leea indica* (Burm. f.) Merr.	Shrub	
157	Vitaceae	*L. setuligera* C.B. Cl.	Shrub	

Table 2. Diversity parameters of the study area.

	Present study	Watve et al. 2003*	Muthuramkumar et al. 2006	Kanade et al. 2008	Joglekar et al. 2015
Study area	Mulshi Forest area, NWG	Mulshi Forest area, NWG	Valparai Plateau, SWG	Chandoli NP, NWG	Koyana WS, NWG
Unit sampling area	0.1ha	0.05–0.1 ha	0.8ha	0.5ha	0.5ha
Total sampling area	0.3ha	0.635ha	4ha	5ha	6ha
Girth class	G>10cm	G>10cm	G>30cm	G>15cm	G>15cm
Number of families	23 (19–21)	31 (9–16)	-	44	41
Number of genera	42 (28–34)	45 (11–20)	-	86	-
Number of species (S)	49 (33–39)	52 (12–20)	144 (38–73)	120 (25–57)	108 (14–42)
Number of individuals (N) per area	444 (133–158)/ 0.3ha	633–1720.0/ 1.0ha	307–453/ 0.8ha	149–657/ 0.5ha	84–544/ 0.5ha
N/S	9.06 (3.5–4.79)	3.92–6.36	-	5.96–19.32	-
Margalef's index	7.87 (6.32–7.57)	6.67–9.14	-	-	-
Simpson's dominance index	0.057 (0.052–0.078)	0.11–0.31	-	-	-
Simpson's reciprocal index (1/D)	17.48 (12.76–19.08)	3.23–9.09	-	-	-
Berger-Parker dominance	0.17 (0.13–0.20)	-	-	-	-
Shannon's index	3.36 (2.97–3.26)	2.77–3.43	-	2.0–3.2	1.5–3.03
Evenness	0.59 (0.59–0.68)	-	-	-	-
Equitability	0.86 (0.85–0.90)	0.63–0.84	-	-	-
Fisher's α index	14.07 (12.7–17.8)	-	11.42–24.62	-	-
Abundance based coverage estimate (ACE)	51.78 (39.99–48.04)	-	-	-	-
Chao-1	51.49 (39.99–48.04)	-	-	-	-
Jack 1	54.33	-	-	-	-
Jack 2	53.50	-	-	-	-

Note: Figures in parentheses indicate the range of values in individual strip transects; *Density extrapolated to 1ha; NWG - northern Western Ghats, SWG - southern Western Ghats.

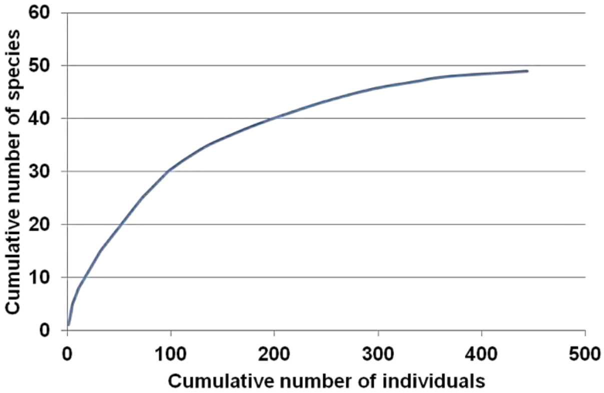

Figure 2. Species accumulation curve.

17.48. Berger-Parker dominance index, which indicates the dominance of most abundant species, was 0.17. Shannon index (H) of the study site was 3.36, while evenness and equitability indices were 0.59 and 0.86, respectively. Fisher's alpha diversity index for the study site was 14.07. The species richness estimators such as Chao-1 and ACE index of the study site were 51.49 and 51.78, respectively. Similarly, Jackknife estimators of species richness Jack 1 and Jack 2 were 54.33 and 53.50, respectively (Table 2). Species accumulation curve (Fig. 2) showed a typical hyperbola-shaped curve reaching approximately to asymptote; the estimated species richness was close to observed species richness (49).

DISCUSSION

Protected areas such as wildlife sanctuaries (WS) and national parks (NP) have high conservation priorities; presently, there are 10 WSs and two NPs within the auspices of NWG, covering an area of 2,151.93km^2. The remaining forest area (~11,350km^2) of NWG, however, does not fall under the protected area network and is mostly composed of discontinuous forest patches that are highly vulnerable to anthropogenic activities (Kale et al. 2010). In the 20th Century, several dams were constructed on the rivers originating in NWG, which created water bodies covering 1,681.33km^2, contributing further to the loss of forest cover of NWG (Panigrahy et al. 2010). Collectively, NWG is under intense pressure of further habitat loss and, together with its topology and anthropogenic activities, the landscape matrix has become a mosaic of disjunct forest patches, dams, agricultural lands, and villages. Habitat loss typically leads to fragmentation; however, fragmented forests often retain mature forest communities. Hence, the cumulative species richness of fragmented patches can be comparable with that of mature forests. This implies that the fragmented forest patches should also be conserved to protect the gene pool, to prevent species extinction, and to maintain forest biodiversity. In view of this, small-scale inventories in fragmented forest patches are very important to document the plant community structure and to create a baseline for the restoration of diversity.

The present study documented the floristic composition of a representative fragmented forest patch of NWG and reported 157 species of flowering plants including 49 tree species from the area of 0.3ha. The number of tree species recorded in the present study constitutes ~11% of the total native tree species of Maharashtra (Ghate & Datar 2009). The number of tree species recorded per unit area was higher than that previously reported in various regions of the WG: 12–20 species in 0.05–0.1 ha in Mulshi Forest area, NWG (Watve et al. 2003); 25–57 species in 0.5ha in Chandoli NP, NWG (Kanade et al. 2008); 14–42 species in 0.5ha in Koyana WS, NWG (Joglekar et al. 2015), and 38–73 species in 0.8ha in Valparai plateau, southern WG (Muthuramkumar et al. 2006). The higher species richness observed in the present study could partly be due to the differences in sampling method and sampling area across different studies since species richness is affected by these two factors and different species maybe over- or under-represented in different locations (Gotelli & Colwell 2001).

The species accumulation curve reached approximately to the asymptote and the observed species number was close to the estimated species richness. Extensive sampling of the whole study area might result in an addition of a few species, reaching estimated species richness and reducing the number of monospecific families. Higher species richness per area indicates a low level of disturbance at the study site; however, very few endemic species were observed. Species reported in the present study are comparable with a previous study in the same area (Watve et al. 2003), and most of the species found were pioneer species (e.g., *Memecylon umbellatum* Burm.f.) with a few climax species (e.g., *Holigarna arnottiana* (Wt.) Kurz). This observation correlates with that of Arroyo-Rodriguez et al. (2009), who reported a high percentage of pioneer species along with remnant species of the mature forest communities in the rain forest fragments in Los Tuxtlas, Mexico.

Tree density of 444 individual trees (G>10cm) from the area of 0.3ha was higher than previously

Image 2. Plant species observed in the study area: A - *Actinodaphne angustifolia* Nees | B - *Anodendron manubriatum* Merr. | C - *Eranthemum roseum* (Vahl) R. Br. | D - *Hemigraphis latebrosa* (Heyne ex Roth) Nees | E - *Memecylon umbellatum* Burm.f. | F - *Murraya paniculata* (L.) Jack | G - *Olea dioica* Roxb. | H - *Turraea villosa* Benn. © Rani Bhagat.

Image 3. Plant species observed in the study area: A - *Asparagus racemosus* Willd. | B - *Cissus elongata* Roxb. | C - *Ensete superbum* (Roxb.) Cheesm. | D - *Ixora nigricans* R. Br. ex Wight & Arn. | E - *Leucas ciliata* Benth. | F - *Macaranga peltata* (Roxb.) Meull. - Arg. | G - *Oberonia recurva* Lindl. | H - *Solena amplexicaulis* (Lam.) Gandhi. © Rani Bhagat.

Image 4. Plant species observed in the study area: A - *Argyreia sericea* Dalz. & Gibs. | B - *Boehmeria macrophylla* Hornem. | C - *Celtis cinnamomum* Lindl. ex Planch. | D - *Entada rheedei* Spreng. | E - *Geissaspis tenella* Bth. | F - *Pavetta indica* Andr. | G - *Tylophora dalzellii* Hook.f. | H - *Xantolis tomentosa* (Roxb.) Raf. © Rani Bhagat.

Image 5. Plant species observed in the study area: A - *Canscora diffusa* (Vahl) R. Br. ex R. & S. | B - *Colebrookea oppositifolia* Sm. | C - *Heteropogon contortus* (L.) P.Beauv. ex R. & S. | D - *Ficus talbotii* King | E - *Jasminum malabaricum* Wight | F - *Osyris quadripartita* Salz. ex Decne. | G - *Psydrax dicoccos* Gaertn. | H - *Sterculia foetida* L. © Rani Bhagat.

reported from various regions of WG (Watve et al. 2003; Muthuramkumar et al. 2006; Kanade et al. 2008; Joglekar et al. 2015). These variations, however, might be caused due to differences in the sampling method and girth classes used in different studies. Nevertheless, the N/S ratio for the study site was comparable with the values previously reported for similar forest type in Mulshi Forest area (Watve et al. 2003) and Chandoli NP (Kanade et al. 2008). Similarly, Margalef's index of species richness was comparable with the values reported at Mulshi Forest area (Watve et al. 2003).

A higher Berger-Parker dominance index was the result of relative dominance of a single species (e.g., *Memecylon umbellatum* Burm.f.). Simpson's dominance index (1/D) was higher compared to a previous study in Mulshi Forest area (Watve et al. 2003); however, this index is known to be affected by the presence of singleton species. Shannon index of the study site was comparable with the values reported for similar forest type at Mulshi Forest area (Watve et al. 2003), Chandoli NP (Kanade et al. 2008), and Koyana WS (Joglekar et al. 2015). Equitability values for the study site suggest a low level of dispersion of species within the study site and were comparable to a previous study at Mulshi Forest area (Watve et al. 2003). Fisher's α index for the study site was within the range of values reported for the forest fragments at Valparai plateau, southern WG (Muthuramkumar et al. 2006).

Under the dominance of *Syzygium* spp. and *Actinodaphne* spp. observed, the present study suggests that the community composition is different than the typical *M-S-A* series forest. A previous study (Watve et al. 2003) in the Mulshi Forest area, NWG, also reported a similar observation for a few locations, where species composition differs from *M-S-A* type and the composition pattern of *Memeylon-Xantolis-Actinodaphne* was reported. Other studies in NWG suggested a subtype of *M-S-A* series forest composed of *Memecylon-Syzygium-Olea* based on abundance (Kanade et al. 2008; Joglekar et al. 2015). These communities, however, are not completely separate since most of the species are shared by both the types. This observation indicates the fragments of a larger forest continuum, where some species became dominant over a small area as per local biotic and abiotic conditions (Watve et al. 2003; Kanade et al. 2008).

In the present study, similar numbers of evergreen and deciduous species were recorded; however, evergreen trees were numerically dominant as compared to deciduous trees. Deciduous tree species were found either alongside streams and upper slopes of the study site having shallow soil depth or at the edge of the forest fragments. The mosaic of evergreen and deciduous tree species along the streams (e.g., *Ficus arnottiana* Miq.) or upper slopes may be explained by habitat heterogeneity and microhabitat preference (Fang et al. 2017). While the occurrence of deciduous tree species at the forest edge (e.g., *Bombax ceiba* L.) may be the result of fragmentation. Edge effect promotes a shift in the functional composition near the forest edge, with the local dominance of pioneer and small-seeded wind-dispersed species (Mendes et al. 2016). Watve et al. (2003) suggested the dependence of these species on germplasm from scrub areas surrounding the forest patches.

CONCLUSIONS

Forest fragmentation has become a global phenomenon and much of the Earth's remaining forest fragments are individually less than 10ha in size while 70% of the world's remaining forests are now found within 1km of the forest edge (Haddad et al. 2015). While some habitats like NWG are patchy by nature, the patchy continuum of forests has further been severely fragmented due to anthropogenic activities (Watve et al. 2003). The large area of NWG is composed of discontinuous and fragmented forests and these patches are categorized as either reserved forest or, occasionally, unclassified forest. While protected areas like WSs and NPs have a high priority for conservation with access restrictions, such restrictions are not being imposed on non-protected areas, which makes them much more vulnerable to anthropogenic activities. The present study revealed that even such small fragmented forest patches could also harbour a high diversity of flowering plants and that they need to be conserved by increasing awareness of the local communities and vigilance for destructive activities. This would aid in conserving the biodiversity of the entire region as a whole.

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Threatened Taxa

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First assessment of bird diversity in the UNESCO Sheka Forest Biosphere Reserve, southwestern Ethiopia: species richness, distribution and potential for avian conservation

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Abstract: The Sheka Zone in southwestern Ethiopia is covered by some of the largest remaining forests in the Eastern Afromontane biodiversity hotspot. Owing to the rich biodiversity and a high degree of endemism, it was declared as a biosphere reserve by UNESCO in 2012 and is considered a Key Biodiversity Area. Detailed knowledge on species diversity and distribution in the reserve is, however, severely limited. From February to April 2016, an assessment of the bird diversity and distribution in the reserve was made for the first time through point count transects, camera-trap recordings and opportunistic observations. In total, 244 bird species were identified, of which 19% was only found within the reserve's designated protected zones. Our study indicates a remarkable bird species richness across the different habitats in Sheka Forest Biosphere Reserve and can be used as a baseline for future monitoring studies and conservation planning.

Keywords: Avifauna, Eastern Afromontane Biodiversity Hotspot, habitat occupation, Horn of Africa, inventory, IUCN.

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Author Contribution: MDB and MB designed the study, MVO, BO, JE and MDB collected the data, BO and MDB analysed the data. MVO, JE and MDB wrote the manuscript.

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INTRODUCTION

Ethiopia is recognized among the 35 most biodiverse regions in the world and its biodiversity is renowned for its high percentage of endemism. The highlands in the southwest, where most of the larger forest tracts remain, are part of the Eastern Afromontane Biodiversity Hotspot (Mittermeier et al. 2011). Natural habitats are highly diverse in this region, where the forest structure changes along a large elevation gradient (Friis 1992), with moist evergreen Afromontane rainforests presenting the dominant vegetation type, but also including bamboo forests and transitional rainforests leading down to semi-deciduous forests at lower altitudes. In most areas, the forests are interspersed with wetlands or, at higher altitude, moorlands. Ethiopian natural forests are however rapidly disappearing (Dessie & Kleman 2007; Reusing 2000), with approximately 11.4% or 12,499,000ha of total forest cover left (FAO 2015).

The Sheka Zone in southwestern Ethiopia still harbors some of the largest remaining Afromontane forests in the country (>100,000ha). Nevertheless, the combination of a rising population, ongoing land-allocation to agricultural investors and a lack of land-use planning are increasing pressure on the remaining natural habitats. As such, the deforestation rate within Sheka is one of the highest in Ethiopia, with severe impacts on local economy, culture and environment (Woldemariam & Fetene 2007). Sheka forest is considered a Key Biodiversity Area (Birdlife International 2017) and, in 2012, it was recognized by UNESCO as the Sheka Forest Biosphere Reserve. This recognition has led to the zonation of the area into core-, buffer- and transition zones (Fig. 1). These are, respectively, devoted to long-term protection of intact forests (core zones), participatory forest management and low-intensity production (buffer zones), and sustainable human settlement and agriculture (transition zones) (Gole & Getaneh 2011). The forest furthermore provides an important refuge for the native genetic diversity of wild crop relatives with significant agricultural value. The most prominent example is the indigenous wild coffee *Coffea arabica*, which can still be found in reasonable densities in the broadleaf forest of Sheka, but also other wild crop relatives that are imperative for local food provisioning such as Enset or 'False Banana' *Ensete ventricosum* and Ethiopian Cardamom *Aframomum corrorima*. All combined, there are strong incentives to safeguard this forest also from an economic and agricultural perspective (De Beenhouwer et al. 2013; Aerts et al. 2015).

Biodiversity and conservation research has seen a recent increase in southwestern Ethiopia, mainly in relation to agroforestry (e.g., Hundera et al. 2013; Tadesse et al. 2014); however, biodiversity studies in remote forest regions such as Sheka have been very limited thus far, despite the recognition as a UNESCO biosphere reserve and strong ongoing habitat degradation. Detailed insights in the diversity, distribution and abundance of species in the area are hardly available. Likewise, information on the bird diversity in Sheka forest is very scarce, but limited research done in the broader region (e.g., Woldegeorgis & Wube 2012) provides clear indications for a large bird species diversity in remaining forest tracts of southwestern Ethiopia. Here, we present a first comprehensive inventory of the bird diversity in Sheka Forest Biosphere Reserve, discuss our observations in relation to the delineated management zones, and highlight the biosphere reserve as an understudied yet highly valuable area for bird conservation and continued biodiversity studies.

MATERIALS AND METHODS

From Masha (around 7.749^{0}N & 35.471^{0}E; ca. 2,250m), the largest village in the area and capital of the Sheka Zone, we surveyed a variety of core-, buffer- and transition zones across the three districts, or 'woredas', situated in the biosphere reserve (Masha, Anderacha and Yeki). Our field expeditions took place from 2 February 2016 until 30 April 2016, and nine different 'kebeles' (the smallest administrative division) were visited across the three woredas (Table 1). The humid highlands of southwestern Ethiopia are characterized by a short rainy season from March to April and a long rainy season from June to October, with an average temperature of 18.4°C and yearly precipitation of 1,783mm. Hence, our expeditions were carried out immediately prior to and during the short rainy season. Permission for the field work was granted by the Ethiopian Wildlife Conservation Authority (EWCA) at the national level, the head office of the Sheka Zone and by kebele leaders on the local administrative level. The study was part of a larger expedition to assess the biodiversity in the reserve.

Birds were identified using visual, vocal and camera trap observations. Photo and audio recordings were made to support identification. When recordings of certain species were lacking, only those with double observations were listed. Visual and vocal assessments were done during early morning point transect surveys and on an ad hoc basis in all locations visited throughout

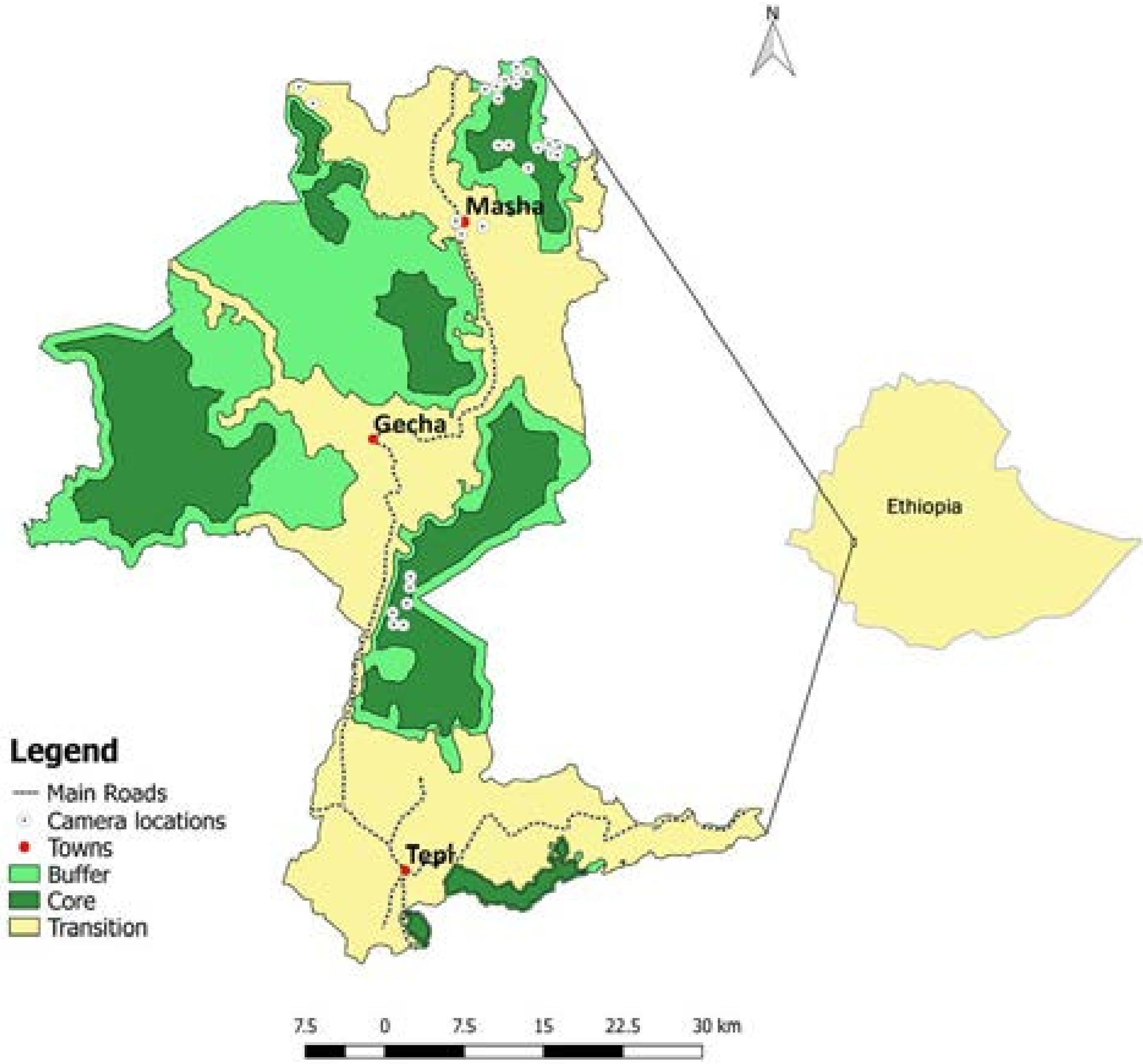

Figure 1. An overview of the Sheka Forest Biosphere Reserve and its location in Ethiopia, showing the proposed zoning into different management zones (see legend; Gole & Getaneh 2011) and camera trapping locations within the reserve. Masha, Gecha and Tepi are the central towns, respectively, in the woredas of Masha, Anderacha and Yeki.

the expedition. Because the delineation between core and buffer zones was not always clear in the field, observations herein were collectively assigned to the 'protected zones' within the reserve. Assessments were carried out covering a wide variety of habitats. These were divided into seven categories for a provisional overview of species' habitat occupation throughout the reserve (Table 2). Early morning point transect surveys consisted of six counts of 10 minutes, interspersed by five minutes of walking in a predetermined direction. All birds seen and/or heard within a perimeter of 25 meters around the observer were noted. In this way, a total of 74 point transect surveys were carried out, with one survey always restricted to the same habitat. Species identification was done using the Helm field guide 'Birds

Table 1. An overview of the locations visited in Sheka Forest Biosphere Reserve during the inventory, highlighting the central areas and field camps around which search efforts were concentrated and their altitude as approximated by GPS readings.

Woreda	Location/kebele	GPS	Altitude (m)
Masha	Masha	7.749°N & 35.471°E	2293
	Ateso	7.711°N & 35.450°E	2332
	Shato forest (north)	7.856°N & 35.506°E	1681
	Shato forest (south)	7.803°N & 35.551°E	1712
	Karina	7.859°N & 35.339°E	2176
	Atele	7.707°N & 35.407°E	2385
Anderacha	Gecha	7.562°N & 35.404°E	2231
	Gandochi	7.417°N & 35.425°E	2576
Yeki	Tepi (and Gilo River)	7.198°N & 35.425°E	1097

Table 2. The studied habitat categories, including the number of point transect surveys conducted per habitat and the average number of bird species recorded per survey. Surveys were not focussed on settlements (Se) and grazing lands (Gr), which instead were assessed through opportunistic search efforts and camera trapping.

Habitat	Description	Surveys	No. of species, survey
Riverine forest (Rf)	Broadleaf forest and woodland along waterways.	9	24, 3
Wetland (We)	Open habitat, either permanently or seasonally saturated with water.	23	22, 3
Moorland (Mo)	Open habitat, characterised by low-growing vegetation on acidic soils.	8	16, 1
Broadleaf forest (Br)	Broadleaf forest and woodland.	22	22, 6
Bamboo forest (Bf)	Evergreen forest with bamboo as main vegetation type.	12	13, 4
Settlement (Se)	Villages and surroundings.	-	-
Grazing Land (Gr)	Grazing land and all other open areas except for wetland and moorland.	-	-

of the Horn of Africa' (Redman et al. 2011) as a main reference. Occasional unknown sounds were recorded and identified afterwards using the xeno-canto database (http://www.xeno-canto.org).

Camera trap monitoring was done with 16 camera traps in 28 different locations (see Fig. 1) for a total of approximately 510 camera trap days. Camera trap locations were selected based on their potential to monitor mammal diversity, but additional bird observations were made of crepuscular species and analysed as part of the present study.

RESULTS

We recorded a total of 244 bird species from 55 different families in the Sheka Forest Biosphere Reserve (Table 3; Images 1–4). Of the species recorded in the reserve during our fieldwork, 47 species or 19% were only found in the designated protected zones. All other species were found across a variety of management zones. Of the 155 species identified during the point transect surveys, 16 species were observed across all studied habitats, of which *Bradypterus cinnamomeus* (89.2% of surveys), *Turdus (olivaceus) abyssinicus* (83.8%), and *Zosterops poliogastrus kaffensis* (78.4%) were the most common bird species identified during the surveys. Riverine forest was the most species-rich habitat sampled with on average 24.3 species sampled per survey, while bamboo forest was the least species rich habitat with an average of 13.4 species recorded per survey (Table 2). Based on our observations, the main habitat types used by each species are noted, except for the species encountered on migration, for which no habitats could be determined (Table 3).

Eleven bird species that were recorded during the surveys are considered threatened based on the IUCN Red List. With the notable exception of the recorded vultures, these observations largely stem from within the designated protected zones of the reserve. Details on these species and their identification are discussed below:

Necrosyrtes monachus (Critically Endangered) (Image 1C)

A smaller brown vulture, identified based on its naked pink head and whitish-grey 'hooded' hindneck and nape. It is common and still very abundant around settlements in the region, but rather rare in a variety of other habitats. Like the other African vultures listed below, it is severely threatened by a combination of factors, including land conversion, active persecution as well as secondary poisoning.

Trigonoceps occipitalis (Critically Endangered)

A rather large blackish vulture with contrasting white belly and large red-colored bill. Singles and pairs are uncommon but found to be widespread in a variety of habitats including settlements.

Gyps africanus (Critically Endangered) (Image 1D)

A typical vulture with a bright brown back, dark brown plumage, dark bill and down feathers on the neck. Seen in groups of up to 20 birds but also often in the presence of other vulture species. Common and widespread in a variety of habitats, most numerous around settlements.

Gyps rueppellii (Critically Endangered)

This vulture is similar to *Gyps africanus* but easily distinguished based on its yellow bill and scaled appearance in adult birds caused by bright edges on dark feathers. Rather uncommon, but widespread and present in a variety of habitats including settlements.

Image 1 . Photographic records of bird species observed in Sheka Forest Biosphere Reserve: A. *Anhinga rufa* | B. *Bostrychia hagedash* | C. *Necrosyrtes monachus* | D. *Gyps africanus* | E. *Buteo augur* | F. *Stephanoaetus coronatus* | G. *Pternistis squamatus* (camera trap recording) | H. *Rougetius rougetii.*

Torgos tracheliotus (Endangered)

A very large, dark brown vulture with a pink head that shows distinctive skin folds. Pairs and solitary birds were encountered only a limited number of times around smaller settlements and agricultural areas.

Aquila nipalensis (Endangered)

A large eagle with brown upper parts and blackish flight feathers, larger and darker than *Aquila rapax*. Observed and photographed on only one occasion while on migration northwards on 18 April 2016 above a highland moorland at Gandochi.

Polemaetus bellicosus (Vulnerable)

A very large brown eagle with white body underparts. Only one sighting in a wetland in the protected zone of Shato where a territorial pair was seen and heard in flight on 24 April 2016.

Balearica pavonina (Vulnerable)

An unmistakable crane with predominantly black body plumage and a crown of golden feathers. Limited number of sightings on a single day during a wetland inventory around the town of Masha.

Terathopius ecaudatus (Near Threatened)

Easily recognised in flight from below, based on the black body plumage, black and white wings and chestnut tail. Observed only one time at Shato forest (south) and two times in highland moorland at Gandochi, where a male was photographed on 30 March 2016.

Stephanoaetus coronatus (Near Threatened) (Image 1F)

Large eagle with crest, giving the head a rather triangular appearance. Barred black and white from below, with chestnut underwing coverts. Widespread and common in the core forested areas, very rare elsewhere. Both juveniles and adults were seen and photographed on several occasions throughout the study.

Rougetius rougetii (Near Threatened) (Image 1H)

A brown rail with white undertail coverts. Very common in highland wetlands, also common in Moorlands and along the Gebba river.

Several species that were found in the reserve during the monitoring occur only in a very restricted range in Ethiopia. Although these species are not considered threatened on the IUCN red list nor are endemic, their isolated distribution within Ethiopia and/or occurrence at the extremes of their distribution ranges deserves special conservation attention. Except for *Cinnyris chloropygius*, these species were exclusively found within the protected zones of the reserve.

Sarothrura elegans

Most common in forest interior, but also more open woodland types. Never seen, but regularly heard at night or early morning during the short rainy season. Sometimes, several males could be heard and were recorded giving a long and low hooting "whoooooooo" lasting approximately three seconds and repeated at intervals of approximately five seconds.

Sarothrura rufa

Adult males have a chestnut red head and chest with otherwise black plumage with narrow but striking white streaks. Adult males were observed two times during an inventory in a wetland around Shato when flushed from about 5m from the observers in a wet grassland.

Bradypterus alfredi

Sound recorded at two different locations in highland bamboo forest were uncommon and localized. A rapid series of short notes all at the same pitch "chit-it chit-it chit-it".

Halcyon malimbica (Image 2E)

A striking blue kingfisher, distinguished from *Halcyon senegalensis* based on its blue breast-band and more extensive amount of black on its wings. Rare and secretive, but present around the largest rivers in the area. Often heard in wetland and riverine forest habitat in Shato forest, and one individual was photographed in lowland riverine forest near Tepi.

Anomalospiza imberbis

A small finch-like species. Males were recognised based on their black bill and yellow head and underparts. Only observed once in the largest wetland at the side of the Gebba River. A male was seen on 28 February 2018 for approximately 30 seconds sitting on top of a shrub at 15m from the observers during a wetland survey.

Cinnyris chloropygius

Males showed a metallic green head, breast and upper parts, a red breast-band and olive belly. Uncommon in open riverine woodland in the lowlands of Tepi, where one territorial male was seen actively foraging during a riverine forest survey by several observers.

Image 2. Photographic records of bird species observed in Sheka Forest Biosphere Reserve: A. *Actophilornis africanus* | B. *Turtur tympanistria* | C. *Poicephalus flavifrons* | D. *Agapornis taranta* | E. *Halcyon malimbica* | F. *Ispidina picta* | G. *Merops albicollis* | H. *Merops pusillus.*

Table 3. Bird species identified within Sheka Forest Biosphere Reserve, with IUCN conservation status (LC: Least Concern, NT: Near Threatened, VU: Vulnerable, EN: Endangered, CR: Critically Endangered), predominant habitat occupation (see Table 2, Mi: Migration), the identification method leading to species detection (OO: opportunistic observation; PT: point count transect observation; CT: camera trap observation), and main verification method (PH: photographic recording; AU: audio recording; DO: double observation). Species endemic to the Horn of Africa (Redman et al. 2011) are indicated with †. Species that were only observed in the protected zones are indicated with ‡. IUCN status according to https://www.iucnredlist.org, accessed on 29 September 2018.

	Species/family	Common name	IUCN	Habitat	Identification	Verification
	Podicipedidae (1)					
1	*Tachybaptus ruficollis*	Little Grebe	LC	Rf, We	CT, OO, PT	PH
	Phalacrocoracidae (1)					
2	*Phalacrocorax africanus*	Long-tailed Cormorant	LC	Rf	OO, PT	DO
	Anhingidae (1)					
3	*Anhinga rufa*‡	African Darter	LC	Rf	OO, PT	PH
	Heliornithidae (1)					
4	*Podica senegalensis*‡	African Finfoot	LC	Rf	OO, PT	DO
	Ardeidae (6)					
5	*Nycticorax nycticorax*‡	Black-crowned Night Heron	LC	Rf	OO	DO
6	*Bubulcus ibis*	Cattle Egret	LC	Gr	OO, PT	DO
7	*Ardeola ralloides*‡	Squacco Heron	LC	Mi	OO	PH
8	*Butorides striata*‡	Striated Heron	LC	Rf	OO	DO
9	*Ardea purpurea*	Purple Heron	LC	Rf	OO, PT	DO
10	*Ardea melanocephala*	Black-headed Heron	LC	Rf, We	OO, PT	DO
	Ciconiidae (5)					
11	*Ciconia ciconia*	White Stork	LC	Mi	OO	DO
12	*Ciconia microscelis*	African Woollyneck	LC	Rf, We, Gr	OO, PT	PH
13	*Ciconia abdimii*	Abdim's Stork	LC	Gr, Se	OO	PH
14	*Anastomus lamelligerus*	African Openbill	LC	Mi	OO	PH
15	*Leptoptilos crumeniferus*	Marabou Stork	LC	We, Se	OO	PH
	Threskiornithidae (2)					
16	*Bostrychia hagedash*	Hadada Ibis	LC	We, Gr, Se	CT, OO, PT	PH
17	*Bostrychia carunculata*†	Wattled Ibis	LC	We, Gr	CT, OO, PT	PH
	Anatidae (5)					
18	*Plectropterus gambensis*‡	Spur-winged Goose	LC	We	OO	DO
19	*Alopochen aegyptiaca*	Egyptian Goose	LC	We, Rf	OO, PT	DO
20	*Anas undulata*	Yellow-billed Duck	LC	Rf	PT	PH
21	*Anas sparsa*	African Black Duck	LC	Rf	OO	PH
22	*Anas crecca*‡	Eurasian Teal	LC	Mi	OO	DO
	Accipitridae (28)					
23	*Milvus migrans*	Black Kite	LC	Gr, Se	OO, PT	PH
24	*Milvus (migrans) aegyptius*	Yellow-billed Kite	LC	Gr, Se	CT, OO, PT	PH
25	*Haliaeetus vocifer*	African Fish-Eagle	LC	Rf	OO, PT	PH
26	*Necrosyrtes monachus*	Hooded Vulture	CR	Gr, Se	CT, PT	PH
27	*Trigonoceps occipitalis*	White-headed Vulture	CR	Gr, Se	PT	PH
28	*Torgos tracheliotus*	Lappet-faced Vulture	EN	Gr, Se	OO	PH
29	*Gyps africanus*	White-backed Vulture	CR	Gr, Se	OO	PH
30	*Gyps rueppellii*	Rüppell's Vulture	CR	Gr, Se	OO	PH
31	*Circaetus cinereus*‡	Brown Snake-Eagle	LC	Br	OO	PH
32	*Circaetus pectoralis*‡	Black-chested Snake-eagle	LC	Br	OO	PH

	Species/family	Common name	IUCN	Habitat	Identification	Verification
33	*Accipiter tachiro*	African Goshawk	LC	Br	OO, PT	PH
34	*Accipiter rufiventris*	Rufous-breasted Sparrowhawk	LC	Br	OO	PH
35	*Accipiter minullus*‡	Little Sparrowhawk	LC	Rf	OO	DO
36	*Accipiter melanoleucus*	Great Sparrowhawk	LC	Br	OO	PH
37	*Aviceda cuculoides*‡	African Cuckoo-Hawk	LC	Br	OO	PH
38	*Polyboroides typus*	African Harrier-Hawk	LC	Br, Gr, Se	OO, PT	PH
39	*Pernis apivorus*	European Honey-Buzzard	LC	Mi	OO	PH
40	*Buteo augur*	Augur Buzzard	LC	Gr, Br	OO, PT	PH
41	*Buteo buteo*	Common Buzzard	LC	Mi	OO, PT	PH
42	*Buteo rufinus*‡	Long-legged Buzzard	LC	Mi	OO	DO
43	*Clanga pomarina*‡	Lesser Spotted Eagle	LC	Mi	OO	PH
44	*Aquila rapax*	Tawny Eagle	LC	Gr	OO, PT	PH
45	*Aquila nipalensis*‡	Steppe Eagle	EN	Mi	OO	PH
46	*Hieraaetus pennatus*‡	Booted Eagle	LC	Mi	OO	DO
47	*Hieraaetus ayresii*	Ayres's Hawk-Eagle	LC	Br	OO	PH
48	*Terathopius ecaudatus*‡	Bateleur	NT	Gr	OO	PH
49	*Lophaetus occipitalis*	Long-crested Eagle	LC	Br, Gr	OO, PT	PH
50	*Polemaetus bellicosus*‡	Martial Eagle	VU	We	OO	PH
51	*Stephanoaetus coronatus*	African Crowned Eagle	NT	Br	OO	PH
	Falconidae (3)					
52	*Falco ardosiaceus*‡	Grey Kestrel	LC	Gr	OO	PH
53	*Falco cuvierii*‡	African Hobby	LC	Rf	OO	PH
54	*Falco subbuteo*‡	Eurasian Hobby	LC	Mi	OO	DO
	Phasianidae (2)					
55	*Pternistis squamatus*‡	Scaly Francolin	LC	Br	CT	PH
56	*Pternistis castaneicollis*†	Chestnut-naped Francolin	LC	Br, Gr	OO	AU
	Sarothruridae (2)					
57	*Sarothrura elegans*‡	Buff-spotted Flufftail	LC	Br	OO	AU
58	*Sarothrura rufa*‡	Red-chested Flufftail	LC	We	OO, PT	DO
	Rallidae (4)					
59	*Amaurornis flavirostra*	Black Crake	LC	Rf, We	OO, PT	PH
60	*Rougetius rougetii*†	Rouget's Rail	NT	Rf, We, Mo	CT, OO, PT	PH
61	*Rallus caerulescens*	African Rail	LC	Rf, We	OO, PT	PH
62	*Gallinula chloropus*	Common Moorhen	LC	Rf	OO	DO
	Gruidae (1)					
63	*Balearica pavonina*	Black Crowned Crane	VU	We	OO	DO
	Jacanidae (1)					
64	*Actophilornis africanus*‡	African Jacana	LC	Rf	CT, OO	PH
	Scolopacidae (4)					
65	*Actitis hypoleucos*	Common Sandpiper	LC	Rf, We	OO	DO
66	*Tringa glareola*‡	Wood Sandpiper	LC	We	OO	DO
67	*Tringa ochropus*	Green Sandpiper	LC	We	OO	DO
68	*Gallinago nigripennis*‡	African Snipe	LC	We	PT	DO
	Columbidae (10)					
69	*Treron calvus*	African Green Pigeon	LC	Br	OO, PT	PH

	Species/family	Common name	IUCN	Habitat	Identification	Verification
70	*Treron waalia*	Bruce's Pigeon	LC	Br	OO, PT	DO
71	*Columba guinea*	Speckled Pigeon	LC	Se	OO	DO
72	*Columba arquatrix*	African Olive Pigeon	LC	Br, Mo, Bf	OO, PT	PH
73	*Turtur afer*‡	Blue-spotted Wood Dove	LC	Br	OO, PT	DO
74	*Turtur tympanistria*	Tambourine Dove	LC	Br, Gr, Se	CT, PT	PH
75	*Streptopelia vinacea*	Vinaceous Dove	LC	Br, Gr	PT	DO
76	*Streptopelia semitorquata*	Red-eyed Dove	LC	Br, Gr, Se	OO, PT	PH
77	*Streptopelia lugens* ‡	Dusky Turtle Dove	LC	Br	PT	DO
78	*Aplopelia larvata*‡	Lemon Dove	LC	Br	CT, OO	PH
	Psittacidae (2)					
79	*Poicephalus flavifrons*†	Yellow-fronted Parrot	LC	Br	PT	PH
80	*Agapornis taranta*†	Black-winged Lovebird	LC	Br	PT	PH
	Musophagidae (1)					
81	*Tauraco leucotis*	White-cheeked Turaco	LC	Br, Bf	OO, PT	AU
	Cuculidae (7)					
82	*Cuculus canorus*	Common Cuckoo	LC	Mi	OO	DO
83	*Cuculus solitarius*	Red-chested Cuckoo	LC	Br, Se	OO, PT	PH
84	*Cuculus clamosus*	Black Cuckoo	LC	Br	PT	AU
85	*Chrysococcyx klaas*	Klaas's Cuckoo	LC	Br, Se	OO, PT	AU
86	*Chrysococcyx cupreus*	African Emerald Cuckoo	LC	Br, Se	PT	PH
87	*Centropus senegalensis*	Senegal Coucal	LC	Br	CT, OO, PT	PH
88	*Centropus monachus*	Blue-headed Coucal	LC	Rf, We, Mo	OO, PT	PH
	Strigidae (2)					
89	*Strix woodfordii*	African Wood Owl	LC	Br	OO	AU
90	*Bubo cinerascens*	Greyish Eagle-Owl	LC	Br, Se	OO	DO
	Apodidae (3)					
91	*Tachymarptis melba*	Alpine Swift	LC	Mi	OO, PT	DO
92	*Apus apus*	Common Swift	LC	Gr, Se	OO, PT	DO
93	*Apus niansae*	Nyanza Swift	LC	Gr, Se	OO, PT	DO
	Coliidae (1)					
94	*Colius striatus*	Speckled Mousebird	LC	Se	CT, OO, PT	PH
	Trogonidae (1)					
95	*Apaloderma narina*	Narina Trogon	LC	Br	PT	AU
	Alcedinidae (8)					
96	*Ceryle rudis*	Pied Kingfisher	LC	Rf	OO, PT	PH
97	*Megaceryle maxima*	Giant Kingfisher	LC	Rf	PT	PH
98	*Halcyon senegalensis*	Woodland Kingfisher	LC	Rf, Br	PT	PH
99	*Halcyon malimbica*‡	Blue-breasted Kingfisher	LC	Rf	PT	PH
100	*Halcyon chelicuti*	Striped Kingfisher	LC	Br	OO	PH
101	*Alcedo semitorquata*‡	Half-collared Kingfisher	LC	Rf	OO, PT	PH
102	*Corythornis cristatus*	Malachite Kingfisher	LC	Rf	OO, PT	PH
103	*Ispidina picta*	Pygmy Kingfisher	LC	Rf, We	OO	PH
	Meropidae (4)					
104	*Merops pusillus*	Little Bee-eater	LC	Gr	OO	DO
105	*Merops (variegatus) lafresnayii*	Blue-breasted Bee-eater	LC	Br, Gr	OO	PH

	Species/family	Common name	IUCN	Habitat	Identification	Verification
106	*Merops apiaster*	European Bee-eater	LC	Gr	PT	DO
107	*Merops albicollis*	White-throated Bee-eater	LC	Rf, Br	PT	PH
	Coraciidae (1)					
108	*Eurystomus glaucurus*	Broad-billed Roller	LC	Rf	OO, PT	DO
	Bucerotidae (1)					
109	*Tockus alboterminatus*	Crowned Hornbill	LC	Br	OO, PT	AU
	Bucorvidae (2)					
110	*Bycanistes brevis*	Silvery-cheeked Hornbill	LC	Br	OO, PT	PH
111	*Bucorvus abyssinicus*	Abyssinian Ground-hornbill	LC	We, Gr	OO, PT	DO
	Lybiidae (4)					
112	*Pogoniulus chrysoconus*	Yellow-fronted Tinkerbird	LC	Br	OO, PT	PH
113	*Pogoniulus pusillus*	Red-fronted Tinkerbird	LC	Br	PT	AU
114	*Lybius bidentatus*	Double-toothed Barbet	LC	Br	OO	PH
115	*Lybius undatus*†	Banded Barbet	LC	Br	OO	DO
	Indicatoridae (4)					
116	*Indicator indicator*‡	Greater Honeyguide	LC	Rf	PT	PH
117	*Indicator variegatus*‡	Scaly-throated Honeyguide	LC	Rf	PT	AU
118	*Indicator minor*	Lesser Honeyguide	LC	Rf, Br	OO	AU
119	*Prodotiscus zambesiae*‡	Green-backed Honeybird	LC	Rf	OO	DO
	Picidae (5)					
120	*Jynx torquilla*	Eurasian Wryneck	LC	Mi	OO	DO
121	*Campethera nubica*	Nubian Woodpecker	LC	Br	PT	DO
122	*Dendropicos fuscescens*	Cardinal Woodpecker	LC	Br	OO, PT	PH
123	*Dendropicos abyssinicus*†	Abyssinian Woodpecker	LC	Br	PT	PH
124	*Dendropicos spodocephalus*	Grey-headed Woodpecker	LC	Gr	OO	DO
	Hirundinidae (12)					
125	*Ptyonoprogne fuligula*	Rock Martin	LC	Se	OO, PT	DO
126	*Riparia paludicola schoensis*	Plain Martin	LC	Gr	OO	DO
127	*Delichon urbicum*	Common House Martin	LC	Gr, Se	OO, PT	DO
128	*Cecropis daurica*	Red-rumped Swallow	LC	Gr, Se	OO, PT	DO
129	*Cecropis senegalensis*	Mosque Swallow	LC	Gr, Se	OO, PT	PH
130	*Cecropis abyssinica*	Lesser Striped Swallow	LC	Gr	OO	DO
131	*Pseudhirundo griseopyga*	Grey-rumped Swallow	LC	Mi	OO	DO
132	*Hirundo rustica*	Barn Swallow	LC	Gr, Se	OO, PT	DO
133	*Hirundo lucida*	Red-chested Swallow	LC	Gr	OO, PT	DO
134	*Hirundo smithii*	Wire-tailed Swallow	LC	Gr, Se	PT	PH
135	*Hirundo aethiopica*	Ethiopian Swallow	LC	Se	OO	DO
136	*Psalidoprocne pristoptera*	Black Saw-wing	LC	We, Gr, Se	OO, PT	PH
	Motacillidae (9)					
137	*Motacilla flava (flava)*	Yellow Wagtail	LC	Gr, Se	OO, PT	DO
138	*Motacilla aguimp*	African Pied Wagtail	LC	Rf	CT, OO, PT	PH
139	*Motacilla clara*	Mountain Wagtail	LC	Rf	OO, PT	PH
140	*Motacilla alba*	White Wagtail	LC	Mi	OO	DO
141	*Anthus cinnamomeus*	Grassland Pipit	LC	We, Gr	CT, OO	PH

	Species/family	Common name	IUCN	Habitat	Identification	Verification
142	*Anthus leucophrys omoensis*	Plain-backed Pipit	LC	Gr	OO	PH
143	*Anthus similis*	Long-billed Pipit	LC	Gr	OO	PH
144	*Anthus cervinus*	Red-throated Pipit	LC	Mi	PT	PH
145	*Anthus trivialis*	Tree Pipit	LC	Mi	OO	DO
	Campephagidae (2)					
146	*Campephaga phoenicea*	Red-shouldered Cuckooshrike	LC	Br	PT	PH
147	*Coracina caesia*	Grey Cuckooshrike	LC	Rf, Br	OO	DO
	Pycnonotidae (2)					
148	*Pycnonotus barbatus schoanus*	Common Bulbul	LC	Br, Mo, Gr, Se	CT, OO, PT	PH
149	*Atimastillas flavicollis*	Yellow-throated Leaflove	LC	Br	PT	DO
	Muscicapidae (20)					
150	*Cossypha semirufa*	Rüppell's Robin-Chat	LC	Br, Bf, Gr, Se	CT, OO, PT	PH
151	*Cossypha heuglini*	White-browed Robin-Chat	LC	Rf	OO	DO
152	*Phoenicurus phoenicurus*	Common Redstart	LC	Mi	OO, PT	DO
153	*Saxicola (torquatus) albofasciatus*	African Stonechat	LC	We, Gr	OO, PT	PH
154	*Saxicola rubetra*	Whinchat	LC	We, Gr	OO, PT	DO
155	*Oenanthe oenanthe*	Northern Wheatear	LC	Mi	OO	PH
156	*Cercomela sordida*	Moorland Chat	LC	We, Mo, Se	OO, PT	PH
157	*Psophocichla litsitsirupa*	Groundscraper Thrush	LC	Se	OO, PT	PH
158	*Monticola saxatilis*	Common Rock Thrush	LC	Mi	OO, PT	DO
159	*Turdus (olivaceus) abyssinicus*	African Mountain Thrush	LC	Br, Bf, Gr, Se	CT, PT	PH
160	*Turdus pelios*	African Thrush	LC	Gr, Se	OO	DO
161	*Zoothera piaggiae*	Abyssinian Ground Thrush	LC	Br	CT, PT	PH
162	*Melaenornis chocolatinus†*	Abyssinian Slaty Flycatcher	LC	Br, Gr, Se	OO, PT	PH
163	*Melaenornis edolioides*	Northern Black Flycatcher	LC	Gr, Se	OO	PH
164	*Bradornis microrhynchus*	African Grey Flycatcher	LC	Br	OO	DO
165	*Bradornis pallidus*	Pale Flycatcher	LC	Se	OO	DO
166	*Muscicapa adusta*	African Dusky Flycatcher	LC	Br, Mo, Bf, Se	PT	PH
167	*Muscicapa striata*	Spotted Flycatcher	LC	Mi	OO	DO
168	*Terpsiphone viridis*	African Paradise Flycatcher	LC	Br, Gr, Se	CT, OO, PT	PH
169	*Myioparus plumbeus*	Lead-coloured Flycatcher	LC	Br	PT	PH
	Locustellidae (6)					
170	*Bradypterus baboecala*	Little Rush Warbler	LC	Rf, We	OO, PT	AU
171	*Bradypterus cinnamomeus*	Cinnamon Bracken Warbler	LC	Br, Mo, Bf	PT	PH
172	*Bradypterus alfredi‡*	Bamboo Warbler	LC	Bf	OO, PT	AU
173	*Acrocephalus baeticatus‡*	African Reed Warbler	LC	Rf	OO, PT	AU
174	*Acrocephalus schoenobaenus‡*	Sedge Warbler	LC	Mi	OO	DO
175	*Chloropeta natalensis*	African Yellow Warbler	LC	We, Gr	PT	PH
	Cisticolidae (8)					
176	*Camaroptera brevicaudata*	Grey-backed Camaroptera	LC	Br, Mo	OO, PT	AU
177	*Eremomela canescens‡*	Green-backed Eremomela	LC	Br	OO	DO
178	*Cisticola (galactotes) lugubris†*	Ethiopian Cisticola	LC	Rf, We, Mo	OO, PT	PH

	Species/family	Common name	IUCN	Habitat	Identification	Verification
179	*Cisticola erythrops*	Red-faced Cisticola	LC	Rf	OO	DO
180	*Cisticola cantans*	Singing Cisticola	LC	Gr, Se	PT	DO
181	*Prinia subflava*	Tawny-flanked Prinia	LC	Gr, Se	PT	PH
182	*Apalis flavida*	Yellow-breasted Apalis	LC	Br, Gr, Se	PT	DO
	Phylloscopidae (3)					
183	*Phylloscopus trochilus*	Willow Warbler	LC	Br, Gr, Se	OO, PT	DO
184	*Phylloscopus collybita*	Common Chiffchaff	LC	Br, Gr, Se	OO, PT	AU
185	*Phylloscopus umbrovirens*	Brown Woodland Warbler	LC	Br, Mo, Bf	OO, PT	PH
	Sylviidae (5)					
186	*Sylvia atricapilla*	Blackcap	LC	Br, Gr, Se	OO, PT	PH
187	*Sylvia borin*‡	Garden Warbler	LC	Mi	OO, PT	AU
188	*Sylvia abyssinica*	African Hill Babbler	LC	Br, Mo	OO, PT	PH
189	*Turdoides leucopygia*	White-rumped Babbler	LC	Br	OO, PT	PH
190	*Parophasma galinieri*†‡	Abyssinian Catbird	LC	Mo, Bf	OO, PT	AU
	Platysteiridae (2)					
191	*Batis erlangeri*	Western Black-headed Batis	LC	Br	PT	AU
192	*Platysteira cyanea*	Brown-throated Wattle-eye	LC	Br	OO, PT	AU
	Zosteropidae (2)					
193	*Zosterops poliogastrus kaffensis*	Montane White-eye	LC	Br, Bf	OO, PT	DO
194	*Zosterops abyssinicus*	Abyssinian White-eye	LC	Br	OO, PT	DO
	Nectariniidae (6)					
195	*Nectarinia tacazze*	Tacazze Sunbird	LC	Br, Mo, Gr, Se	OO, PT	PH
196	*Cinnyris cupreus*	Copper Sunbird	LC	Br, Gr, Se	OO, PT	DO
197	*Cinnyris venustus fazoqlensis*	Variable Sunbird	LC	Br, Gr, Se	PT	PH
198	*Cinnyris chloropygius*	Olive-bellied sunbird	LC	Rf	OO	DO
199	*Chalcomitra senegalensis*	Scarlet-chested Sunbird	LC	Br	PT	AU
200	*Cyanomitra olivacea ragazzii*	Olive Sunbird	LC	We, Br, Gr	PT	PH
	Laniidae (3)					
201	*Lanius humeralis*	Northern Fiscal	LC	We, Gr, Se	PT	PH
202	*Lanius excubitor leucopygos*	Great Grey Shrike	LC	Mi	OO	DO
203	*Lanius collurio/isabellinus*‡	Red-backed/Isabelline Shrike	LC	Mi	PT	DO
	Malaconotidae (3)					
204	*Laniarius aethiopicus*	Ethiopian Boubou	LC	Br, Gr, Se	CT, OO, PT	PH
205	*Dryoscopus cubla*	Northern Puffback	LC	Br, Gr, Se	OO, PT	AU
206	*Tchagra senegalus*	Black-crowned Tchagra	LC	Br	OO	DO
	Oriolidae (3)					
207	*Oriolus oriolus*‡	Eurasian Oriole	LC	Mi	OO, PT	PH
208	*Oriolus larvatus rolleti*	Black-headed Oriole	LC	Br	OO, PT	DO
209	*Oriolus monacha*†	Abyssinian Oriole	LC	Br, Bf	OO, PT	PH
	Corvidae (3)					
210	*Corvus capensis*	Cape Crow	LC	Se	OO, PT	PH
211	*Corvus rhipidurus*	Fan-tailed Raven	LC	Se	OO	PH
212	*Corvus crassirostris*†	Thick-billed Raven	LC	Gr, Se	CT, OO, PT	PH

	Species/family	Common name	IUCN	Habitat	Identification	Verification
	Buphagidae (1)					
213	*Buphagus erythrorynchus*	Red-billed Oxpecker	LC	Gr	OO	PH
	Sturnidae (8)					
214	*Poeoptera stuhlmanni*	Stuhlmann's Starling	LC	Br	OO, PT	PH
215	*Onychognathus morio*	Red-winged Starling	LC	Br	OO	DO
216	*Onychognathus tenuirostris*	Slender-billed Starling	LC	Br, Gr	PT	DO
217	*Lamprotornis chalybaeus*	Greater Blue-eared Starling	LC	Br, Gr, Se	OO, PT	PH
218	*Lamprotornis splendidus*‡	Splendid Starling	LC	Rf, Br	OO, PT	DO
219	*Lamprotornis purpuroptera*	Rüppell's Starling	LC	Rf	OO, PT	AU
220	*Pholia sharpii*	Sharpe's Starling	LC	Br, Bf	OO, PT	PH
	Passeridae (1)					
221	*Passer swainsonii*	Swainson's Sparrow	LC	Gr, Se	OO, PT	PH
	Ploceidae (7)					
222	*Ploceus cucullatus abyssinicus*	Village Weaver	LC	Se	OO, PT	DO
223	*Ploceus ocularis*	Spectacled Weaver	LC	Br, Gr, Se	OO, PT	DO
224	*Ploceus nigricollis*	Black-necked Weaver	LC	Br	OO	PH
225	*Ploceus baglafecht*	Baglafecht Weaver	LC	Br, Gr, Se	OO, PT	DO
226	*Amblyospiza albifrons*‡	Grosbeak Weaver	LC	Rf, We	PT	PH
227	*Anaplectes rubriceps*	Red-headed Weaver	LC	Br	OO	DO
	Viduidae (5)					
228	*Anomalospiza imberbis*‡	Cuckoo Finch	LC	Rf, We	OO	DO
229	*Euplectes axillaris*‡	Fan-tailed Widowbird	LC	Rf, We	PT	DO
230	*Euplectes albonotatus*‡	White-winged Widowbird	LC	Rf, We	PT	DO
231	*Vidua macroura*	Pin-tailed Whydah	LC	Gr, Se	OO	DO
232	*Vidua chalybeata*	Village Indigobird	LC	Gr, Se	OO	PH
	Estrildidae (8)					
233	*Mandingoa nitidula*	Green Twinspot	LC	Br	OO	DO
234	*Cryptospiza salvadorii*	Abyssinian Crimsonwing	LC	Br, Bf	PT	AU
235	*Lagonosticta senegala*	Red-billed Firefinch	LC	Gr, Se	OO, PT	PH
236	*Coccopygia quartinia*	Yellow-bellied Waxbill	LC	Br, Gr, Se	OO, PT	PH
237	*Estrilda astrild peasei*	Common Waxbill	LC	Gr, Se	CT, OO, PT	PH
238	*Estrilda (Paludicola) ochrogaster*	Abyssinian Waxbill	LC	Gr, Se	OO, PT	DO
239	*Lonchura cucullata*	Bronze Mannikin	LC	Gr, Se	OO	DO
240	*Spermestes bicolor poensis*	Black-and-white Mannikin	LC	Br, Gr	PT	PH
	Fringillidae (4)					
241	*Serinus mozambicus*	Yellow-fronted Canary	LC	Gr	OO	DO
242	*Serinus citrinelloides*	African Citril	LC	Gr, Se	OO, PT	PH
243	*Serinus tristriatus*	Brown-rumped Seedeater	LC	Gr, Se	OO, PT	PH
244	*Serinus striolatus*	Streaky Seedeater	LC	Gr, Se	PT	PH

Image 3. Photographic records of bird species observed in Sheka Forest Biosphere Reserve: A. *Lybius bidentatus* | B. *Hirundo smithii* | C. *Anthus cervinus* | D. *Saxicola (torquatus) albofasciatus* | E. *Turdus (olivaceus) abyssinicus* | F. *Zoothera piaggiae* (camera trap recording) | G. *Myioparus plumbeus* | H. *Bradypterus cinnamomeus*

Image 4. Photographic records of bird species observed in Sheka Forest Biosphere Reserve: A. *Lanius humeralis* | B. *Oriolus monacha* | C. *Ploceus nigricollis* | D. *Serinus tristriatus*.

Twelve of the bird species observed inside the reserve are considered endemic to the Horn of Africa. All of these endemic species were encountered regularly within suitable habitat. Details on species identification are listed below (except for *Rougetius rougetii*, already discussed above):

Bostrychia carunculata

A dark ibis with white shoulder patches and a small wattle hanging from its throat. Common and abundant around highland wetlands and grasslands.

Pternistis castaneicollis

A large francolin with black forehead and creamy white belly. Uncommon but widespread in a variety of open woodland and forest edges, where often identified by its early morning call. On one occasion a large group (six birds) was seen in a tea plantation near the Gebba River.

Poicephalus flavifrons (Image 2C)

A medium-sized green parrot, identified by the presence of yellow colouring on the head. Common in a wide variety of forest and woodland, rare around farmland.

Agapornis taranta (Image 2D)

A bright green lovebird with green rump and red forehead. Common in highland woodland, rather rare in a variety of other habitats.

Lybius undatus

A barbet with red forecrown and barred plumage. Rare in open highland forest but common in lowland forest areas near Tepi.

Dendropicos abyssinicus

Small woodpecker with green back, heavily barred wings and bright red rump. Common in a variety of highland forest where identified and photographed on several occasions during the study.

Melaenornis chocolatinus

A large, dark grey-brown highland flycatcher with conspicuous yellow eye. Very common around settlements and a wide variety of other highland habitats.

Cisticola (galactotes) lugubris

A cisticola with black and grey streaked mantle and rufous crown. Extremely common and abundant around wetland, highland moorland and big rivers.

Parophasma galinieri

A distinctive grey bird with whitish forehead and orange-red undertail coverts. Common in highland bamboo forest, where recorded in high densities in forest edges around moorlands, very rare elsewhere.

Oriolus monacha (Image 4B)

A large black-headed oriole with grey wing panel. Very common in a wide variety of highland habitats, not restricted to forests.

Corvus crassirostris

A large raven with white patch on nape and very large bill. Common and abundant around settlements and farmland, rare around wetlands and open forest and not recorded from the core zones.

DISCUSSION

This study highlights the importance of the Sheka Forest Biosphere Reserve for globally threatened and Ethiopian endemic bird species, and in particular raptors and vultures. The results not only emphasize a high species richness in the reserve, but also indicate the importance of the proposed zonation, with increased control and protection, for bird conservation. Our findings are comparable to other recent ornithological studies in Ethiopia (e.g., Engelen et al. 2017; Rodrigues et al. 2018), showing a structurally diverse landscape, mostly in traditional low-intensity use, supporting a diverse range of bird species, and with undisturbed forest habitats and wetlands presenting a central refuge for vulnerable range-restricted and specialist bird species.

Our inventories were nevertheless confined to the short Ethiopian rainy season, as well as a subset of kebeles and transition-, buffer-, and core zones. Additional bird species, including seasonally present migrants, can undoubtedly be recorded during future studies in different periods and subregions. For instance, two endemic red-listed species, expected to occur in the reserve based on distribution maps, were not found (*Macronyx flavicollis* and *Cyanochen cyanoptera*). More extensive surveys, specifically during the long rainy season and in the vast moorlands in the eastern highlands of Anderacha woreda might still indicate their continued presence. In addition, point transect surveys were mainly conducted to map species diversity and distributions across habitats, but were inadequate to accurately characterize the relative abundance of species in the reserve. Thus, our study provides a first indication of bird species richness in Sheka forest, and is a baseline that needs complementary monitoring studies to provide more detailed insights in its species composition, population sizes and dynamics. Our study also showed the added value of camera trapping to record crepuscular species, with *Pternistis squamatus* and *Zoothera piaggiae* only being visually observed through camera trap observations.

The large elevation and climatic differences that are present in the reserve add up to a large habitat variation and exceptionally rich bird diversity, underlining the protected status assigned to Sheka forest and the urge to safeguard its habitats from ongoing degradation. Our observations furthermore emphasize the understudied nature of this remote biosphere reserve and the importance of continued biodiversity studies to inform conservation planning. The forests of Sheka provide innumerable services to local communities and many people are directly relying on forest resources for their subsistence. As a result, the forests have been sustained through a long tradition of natural resource management (Woldemariam & Fetene 2007), making Sheka Forest Biosphere Reserve an ideal subject for directed long-term and community-based initiatives to conserve some of the largest remaining Afromontane rainforests.

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Roadkill of animals on the road passing from Kalaburagi to Chincholi, Karnataka, India

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Abstract: The road passing from Kalaburagi to Chincholi in Karnataka, India, is around 70km and is a state highway having different types of moderately thick vegetation on either side. The animals utilizing this vegetation face huge threats from vehicular traffic, as was observed in recent years. Although this road does not have heavy traffic, there are significant numbers of roadkills. This study was conducted from February 2015 to January 2016. During the one-year period of the study, the mean frequency of heavy vehicles was 154 per day. Among the 283 roadkills recorded, 52 individuals belonged to the class Amphibia, constituting 18.37% of the total roadkills; no amphibian was killed in the summer season whereas 35 and 17 individuals were killed in the rainy season and in the winter season, respectively. Fifty-two individuals belonged to the class Reptilia, constituting 18.37% of the total roadkills; on an average, 10±5.8 individuals were killed in the summer season, 2.5±0.71 in the rainy season, and 3.5±2.12 in the winter season. Sixty-one individuals belonged to the class Aves, constituting 21.55% of the total roadkills; on an average, 5.71±3.03 individuals were killed in the summer season, 2.66±2.08 in the rainy season, and 4.33±3.51 in the winter season. One-hundred-and-eighteen individuals belonged to the class Mammalia, which was the most affected among the roadkills, constituting 41.69% of the total roadkills; on an average, 5.33±5.08 individuals were killed in the summer season, 5±3.9 in the rainy season, and 4.6±2.7 in the winter season. Under the IUCN Red List category, the majority of the species in this study are considered Least Concern and some of them are not even mentioned. The present study helps to know the problems and threats faced by wild animals and is the first work carried out in the region.

Keywords: Mammalia, seasonality, vehicular traffic.

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INTRODUCTION

Roads negatively impact animals in a variety of ways, one of the most obvious impacts being vehicle-induced mortality (Trombulak & Frissell 2000; Spellerberg 2002; Das et al. 2007; Sheshadri et al. 2009). The effects range from habitat loss and fragmentation (Richardson et al. 1997) to affecting wild animal distribution pattern, movement, breeding, and density (Reijnen et al. 1995). The taxa affected range from amphibians (Fahrig et al. 1995; Seshadri et al. 2009) to reptiles (Rosen & Low 1994; Drews 1995; Gokula 1997; Das et al. 2007) to birds (Drews 1995; Reijnen et al. 1995) and mammals (Drews 1995; Newmark et al. 1996; Richardson et al. 1997). More attention has been given in North America, Australia, Europe, and Africa to assess such impacts, but Asia has not paid the required attention to this aspect (Baskaran & Boominathan 2010). Recent development activities such as increase in the number of highways, vehicular traffic, and widening of roads are the prime reason for the destruction of wildlife and their habitats (Gokula 1997; Gruisen 1998; Vijayakumar et al. 2001; Das et al. 2007). Therefore, non-governmental organizations and conservationists in India are protesting against the construction of new roads and also the upgrading or widening of existing roads, especially in protected areas (Baskaran & Boominathan 2010). The present paper is the first account of roadkill from Hyderabad–Karnataka region.

MATERIALS AND METHODS

Study Area

Chincholi Konchavaram Forest is situated around 8km away from our study area, which is the wildlife sanctuary of southern Indian dry forest which is at par with the Western Ghats of Karnataka. Kalaburagi is called Sun City because of its high temperature, and as we move towards Chincholi the temperature comparatively drops because of rich vegetation. The average rainfall and temperature of Kalaburagi are 200mm and 34^0C, respectively. The average rainfall and temperature of Chincholi are 887mm and 27.1^0C, respectively.

Figure 1. The road from Kalaburagi to Chincholi, Karnataka, India.

Our study area lies between Kalaburagi (17.329^{0}N & 76.834^{0}E; 454m) and Chincholi (17.461^{0}N & 77.419^{0}E; 462m), covering a distance of 70km and having a width of 45m (SH-10 from Gulbarga University to Madbul, SH-125 from Madbul to Kodla cross, SH- 32 from Kodla cross to Chincholi). About 5km of the SH-10 has crop fields on either side while the remaining stretch has scrub jungles. Further, the SH-125 road stretch has crop fields on either side and a small part of the road has scrub jungles. Most of the road stretch of SH-32 has thick vegetation on either side; some of the area is dominated by palm vegetation. The entire 70km of the road passes through 13 villages. The vegetation present on either side of the road consists of the following plant species, namely, *Eucalyptus globules, Ficus benghalensis, F. religiosa, Azardirachta indica, Phoenix sylvestris, Capparis* spp., *Albizia lebbeck, Pithecellobium dulce, Peltophorus pterocarpum, Acacia nilotica, Prorosopis julifora, Pongamia pinnata, Ailianthus excelsa, Calotropis* spp., *Euphorbia toucan, Vitex negundo*, and *Cassia auriculata.*

Methods

Sampling was carried out from February 2015 to January 2016 on the road from Kalaburagi to Chincholi via Madbul, covering a distance of 70km (Fig. 1). We surveyed the road in a Thar Jeep systematically from 07.00h to 10.00h at a speed of 15–20 km/h. The entire road was surveyed in one stretch, four times a month on holidays so as to avoid inconvenience to the traffic. The road kill encountered were recorded and the overall percentage of mortality was calculated season-wise.

Traffic flow was studied 12 times a year, i.e., on a Monday of every month during our study period (Monday was selected to record traffic flow due to high traffic intensity on that day). The traffic intensity was recorded manually as the mean number of vehicles on the road in each 1-hour interval around 24 hours. Traffic flow, type of vehicle, and their movement per day were calculated.

Images of dead animals were taken, and the dead animals were removed from the road to avoid repetition. The recorded roadkills were categorized and noted according to the type of vegetation. Identification was done using field guides (Grimmett et al. 1998; Daniel 2002; Menon 2003). No preservation was done during our survey.

RESULTS

Traffic flow in our study area was not very high around the year. Traffic flow recorded during the period of February 2015–January 2016 reveals that the mean frequency of vehicles was 154 per day (24h). The maximum contribution to the traffic flow was made by light vehicles (59%) and the minimum contribution by heavy vehicles (41%) (Table 1; Fig. 2).

During our study period, 283 individuals belonging to 26 species were recorded. Among these, Amphibia and Reptilia constituted 18.37% each, Aves 21.55%, and Mammalia 41.69% (Fig. 3).

Among the 52 recorded individuals of the class Amphibia (Table 2), one species was *Duttaphrynus melanostictus*; the other group of frogs was unidentified.

Table 1. Traffic flow (number of vehicles per day) on S-10, SH-125, and SH-32 from Kalaburagi to Chincholi in Karnataka, India, during the study period of February 2015–January 2016.

Months	Mean number of vehicles per day		Total
	Heavy vehicles	Light vehicles	
February	60	90	150
March	62	94	156
April	61	98	159
May	65	97	162
June	60	94	154
July	64	94	158
August	62	93	155
September	64	91	155
October	65	89	154
November	67	88	155
December	61	83	144
January	60	87	147
Annual total	751	1098	1849

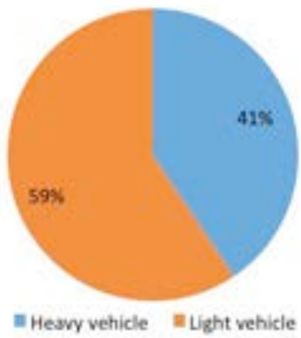

Figure 2. Composition of traffic flow from Kalaburagi to Chincholi in Karnataka, India.

Table 2. Overall roadkills recorded during February 2015–January 2016 in the study area showing various species of roadkills.

	Class	Common name of the species	Scientific name of the species	Number of individuals killed	Red List status
1	Amphibia	Black-spectacled Toad	*Duttaphrynus melanostictus*	25	Least Concern
2		Unidentified frogs		27	-
3	Reptilia	Yellow Monitor	*Varanus flavescens*	11	Least Concern
4		Dhaman	*Ptyas mucosa*	05	Not mentioned in the Red Book
5		Water Snake	*Xenochrophis pisicator*	03	Not mentioned in the Red Book
6		Unidentified snakes		06	-
7		Common Garden Lizard	*Calotes versicolor*	11	Not mentioned in the Red Book
8		Asian Chameleon	*Chamaeleo zeylanicus*	16	Least Concern
9	Aves	Greater Coucal	*Centropus sinensis*	20	Least Concern
10		Laughing Dove	*Spilopelia senegalensis*	09	Least Concern
11		Ring-necked Dove	*Streptopelia capicola*	03	Least Concern
12		Common Lora	*Aegithina tiphia*	08	Least Concern
13		House Crow	*Corvus splendens*	06	Least Concern
14		Rock Dove	*Columba livia*	05	Least Concern
15		Unidentified birds		10	-
16	Mammalia	Small Indian Civet	*Viverricula indica*	06	Least Concern
17		Jungle Cat	*Felis chaus*	04	-
18		Asian Palm Civet	*Paradoxurus hermaphrodites*	05	-
19		Grey Wolf	*Canis lupus*	02	Least Concern
20		Red Fox	*Vulpes vulpes*	02	Least Concern
21		Domestic/ Feral Dog	*Canis lupus familiaris*	20	Not mentioned in the Red Book
22		Indian Grey Mongoose	*Herpestes edwardsii*	06	Least Concern
23		Indian Crested Porcupine	*Hystrix indica*	15	Least Concern
24		Brown Rat	*Rattus norvegicus*	03	Least Concern
25		Wild Pig	*Sus scrofa*	03	Least Concern
26		Indian Hare	*Lepus nigricollis*	06	Least Concern
27		Three-striped Ground Squirrel	*Lariscus insignis*	15	Least Concern
28		Southern Plain Grey Langur	*Semnopithecus hypoleucos*	20	Least Concern

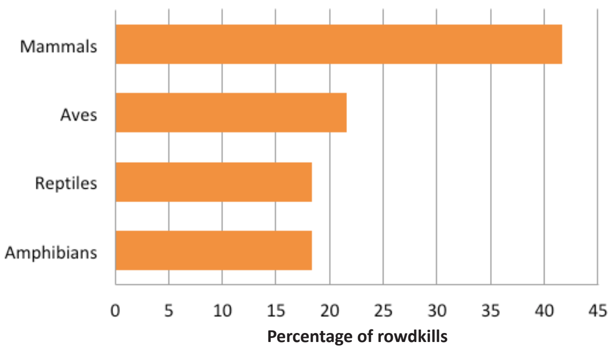

Figure 3. Class-wise composition (in %) of roadkills recorded during the study period.

Table 3. Season-wise mean roadkill recorded in the study area.

Class \ Season	Summer	Rainy	Winter
Amphibia	0	35	12
Reptilia	10±5.8	2.5±0.71	3.5±2.12
Aves	5.71±3.035	2.66±2.08	4.33±3.51
Mammalia	5.33±5.08	5±3.9	4.6±2.7

In summer, no amphibians were found killed; 35 individuals were killed in the rainy season and 12 in the winter season (Table 3).

Among the 52 recorded individuals of the class Reptilia (Table 2), the highest number of kills was of


Image 1. Small Indian Civet.


Image 2. Jungle Cat.

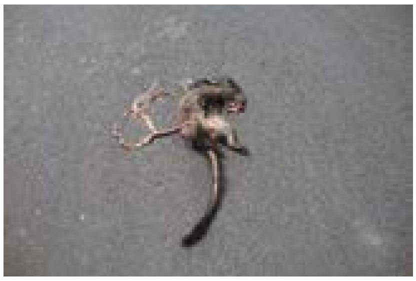
Image 3. Asian Palm Civet.


Image 4. Grey Wolf.


Image 5. Porcupine.


Image 6. Wild Rat.


Image 7. Grey Langur.


Image 8. Jungle Cat.


Image 9. Wild Boar.


Image 10. Squirrel.


Image 11. Unidentified mammal.


Image 12. Greater Coucal.


Image 13. Dove.


Image 14. Snake.


Image 15. Yellow Monitor.


Image 16. Asian Chameleon.

Chamaeleo zeylanicus, followed by *Varanus flavescens, Calotes versicolor*, and *Ptyas mucosa*; the least number of kills was of *Xenochrophis pisicator*. Chameleons are very common in this area and are not found in any other talukas of Kalaburagi District. Seasonally, on an average, 10±5.8 reptiles were killed in the summer season—the highest number of roadkills among all seasons, followed by 3.5±2.12 in the winter season, and the lowest of 2.5±0.71 in the rainy season (Table 3; Images 1–16).

The 61 recorded individuals of the class Aves belonged to six species (Table 2). *Centropus sinensis* was frequently found killed in road collisions (20 individuals), followed by *Spilopelia senegalensis, Aegithina tiphia*, *Corvus splendens*, *Columba livia*, and *Streptopelia capicola.* Ten individuals of birds were unidentified. On average, the highest number of roadkills of birds was in the summer season with 5.71±3.03 individuals, followed by 4.33±3.51 in the winter season and the lowest of 2.66±2.08 in the rainy season (Table 3).

Among all the classes, Mammalia had the highest number of roadkills with 107 individuals belonging to 17 species (Table 2), which makes 41.69%. Out of the 107 individuals of mammals killed, the highest killed were *Semnopithecus dussumieri* and *Canis lupus familiaris* with 20 individuals each; followed by *Hystrix indica and Lariscus insignis* with 15 individuals each; *Viverricula indica, Herpestes edwardsii*, and *Lepus nigricollis* with six individuals each; *Paradoxurus hermaphrodites* with five individuals; *Felis chaus* with four individuals; and *Rattus norvegicus and Sus scrofa* with three individuals each. The least killed were *Canis lupus and Vulpes vulpes* with two individuals each. Season-wise average roadkill of mammals is 5.33±5.08 in the summer season, 5±3.9 in the rainy season, and 4.6±2.7 in the winter season (Table 3). In our observation, no Hanuman Langur was killed in the summer season, which may be due to very high temperature of nearly 40ºC which restricts the species movement on the road. According to the local Hindu tradition, burial of monkeys is carried out by the local people by performing rituals as performed for humans, for they consider the species sacred (as an avatar of Hanuman).

DISCUSSION

In our present study, greater mortality was observed in amphibians due to their slow moving behaviour. This was also true with the findings of Bhaskaran & Bhoominathan (2010). Our results are true only with amphibians. Among reptiles, however, except snakes and lizards, the rest were killed in all seasons. Since snakes and lizards have the habit of basking on the road during winter months, their roadkill incidents were more in the winter season. Our observations are similar to that of Vijayakumar et al. (2001).

Granivorous birds were killed while feeding on grains spread on either side of the road whereas insectivorous and carnivorous birds were killed while feeding on any live or dead animals found on the road.

Among mammals, comparatively higher mortality was found in the case of Hanuman Langurs due to their social habits and human-modified behaviours. They have the habit of keeping themselves close to roads and performing all their activities without bothering much about speeding vehicles. During fighting and chasing, they collide with vehicles and get injured or die as reported by Ramesh (2013).

Most of the mammalian species killed on the road as recorded in the present study are nocturnal in habit (Jungle Cat, Small Indian Civet, Asian Palm Civet, Indian Grey Mongoose, Grey Wolf, and Red Fox). Porcupine is nocturnal and insectivorous and gets killed while feeding on insects on roads. Wild Boars and Indian Hares are killed while crossing roads (Baskaran & Boominathan 2010). The composition of the roadkills varied according to vegetation. Mammalian mortality was high in areas where there was thick vegetation on either side of the road (Selvan et al. 2012)—there was a tendency for mammals to get killed in dense forests (Clevenger & Kociolek 2003).

CONCLUSIONS

Our results show that the average roadkill in the area was 23.58% every month. Human development activities are directly related to the increase in the number of roadkills (Gokula 1997). As a precautionary measure, visibility on either side of the road should be increased by clearing bushes; this helps the driver to avoid accidents. Other measures such as shining signboards, street lights, and speed-breakers can minimize the roadkill of large-bodied animals or small amphibians and reptiles (Selvan et al. 2012).

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COMMUNICATION

Ceriagrion chromothorax sp. nov. (Odonata: Zygoptera: Coenagrionidae) from Sindhudurg, Maharashtra, India

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PLATINUM OPEN ACCESS

Abstract: *Ceriagrion chromothorax* sp. nov. is described from Western Ghats, India, based on six males and one female collected from Sindhudurg District of Maharashtra.

Keywords: Damselfly, Devgad, new species, Sindhudurg Marsh Dart, taxonomy, Western Ghats.

Marathi Abstract: सिंधुदुर्ग मार्श डार्ट ही पश्चिम घाटातील विमलेश्वर, जिल्हा सिंधुदुर्ग येथे आढळलेली टाचणीची नवी प्रजाती आहे. गोळा केलेल्या सहा नर आणि एक मादी अशा नमुन्यांच्या आधारे या प्रजातीचे वर्णन करण्यात आले आहे.

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Author Contribution: DS took all the photographs from field, collected the specimens, made illustrations and helped in writing the manuscript. SJ wrote the manuscript and made the close-up images of anal appendages, genitalia and prothorax.

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INTRODUCTION

Ceriagrion is a diverse and widespread genus of damselflies (Zygoptera) within the family Coenagrionidae with 51 species (Schorr & Paulson 2018). This genus consists of many closely related species, which are difficult to diagnose without thorough examination of the prothorax and male genital ligula (Asahina 1967; Dijkstra 2005). Asahina (1967) provided a review of this genus from the Oriental region, which still remains the most complete account.

Four species of *Ceriagrion* are currently known from the Western Ghats of India (Fraser 1933a; Subramanian & Babu 2017; Subramanian et al. 2018). Here we describe a fifth species—*Ceriagrion chromothorax* sp. nov. from Vimaleshwar, Sindhudurg District, Maharashtra. This species is morphologically similar to *Ceriagrion coromandelianum* (Fabricius, 1798), and *C. indochinense* Asahina, 1967, but can be distinguished from them by its chrome yellow synthorax, structure of the prothorax, and the shape of caudal appendages.

MATERIALS AND METHODS

The new species was first photographed in August 2017. Subsequently, DS collected three males in August and September 2017, a copula along with two more males was collected in August 2018. The collected specimens were examined using Leica (Leica Microsystems, Germany) stereomicroscopes for close up imaging. Multiple images were stacked to generate greater depth of field; scale bars were added using Leica Application Suite (Leica Microsystems, Germany) or ImageJ (Schneider et al. 2012).

The general morphological terms are following Garrison et al. (2010), and Riek & Kukalova-Peck (1984) was referred for wing venation terminology, along with Kennedy (1920) for genital ligula and Asahina (1967) for prothorax.

The holotype has been pinned, while the two paratypes were preserved in ethanol. Specimens are deposited at the Research Collections, National Centre for Biological Sciences, Bangalore.

The following abbreviations are used in the text: FW = fore wing, HW = hind wing, Ax & Px= antenodal and postnodal nervures, Pt= pterostigma, S1:S10= first to last abdominal segments.

Ceriagrion chromothorax sp. nov.
(Images 1a,b, 2a,b, 3a,b,c, 4a)

urn:lsid:zoobank.org:act:78B8744D-467C-4B5E-A393-73BDE57A6BC9

Common name: Sindhudurg Marsh Dart.

Holotype: Male (NCBS-BB921), 4.viii.2017, Vimaleshwar, Devgad, Sindhudurg District, Maharashtra, India, (16.433^{0}N & 73.395^{0}E; elevation ~27m), Dattaprasad Sawant leg.

The locality and collector of the following allotype and paratypes are same as holotype, except date of collection.

Allotype: Female (NCBS-BH969), 16.viii.2018.

Paratypes: 2 males (NCBS-BB922, NCBS-BB923), 27.ix.2017; 1 male (NCBS-BH970, collected in copula with allotype female), 16.viii.2018; 2 males (NCBS-BH971, NCBS-BH972), 19.viii.2018.

Etymology: The name '*chromothorax*' is given for the bright yellow (=chromo) thoracic coloration (Image 1).

Description of holotype male (Images 1–5)

Head: Labium dark brown; labrum, anteclypeus, postclypeus, postfrons yellow, upper half of antefrons brown, rest yellow. Vertex and postocular lobes pale yellow; eyes olive green.

Prothorax (Image 4): Yellow; anterior lobe with paired black marking dorsally, extending from the anterior border of latero-medial lobes; posterior lobe of the prothorax flat at the anterior border and medially, raised at the posterior border and laterally; posterior border trilobate; the posterior border of the central lobe not straight.

Synthorax (Images 1&2a): Mesostigmal plates: lateral carina shaped half-hexagon, pointed anteriorly; anterior carina robust, broader at the meeting point with lateral carina; lateral carina not extending beyond acrotergite; posterior carina rudimentary not extending even halfway from lateral carina to median pit; mesostigmal lamina raised; remus large; anterior carina and anterior 1/3rd of lateral carina black. *Synthorax* bright yellow in live individuals, due to the flash used while photographing dorsum appears olive green in some individuals; slightly darker on dorsum paler yellow ventrally, black spots at the posterior end of meta and mesopleural sutures, small black spot at the junction of mesepimeron and metepisternum, 45 degrees from metastigma. Mesocoxa and metacoxa dull with faint pruinescence. Legs bright yellow, gradually pale brown towards the claws; small black dot at base of femur on the posterior side; base of the claws black; femur and tibia with large black spines. Metascutum

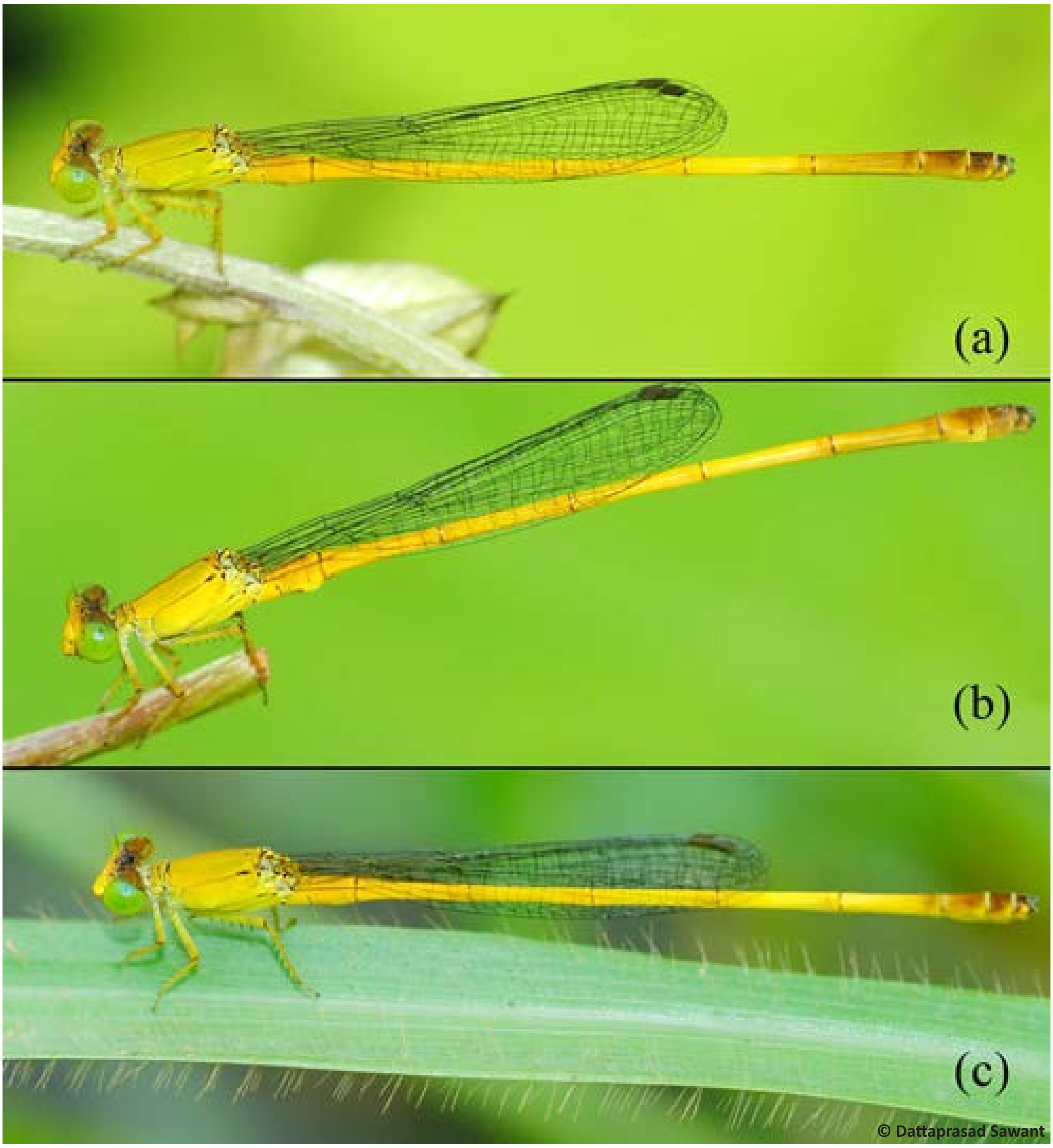

Image 1. *Ceriagrion chromothorax* sp. nov.: (a) & (b) holotype male (NCBS-BB921) in situ | (c) male from Wada Village (not collected), 18.viii.2018.

and mesoscutum yellow with slight pruinescence.

Wings (Image 2b): Hyaline; Ax 2, Px: FW= 11, HW= 10. Pt: dark brown, slightly darker in HW, spanning just more than one cell; arculus lying at the level of second Ax; petiolated from anal vein; radial vein arising at the level of nodus.

Abdomen (Image 2a): Bright yellow; S2–6 posterior border dorsally faint brown; S7–8 faint brown dorsally, S9–10 dark brown; dorsum of S10 black, extended at the anterior border.

Genital ligula (Image 5): Description of genital ligula mainly based on paratype; genitalia was not dissected from the holotype to keep the specimen intact, but the holotype genitalia was observed under the microscope

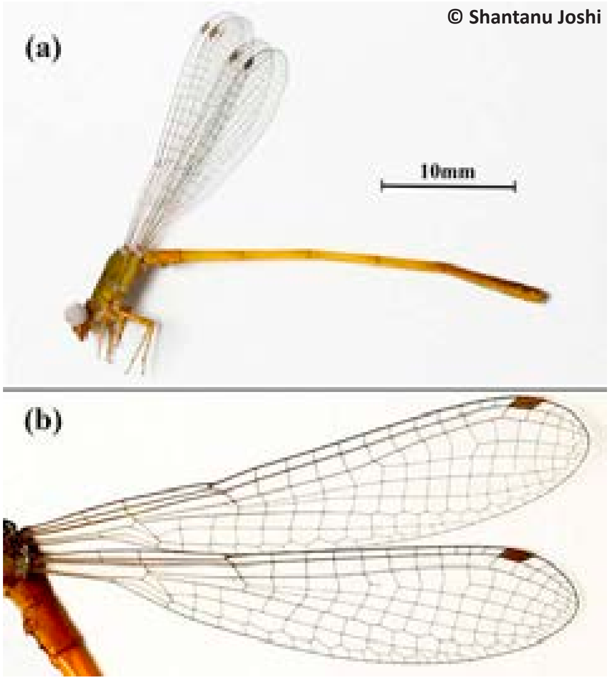

Image 2. Holotype male (BB921): (a) lateral habitus | (b) wings.

Image 4. Prothorax: (a) holotype male | (b) paratype (BB923) male. Caudal appendages (paratypes): (c) BH970 | (d) BB923.

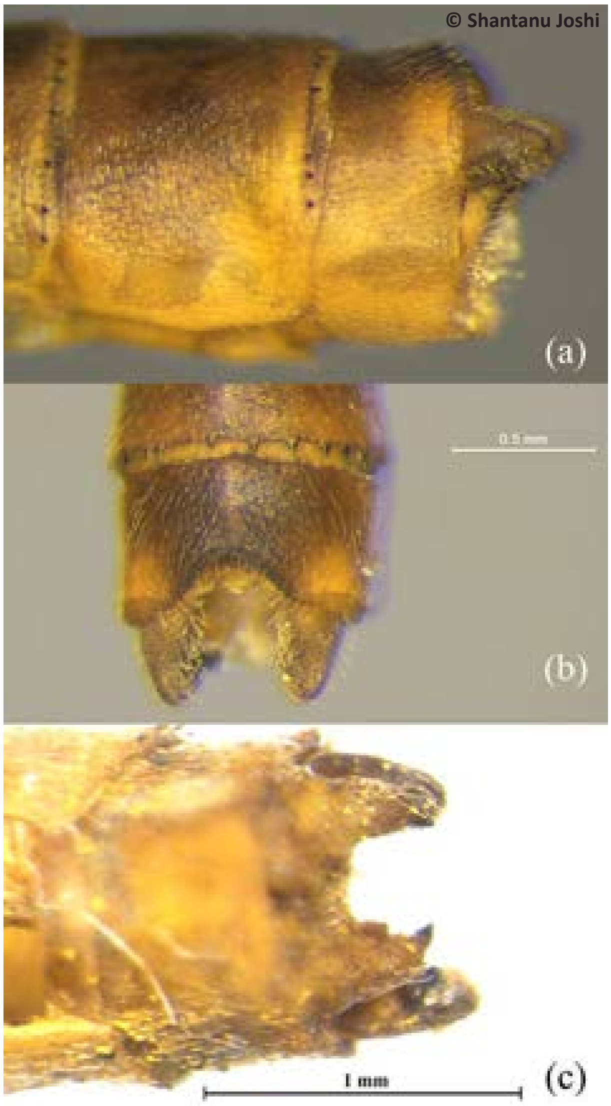

Image 3. Holotype male caudal appendages: (a) lateral | (b) dorsal | (c) ventral.

after relaxing the specimen to confirm characters described here. Laterally, ventral half of first segment one black, rest pale brownish-yellow; anterior 1/4th of second segment black, continued as dark brown; black medial marking faintly visible in ventral view; third segment bi-lobed, folded internally with brown apex, and darker terminal fold; apex of terminal segment visible between the two lobes in ventral view, lateral margins of lobes straight till midway and expanded thereon.

Caudal appendages (Image 3): Cerci longer than paraprocts, broader at base; the apex pointed, curved ventrally and inwards, ending in a black spine often not visible in lateral view (Images 3 & 4); laterally paraprocts appear conical or blunt apically depending on the angle; apex inwardly curved, ending in a spine as seen in ventral and dorsal views; cerci dark brown covered densely with yellow setae especially at the inwardly curved apical spine. Apex of paraprocts black, base pale brown; both covered with setae.

Measurements (in mm): abdomen + anal appendages

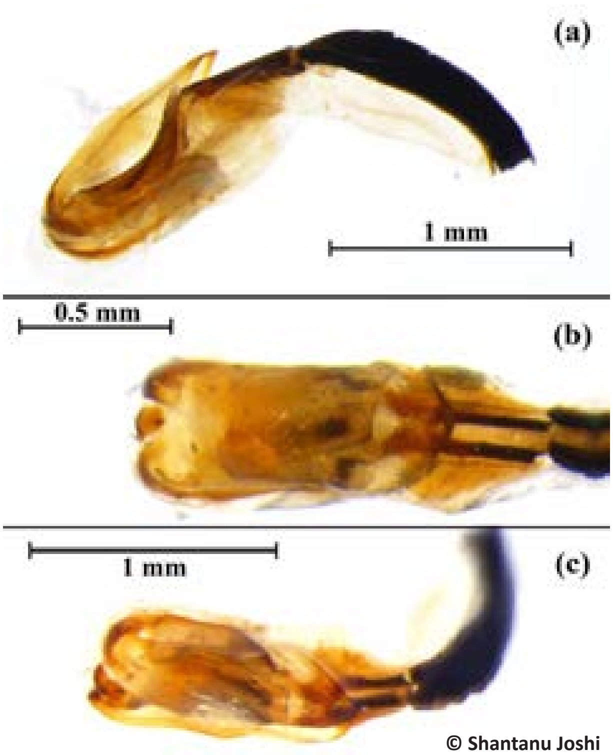

Image 5. Genital ligula of paratype (BB923) male: (a) lateral | (b) ventral | (c) ventro-lateral.

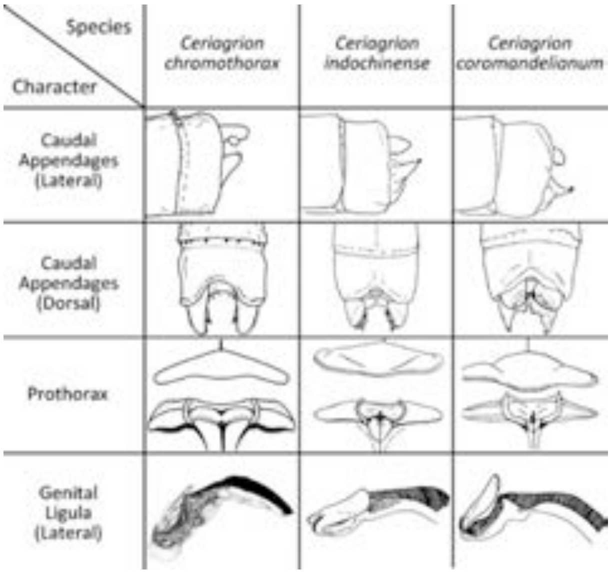

Figure 1. Compilation of diagnostic characters of *Ceriagrion* spp. Illustrations of *Ceriagrion chromothorax* sp. nov. hand-drawn by Dattaprasad Sawant, except the genital ligula which is drawn by Paresh churi. Other images edited from Asahina (1967). Compiled by Shantanu Joshi.

= 37.2, HW= 21.5, FW= 22.5, genital ligula= 2.1, cerci= 0.5.

Variation in paratype males

Px: FW: 11–12, HW: 10–11. The paratypes and holotype show slight variation in the brown markings on dorsum of S5–10, particularly evident living specimens. In some males, the markings are only restricted to the posterior half of segments. Due to the angle and the position of paraprocts the caudal appendages appear slightly different in paratype males (Image 4c&d).

Description of allotype female (Image 6–7, 10)

Head: Pale olive, frons with paired black spots at the ventral border; vertex and occipital area pale brown; eyes olive green, blue at dorsum in live individuals; faint greenish-yellow in the pinned specimen.

Prothorax (Image 6): Propleuron with a black marking laterally; anterior lobe with a paired black stripe darker at the posterior border; anterior border of anterior lobe raised, bilobed; medial lobes more rounded than in male; posterior lobe tri-lobed similar to the male.

Synthorax (Image 10): Mesostigmal plates similar to male; yellow, except a conspicuously black and large depression below mesostigmal plates; lateral carina slightly curved; anteriorly curved towards the junction with lateral carina on both sides, anterior carina black; rest of the synthorax pale greenish yellow, darker dorsally, especially the mesepisternum. Legs: coxae white; dorsal 2/3rd of femur dirty white, rest pale brown; posterior face of femur dark brown, broader at the ventral margin; tibia and tarsus pale brown; legs covered with black spines.

Wings: Similar to male, hyaline, with black venation, basal veins dark brown; pterostigma dark brown, quadrate; Px: FW: right=10, left=11, Ax: 2 in all wings.

Abdomen (Image 10): S1 pale brown, S2–5 yellow; laterally and ventrally posterior 1/3rd of S5 and S6–10 pale brown; S2–7 and S9 with black marking at the posterior margin, darker sequentially, S7 with a black marking at the anterior margin; S8 black latero-dorsally, anterior half of S9 black laterally; S10 pale with faint dark brown markings at the anterior margin dorsally.

Caudal Appendages (Image 7): Cerci brown, stylus dark brown, valve pale brown; cerci laterally flattened, curved inwards approximately 45 degrees, covered with yellow setae; stylus simple reaching to half the length of cerci posteriorly, in lateral view; slightly tapering in the middle, slightly expanded at the apex.

Differential diagnosis

Ceriagrion chromothorax sp. nov. is similar to *C. coromandelianum,* and *C. indochinense,* the latter has not been recorded from India but could possibly occur

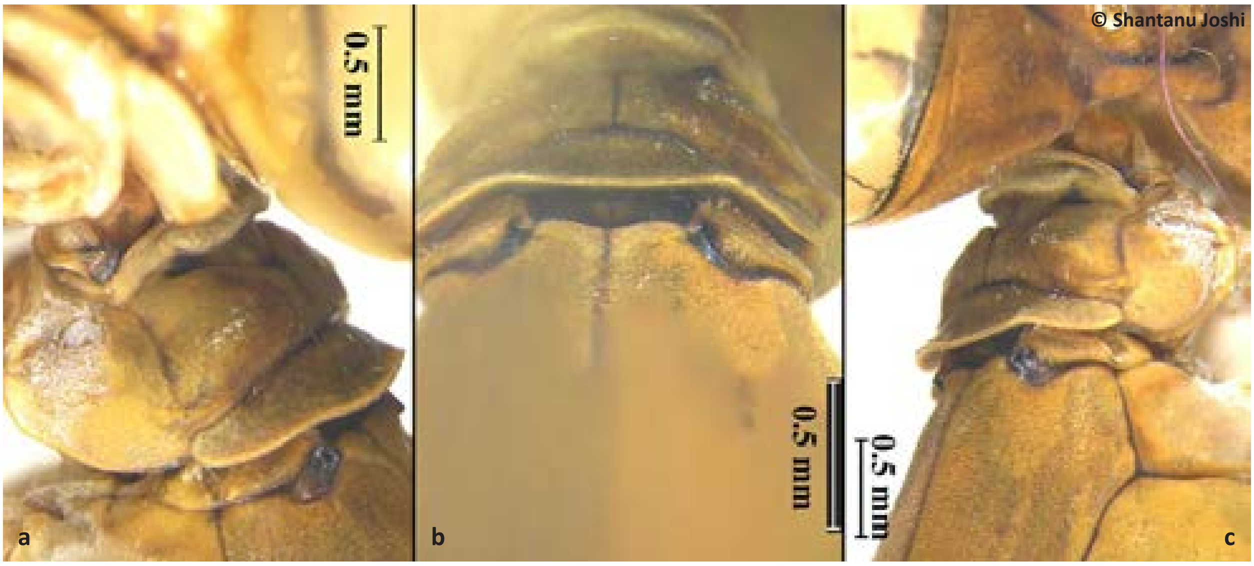

Image 6. Prothorax of *Ceriagrion chromothorax* sp. nov. allotype female (BH969). a - right lateral | b - dorsal; c - left lateral views.

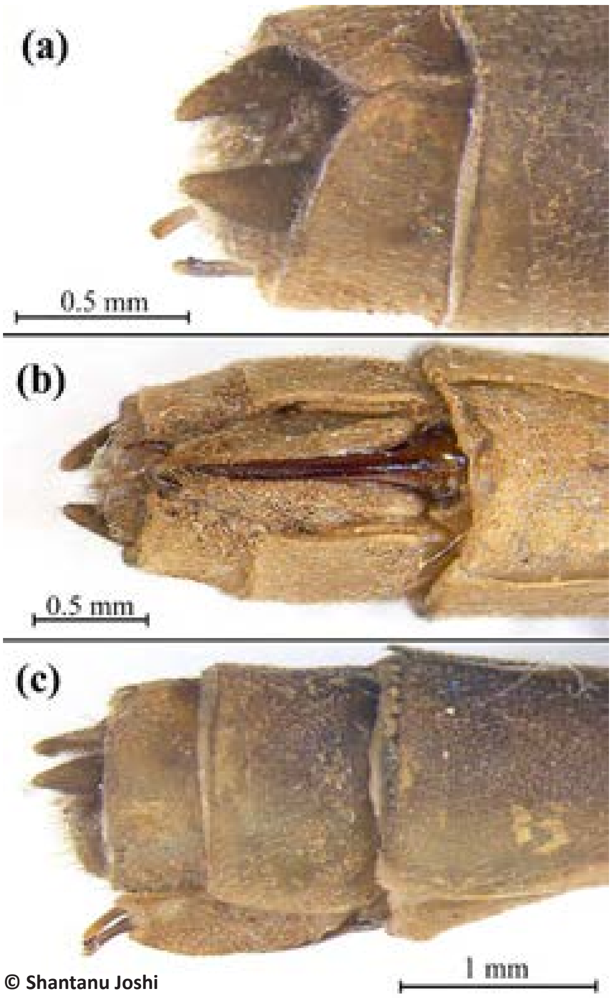

Image 7. Caudal appendages of *Ceriagrion chromothorax* sp. nov. allotype female (BH969): a - dorso-lateral | b - ventral | c - lateral.

in the northeast. The above three species share the character of yellow or olivaceous thoracic and abdominal coloration, but they differ with respect to the shape of their anal appendages, structure of prothorax and mesostigmal plate. *Ceriagrion fallax*, occurs in northern India but not in western India, it is similar to the three above-mentioned in terms of the yellow abdominal coloration, but is readily distinguishable using the following characters: a) S7–10 extensively black, b) shape of posterior lobe of prothorax and mesostigmal plates, and c) shape of anal appendages.

Ceriagrion chromothorax males can be distinguished from *C. coromandelianum* and *C. indochinense* by: a) shape and length of cerci and paraprocts (paraprocts shorter than cerci in *C. chromothorax*, while longer than cerci in the two latter species, Fig. 2, Images 3,4,10), b) shape of the prothorax and mesostigmal plates (Images 4; Fig. 2), and c) completely yellow thorax (Image 1–2: green in *C. coromandelianum* and *C. indochinense* (Image 8). The genital ligula is similar in these three species, but in *C. chromothorax* the third segment is conspicuously bi-lobed (Image 5b&c).

Ceriagrion chromothorax is very similar to *C. indochinense* in the following characters: a) thoracic coloration, b) larger size (in relation to *C. coromandelianum)* and shape of paraprocts; but these two species differ most conspicuously in the structure of the mesostigmal plate of the thorax. The caudal appendages of *C. chromothorax*, although similar to *C. indochinense,* can be differentiated by the longer cerci, and the inwardly curved, apical spine of the paraprocts.

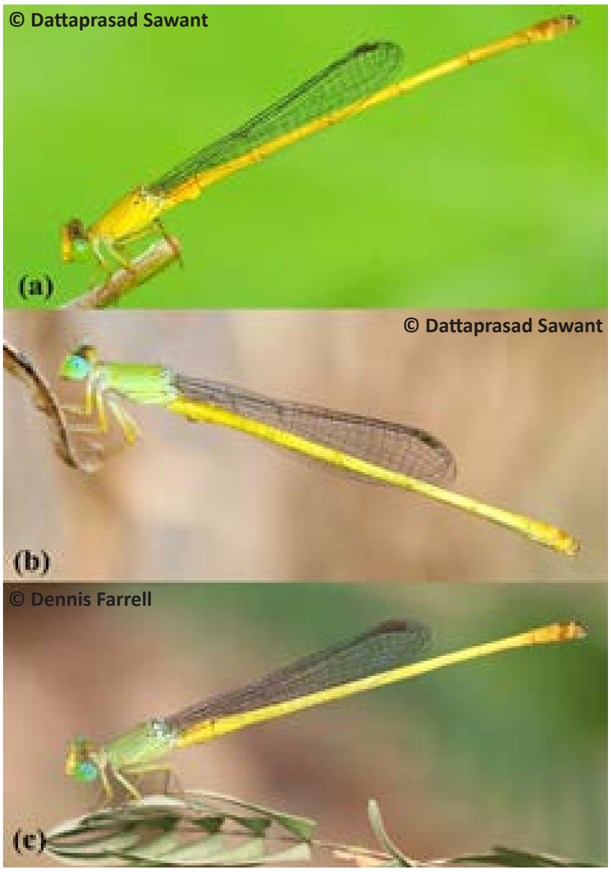

Image 8. Males of: (a) *Ceriagrion chromothorax* sp. nov. | (b) *C. coromandelianum* | (c) *C. indochinense*.

The structure of mesostigmal plates is unique in *C. chromothorax*, especially the shape of the lateral carina (Fig. 1). The posterior lobe of the prothorax in *C. chromothorax* differs in shape from *C. coromandelianum* and *C. indochinense* (the posterior margin of medial lobe is straight, not curved, posterior margin of lateral lobes less curved (Images 4,10 & Fig. 1).

Ceriagrion chromothorax is a larger species with a slimmer abdomen as compared to the widespread *C. coromandelianum*. Cerci are almost as long as paraprocts in *C. chromothorax*, while cerci are much shorter than paraprocts in *C. coromandelianum* (Fig. 2). These two characters along with the shape of the mesostigmal plates can be used to separate these two sympatric *Cerigarion* species. The female of this species is more difficult to distinguish from *C. coromandelianum*, and is also similar to another co-occurring species, *C. olivaceum*. Females of these three species have olive green thorax and pale brown abdominal coloration; however, the female of *C. chromothorax* can be distinguished from similar *Ceragrion* species by: a) shape of its mesostigmal plates (especially the lateral carina, Image 6), and b) dark markings at the posterior border of S2-7 (Image 9).

Habitat, habits and notes on congeneric species

A total of 14 visits were made to the type locality by

Image 9. Copulae of *Ceriagrion chromothorax* sp. nov. observed at the type locality on 16.viii.2018.

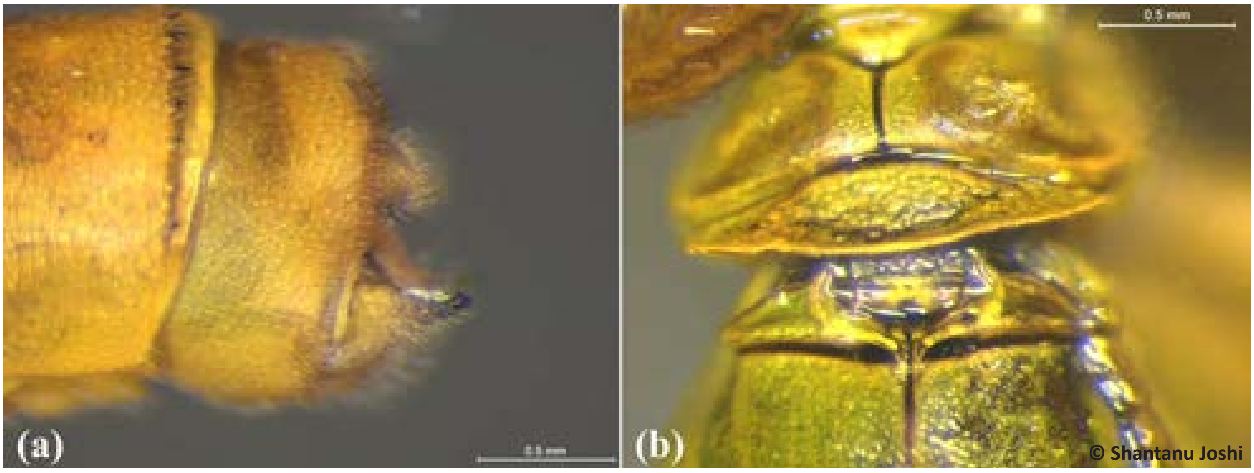

Image 10. *Ceriagrion coromandelianum* male collected on 15.viii.2018 from National Centre for Biological Sciences, Bangalore, Karnataka: (a) - Anal appendages | (b) prothorax.

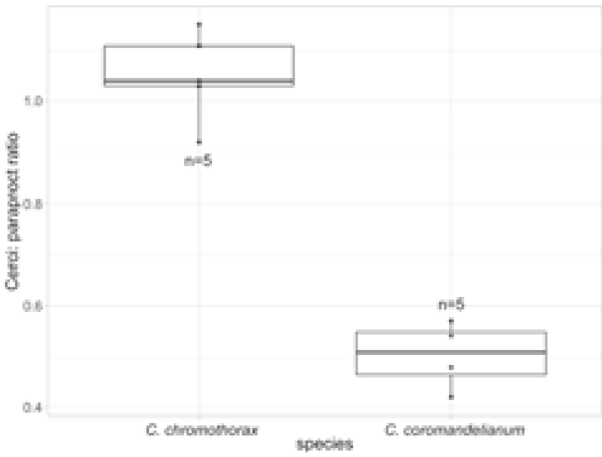

Figure 2. Cerci: paraproct ratio in *Ceriagrion chromothorax* vs. *C. coromandelianum*. For *C. coromandelianum*, the ratio was calculated using illustrations from Asahina 1967, Lahiri 1987, Fraser 1933a, and two males collected on 15.viii.2018 from National Centre for Biological Sciences, Bangalore, Karnataka. A ratio of 0.5 indicates that cerci and paraprocts are of equal length.

DS, from July 2017 to November 2018. Two individuals of *C. chromothorax* were first observed in July 2017, in the bushes near a banyan tree (*Ficus benghalensis*) at a weir dam (locally known as 'Bandhara') on a stream (Image 11). On two subsequent visits conducted on 4 and 10 August two males were observed, the holotype male (Images 2–4) was collected on fourth. On the next visit to the same locality on 27 September 2017, DS observed three *C. chromothorax* males out of which two were preserved as paratypes (with no sign of the female). In the month of November and December no individuals of *C. chromothorax* were observed, while density of *C. coromandelianum* increased. More than 15 males were observed along with three copulae on 16 August 2018, one copula was collected, from which the female allotype is described. *C. chromothorax* was observed at an additional locality in Wada Village (Image 12), Sindhudurg District, Maharashtra (GPS coordinates: 16.443946, 73.392725), approximately two kilometers from the type locality. Habitat where the species was observed in Wada was an isolated muddy pond, surrounded by rice paddy fields and coconut plantations around it. Four males, but no females were observed at the pond on 18 August 2018

Both the type locality and the other locality at Wada (Image 12) are seasonal. Water starts building up from June with the start of monsoon. July-September the water levels remain high, aquatic vegetation is most abundant during this period (see Image 11a). From the end of September water levels start reducing, high fluctuations in water levels can be seen during this period dictated by infrequent storms and rain. February onwards there was almost no flowing water (see Image 11b&g, Image 12), with only a few puddles left along with some odonate species such as *Amphilagma parvum* and *Tramea* sp.

Four *Ceriagrion* species, viz., *C. cerinorubellum* (Brauer, 1865), *C. olivaceum* (Laidlaw, 1914), *C. rubiae* (Laidlaw, 1916), and *C. coromandelianum* were observed co-occurring with *C. chromothorax* at the type locality. All five *Ceriagrion* species were observed simultaneously from July–September, whilst October–November onwards only *C. coromandelianum* and *C. cerinorubellum* were present. *C. chromothorax* males were observed aggressively interacting with *C. coromandelianum*, *C. cerinorubellum*, *Pseudagrion rubriceps*, and *Pseudagrion*

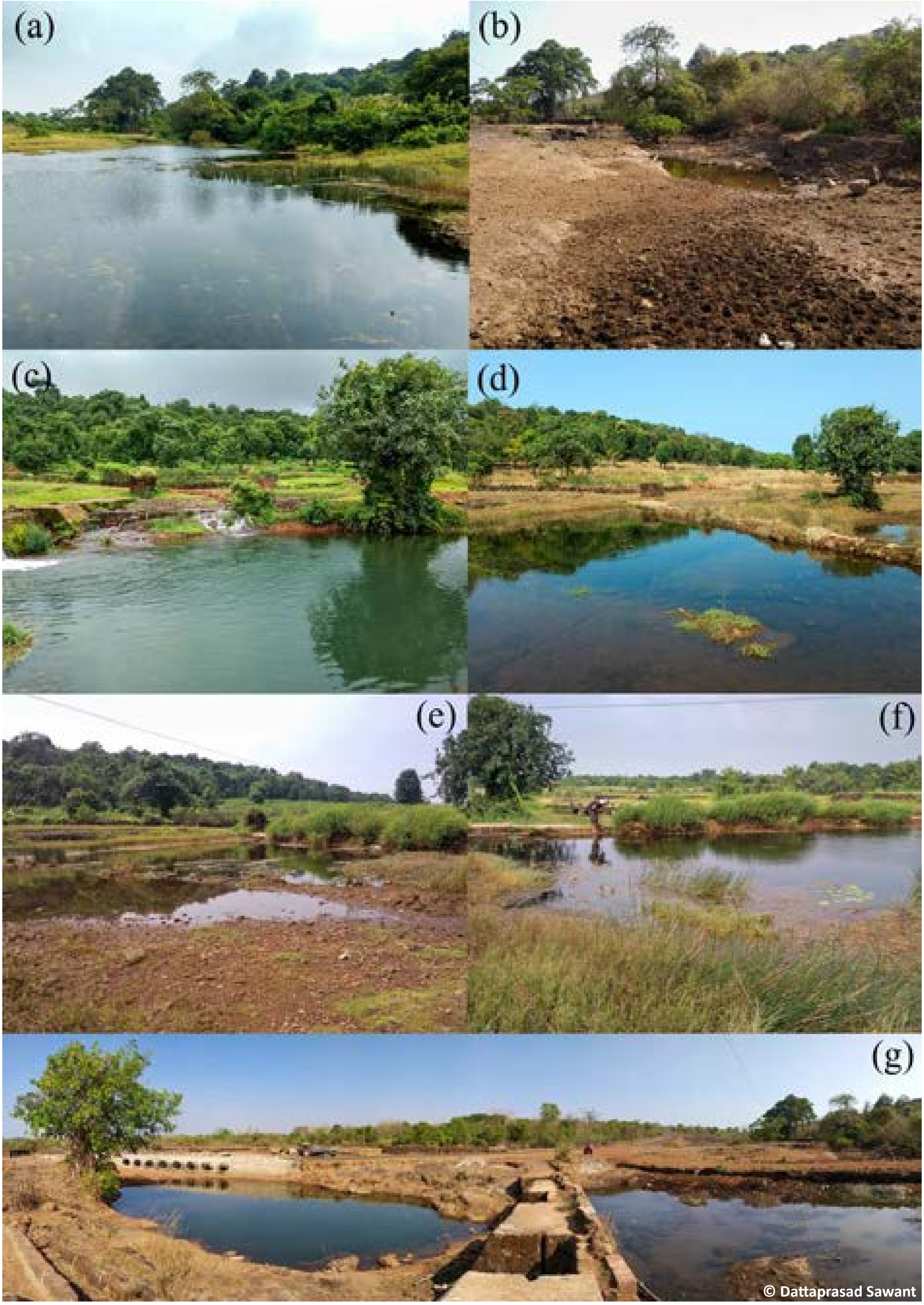

Image 11. Type locality: Vimaleshwar, Devgad, Sindhudurg District, Maharashtra, India (16.433 N, 73.395 E) on (a) 30.ix.2017 | (b) 14.ii.2019 | (c) 16.viii.2018 | (d) 24.xi.2018 | (e) 27.ix.2017 | (f) 27.ix.2017 | (g) 14.ii.2019.

Image 12. Habitat at Wada (16.443°N & 73.392°E), the second locality where *Ceriagrion chromothorax* sp. nov. was observed. Image captured on 25.iii.2019.

malabaricum. *C. chromothorax* males were observed feeding six times, following prey species were observed: a) a small white moth, b) a teneral *Pseudagrion microcephalum*, and c) *C. coromandelianum* (on four separate occasions). This species prefers aquatic vegetation/grasses along the edges and wasn't observed in the deeper parts of the water body.

DISCUSSION

Ceriagrion is a genus of small to medium-sized generally brightly coloured damselflies with 51 species found across Africa, Asia and Australia and with a single representative in Europe. Most species are widespread, but certain groups have incredible cryptic diversity, which remains understudied especially in Asia. One such group comprises seven species (including *C. chromothorax*), which are found in mainland southern and southeastern Asia and are similar in appearance, having yellow abdominal coloration together with a yellow or olive thorax.

Of the seven species *C. coromandelianum* is undoubtedly the most widespread. In Western Ghats two 'yellow' *Ceriagrion* occur: *C. coromandelianum* and *C. chromothorax* sp. nov. (*C. chromothorax* being the only endemic representative of the genus in Western Ghats and India). *Ceriagrion coromandelianum, C. fallax,* and *C. indochinense* are widespread, whilst *C. nigroflavum*, *C. melanurum*, and *C. pallidum* have comparatively restricted distributions. *Ceriagrion nigroflavum* is closely related to *C. fallax* with which it occurs in Myanmar, Thailand and Laos. Although *C. nigroflavum* appears to be widely distributed, it is the only Asian *Ceriagrion* whose female remains unknown (Dow 2010). In addition, it is known from only a handful of specimens with no records since 1952. *Ceriagrion pallidum* was described from Laos and remains poorly known. Although, Fraser (1933b) mentions it as "similar to *C. azureum* and *C. olivaceum"* (two very different species), this species resembles immature or teneral coloration in *C. coromandelianum* and *C. indochinense* (Farrell 2016). *Ceriagrion melanurum*, another species similar to *C. fallax*, is distributed in China including Taiwan, the Korean Peninsula and Japan.

This description of a new species from the Western Ghats, a reasonably well studied region in terms of Odonata, is surprising and suggests that it has been misidentified as *C. coromandelianum* in the field by previous workers. This is the first new *Ceriagrion* species to be described from Asia in more than 50 years (Schorr & Paulson 2018). The type locality of this species is a non-protected area rich in odonate diversity, with more than 60 odonate species (Dattaprasad Sawant, pers. comm. 28 March 2019).

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The diversity and distribution of polypores (Basidiomycota: Aphyllophorales) in wet evergreen and shola forests of Silent Valley National Park, southern Western Ghats, India, with three new records

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Abstract: The present study was conducted to document the diversity and distribution of polypores in wet evergreen and shola forests of Silent Valley National Park, Kerala State, in the southern Western Ghats, India. A combination of opportunistic and plot-based sampling was carried out in order to maximize the documentation of polypore distribution. The study was conducted throughout the entire study period of 2013–2015. Fifty-seven polypore species in 29 genera belonging to seven families were documented from the national park. The wet evergreen forest was enriched with 52 species whereas the shola forest harboured 20 polypore species. Fifteen species were found in both ecosystems while five species were exclusively found in the shola forest. The Polyporaceae was the dominant family with 30 species, followed by Hymenochaetaceae with 16 species, and Fomitopsidaceae and Meripilaceae with three species each. Ganodermataceae and Schizoporaceae made their presence with two species each while only one species was reported under family Meruliaceae. Among the polypores documented, 42 species were annuals and 15 were perennials. While analyzing the rot characteristics of the recorded polypores, it was found that white rot polypores have notable dominance over brown rot polypores. Out of the 57 species analysed, 52 polypores were white rotters and only five species were brown rotters. During the present study, three species (*Phylloporia pectinata*, *Trametes menziesii*, and *Trametes ochracea*) were found to be new records from the southern Western Ghats. An identification key was developed for the polypores documented from Silent Valley National Park based on micro and macro morphological features.

Keywords: Brown rot, evergreen forest, new record, Polyporaceae, shola forest, white rot.

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Author Contribution: CKA carried out research and performed analyses as part of his MSc programme under the guidance of KV and PNIG. All the authors wrote the paper together.

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INTRODUCTION

The polypores are fascinating and specialized wood-rotting macrofungi that play a major role in decomposition and biomass turnover in forest ecosystems. Wood rotting polypores are important elements of forest ecosystems since they decompose wood and coarse wood debris, and play a primary and central role in nutrient cycling. Most polypores depend on woody substrates while the rest are terrestrial. Most of them inhabit living wood as parasites subsequently killing them slowly and continue as saprophytes while the remaining are true saprophytes. Taxonomically, polypores are macro fungi under the division Basidiomycota and order Polyporales. They produce holobasidia and ballistosporic basidiospores typically on the inside of the tubes lining the underside of fructifications (Leelavathy & Ganesh 2000). The importance of polypores and the diversity of polypores in tropical forests were not known or not properly assessed. The tropics are a very rich source of potentially useful polypores, many of which probably have not even been recognized, described, or named (Yamashita et al. 2015).

The first Indian record of a member of polyporales was by Klotzsch (1832) when he described a total of four polypores from India. In 1833, Klotzsch described 25 polypores from the Himalayan valleys. Sundararaman & Marudarajan (1925) reported 11 species of polypores from Chennai. Butler & Bisby (1931) brought together all the records of Indian fungi in their valuable compilation The Fungi of India, which included 293 polyporoid species under 16 genera. Bakshi (1971) gave an account of 355 species of polypores belonging to 15 genera in his most outstanding work Indian Polyporaceae (on trees and timber). Roy & De (1996) listed 114 poroid species in Polyporaceae of India based on exhaustive studies on fungi belonging to the family Polyporaceae collected from different parts of India. Further, Florence (2004) reported 555 species of basidiomycetes under 179 genera from Kerala State. Bhosale et al. (2005) gave a tabulated account of 251 species of order *Aphyllophorales* from the Western Ghats. Swapna et al. (2008) reported 778 species of macrofungi belonging to 101 genera under 43 families from the semi-evergreen and moist deciduous forests of Shimoga District, Karnataka.

The study of the polypores of Kerala was initiated by Rangaswami et al. (1970). In his outstanding work Fungi of South India, 44 polyporoid species representing 13 genera were described, of which five species were from Kerala. Roy & De (1996) in their work Polyporaceae of India reported six polypore species from Kerala. Leelavathy & Ganesh (2000) reported 78 species belonging to 26 genera under families Ganodermataceae, Hymenochaetaceae, and Polyporaceae in their classical work Polypores of Kerala. The majority of the specimens described in that treatise was collected by the authors during the period 1983–1987 from the forests as well as inhabited areas of central and northern Kerala. Florence & Yesodharan (2000) reported 35 polypores from the Peechi-Vazhani Wildlife Sanctuary. Florence (2004) recorded 93 species of polypores from the state. Lately, Mohanan (2011) identified and described a total of 89 species of polypores belonging to 32 genera from different forest ecosystems in Kerala. Recently, Iqbal et al. (2016) reported 36 polypores under 21 genera belonging to six families from Peechi-Vazhani Wildlife Sanctuary.

In Kerala, studies on polypores are done not much exhaustively as compared to mushrooms (Agaricales). The literature shows only sporadic reports and the assessments are still preliminary. Even though the polypores of Kerala were studied in detail by Bakshi (1971), Leelavathy & Ganesh (2000), and Mohanan (2011), much of the forests remain unexplored. Here we summarise the findings of the exploration of polypore diversity in specialized ecosystems like wet evergreen and shola forests of the Silent Valley NP from March 2014 to February 2015.

MATERIALS AND METHODS

Study area

The Silent Valley National Park (SVNP) lies within the geographical extremes of latitudes 11°,2′ N–11°, 13′ N & longitudes 76°, 24′ E–76°, 32′ E (Fig. 1) in the southwest corner of the Nilgiri Hills of the southern Western Ghats. Silent Valley National Park constitutes part of the core area of India's first biosphere reserve, the Nilgiri Biosphere Reserve. The terrain of the SVNP is generally undulating with steep escarpments and many hillocks. The elevation ranges from 900–2300 m with the highest peak at 2383m (Anginda Peak). Both the southwestern and northeastern monsoon cause rains in this area. The major share, however, comes from the southwestern monsoon, which sets in during the first week of June. The heaviest rainfall is during the months of June, July, and August. Variation in the intensity of rainfall is observed across the area. The elevated hills on the western side of Silent Valley receive an average of 5045mm rainfall, and near Walakkad the rainfall received goes up to 6500mm.

The forests exhibit considerable variation in floristic

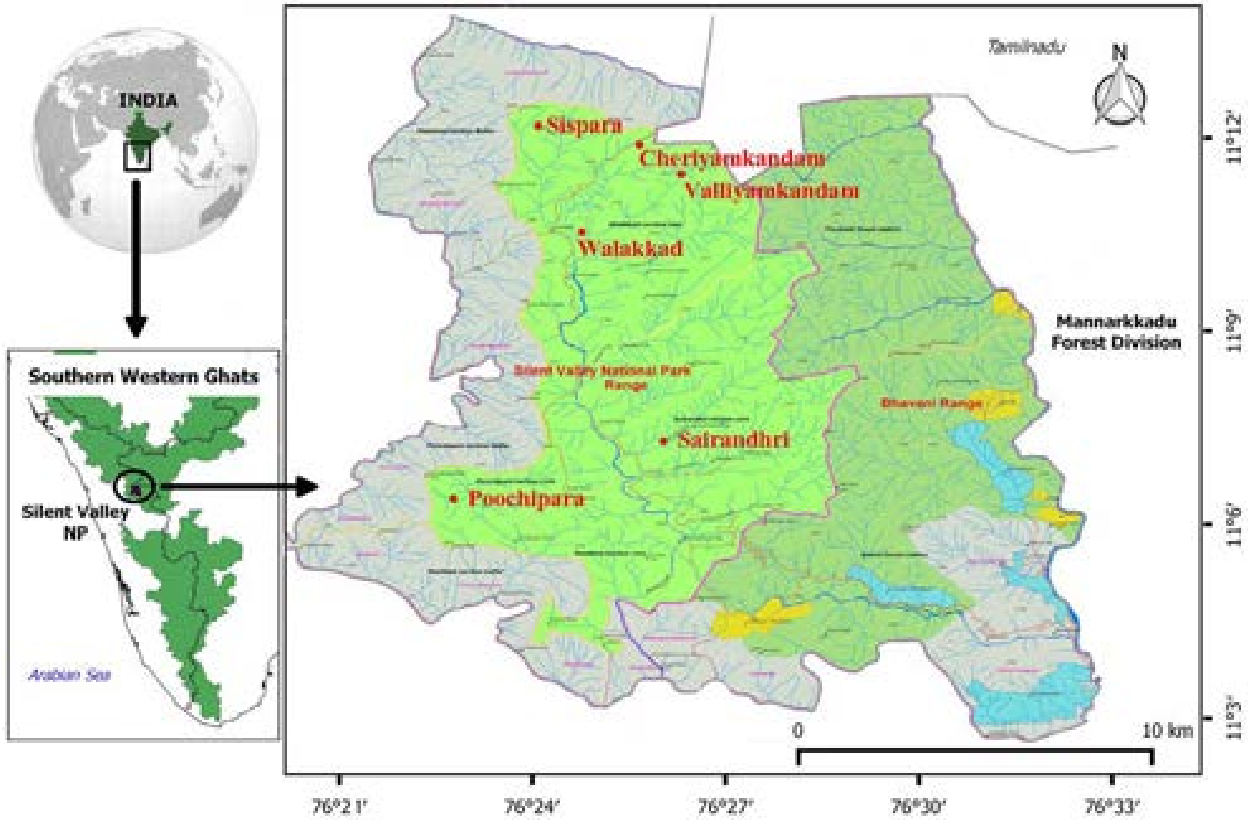

Figure 1. Silent Valley National Park, southern Western Ghats, India.

composition, physiognomy, and life forms due to climatic, edaphic, and altitudinal variations. About 75–80 % of the land in the protected area is covered with thick woody vegetation and about 20% of the area has grassland and a small area is under rocky patches with a little vegetation cover. The Silent Valley, in general, embodies vast stretches of wet evergreen forest in the undulating hills and valleys between an elevation of 900–1500 m. The evergreen forest of Silent Valley is the home par excellence of the broad-leaved evergreen trees in multi-storeyed canopies often reaching up to 40m or more. The dominant tree species in this type of forests are usually about 45m in height, and consists generally of *Cullenia exarillata*, *Machilus macrantha*, *Elaeocarpus munronii*, *Palaquim ellipticum*, *Mesua ferrea*, *Calophyllum inophyllum*, *Cinnamomum malabatrum*, *Canarium strictum*, *Syzygium cumini*, *Syzygium laetum*, *Dysoxylum malabaricum*, *Poeciloneuron indicum*, *Mangifera indica*, *Artocarpus integrifolia*, *Holigarna grahamii*, *Hopea glabra*, and *Garcinia gummi-gutta.*

The shola forests are seen in cliffs and sheltered folds above 1800m where water is available in surplus. The Sispara area is enriched with typical shola forests. Because of winds and high altitudes, these forests are stunted, the trees seldom attaining a height above 10m. Lauraceae and Myrtaceae members constitute the bulk of the flora. The dominant species found are *Rhododendron arboreum*, *Schefflera rostrata*, *Ternstroemia gymnanthera*, *Michelia nilgirica*, *Gordonia obtusa*, *Ilex wightiana*, *Meliosma pinnata*, *Cinnamomum sulphuratum*, *Cinnamomum wightii*, *Litsea floribunda*, *Litsea stocksii*, *Euonymaus crenulatus*, *Glochidion ellipticum*, and *Symplocos racemosa*.

Survey methodology, collection, identification, and preservation of polypores

The polypores were surveyed in Silent Valley National Park (SVNP) from March 2014 to February 2015. Six permanent sample plots of size 100m × 100m were established in evergreen and shola forests (three in each ecosystem) as per the methodology followed in earlier studies (Yamashita et al. 2010; Mohanan 2011). In evergreen forests, the sample plots were taken in three different locations: Sairandhri, Poochipara, and Walakkad sections (Images 1–3). Three sample plots of shola forest were taken in different locations: Sispara, Cheriyamkandam, and Valliyamkandam (Images 4–6). The sample plots were visited during the premonsoon, monsoon, and post-monsoon periods for the documentation of polypores, including collection of sporocarps, labelling, identification of rot character, taking photographs, and recording macromorphological description and details of substratum in the illustrated data sheet. The rot characters were documented by examining the substrate characters and basal attached portion of polypores. A total area of 60000m^2 was surveyed in each of the three climatic seasons. Additional collection of polypores was also made from "off-plots" in the study area. Thus, a combination of opportunistic and plot-based survey was carried out to maximize the documentation of polypore diversity and distribution.

The polypore specimens collected from the study area were kept in paper bags and brought to the lab. The specimens were properly air-dried or oven-dried at 70^{o}C and stored in polythene zip-cover under less humid conditions. The specimens were identified based on their macro and micro morphological features. The colour names and colour codes of the specimens were given as per Kornerup & Wanscher (1967). The identification keys provided by Bakshi (1971) and Leelavathy & Ganesh (2000) were used for the confirmation of polypore species. The micromorphological characteristics of the polypores were studied using a Lieca DM 750 microscope. Some of the specimens were compared with those in the herbaria at Kerala Forest Research Institute, Peechi. The taxonomy and nomenclature are as per indexfungorum. All the specimens collected during the study period were catalogued and kept under less humid conditions in the Department of Forest Management and Utilization, College of Forestry, Kerala Agricultural University.

The diversity of polypores was calculated using PAST 3.14. The following formulae have been used to determine the diversity of polypores:

1. Simpson Index of Diversity, $D = 1- \sum (ni / N)^2$ (Simpson 1949)

Where,

ni - Number of individuals of the species

N - Total number of individuals in the plot

D - Diversity

2. Shannon-Weiner's Index, H = 3.3219 (Log N-1/N ∑ ni log ni) (Shannon & Weiner 1963)

Where,

ni - Number of individuals of the species

N - Total number of individuals

3. Pielou's Evenness Index, E = (LnN-1/N ∑ ni ln ni)/Ln N (Pielou 1966)

Where,

ni - Number of individuals of the species

N - Total number of individuals

4. Berger-Parker Dominance Index, D = nmax/N

Where,

nmax - Highest value of number of individuals of species

N - Total number of individuals

5. Margalef Richness Index, R = (S-1)/N (Margalef 1968)

Where,

S - Total number of species

N - Total number of individuals

6. Sorenson Similarity Index

Similarity of each polypore community was calculated by the following equation:

QS = 2c/a+b

Where, a & b represent the species numbers occurring in two different plots, and c the species occurring in both plots (Sorenson 1948).

RESULTS

Fifty-seven polypore species in 29 genera belonging to seven families were documented (Table 1). The wet evergreen forest was enriched with 52 species whereas the shola forest harboured 20 polypore species. Fifteen species were found in both ecosystems while five species were exclusively found in shola forest (Fig. 2).

The Polyporaceae was the dominant family with 30 species followed by Hymenochaetaceae (16 sp.), Fomitopsidaceae, and Meripilaceae with three species each. Ganodermataceae and Schizoporaceae made their presence with two species each while only one species was reported under the family Meruliaceae (Fig. 3). Among the polypores documented, 42 species were annuals and 15 were perennials. While analyzing the rot characteristics of the recorded polypores, it was found that the white rot polypores had a notable dominance over brown rot polypores. Out of the 57 species analysed, 52 polypores were white rotters and only five species were brown rotters.

During the present study, five species (*Inonotus pachyphloeus*, *Phylloporia pectinata*, *Trametes menziesii*, *Trametes ochracea*, and *Trametes pubescens*) were found to be new records from the southern Western Ghats. An identification key was developed for the

Table 1. Species composition of polypores in the wet evergreen and shola forests of Silent Valley National Park.

						Study areas					
						Evergreen			Shola		
	Species	Image no.	Family	Habit	Rot	Sairandhri	Poochippara	Walakkad	Sispara	Cheriyamkandam	Valliyamkandam
1	*Abortiporus biennis* (Bull.) Singer	12	Meruliaceae	A	W	+	-	+	-	-	-
2	*Cellulariella acuta* (Berk.) Zmitr. & V. Malysheva	13	Polyporaceae	A	W	+	+	+	-	-	+
3	*Coriolopsis telfairii* (Klotzsch) Ryvarden, 1972	14	Polyporaceae	A	W	+	+	+	-	-	-
4	*Cyclomyces setiporus* (Berk.) Pat.	15	Hymenochaetaceae	A	W	A	+	-	-	-	-
5	*Daedalea dochmia* (Berk. & Broome) T. Hatt.	16	Fomitopsidaceae	P	B	+	+	+	-	-	-
6	*Earliella scabrosa* (Pers.) Gilb. & Ryvarden	17	Polyporaceae	A	W	+	+	+	+	-	+
7	*Favolus tenuiculus* P. Beauv.	18	Polyporaceae	A	W	+	+	+	-	-	-
8	*Fomes extensus* (Lev.) Cooke	19	Polyporaceae	P	W	+	-	-	-	-	-
9	*Fomes pseudosenex* (Murrill) Sacc. & Trotter	20	Polyporaceae	P	W	+	+	-	-	-	-
10	*Fomitopsis feei* (Fr.) Kreisel	21	Fomitopsidaceae		B	+	+	+	-	-	-
11	*Fomitopsis palustris* (Berk. & M.A. Curtis) Gilb. & Ryvarden	22	Fomitopsidaceae	A	B	+	-	+	-	-	-
12	*Fulvifomes cesatii* (Bres.) Y.C. Dai	23	Hymenochaetaceae	A	W	A	-	v	+	-	-
13	*Funalia caperata* (Berk.) Zmitr. & V. Malysheva	24	Polyporaceae	A	W	+	+	+	-	-	-
14	*Fuscoporia contigua* (Pers.) G. Cunn.	25	Hymenochaetaceae	P	W	+	+	+	-	-	-
15	*Fuscoporia ferrea* (Pers.) G. Cunn.	26	Hymenochaetaceae	A	W	+	+	+	-	-	-
16	*Fuscoporia senex* (Nees& Mont.) Ghob.-Nejh.	27	Hymenochaetaceae	A	W	+	+	+	-	-	-
17	*Fuscoporia wahlbergii* (Fr.) T. Wagner & M. Fisch.	28	Hymenochaetaceae	P	W	+	+	-	+	+	-
18	*Ganoderma australe* (Fr.) Pat.	29	Ganodermataceae	P	W	+	+	+	-	+	-
19	*Ganoderma lucidum* (Curtis) P. Karst.	30	Ganodermataceae	A	W	+	+	+	+	-	+
20	*Hexagonia tenuis* (Hook.) Fr.	31	Polyporaceae	A	W	+	+	+	-	-	-
21	*Inonotus luteoumbrinus* (Romell) Ryvarden	32	Hymenochaetaceae	P	W	+	+	-	-	-	-
22	*Inonotus pachyphloeus* * (Pat.) T. Wagner & M. Fisch.	33	Hymenochaetaceae	P	W	+	+	-	-	-	-
23	*Inonotus* sp.	34	Hymenochaetaceae	P	W	+	+	-	-	-	-
24	*Inonotus tabacinus* (Mont.) G. Cunn.	35	Hymenochaetaceae	A	W		+				
25	*Leucophellinus hobsonii* (Berk. ex Cooke) Ryvarden	36	Schizoporaceae	A	W	-	-	-	+	-	-
26	*Microporellus obovatus* (Jungh.) Ryvarden	37	Polyporaceae	A	W	+	+	+	-	+	-
27	*Microporus affinis* (Blume & T. Nees) Kuntze	38	Polyporaceae	A	W	+	+	+	-	-	+
28	*Microporus* sp.	39	Polyporaceae	A	W	A	+	-	-	-	-
29	*Microporus xanthopus* (Fr.) Kuntze	40	Polyporaceae	A	W	+	+	+	+	+	-
30	*Neofomitella rhodophaea* (Lev.) Y.C. Dai	41	Polyporaceae	A	B	+	+	+	-	-	-
31	*Nigroporus vinosus* (Berk.) Murrill	42	Polyporaceae	A	W	+	+	+	-	-	-
32	*Phellinus dependens* (Murrill) Ryvarden	43	Hymenochaetaceae	P	W	+	+	+	-	-	-
33	*Phellinus fastuosus* (Lev.) S. Ahmad	44	Hymenochaetaceae	P	W	+	+	+	+	-	-

						Study areas					
						Evergreen			Shola		
	Species	Image no.	Family	Habit	Rot	Sairandhri	Poochippara	Walakkad	Sispara	Cheriyamkandam	Valliyamkandam
34	*Phellinus gilvus* (Schwein.) Pat.	45	Hymenochaetaceae	A	W	+	+	+	-	-	-
35	*Phellinus nilgheriensis* (Mont.) G. Cunn.	46	Hymenochaetaceae	P	W	+	+	+	+	-	+
36	*Phellinus zealandicus* (Cooke) Teng	47	Hymenochaetaceae	A	W	+	+	+	-	-	-
37	*Phylloporia pectinata* * (Klotzsch) Ryvarden	48	Hymenochaetaceae	P	W	-	-	-	-	+	+
38	*Polyporus dictyopus* Mont.	49	Polyporaceae	A	W	+	-	+	-	-	-
39	*Polyporus grammocephalus* Berk.	50	Polyporaceae	A	W	+	+	+	-	-	-
40	*Polyporus leprieurii* Mont.	51	Polyporaceae	A	W	+	+	+	-	-	-
41	*Polyporus* sp.	52	Polyporaceae	A	W	+	-	-	-	-	-
42	*Rigidoporus lineatus* (Pers.) Ryvarden	53	Meripilaceae	A	W	+	+	-	-	-	+
43	*Rigidoporus microporus* (Sw.) Overeem	54	Meripilaceae	A	W	A	+	-	-	-	-
44	*Rigidoporus ulmarius* (Sowerby) Imazeki	55	Meripilaceae	P	B	+	-	+	-	-	-
45	*Schizopora paradoxa* (Schrad.) Donk	56	Schizoporaceae	A	W	+	+	+	-	+	+
46	*Spongipellis unicolor* (Schwein.) Murrill	57	Polyporaceae	A	W	+	-	-	-	-	-
47	*Trametes cingulata* Berk.	58	Polyporaceae	A	W	+	+	-	-	-	-
48	*Trametes cotonea* (Pat.) Ryvarden	59	Polyporaceae	A	W	+	-	+	-	-	-
49	*Trametes hirsuta* (Wulfen) Pilat	60	Polyporaceae	A	W	+	+	-	-	-	+
50	*Trametes marianna* (Pers.) Ryvarden	61	Polyporaceae	A	W	+	+	+	-	-	-
51	*Trametes maxima* (Mont.) A. David & Rajchenb	62	Polyporaceae	A	W	+	+	+	-	-	-
52	*Trametes menziesii* * (Berk.) Ryvarden	63	Polyporaceae	A	W	+	+	+	+	+	+
53	*Trametes ochracea* * (Pers.) Gilb. & Ryvarden	64	Polyporaceae	A	W	-	-	-	+	+	+
54	*Trametes pubescens* * (Schumach.) Pilat	65	Polyporaceae	A	W	-	-	-	+	+	+
55	*Trametes versicolor* (L.) Lloyd	66	Polyporaceae	A	W	-	-	-	+	+	+
56	*Trichaptum biforme* (Fr.) Ryvarden	67	Polyporaceae	A	W	+	+	+	-	-	-
57	*Trichaptum byssogenum* (Jungh.) Ryvarden	68	Polyporaceae	A	W	+	-	+	-	-	-

A - Annual, P - Perennial, W - White rot, B - Brown rot, * New report from southern Western Ghats, + Present, - Absent

polypores documented from Silent Valley National Park based on their micro and macro morphological features (Appendix 1).

Phylloporia pectinata **(Klotzsch) Ryvarden**

Fruit body annual, solitary, imbricate, effused reflexed to pileate, attached with a broad base, 1–1.5 x 1.5–2.5 x 0.2–0.4 cm; pileus surface concentrically grooved, highly velutinate, smooth glabrous, uneven, dark brown (6F8), margin smooth, entire, velutinate. Pore surface dark brown (6F8); pores not visible to naked eye, 9–10 per mm, pore mouth 70–100 µm wide, margin distinct; pore tubes of varying length, 1–2 mm long, shining; dissepiments thin (40) 50–70 (120) µm thick; context uniform, shining, brownish orange (6E7), 0.8–1 mm thick.

Hyphal system dimitic. Skeletal hyphae yellowish-brown, thick walled, usually unbranched, but extremities sparsely branched, bent sometimes, lumen narrow, 2.5–3.5 µm in diameter. Basidiospore yellowish, round to globose to slightly sub globose, slightly thick walled. Basidia long, clavate, sleritmata incipient, four-spored,

Image 1. Wet evergreen forest at Sairandhri.

Image 2. Wet evergreen forest at Poochippara.

Image 3. Wet evergreen forest at Walakkad.

Image 4. Shola forests at Sispara.

Image 5. Shola forests at Cheriyamkandam.

Image 6. Shola forests at Valliyamkandam.

7–8 x 2.5–3 µm (Image 7).

Decay: White rot.

Specimen examined: On decaying log of *Cinnamomum sulphuratum*, Cheriamkandam, Silent Valley National Park, ACK 45/23-5-2014; ACK 39/30-1-2015; ACK 20, 32/28-2-2015; ACK 22/30-3-2015.

This species was reported on the bark of *Glycosmis pentaphylla*, from Kolkata, WB (Berkeley 1839).

***Trametes menziesii* (Berk.) Ryvarden**

Fruitbody annual, solitary, imbicate, confluent, laterally stipitate, flabelliform to spathulate, lobed towards margin, stipe prominent when young, 1.5–4-5 x 1–4 x 0.15 cm. Pileus surface uneven, orange white (5A2), radially folded, concentrically zonate, warty towards base, finely velutinate towards margin, shining, margin very thin, stipe rudimentary to 5mm, spreading at base, greyish-orange (5B4), tough, soft hyphae, angulate, to give a warty appearance; pore surface brown (6E7) to greyish-brown (5B3); pores almost visible to naked eye, 5–6 per mm, pore mouth (50) 70–90 (110) µm wide, uneven stripe, margin distinct, shining, young and smaller towards margin, older region yellowish brown, margin lighter; dissepiments thin (30) 50–70 (100) µm thick; pore tubes pale orange (5B3), uniform, 1.5mm long; context less than 1mm, homogenous towards margin, pores angular, round when young.

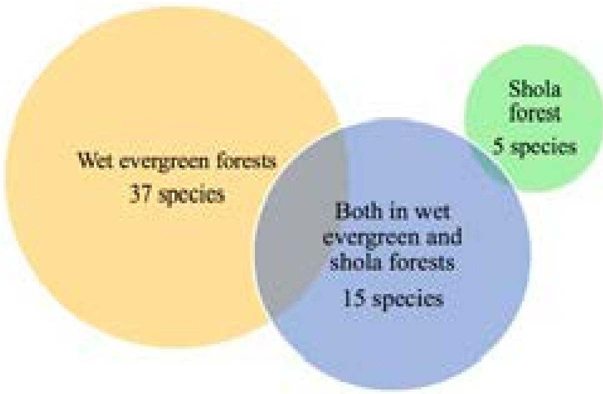

Figure 2. Habitat-wise analysis of polypores.

Hyphal system trimitic. Generative hyphae hyaline, thin slightly thick walled, septate with clamp connections, branched, (3) 3.5–4.5 (5) µm in diam. Skeletal hyphae hyaline, thin to slightly thick walled, 4–5 in diameter (Image 8).

Decay: White rot.

Specimen observed: On decaying log of *Cullenia exarillata*, Sairandhri, Silent Valley National Park, ACK 13/29-7-2014; ACK 43/28-8-2014; ACK 58/19-10-2014, ACK 9/9-12-2014; ACK 21/30-1-2015; 35, 38, 41/28-2-

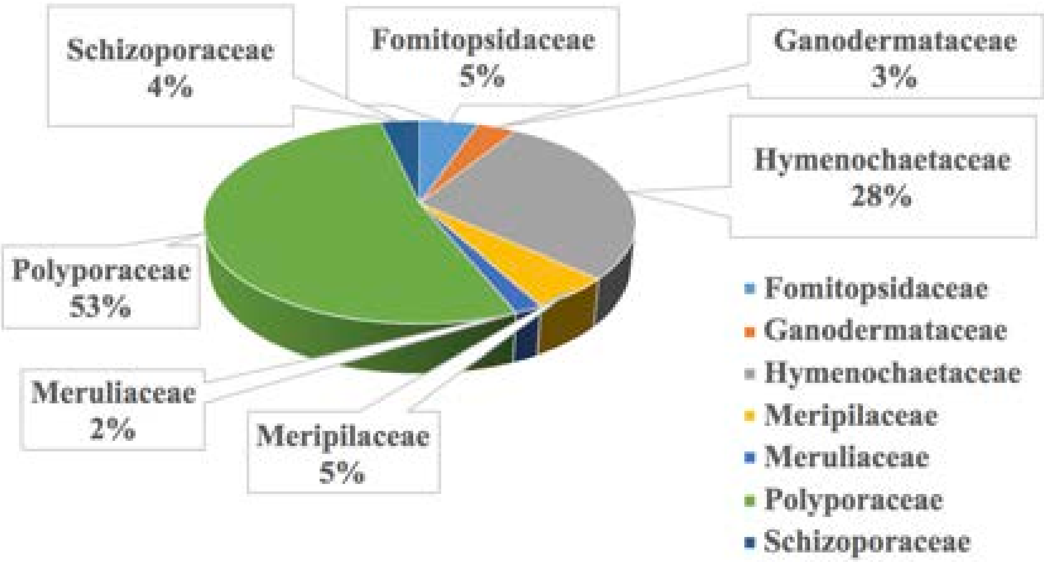

Figure 3. Family-wise distribution of polypores.

2015; ACK 41/30-2-2015.

The species was earlier reported on trunks, from Sikkim (Berkeley MJ 1854), on logs of *Shorea robusta* and stumps of *Euphorbia nerrifolia* (Bose 1921) in Lokra Hills, Assam (Bose 1934), and on a stump of *Querscus* sp. in Arunachal Pradesh (De 1985).

Trametes ochracea **(Pers.) Gilb. & Ryvarden**

Fruitbody annual, solitary, imbricate, confluent, attached with broad base, often centrally stipitate but growth not uniform, coriaceous while flesh, hard and pliable when dry, almost round to applanate, flabelliform while young, 0.8–2 x 1–3 x 0.1–0.2 cm. Pileus surface concentrically zonate, light brown (7D1) to dark brown (8F7) to reddish brown (8D8, 9E6) to grey (9D1), finely velutinate to glabrous, shining, margin uneven, smooth, incurved, thin when dry, stipe rudimentary, dark brown (8F8), warty, velutinate; pore surface even shining, brownish orange (5C4); pores not visible to naked eye, margin very thin but distinct, 6–7 per mm, pore mouth (100) 120–140 (155) µm wide; pore tube uniform, 0.1–0.15 cm long, pale yellow (4A3); dissepiments thin (40) 50–60 µm thick; context yellowish-white (4E2), concolorous, with poretubes, very thin, less than 1mm, homogenous.

Hyphal system trimitic. Generative hyphae hyaline, thin walled, closely branched, zigzag, septate with clamps, 2–3 µm in diameter. Binding hyphae hyaline, sparsely branched, thick-walled with narrow lumen, nonseptate, 2–3.5 µm in diameter. Skeletal hyphae hyaline to slightly brownish, long and branched, thick-walled, nonseptate, lumen narrow, sometimes obliterated, 4–5 (7) µm in diameter. Basidia broadly clavate, four spored, 3.5–4.5 x 6–7 µm. Cystidia none. Basidiospore not observed (Image 9).

Decay: White rot.

Specimen observed: On a decaying log of *Cinnamomum sulphuratum*, Sisppara, Silent Valley National Park, Herb. ACK 1, 13/28-2-2015; ACK 20, 40/30-3-2015.

This species was reported earlier on dead branches from Mumbai, MS (Theissen 1911) and on stumps and logs of a deciduous tree from Shillong, Meghalaya (Bose 1946).

In order to understand the diversity attributes of the polypores in wet evergreen and shola forests, the diversity, richness, dominance, and evenness were analyzed using Simpson diversity index, Shanon-Wiener index, Pielou's evenness index, Berger-Parker dominance Index, and Margalef richness Index (Table 2).

In wet evergreen forest, Simpson's Index of diversity was observed to be 0.92 while in shola it was only 0.78. The wet evergreen forest showed higher Shanon-Wiener Index value (2.83) than that in shola forest (2.02). The Margalef richness index was also found to be relatively high in wet evergreen forest (3.15) while it was 1.74 in shola forest. The evenness in the distribution of polypores was observed to be comparatively higher in wet evergreen forest with Pielou's evenness index 0.84 than in shola forest (0.77). The shola forest showed more Berger-Parker dominance index value (0.42) in the polypore distributon while it was only 0.12 in evergreen forest (Table 2).

Sorenson's similarity index was worked out to find the

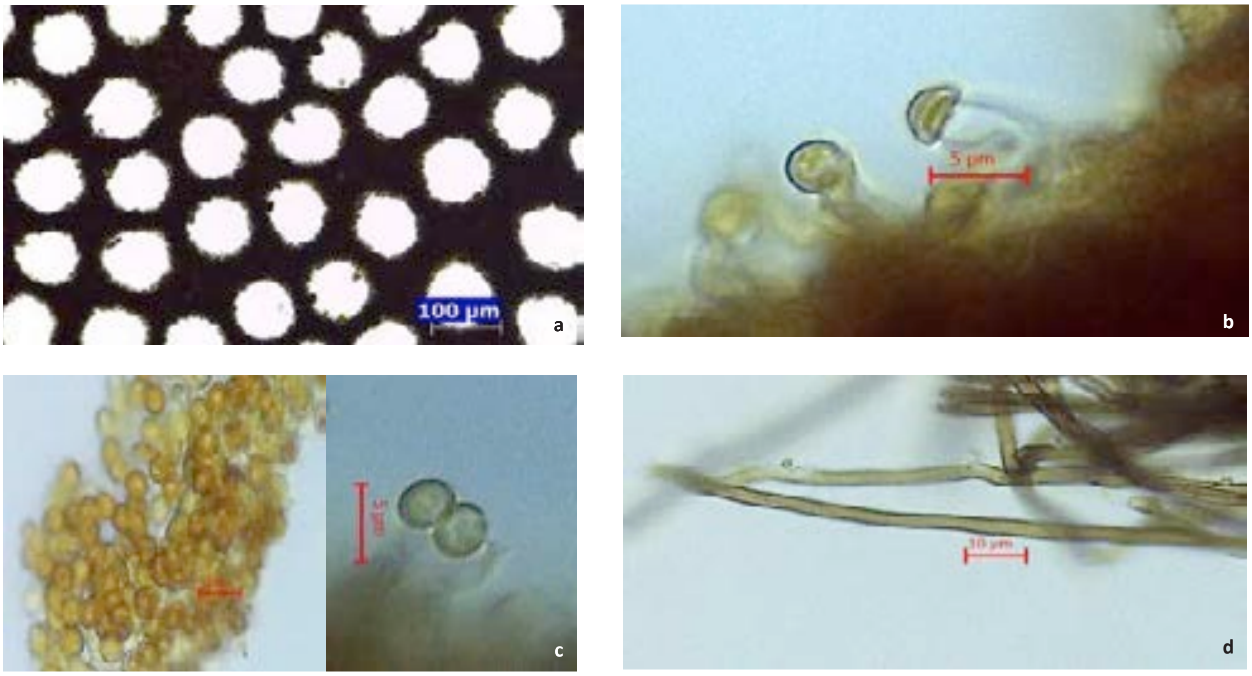

Image 7. ***Phylloporia pectinata*** **(Klotzsch) Ryvarden: a - Pore surface, b - Basidia, c - Spore, d - Skeletal hyphae.**

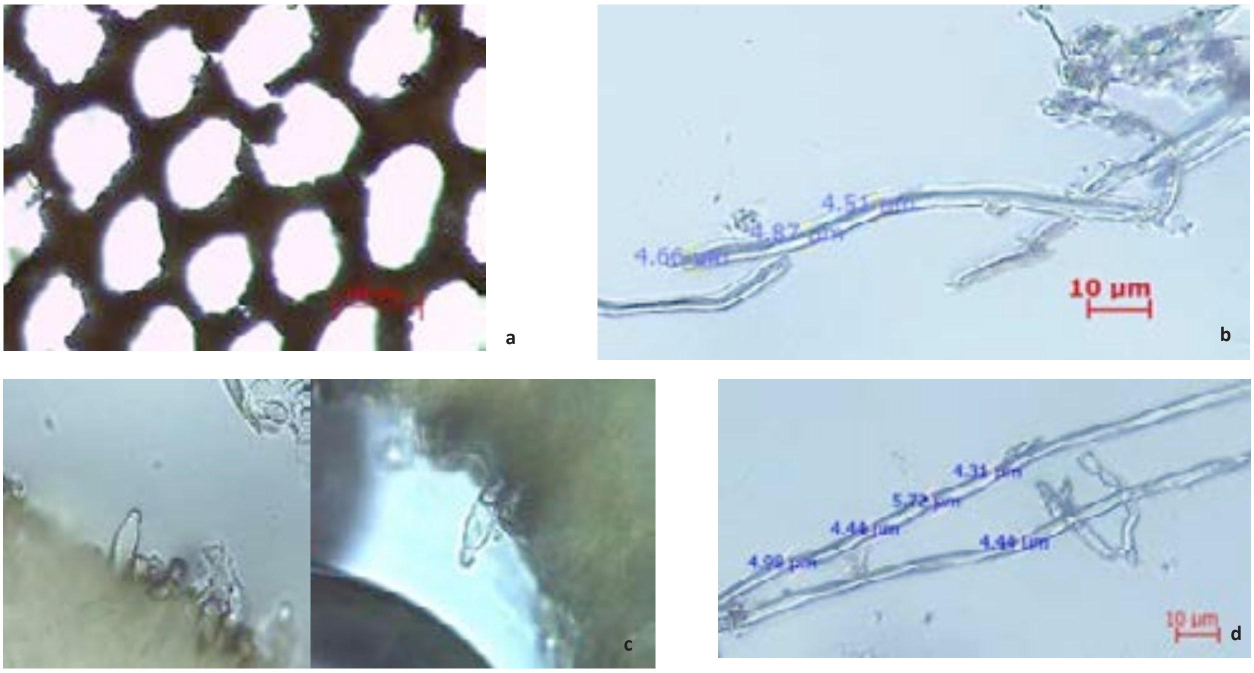

Image 8. ***Trametes menziesii*** **(Berk.) Ryvarden: a - Pore surface, b - Generative hyphae, c - Basidium, d - Skeletal hyphae.**

similarity of polypore community in the wet evergreen forest and shola forest during different seasons. In all the seasons similarity between polypore community in the two ecosystems was found to be low (0.44).

DISCUSSION

The present study on the diversity and distribution of polypores in wet evergreen and shola forest of Silent Valley National Park reported 57 species altogether. The species composition analysis of polypores in the wet

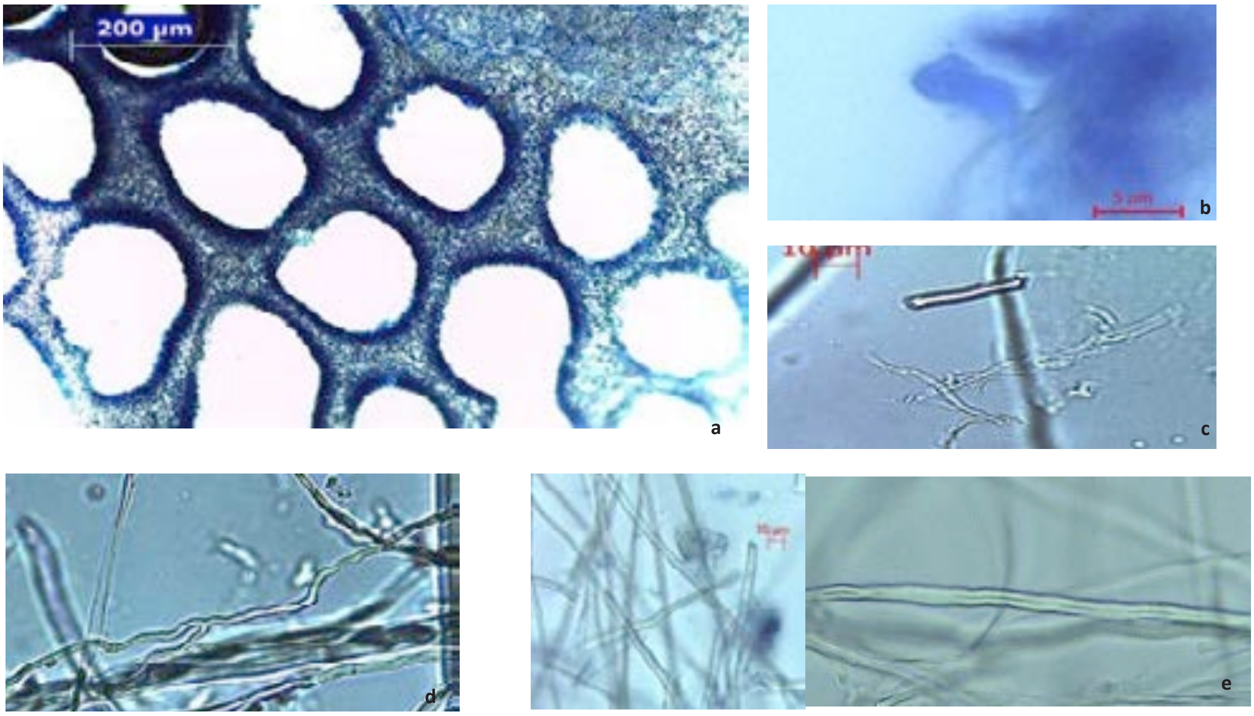

Image 9. *Trametes ochracea* (Pers.) Gilb. & Ryvarden: a - Pore surface, b - Basidia, c - Generative hyphae, d - Binding hyphae, e - Skeletal hyphae.

evergreen and shola forests highlighted the dominance of family Polyporaceae over others in all seasons. Of the 57 species identified, 52.63% belonged to Polyporaceae and 28.07% belonged to Hymenochaetaceae followed by Fomitopsidaceae and Meripilaceae with 5.26% each. The families Ganodermataceae and Schizoporaceae constituted 3.50% each. Meruliaceae (1.75%) was with the least number of species. The rot character analysis proved the dominancy of white rot polypores over brown rotter with 91.22% of the total species. This observation is in agreement with Lyngdoh & Dkhar (2014), Leelavathy & Ganesh (2000), Florence & Yesodharan (2000), Mohanan (2008, 2011), and Iqbal et al. (2016).

It was suggested that brown-rot has been repeatedly derived from white-rot (Gilbertson 1980). In contrast, it was also suggested that brown-rot fungi forms the plesiomorphic form in the homobasidiomycetes, and that white-rot has been repeatedly derived by elaborated wood decay mechanisms (i.e., gaining the ability to degrade lignin) (Nobles 1965, 1971). Studies by Ryvarden (1991) and Worrall et al. (1997), however, have supported Gilbertson's view that brown-rot fungi were derived from white-rot fungi.

White-rot fungi occur frequently on hardwoods while brown-rot fungi have an obvious preference for coniferous substrates (Tuor et al. 1995; Schmidt 2006; Karami et al. 2014). Hardwood lignin is composed mainly of gluaiacyl and syringyl units. Lignin distribution, content, and composition have a significant influence on decay resistance (Frankenstein & Schmitt 2006). White-rot fungi achieve wood degradation with several different combinations of peroxidases and oxidases like ligninase, Manganese peroxidase (Mnp), Lignin peroxidase (Lip), and lactase and are able to utilize a wide variety of substrates (Tuor et al. 1995). On the other hand, white rot fungi have a geographic distribution not corresponding to their most suitable hosts (Gilbertson 1980). These views support the high proportion of white rot polypores in the study area.

Leelavathy & Ganesh (2000) have reported 19 species of polypore from the national park area. Of these, 15 species were observed during the present study. Species like *Hexagonia sulcata, Pycnoporus sanguineus*, *Trametes modesta,* and *Coriolopsis sanguinaria* were not observed during the present study. Polypore diversity exploration in the present study added five new reports to polypores of southern Western Ghats. The identities of the species were confirmed by comparing the characters described for the specimens collected by Bakshi (1971), Ryvarden & Jonansen (1980), and Leelavathy & Ganesh (2000).

The wet evergreen forest showed relatively high polypore diversity and evenness than that of the shola forest (Table 2). Also, wet evergreen forest showed relatively high species richness (29 species) than that

Table 2. Diversity Indices of polypores of wet evergreen and shola forests.

Forest type	Simpson diversity Index	Shanon-wiener Index	Margalef richness Index	Pielou's evenness Index	Berger-Parker dominance Index
Wet evergreen forest	0.92	2.83	3.15	0.84	0.12
Shola forest	0.78	2.02	1.74	0.77	0.42

of shola forest (14 species). In wet evergreen forest, Simpson's Index of diversity was observed to be 0.92, i.e., if 100 pairs of polypores were taken at random, 92 will comprise different species while in shola it was only 0.78. The species richness was also found to be relatively high in wet evergreen forest than in shola forest. The less polypore diversity and richness in the shola forest can be explained on the basis of the theory of ecological niches and strategies of saprophytic fungi by Cooke & Rayner (1984). The availability of suitable substrate is an important determinant of polypore diversity. Two characteristics of substrates influencing patterns of fungal development are the ease with which they can be assimilated and their spatial and temporal distribution (Cooke & Rayner 1984).

The arborescent floras of the two forest types also contained many disjunctively distributed species. Only a few species were found to be common to both ecosystems. Tree species of shola forest is characterized by much stunted habit (seldom attaining a height above 15m) with spreading, umbrella-shaped canopy, and crooked and twiggy branches and branchlets (Nair & Menon 2000). The trees are very often covered with several epiphytic lichens, mosses, ferns, and orchids. Even though they are mostly associated with living trees, they will remain on the logs of early stages of decay. The number of logs was also noticed to be comparatively less in shola forest. It has been pointed out that a broad diversity of host tree species of various volumes, diameters, and degrees of decomposition seem to be major factors contributing to the diversity of the wood-rotting fungi (Kuffer & Senn-Irlet 2005). Thus, the less availability of suitable substrate is a major factor for the low diversity and richness of polypores in shola forest.

The ecological strategy of polypores is strongly influenced by three factors: competition, stress, and disturbance (Cooke & Rayner 1984). Competition involves the struggle for capture and defence of resources between neighbours. In shola forest, the tree branches are often covered with several epiphytic lichens, mosses, ferns, and orchids which could be a barrier for the germination and establishment of polypores. Similarly, the undergrowth of shrubs like *Strobilanthus* sp. was found to prevent light on the fallen logs. The shady environment around the logs is not favourable for polypore establishment. Light has a wide range of effects on basidiomycete fruiting such as production, development, and abundance (Moore et al. 2008). Additionally, the undergrowth of *Strobilanthus* sp. may also prevent spore dispersal of the polypores in shola forests.

Further, the stress may be any form of continuously imposed environmental extremes that tend to restrict fruitbody production of polypores (Cooke & Rayner 1984). The low temperature of the shola forest could also be a limiting factor for polypore diversity. Extension rate of mycelial cord-forming basidiomycetes generally increases as the temperature does, up to optima of about 20–25 °C (A'Bear et al. 2014). The low temperature of the shola forest also cause physiological dryness to the plants growing there, restricting their moisture absorption capability from the topsoil, which is often frozen (Nair & Menon 2000). The lower temperature is, therefore, an important determinant of polypore diversity in shola forests. Finally, the disturbance describes a state in which the whole or part of the total fungal biomass is destroyed or subjected to new selection pressures by a drastic change in environmental conditions (Cooke & Rayner 1984). The severe low temperature in the shola forest could be acting as a disturbance for most of the polypores.

The evenness in the distribution of polypores was found to be comparatively high in wet evergreen forest with Pielou's Evenness Index 0.84 than in shola forest (0.77). On the other hand, shola forest showed more Berger-Parker Dominance Index value (0.42) in polypore distribution, which was low (0.12) in evergreen forest. This could be due to polypores that can tolerate the prevailing environmental severity and dominate over the rest. Species like *Phylloporia pectinata*, *Fulvifomes cesatii*, *Leucophellinus hobsonii*, *Trametes ochracea*, and *Trametes pubescens* were recorded only from high altitude shola forest, indicating their environmental tolerance and adaptation to disturbances.

The present study recorded 57 polypore species with a few new records from the southern Western Ghats. Much of the forests in the Western Ghats remain unexplored in case of diversity and ecology of polypores. More detailed explorations have to be done for understanding the actual diversity and ecological functions of polypores in forest ecosystems.

Image 12. *Abortiporus biennis*.

Image 13. *Cellulariella acuta*.

Image 14. *Coriolopsis telfairii*.

Image 15. *Cyclomyces setiporus*.

Image 16. *Daedalea dochmia*.

Image 17. *Earliella scabrosa*.

Image 18. *Favolus tenuiculus*.

Image 19. *Fomes extensus*.

Image 20. *Fomes pseudosenex*.

Image 21. *Fomitopsis feei*.

Image 22. *Fomitopsis palustris*.

Image 23. *Fulvifomes cesatii*.

Image 24. *Funalia caperata*.

Image 25. *Fuscoporia contigua*.

Image 26. *Fuscoporia ferrea*.

Image 27. *Fuscoporia senex*.

Image 28. *Fuscoporia wahlbergii*.

Image 29. *Ganoderma australe*.

Image 30. *Ganoderma lucidum*.

Image 31. *Hexagonia tenuis*.

Image 32. *Inonotus luteoumbrinus*.

Image 33. *Inonotus pachyphloeus*.

Image 34. *Inonotus* sp.

Image 35. *Inonotus tabacinus*.

Image 36. *Leucophellinus hobsonii*.

Image 37. *Microporellus obovatus*.

Image 38. *Microporus affinis*.

Image 39. *Microporus* sp.

Image 40. *Microporus xanthopus*.

Image 41. *Neofomitella rhodophaea*.

Image 42. *Nigroporus vinosus*.

Image 43. *Phellinus dependens*.

Image 44. *Phellinus fastuosus*.

Image 45. *Phellinus gilvus*.

Image 46. *Phellinus nilgheriensis*.

Image 47. *Phellinus zealandicus*.

Image 48. *Phylloporia pectinata*.

Image 49. *Polyporus dictyopus*.

Image 50. *Polyporus grammocephalus*.

Image 51. *Polyporus leprieurii*.

Image 52. *Polyporus* sp.

Image 53. *Rigidoporus lineatus*.

Image 54. *Rigidoporus microporus*.

Image 55. *Rigidoporus ulmarius*.

Image 56. *Schizopora paradoxa*.

Image 57. *Spongipellis unicolor*.

Image 58. *Trametes cingulata*.

Image 59. *Trametes cotonea*.

Image 60. *Trametes hirsuta*.

Image 61. *Trametes marianna*.

Image 62. *Trametes maxima*.

Image 63. *Trametes menziesii*.

Image 64. *Trametes ochracea*.

Image 65. *Trametes pubescens*.

Image 66. *Trametes versicolor*.

Image 67. *Trichaptum biforme*.

Image 68. *Trichaptum byssogenum*.

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Appendix 1. Key to genus and species of Polypores

Ganodermataceae Donk,
Bull. bot. GdnsBuitenz. 17(4): 474 (1948)

1. Fruitbody leathery, (sub) stiptate; pileus surface laccate, reddish brown or greyish .... *Ganoderma lucidum*
1'. Fruitbody sessile, surface never laccate, brownish or darker .... *Ganoderma australe*

Hymenochaetaceae Donk,
Bull. bot. GdnsBuitenz. 17(4): 474 (1948)

1. Sporophore annual or perennial; hyphal system dimitic, generative hyphae hyaline, thin-walled 2
1'. Sporophore usually annual; hyphal system monomitic ... 3

2. Context homogeneous; tubes stratified in perennials .... ***Phellinus***
2'. Context duplex with spongy upper layer........................... .. ..***Phylloporia*** (*P. pectinata*)

3. Sporophore annual, resupinate, setae absent...................... .... ***Fulvifomes*** (*F. cesatii*)
3'. Sporophore annual or perennial, never resupinate, setae present or absent 4

4. Hyphal system monomitic .... ***Inonotus***
4'. Hyphal system dimitic 5

5. Sporophore annual, coriaceous, concentrically lamellate to minutely poroid, spores hyaline .... ***Cyclomyces*** (*C. setiporus*)
5'. Sporophore annual to perennial, hard woody, strictly poroid, spores hyaline or greyish .... ***Fuscoporia***

Phellinus **Quel.,**
Enchir. fung. (Paris): 172 (1886)

1. Setae present in trama or hymenium 2
1'. Setae absent 4

2. Sporophore annual, pileus surface hirsute to glabrous....... .. .. *Phellinus gilvus*
2'. Sporophore perennial, glabrous 3

3. Setae up to 12–15 x 5–7 µm .... *Phellinus dependens*
3'. Setae up to 25–40 x 7–10 µm .... *Phellinus zealandicus*

4. Fruitbody flabelliform to spathulate, velutinate when young; spores subglobose .... *Phellinus fastuosus*
4'. Fruitbody applanate to ungulate, glabrous, spores globose .... *Phellinus nilgheriensis*

Inonotus **P. Karst.,**
Meddn Soc. Fauna Flora fenn. 5: 39 (1879)

1. Hymenial and setal hyphae absent 2
1'. Hymenial and setal hyphae present 3

2. Pores 6–7 per mm; hyphal system monomitic; spores globose .... *Inonotus* sp. nov.
2'. Pores 4–5 per mm; hyphalsystem dimitic; spores 5–6 x 4.5–5 µm .... *Inonotus luteoumbrinus*

3. Setal hyphae abundant, 12–20 µm broad; hyphalsystemdimitic .... *Inonotus pachyphloeus*
3'. Setal hyphae 7.5–10 µm broad; hyphal system monomitic .... *Inonotus tabacinus*

Fuscoporia **Murrill,**
N. Amer. Fl. (New York) 9(1): 3 (1907)

1. Fruitbody pileate; pores 4–5 per mm 2
1'. Fruitbody resupinate; pores 6–7 per mm 3

2. Setae 15–25 µm long; decay: white stringy .... *Fuscoporia senex*
2'. Setae 30–40 µm long; decay: white rot .... *Fuscoporia wahlbergii*

3. Pores irregular, angular to daedaloid ... *Fuscoporia contigua*
3'. Pores smooth round .... *Fuscoporia ferrea*

POLYPORACEAE Fr. ex Corda [as 'Polyporei'],
Icon. fung. (Prague) 3: 49 (1839)

1. Hymenophore angular, hexagonal or daedaloid 2
1'. Hymenophore poroid 3

2. Hymenophore hexagonal .... ***Hexagonia*** (*H. tenuis*)
2'. Hymenophore daedaloid or lamellate .... ***Cellulariella*** (*C. acuta*)

3. Context not xanthochroic, hyphal system dimitic or trimitic, clamps present or not 4
3'. Context not xanthochroic, hyphal system dimitic or trimitic, clamps present or not 6

4. Sporophore annual, leathery, pileus surface yellowish-brown, hairs present 5
4'. Sporophore perennial, heavy woody, glabrous .... ***Fomes***

5. Pileal surface yellowish, hispid to scrupose, pores angular, up to 2 per mm; dissepiments often sharp or tricolor .... ***Coriolopsis*** (*C. telfairii*)
5'. Sporophore brown, soft, tomentose, pores round, 3–5 per mm; dissepiments smooth .... ***Funalia*** (*F. caperata*)

6. Sporophore stipitate, stipe central or lateral 7
6'. Sporophore resupinate to pileate, never stipitate 9

7. Stipe central, hyphal system dimitic .... ***Polyporus***
7'. Stipe lateral, hyphal system trimitic 8

8. Spore elliptical, coralloid elements present ...... ***Microporus***
8'. spores globose to subglobose; coralloid elements absent .... ***Microporellus*** (*M. obovatus*)

9. Pileus surface vinaceus brown, context reddish-brown .... ***Nigroporus*** (*N. vinosus*)
9'. Pileus surface yellowish, context lighter 10

10. Pileus surface with prominent hairs, pore round to daedaloid to irpicoid .... ***Trichaptum***
10'.Pileus surface almost glabrous, pore mouth minute 11

11. Pore tubes sunk into even depth in forming a uniform stratum 12
11'Pore tubes sunk into uneven stratum .... ***Trametes***

12. Pore small, more than 6 per mm .... ***Neofomitella*** (*N. rhodophaea*)
12'. Pores large, 1 per mm .... ***Spongipellis*** (*S. unicolor*)

Fomes **(Fr.) Fr.,**
Summa veg. Scand., Section Post. (Stockholm): 319 (adnot.), 321 (1849)

1. Fruitbody triquetrous, context with a black crusty line ………. ……………………………………………………………… *Fomes extensus*

1'. Fruitybodyconchate, irregular, context without black crusty line …………………………………………………… *Fomes pseudosenex*

Polyporus **P. Micheli ex Adans.,**
Fam. Pl. 2: 10 (1763)

1. Stipe central to eccentric …………………… *Polyporus leprieurii*
1'. Stipe lateral ………………………………………………………………… 2

2. Pores more than 10 per mm; dissepiments 20–30 µm thick ……………………………………………………………… *Polyporus* sp. nov.
2'. Pore less than 8 per mm; dissepiments more than 35 µm thick ………………………………………………………………………………… 3

3. Pileus surface orange yellow to greyish, radially straite; pore surface brownish-yellow to light orange …………………………… … ……………………………………………… *Polyporus grammocephalus*
3'. Pileus surface corn to hair brown; pore surface yellowish-white ………………………………………………… *Polyporus dictyopus*

Microporus **P. Beauv.,**
Fl. Oware 1: 12 (1805)

1. Stipe central, funnel-shaped ……….. *Microporus xanthopus*
1'. Stipe lateral, flabelliform ……………………………………………… 2

2. Pore mouth 50–70 µm wide; dissepiments 35–75 µm thick ………… …………………………………………………… *Microporus affinis*
2'. Pore mouth 90–100 µm wide; dissepiments 50–60 µm thick …………………………………………………… *Microporus* sp. nov.

Trichaptum **Murrill, Bull.**
Torrey Bot. Club 31(11): 608 (1904)

1. Pileus surface hispid, yellowish-grey to violet, pores 1–2 per mm …………………………………………… *Trichaptum byssogenum*
1'. Pore surface tomentose, yellowish-white with greyish patch; Pores 3–5 per mm ……………………… *Trichaptum biforme*

Trametes **Fr., Fl. Scan.: 339 (1836)**

1. Pileus surface hirsute, velutinate …………………………………… 2
1'. Pileus surface glabrous ………………………………………………… 6

2. Pileus surface azonate, white to cream coloured …………. 3
2'. Pileus surface yellowish to brownish coloured ……………. 4

3. Pores 2–3 per mm, basidiospores cylindric to elliptic, 4–5 x 2.5–3 µm …………………………………………………… *Trametes cotonea*
3'. Pores 4–5 per mm, basidiospores oval, 6–7 x 2.5 µm ………… ……………………………………………………… *Trametes pubescens*

4. Pore surface white to cream …………….. *Trametes versicolor*
4'. Pore surface yellowish to yellowish-grey ……………………… 5

5. Pileus surface velvety tomentose with glabrous bands ……. ………………………………………………………… *Trametes ochracea*
5'. Pileus surface with coarse hairs in bundles …………………… ……………………………………………………………… *Trametes hirsuta*

6. Pore surface irpicoid to dentate …………. *Trametes maxima*
6'. Pore surface smooth ……………………………………………………… 7

7. Pileus surface yellowish; pores 6–8 per mm ………………….. .. ………………………………………………………… *Trametes marianna*
7'. Pileus surface with dark zonations in bands, Pores less than 5 per mm ………………………………………………………………………… 8

8. Laterally substipitate to very narrow attachment; Pileus surface with narrow grey zonations ………. *Trametes menziesii*
8'. Attachment with broad lateral base; Pileus surface sooty brown broad strations …………………………… *Trametes cingulate*

Meripilaceae Julich
Biblthca Mycol. 85: 378, 1981

1. Encrusted cystidia present ……………… *Rigidoporus lineatus*
1'. Cystidia usually absent, if present mucronate, not encrusted ……………………………………………………………………………………… 2

2. Spores size: 4–5 µm or 4–5 x 3.5–4.5 µm; decay causing white rot ………………………………………… *Rigidoporus microporus*
2'. Spores size: 5–6 µm; decay causing brown cuboidal rot ….. ……………………………………………………… *Rigidoporus ulmarius*

Schizoporaceae Julich,
Biblthca Mycol. 85: 389 (1982)

1. Sporophore resupinate; pores 4–6 per mm …………………… ………………………………………………… ***Schizopora*** (*S. paradoxa*)
1'. Sporophore effused reflexed, pileus surface hispid to strigose; Pores 1 per mm …………. ***Leucophellinus*** (*L. hobsonii*)

Fomitopsidaceae Julich,
Biblthca Mycol. 85: 367 (1982)

1. Sporophore annual, coriaceous ……………………… ***Fomitopsis***
1'. Sporophore perennial, hard, woody ……………………… ….. …………………………………………………… ***Daedalea*** (*D. dochmia*)

Fomitopsis **P. Karst.,**
Meddn Soc. Fauna Flora fenn. 6: 9 (1881)

1. Pileus surface rust brown to reddish blonde; Spore cylindric to ellipsoid, 4–6 x 1.5–2.5 µm ……………………… *Fomitopsis feei*
1'. Pileus surface white cream to pure yellow; Spore cylindric to oblong ellipsoid ……………………………… *Fomitopsis palustris*

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Recent photographic records of Fishing Cat *Prionailurus viverrinus* (Bennett, 1833) (Carnivora: Felidae) in the Ayeyarwady Delta of Myanmar

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Abstract: The distribution of the Fishing Cat *Prionailurus viverrinus* (Carnivora: Felidae) in Myanmar remains poorly known owing to a paucity of verifiable field records. We here present two recent photographic records that confirm the occurrence of the Fishing Cat in the Ayeyarwady Delta of southern Myanmar. Our photographic records together with other reports and the availability of suitable wetland habitat suggest that the Ayeyarwady Delta is globally important for Fishing Cat conservation. Deforestation, driven largely by agriculture, however, is of concern for the future survival of the Fishing Cat in Myanmar. Additional surveys are warranted to further resolve the distribution of the Fishing Cat in Myanmar.

Keywords: Carnivore, conservation status, distribution record, wetland.

The Fishing Cat *Prionailurus viverrinus* is a small, wetland-dependent cat with an extensive albeit discontinuous geographic range in southern and southeastern Asia (Mukherjee et al. 2016; Chutipong et al. 2019; Poudel et al. 2019). The distribution and occurrence of the Fishing Cat within this extensive geographic range remains ill-defined and poorly known owing to the 1) the paucity of recent authenticated records, the 2) the numerous unauthenticated, ambiguous, and erroneous records, and the 3) the difficulties associated with detecting this small cat in the wild (Mukherjee et al. 2016). This situation is lamentable because Fishing Cat populations are thought to be declining at an alarming rate in all range countries, especially those in southeastern Asia (Mukherjee et al. 2016). Accurate distribution data, particularly from protected areas, are an essential prerequisite for designing effective conservation strategies (Dodd & Franz 1993; Stohlgren et al. 1994). Indeed, targeted conservation efforts for Fishing Cat are frequently hindered by the lack of reliable distribution and occurrence data (Duckworth et al. 2009, 2010; Mukherjee et al. 2012, 2016; Than Zaw et al. 2014).

Similar to other range countries in southeastern Asia (e.g., Duckworth et al. 2010; Rainey & Kong 2010), data on the occurrence and distribution of Fishing Cat in Myanmar are sparse (Than Zaw et al. 2014; Mukherjee et al. 2016). According to Morris (1936), two Fishing Cats were encountered and one collected along the Chindwin River near Dalu (Taro) in what is now Hukaung Valley Wildlife Sanctuary (Fig. 1). Shepherd & Nijman (2008)

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recorded 37 Fishing Cat skins offered for sale at illicit wildlife markets in Tachilek during 1991–1992, although the origin of these skins could not be determined with any degree of certainty. Furthermore, given the frequent misidentifications of even living animals, the reliability of these identifications are open to question. Similarly, a mounted specimen of unknown provenance (but presumably from Myanmar) was photographed in a Yangon curio shop in 2011 (Than Zaw et al. 2014). In the Ayeyarwady Delta, Forest Department staff reportedly observed Fishing Cats during an Estuarine Crocodile *Crocodylus porosus* survey of Meinmahla Kyun Wildlife Sanctuary (MKWS; Fig. 1), although no corroborating evidence (such as images) are available to confirm these sightings (Thorbjarnarson et al. 1999). Five Fishing Cats held in the Yangon Zoo were said to be captive-bred progeny from adults collected in the region during the late 1990s (Than Zaw et al. 2014). Despite the paucity of recent verifiable field records, Mukherjee et al. (2016) nonetheless suggested that Ayeyarwady Delta is likely to represent a globally important area for Fishing Cat conservation owing to the widespread availability of potentially suitable habitat. We here present two recent photographic records of known provenance that confirm the occurrence of Fishing Cat in the Ayeyarwady Delta. To our knowledge, these are the first verifiable locality-based records of Fishing Cat in Myanmar since the account of Morris (1936).

Our first photographic record of a Fishing Cat was taken by Onishi Shingo in MKWS on 20 February 2016 (Image 1). MKWS is an ASEAN Heritage Site comprising 137km^2 of mangrove swamp, scrub forest, and wet grassland in the lower Ayeyarwady Delta (Beffasti & Galanti 2011). Much of MKWS is being converted to Phoenix Palm *Phoenix paludosa* thickets as a result of widespread illegal cutting of mangroves for fuelwood (Harris et al. 2016). The Fishing Cat was photographed from a passing boat while sitting on the bank of a tidal creek (Fig. 1; Polaung Lay Chaung; 15.973^{0}N & 95.287^{0}E; altitude = 1.0m). The bedraggled appearance of the cat suggests that it was foraging in the creek shortly before the image was taken.

Our second photographic record of a Fishing Cat was obtained from an automated game camera deployed at a commercial fish pond approximately 17km north of Maubin (Maubin Township) in Ayeyarwady Region. This low-lying site (16.819^{0}N & 95.695^{0}E; altitude = 4.0m) is located within an anthropogenic landscape characterized by commercial fish ponds, rice fields, and natural wetlands laced with an extensive network of creeks, drainage ditches, and irrigation canals. Fallow agricultural fields, natural wetlands, and embankments along creeks and canals support dense stands of high grass. During a casual conversation with two villagers participating in a Sarus Crane *Antigone antigone* survey (Thet Zaw Naing & Naing Lin unpub. data), we learned that small wild cats, perhaps Fishing Cats, are occasionally taken in traps and snares set for civets (Viverridae), the latter being locally hunted for domestic consumption. In response to these reports, we visited the site in April 2018 and noted tracks and scats (with a diameter <25mm), consistent with published descriptions for those of Fishing Cats (Francis 2008; Cutter 2015; Naidu et al. 2015; Platt & Duckworth 2019).

We returned in May 2018 and deployed automated game cameras (HCO Scout Guard®) without bait in the bed of a recently drained fishpond having an abundance of felid tracks. The berm surrounding the fish pond supported dense stands of tall grass, while pools of standing water, some containing fish, aquatic vegetation, and emerging grass, were present in the pond bed. From 09 to 11 May 2018, we deployed three motion-sensitive game cameras, (programmed to take a single burst of three images at 1-min intervals) for six trap nights. Each game camera was set in the early evening (ca. 17.00h) and recovered the following morning (ca. 07.00h) to reduce the likelihood of theft. The game cameras were positioned to cover likely avenues of wildlife movement along the periphery of the drying pond.

On the night of 10–11 May 2018, one game camera captured a sequence of four images (04.27–04.33 h) of a Fishing Cat (Image 2). The first image shows a cat moving perpendicular to the field of view along the edge of the vegetation-mud interface. In the following image, the cat is standing <30cm away from the lens and looking directly into the camera. Owing to the proximity of the cat to the camera, the image is washed out and little detail is evident other than the silhouette of the head. The third and fourth images were taken about five minutes later and show a Fishing Cat moving perpendicular to the field of view in the same direction as the individual captured in the first image. The legs and belly of the cat in the last two images appear to be wet, indicating the cat was wading in shallow water shortly before the camera was triggered. Although Leopard Cat *Prionailurus bengalensis* could potentially occur in the Ayeyarwady Delta, we identified the cat in our images as a Fishing Cat based on its large body size, pale grey colouration of the fur, relatively small black spots in distinct rows, short tail, neck stripes, and smallish, rounded ears positioned well back on the head. In contrast, Leopard Cat is smaller with a less elongated head, yellowish-brown fur which is

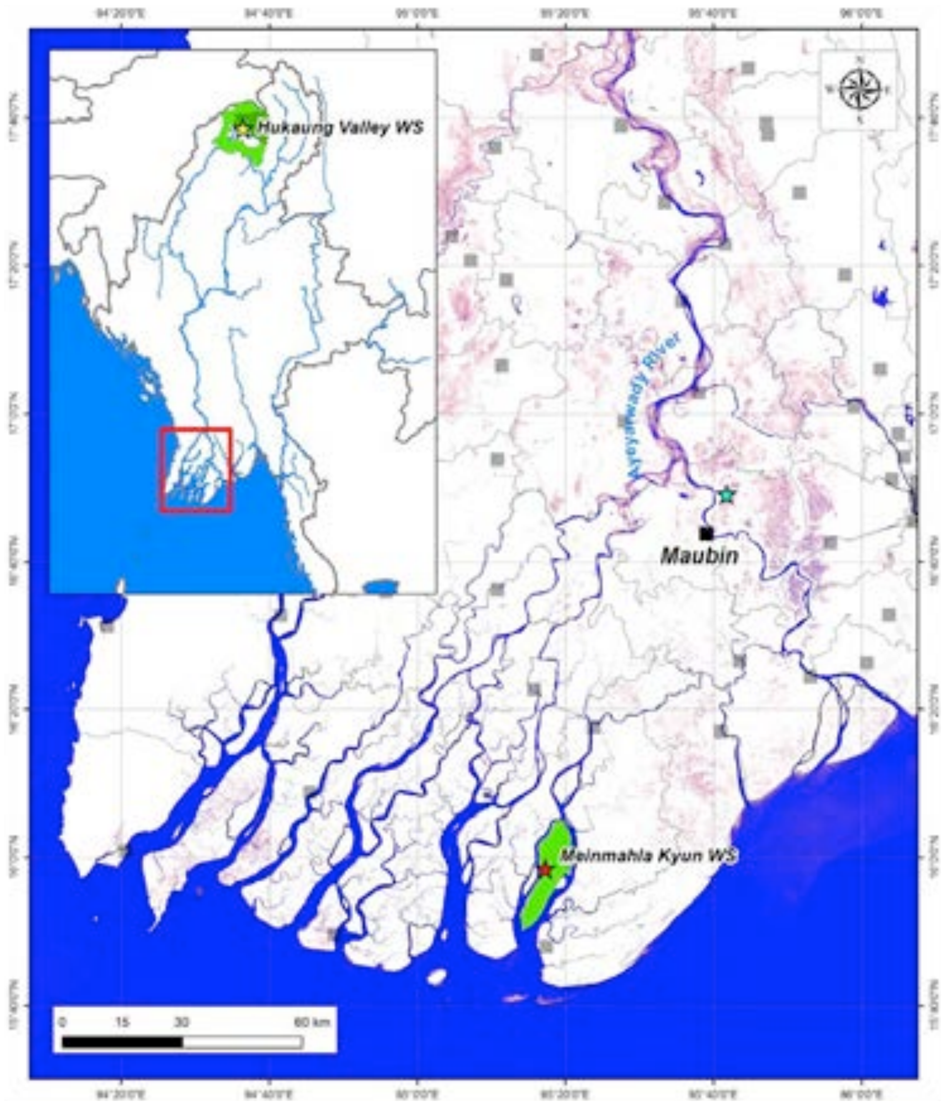

Figure 1. Confirmed locality records for Fishing Cat *Prionailurus viverrinus* in the Ayeyarwady Delta. Red and blue stars denote Fishing Cats photographed along Polaung Chaung in Meinmahla Kyun WS and at a commercial fish pond near Maubin, respectively. Grey squares indicate urban population centres. Inset shows Hukaung Valley WS and Ayeyarwady Delta (red box) within Myanmar. Yellow star denotes approximate location of specimen collected by Morris (1936).

lighter on the underside, large black or brown spots, and a longer, bushy tail (Sunquist & Sunquist 2002; Francis 2008; Breton & Sanderson 2011).

Our recent (2016 & 2018) photographic records confirm the occurrence of Fishing Cat at two widely separated locations (ca. 105km apart) in the Ayeyarwady Delta and provide conclusive evidence for its occurrence in Myanmar (Than Zaw et al. 2014; Mukherjee et al. 2016). Importantly, our photographic records compliment previous unconfirmed reports from the Ayeyarwady Delta (Thorbjarnarson et al. 1999; Than Zaw et al. 2014). As suggested by Mukherjee et al. (2016), the Ayeyarwady Delta is globally important for Fishing Cat conservation, possibly supporting a "large" population owing to the extent of potential habitat in the region.

Habitat destruction, particularly of coastal mangrove forests, is of great concern for Fishing Cat conservation both globally (Sunquist & Sunquist 2002) and specifically in the Ayeyarwady Delta (Mukherjee et al. 2016). Spatial analysis of forest cover change in Myanmar indicates that mangroves are experiencing some of the highest deforestation rates of all forest types, with 20% lost in the Ayeyarwady Delta between 1990 and 2000 (Blasco et al. 2001; Leimgruber et al. 2005). According to Holmes et al. (2014), 92% of mangrove forests in the delta are impacted by some form of anthropogenic disturbance, ranging from occasional fuelwood collection to complete

Image 1. Fishing Cat photographed along Polaung Chaung in Meinmahla Kyun Wildlife Sanctuary on 20 February 2016.

Image 2. Fishing Cat recorded by an automated game camera deployed at a commercial fish pond near Maubin on 11 May 2018. © Wildlife Conservation Society–Myanmar Program.

clearance, with agricultural expansion being the primary driver of deforestation in this region (Webb et al. 2014). Only about 25,000ha of mangrove forest remain in the delta, with MKWS containing the largest contiguous tract (Holmes et al. 2014; Webb et al. 2014; Harris et al. 2016). Although complacency is unwarranted, Fishing Cat appears capable of surviving in human-modified landscapes (Mukherjee et al. 2016) and may be less affected by mangrove forest loss than other wetland fauna. Janardhanan et al. (2014) even suggest that commercial fish ponds may enhance Fishing Cat populations by providing a source of readily obtainable food.

Globally, poaching, subsistence hunting, and retribution killings for livestock depredation are all considered threats to the continued survival of Fishing Cat populations (Mukherjee et al. 2016). That said, we have yet to find any evidence of widespread hunting of Fishing Cat in the Ayeyarwady Delta. The limited sample of villagers we talked to mentioned only the occasional capture of small wild cats, perhaps Fishing Cat, as by-catch in traps intended for civets. More extensive interview-based surveys (e.g., Platt et al. 2017), however, complemented by objectively triangulated information relevant to species identification are required to fully assess the threats posed by harvesting to Fishing Cats in the Ayeyarwady Delta. In addition to anthropogenic threats, MKWS harbours one of the largest remaining populations of Estuarine Crocodile in mainland southeastern Asia (Platt et al. unpub. data; Thorbjarnarson et al. 2000) and Fishing Cat is probably vulnerable to crocodile predation when foraging along tidal creeks. Although we are unaware of any verified records of crocodiles preying on Fishing Cats, similar-sized terrestrial mammals are well-documented in the diet of Estuarine Crocodiles (e.g., Evans et al. 2017; Samarasinghe & Alwis 2017).

In conclusion, additional surveys are warranted and, in light of range-wide declines, urgently needed to resolve the distribution and conservation status of the Fishing Cat in Myanmar. Given the availability of habitat and confirmed occurrence of Fishing Cat in the Ayeyarwady Delta, this region should be prioritized for initial survey efforts. Follow-up efforts should target wetlands throughout the coastal zone, particularly those in Rakhine and Mon states and Tanintharyi Region where significant tracts of mangrove forests, grass swamps, and other wetlands still remain. Importantly, survey efforts should not be restricted to coastal habitats. The historical record from the Hukaung Valley in northern Myanmar (Morris 1936) indicates that Fishing Cat could potentially occur anywhere in the Ayeyarwady-Chindwin River basin where appropriate habitat is present.

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SHORT COMMUNICATION

Rediscovery of Van Hasselt's Mouse-eared Bat *Myotis hasseltii* (Temminck, 1840) and its first genetic data from Hanoi, northern Vietnam

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Abstract: This paper presents the rediscovery of Van Hasselt's Mouse-eared Bat *Myotis hasseltii* after nearly 50 years and its genetic data from Hanoi, northern Vietnam. In addition, a snapshot of the impacts of urbanization on the current distribution and conservation status of this native bat species in Hanoi is also provided.

Keywords: Bioindicators, Chiroptera, conservation, distribution, habitat, mammals, urbanization.

So far, scientific understanding regarding the potential ecological and environmental impacts of urbanization on native biodiversity in Hanoi and other cities in Vietnam is patchy (Duan & Mamoru 2009; World Bank 2011; Nong et al. 2015). To address this issue, research on bat assemblages along a gradient of urban to suburban, agricultural, semi-natural, and forested

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areas in the Hanoi Capital Region of northern Vietnam has been underway since 2009 (Tu 2009, 2017). Bats, one of the native mammalian groups occurring in urban areas, were chosen because they play many important economic and ecological roles in local ecosystems (Jung & Threlfall 2016) and can be regarded as bioindicators that reflect changes in population status of overall biodiversity under the influence of anthropogenic alteration (Jones et al. 2009).

During such fieldwork on 20 January 2017 at Xom Hau, a suburb of Hanoi (21.136N & 105.860E), an adult male mouse-eared bat (Vespertilionidae: *Myotis*) was captured by a hand-net. The individual was taken as a voucher following the guidelines approved by the American Society of Mammalogists (Sikes et al. 2011) and deposited in the Institute of Ecology and Biological Resources, Hanoi, Vietnam (IEBR), under the registration number VN17-26 for further investigation. The external and craniodental characters of the specimen were examined in detail using reference specimens housed in the IEBR and the Hungarian Natural History Museum (HNHM) and published identification keys (i.e., Bates et al. 1999; Kruskop 2013). In addition, the 5' fragment of the mitochondrial cytochrome c oxidase subunit I gene (COI, 685nt) was also sequenced at the Infectious Disease Surveillance Center, National Institute of Infectious Diseases (IDSC, NIID), Tokyo, Japan, using a primer set, MammMt-5533F(CYCTGTSYTTRRATTTACAGTYYAA)/ MammMt-7159R (GRGGTTCRAWWCCTYCCTYTCTT) following the protocol presented in Arai et al. (submitted). The new sequence (Genbank accession number: MK605400) was compared with those of *Myotis* specimens available in the international nucleotide databases (i.e., the Barcode of Life Data Systems (BOLD), GenBank) for corroborating the morphology-based identification. Our analyses confirmed the specimen's identity as Van Hasselt's Mouse-eared Bat *Myotis hasseltii* (Temminck, 1840) (Table 1; Fig. 1; Image 1). This species is sporadically distributed in the Indo-Malayan region, from Sri Lanka, northeastern India, Myanmar, Thailand, Cambodia, and Vietnam southward to peninsular Malaysia, Java, and Borneo (Corbet & Hill 1992; Kruskop 2013).

Prior to our findings, only two instances of occurrence of this species were known in Vietnam. The first record was from three locations within the Hanoi Capital Region, namely Xuan Dinh (21.075N & 105.78E), Yen So (20.97N & 105.867E), and Co Loa (21.113N & 105.873E) during 1966–1971 (Topál 1974; Image 2). The only other documented occurrence of the species in Vietnam is from the southern part of the country, in the provinces of Dong Nai (11.117N & 107.45E), Soc Trang (9.60N & 105.967E), and Ho Chi Minh City (10.583N & 106.883E) in the late 1990s (Francis et al. 2010; Kruskop 2013). Our findings represent the rediscovery of *M. hasseltii* in the Hanoi Capital Region after about half a century and the only record of the species in Vietnam in the last 20 years.

Previous studies indicate that the Van Hasselt's Mouse-eared Bat roosts in crevices in buildings and feeds on insects flying above water or possibly even small fishes. Such ecological traits suggest that it can adapt to anthropogenic habitats and relies on the

Table 1. External and cranial measurements (in mm) of *Myotis hasselti* and its most similar sister species *M. horsfieldii* collected in Vietnam.

Characters	*M. hasseltii*				*M. horsfieldii*
	Bates et al. 1999 (min–max)	Past surveys during 1966–1971 (Topál 1974) (mean ± SD) (n)		This study	Bates et al. 1999 (min–max)
Sex		Female	Male	Male	
Forearm length (FA)	38.8–39.1	-	38.81 (1)	37.8	34.3–36.8
Tail length (T)	36.6–40.9	-	15.87 (1)	41.6	33–38.9
Ear length (E)	15.6–15.7	-	-	16.5	12.2–15.8
Tibia length (Tib)	17.2–17.9	-	16.62 (1)	16.8	15.1–17.1
Foot length (HF)	10.8–10.9	-	9.5 (1)	11.1	8.1–9.9
Greatest length of skull (GLS)	16.0–16.3	16.07 ± 0.20 (4)	16.11 ± 0.16 (8)	16.09	14.7–15.7
Codylo-canine length (CCL)	13.8–14.0	13.98 ± 0.17 (4)	14.01 ± 0.10 (8)	13.97	12.9–13.5
Posterior palatal width (M^3M^3)	6.1–6.2	6.23 ± 0.11 (4)	6.24 ± 0.08 (8)	6.06	5.8–6.1
Breadth of braincase (BB)	7.7–7.7	8.03 ± 0.08 (4)	7.97 ± 0.08 (8)	7.87	6.9–7.5
Maxillary toothrow length (CM^3)	5.7– 5.8	5.81 ± 0.07 (4)	5.85 ± 0.07 (8)	5.54	5.4–5.8
Mandible length (ML)	11.3–11.6	11.22 ± 0.20 (4)	11.30 ± 0.16 (8)	11.2	10.5–11.2
Mandibular toothrow length (CM_3)	6.2–6.3	6.18 ± 0.10 (4)	6.22 ± 0.06 (8)	6.03	5.9–6.3

Image 1. Portrait (not to scale) and different views of skull (scale = 10mm) of the newly collected specimen of *Myotis hasseltii* from Vietnam (VN17-26).

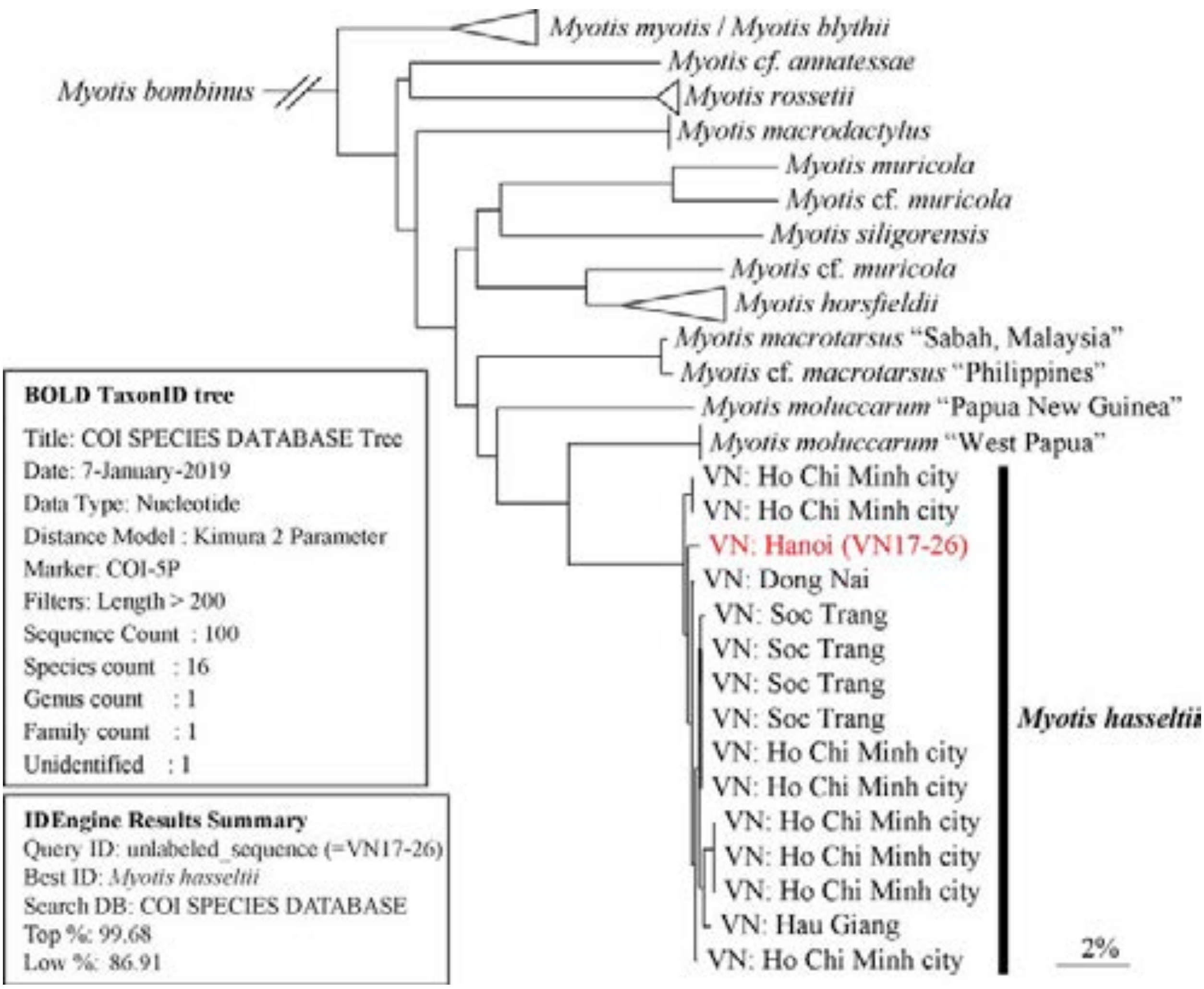

Figure 1. Taxon ID tree created by BOLD Identification Engine (Ratnasingham & Hebert 2007) indicating the identity (<1%) between the newly collected specimen (IEBR.VN17-26) and barcode records of *Myotis hasseltii.*

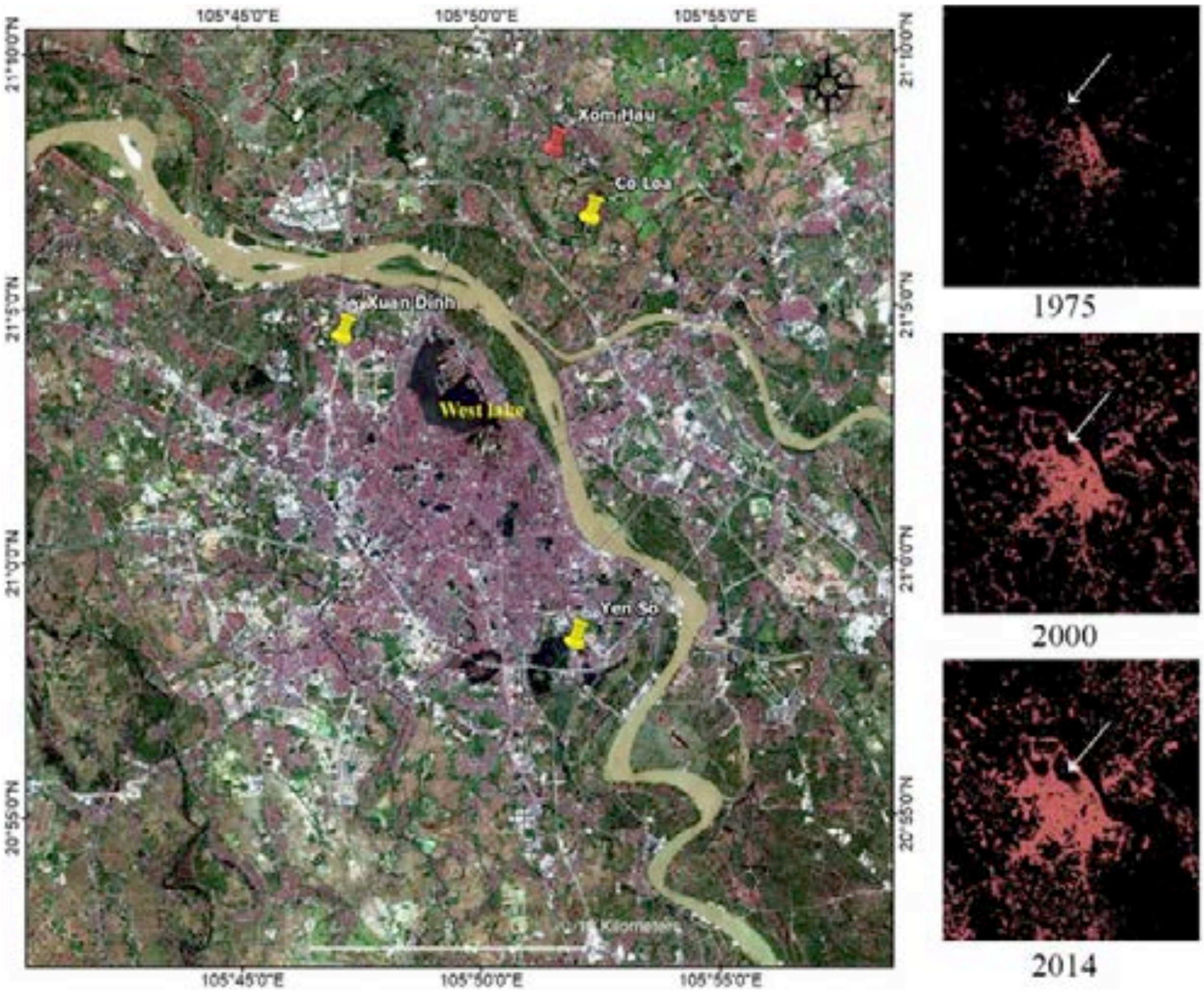

Image 2. Hanoi with the earlier (yellow) and present (red) collecting locations of *Myotis hasseltii* (left) and the steps of urban expansion from 1975, 2000, and 2014 (right) (Landsat satellite images derived from the U.S. Geological Survey EarthExplorer). Arrows indicate the location of the West Lake.

availability of local water bodies for foraging (Bates & Harrison 1997; Kruskop 2013; Wellappulli-Arachchi et al. 2014). Our specimen was captured while it was foraging over a water body located in a peri-urban area, thus indicating a similar habitat preference. This small pond is surrounded by paddy fields, orchards, and a low density of buildings and is currently used as a family's fish farm (Image 3). Since 2009, over 2,200 bats have been captured and identified during our monitoring surveys to assess the temporal variation in activity patterns of bat assemblages along the urbanization gradient in the Hanoi Capital Region (most of those were released to the wild after examination). This was the first time that *M. hasseltii* was captured and the low capture rate of this species suggests that it is an uncommon species in present-day Hanoi. It should

Image 3. Habitat of the collection site of *M. hasseltii* in Xom Hau, Hanoi, Vietnam.

be noted that during the last few decades, Hanoi has experienced a rapid urban sprawl associated with fast economic growth and population boom. As a result, a large portion of the peri-urban areas of Hanoi that cover two of the three previous collecting sites of *M. hasseltii*, namely Xuan Dinh and Yen So (Topál 1974), have already been converted into core urban areas with a decrease in natural habitats and water surfaces. The other former site, Co Loa, and the present collection locality, Xom Hau, have retained a considerable part of their natural habitats (Duan & Mamoru 2009; Nong et al. 2015; Images 2 & 3). Although additional surveys are needed, current evidence suggests that the loss or reduction of suitable habitats (i.e., natural vegetation and water bodies) as the result of anthropogenic pressure might play a significant role in the potential local extinction of *M. hasseltii* in the former collecting sites that have now become urbanized. Since these places are still undergoing unplanned expansion (Duan & Mamoru 2009; Nong et al. 2015), it is predictable that the native biodiversity of Hanoi will continue to decline. Assessments of the influences of human-induced habitat changes on urban biodiversity in tropical and subtropical areas, including impacts on bats, are urgently needed to support long-term biodiversity conservation efforts in human-dominated landscapes.

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Notes on the diet of adult Yellow Catfish *Aspistor luniscutis* (Pisces: Siluriformes) in northern Rio de Janeiro State, southeastern Brazil

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Abstract: Diet of adult specimens of Yellow Catfish *Aspistor luniscutis* (Valenciennes, 1840) was determined through stomach contents analysis. The specimens were target of commercial gillnet fisheries in northern Rio de Janeiro State, southeastern Brazil. In this region, *A. luniscutis* is a generalist benthophagous feeder, consuming most available prey species with crustaceans, especially penaeid shrimps, brachyuran crabs, and sciaenid fish dominating.

Keywords: Ariidae, catfish, stomach content, tropical coastal waters.

Ariidae include ~120 species of marine and freshwater catfishes, important to fisheries in tropical and subtropical waters (Froese & Pauly 2018). Many species undertake seasonal movements in different phases of their life cycle, seeking out river mouths and coastal lagoons in the spawning period and/or during the pre-maturation phase (Azevedo et al. 1999; Schmidt et al. 2008). They are generalist benthophagous feeders, consuming fishes and invertebrates, including crustaceans, molluscs and polychaetes (Denadai et al. 2012; Tavares & Di Beneditto 2017; Froese & Pauly 2018).

Along the Brazilian coastal waters, there are 21 species of ariid catfishes, including the Yellow Catfish *Aspistor luniscutis* (Valenciennes, 1840) (Menezes et al. 2003). *Aspistor luniscutis* (Image 1) inhabits marine and brackish waters from French Guiana to southern Brazil, primarily inside bay areas (Marceniuk & Menezes 2007; Schmidt et al. 2008; Possatto et al. 2016), reaching sexual maturity around 17cm length, and growing up to 120cm (Denadai et al. 2012; Froese & Pauly 2018).

Little research has been carried out on the feeding habits of *A. luniscutis*. Mishima & Tanji (1982) recorded crustaceans, mainly decapods, as the preferential food items in the diet of juvenile and adult fish along the Cananéia estuary (~25°S, 047°W). Denadai et al. (2012) and Guedes et al. (2015) observed fish scales as the major dietary component in juvenile specimens from Caraguatatuba Bay (~23°S, 043°W) and Sepetiba Bay (~22°S, 043°W), respectively.

Aspistor luniscutis is the target of artisanal fisheries in the inner estuary of Paraíba do Sul River and adjacent marine coastal waters (FIPERJ 2015), however,

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information about its feeding habits is locally non-existent. In this study, we analyse the feeding habits of adult specimens of *A. luniscutis* from northern Rio de Janeiro State, southeastern Brazil (~21^{0}S, 041^{0}W), to evaluate preferential food items.

Materials and Methods

The sampling site encompassed the inner estuary of Paraíba do Sul River and adjacent marine coastal waters (Fig. 1). In 2015 (December), 2016 (November) and 2018 (July and August), 95 specimens of *A. luniscutis* (41.5±6.1 cm mean total length; 545.6±194.8 g mean total weight) were obtained for stomach content analysis along this area. The specimens were adults based on their total length.

Stomach of each specimen was removed from the abdominal cavity, and the contents were washed in running water using a 500µm mesh-size sieve and preserved in 70% ethanol. The food items recovered were analysed using a stereomicroscope. Partially digested fish, fish bones (e.g., vertebrae, heads/skulls), scales and crystalline lenses, partially digested crustaceans, crustacean carapaces and mollusc shells were recorded in the stomach contents. The prey species were identified and measured whenever possible. The otoliths of *Cathorops spixii, Anchoa filifera*, *Paralonchurus brasiliensis*, *Micropogonias furnieri*, *Isopisthus parvipinnis* and *Symphurus plagusia* removed from the fish skulls confirmed the species identity and back-calculated the original size of the ingested fish using the regression equations proposed by Di Beneditto et al. (2001).

The representation of the food items in the *A. luniscutis* diet was calculated by the percentage of frequency of occurrence (FO%): number of stomachs with a given food item divided by the total number of stomachs with food items. Bias in the interpretation of feeding habits is expected when only FO% is applied, because the presence or absence of a given food item in the stomach contents does not consider the amount of food consumed (Wetherbee & Corte´s 2004). This variable, however, represents population-wide feeding

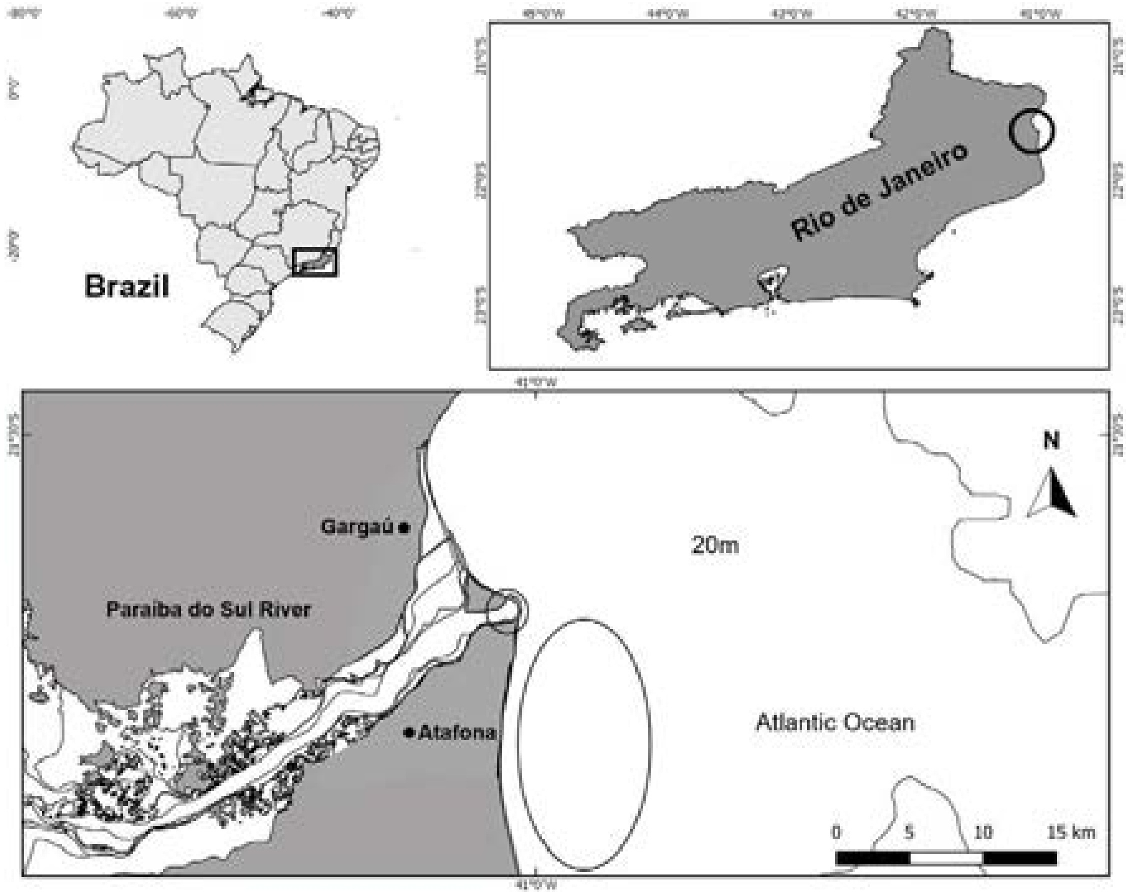

Figure 1. Northern Rio de Janeiro State, southeastern Brazil, where the adult specimens of Yellow Catfish *Aspistor luniscutis* were captured (black circle).

Image 1. *Aspistor luniscutis*.

habits allowing an assessment of food ingestion (Cortés 1997).

Results and Discussion

From 95 specimens of *A. luniscutis* captured along the study area, 64.2% (n=61 specimens) had food remains inside their stomach contents (Table 1). In many stomach contents, only prey remains such as carapace fragments were recovered (Tables 1 and 2). The tooth-plates of ariid catfishes are suitable for dealing with broad classes of prey, conferring dietary flexibility (Blaber et al. 1994). In *A. luniscutis*, tooth-plates associated with vomer are fused as a single large plate, indistinct in adult specimens (Marceniuk & Menezes 2007). The complex mouth apparatus allows catfish to crush their prey, often making it difficult to identify them (Denadai et al. 2012)

Considering all *A. luniscutis* specimens with food remains in the stomach contents (n=61), fish (partially digested fish, head/skull, spines, vertebrae, scales and crystalline lenses) occurred in 37.7% (n=23) and crustacean remains (partially digested decapod—shrimps and crabs—and their carapace fragments) in 62.3% (n=38) (Table 2). The sciaenid fish *P. brasilensis* was the most frequent prey, present in nine stomach contents, with an additional seven fish species identified. Besides the penaeid shrimp *Xiphopenaues kroyeri*, brachyuran crabs belonging to four species were also recorded. In general, prey species had less than 10cm length/carapace width.

The analysis of stomach contents corroborated previous studies describing ariid catfishes as generalist benthophagous feeder (Mishima & Tanji 1982; Denadai et al. 2012; Guedes et al. 2015; Tavares & Di Beneditto 2017). Most food items consumed by *A. luniscutis* are bottom-associated resources and commonly ocurring year-round in the study area (Di Beneditto & Lima 2003; Gomes et al. 2003; Fernandes et al. 2014). *Paralonchurus brasiliensis* and the other fish species are by-catch in local shrimp fishery in the marine coastal waters, whose main target is the penaeid *X. kroyeri* (Di Beneditto & Lima 2003; Fernandes et al. 2014). The diversity of brachyuran crabs is high along the study area (Di Beneditto et al. 2010), and therefore the availability

Table 1. Items recovered from the stomach contents of adult specimens of the Yellow Catfish *Aspistor luniscutis* in northern Rio de Janeiro State, southeastern Brazil (~21^{0}S). FO: frequency of occurrence.

Items recovered in stomach contents (61 stomachs with food items)	Number of stomachs	FO (%)
Fish	10	16.4
Penaeid shrimp	10	16.4
Brachyuran crab	14	22.9
Mollusc shell	2	3.3
Sediment	9	14.7
Organic material (without identification)	1	1.6
Fish + Penaeid shrimp	11	18.0
Fish + Brachyuran crab	2	3.3
Fish + Sediment	1	1.6
Penaeid shrimp + Brachyuran crab	1	1.6

Table 2. Fish and crustaceans identified in the stomach contents of adult specimens of the Yellow Catfish *Aspistor luniscutis* in northern Rio de Janeiro State, southeastern Brazil (~21⁰S).

Species/ items	Number of stomachs with the species/ items	Size range (cm)
Fish		
Paralonchurus brasiliensis Steindachner, 1875	9	4.0–8.0
Micropogonias furnieri Desmarest, 1823	1	12.5
Isopisthus parvipinnis Cuvier, 1830	1	2.4
Cathorops spixii Agassiz, 1829	1	7.0
Trichiurus lepturus Linnaeus, 1758	1	-
Anchoa spinifera Valenciennes, 1848	1	15.0
Symphurus plagusia Bloch & Schneider, 1801	1	12.0–16.0
Diodontidae spines	1	-
Fish partially digested, scales, crystalline lens	12	-
Crustaceans		
Penaeid shrimps		
Xiphopenaeus kroyeri Heller, 1862	6	3.0–7.0
Carapace fragments	18	
Brachyuran crabs		
Eurypanopeus abbreviates Stimpson, 1860	3	2.0–3.0
Heterocrypta lapidae Rathbun, 1901	1	3.0
Persephona mediterranea Herbst, 1794	I	1.1
Callinectes sp.	1	1.1–3.5
Carapace fragments	13	-

Note: For fish species, the size range is standard length; for penaeid shrimps, the size range is total length; and for brachyuran crabs, the size range is carapace width.

of prey species is a major factor influencing the feeding habit of the fish species.

The record of *A. filifera* in the stomach content of one specimen of *A. luniscutis* could also suggest a pelagic feeding habit, since this prey is an engraulid fish associated with the water column (Froese & Pauly 2018). The saprophagous feeding behaviour (ingestion of dead prey) when the prey is already on the benthic bed/floor is observed in ariid catfishes (Denadai et al. 2012). Thus, it is a plausible explanation for the presence of *A. filifera* in the diet.

The first information on the feeding habits of adult specimens of *A. luniscutis* in northern Rio de Janeiro State reveals that crustaceans, especially penaeid shrimps and brachyuran crabs, and sciaenid fish are the main prey items. According to literature, *A. luniscutis* based its diet on fish scales (Denadai et al. 2012; Guedes et al. 2015) and crustaceans (decapods) (Mishima & Tanji 1982). Meanwhile, in our study area fish scales were rare and present in only one stomach content. Decapods (penaeid shrimps and brachyuran crabs) were more frequent than fish in the stomach contents, revealing their importance as prey for *A. luniscutis*.

In order to improve the understanding on how *A. luniscutis* uses the habitat and available resources along northern Rio de Janeiro State, further stomach contents analysis should include more ontogenetic phases of the species, as juveniles and subadult specimens. This will allow to investigate intraspecific strategies concerning the use of available food resources.

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Waterbirds from the mudflats of Thane Creek, Mumbai, Maharashtra, India: a review of distribution records from India

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Abstract: Thane creek is one of the coastal and marine protected sites located in Mumbai which declared as a sanctuary recently in 2015. Creek region provides diverse habitat to birds for feeding, nesting and resting, making it a potential bird watching sight for ornithologists and enthusiasts. This article presents some interesting observations of waterbird species recorded from mudflats of Thane creek near Bhandup Pumping Station, Mumbai and also reviewed their previous records from various states of India.

Keywords: Bhandup Pumping Station, bird watching, mangrove, waterbirds.

Thane Creek, near Bhandup Pumping Station, is an area located in a central suburb of Mumbai, India that shows heterogeneous habitat including mangroves, interspersed with salt pans and marshland. It measures about 2.25km^2 (19.150^{0}N & 72.956^{0}E). Diverse habitat of the region offers wide range of opportunities to birds for feeding, nesting and resting, making it a potential bird watching sight for ornithologists and enthusiasts.

Thane Creek (Image 1) is situated between 19.004^{0}N to 19.250^{0}N latitudes & 72.933^{0}E to 73.000^{0}E longitudes spread over around 26km long, and connects to the Mumbai Harbor on its south and to Ulhas River on its north near Thane City. The substratum of the creek is made up of consolidated and unconsolidated boulders intermingled with loose rocks, and rarely with sand and gravel. Extensive mudflats (Image 1) are formed along the banks of the creek which are characterized by growth of mangroves (Athalye 2013). The mudflats of the mangrove ecosystems are reported to play a significant role in the conservation of resident birds, migratory and endangered birds (Chaudhari-Pachpande & Pejaver 2016).

Studies are available on avifaunal diversity of India (Praveen et al. 2016a). Present survey was conducted from December 2015 to May 2018. Equipment such as Olympus DPSI 10 X 50 wide angle binocular & digital camera model Cannon 700D with Cannon 100–400 mm IS-II telephoto lens was used for the present study. The waders feeding in the intertidal area were observed during the low tide. The bird species were identified using standard field guides (Rasmussen & Anderton 2012; Grimmett et al. 2013) and care was taken to avoid disturbing the birds during the survey.

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Image 1. Overview of mudflats of Thane Creek.

Most birds have specific habitat requirements from season to season, a loss of which may lead to their extinction. Chaudhari-Pachpande & Pejaver (2016) highlighted that habitat destruction is considered as one of the main reasons for such a decrease in bird species population. Wetlands are reported as highly fragile ecosystem due to increasing anthropogenic stress. Therefore, this calls for an urgent need for conservation of bird habitats to sustain their population. In this study, we report some interesting observations of water bird species and also review their previous records from various states of India. This urban diversity of water birds, however, could be under the threat from various anthropogenic activities. Such urban pockets of habitats need to be conserved.

A brief account of observations of species is given below:

Long-billed Dowitcher *Limnodromus scolopaceus*

The Long-billed Dowitcher is a recent addition to the avifauna of the Indian Subcontinent (Holt 1999), and is considered a vagrant to the area (Rasmusssen & Anderton 2012). On 24 February 2018, while observing waders on the mudflats of Thane Creek (19.133^{0}N, 72.962^{0}E), a lone, adult individual in non-breeding plumage was observed near Bhandup Pumping Station. In the morning, Omkar Dilip Adhikari and Himanshu Tembhekar spotted a wader looking very similar to a snipe foraging in the mudflats along with a flock of other species of the waders such as Common Sandpiper, Common Redshank, Common Greenshank, Wood Sandpiper, Black-tailed Godwit and Little Stint on low tide. The author photographed these birds.

It was suspected to be a one of the American dowitchers in the field; later while comparing the photographs with other dowitchers, the author observed and found the thick and straight bill twice as long as head in size and greenish at base, supercilium straight till the eye, grey-washed breast with lightly barred flanks, thick neck and bulky shoulders, short greenish-yellow legs. On further study it was identified as Long-billed Dowitcher (*L. scolopaceus*) (Rasmussen & Anderton 2005; Grimmett et al. 2013) (Image 2)

On the next day at forenoon, the author observed it again at the same place foraging on mudflats for approximately four hours from low tide to high tide. At high tide the bird took off and disappeared into the nearby mangroves. The sewing machine-like behavior was observed while feeding on marine worms, very small crustaceans, shell animals, and small marine flora. Later, the same species were observed and photographed by many bird enthusiasts in next 12 days at the same spot.

Sharma et al. (2013) states that *L. scolopaceus* was observed and documented six times from various states of India such as Rajasthan, Haryana, Gujarat, and Punjab along with the other waders. Recently, Sreenivasan (2016) reported its occurrence from Kerala State and he considered this report as the first record from peninsular India. This species was observed twice at Thane Creek in last two years (2017–2018). Firstly, the sighting of this bird was reported by a birdwatcher Ronit Datta (pers. comm. January 2017) from Thane Creek on 17 January 2017 in morning session. On same day, author also observed the same species at same location but in evening session. Bird activity was observed for next three days while feeding on mudflats especially at low tide.

Image 2. Long-billed Dowitcher.

Black-necked Grebe *Podiceps nigricollis*

Podiceps nigricollis is a rare winter migrant which breeds in Baluchistan and spends winters mainly in Pakistan, northwestern India, and Nepal (Rasmusssen & Anderton 2012). Prasad (2003) states that Black-necked Grebes are rare winter visitors to western Maharashtra and very few sightings have been recorded from this region. Recently, on 26 October 2017, the bird was observed and photographed (Image 3) at Bhandup Pumping Station (19.139303^{0}N, 72.962901^{0}E) along with the four individuals of Little Grebe *Tachybaptus ruficollis*. The author also observed this individual feeding on small fish, crustaceans and small insects. Like other grebe species, sunbathing behavior by raising its rump and facing away from the sun was observed. Earlier, in the month of October 2017, the same species were photographed by Akshay Shinde at Bhandup Pumping Station. The bird was observed while feeding on tadpoles, small fish and insects. Previously, this species was reported from various states of India such as Maharashtra (Raha 2013), Gujarat (Sukumar & Mani 2016), Odisha (Nair et al. 2015), Uttarakhand (Bhatt et al. 2015), Jammu & Kashmir (Khan 2016; Quadros et al. 2016), Assam (Choudhury 2006), and Himachal Pradesh (Kumar 2015).

Image 3. Black-necked Grebe.

Image 4. White Stork.

White Stork *Ciconia ciconia*

This species is a widespread winter visitor to India, passage migrant to Afghanistan and Pakistan; vagrant to Sri Lanka. It breeds in Europe spreading to central Asia (Rasmussen & Anderton 2012; Grimmett et al. 2013). According to Kasambe et al. (2015), *Ciconia ciconia* is an uncommon winter visitor to western Maharashtra with decreasing numbers in south but more common in Gujarat than other states in India. On

21 February 2016, the bird was observed in flight by the Omkar Dilip Adhikari and Himanshu Tembhekar (Image 4). In January 2017, it was observed while resting on mudflats. Kasambe et al. (2015) have compiled the data of recent records of this species from various districts of Maharashtra State. Here we report one more recent record of White Stork from Mumbai region. This species has been observed and documented from several states of India such as Gujarat (Akhtar & Tiwari 1993; Kasambe et al. 2015), Rajasthan (Prater 1931; Jayapal et al. 2012–13), Karnataka (Praveen 2016b), Andhra Pradesh (Ahmed 1996), Tamil Nadu (Daniels 2016), Kerala (Praveen 2015), Assam (Choudhury 2006), Bihar (Dey et al. 2014), Arunachal Pradesh (Borang 2015), Goa (Baidya & Bhagat 2018), Himachal Pradesh (Prasad 2006), and Uttarakhand (Bhatt 2015).

Grey-headed Lapwing *Vanellus cinereus*

The observation was published in Adhikari (2018) and (Roshnath 2017) discussed the previous records of this species from several states of India.

White-tailed Lapwing *Vanellus leucurus*

The White-tailed Lapwing is a winter visitor to India. This species breeds in Russia and migrates in winter to northeastern Africa, the Middle East, and the Indian subcontinent, later to return to their breeding grounds in March and April. It is occasionally sighted in the western region of Maharashtra State, India, but rarely documented (Satose et al. 2016). Recently, on 19 December 2017, the bird was observed and photographed (Image 5) by local birdwatcher Omkar Nar while resting on mudflats. Previously, this species has been reported from various states of India such as Kerala (Praveen 2015), Himachal Pradesh (Kumar 2015), Delhi (Urfi 2003), Uttar Pradesh (Ansari & Nawab 2015), Rajasthan (Mohan & Gaur 2008), Maharashtra (Satose et al. 2016), Chhattisgarh (Chandra 2015), Uttarakhand (Mohan & Sondhi 2015), Goa (Baidya & Bhagat 2018), Calcutta, and Odisha (Rasmussen & Anderton 2012).

Image 5. White-tailed Lapwing.

Image 6. Common Shelduck.

Common Shelduck *Tadorna tadorna*

Tadorna tadorna is a widespread winter visitor to India (Rasmussen & Anderton 2012). On 7 January 2017, at 17.30h, the author accompanied by wildlife photographers Souvik Kundu and Shyam Iyer observed and photographed (Image 6) a total of four pairs of Common Shelduck in mixed flock of ducks such as Northern Shovellers, Gargeny Ducks, Gadwall Ducks and Common Teal. Two weeks before this observation (Patil & Pawar 2017) reported sighting of same species from Panje wetland, Uran, Navi Mumbai, and also mentioned that the above report stands as the first record of its occurrence on the western coast of Maharashtra. The bird was observed while foraging in shallow water by upending and head dipping, and mostly by digging, scything and dabbling on mudflats. The author made a note of its diet which includes small fishes, molluscs, insects, crustaceans, marine worms and plant materials. Previously, this species has been reported from various states of India such as Maharashtra (Raha 2013; Patil & Pawar 2017), Uttar Pradesh (Searight 1928; Quadros et al. 2016), Jammu & Kashmir (Quadros et al. 2016), Punjab (Waite 1933), Odisha (Fooks 1939; Bhujabal 2014), Delhi (Goswami 2014), Bihar (Dey et al. 2014), Manipur (Higgins 1913), Uttarakhand (Bhatt 2015), West Bengal (Inglis 1934), Himachal Pradesh (Kumar 2015), Gujarat (Maharao of Kutch 1971; Vyas & Munjpara 2009), Assam (Lahkar 2009), Arunachal Pradesh (Borang 2015), Karnataka (Ghorpade 2016), and Andhra Pradesh & Telangana (Taher 2016).

White-winged Tern *Chlidonias leucopterus*

Pittie et al. (2005) state that the White-winged Tern *Chlidonias leucopterus* has been described as a winter visitor to Assam, Bangladesh, and Sri Lanka, irregularly in the rest of the Indian peninsula and in the Maldives and Andaman Island. They also reviewed its distribution from various states of India and summarized its previous records by placing them roughly into three zones such as western coast (Maharashtra, Gujarat, Goa, Kerala), eastern coast (Odisha, Tamil Nadu) and inland (Jammu & Kashmir, Punjab, Rajasthan, Jharkhand, Delhi, Karnataka, Madhya Pradesh). Further, they confirm that migration of the White-winged Tern is more common along the east and west coasts of India, than it is in the central (inland) India. Singh (2016) reported first record of this species from Manipur State. He discussed that it was possibly less vagrant than appears, as responsible to be overlooked among the numerous Whiskered Terns with which it keeps in winter, and is impossible to distinguish from goodly before it starts moulting into its distinctive summer plumage. Its group loving nature and the fact that it keeps with Whiskered Terns is well documented. Amin & Sheth (2016) reported occurrence of White-winged Tern along with the flock of Whiskered Terns in breeding plumage from Bhandup Pumping Station and one more sighting of this species along with the flock of Whiskered Terns in breeding plumage was recorded on 15 April 2017 from the same location by local bird watcher Avinash Bhagat (pers. comm. 15 April 2017). It is quite possible that this species might be a regular visitor of this place but remained overlooked due to its occurrence with a flock of Whiskered Terns and its appearance in non-breeding plumage in the western coast of Maharashtra.

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Short Communication

Moths of the superfamily Tineoidea (Insecta: Lepidoptera) from the Western Ghats, India

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Abstract: Ten species of the superfamily Tineoidea were collected from different localities of the Western Ghats in the states of Goa, Gujarat, Maharashtra, Karnataka, Tamil Nadu and Kerala; of the genera *Edosa* Walker, *Cimitra* Walker, *Monopis* Hübner, *Compsoctena* Zeller, and *Clania* Walker are present. All the ten species are recorded for the first time from the Western Ghats.

Keywords: Light trap, Microlepidoptera, new records.

The topography and climatic conditions of the Western Ghats are quite diverse and unique. The Western Ghats cover an area of about 160,000km^2 and stretches for 1,600km from the mouth of river Tapti in the north to Cape Camorin in the south and are one of the hot biodiversity spots of India with great diversity in flora and fauna. The average mountain ranges are with an average height of about 1,200m running parallel to the western coast of southern India in the states of Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala. Except for a single major gap of about 24km called Palghat Gap and some small passes like Goa Gap, Bhor Ghat, and Thal Ghat, these ranges of the Western Ghats are almost continuous. The Western Ghats are known by various names in different areas, i.e., as the Sahyadri mountains in Maharashtra and Karnataka, Nilagirimalai in Tamil Nadu and Sahyaparvatam in Kerala. The Anaimudi Peak (2,695m) is the highest peak of the Western Ghats which lies in the ranges of the state of Kerala. The Anaimudi Peak also acts as a nodal point from where three ranges radiate to different directions, i.e., the Anaimalai Hills in the north, the Palni Hills in the north-east, and the Cardamom Hills in the south. According to Scoble (1995) the order Lepidoptera is divided into primitive Lepidoptera, early Heteroneura, lower Ditrysia, and higher Ditrysia. Further, the lower Ditrysia, the larvae of which are often concealed rather than external feeders, includes the superfamilies Tineoidea, Gracillarioidea, Yponomeutoidea, Gelechioidea, Cossoidea, Tortricoidea, Castnioidea, Sesioidea, Zygaenoidea, Immoidea, Copromorphoidea, Schreckensteinoidea, Urodoidea, Epermenioidea, Alucitoidea, Pterophoroidea, Hyblaeioidea, Thyridoidea, and Pyraloidea. Moths from three families—Tineidae, Eriocotidae, and Psychidae—were collected.

Material and Methods

Survey-cum-collection tours were conducted from different localities of states Goa, Maharashtra, Karnataka, Tamil Nadu, and Kerala falling in the jurisdiction of

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Western Ghats during March 2003 to October 2006 (Fig. 1). The details are provided in Table 1. Due to nocturnal behaviour, adult moth diversity referable to different families, i.e., Tineidae, Eriocottidae, and Psychidae, the adults were collected with the help of a portable light trap (Image 1). The portable trap comprises a funnel (diameter top 30cm, bottom 6cm, height 30cm) fitted with baffle plates so that the moths once visiting the light get trapped around the lamp. The source of light to attract the moths was a 125w mercury vapour lamp fixed in the funnel. The funnel is fixed on the top of a collecting chamber (30cm x 30cm x 12cm) fitted with a sliding collecting tray (29cm x 29cm). For fumigation of chamber with 1,1,2,2- tetrachloroethane as a killing agent for the adult moth, a petri dish containing cotton soaked with the aforesaid chemical was placed in a corner of the tray. Some of the moths were captured individually in glass killing tubes of various sizes (2cm x 7cm to 5cm x 15cm) charged with ethyl acetate poured over the a layer of plaster of Paris at the bottom of the tube from various locations. Besides the portable light trap, some collection was also made by hanging the source of light (125w mercury vapour lamp) on a white sheet or a white-washed wall. As per techniques being used in lepidopterology (Lindquist 1956; Hodges 1958; Tagestad 1974; Robinson, 1976a; Zimmerman 1978; Nielson 1980; Sokoloff 1980; Mikkola 1986; Landry & Landry 1994), the entire collected specimens were processed for further biosystematics studies.

Figure 1. Area surveyed.

Observation

In the present research work, 43 specimens belonging five genera of 10 species of moths of the superfamily Tineoidea was collected and identified from available literature (Hampson 1892; Robinson 1976; Robinson & Tuck 1993; Robinson et al. 1994; Rose & Pathania 2003; Pathania & Rose 2004; Pathania et al. 2006), and with the reference collections housed in the National Pusa Collection, Division of Entomology, IARI, New Delhi and from the Museum of Department of Zoology & Environmental Sciences, Punjabi University, Patiala. All the colections are deposited in the Museum of Department of Zoology & Environmental Sciences, Punjabi University, Patiala (No TIN.1-43). The details are provided below:

Phylum: Arthropoda
Subphylum: Hexapoda
Class: Insecta
Order: Lepidoptera
Superfamily: Tineoidea

Image 1. Portable light trap.

I. Family: Tineidae

Tineidae Latreille, 1810, Considerations generals Animaux Crustaces Arachnides Insectes: 347, 363 (as Tineites).

Type-genus: *Tinea* Linnaeus, 1758, Syst. Nat. (Edn. 10) 1: 534.

Subfamily: Perissomasticinae

Perissomasticinae Gozmany, 1965, Fauna Hungariae 16(2): 117.

Type-genus: *Perissomasix* Warren & Rothschild, 1905, Novit. Zool. 12: 33, included in Fletcher 1929 and in G.N.M.W. 6 within the Tineidae.

Genus: *Edosa* Walker

Edosa Walker, 1866, List Specimens lepid. Insects Colln. Br. Mus. 35: 1818.

Chrysoryctis Meyrick, 1886, Ann. Mag. Nat. Hist. (5)17: 530. Type species: *Oecophora irruptella* Walker, 1864, List Specimens Lepid. Insects Colln. Br. Mus. 29: 686.

Episcardia Ragonot, 1895, Bull. Soc. ent. Fr.: 105. Type species: *Psecadia lardatella* Lederer, 1858, Wien. ent. Monatschr. 2: 151.

Sphallesthasis Gozmany, 1959, Acta. Zool. Hung., 5: 347. Type species: *Sphallesthasis similis* Gozmany, 1975, ibidem 5: 348.

Bilobatana Zagulajev, 1975, Fauna SSSR 108: 250. Type species: *Tinea caerulipennis* Ershoff, 1874, in Fedchenko, Reise Turkestan 2(5) 3: 97.

Type-species: *Edosa hemichrysella* Walker, 1866, List Specimens Lepid. Insects. Colln. Br. Mus. 35: 1819, by monotypy.

1. *Edosa glossopterai* Rose & Pathania

Edosa glossoptera Rose & Pathania, 2003, Uttar Pradesh, J. Zool. 23(3): 201–211.

Material examined*:* Reg.no TIN/1, 28.ii.2004, 1 male, Goa, Ponda District, Ponda, 15.399^{0}N, 74.0124^{0}E, 85m, coll. A. Katewa.

Distribution: Himachal Pradesh (Rose & Pathania 2003).

Remarks: The species is a new record from the Western Ghats in India.

2. *Edosa opsigona* (Meyrick)

Tinea opsigona Meyrick, 1911. J. Bombay nat. Hist. Soc. 21: 123.

Epicarda nepalensis Petersen, 1982, Reichenbachia 20: 73.

Material examined*:* Kerala: Palakkad District, Agli, 11.101^{0}N, 76.647^{0}E, 520m, 07.x.2003, 01 male; Karnataka: Uttar Kannada District, Ganeshgudi, 14.793^{0}N, 74.686^{0}E, 480m, 21.vii.2004, 01 male; Gujarat: District The Dangs, Waghai, 20.773^{0}N, 73.497^{0}E, 180m, 28.ix.2005, 01 male; Maharashtra: Mumbai District, Malshej Ghat, 19.340^{0}N, 73.774^{0}E, 690m, 02.x.2005, 01 males, (Reg. no TIN/2–6), coll. A. Katewa.

Distribution: Nilgiri Hills, northern Coorg, Sri Lanka (Meyrick 1911), Uttrakhand, Himachal Pradesh, and Punjab (Rose & Pathania 2003).

Remarks: *Edosa opsigona* (Meyrick) has earlier been reported from Tamil Nadu and Karnataka and it is collected from states Kerala, Gujarat and Maharashtra for the first time in the Western Ghats.

3. *Edosa neoopsigona* Rose & Pathania

Edosa neoopsigona Rose & Pathania, 2003, Uttar Pradesh, J. Zool. 23(3): 201–211.

Material examined*:* Goa: Sanguem District, Molem, 15.386^{0}N, 74.229^{0}E, 110m, 23.ii.2004, 1 male; Ponda District, Ponda, 15.399^{0}N, 74.012^{0}E, 85m, 28.ii.2004, 1 male, (Reg. no TIN/7–8), coll. A. Katewa.

Distribution: Punjab, Himachal Pradesh and Jammu and Kashmir (Rose & Pathania 2003).

Remarks: *Edosa neoopsigona* Rose & Pathania is reported for the first time from the hot biodiversity spot of Western Ghats.

4. *Edosa paraglossoptera* Rose & Pathania

Edosa paraglossoptera Rose & Pathania, 2003, Uttar Pradesh, J. Zool. 23(3): 201–211.

Material examined: Kerala: Palakkad District, Agli, 11.101^{0}N, 76.647^{0}E, 520m, 07.x.2003, 01 male; Karnataka: Uttar Kannada District, Ganeshgudi, 15.284^{0}N, 74.530^{0}E, 480m, 21.vii.2004, 01 male; Gujarat: The Dangs District, Waghai, 20.773^{0}N, 73.497^{0}E, 180m, 28.ix.2005, 01 male, (Reg. no TIN/9–11), coll. A. Katewa.

Distribution: Himachal Pradesh (Rose & Pathania 2003).

Remarks: *Edosa paraglossoptera* Rose & Pathania is being reported for the first time from the areas.

5. *Edosa sattleri* Rose & Pathania

Edosa satleri Rose & Pathania, 2003, Uttar Pradesh, J. Zool. 23(3): 201–211.

Material examined*:* Tamil Nadu: Nilgiris District, Doddabetta, 11.400^{0}N, 76.735^{0}E, 2640m, 01.x.2003, 01 male; Gujarat: The Dangs District, Ahwa, 20.758^{0}N, 73.686^{0}E, 520m, 29.ix.2005, 02 males, (Reg. no TIN/12–14), coll. A. Katewa.

Disitrbution: Uttranchal (Rose & Pathania 2003).

Remarks*:* *Edosa sattleri* Rose & Pathania is a new record from the Western Ghats.

Subfamily: Hapsiferinae

Hapsiferinae Gozmany, 1968, June 29, Acta Zool. Acad. Sci. Hung 14: 326.

Type-genus: *Hapsifera* Zeller, 1847, Isis Oken, Leipzig 1847: 32.

Genus: ***Cimitra*** **Walker**

Cimitra Walker, 1864, *List* Specimens lepid. Insects Colln Br. Mus. 29: 779.

Type-species: *Cimitra seclusella* Walker, 1864, ibidem 29: 780, by monotypy.

6. ***Cimitra seclusella*** **Walker**

Cimitra seclusella Walker, 1864, List specimens lepid. lnsects Colln Br. Mus. pt. 28, P 479.

Material examined: Kerala: Palakkad District, FRH, Parambikulam, 76.355^{0}E, 10.202^{0}N 580m, 16.ix.2004, 02 males, Idukki District, Vallakadavu, 77.206^{0}N, 9.601^{0}E, 780m, 09.ix.2004, 04 males, 10.ix.2004, 01 male, 12.ix.2004, 01 male; District Pathanamthitta, Wadaserikera, 9.264^{0}N, 76.787^{0}E, 30m, 07.ix.2004, 02 males; Karnataka: Uttar Kannada District, Ganeshgudi, 15.284^{0}N, 74.530^{0}E, 480m, 14.x.2005, 01 male, 16.x.2005, 01 male, (Reg. no TIN/15–26), coll. Katewa A.

Distribution: India, Nepal, Sri Lanka, Taiwan, Myanmar, Vietnam, western Malaysia, Jawa (Robinson et al. 1994), Himachal Pradesh, Uttarakhand, Punjab (Pathania et al. 2006).

Remarks*:* The genus *Cimitra* Walker with seven species is reported only in tropical Africa and *Cimitra seclusella* Walker is the only species to be available in Southeast Asia (Robinson et al. 1994). Pathania et al. (2006) have reported it for the first time from the Shivaliks in northern India. It is a new record from the Western Ghats.

Subfamily: Tineinae

Tineinae Latreille, 1810, Considerations generales Animaux Crustaces Archnides Insectes 347, 363 (as Tineidae).

Type-genus: *Tinea* Linnaeus, 1758, Syst. Nat. (Edn. 10) 1: 534.

Genus: ***Monopis*** **Hübner**

Monopis Hübner, (1852) 1816, Verz. bekannter Schmett. : 401.

Type-species: *Tinea rusticella* Hübner, 1776, Samml. eur. Schmett. 8: 61, pl. 3 fig. 17, pl. 49 fig. 339, by monotypy.

7. ***Monopis monachella*** **(Hübner)**

Tinea monachella Hübner, 1796 (Tineae), in Sammlung Europaischer Schmetterlinge, pt. 8, p. 65, pl. 21, fig. 143.

Blabophanes monachella Meyrick, 1883, Ent. Mon. Mag., 20, p. 36; 1894, Trans. R. ent. Soc. Lond. p. 27.

Monopis monachella Meyrick, 1895, Handbook British Lepidoptera, p. 785; Semper, 1902, Schmetterlinge Philippinischen Inseln, 2, p. 705; Meyrick, 1914, Ent. Mitteil, Suppl., 3, p. 59; 1928, Rev. Handbook British Lepidoptera, p. 823; 1930, in de Joannis, Ann. Soc. ent. France, 99, p. 742; Walsingham 1897, Trans. R. ent. Soc. Lond, p. 63; 1907, in Sharp, Fauna Hawaiiensis, 1, pt. 5, p. 727; Rebel, 1901, in Staudinger andRebel, Cat. Lepidopteren palaearktischen Faunengebietes, pt. 2, p. 236; no. 4536; Pierce and Metcalfe, 1935, Gen. *Tineina* British Is., p. 97; pl. 59; Diakonoff, 1948, Treubia, 19, p. 219; Walsingham, 1897, Trans. R. ent. Soc. Lond., p. 63.

Bladophanes longella Butler, 1881, Ann. Mag. nat. Hist. Scr., 7, p. 396, no. 29: Walsingham, 1887, in Moore, Lepid. Ceylon, 3, p. 503, pl. 209, fig. 1.

Material examined: Kerala: Palakkad District, Mukkali, 11.058^{0}N, 76.540^{0}E, 560m, 22.ix.2004, 01 male; Karnataka: Uttar Kannada District, Ganeshgudi, 15.284^{0}N, 74.530^{0}E, 480m, 16.x.2005, 01 male, (Reg. no TIN/27–28) coll. A. Katewa.

Distribution: India, Myanmar and Sri Lanka (Fletcher 1921), and Punjab (Pathania & Rose 2004).

Remarks: In the abense of any precise information about the locality, the collection of *Monopis monachella* (Hübner) from the Western Ghats plugs this void to some extent as far as its distribution is concerned in India.

8. ***Monopis longella*** **(Walker)**

Tinea longella Walker, 1863, List Specimenss lepid. Insects Colln Br. Mus., pt. 28, p. 479.

Material examined: Karnataka: Kodagu District, Nisargadhama, 12.440^{0}N, 75.936^{0}E, 1080m, 17.xi.2002, 01 male; Uttar Kannada District, Kulgi, 15.166^{0}N, 74.637^{0}E, 360m, 17.vii.2004, 01 male; Maharashtra: Mumbai District, Malshej Ghat, 19.340^{0}N, 73.774^{0}E, 690m, 02.x.2005, 01 male, (Reg. no TIN/29–31), coll. A. Katewa.

Distribution: Northeastern India, Sikkim, Nepal, western Malaysia, Thailand (Robinson et al. 1994) and Himcahal Pradesh (Pathania & Rose 2004).

Remarks: In view of above, *Monopis longella* (Walker) is being reported for the first time from the Western Ghats.

Family: Eriocottidae

Eriocottidae Spuler, 1898, Sber. Phys. med. Soc. Erlangen 30: 36 (as Eriocottinae).

Type-genus: *Eriocottis* Zeller, 1847, Isis Oken, Leipzig: 812, included in Fletcher 1929 within Incurvariidae.

Genus: *Compsoctena* Zeller

Compsoctena Zeller, 1852, Lepid. Microptera, quae J.A. Wahlberg in Caffrorun terra collegit: 86.

Type-species: *Compsoctena primella* Zeeler, 1852, ibidem, 87, by monotypy.

9. *Compsoctena robinsoni* Pathania & Rose

Compsoctena robinsoni Pathania & Rose, 2004, Zoos' Print Journal 19(6): 1501–1504.

Material examined*:* Kerala: Thiruvananthapuram District, FRH, Vithura, 8.675^{0}N, 77.085^{0}E, 120m, 04.ix.2004, 02 males; 05.ix.2004, 01 male; Karnataka: Uttar Kannada District, Ganeshgudi, 15.284^{0}N, 74.530^{0}E, 480m, 21.vii.2004, 02 males; Kodagu District, Sampaje, 12.497^{0}N, 75.556^{0}E, 100m, 13.xi.2002, 01 male; Tamil Nadu: Nilgiris District, Doddabetta, 11.400^{0}N, 76.735^{0}E, 2,640m, 01.x.2003, 02 males, (Reg. no TIN/32–39), coll. A. Katewa.

Distribution: Himcahal Pradesh (Pathania & Rose 2004).

Remarks: Eight specimens collected from the Western Ghats were compared with the type material and have been identified as *Compsoctena robinsoni* Pathania & Rose. The species is being reported for the first time from the area under reference.

Family: Psychidae

Psyche Schrank, Fauna Boica, ii, 2 Abth. P. 87 (1802).

Type genus: *Psyche* Schrank, Fauna Boica, ii, 2 Abth. P. 87 (1802).

Subfamily: Oeceticinae

Oiketticus, Lands. Guild. Trans. Linn. Soc. Xv, p. 375 (1827).

Type-genus: *Oiketticus*, Lands. Guild. Trans. Linn. Soc. Xv, p. 375 (1827).

Genus: *Clania* Walker

Clania Walker, 1865, Cat. Lep. Het. Brit. Mus. 4: 963, Type- species: *Oiketicus lewinii* Westwood.

Eumeta Walker, 1855, Cat. iv, p. 964.

Cryptothelea Walker, 1855, Cat. iv, p. 970.

Lansdownis Heylaerts, 1888, Ann. Soc. Ent. Belg. xxv, p. 66.

Type species: *lewinii* Westwood.

10. *Clania crameri* Westwood

Clania crameri Westwood, P.Z.S. 1854, p. 236; Moore, Lep. Ceyl. ii, pl. 118, figs. 1, 1a (larva-case); C. & S. no. 490.

Material examined: Kerala: Thiruvananthapuram District, Vithura, 8.675^{0}N, 77.085^{0}E, 1120m, 04.ix.2004 01 male; Idukki District, Vallakadavu, 77.206^{0}E, 9.601^{0}E, 780m, 11.ix.2004, 01 male; Goa: Sanguem District, Mollem, 15.386^{0}N, 74.229^{0}E, 110m, 24.ii.2004, 01 male; Ponda District, Ponda, 15.399^{0}N, 74.012^{0}E, 85m, 29.ix.2004, 01 male, (Reg. no TIN/40–43) coll. A. Katewa.

Distribution: Shanghai, India (Canara, Nilgiris), Sri Lanka, Borneo, Celebes (Hampson 1892).

Remarks: Hampson (1892) has listed the species from Canara and Nilgiris, yet the same is reported for the first time from two other states, i.e., Kerala and Goa of the said ecozone.

Discussion

During our survey-cum-collection tours, 10 species of the superfamily Tineoidea have been collected from six states of Goa, Gujarat, Maharashtra, Karnataka, Tamil Nadu and Kerala falling in the jurisdiction of Western Ghats. Tineoidea is one of the ditrysiian superfamily of micro moths are generaly known as cloth moths, bagmoths etc. The main characters are antenna

Table 1. Collection localities.

	State	Cited localities
1	Goa	Keri, Mollem, Ponda.
2	Gujarat	Dharmpur, Vaghai, Ahava, Saputara.
3	Maharashtra	Allefata, Malshej Ghat, Sanjay Gandhi National Park, Satara, Mahableshwar, Amboli.
4	Karnataka	Londa, Ganeshgudi, Khanapur, Ramnagar, Nagargalli, Karwar, Kasarkod, Shimoga, Shettihalli, Honnawar, Jog Falls, Bhagwati, Chickmagalur, Kemmanagundi, Kallatgiri Falls, Madikeri, Kulgi, Dandeli, Gundya, Baghamandala.
5	Tamil Nadu	Ooty, Coonoor, Doddabetta, Kanyakumari, Coimbatore.
6	Kerala	Mukkali, Agli, Neyyar Wildlife Sanctuary (WS), Shendurini WS, Vithura, Rani, Vadasarikera, Kumili, Periyar WS, Vallakadavu, Deviculam, Maryur and Parambikulam WS.

filiform, maxillary palpus usually five segmented and forewing with vein R5 terminating on costa or apex of family Tineidae and antenna often bipectinate, maxillary palpus usually four segmented and forewing with vein R5 terminating on termen in family Eriocottidae. These species are recorded for the first time from the Western Ghats. The Western Ghats is one of the largest forest area in the southern part of India. The tropical evergreen forests, moist deciduous forests, scrub jungles, sholas, savannas are the dominant vegetation in the mentioned areas.

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SHORT COMMUNICATION

Winter season bloomer Hairy Bergenia *Bergenia ciliata* (Haw.) Sternb. (Saxifragales: Saxifragaceae), an important winter forage for diverse insect groups

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Abstract: Pollinators can play an important role in production improvement in organic farming. It is, therefore, essential to ensure their year-round availability, particularly in winter season in Sikkim Himalaya. Thus, attempts were made to explore resources which could support and provide switching over platforms to pollinators during the winter season. Among the few observed forage species, *Bergenia ciliata* was found to be an important species that supports a diverse group of pollinators by providing the necessary forage. Therefore, *B. ciliata* is to be protected and managed to provide forage to pollinator insects during winter season.

Keywords: Eastern Himalaya, insect diversity, pollination management.

In agro-ecosystems, availability of insect pollinators is essential for improved production, as they benefit the yields up to 75% of globally important crop species (Klein et al. 2007). Worldwide, the value of insect pollination services to agriculture is estimated to cost around 153 billion Euro per annum (Gallai et al. 2009). Sikkim, recently inscribed as the first organic state of India, has subtropical to temperate and alpine type of climatic conditions with an elevation range from 300m to 8,500m. This eastern Himalayan state is situated between $27^{0}04'46''$–$28^{0}07'48''$ N & $88^{0}00'58''$–$88^{0}55'25''$ E and internationally bordered by Tibet to the north-east, Bhutan to the south-east and Nepal to the west (Pandey et al. 2018). Being an integral part of the global Biodiversity Hotspot (Myers 2000), Sikkim harbors approximately 5,580 plant species (SBAP 2012). The livelihoods of inhabitants mostly (75%) depend on agriculture and contributes about 17% to the gross domestic production of the state (Kumar 2012). Mostly, the low elevational agricultural landscapes are utilized for double crop production while the higher landscapes are utilized for single crop production (Sundriyal et al. 1994). Sikkim possesses a rich agro-biodiversity that consists of about 132 species of vegetables; more than 126 landraces of cereals, 38 spices/condiments; 34 cultivars of pulses and beans; and 18 cultivars of oilseeds; (Sharma et al. 2016) within 7,096 km^2. Inhabitants, however, prefer to grow low-land high-incentive crops like large cardamom, *Amomum subulatum* and other entomophilous crops like cucurbits, vegetables and flowers for livelihood, which have varying levels of

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pollinator dependency (Pratap et al. 2012; Gaira et al. 2016).

Being the first organic state of the country, Sikkim has to evolve methods that can compensate the input costs without hampering the yield. Garibaldi et al. (2016) have demonstrated how ecological intensification can create synchronous biodiversity and yield outcomes in small and large farms of pollinator-dependent crop systems. Although the state policy has provisions that can be considered pollinator friendly, yet it lacks any mention of pollinators, pollination services and pollination management (SPOF 2015). As agro-ecosystems are turning into more profitable cultivation of cash crops largely comprising entomophilous ones, the management of pollination services has become a cause for concern in recent times. It has been observed that flowering resources not in synchrony with crop bloom can play a crucial role in pollination management and need to be identified because year-round availability of foraging resources is important to maintain the pollinator abundance and richness (Kapkoti et al. 2016a). In view of the above this study was attempted to find such important non-crop forage species which can be managed along the agro-ecosystems to support sustaining pollinator population.

Materials and Methods

During the winter months (i.e., January–March), different surveys were conducted in nearby areas of Fambong Lho Wildlife Sanctuary (27^{0}21'50.89"N and 88^{0}34'07.54"E; 2,025m), East Sikkim, eastern Himalaya, India. Among the few blooming forage species, *Bergenia ciliata* Sternb (Saxifragaceae), locally known as Pakhanbhed was observed to be visited by a diverse group of insects. Data on insect visitation was recorded to assess the importance of *B. ciliata* as a potential winter forage resource by following Kapkoti et al. (2016b) with some modifications. Populations of *B. ciliata* were identified near the Fambong Lho Wildlife Sanctuary and weekly data on visiting insect diversity and visitation pattern were collected for one month. Observations were recorded for 30 minutes each during 11.00–11.30 h and during 16.00–16.30 h on both sunny and cloudy days. A total of 500 flowers were monitored during the main flowering period of *B. ciliata* and insect visitors were photographed for identification.

Result and Discussion

The flowers of *B. ciliata* were visited by a diverse group of insects (Fig. 1, Image 1). A total of eight insect visitors were observed within the monitoring time (Table 1). Maximum number of forager species were recorded on sunny days. Mostly the flies, *Musca domestica* and *Aglais cashmirensis* visited the flowers to forage on cloudy days (Fig. 1). Overall, the maximum average density and flower visitation time was recorded for insects belonging to the order Diptera (Table 1). Species belonging to order Diptera are reported to visit more than 550 species of flowering plants regularly and considered potential (Larson et al. 2001) or primary pollinators for many plant species, both wild and cultivated (Ssymank & Kearns 2009). *Bergenia ciliata* blooms in winter with an extended flowering time from January–April, this provides a valuable alternative to foraging pollinators, when resources start dwindling and become scare successively in winter. The flowering in *B. ciliata* continues to support till spring, when resources like, large cardamom and others start flowering. Kapkoti et al. (2016b) stated that non-cropping species play a key role in ensuring pollinator abundance and existence of natural habitats that help in the proliferation of diverse floral elements with variation in flowering phenologies. In this context, it is appropriate to recommend *B. ciliata* for cultivation across the farms to play its role in ensuring pollinator availability in the habitat.

Table 1. Insect visitors of *Bergenia ciliata*.

Common name	Scientific name	Order	Family
Honey Bee	*Apis cerana*	Hymenoptera	Apidae
Bumble Bee	*Bombus* sp.	Hymenoptera	Apidae
Wasp	*Vespula* sp.	Hymenoptera	Vespidae
Syrphid	*Eristalis tenax*	Diptera	Syrphidae
Hoverfly	-	Diptera	Syrphidae
House Fly	*Musca domestica*	Diptera	Muscidae
Painted Lady	*Cynthia cardui*	Lepidoptera	Nymphalidae
Tortoise Shell	*Aglais cashmiriensis*	Lepidoptera	Nymphalidae

Besides, *B. ciliata* is also a well-recognized herbal medicine and widely used in the local traditional medicinal practices across Bhutan, India Nepal, Pakistan and some other countries (Shrestha & Joshi 1993; Rai et al. 2000). This deciduous medicinal herb grows up to 50cm tall in rocky and stony habitats with an extensive distribution range from 1,500–3,000 m in Sikkim and other temperate regions of Himalaya (Rai et al. 2000; Sanghamitra et al. 2001). Terrace cropping system is commonly opted in Sikkim and the habitat characters of *B. ciliata* can be utilized to manage this species along the fringes of agricultural terraces in integrated cropping mode. This approach will create an opportunity for the

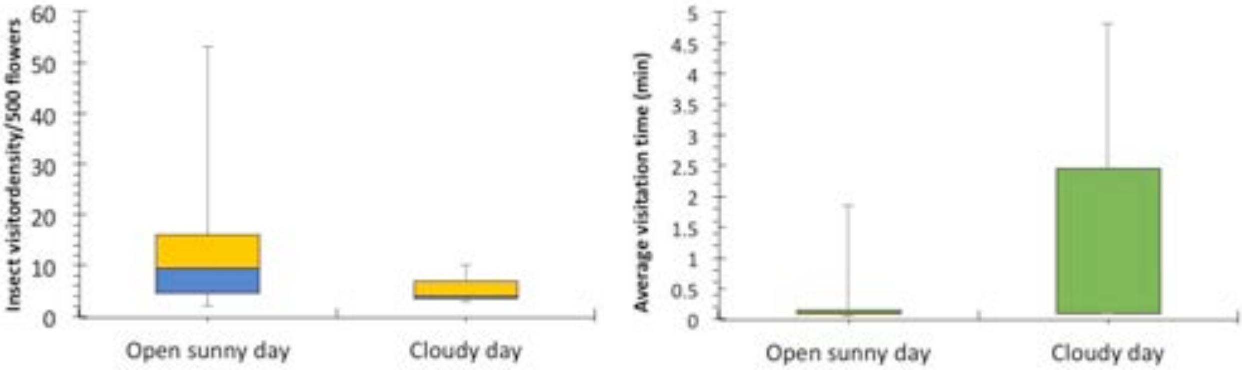

Figure 1. Insect visitor density and visitation time in *B. ciliata* during open sunny day and cloudy day: A - insect visitor density | B - insect visitation time (Data was collected for one month (30min each day)).

Image 1. Insect visitor diversity of *Bergenia ciliata* during dearth period: A - Syrphid | B - Hover Fly | C - Honey bee | D - Tortoise shell | E - Painted lady | F - House fly. © Aseesh Pandey.

farmers to succeed. This integrated management plan can be implemented between 1500m and 3000m to cover attitudinally diverse crops and to address the issue of the organic produce and sustainable utilization of *B. ciliata*.

Recommendations

A cautious approach is required to ensure year-round availability of pollinators along the agro-ecosystems. We recommend inclusion of crop-pollinator interactions in the Sikkim state policy on organic farming, with clear mention of pollination and pollinators to strengthen its second principle i.e. ecology (management of ecological processes), which is essential for fruit and seed set.

Furthermore, a comprehensive calendar of non-crop foraging resources needs to be developed, with special mention of high value species like *B. ciliata,* which could benefit the community with multiple ways through provisioning of improved goods and services.

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PLATINUM
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Kerala state bird checklist: additions during 2015 – May 2019

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Praveen (2015) compiled a list of 500 species of birds occurring in the state of Kerala. Since then birdwatchers of the state have been actively documenting more bird species in the region. Here is an update on the additions and corrections to this list based on records made during the years 2015–2019 with some older records that were confirmed retrospectively. All publicly available record till 15 May 2019 have been considered for this note.

1. Fulvous Whistling Duck *Dendrocygna bicolor*:

a. A single bird was photographed along with Lesser Whistling Ducks *D. javanica* by Sumesh P.B. on 04 January 2017 from Changaram wetlands, Alappuzha District (Sumesh 2017).

b. A single bird was photographed along with Lesser Whistling Ducks *D. javanica* by Raphy Kallettumkara on 23 March 2019 from Pathikade Chira, Thrissur District (Kallettumkara 2019). An unconfirmed sight record by K.K. Neelakantan was also from a flooded field in Thrissur district on 02 August 1984 (Sashikumar et al. 2011).

2. Common Pochard *Aythya ferina*: A pair was observed and male bird was photographed by P.C. Rajeevan on 05 November 2016 from Chemballikundu wetlands, Kannur District (Rajeevan 2017).

3. Spotted Crake *Porzana porzana*:

a. A juvenile that flew into the house of Prashobh Kumar Vijayan at Thottappally beach, Alappuzha on 03 October 2015 was recovered and identified as this species from photographs (Narayanan et al. 2016).

b. A single bird was photographed by K.E. Bijumon on 06 January 2019 from Ezhome wetlands, Kannur district (Rajeevan & Bijumon 2019).

4. Long-billed Dowitcher *Limnodromus scolopaceus*: A single bird was photographed by P.P. Sreenivasan on 02 January 2016 and seen again on the next day from Vadakkekad paddyfields, Thrissur District (Sreenivasan 2016).

5. Mew Gull *Larus canus*:

a. A single bird photographed by Arun Bhaskaran on 02 February 2017 from Ponnani beach, Malappuram District (Bhaskaran 2018).

b. Another bird was photographed at the same locality a year later on 01 May 2018 by Nesrudheen P.P. and Arun Bhaskaran (Nesrudheen & Bhaskaran 2018).

c. A single bird was photographed at the same locality on 02 January 2019 by Abdulla Paleri (Paleri 2019) and subsequently seen by Arun Bhaskaran on 08

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February 2019 (Bhaskaran 2019).

6. Black Tern *Chlidonias niger*: A single bird in wintering plumage was photographed by Govind Girija, Jayadev Menon, Jude Kurishinkal, Navin Antony, and Premchand Reghuvaran on 19 November 2017 from Aniyil beach, Ernakulam District (Reghuvaran 2018).

7. Black-naped Tern *Sterna sumatrana*: A single bird was photographed by Krishnakumar K. Iyer on 28 April 2018 from Ponnani beach, Malappuram District (Iyer 2018).

8. Eastern Marsh Harrier *Circus spilonotus*:

a. An adult female bird was photographed by Raphy Kallettumkara on 02 April 2017 from a wetland in Irinjalakuda, Thrissur District (Kallettumkara 2017a).

b. Another adult female bird photographed by Kamal Hari Menon & Raphy Kallettumkara on 08 February 2014 from Thommana Kole wetlands was retrospectively identified as this species (Menon & Kalletumkara 2014).

9. Blue-throated Bee-eater *Merops viridis*: A single bird was photographed by Sasidharan Manekkara on 26 May 2013 from the breeding colony of Blue-tailed Bee-eaters *M. philippinus* at Kankole, Kannur District was initially suspected to be of captive origin and was hence kept out of Praveen (2015). This, however, was subsequently argued to be a wild vagrant (Manekkara 2017) and hence an addition.

10. European Bee-eater *Merops apiaster*: One bird photographed by Rison Thumboor on 28 November 2016 from Thommana Kole wetlands, Thrissur District (Thumboor & Varghese 2017).

11. Eurasian Hobby *Falco subbuteo*:

a. One individual was photographed by Abhilash Arjunan on 14 December 2015 from Punchakkari wetlands, Thiruvananthapuram District (Abhilash 2016).

b. M.C. Prashantha Krishna photographed a bird from Gumpe Hills, Kasaragod District on 05 November 2016 (Krishna 2016).

c. Raphy Kallettumkara photographed a soaring bird on 07 November 2016 from Ayanikkad Kole wetlands, Thrissur District (Kallettumkara 2016b).

d. P.C. Rajeevan and K.E. Bijumon photographed a bird from Madayipara Hill, Kannur District on 04 November 2018 (Bijumon 2018).

e. Mujeeb P.M. photographed a bird from Ponkunnu hill, Kozhikode District on 19 December 2018 (Mujeeb 2018).

12. White-spotted Fantail *Rhipidura albogularis*:

a. A single bird was photographed by Raphy Kalletumkara and K.C. Raveendran on 10 December 2016 from Malampuzha, Palakkad District (Kalletumkara 2017b).

b. Subsequently photographed from the same site by Rajesh Radhakrishnan on 18 February 2018 (Radhakrishnan 2018).

13. Crested Bunting *Emberiza lathami*:

a. A first winter male was photographed on 16 December 2018 from Kanjikode, Palakkad District by Vivek Sudhakaran, Praveen Velayudhan and Deepak Muraleedharan (Sudhakaran et al. 2019).

b. An adult female was photographed on 23 March 2019 from Cheerakavu, Thrissur District by Anisha Tomy (Tomy 2019).

14. Chestnut-eared Bunting *Emberiza fucata*: A first winter male was photographed on 30 March 2015 from Ezhumanthuruthu, Kottayam District by P.J. George (George 2015). It was initially suspected to be of unknown origin and hence, was kept out of Praveen (2015). This was subsequently reported from Kodagu, Karnataka in the same period of the year during spring migration (Monnappa & Kumar 2018) and hence supporting the theory of a 'wild vagrant'. Hence, we add this species to the state checklist.

15. Yellow-breasted Bunting *Emberiza aureola*: A single bird was photographed on 11 November 2018 from Eriam, Kannur District by P.C. Rajeevan and Bijumon K.E. (Rajeevan & Bijumon 2019).

16. Little Bunting *Emberiza pusilla*: A single bird was photographed on 26 February 2016 from Munnar-Thekkady road, Idukki District by James A. Eaton and Jijo Mathew (Eaton & Mathew 2016).

17. Sand Martin *Riparia riparia*: Though there were records of this species or Pale Sand Martin *Riparia diluta* from Kerala, Praveen (2015) kept both species out of the state checklist due to challenges in identification. Since then more definite reports have occurred from Kerala as listed in Chandran (2018).

a. Two birds were photographed along with a group of Barn Swallows *Hirundo rustica* on 13 November 2014 by Abhinand Chandran from Kadamakudy, Ernakulam District.

Table 1. Additions to the birds of Kerala checklist.

	English name	Species name	Authority	Malayalam name	Vernacular name	IUCN	EN	WPA	CITES
	Order Anseriformes								
	Family Anatidae (ducks, geese, swans)								
1	Fulvous Whistling-Duck	*Dendrocygna bicolor*	(Vieillot, 1816)	വലിയ ചൂളൻ എരണ്ട	Valiya chūḷan eraṇṭa	LC		Sch.I	
2	Common Pochard	*Aythya ferina*	(Linnaeus, 1758)	ചെന്തലയൻ എരണ്ട	Chentalayan eraṇṭa	VU		Sch.IV	
	Order Gruiformes								
	Family Rallidae (rails and coots)								
3	Spotted Crake	*Porzana porzana*	(Linnaeus, 1766)	പുള്ളി നെല്ലിക്കോഴി	Puḷḷi nellikkozhi	LC		Sch.IV	
	Order Charadriiformes								
	Family Scolopacidae (sandpipers)								
4	Long-billed Dowitcher	*Limnodromus scolopaceus*	(Say, 1822)	കരിപ്പ്രാക്കാട	Karipprākkāṭa	LC		Sch.IV	
	Family Laridae (gulls and terns)								
5	Mew Gull	*Larus canus*	Linnaeus, 1758	മ്യൂ കടൽക്കാക്ക	Myū kaṭalkkākka	LC		Sch.IV	
6	Black Tern	*Chlidonias niger*	(Linnaeus, 1758)	ആളക്കറുപ്പൻ	Āḷakkaṟuppan	LC		Sch.IV	
7	Black-naped Tern	*Sterna sumatrana*	Raffles, 1822	പിടലികറുപ്പൻ ആള	Piṭalikaṟuppan āḷa	LC		Sch.IV	
	Order Accipitriformes								
	Family Accipitridae (kite, hawks and eagles)								
8	Eastern Marsh Harrier	*Circus spilonotus*	Kaup, 1847	കിഴക്കൻ കരിതപ്പി	Kizhaakkan karitappi	LC		Sch.I	App.II
	Order Coraciiformes								
	Family Meropidae (bee-eaters)								
9	Blue-throated Bee-eater	*Merops viridis*	Linnaeus, 1758	നീലകണ്ഠൻ വേലിത്തത്ത	Nīlakaṇṭan vēlittatta	LC		Sch.IV	
10	European Bee-eater	*Merops apiaster*	Linnaeus, 1758	യൂറോപ്യൻ വേലിത്തത്ത	Yūṟopyan vēlittatta	LC		Sch.IV	
	Order Falconiformes								
	Family Falconidae (falcons and caracaras)								
11	Eurasian Hobby	*Falco subbuteo*	Linnaeus, 1758	വരയൻ പുള്ള്	Varayan puḷḷ	LC		Sch.IV	App.II
	Order Passeriformes								
	Family Rhipiduridae (fantails)								
12	White-spotted Fantail	*Rhipidura albogularis*	(Lesson, 1832)	ശ്വേതകണ്ഠൻ ആട്ടക്കാരൻ	Śvētakaṇṭan āṭṭakkāran	LC		Sch.IV	
	Family Emberizidae (old world buntings)								
13	Crested Bunting	*Emberiza lathami*	J.E. Gray, 1831	കൊമ്പൻ തിനക്കുരുവി	Komban tinakkuruvi	LC		Sch.IV	
14	Chestnut-eared Bunting	*Emberiza fucata*	Pallas, 1776	ചെഞ്ചെവിയൻ തിനക്കുരുവി	Chenjeviyan tinakkuruvi	LC		Sch.IV	
15	Yellow-breasted Bunting	*Emberiza aureola*	Pallas, 1773	മഞ്ഞമാറൻ തിനക്കുരുവി	Manjamaran tinakkuruvi	CR		Sch.IV	
16	Little Bunting	*Emberiza pusilla*	Pallas, 1776	ചിന്ന തിനക്കുരുവി	Chinna tinakkuruvi	LC		Sch.IV	
	Family Hirundinidae (swallows)								
17	Sand Martin	*Riparia riparia*	(Linnaeus, 1758)	മണൽ കത്രിക	Maṇal katrika	LC		Sch.IV	

	Family Phylloscopidae (old world leaf warblers)								
18	Yellow-browed Warbler	*Phylloscopus inornatus*	(Blyth, 1842)	മഞ്ഞപ്പുരികൻ ഇലക്കുരുവി	Manjappurikan Ilakkuruvi	LC		Sch.IV	
	Family Leiothrichidae (babblers, laughing-thrushes and allies)								
19	Banasura Laughingthrush	*Montecincla jerdoni*	(Blyth, 1851)	ബാണാസുര ചിലപ്പൻ	Banasura Chilappan	EN		Sch.IV	
20	Ashambu Laughingthrush	*Montecincla meridionalis*	(Blanford, 1880)	തെക്കൻ ചിലുചിലുപ്പൻ	Thekkan Chiluchilappan	VU		Sch.IV	
	Family Sturnidae (starlings)								
21	Purple-backed Starling	*Agropsar sturninus*	(Pallas, 1776)	ചെന്നീലിക്കാളി	Chennīlikkāḷi	LC		Sch.IV	
	Family Muscicapidae (chats and flycatchers)								
22	White-bellied Sholakili	*Sholicola albiventris*	(Blanford, 1868)	വെള്ളവയറൻ ചോലക്കിളി	Veḷḷavayaṟan Cholakkiḷi	VU		Sch.IV	
23	Blue-and-white Flycatcher	*Cyanoptila cyanomelana*	(Temminck, 1829)	ഇന്ദ്രനീലി പാറ്റപിടിയൻ	Indranīli pāṟṟapiṭiyan	LC		Sch.IV	
24	Ultramarine Flycatcher	*Ficedula superciliaris*	(Jerdon, 1840)	കടുംനീലി പാറ്റപിടിയൻ	Kaṭunnīli pāttapiṭiyan			Sch.IV	
25	Rufous-tailed Rock Thrush	*Monticola saxatilis*	(Linnaeus, 1766)	ചെമ്പുവാലൻ പാറക്കിളി	Chempuvālan pāṟakkiḷi	LC		Sch.IV	
26	Pied Wheatear	*Oenanthe pleschanka*	(Lepechin, 1770)	വെള്ളക്കറുപ്പൻ നെന്മണിക്കുരുവി	Veḷḷakkaṟuppan nenmaṇikkuruvi	LC		Sch.IV	
	Family Turdidae (thrushes)								
27	Eye-browed Thrush	*Turdus obscurus*	J.F. Gmelin, 1789	പുരികപ്പുള്ള്	Purikappuḷḷu	LC		Sch.IV	

IUCN: Red List categories. CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern
EN: Endemic status (No new endemic species has been added and retained for completeness)
WPA: Schedules (I, II, III, IV) as per Indian Wildlife (Protection) Act, 1972
CITES: Appendics (I, II, III) as per http://www.cites.org/eng/app/appendices.php

b. A single bird was photographed by Abhijith Surendran on 01 January 2017 from Changaram wetlands, Alappuzha District.

c. A single bird photographed on 10 January 2017 by Harikumar Mannar from Kuttanad wetlands, Alappuzha District.

d. Two birds photographed on 02 October 2017 from Kadamakudy, Ernakulam District by Premchand Reghuvaran.

e. A single bird photographed on 15 December 2017 by Manoj Karingamadathil & Jameela P. from Manakodi Kole wetlands, Thrissur District.

18. Yellow-browed Warbler *Phylloscopus inornatus:*

A single bird was photographed on 17 February 2019 from Pothamedu, Munnar, Idukki district by Julien Mazenauer (Mazenauer 2019; Mazenauer in press). Prior to this Paul Holt reported this species on 14 February 1995 incidentally also from Munnar (Sashikumar et al. 2011), but was not considered for the state checklist due to the failure to satisfy the inclusion criteria documented therein.

19. Purple-backed Starling *Agropsar sturninus*:

a. An adult male was photographed along with Rosy Starlings *Pastor r*oseus and Common Mynas *Acridotheres tristis* on 14 November 2015 from Vellayani-Punchakkari paddyfields, Thiruvananthapuram District by K.G. Dilip and C.G. Arun (Dilip & Arun 2016).

b. An adult male was photographed along with Common Mynas *Acridotheres tristis* on 14 October 2016 from Thommana Kole wetlands, Thrissur district by Raphy Kallettumkara (Kallettumkara 2016a) and retrospectively identified as this species.

c. Two adult male birds were photographed along with Chestnut-tailed Starlings *Sturnia malabarica* on 21 October 2018 from Uppungal Kole, Malappuram District by P.P. Nesrudheen (Nesrudheen 2018).

d. An adult male was photographed along with Chestnut-tailed Starlings *Sturnia malabarica* on 12 December 2018 from Kozhukkully, Thrissur District by K.B. Nidheesh, Bavish Usha Balan and Sreekumar Govindankutty (Nidheesh 2018).

20. Blue-and-white Flycatcher *Cyanoptila cyanomelana*:

a. A first winter male transitioning to breeding plumage was photographed on 05 February 2017 by Mathew Thekkethala from Nelliampathy Hills, Palakkad District (Thekkethala 2018).

b. A male bird was photographed on 02 February 2018 by James A. Eaton from Neriamangalam-Painavu Road, Ernakulam District (Roddis & Loseby 2018).

c. A male bird was photographed on 23 November 2018 by Manoj Kanakambaran from Kanthalloor, Idukki District (Kanakambaran 2018) and the species continue to be wintering in the same site at least till 28 February 2019.

21. Ultramarine Flycatcher *Ficedula superciliaris*: A first winter male was photographed on 14 November 2015 from Santhigiri, Idukki District by P.J. George (George 2016).

22. Rufous-tailed Rock Thrush *Monticola saxatilis*: A first winter male was photographed on 18 November 2015 from Nangiarkulangara, Alappuzha District by S.R. Prasanth Kumar (Balar et al. 2016).

23. Pied Wheatear *Oenanthe pleschanka*:

a. A first winter bird was photographed on 20 December 2015 by Premchand Reghuvaran from Bekal Fort, Kasaragod District (Reghuvaran 2016).

b. A sub-adult was photographed on 25 September 2016 by Jayan Thomas from Madayipara, Kannur District (Thomas 2017).

24. Eye-browed Thrush *Turdus obscurus*: A single bird was photographed by P.B. Samkumar on 10 December 2017 from Iringole Kaavu, Ernakulam District (Samkumar 2017).

With this update, 24 species have been added to the state checklist. The taxonomic update of 2018 (Praveen et al. 2018) elevated a number of subspecies found in the country to the species level, this does impact the number of species found in Kerala: adding Banasura Laughingthrush *Montecincla jerdoni* (split from Nilgiri Laughingthrush *M. cachinnans*), Ashambu Laughingthrush *M. meridionalis* (split from Palani Laughingthrush *M. fairbanki*) and White-bellied Sholakili *Sholicola albiventris* (split from Nilgiri Sholakili *S. major*). The new taxon, Ashambu Sholakili *S. ashambuensis,* described by Robin et al. (2017) is treated as a subspecies of *S. albiventris* by global taxonomies (Clements et al. 2018, Gill & Donsker 2019), as well as the national checklist (Praveen et al. 2019), and we too follow the same treatment here. This takes the total number of species in the Kerala checklist to 527 (Table 1). Malabar Starling *Sturna malabarica blythi* is accepted as a full species by some taxonomies (Gill & Donsker 2019, Clements et al. 2018) but is not accepted in Praveen et al. (2019) or HBWAlive (Craig & Feare 2018) and hence not counted here. Of this, 515 species are supported either by a validated specimen or a clear photograph. The following 12 birds find a place in the state checklist purely based on sight records: Great White Pelican *Pelecanus onocrotalus*, Little Bittern *Ixobrychus minutus*, White-cheeked Tern *Sterna repressa*, Imperial Eagle *Aquila heliaca*, Hen Harrier *Circus cyaneus*, White-tailed Eagle *Haliaeetus albicilla*, Eurasian Crag-Martin *Ptyonoprogne rupestris*, Grey-throated Martin *Riparia chinensis*, Common Chiffchaff *Phylloscopus tristis*, Common Starling *Sturnus vulgaris*, Red-breasted Flycatcher *Ficedula parva*, and Black Redstart *Phoenicurus ochruros* (Sashikumar et al. 2011).

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NOTE

What is in a name? The birthright of *Oxyopes nilgiricus* Sherriffs, 1955 (Araneae: Oxyopidae)

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While studying Lynx spider collections from the Oriental region, Sherriffs (1955) described two new species, namely *Oxyopes daksina* Sherriffs, 1955 (Sri Lanka) and *O. nilgiricus* Sherriffs, 1955 (southern India and Sri Lanka). The descriptions were based on collections deposited in the British Museum of Natural History (BMNH), London. Sherriffs designated types for the former species; he, however, did not seem to designate any specific holotype or paratype for the latter. He examined one adult male, collected by Oates from the Nilgiri Mountains, southern India. Additionally, he examined other material (1 male and 1 female) collected by Barnes from Sri Lanka (erstwhile Ceylon). It is quite obvious that the specimen from the Nilgiris could be the holotype since he christened the species *O. nilgiricus* after the Nilgiri Mountains.

The species superficially resembles *O. hindostanicus* Pocock, 1901, but is different in its palpal configuration; the palpal patella does not bear any apophysis (whereas two retrolateral apophyses are present in *O. hindostanicus*) (cf. Fig. 32 with Fig. 34 in Sherriffs 1955). He mentions, in particular, the second male from Sri Lanka to be of interest due to the peculiar morphology of its right palp. It probably was due to a malformation or a physical injury that occurred either while hunting prey or from a previous mating session with an aggressive female which ended up in conflict.

The species was, however, overlooked by subsequent authors who enlisted the spider diversity of India, from Tikader (1987), Siliwal et al. (2005), and Sebastian & Peter (2009) to Keswani et al. (2012). The distribution of the species as shown in the world catalog also mentions only Sri Lanka (WSC 2018). It is nevertheless astounding, that a species bearing its origin in its name, to be missing from the lists for about 63 years since its first description in 1955.

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Study on biological and ecological characteristics of mudskippers

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Fish are the most diverse and numerous group of vertebrates in the world. This indicates the importance of fish among vertebrates in biodiversity and evolutionary studies since they exhibit morphological, physiological, and behavioural adaptations (Sattari 2003). Access to biological and ecological information on fish stocks can be very helpful in understanding the status of fish in the future. In other words, the ecological data presented on the status of fish species in aquatic ecosystems can be highly effective in directing and achieving management-protection policies in the future. Hence, this information can be used by experts and fishery managers.

Mudskippers (Teleostei: Gobiidae: Oxudercinae) are a group of fish that live in intertidal zones of mangrove ecosystems (Graham 1997; Abdoli et al. 2017). According to Polgar & Crosa (2009), there are about 30 species of mudskippers around the world that belong to four genera: *Periophthalmus*, *Periophthalmodon*, *Boleophthalmus*, and *Scartelaos*. These fishes are air-breathing gobies that are found in the coasts of Africa, Asia, and Australia (Kutschera et al. 2008; Kutschera & Elliott 2013). Therefore, these fishes can be used as ecological indicators to study and detect pollution levels in aquatic ecosystems.

Mudskippers live in ecosystems that have severe environmental conditions such as large fluctuations in temperature, high turbidity, low oxygen, and high levels of pollution (Abdoli et al. 2017). In spite of these conditions, they adapt themselves to live in these ecosystems (Murdy 1989). In fact, adaptation in morphological, physiological and behavioural traits enable them to move between aquatic and terrestrial habitats (Colombini et al. 1996; Kutschera et al. 2008).

Due to the ecological importance of mudskippers, it is necessary to provide a comprehensive reference about these fishes. Therefore, the present work aims to introduce the current book titled *Fishes out of Water: Biology and Ecology of Mudskippers* edited by Zeehan Jaafar and Edward O. Murdy. This book contains 15 chapters published by CRC press in 2017. Because of its valuable content, this book has become a complete reference on mudskippers. This valid reference will be useful for a wide range of students, researchers, and specialists in the fields of evolution, environment, fish behaviour, and physiology.

This work attempts to review the chapters of this book. In the current book, the aspects of biology and ecology of mudskippers such as anatomy, distribution,

Fishes Out of Water: Biology and Ecology of Mudskippers, 1st Edition.
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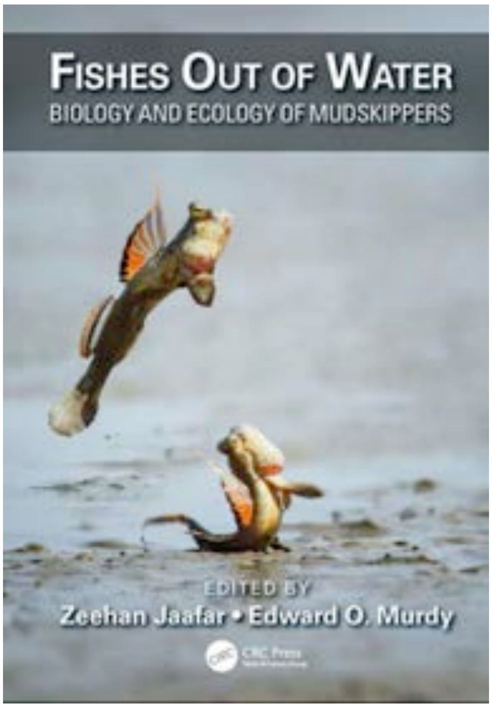

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systematics, physiology, and conservation are studied. The unique adaptations of these fishes in nature are also fully explored.

The first chapter examines the taxonomy and systematic aspects of mudskippers. In this chapter, the authors state that mudskippers are tropical and subtropical fishes belonging to the family Oxudercidae and subfamily Oxudercinae (Order: Gobiiformes). They also provide the first reports on the description of mudskipper species. For example, the authors state that *Gobius pectinirostris* and *G. barbarus* were first described in 1758 and 1766, respectively. The second chapter focuses on the distribution of mudskippers in the world. The findings have shown that mudskipper species are widely distributed in the tropical and subtropical coastal habitats of the Indo-West Pacific (IWP) and the eastern Atlantic. Chapters 3 and 4 study the early development, age, and growth of mudskippers. The authors investigate early development in some species of mudskippers (*Ps. argentilineatus* and *Ps. modestus*). The study on the development of mudskipper species in their early life stages can provide useful information on the growth pattern of the species.

Chapter 5 reviews respiratory and circulatory adaptations in mudskippers. In this chapter, the authors focus on respiratory organs in mudskipper species. They state that these species have been considered aquatic air-breathing fishes. Therefore, the respiratory system of these fishes is different from that of others. In chapter 6, the structure and function of sensory organs are investigated. The olfactory organ is considered important and key in the respiratory system of fish. The structure of the olfactory organ in mudskippers is very different from that in other fish and is of a unique type. Studies have shown that the unique structure of the olfactory organ in mudskipper species can be the result of adaptation in specific conditions (from aquatic habitat to land). Chapter 7 focuses on nitrogen metabolism and nitrogenous waste excretion in two mudskipper species, *Periophthalmodon schlosseri* and *Boleophthalmus boddarti*. The obtained results show that these fish species have ornithine-urea cycle in their bodies. This cycle can establish a balance for fish in aquatic and terrestrial habitats. In Chapter 8, locomotion patterns of mudskippers in aquatic and terrestrial environments are investigated. The authors reviewed 'sustained' and 'burst' locomotor patterns in these fishes. These locomotor patterns have also been formed to adapt the fish to environmental conditions. Chapters 9 and 10 examine the biological characteristics of mudskippers, including reproductive strategy and feeding behaviour. Authors state that ecological conditions like hypoxia can affect these biological characteristics.

Chapter 11 focuses on territoriality, aggression, and courtship behaviours in mudskipper species. Territory behaviour in these fishes usually occurs to preserve their habitats. Courtship behaviour, however, is carried out by male fishes during mating to attract attention of many more females. The investigation of these behaviours can be useful to the study of ethology in mudskippers.

Chapter 12 is intended to investigate the spatiotemporal changes in the distribution of mudskipper species. In this chapter, the authors acknowledge that the spatiotemporal variations of mudskipper species indicate their adaptation to semi-terrestrial habitats. In Chapter 13, the care and management of mudskipper species in captivity conditions are investigated. In fact, mudskippers are very interesting and attractive fishes and there is a high tendency to keep them in captivity. Therefore, it is necessary to manage these fish species in artificial environments such as aquariums. In this chapter, authors provide important and useful information about the proper preservation of mudskipper species in aquariums. This information is derived from the biological and ecological characteristics of mudskippers in natural habitats. Chapter 14 investigates the conservation of fish habitats. Anthropogenic activities are one of the most important factors that can destroy the habitats of fishes. Coastal development, pollution of water resources, and creation of heterogeneity in habitats such as mangrove forests are examples of anthropogenic activities that affect the habitats of mudskippers. Unfortunately, human dependence on natural resources such as forests and aquatic ecosystems has increased the severity of these effects.

In chapter 15, the final chapter, the leading challenges of future researches about mudskippers are discussed. The authors state that little works have been carried out on their natural history and ecology. Therefore, it is necessary to carry out further researches with the aim of examining the biological and ecological characteristics of mudskippers. In addition, the authors explain that coastal development in different parts of the world, such as Australia, has destroyed the habitats of mudskippers. Hence, local government and international organizations should lay down appropriate rules for protecting the habitats of these aquatic species.

The strengths of the current book can be summarized as followed:

a) The study on the biology and ecology of mudskippers is interesting and attractive.

b) Each chapter is written by a number of expert authors and specialists. In addition, both editors have done many studies on mudskippers and have high expertise and experience in this field.

c) Simple and expressive language.

d) The proper structure and arrangement of chapters will draw the reader's attention to research topics.

e) Use of up-to-date and new references.

The current book can be used as an ideal and perfect reference for the study on the biology and ecology of mudskippers. Therefore, we recommend that copies of this book be distributed to universities and research institutes. Considering the ecological importance of mudskippers among fish, this book can provide useful information for biologists, ecologists, ichthyologists, and other enthusiasts.

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