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Caption: Resplendent Shrub Frog *Raorchestes resplendens* in Eravikulam National Park. © Sandeep Das.

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ARTICLE

Use of an embedded fruit by Nicobar Long-tailed Macaque *Macaca fascicularis umbrosus*: II. Demographic influences on choices of coconuts *Cocos nucifera* and pattern of forays to palm plantations

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Abstract: Adaptive pressures of human-induced rapid environmental changes and insular ecological conditions have led to behavioral innovations among behaviorally flexible nonhuman primates. Documenting long-term responses of threatened populations is vital for our understanding of species and location-specific adaptive capacities under fluctuating equilibrium. The Nicobar Long-tailed Macaque *Macaca fascicularis umbrosus*, an insular sub-species uses coconuts *Cocos nucifera*, an embedded cultivar as a food resource and is speculated to have enhanced its dependence as a result of anthropogenic and environmental alterations. We explored demographic patterns of use and abandonment of different phenophases of fresh coconuts. To study crop foraging strategies, we recorded daily entry and duration of forays into coconut plantations. We divided age-classes into early juvenile (13–36 months), late juvenile (37–72 months), and adults (>72 months) and classified phenophase of coconuts into six types. Consistent with the theory of life history strategies, late juveniles were found to use a greater number of coconuts, which was considerably higher in an urban troop but marginally higher in a forest-plantation dwelling group. Except in late juveniles, males consumed a higher number of coconuts than females in the remaining age-classes. Owing to developmental constraints, juveniles of both types used higher proportion of immature coconuts though adults showed equitable distribution across phenophases. Pattern of entries to plantations and duration of forays were uniform through the day in the urban troop but modulatory in the forest-plantation group, perhaps due to frequent and hostile human interferences. Observations corroborating adaptations to anthropogenic disturbances are described.

Keywords: Coconut phenophases, hard to process food**,** human-induced rapid environmental change, human-macaque competition, dependence on coconut, coconut-based resource competition, coconut consumption, Nicobar archipelago

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INTRODUCTION

Among the many challenges that primates and their habitats face globally, rapid and escalating anthropogenic changes in the age of the Anthropocene are having an irreversible effect on primate populations leading to exclusion, extinction (~60% of primate species, Estrada et al. 2017) and severe constriction of ranges in most primate species (~75% of primate species), (Estrada et al. 2017; Erinjery et al. 2017; Kalbitzer & Chapman 2018). Although a few dietary and habitat generalist primate species are beginning to show indication of behavioural adaptation to anthropogenic habitats (McLennan et al. 2017; Santini et al. 2019), many specialist primate species are trapped in their ecological niches constrained by their phylogeny, life-history, physiology and/or limited phenotypic plasticity (Vázquez & Simberloff 2002; Fisher & Owens 2004; Kalbitzer & Chapman 2018). Even among populations that are synanthropic/commensal to humans, many studies have enunciated the impact of habitat modification on a variety of socioecological (Back et al. 2019), parasitological (Kouassi et al. 2015; Zanzani et al. 2016; Kumar et al. 2018;) and health variables (Kaur et al. 2008; Muehlenbein et al. 2010). Many flexible populations of Apes, Old and New world primate populations subsisting in anthropogenic habitats especially of the genus, *Pan*, *Macaca*, *Papio*, *Cebus*, *Cholorcebus*, and *Saimiri* exhibit evidences of compensating for dietary stress with expansion of dietary resources (like crops and synthetic foods) and associated supplemental foraging strategies (*Pan*, Hockings et al. 2015; *Macaca*, Ilham et al. 2017; Brotcorne et al. 2017; *Papio*, Fehlmann et al. 2017; *Cebus*, Back et al. 2019; *Cholorcebus*, Thatcher et al. 2020; *Samiri*, Campêlo et al. 2019). Many of such food-enhanced populations show complex sensorimotor intelligence associated with extraction of embedded food resources and feed on food items novel to their ancestral diet (e.g., oil-palm nut processing by Burmese Long-tailed Macaque, Luncz et al. 2017).

Alongside many novel frugivore-fruit relationships, the relationship between the Nicobar Long-tailed Macaque *Macaca fascicularis umbrosus* (Images 1,2) and the coconut *Cocos nucifera L.*, a perennial cash crop is particularly intriguing since both the species have colonised the Nicobar archipelago of the Andaman & Nicobar Islands. Although the nature of dependence of the macaque species on wild varieties of coconuts occurring in the islands is unknown, domesticated land races of coconuts have arrived on the island ~2,250 years ago (see Gunn et al. 2011; Niral & Jerard 2018). Groups of macaques closest to coconut palm plantations are exposed to the drupe and thus, familiar to 'domesticated' coconuts and coastal groups that have had prolonged exposure to coconut palms have a much higher dependence than recently exposed inland groups (Das et al. 2020). Systematic destruction of habitats for expansion of coconut horticulture and agriculture (Arora 2018), human habitations and defence establishments along with environmental changes/catastrophes (aridity/Indian ocean tsunami) have disproportionately affected groups on the edge of their habitats (Karnauskas et al. 2016; Reddy 2018), constituted largely by coastal populations of long-tailed macaques (Umapathy et al. 2003; Velankar et al. 2016). Under such circumstances, it becomes essential to study the adaptive pressures of both, gradual and extreme habitat alterations on coastal populations and the resultant behavioural responses, especially in context of dietary expansion and foraging innovations. Since, many such dietary adaptations can have adverse effects on survival and/or persistence of a species in an agriculture ecotone especially, if these resources are shared or cultivated by humans (Hockings et al. 2015; Hill 2017; Kalbitzer & Chapman 2018), it becomes vital to study behavioural flexibilities to explicate adaptive capacities of species and/or population(s) experiencing anthropogenic pressures. Behavioural flexibilities within a group, however, are not expressed identically across demographic classes and age-sex class-specific strategies prevail as a result of distinct life histories (Stamps & Krishnan 2017). For instance, studying the dynamics of group fission in Sumatran Long-tailed Monkey, van Schaik & Noordwijk (1985) described age and social affiliation-specific disintegration of foraging parties with large-bodied sub-adults foraging solitarily during fruiting seasons. Even size and hardness of fruits fed varied along the age-sex axes (van Schaik & Noordwijk 1985). Although many sub-species of long-tailed macaques have been documented to feed on complex embedded resources (like *Opuntia* spp., Tan et al. 2016; *Terminalia catappa,* Falótico et al. 2017; *Elaeis guineensis*, Proffitt et al. 2018) including usage of stone tools to access few of them, variation in the use of these resource items along demographic axes has been seldom investigated (c.f. intertidal shellfishes, Gumert et al. 2011). We adopted the HIREC framework (human-induced rapid environmental change) expounded by Sih et al. (2016) to understand adaptive pressures specific to individual species along with commensurate dietary flexibilities, adaptive potential, and overall phenotypic flexibility in response to extreme anthropogenic

Image 1. Adult females of Nicobar Long-tailed Macaque *Macaca fascicularis umbrosus* (Temple Run group) seated on the wall of a temple complex enclosing a small cluster of coconut palms. © Reshma, P.B., Research Asssitant, Nicobar Project.

Image 2. A juvenile female of Nicobar Long-tailed Macaque Macaca fascicularis umbrosus (Baywatch group) feeding on coconut kernel. © Sayantan Das.

changes to ecosystems. We estimated that the severity of HIREC would be compounded in an insular condition due to the ecological fragility of island ecosystems leading to the exertion of stronger adaptive pressures on coastal groups of long-tailed macaques than on inland/mainland groups (e.g., many island populations of long-tailed macaques (e.g., Malaivijitnond et al. 2007; Luncz et al. 2017) and capuchin monkeys show tool-use behavior (e.g., Barrett et al. 2018)). Despite phylogenetic constraints on expression of behavior, we expected insular populations of long-tailed macaques to express greater behavioral flexibility, quicker learning, proficient extractive foraging and greater tendency of dietary expansion (e.g., Malaivijitnond et al. 2007; Tan et al. 2015, 2016). Thus, the human-macaque interface in the heterogeneous habitat of Nicobar Islands creates a virtual experimental condition for studying emergence of foraging and other dietary adaptations and/or innovations under conditions of HIREC.

In the current study, we focused on how demographic categories, i.e., age and sex compared to each other and to other similar groups in their use of phenophase of coconuts. We also aimed to study contingent acquisition and abandonment of coconuts by age-classes and describe their probable causes. Based on the theory of life-history strategies in macaques, we hypothesized that older juveniles (3–6 yrs) would feed on the highest number of coconuts followed by adults (>6yrs) and younger juveniles (1–3 yrs) due to the largest energy requirement of older juveniles among all age-classes. Comparison of the two sexes though is less straightforward since both, reproductive females and adult males have high energetic requirements for procreation and for maintenance of larger body size, respectively (e.g., Collins 1984; van Schaik & Noordwijk 1985). Since procreation lasts for a shorter time scale than body maintenance, we expected adult males to feed on a higher number of coconuts than adult males. For the remaining age classes, we expected no difference between the two sexes. Because the husk and the shell of the coconut gets progressively tougher and harder with development, we expected adults to process higher number of mature coconuts than by juveniles though tender coconuts will continue to be preferred choices by all age-classes due to the ease of extractive processing.

The marginal value theorem (MVT) within optimal foraging theory postulates that the time spent in resource patches by individuals/groups follows maximization of net energy, i.e., the difference in energy invested in foraging and the energy gained by ingestion (Pyke et al. 1977; Charnov & Orians 2006). Group-level patterns of decisions pertaining cultivar use and plantation visitation is comprehensively specified by MVT, which assumes a greater prominence when conjoined to the HIREC framework since cultivar (resource) attractiveness, cultivar (resource) value and risks from human and non-human crop defenders are introduced as additional factors. In this study, we were interested in expounding and contrasting patch entry and patch use by two groups with different degrees of coconut-dependence, different experiences of human hostilities and different distribution of coconuts, throughout the day. A secondary intent was to generate data that would serve as a baseline for more detailed studies on movement and foraging decisions in contested landscapes. Further, we used the MVT framework within HIREC to obtain insights into the processes governing entry/exit and patch usage dynamics of the focal groups.

METHODS

Study site

We undertook the study at Great Nicobar and Katchal in the Nicobar archipelago of Andaman & Nicobar Islands lying between 93.634–93.953E & 6.735–7.229N, and 93.301–93.475E & 7.873–8.026N, respectively (Figure 1). The major forest types in these islands are the Andaman tropical evergreen forest and the Andaman semi-evergreen forest (India State of Forest Report 2019). Due to their isolation from continental mainland, the islands have high degree of endemism with an extremely poor mammalian diversity (Nayar & Shastry 1987; Balakrishnan 1989; Rao 1989). The Nicobar Long-tailed Macaque is found across all vegetation types in the archipelago including littoral beach formations, mangrove vegetations on coastal regions, low land swamps and inland wet evergreen vegetations (Hajra et al. 1999; Arora 2018). Over the past century, unregulated phases of human migrations and unsustainable developmental initiatives have led to large-scale deforestation on the eastern coast of the islands altering local climatic conditions and threatening biodiversity. Human settlements, agricultural/production landscapes and other human-dominated spaces on the eastern coast are the primary centers of human-macaque hostilities (Rajeshkumar 2017). We chose to study coastal groups of Nicobar Long-tailed Macaque in the two islands that ranged within human-dominated spaces and showed considerable dependence on anthropogenic food resources.

Study groups

We studied two groups of long-tailed macaques, one in each island. The study groups ranged in coastal areas of the two islands. The first group, Temple Run (TR) subsisted within a matrix of semi-urban area, patchily-distributed native vegetation, advanced secondary forest and home garden/plantation of Campbell Bay town in Great Nicobar. Coconut palms occurred in sparse numbers within small (0.04ha) to moderate-sized gardens (0.5ha) maintained at government offices,

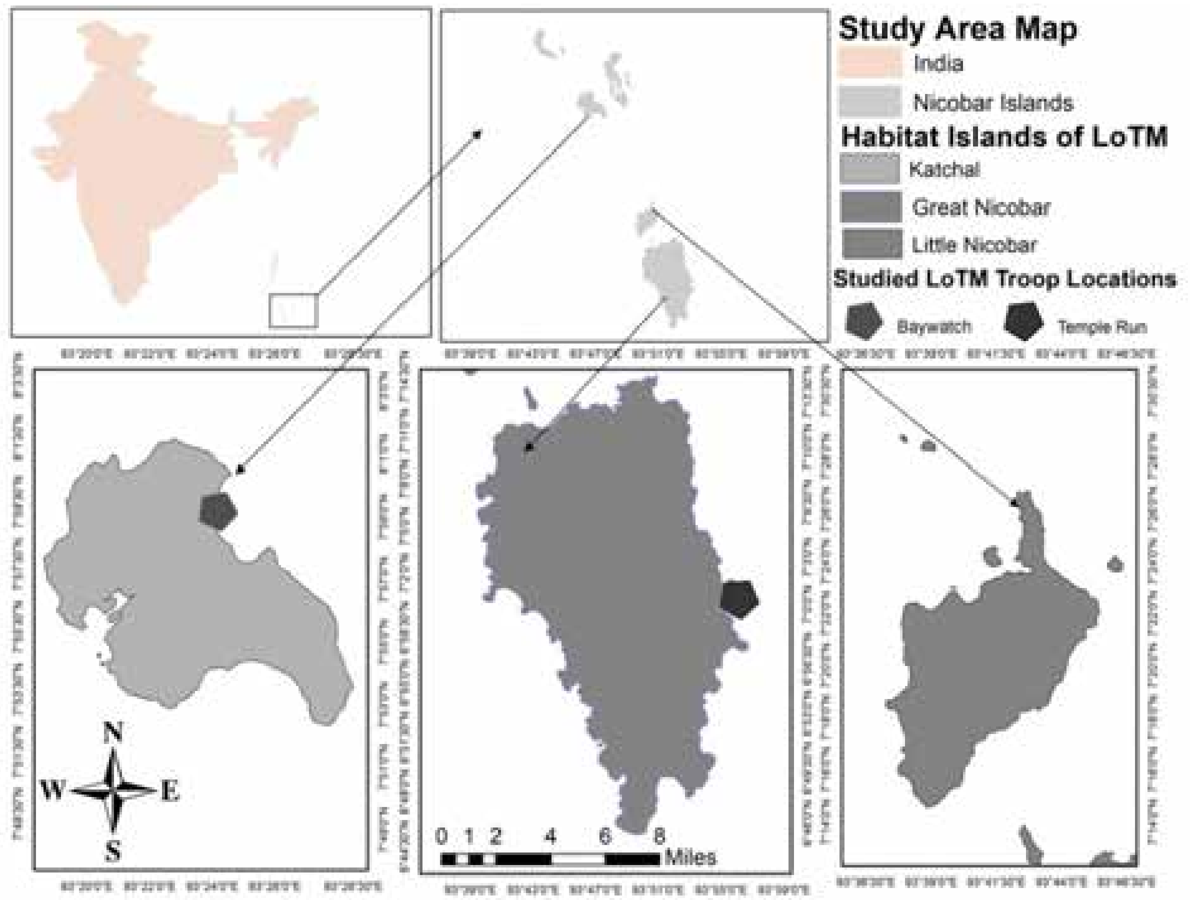

Figure 1. Depiction of the study area showing the distribution of Nicobar long-tailed macaque in the Nicobar islands of India alongside location of the two study groups.

residential areas, temples and other public spaces. Therefore, TR had access to coconuts almost throughout the day (see Das et al. 2020). The second group, Baywatch (BW) used a cumulative coconut plantation area of 5.75ha spread across three patches that ran along the northeastern coast of Katchal. Alongside, the group also accessed semi-altered mixed evergreen forest and other coastal native vegetations. The group had six of (probably) seven–eight sleeping sites adjacent to palm plantations and largely consumed coconut at dawn and dusk. For information on the demographic structure of the two groups, see Das et al. (2020). The troops used coconuts considerably in general and used tougher and mature coconuts consistently, in specific. Conclusively, the troops displayed remarkable proficiencies in extractive foraging of coconuts signifying a long and an involved relationship with the nut, however, both the troops faced immense hostility from humans/dogs within agricultural and other anthropogenic landscapes as a result of crop depredation. Even so, active dispelling of macaques of both troops neither had an effect on their daily allocation of time spent in coconut plantation nor on daily coconut consumption (Das et al. 2020).

Field methods

Post habituation of the two groups, we began data collection from March 2018 for a period of 24 months and 20 months for TR and for BW, respectively. We followed TR from March 2018 to February 2020 and BW from March 2018 to October 2019. We divided the observation period into two annual cycles which began in March and ended in February as a result of the annual periodicity in coconut consumption (see Das et al. 2020). Due to our failure to identify immature individuals of TR group in the first annual cycle of the study, we report the results from the second annual cycle alone. Groups were followed from dawn to dusk at least once a week and for a minimum of five days in a month with sampling day considered as successful only if all coconuts acquired by a troop were accounted for. We noted coconut acquisition by the groups within an *all occurrence* behavioral sampling framework with each session continuing for 10 minutes. We recorded entry and exit schedules into coconut palm plantations of the troops, acquisitions of fresh coconuts from direct (from palm) and indirect (from other individuals and from ground) sources followed by their respective fates, i.e., either processed (if liquid endosperm is accessed) or unprocessed (if liquid endosperm is not accessed) and finally, age and sex classes of individuals (wherever possible) acquiring them. The sampling challenges presented by the two troops as a result of the habitats they occupied led to minor difference in the field protocol followed. This included an inability to record phenophases of coconuts acquired by TR group as a result of inaccessibility to coconut palms. For description of the six phenophases of coconut and their identifying features, see Das et al. (2020). We combined the third and the fourth phenophases due to similarities in their developmental characteristics and for the purpose of easier representation. Demography of the two groups was assessed on a monthly basis.

Data analysis

We classified the life span of Nicobar Long-tailed Macaques into three classes, 13–36 months (early juveniles, EJ), 37–72 months (late juveniles, LJ) and >72 months (Adult, AD) based approximately on (1) coconut handling/processing proficiency and on (2) conventional age classifications for Macaques. We assessed the age-classes of individuals on a monthly basis. For the purpose of testing inter-annual consistencies, we partitioned the dataset of BW into the two annual cycles described previously and presented data of TR over a single annual period only. Whereas, to contrast temporal visit patterns to palm plantations (within a day) by TR with BW, we averaged data across the two annual cycles and represented them as 'frequency of entry' during 10 minutes slots along with corresponding time spent in plantations.

Unprocessed coconuts emerge when macaques acquire coconuts directly (from palm or ground) or indirectly (snatch from a conspecific) but leave them unfed as a result of unsuitability of coconut (i.e., coconut is diseased/disfigured/barren), incapability to process, mishandling (slippage while on the palm), imminent threat (sudden appearance of human/dog), probable satiation or other indecipherable reasons (for e.g., young juveniles can indiscriminately pluck coconuts when learning the technique of 'plucking and dislodging coconuts'). We expressed consumption and abandonment of coconuts in two different units across three temporal scales, 1) as proportion in an annual coconut consumption cycle, 2) as *per capita* mean in a month, and 3) as *per capita* mean throughout the study. Similarly, coconuts used by BW was expressed in two ways to reflect 1) overall share of different phenophases of coconuts and 2) proportionate share of different phenophases of coconuts within demographic classes. We compared (1) proportion data using Chi-squared test of multiple proportion and (2) *per capita* figures across demographic classes, months, annual feeding cycles and groups using parametric/non-parametric comparison of means/ranks between two (e.g., t-test, Mann-Whitney U test) or more groups (e.g., ANOVA, Kruskal-Wallis test). All statistical analyses in this section were carried out using GraphPad Prism v.8.3.1 (GraphPad Software 2020).

To test seasonality of coconut use by the demographic classes, we fitted monthly *per capita* figures with the standard equation for seasonality $y = \alpha + \beta\sin(2\pi t) + \gamma\cos(2\pi t) + \varepsilon$. In order to test the hypothesis that (1) males have an overall greater consumption of processed coconuts than females and (2) that late juveniles disproportionately determined use of processed coconuts, we used a mixed effects modeling approach using maximum likelihood estimation with Laplace approximation. We used coconuts consumed by a demographic class (during a sampling day) as the dependent variable, month of sampling as the random factor and group identity, age-class (computed monthly) and sex as the fixed factors. To control for number of individuals in a given demographic class, we used an offset term, log (#of individuals). As a result of the versatile computing ability of the R Statistical Programming Language, we used RStudio v.1.3 (RStudio Team 2020) for all statistical analyses discussed in this section.

Finally, we illustrated frequency of entry to coconut plantation across the day and represented duration of time spent by a group on entry at a given time slot as mean ±SD. To depict trends, we used a fifth order polynomial equation. We plotted frequency of entry to coconut palm plantation alongside corresponding duration of time spent in the plantation by collating data from across all sampling days. All graphical illustrations were carried out in GraphPad Prism v.8.3.1 (GraphPad Software 2020).

Ethical note

The present study was exclusively observational and did not involve any invasive or controlled experimentation. Clearance for the observational protocol was received from the Institutional Animal Ethics Committee of the University of Mysore and complied with the Code of Best Practices for Field Primatology.

RESULTS

We undertook a total of 75 and 134 successful field samplings during a period of 12 and 20 months during which we recorded a cumulative of 746 and 7,382 processed coconuts, and 243 and 566 unprocessed coconuts in TR and in BW, respectively. Since a considerable proportion of data emerged from scanning as opposed to direct observations, information on demographic identity of the processing individual could not be established. Hence, the dataset used for demographic comparisons comprised a slightly smaller subset. We found evidences for variation in the use of coconuts across the gradients of age, sex, group, and month (see Das et al. 2020). We describe the results of this study below.

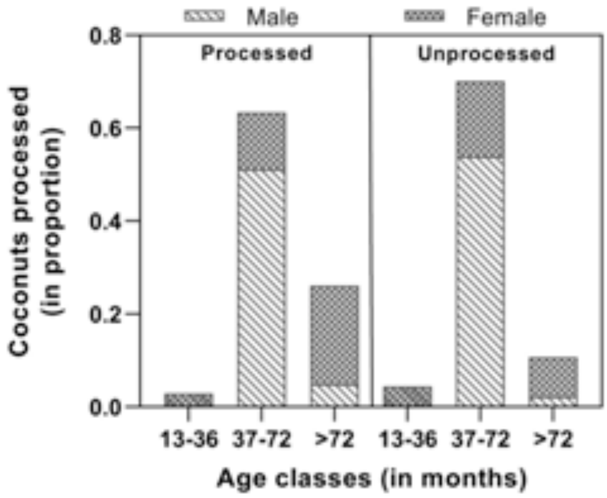

Figure 2. Representation of demographic classes in the sample of processed and unprocessed coconuts recorded in the Temple Run group during March 2019–February 2020. The sex classes within each age-class are demarcated.

Age-specific acquisition of processed and unprocessed coconuts by Temple Run group in a single annual cycle and by Baywatch group in two consecutive annual cycles

We found contrasting results in the demographic shares of processed coconuts between TR and BW groups though coconuts left unprocessed by the two groups showed similar trends. With an aggregate EJ:LJ:AD ratio of 4:5.8:5.5 TR showed the following crude order of coconuts processed, LJ>AD>EJ ($\chi^{2.TR}_{LJ>AD}$=267.17, df=1, *p*<0.0001; $\chi^{2.TR}_{EJ<AD}$=119.03, df=1, *p*<0.0001; $\chi^{2}_{EJ<LJ}$ =1148.16, df=1, *p*<0.0001; Figure 2). On the contrary, with an aggregate EJ:LJ:AD ratio of 8:6.6:14 and 11.3:10.2:14 during the first (AC-1) and the second annual cycles (AC-2), respectively, BW exhibited the following order of demographic classes in the number of coconuts processed, AD>LJ>EJ ($\chi^{2.AC-1}_{AD>LJ}$=408.73, df=1, *p*<0.0001; $\chi^{2.AC-1}_{LJ>EJ}$=287.28, df=1, *p*<0.0001; $\chi^{2.AC-1}_{AD>EJ}$=1532.14, df=1, *p*<0.0001: $\chi^{2.AC-2}_{AD>LJ}$=84.67, df=1, *p*<0.0001; $\chi^{2.AC-2}_{LJ>EJ}$=1128.32, df=1, *p*<0.0001; $\chi^{2.AC-2}_{AD>EJ}$ =2027.09, df=1, *p*<0.0001; see Figure 3). An indicator of resources un-utilized and perceived crop depredation

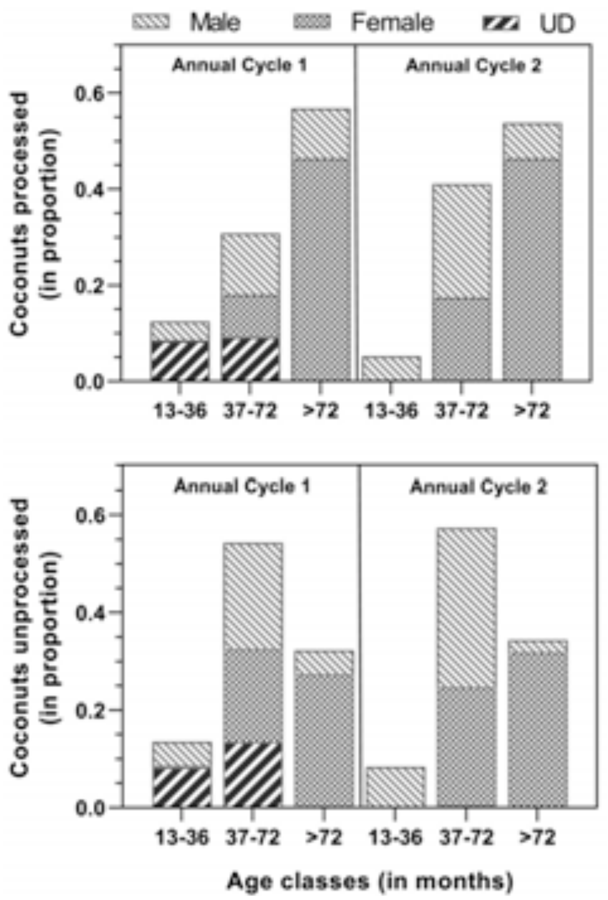

Figure 3. Representation of demographic classes in the sample of processed (top) and unprocessed coconuts (bottom) recorded in the Temple Run group during March 2018–October 2019. The sex classes within each age-class are demarcated.

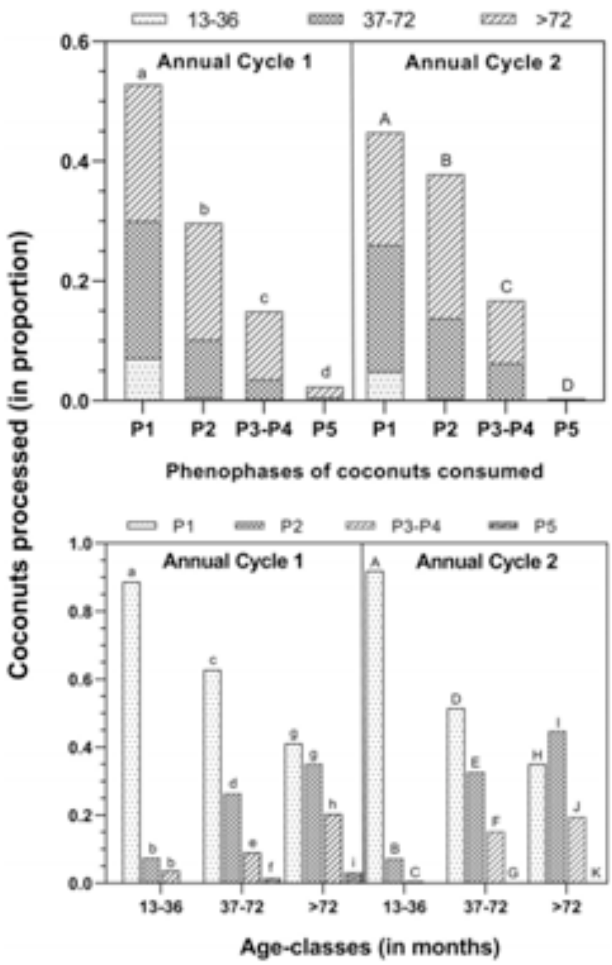

Figure 4. Relative use of processed coconuts by Baywatch group expressed as overall proportions of phenophases with demarcations of age-classes (top) and age class-specific proportions of phenophases (bottom). Note that the y-axes of the two graphs is identical but the x-axes are different.

by coconut horticulturists, the number of coconuts left unprocessed were also assessed in a similar manner. We found late juveniles to be the highest contributors to unprocessed coconuts across both troops and across both annual cycles (in BW) coherently followed by adults and early juveniles ($\chi^{2.TR}_{LJ>AD}$=313.49, df=1, p<0.0001; $\chi^{2.TR}_{EJ<AD}$=7.73, df=1, p=0.02; $\chi^{2}_{EJ<LJ}$=464.18, df=1, p<0.0001: $\chi^{2.AC-1}_{LJ>AD}$=34.09, df=1, p<0.0001; $\chi^{2.AC-1}_{EJ<LJ}$=148.70, df=1, p<0.0001; $\chi^{2.AC-1}_{EJ<AD}$=34.06, df=1, p<0.0001: $\chi^{2.AC-2}_{LJ>AD}$=26.92, df=1, p<0.0001; $\chi^{2.AC-2}_{EJ<LJ}$=178.25, df=1, p<0.0001; $\chi^{2.AC-2}_{EJ<AD}$=53.25, df=1, p<0.0001). In absolute terms, late juveniles in TR abandoned coconuts 5.6 times more than adults and 17.5 times more than early juveniles. Late juveniles in BW discarded coconuts 1.69 times and 1.67 times more than adults in the first and the second annual cycles, respectively, and 4 times and 6.8 times more than early juveniles in the first and the second annual cycles, respectively. Sex-specific shares of coconut consumption across each demographic class are also presented in Figure 2 and in Figure 3.

Use of different phenophases of processed coconuts by Baywatch group expressed as overall proportions and as demographic class-specific proportions across two annual cycles

A stable pattern was revealed in phenophases of coconuts used across both annual cycles. The order of phenophases use emerged to be the following P1>P2>P3/P4>P5 ($\chi^{2.AC-1}_{Overall}$=497.92, df=3, p<0.0001; $\chi^{2.AC-2}_{Overall}$=1684.94, df=3, p<0.0001) (Figure 4). Comparison of absolute figures of phenophases consumed in the first annual cycle revealed P1 to be consumed more than P2 by a factor of 1.8, more than P3 by a factor of 3.5 and finally, more than P5 by a factor of 21.8 times. Similar figures in the second annual cycle differed by a small margin with P1 consumed 1.2 times more than P2, 2.67 times more than P3/P4 and finally, 104.6 times more than P5. Depiction of stacked columns of coconuts processed by the demographic-classes in the first graph of Figure 4 is for visual illustration alone.

To determine choice of phenophase of processed coconuts used by a demographic class, we plotted the second graph of Figure 4. Note that the proportions within each age-class add to unity. Individuals in the age-class of 13–36 months, i.e., early juveniles fed a disproportionately low number of P2 (7.5%) and P3 coconuts (3.8%) relative to P1 (88.7%) coconuts with no representation of P5 coconuts. Early juveniles showed the following order of preference based on the number of coconuts processed, P1>P2=P3/P4 ($\chi^{2,AC-1}_{Overall,EJ}$=153.63, df=3, p<0.0001) and P1>P2>P3/P4 ($\chi^{2,AC-2}_{Overall,EJ}$=435.37, df=3, p<0.0001) during the first and the second annual cycles, respectively. Late juveniles of the next age category fed on all classes of phenophase and had the following sequence of preference, P1>P2>P3/P4>P5($\chi^{2,AC-1}_{Overall,LJ}$=287.80, df=3, p<0.0001; $\chi^{2,AC-2}_{Overall,LJ}$=823.60, df=3, p<0.0001) across both annual cycles. Proportion of P1 and P5 coconuts processed by late juveniles decreased from 62.8% to 51.6% and from 1.7% to 0.4%, respectively whereas proportion of P2 and P3/P4 processed coconuts increased from 26.4% to 32.8% and from 9.1% to 15.3%, respectively. Finally, adults exhibited slight variability in their choice of coconuts across the two annual cycles displaying the following order of preference, P1=P2>P3/P4>P5 ($\chi^{2,AC-1}_{Overall,AD}$=167.68, df=3, p<0.0001) in the first feeding cycle and the order, P2<P1>P3/P4>P5 ($\chi^{2,AC-2}_{Overall,AD}$ =824.94, df=3, p<0.0001) in the second feeding cycle (Figure 4). Corresponding alterations in the proportionate consumption of different phenophases of coconuts between the two annual cycles also became apparent, for example increase in use of P1, P3/P4 and P5 coconuts from 35.1% to 41.1%, from 19.5% to 20.4% and from 0.5% to 3.3%, respectively and decline in the use of P2 coconuts from 44.9% in the first annual cycle to 35.1% in the second annual cycle.

Abandonment of different phenophases of coconuts (unprocessed) by Baywatch group expressed as overall proportions and as demographic class-specific proportions

We found all phenophases of coconuts represented in the unprocessed category of coconuts. We found that the phenophase(s) that is/are processed the most is/are also the one(s) that is/are left unprocessed the most; we found P1(50%) to be the highest unprocessed coconut in the first annual cycle ($\chi^{2,AC-1}_{Overall,P1}$=36.86, df=3, p<0.0001) whereas both, P1(42.4%) and P2(30.9%) emerged as the phenophases with the highest unprocessed coconut in the second annual cycle ($\chi^{2,AC-2}_{Overall}$ =95.59, df=3, p<0.0001; $\chi^{2,AC-2}_{P1=P2}$=6.75, df=1, p=0.08). The order of the remaining

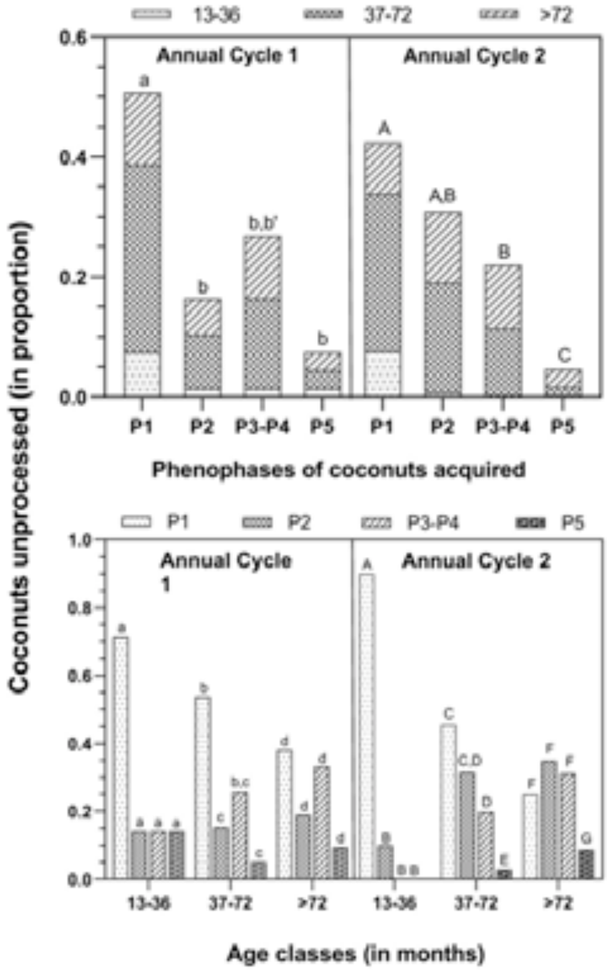

Figure 5. Relative abandonment of unprocessed coconuts by Baywatch group expressed as overall proportions of phenophases with demarcations of age-classes (top) and age class-specific proportions of phenophases (bottom). Note that the y-axes of the 2 graphs is identical but the x-axes are different.

phenophases did not show any consistent pattern across the annual cycles. In the first annual cycle, the proportion of P3/P4(26.5%) coconuts left unprocessed was higher than P5 (7.4%) ($\chi^{2,AC-1}_{P3-P4>P5}$=9.46, df=1, p<0.0001) but equivalent to P2(16.2%) ($\chi^{2,AC-1}_{P3-P4=P2}$=2.18, df=1, p=0.54) whereas the proportion of P2 coconuts left unprocessed was comparable to P5 ($\chi^{2,AC-1}_{P2=P5}$=2.60, df=1, p=0.46). In the next annual cycle, we obtained the following order of phenophases, P3/P4(22.03%) > P5(4.66%) coconuts ($\chi^{2,AC-2}_{P3-P4>P5}$=32.94, df=1, p<0.0001) (Figure 5).

As opposed to processed coconuts, all the phenophases were represented in unprocessed coconuts across all the demographic classes. On analyzing the proportion of phenophases of coconuts left unprocessed by individual demographic classes across the annual cycles, we found that the highest processed phenophase emerged as the highest unprocessed coconut in the

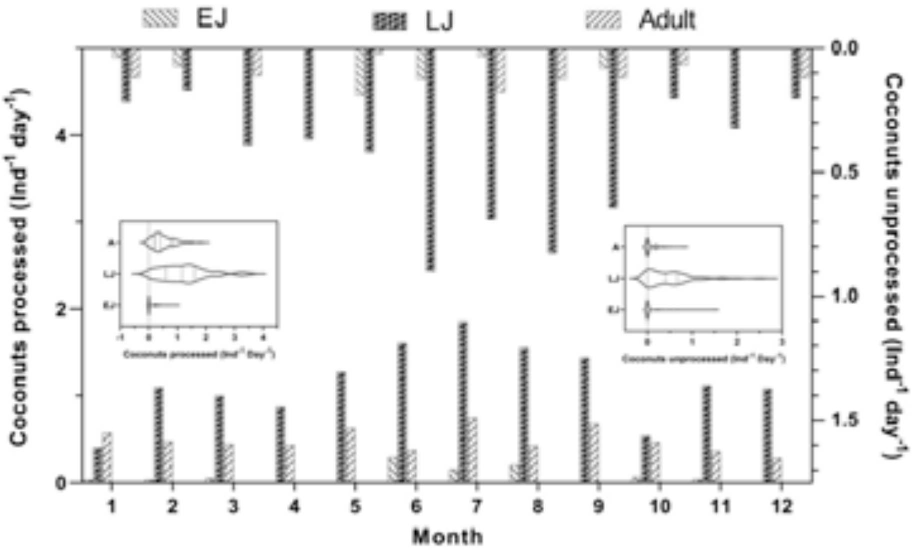

Figure 6. Monthly *per capita* use of processed coconuts and *per capita* abandonment of unprocessed coconuts by different age-classes of the Temple Run group during March 2019–February 2020. Overall comparison of *per capita* use of processed coconuts and *per capita* abandonment of unprocessed coconuts by age-classes are illustrated using violin plots within the graph (inset).

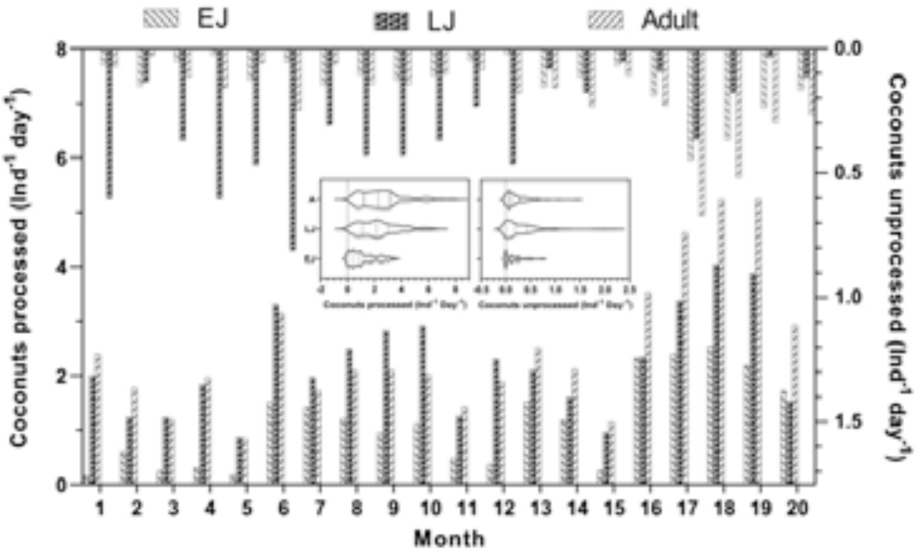

Figure 7. Monthly *per capita* use of processed coconuts and *per capita* abandonment of unprocessed coconuts by different age-classes of the Baywatch group during March 2018–October 2019. Overall comparison of *per capita* use of processed coconuts and *per capita* abandonment of unprocessed coconuts by age-classes are illustrated using violin plots within the graph (inset).

case of early juveniles ($\chi^{2,AC-2}_{Overall,EJ}$=60.80, df=3, *p*<0.0001) in the second annual cycle alone. In the remaining demographic classes however, no single phenophase of unprocessed coconuts emerged as the single highest. For instance, all phenophases were equally represented among early juveniles in the first annual cycle ($\chi^{2,AC-1}_{Overall,EJ}$ =8.00, df=3, *p*=0.046); P1 and P3 were comparable in the first annual cycle ($\chi^{2,AC-1}_{P1=P3}$=7.06, df=1, *p*=0.07), and P1 and P2 were comparable in the second annual cycle ($\chi^{2,AC-2}_{P1=P2}$=5.72, df=1, *p*=0.13) among late juveniles and almost all phenophases were equivalently left unprocessed by adults in both annual cycles ($\chi^{2,AC-1}_{Overall,AD}$ =5.78, df=3, *p*=0.12; $\chi^{2,AC-2}_{Overall,AD}$=17.20, df=3, *p*=0.0006). It is interesting to note that P5 coconuts occurred in noticeable proportions (EJ^{AC-1}=12.5%, LJ^{AC-1}=5.1%, AD^{AC-1}=9.5%; EJ^{AC-2}=0%, LJ^{AC-2}=2.9%, AD^{AC-2}=8.8%) across all demographic classes in both annual cycles except in the case of early juveniles in the second annual cycle.

Age-class specific monthly use of processed coconuts and abandonment of unprocessed coconuts by Temple

Table 1. Results of the generalized linear mixed effects model with number of processed coconuts consumed as the dependent variable, month as the random factor and age-class, group identity and sex as the fixed factors. To control for number of individuals in an age-class, we have used an offset term, log (number of individuals). Model fitting has used maximum likelihood method along with Laplace approximation.

Coefficient	Estimate (β)	SE	Z	*p*
Processed coconuts~ Age class * Sex + Age Class*Group + (1 |Month)				
Intercept	0.268	0.097	2.762	0.0058
Early juvenile	-1.739	0.097	-17.89	<0.0001
Late juvenile	0.221	0.042	5.26	<0.0001
Male	0.218	0.050	4.40	<0.0001
Temple Run	-1.243	0.075	-16.54	<0.0001
Early juvenile: Male	0.520	0.118	4.40	<0.0001
Late juvenile: Male	-0.198	0.067	-2.94	0.0032
Early juvenile: Temple Run	-0.516	0.217	-2.375	0.0175
Late juvenile: Temple Run	0.752	0.088	8.20	<0.0001

*Adult (Age class), Female (Sex class) and Baywatch (Group) have been used as reference categories

Run group

Over and above annual trends, we were interested in monthly patterns of coconut use and coconut abandonment by demographic classes of the two groups while controlling for class size, i.e., number of individuals in a demographic class leading to the computation of *per capita* figures. We present the results of the two groups, TR and BW, in separate sections followed by comparisons of the two groups in the final section. All comparisons use *per capita* values.

Considering a single annual cycle, while early juveniles and adults in TR showed a stable use of processed coconuts across months (KW^{TR}_{EJ}=24.22, *p*=0.01, no difference between months on Dunn's correction for multiple comparison; KW^{TR}_{AD}=8.95, *p*=0.63), late juveniles showed a minor inter-month difference ($F^{TR}_{EJ}(11,64)$ =2.17, *p*=0.03; $\mu_{Sep-2019}>\mu_{Mar-2019}$) (Figure 6). As a result of an almost constant use of processed coconut across months and perhaps, lack of greater temporal coverage, no seasonality was observed in the use of processed coconuts by any of the demographic classes. At the level of individual month, we found near-consistent difference between early juveniles and late juveniles but no difference between late juveniles and adults (Figure 6). In contrast, pooling the data through the entire annual cycle showed a distinct demographic pattern with LJ>AD>EJ ($F^{TR}_{Overall}$=112.50, *p*<0.0001) (Figure 6 inset). Similar to the analyses of processed coconuts, we found no variation in the number of coconuts left unprocessed by the demographic classes across months (KW^{TR}_{EJ}=9.99, *p*=0.53; KW^{TR}_{LJ}=21.66, *p*=0.03, no difference between months on Dunn's correction for multiple comparison; KW^{TR}_{AD}=19.18, *p*=0.06; Figure 6) though across five of the 12 months, there were minor differences across age-classes within a month in which late juveniles emerged as the highest contributor to *per capita* abandonment of coconuts. Consistent with our hypothesis, the following order of coconuts left unprocessed emerged when data for the entire study were pooled together, LJ>AD=EJ ($Friedman^{TR}_{Overall}$=68.62, *p*<0.0001; $\Sigma Rank_{AD}-\Sigma Rank_{EJ}$=16.5, p=0.053) (Figure 6 inset). Expectedly, results from generalized linear mixed modeling approach to determine relative influence of the three demographic classes on use of processed and desertion of unprocessed coconuts showed that late juveniles exerted greatest influence followed by adults and early juveniles after controlling for variations due to month and number of individuals within a demographic class (Table 1).

Age-class specific monthly use of processed and abandonment of unprocessed coconuts by Baywatch

On comparing individual demographic classes in their use of processed coconuts across months, we found both, early juveniles (KW^{BW}_{EJ}=66.62, *p*<0.0001) and adults to have unequal use (F^{BW}_{EJ}=5.99, *p*<0.0001) though late juveniles showed a constant consumption pattern (KW^{BW}_{EJ}=41.98, *p*=0.002; No difference between months on Dunn's correction for multiple comparison) across the 20 months of the study. As a consequence, no seasonality in the processing of coconuts was revealed in any demographic class. Next, we attempted to contrast the demographic classes at the level of individual months. The differences among the age-classes appeared to be more subtle than TR since 11 out of the 20 months did not record any difference among the age-classes. Even among months (N_{EJ}=7)

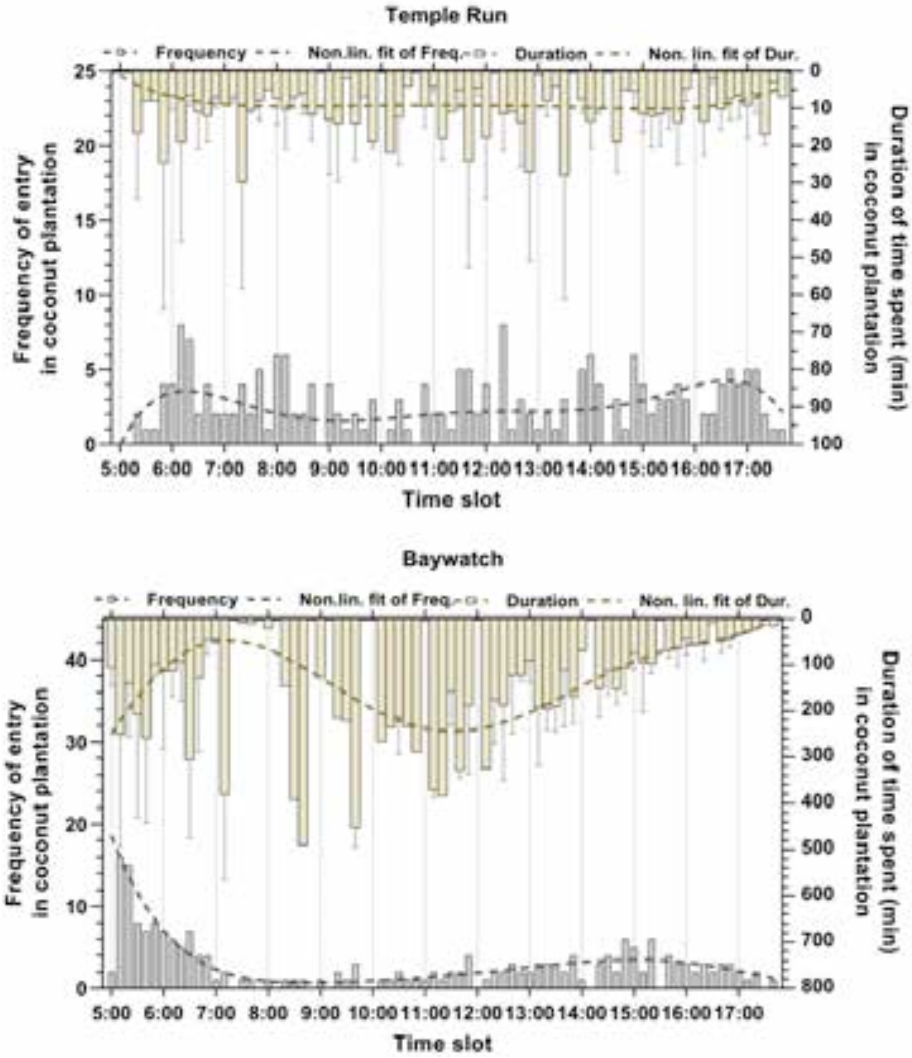

Figure 8. Illustration of 'frequency of entry' and corresponding 'duration of time spent' in coconut palm plantations by Temple Run group (top) and by Baywatch group (bottom). Additional features in the graph include polynomial regression curves to depict trends of distributions shown as dotted lines. Note that the scales of the Y1 and Y2-axes of the two graphs are different.

where difference among age-classes were retrieved, early juveniles emerged to have the lowest *per capita* coconut processing value. Pooling data from the 20 months of observation, we firmly established early juveniles to have the lowest use of processed coconuts (μ_{EJ}±SD=1.12±0.95) but late juveniles (μ_{LJ}±SD=2.24±1.41) and adults (μ_{AD}±SD=2.45±1.58) had almost equal use of processed coconuts leading to the following order of consumption, LJ~AD>EJ ($\text{Friedman}^{BW}_{Overall}$=107.10, *p*<0.0001; $\Sigma Rank_{AD}$-$\Sigma Rank_{LJ}$=33.0, p=0.054). A distinct difference among the three demographic classes in BW was revealed with generalized linear mixed model wherein, late juveniles emerged to exert greater influence on overall use of processed coconuts than the remaining age classes (Table 1).

We analyzed data on unprocessed coconuts by demographic classes in a manner similar to processed coconuts. Late juveniles did not vary in abandonment of unprocessed coconuts across months (KW^{BW}_{LJ}=48.59, *p*=0.0002; No difference between months on Dunn's correction for multiple comparison) though early juveniles (KW^{BW}_{EJ}=45.58, *p*=0.0006) and adults did (KW^{BW}_{AD}=58.54, *p*<0.0001) (Figure 7). When demographic classes were compared during each individual month, we found no difference among age-classes during 11 months; at least one difference in paired comparison of age-classes in seven months and just two months during which late juveniles superseded both age-classes (March 2018 and December 2018). Considering overall aggregate figures of unprocessed coconuts discarded by each demographic class, our result matched the trend obtained for processed coconuts, AD=LJ>EJ (

Table 2. Results of the generalized linear mixed effects model with number of unprocessed coconuts consumed as the dependent variable, month as the random factor and age-class, group identity and sex as the fixed factors. To control for number of individuals in an age-class, we have used an offset term, log (number of individuals). Model fitting has used maximum likelihood method along with Laplace approximation.

Coefficient	Estimate (β)	SE	Z	*p*
Unprocessed coconuts ~ Age Class*Group + (1 |Month)				
Intercept	-2.293	0.113	-20.259	<0.0001
Early juvenile	-0.577	0.137	-4.206	<0.001
Late juvenile	1.152	0.090	12.768	<0.0001
Temple Run	-0.338	0.203	-1.662	0.0966
Early juvenile: Temple Run	0.070	0.369	0.189	0.850
Late juvenile: Temple Run	0.767	0.217	3.528	<0.001

*Adult (Age class) and Baywatch (Group) have been used as reference categories

$\text{Friedman}^{BW}_{Overall}$=107.10, *p*<0.0001; $\Sigma Rank_{AD}$-$\Sigma Rank_{LJ}$=7.0, p>0.99) (Figure 7 inset). Although, macaques of both troops avoided heavily defended regions of palm plantations, we did not find any difference in the number of coconuts left unprocessed among high (HR), moderate (MR) and low risk (LR) areas of coconut plantations($\chi^{2,TR}_{HR\sim MR}$=2.51, p=0.54; $\chi^{2,TR}_{HR\sim LR}$=3.21, p=0.33; $\chi^{2,BW}_{HR\sim MR}$=0.01, p=0.99; $\chi^{2,BW}_{HR\sim LR}$=4.15, p=0.13).

The results of the generalized linear mixed effects model considering processed coconuts from both groups revealed that males superseded females by a mean difference of 0.22 in *per capita* coconut consumption after adjusting for age-class. We also found late juveniles to have an overall highest mean *per capita* use of processed coconuts followed by adults and early juveniles (Table 1) despite late juveniles in BW consuming an equivalent number of coconuts as adults in BW. Among other comparisons, BW and each representative age-class of BW had higher mean *per capita* use of processed coconuts than TR and its corresponding age-classes (Table 1). In contrast, when unprocessed coconuts from both groups were pooled, BW and TR were comparable along with early juveniles of both the troops (Table 2). Comparing age-classes of the two groups in their abandonment of unprocessed coconuts, we found that adults of BW superseded adults of TR and conversely, late juveniles of TR surpassed late juveniles of BW. In addition, an overall age-class related differences persisted where the mean difference in *per capita* abandonment of coconut processing between LJ and AD, and between EJ and AD were 1.15 and 0.58, respectively (Table 2).

Hourly pattern of entry into coconut plantations and corresponding duration of foray by Temple Run and Baywatch groups

Temple Run exhibited a low but an approximately uniform frequency of entry (~2–3 entries every 10 minutes) into plantations throughout the day with minor peaks appearing at ~06.30h and at ~16.45h. An analogous trend was obtained in pattern of duration of time spent which rose from an average of 0 min at 05.00h to 4 min at 06.00h and remained at an average of 10 min till ~17.00h before declining to 0 min.

Unlike the trends of foray duration obtained in TR, BW began their entry into plantation slightly early and at a frequency of 16 (if the initial frequency of 2 at 05.00h is ignored) at 05.10h after which, the trend of entry declined sharply till 07.50h to null. Frequency of entry gradually picked up to 6 till 14.50h and gradually fell to null again at ~17.30h. Although similar in form but widely different in magnitude, BW spent more time in coconut plantations between roughly 09.30–13.30 h with peak average duration reaching 250 minutes (as estimated from the polynomial trend line). Average duration of foray into plantation at the tail of the trend line showed an asymptotic relationship with the straight line slope of one (θ=45°) due to the constraint of activity period of the species.

DISCUSSION

In the first part of our article (Das et al. 2020), we applied the HIREC framework to study differential use of coconut palms and palm plantations by a wide variety of groups of long-tailed macaques differing in their exposure to coconut and thus, to agricultural landscapes, habitat alterations and to biotic threats from crop defending dogs/humans. In the present article, we extended the HIREC framework to study the response of demographic classes and decompose the use and abandonment of coconuts. We found late juveniles to consume and abandon the highest number of coconuts across annual cycles. On overall comparison by pooling data from both groups, males emerged to use a higher share of processed coconuts than females though sex-difference reversed in the late juvenile age class. Due to a skewed sex ratio (TR=1:4, BW=2:14) in the adults, sex differences in the use of processed coconuts should be interpreted with caution. Early juveniles constrained by their physiology and limited processing repertoire almost exclusively used P1 coconuts though with maturity, individuals used higher phenophases of coconuts. Adult individuals were found to equalize their choice of coconuts across phenophases than late juveniles. The MVT construct predicts patch-usage and patch-leaving decisions (e.g., Wajnberg et al. 2000). Similar to results obtained in the first part of the article (Das et al. 2020), entry into coconut plantations were slightly more frequent during dawn and dusk though usage of plantation remained stable through the day. Temple Run showed a uniform frequency of use of coconut clusters/plantations through the day but BW showed temporal modulations. The corresponding profile of the distribution of 'duration of foray' between the two groups, however, was highly variable. The two groups also differed with regard to the spatial proximities of their respective sleeping sites to nearest coconut plantations. Temple Run consistently chose sites that were slightly aloof from human habitations and hence, distant from palm plantations. On the other hand, Baywatch had six of a potential eight sleeping sites within 100m from palm plantations with three of them located inside less-disturbed (i.e., low risk) regions of the plantations. As a result of a relatively wider (though sparse) distribution of coconut palm occurring within the range of TR, they accessed coconut throughout the day in contrast to BW.

Age-specific use of processed coconuts and abandonment of unprocessed coconuts by Temple Run group in a single annual cycle and by Baywatch group in two consecutive annual cycles

The pattern of age-class governed unprocessed coconuts mirrored the trend of processed coconuts. Dynamics of the un-standardized age-class recorded in the dataset of BW, however, showed less consumption of coconuts by late juveniles than adults due to a much smaller count of late juveniles and as a result of stable demographic structure, the trend remained constant over annual cycle. The disproportionately high records of unprocessed coconuts abandoned by late juveniles relative to other age-classes reflects indiscriminate and perhaps, naïve acquisition/plucking of coconuts since a large subset is often unsuitable for consumption with coconut abandonment, emerging as a byproduct of pedagogic explorations of coconut. As is apparent, such explorative tendencies are limited to young juveniles, since they are physiologically/cognitively/mechanically constrained but not in adults as they have the requisite cognitive and motor skills to harvest desired coconuts. In support of age-related proficiency of food processing, description of cashew (*Anacardium* spp.) processing by Wild Bearded Capuchins *Sapajus libidinosus* also found age to be a strong predictor of success in opening fresh and dry forms of the nut (Visalberghi et al. 2016).

Use of different phenophases of processed coconuts by Baywatch group expressed as overall proportions and as demographic class-specific proportions across two annual cycles

The frequency of use of phenophases of processed coconuts followed the developmental order of phenophases with the most immature stage(s) of coconut being used by all age-classes over all the subsequent phases of coconut. The share of P2 and P3/P4 phenophases in the diet of early juveniles were meager and records were made only from the oldest individuals in the category. Conversely, higher age-classes had greater representations in mature phenophases of coconuts with adults displaying skilled use of tougher/harder coconuts than late juveniles. A study by Schaik & Noordwijk (1985) on Sumatran Long-tailed Macaques also found adult males to select native wild fruits with hard rinds relative to juveniles of <2 yrs. In contrast, Visalberghi et al. (2016) found that adult females process a higher number of both dry and fresh cashews. Analyses of the relative use of different phenophases of coconuts within individual age-category clearly expounded age-related patterns of resource use which denote a strong ontogenetic effect on extractive foraging of coconuts. Similarly, balance and optimality in choice of phenophases also seem to be achieved at adulthood.

Abandonment of different phenophases of coconuts (unprocessed) by Baywatch group expressed as overall proportions and as demographic class-specific proportions

The trend of age-related unprocessed coconuts was incoherent across annual feeding cycles, however, age-class with the highest explorative tendencies was found responsible for the highest number of unprocessed coconuts. It is intriguing to note that despite being incapable to process P4 and P5 coconuts, early juveniles proactively made efforts to dislodge and dehusk these coconuts. For the remaining age-classes, incidences of unprocessed coconuts were almost uniformly distributed across the phenophases with P1-P3 showing highest incidences among late juveniles in the first annual cycle and P1-P2 occurring in higher numbers in the second annual cycle. Curiously, despite their proficiencies in coconut processing, even adults showed a substantial abandonment of P5 coconuts.

Age-class specific per capita use of processed and abandonment of unprocessed coconuts by Temple Run and Baywatch groups across months

Representation of the monthly use of processed coconuts and abandonment of unprocessed coconuts by age-classes distinctly identified late juveniles to supersede the remaining age-classes though a slight difference was noted in the month with the highest average *per capita* use/un-use (September in TR and August in BW; similar to overall coconut consumption in Das et al. (2020)). Analyses of pooled data from the entire study period in the two troops reaffirmed the distinction of late juveniles in TR though late juveniles were marginally comparable to adult females in use of processed coconuts. The difference in the results of the two groups is attributable to the disparity in their food habits. As opposed to the natural diet of BW, TR has a considerable dependence on human-cultivated and artificially manufactured food items (Das et al. 2020). Late juveniles displayed adult-like use of coconuts and developed commensurate sensorimotor and cognitive skills requisite for extractive foraging, a direct evidence of high dietary dependence on the drupe. Similar to Long-tailed Macaque, Wild Bearded Capuchins were also found to show age-specific hierarchy in average *per capita* processing of fresh cashew nuts. Adults and late juveniles processed equal number of dry cashew nuts on an average (Visalberghi et al. 2016). Remarkably, the seasonality in the overall use of processed coconuts noted in Das et al. (2020) failed to prevail when consumption was decomposed into age-classes. The absence of seasonality in coconut-use by age-classes prompts us to speculate that as a consequence of coconut scavenging, i.e., feeding kernel and/or drinking water from an already processed coconut, cumulative harvest can satiate the entire group. Males consumed higher coconuts in all age-classes, except in late juvenile stage possibly, as a result of dimorphism in body sizes, which either, indicates non-coconut resource use by females or that body-size maintenance by adult males trump energy requirements of reproduction in females. Consistent with the trend of crude comparisons of abandoned unprocessed coconuts by age-classes, late juveniles had the highest overall *per capita* contributions to unprocessed coconuts, especially in TR. Despite lower use and hence, lower dependence on coconuts by late juveniles in TR relative to their counterparts in BW, late juveniles in TR showed significantly higher abandonment of coconuts indicating inefficacious handling and/or selection of coconuts, an indication of suboptimal coconut foraging/processing strategy. It is also to be noted that coconuts left unprocessed can often be processed by the same or a different individual and hence, is not a veritable index of crop loss.

Hourly pattern of entry into coconut plantations and corresponding duration of foray by Temple Run and Baywatch groups

Temporal profile of entries to plantations and duration of forays were largely modulated by the spatial distribution of coconut palms within the range of groups. BW appeared to prefer coconuts as their first choice of food at the beginning of the day, strategically choosing sleeping sites that were either adjacent to or inside palm plantations. Correspondingly, the distribution of time spent in the morning during the first phase foray was very high and coincided with the first foraging bout. Forays into plantations later in the morning (i.e., after 07.20h) tended to be shorter than forays undertaken earlier (i.e., around 05.20h), possibly because sources of hydration and/or food has been accessed. Subsequent use of plantations through the day remained relatively low gradually increasing after 12.30h and peaking at 15.30h, which corresponds to evening bouts of foraging. As a result of the edge distribution of the plantations within the home range of the group, duration of time spent in mid-afternoon tended to be longer as suitable foraging patches were distantly located from the range edge. Patch-exit decisions by BW were sporadically coerced by threats from humans/dogs guarding the plantations, creating a landscape of fear that groups responded to even in the absence of threat (Lindshield 2014; Gallagher et al. 2017). For instance, arboreal paths were preferred to enter risky areas of the plantation and nervous terrestrial locomotion were noted among the most vulnerable members of the group as is often reported in crop-foraging populations of non-human primates (e.g., Long-tailed macaques, Riley & Priston 2010; Chimpanzee, Krief et al. 2014). The second group, TR on the other hand had access to relatively uniform distribution of coconut palms/clusters throughout its home range and therefore, entered/exited clusters regularly throughout the day spending almost equivalent duration throughout the day. Hostilities, however, did not have any effect on proportion of coconuts abandoned in riskier human areas. The lack of sharp peaks in the temporal distribution of plantation entry could also be a strategy in response to anthropogenic hostilities faced there. By flattening the temporal curve of plantation entry through the day, the probability of occurring in plantations through the day although low, becomes finite and hence, possibility of facing resistance becomes low. Therefore, alongside physiological (like hunger and thirst) and resource-based (like abundance, distribution and nutrition) factors, spatiotemporal pattern of threat from human/dog modulates resource patch usage. Applying the HIREC-MVT construct, we infer that coconuts are highly energetic sources of food and nutrition for the species and are lucrative enough to risk entry into moderately-defended portions of plantations. Selective pressures of this human-macaque interface especially, for an edge population has also prompted the development of surreptitious foraging tactics in both the groups, exemplified by suppression of vocal communication, heightened vigilance, spurts of rapid movements and controlled motor actions to reduce noise.

To summarize, extractive foraging of an embedded and heavily-defended cultivar, like coconut have challenged macaques in many ways. For example, the embedded/encased nature of the fruit permits early juveniles to exploit only tender phenophases of coconuts. Adults face similar hurdles with mature stages of coconuts and hence have a balanced choice of phenophases that optimizes net benefits. Even context-specific choice of phenophases by adults though not explored in this article is suspected, which could further elucidate cognitive proficiencies of adults in determining suitability of coconut. It is remarkable to note that description of the use of a single dietary resource generated the order of consumption precisely as predicted by the theory of life-history strategies. A second class of challenge emanates from coconut foraging from highly defended plantations, which is studied by describing temporal strategies of plantation entry and plantation use. The groups were found to employ deceptive strategies suited to minimize detection by maintaining the probability of entry to plantations at a non-zero level through the day and by adopting covert communications and clandestine movements inside plantations, a subject matter that we will further explore.

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Author contributions: SD and MS designed the study and its methodologies; SD, RCD, AA, SH and RR undertook field data collection; SD organized and assimilated the data; SD performed the analyses; SD prepared the figures; SD drafted the manuscript; MS and SH provided editorial inputs to the manuscript.

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COMMUNICATION

Habitat preference and current distribution of Chinese Pangolin (*Manis pentadactyla* L. 1758) in Dorokha Dungkhag, Samtse, southern Bhutan

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Abstract: The Chinese Pangolin (CP), *Manis pentadactyla* L. is one of the two pangolin species recorded in Bhutan. Not many studies, however, were carried out on the species in Bhutan. The present study was carried out to assess the habitat preference and current distribution of CP, *Manis pentadactyla* in Dorokha Dungkhag, Samtse from January to March 2017. Belt transect method consisting of 100 x 100 m each was used to assess the habitat preference and estimate burrow density, coupled with an extensive search of indirect signs of pangolin presence (burrows, scat, footprint, scales, scratches) was utilized to determine the current distribution of the CP. Modelling of habitat was carried out using QGIS and Maxent. A total of 181 burrows were recorded from 48 plots with burrow density of 0.104 per hectare. These were mostly distributed in the habitat dominated by needlework trees (*Schima wallichii),* evergreen broadleaf (*Castanopsis hytrix*) and shrubs (*Viburnum* species). The preferred habitat of the CP was recorded to range from an altitude of 1,300–1,700 m, with highest feeding activities recorded within the periphery of cardamom plantation and adjacent forested area. A higher burrow density was recorded in humid soils, with high termite presence, and in the vicinity of human settlements. Habitat modelling revealed that 23.57km^2 of the study area was highly suitable and 37.88km^2 was a suitable habitat for the species. Similar studies are suggested to be carried out in other parts of Bhutan in different seasons to better understand the species and its distribution in the country.

Keywords: Burrow, *Manis pentadactyla*, density, distribution, modelling, threatened species

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Author contribution: Dago Dorji and Jambay designed and conducted the study. Data compilation: Dago Dorji and Jambay. Manuscript writing: Dago Dorji and Jambay. Improved manuscript writing and editing: Chong Ju Lian and Tshering Dorji.

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INTRODUCTION

The Chinese Pangolin (CP) *Manis pentadactyla* L. is one of the eight species belonging to the order Pholidota, family Manidae, and genus *Manis* (IUCN Pangolin Specialist Group 2020). The word "Manis" is from 'manes' which is Latin for spirit of the dead (Gotch 1979), while "pangolin" is derived from the Malay phrase 'Pen Gulling' meaning "rolling ball" (Pearsall 2002). In Bhutan the pangolin is known as 'Saghu' (in Dzongkha, the national Language) and 'Salak' (in Lhotshamkha, the southern Bhutan dialect), due to its scaly armored body (Wangchuk 2013).

Pangolins are nocturnal, elusive, non-aggressive, solitary, insectivorous, and are known to utilize burrows (Gaubert 2011). Of the four species found in Asia, the CP is found in eastern Asia, northern southeastern Asia and parts of southern Asia (Katuwal et al. 2015; Wu et al. 2020). It is found in Bhutan, Bangladesh, China, Hong Kong, Taiwan, India, Laos, Myanmar, Nepal, Thailand, and Vietnam (Challender et al. 2019). In neighboring India, the CP is reported to occur in northern Bihar, south of the Nepalese border (Muarya et al. 2018), while in the north-east which borders Bhutan, the species has been recorded in Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Tripura, and Mizoram (Zoological Society of India 2002; Srinivasulu & Srinivasulu 2012). The species occupies a number of different habitats including primary and secondary forest, tropical forests, bamboo forest, grassland and agriculture fields (Katuwal et al. 2015). In Bhutan, the CP is mostly found in southern districts such as Samtse, Samdrup Jongkhar, Sarpang, Pemagatshel, and Chukha (Wangchuk et al. 2004).

In recent decades, there has been a notable decline in the population of CP across its range. Its numbers and population are decreasing, primarily due to hunting, poaching, and habitat destruction (Challender et al. 2019). Unsustainable hunting and poaching for international and local use are currently the main threats to the CP (Wu et al. 2020), as pangolins are poached mainly for their scales that are used in traditional medicine and for their meat (Newton et al. 2008). Due to its rampant population decline, it was listed as Critically Endangered (IUCN 2014) and in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2016).

In Bhutan, habitat destruction and illegal poaching had become rampant issues (Wangchuck 2013) which might lead to localized extinction of the CP. As such, a clear understanding of the species habitat ecology, habitat preferences and local distribution pattern is immensely important for any species-specific conservation plan. Most information on the ecology of the CPs, however, is from Taiwan and southern China studies (Wu et al. 2020) and there is no reliable information on CP in Bhutan, despite their paramount ecological roles (Fairhead et al. 2003; Challender et al. 2014) in the ecosystems. This could have severe implications on the conservation of the Critically Endangered CP. Therefore, the results of this study will contribute to the scientific information about the habitat preferences and also the current distribution of CP in the southwestern part of Bhutan for better conservation measures in the near future.

METHODS

Study area

The study was conducted in Dorokha Dungkhag block (27.07–26.95˚N & 89.09–89.30˚E) which spans an area of 256.4km² under the Samtse District in southwestern Bhutan (Figure 1). The Dungkhag consists of three blocks (geog), namely, Dophuchen, Dumtoed, and Denchukha, with the altitude ranging from 1,000–2,500 m, with daily temperature between 12–15°C in winter to 26–32°C in summer. The climatic condition is hot and wet in summer, and cold and dry in winter with mean annual rainfall ranging from 1,200 to 3,000 mm. The study area is mostly covered by Himalayan subtropical broad-leaf forest and few shrub species. The broadleaved forests are mostly dominated by needlework trees (*Schima wallichii*), evergreen broadleaf (*Castanopsis hytrix), Beischmiedia roxburghian*, and shrubs like *Viburnum* sp., while the agricultural landscape consists of cardamon (*Amomum subulatum)* plantations. For this study, the vegetation was classified as cool broadleaved forest (CBL), which is found on moist exposed slopes, and along the foothills, and warm broadleaved forest (WBL) which is found higher up, extending to 2,000m.

Field data collection

A preliminary survey was carried out to assess the current status of CP in the study area and to identify the potential sites where the CP could occur. The survey was conducted after discussion with the Dorokha Forest Range staff, local community and community forest members from the three geogs to ascertain and validate the presence of CP. Based on the information obtained, an extensive survey of 90 days was carried out from 01 January 2017 to 30 March 2017 in the identified areas to determine the presence/absence of the species and to know the general distribution of the CP in the study area.

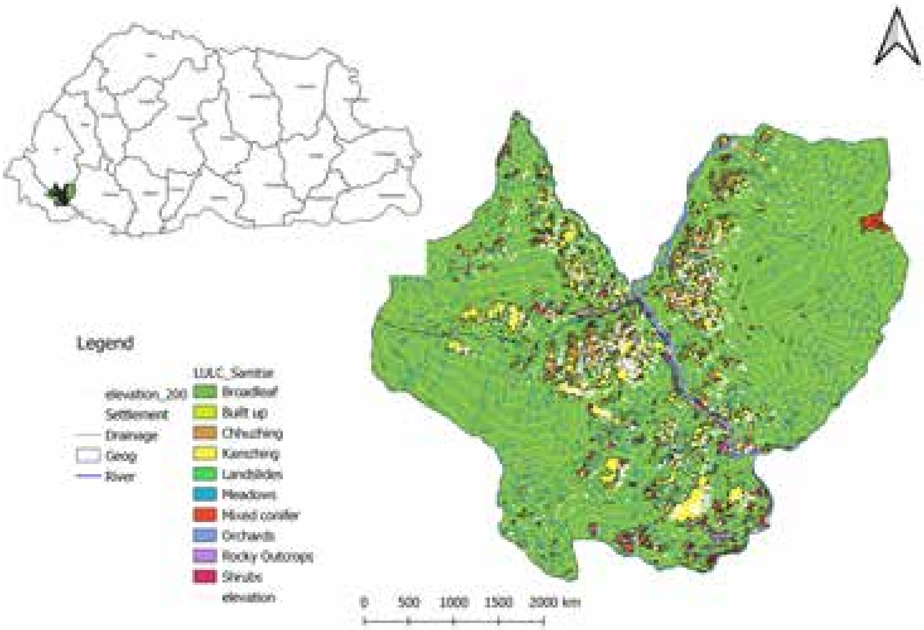

Figure 1. Study area, Dorokha Dungkhag.

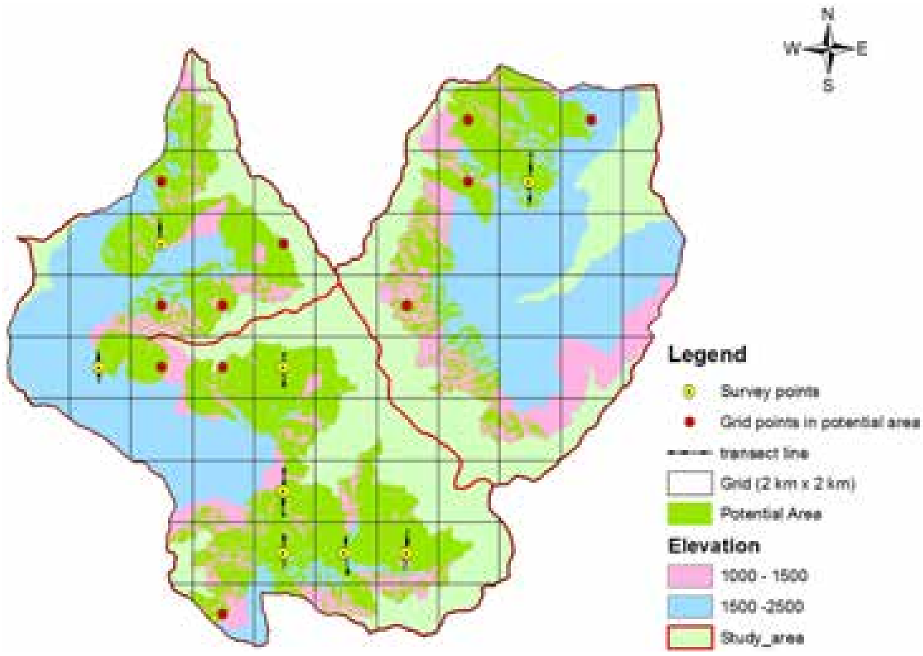

Figure 2. Distribution of transects plots used for the study.

Field sightings and records of indirect signs were used to investigate the current distribution of CP in the study area (Mahmood & Hussain 2014). The whole Dorokha Dungkhag area was searched for direct sighting and indirect signs (burrow, footprint, scales, scat) of CP, and coordinates using the global positioning system (GPS) was recorded wherever the indirect and direct sightings of the species were observed. The QGIS software (version 2.18.20) was then used to generate a map illustrating the current distribution pattern of the CP in Dorokha Dungkhag.

We adopted the belt transect method for investigating CP habitat preference and burrow density (Rogor 1991). This method is usually used for low density, rare and elusive animals. A total of eight transects with a plot of 100m x 100m size was laid out at every 100m with a total of six plots per transect (Figure 2). Habitat parameters such as altitude, ground and canopy cover, dominant species, soil type, nearest distance from water body, road, settlements were recorded (Chalise & Bhandari 2014). Indirect signs like burrows, scats, footprints, scales and scratches in each plot were also recorded to assess the habitat preference and burrow density.

The burrows were classified into two different types, namely living burrows which are much deeper in depth than feeding burrows and feeding burrow (less than 1m depth with presence of ants and termite colonies). A living burrow is categorized as active if any indirect signs of the species such as footprints, scale prints or presence of faecal samples are recorded around that particular burrow (Mahmood et al. 2014). Feeding burrows were further classified into new burrows (recently active) and old burrows (more than one year old) (Chalise & Bhandari 2014). The burrow density was estimated by counting the number of active living burrows in all the plots in a transect according to Irshad et al. (2015).

The habitat preference in different habitat parameters namely canopy and ground cover, elevation, slope, aspect, soil type, distance from water bodies and settlements were assessed using the Statistical Package for Social Science (SPSS) version 23 and Microsoft Excel. A non-parametric Kruskal-wallis test was performed to compare the relationship between the habitat parameters and numbers of CP evidences. Spearman rho correlation was conducted between number of CP burrow with slope, elevation, crown, and ground cover to evaluate their association. The burrow density (D) was estimated at eight selected sampling sites by counting active living burrows following Begon (1979).

We used MaxEnt (version 3.3.3k) for estimating the probability distribution of the CP in the area and for predicting potential suitable habitat for the species (Jennings & Vern 2011; Wilting et al. 2010). Indirect active signs and direct sightings of the CP were used as presence points and we took eight related environmental variables (elevation, aspect, slope, settlement, drainage, landuse, temperature, precipitation) to estimate the probability distribution for its occurrence. Maxent models help to assess the importance of each environmental variable on a species distribution and the mean value generated by the model is used for the whole targeted area (Elith et al. 2011; Phillips et al. 2006).

All the spatial layers were processed using QGIS software (version 2.18.20). We converted all the layers (raster format) into ASCII format with a standard cell size of 30 m based on the resolution of the Digital Elevation Model (DEM) and occurrence record in comma separated value (.csv) format which was then imported to the Maxent software.

Model performance was assessed by using the training and test data for the area under the curve (AUC) of the receiver-operating characteristic (ROC) plot. The data were jackknifed by the inbuilt model's feature for evaluating each environmental variable's influence on the predicted suitable habitat distribution of CP. The percent contribution of each variable was calculated on the basis of how much the variable contributed to an increase in the regularized model gain as averaged over each model run. The habitat suitability for wildlife then was classified based on the logistic threshold value of maximum of test sensitivity and specificity (Jiménez & Lobo 2007) with area above the logistic threshold of maximum test sensitivity and specificity classified as being suitable habitat.

RESULTS AND DISCUSSION

General information on burrow characteristics

A total of 181 burrows and two direct sightings of the CP was reported during the sampling period of three months (Table 1).

Habitat preference of the CP

Among 181 burrows and two direct sightings observed from three different habitat types—agricultural land (AL), WBL, and CBL. The highest number of burrows (n = 87) was observed from AL. One-way ANOVA showed significant difference in the numbers of CP evidence recorded in different habitats (Kruskal-Wallis chi-squared H (3) 6.537, p .038). The presence of more burrows in the AL could be due to the availability of prey (ants and termites inside burrow) which was comparatively higher in AL (cardamom cultivation area) as compared to other habitat types during the field survey. Similarly, Wangchuk (2013) observed more pangolin evidence in cardamom area in Tendruk and Norgaygang block in Samtse.

Generally, pangolins are found in a wide range of habitats including primary and secondary tropical forests, limestone forests, bamboo forests, broadleaf and coniferous forests, grasslands and agricultural fields (Gurung et al. 1996; Azhar et al. 2013; Katuwal et al. 2015). In China, Wu et al. (2003) reported that CP preferred broad-leaved forest dominated by *Schima superba, Machilus chinensis* and undergrowth with good shelter mainly comprised of *Woodwardia japónica, Blechnum orientale, Dicranopteris dichotoma* while in Nepal, pangolins are found in forest patches and agricultural land near human dominated landscapes

Table 1. Number of burrow types and size recorded.

Types of burrow	Burrow condition	No. of burrow recorded	Burrow size	
			Circumference (cm)	Depth (cm)
FD	Old	66	69.3 ± 5.7	62.8 ± 28.4
FD	New	95	69.8 ± 7.1	66.1 ± 30.1
LB	Active	05	73.8 ± 4.6	
LB	inactive	15	69.2 ± 8.7	252.6 ± 23.8

FD—Feeding burrow | LB—Living burrow (The depth of active living burrow was not measured).

(CITES 2016), with mixed forest containing various tree species dominated by *Shorea robusta*, *Schima wallichii*, *Castanopsis indica*, and *Alnus nepalensis* as the main habitat type which recorded majority of the pangolin burrows (74%) (Suwal et al. 2020).

In this study, relationship between canopy cover and burrow counts were analyzed to determine the influence of canopy cover over the number of burrows in an area. Results revealed that in WBL within canopy cover ranging from 26–50 %, burrows were high (n = 50), and only one burrow recorded within the within canopy cover of 51–75 %. While in CBL, 44 burrows were within canopy cover of 26–50%, and only one burrow within canopy cover of 51–75 %. As such, burrows were high (n = 94) within the canopy cover ranging from 26–50 %; and low (n = 2 burrow) within the canopy cover of 51–75 %. A negative correlation between the canopy cover and the number of pangolin burrow was shown, (r (48) = -.310, p = 0.016), indicating that burrows increase when crown cover decreases and vice-versa ($R2$ = 0.33). The reason could be because more tree stumps and some dead trees were found in the open canopy cover that provides a good nesting area for termites during field survey. Similar results were reported by Bhandari & Chalise (2014) which could be due to the presence of their prey i.e. termites in open spaces. A study conducted by Hemachandra et al. (2014) also revealed that termites' occurrence was highest in dry than wet areas.

As for ground cover, the number of burrow count were high (n = 100) within the ground cover of 76–100 % and low (n = 8) within the ground cover 0–25%. Spearman's correlation shows positive relationship of burrow counts to ground cover r (48) = .241, p = .050, indicating that the increase in burrows with increase in ground cover and vice-versa. This suggests that the CP tend to avoid open ground and preferred dense ground cover layer for locomotion and feeding in order to avoid. Wu et al. (2003) also reported that CP used dense ground cover for protection of their burrow entrance while Suwal et al. (2020) inferred that pangolins prefer areas with medium canopy cover (50-75%).

For elevation, evidence of CP was recorded between 1,026–2,100 m. The highest record of CP occurrence in the entire study area was recorded at elevation of 2100m. Within this elevation range, results showed that CP preferred elevation of μ = 1533m and SD = 267m. The number of CP burrow to elevation showed a negative relationship, (r (48) -.585, p 0.001), indicating that the species prefers lower altitude but are mostly in mid elevation during winter. Similar results were also reported in Nepal by Bhandari & Chalise (2014). This could be due to the decrease in the diversity of termites with increase in the elevation as reported by Hemachandra et al. (2014).

Slope utilization by CP were observed between 5–65 % (with μ = 34.56%, SD = 12.87%) slope with preference for gentle slopes. The Spearman's rho correlation showed strong negative association between slope and the number of occurrences of CP burrows (r = -.551, p = 0.001). In WBL, slope range of 25–45 % were the most preferred with 61 burrows recorded. Similarly, with CBL and AL, slope gradient of 25–45 % recorded highest number of burrows (n = 45, n = 27) respectively. In China, Wu et al. (2004) reported that the CP burrows were mostly recorded at slope between 30–60 % while Suwal et al. (2020) reported that pangolins were more observed between 30–50 % slope in Nepal. In the study area, it should be noted that soft clayey loam soil was dominant in the slope gradient from 24–45 % which may facilitate digging of burrows.

Additionally, a higher number of burrows were observed in the northeast aspect (n = 64) followed by northwest (n = 63) while minimum burrows were encountered in southwest (n = 4). There were, however, no burrows encountered in south and west aspect in both the forest types (Figure 3). Kruskal-Wallis test showed that a significant difference between the mean numbers of burrow and the aspect, (H (7) = 15.64, p = .016) with a mean rank score highest in northwest with 30.62

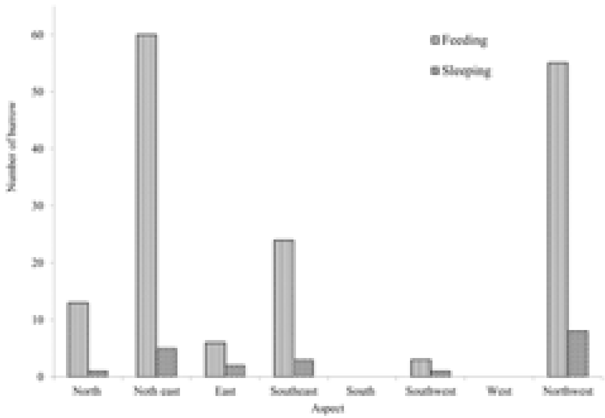

Figure 3. Number of pangolin burrows in different aspect.

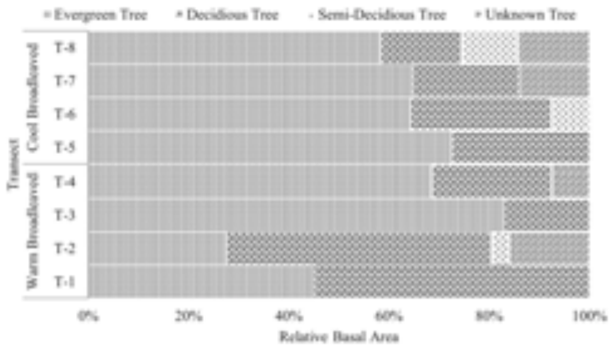

Figure 4. Life form of tree layer.

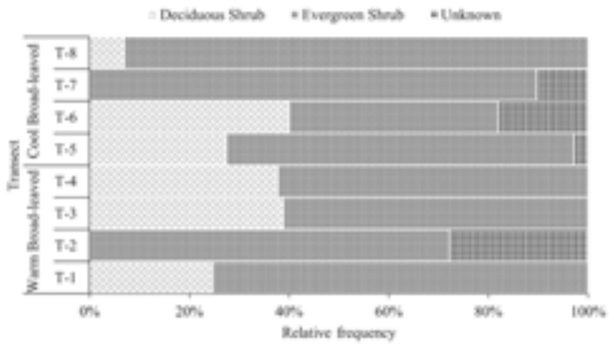

Figure 5. Life forms of shrub layer.

and minimum mean rank score of 6 in the west. Most pangolin burrows encountered in the present study site were from the northeast and northwest. Similarly, this finding is in agreement with Bhandari & Chalise (2014), who reported that pangolin burrows were mostly found in northwest aspect in the Nagarjun Forest, Shivapuri Nagarjun National Park in Nepal. Also, according to Wu et al. (2004), the pangolin burrow entrance often faces the sun, probably to maintain the burrow temperature in winter.

For soil type, the highest number of burrows were in the clay loam soil (*n* = 78), followed by sandy loam (*n* = 53) and the least in the silty loam (*n* = 7). No burrows were recorded in sandy and loamy soils. This could be due to the presence of more termites in clay loam and sandy loam soil in the study area. The clay loam and sandy loam soils form soft layers, which may be generally preferred by the Chinese Pangolin due to the ease of burrowing in the soil as Wu et al. (2004) noted that the species mainly prefer soil that is moist, rich and of a certain soft layer thickness to dig burrows.

As for vegetation, a total of 24 families and 42 tree species were recorded from 48 plots. Trees were classified into three major forms namely evergreen (22 species), deciduous (13 species), semi-deciduous tree (one species) and unidentified (five species). Vegetation in the potential sites of CP consisted of 60%

Table 2. Dominant and co-dominant tree species in the study area.

Species	Relative density	Relative dominance	Relative frequency	IVI
Schima wallichii	26.04	11.03	31.09	68.16
Castanopsis hytrix	17.08	16.14	21.72	54.94
Viburnum sp. (Asaray)	10.42	3.65	14.98	29.05
Beischmiedia roxburghiana	5.63	13.62	7.49	26.73
Nyssa javanica	5.21	12.43	7.49	25.13
Engelhardtia spicata	11.46	6.66	3.00	21.11
Acer thomsonii	6.04	5.21	8.24	19.49
Macaranga denticulata	9.17	7.04	1.50	17.70
Cinnamomum bejolghota	2.92	10.69	0.37	13.99
Euaria aquaminita	3.54	8.87	1.50	13.91
Caeserea glomerita	2.50	4.96	2.62	10.09
Mean	9.09 ± 6.79	9.12 ± 3.80	9.09 ± 9.31	27.3 ± 17.28

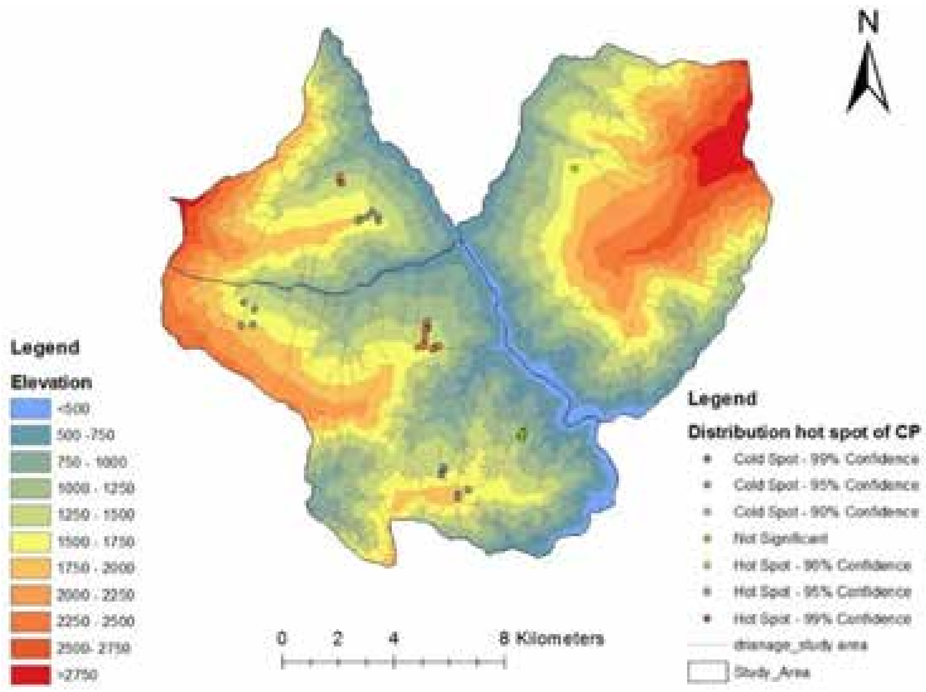

Figure 6. CP occurrences in the study area based on direct and indirect signs.

evergreen, 30.1% deciduous, 1.4% semi-deciduous and 6.4% unidentified tree species (Figure 4). Overall, the most dominant tree species recorded with maximum Importance Value Index (IVI) was *Schima wallichii* (IVI = 68.16) followed by *Castanopsis hytrix* (IVI = 54.94) and *Viburnum* species (IVI = 29.05), while least for *Cinnamomum bejolghota* (IVI= 13.99) (Table 2).

(Note: IVI determined Species dominance encountered in the study area. Higher the IVI, more dominant tree species in the area)

A total of 18 species from 14 families of shrubs were recorded and categorized into three forms namely deciduous shrub (nine species), evergreen (12 species) and unidentified shrubs (six species). Two dominant species (*Maesa chisia* and *Edgeworthia gardneri)* were recorded from WBL and *Daphne bholua* and *Daphne sureli* from CBL. *Maesa chisia* was the common dominant species in both forests. Furthermore, both forests were dominated by evergreen shrub species (Figure 5). Shanon-Wiener diversity index (H') for the CBL, where burrows were recorded showed the highest tree diversity (H'= 2.36) as compared to WBL (H'= 2.14). Similarly, shrub diversity was high (H'= 2.23) in CBL as compared to WBL (H'= 1.80). Species richness (SR = 7) for trees species and (SR = 31) for shrub species were observed comparatively lesser in broad-leaved forest, (SR = 8 for species in and SR = 29 for shrub species) than warm-tree cool broad-leaved forest.

Burrow Density of CP

Eight sampling sites were utilized to estimate burrow density of CP where only active living/sleeping burrows were considered (Begon 1979). Permanent plots in the belt transect were recorded repetitively after 30 days for three months from January 2017 to March 2017. A total area of 48,000 m^2 from a 48 sample plots were surveyed and recorded only five active living burrows. As such, overall burrow density of the study area was found to be 0.104 signs per hectare which is lower than Bhandari & Chalise (2014) with 0.833 signs per hectare in the Nagarjun Forest, Shivapuri Nagarjun National Park in Nepal. This could be as only active living burrows were recorded in this study.

Current distribution of the CP

Extensive search of indirect signs and direct sightings of CP along the eight transects was then used to assess the distribution of the species in the three blocks under Dorokha Sub-District. All blocks recorded the presence of CP. In the Dophuchen block, CP signs were recorded from Dagap, Manidara, Basentey, Satakha, Laptsegaon, Sengdhen, Wangchuk, Jigme, Mithin, and Mithun Top villages, while in the Dumtoed block, the species' signs were sparse, being only in a few localities in Daragaon, Gairegaon, Khalinggaon, and Kuchey villages. The presence of CP, however, were observed only from Relukha village in the Denchukha block.

Among these villages, CP presence was found

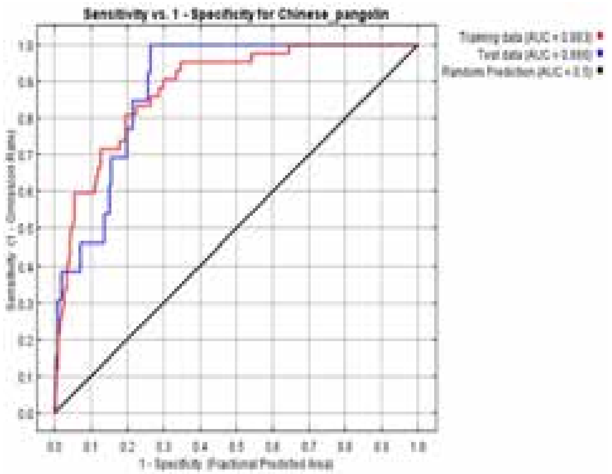

Figure 7. Model analysis of AUC curve of Chinese Pangolin.

Table 3. Percent of contribution by environmental variables to Chinese Pangolin distribution.

Environmental variables	Percent contribution
Elevation	34.3
Settlement	23.4
Aspect	16.5
Drainage	10.1
Land use	5.9
Mean temperature	4.9
Slope	4.3
Mean precipitation	0.6

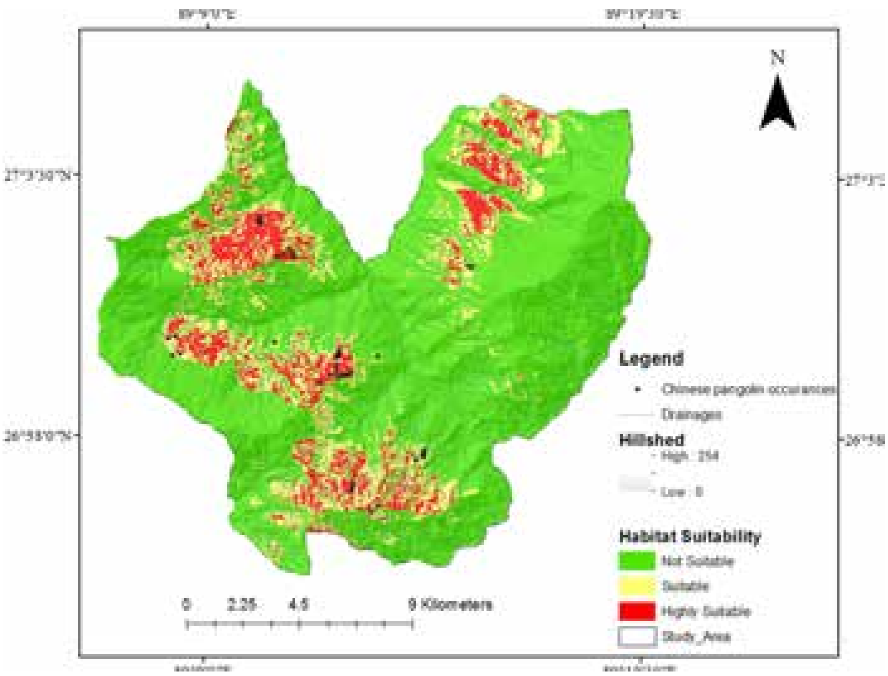

Figure 8. Habitat Suitability map of Chinese Pangolin in the study area.

comparatively more in Dogap, Manidara and Basentry villages under Dophuchen block, Daragaon village under Dumtoed block as indicated by the red dots (Figure 6). This could be due to the existence of more cardamom cultivation and soft soil. The species presence was more moderate in Laptsekha under Dophuchen and Relukha under Denchukha block as indicated by green dots (Figure 6). The presence of CP (indicated by the orange dots) in Sengdhen, Satakha, Mithun under Dophuchen and Gairegaon and Khalingtar villages under Dumtoed block, however, was very low which might be due to the high elevation in these areas.

The Maxent program predicted few patches of the study area as high probability of CP occurrence. The high probability areas are located in close proximity to human settlements and correspond to broad-leaved forest (performed with 0.883 for training data and 0.886 for test data (Figure 7). The Maxent result showed that currently 23.57km^2 of the study area is classified as highly suitable habitats (as indicated by red), 37.88km^2 of the study area as suitable habitat (yellow color) with the remaining study area of 194.98km^2 not suitable habitat for the CP (Figure 8). In this study, modelling was influenced by the variable "elevation" which contribute

Image 1. Chinese Pangolin sighting in the study area.

Image 2. Chinese Pangolin burrow.

Image 3. Pangolin habitat near settlement

Image 4. Overview of habitat of Chinese Pangolin.

Image 5. Chinese Pangolin sighting in agriculture land.

to 34.3% of the model gain followed by "settlement" with 23.4% contribution. This is due to more evidence of the presence of the species to settlements and mid elevation between 1,250–1,500 m. The least contributed variable was "mean precipitation" (0.6%) indicating that mean precipitation is not an important factor for the species distribution. Likewise, the variable "slope" contributed 4.3% (Table 3) as the presence of CP was recorded in almost all the slopes (5–65 %) in the study area although it prefers gentle slope (25–45 %).

CONCLUSION AND RECOMMENDATION

This study provides more in-depth information on the CP distribution and habitat preference in a mountainous country like Bhutan and should serve as a baseline for future monitoring. The information obtained from the research will also prove to be significant to the Chinese Pangolin conservation in Bhutan, such as habitat recovery and management, population management, population assessment and others. Although, CP population is declining globally, Bhutan holds potential as a conservation stronghold for pangolins due to its strict conservation laws namely Forest and Nature Conservation Rules 2017 and management practices.

CP was encountered in very low density in the study area and distributed in few villages of Dorokha Dungkhag with burrow density of 0.104/ha. Burrow distribution was highly influenced by the elevation, aspect and soil type while the highest elevation record of CP occurrence in the current study area was 2100 m. We also observed CP presence near human settlements, in Agriculture land and adjacent forest. Results of this study shows that 56.95% of the potential area of CP in the study areas is close to human settlement (Agricultural land), as CP prefer to choose termites nest for its greater biomass that is mostly found in Cardamom cultivation area especially in winter. As a result, population of the species may be decreasing as they make easy targets for hunters. As such, detailed studies need to be conducted to envisage its ecological or social implications with an in-depth study focusing on distribution of pangolins in Bhutan to ensure that appropriate conservation measures are in place. At the same time, relevant authorities such as the Samtse Forest Division could implement programs targeted to the farmers residing in the potential habitat of CP on the legislation protecting pangolins, their ecological roles and benefits of CP conservation in order to change the attitude of local people towards pangolins.

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COMMUNICATION

A checklist of mammals with historical records from Darjeeling-Sikkim Himalaya landscape, India

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Abstract: A region-specific species checklist is an important resource for biodiversity documentation and conservation. This review provides an updated mammal species checklist for the biodiversity hotspots of the Darjeeling-Sikkim landscape in Eastern Himalaya. The list was compiled by systematically reviewing 94 available publications spanning 178 years from 1841 to 2019, for mammals from the region. The species checklist is envisioned to aid in understanding the current status of mammal records, historical distribution, ranked conservation status of mammals, and research gaps. A total of 173 mammal species under 11 orders and 33 families, including the recently upgraded taxon, Sikkim Pika *Ochotona sikimaria* was enlisted. There are 25 species included in the IUCN threatened categories, 58 species listed in the CITES Appendices, and 112 species included in the schedules of the Wildlife (Protection) Act, 1972 in India. Although mammals receive the maximum research attention in the landscape, small mammals and bats have rarely been subjected to systematic studies in recent years.

Keywords: Biodiversity hotspot, Eastern Himalaya, research trends, updated checklist

Nepali सार: क्षेत्र विशेषको हिसाबले प्रजातिको सूची जैववविधिताको संरक्षण र दस्तावेजीकरणका लागि महत्त्वपूर्ण संसाधन हुन्छ। यस समीक्षामा पूर्वी हिमालय अन्तर्गत दार्जीलिङ-सिक्किमि परक्षित्रको जैववविधिता केन्द्रमा पाइने स्तनधारी प्राणीहरूको ताजा सूची उपलब्ध गराइएको छ। यो सूची, यस भेकमा पाइने स्तनधारी प्राणीहरूका लागि सन् 1841 देखि 2019 सम्म 178 वर्षको अवधिमा प्रकाशति 94 वटा लेख अनि प्रकाशनको योजनाबद्ध तरिकाले समीक्षापछि तयार पारिएको हो। यो सूची, ती स्तनधारी प्राणीहरूको वर्तमान स्थिति, पूर्वमा यसका थात-थलो अर्थात् ती प्राणीहरू पाइने इलाका, ती स्तनधारीहरूको संरक्षण स्थिति तथा शोधकार्यको सन्दर्भमा देखिएका अन्तर वा कमीबारे बुझ्नका लागि तयार पारिएको हो। हालै मात्र सूचीबद्ध गरिएको लँडि मुसा (Sikkim Pika *Ochotona sikimaria*) सहित 11 प्रजाति तथा 33 परिवार अन्तर्गत कूल 173 वटा स्तनधारी प्राणी सूचीबद्ध गरिएका छन्। यसमा आइयुसीएनको सङ्कटग्रस्त सूचीमा सामेल 25 वटा प्रजाति, सीआइटीईएसको परशिष्टिमा सूचीबद्ध 58 वटा प्रजाति तथा भारतीय वन्यप्राणी (संरक्षण) ऐन, 1972 को अनुसूचीमा सामेल 112 वटा प्रजातिका स्तनधारी प्राणी छन्। कुनै परक्षित्रमा स्तनधारी प्राणीमाथि धेरै शोध कार्य गर्ने गरिए तापनि, हालका वर्षहरूमा स-साना स्तनधारी प्राणी लगायत चमेराहरूमाथि धेरै कम प्रणालीबद्ध अध्ययन गरिएका छन्।

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Author contribution: SP conceptualized, collected data, analyzed and prepared manuscript. TN collected data, analyzed and prepared manuscript.

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INTRODUCTION

A region-specific species checklist that summarises and documents the current status is an important resource for biodiversity documentation and conservation (Nameer et al. 2015). Mammals form a significant taxon, often considered for monitoring because of their vulnerability to hunting and sensitivity to human activity (Robinson & Bodmer 1999). In a review of biodiversity research trends in Eastern Himalaya, Kandel et al. (2016) showed that mammals were the most studied taxa in the region. Mammals have been documented in Darjeeling-Sikkim Himalaya in the form of anecdotal accounts, collection records, compiled reports, laboratory-based studies on pathogens found in wild animals, field surveys, and ecological works (Blyth 1841, 1863; Hodgson 1847; Anderson 1881; Blanford 1888; Sclater 1891; Dalgilesh 1906; Shebbeare 1914; Thomas 1915, 1916a,b, 1920; Elwes 1916; Millard et al. 1916a, 1916b; Primrose 1916; Wroughton 1916a,b,c, 1917; Hinton 1918; Fry 1923; Baldry 1932; Sanborn 1932; Wood 1933; Matthews 1934; Pinckney 1939; Gabb 1945; Maclaren 1949; Dutt-Mazumdar 1955; Saha 1955; Ellerman 1961; Hill 1963, 1986; Ellerman & Morrison-Scott 1966; Gurung & Agarwal 1969; Chatterjee et al. 1970, 2018; Khajuria & Ghose 1970; Topál 1970; Pal & Dasgupta 1982, 1984; Bandyopadhyay & Dasgupta 1984a,b; Dey et al. 1984; Ghose 1984; Das 1986, 2003; Hill et al. 1986; Dasgupta 1987, 1991; Agrawal et al. 1992; Saha et al. 1992; Pradhan 1995; Banerjee et al. 1996; Ganguli-Lachungpa 1997; Avasthe & Jha 1999; Biswas et al. 1999; Agrawal 2000; Molur et al. 2002, 2003, 2005; Sharma & Lachungpa 2002; Chakraborty 2003; Brandon-Jones 2004; Vijayan et al. 2004; Ghosh 2005, 2008; Chattopadhyay et al. 2006; Sanyal et al. 2007; Lachungpa 2009; Groves & Grubb 2011; Sathyakumar et al. 2011a,b; Ghose et al. 2012; Mallick 2012, 2019; Ghose et al. 2014; Khatiwara & Srivastava 2014; Sharma et al. 2015; Dahal et al. 2017; Saikia et al. 2017; Saikia 2018). The advancements in technology and its applications for wildlife research has enabled photographic records and molecular identification of new species for taxonomic revision while also providing insights into mammal behavioral ecology (Sathyakumar 2001; Chanchani et al. 2010;Bashir et al. 2011; Rawat & Tambe 2011;Ghose et al. 2012, 2014;Dahal et al. 2017; Srivastava & Kumar 2018).

Many attempts in the past to compile mammal records in Darjeeling-Sikkim Himalaya have been carried out. One-hundred-and-fifty-six mammals were recorded in Sikkim by Avasthe & Jha (1999), 169 by Vijayan et al. (2004), 91 by Chattopadhya et al. (2006), and 125 by Chakraborty (2011). Similarly, from Darjeeling, Agrawal et al. (1992) listed 128 mammals, Pradhan & Bhujel (2000) recorded 128 mammals, Mitra (2004) documented 180 mammals, and Sanyal et al. (2007) recorded 126 mammals. All these compilations do not take into account the recent changes in taxonomy, such as Sikkim Pika *Ochotona sikimaria* from Sikkim (Dahal et al. 2017), which was recently upgraded from subspecies to species. The latest species enumeration in Sikkim enlists 125 mammal species (Chakraborty 2011), 126 in Darjeeling, including Kalimpong (Sanyal et al. 2007) and a separate list for Kalimpong stands at 99 species (Mallick 2012).

This necessitated a methodological literature review of mammal species recorded so far to compile a species list of mammals recorded in the landscape. The reviewed species list is envisioned as a precursor to initiate systematic documentation of mammals in the Darjeeling-Sikkim Himalaya landscape. The reviewed species list aims to aid in understanding the current status of mammal records, their distribution and ranked conservation status, and patterns emerging from these records, along with other knowledge gaps in the region. The compiled species list would also be a reference for systematic field surveys to establish new detection localities, distribution range, and catalogue any new species records. The completeness of any inventory from such field surveys could also be compared against this generated species list.

MATERIALS AND METHODS

The study area comprising of Darjeeling, including the newly formed district Kalimpong, (26.45°–27.22° N & 87.98°–88.88°E) in West Bengal and the Himalayan state of Sikkim (27.05°–28.12° N & 88.05°–88.95° E) forms a part of the Eastern Himalaya, India (Figure 1). Hereafter, Darjeeling would imply both the districts of Kalimpong and Darjeeling.

Darjeeling and Sikkim are rich repositories of valuable biodiversity, which always have interested naturalists and natural scientists from as early as the 19th century, as a result of which there is a body of literature which records mammals and other taxa from the region.

A thorough literature survey, both offline and open-access online, of published articles (67), books (17), book section (4), report (4), thesis (1), and news article (1), which include archived literature from various issues of very old journals available at the libraries of Darjeeling

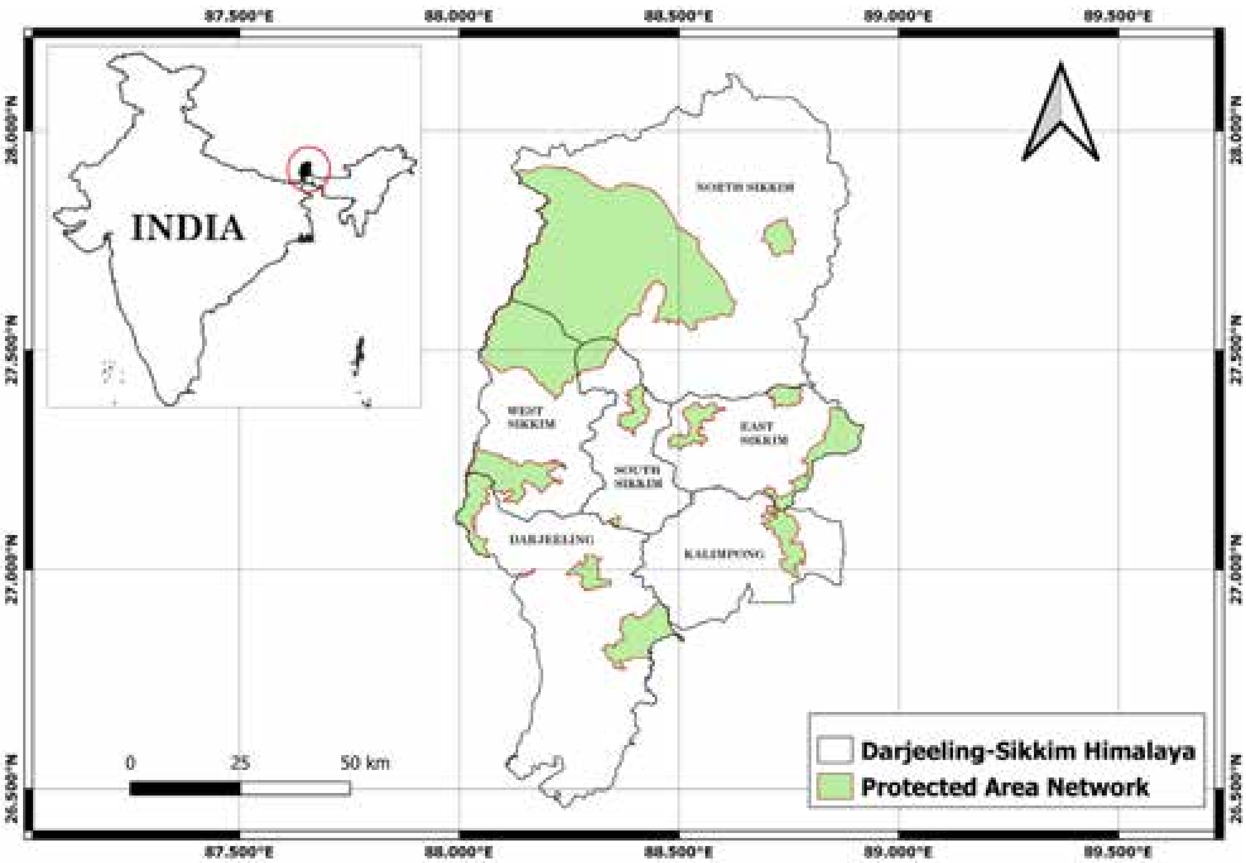

Figure 1. Darjeeling-Sikkim Himalaya Landscape.

Natural History Museum and Darjeeling Government College, articles from the Journal of the Bombay Natural History Society and Journal of the Asiatic Society of Bengal available in the Biodiversity Heritage Library was done and then used to prepare a checklist of mammals recorded so far from Darjeeling-Sikkim Himalaya.

To update this checklist, necessary corrections from previous publications were made, which include synonyms reported as two different species, subspecies elevated to species, revised nomenclature, and inclusion of new species recorded and not recorded previously. Exclusion of historical species records from singular grey literature not supported by IUCN Red List distribution range and inclusion of species, whose distribution was found to not overlap with IUCN distribution range but supported by peer-reviewed literature were also included. The nomenclature and taxonomic arrangement of the species of the mammals in the checklist are based on the checklist of mammals of southern Asia by Nameer (2015) and cross-checked with the IUCN Red List of Threatened Species for updated nomenclature (IUCN 2020). The present status of each species was also determined at the landscape level based on records updated until 2019, and categorized as Extinct (based on subsequent studies revealing species absence in previously recorded sites or no reports for more than 20 years), Present (species reported within the last 20 years), and Uncertain (reported more than 20 years ago and needs further exploration to confirm species presence). The spellings of location names are kept,as-is from the cited literature.

RESULTS

A total of 94 relevant pieces of literature from available sources for mammalian diversity in Sikkim-Darjeeling Himalayan landscape were reviewed. The majority of literature available pertains to cataloguing, species records, new sightings, and reports accounting for 54 sources. Some studies, however, relate to taxonomy (15), ecology (12), pathology (6), genetics &evolution (2), ethno-zoology (2), and conservation (3). This review covered a span of 178 years dating from 1841 to 2019 and revealed a historical record of 173 species representing 11 orders and 33 families in this landscape

(Appendix 1). A total of 153 and 145 mammalian species were listed from Sikkim and Darjeeling, respectively. Of the 173 species with historical records in Darjeeling-Sikkim Himalaya landscape, 168 species are currently present; one species—Pygmy Hog *Porcula salvania*,is locally extirpated, and four species—Indian Gerbil *Tatera indica*, Little Indian Field Mouse *Mus booduga*, Hispid Hare *Caprolagus hispidus*, and Black-striped Weasel *Mustela strigidorsa*, need further exploration to confirm their presence.

The available literature, when grouped as <1900 and a decade each after, showed that the number of publications peaked at two points, first during 1911–1920 (n=13) followed by a general decline until1980. After that, the trend showed a rise in publications from 1981 onwards (Figure 2). The other peak was during 2010–2019 (n=19), however, it is expected that the number of publications is likely to increase by the end of the decade. A closer look at recent studies from 2000–2019, 44 literature in total, showed that the maximum number of studies pertain to medium and large-sized mammals (56.8%) followed by mammals in general (18.2%), bats (13.6%) and small mammals (11.34%). Only one empirical study based on fieldwork for small mammals, 11 for medium and large-sized mammals, four for mammals in general were carried out. However, no study on bats was conducted during during this period.

Of 173 species, 17 species are endemic to southern Asia (Nameer 2015), namely Tarai Gray Langur *Semnopithecus hector*; Royle's Mountain Vole *Alticola roylei*; Bhutan Giant Flying Squirrel *Petaurista nobilis*; Lesser Bandicoot Rat *Bandicota bengalensis*; Little Indian Field Mouse *Mus booduga*; Himalayan White-bellied Rat *Niviventer niviventer*; Hispid Hare *Caprolagus hispidus*; Indian Hare *Lepus nigricollis*; Indian Leaf-nosed Bat *Hipposideros lankadiva*; Sombre Bat *Eptesicus tatei*; Indian Pangolin *Manis crassicaudata*; Bengal Fox *Vulpes bengalensis*; Sloth Bear *Melursus ursinus*; Pygmy Hog *Porcula salvania*; Chital *Axis axis*; Himalayan Musk Deer *Moschus leucogaster,* and the recently elevated species Sikkim Pika *Ochotona sikimaria*, a species endemic to eastern Himalaya (Dahal et al. 2017; Dahal et al. 2020).

Order Chiroptera represents the maximum number of species (n=54 species) followed by order Carnivora (n=40) and order Rodentia (n=37) (Figure 3). Family Vespertilionidae of order Chiroptera has the maximum number of representations, with 30 species. Besides this, there are six other families (Pteropodidae, Rhinolophidae, Hipposideridae, Megadermatidae, Emballonuridae, and Molossidae) of the same order amounting to a total of 56 species (Figure 4). The least

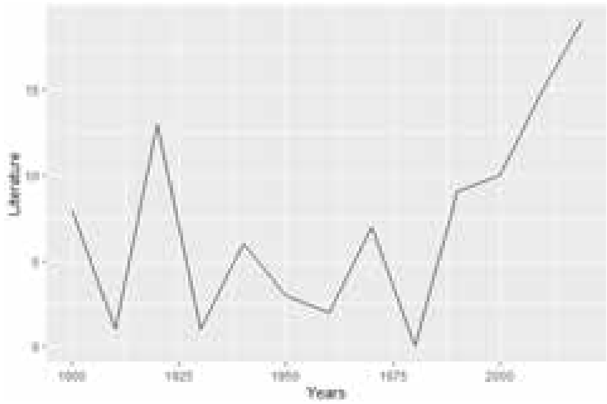

Figure 2. Trend of publication on mammals from 1841–2019 in Darjeeling-Sikkim Himalaya.

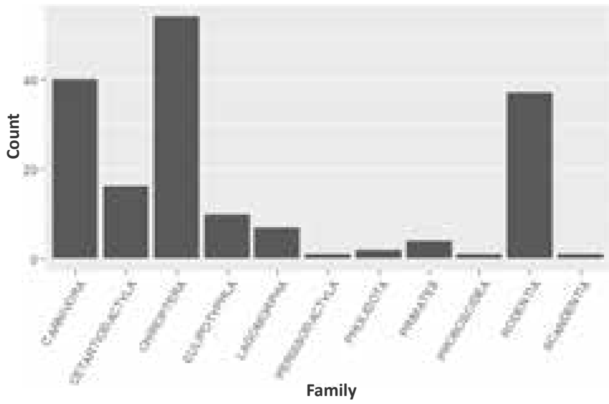

Figure 3. Order-wise representation of mammal diversity in Darjeeling-Sikkim Himalaya.

represented families are Elephantidae, Tuapaiidae, Spalacidae, Hystricidae, Talpidae, Megadermatidae, Molossidae, Prionodontidae, Ailuridae, and Equidae, represented by one species each (Figure 4) (Appendix 1).

According to the IUCN Red List, of the 173 species of mammal recorded from Darjeeling-Sikkim Himalayan landscape, 25 species belong to threatened category (2 Critically Endangered(1.2%), 10 Endangered (5.8%), and 13 Vulnerable(7.5%)); 14 species (8.1%) are Near Threatened; 129 species (74.6%) are Least Concern; four species (2.3%) are Data Deficient; and one species (0.6%) not assessed (Appendix 1). The total number of species falling under various appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) accounts for more than one-fourth (n=54 species) of the total species found in Darjeeling-Sikkim Himalaya, of which 24 species are listed under Appendix I, 15 underAppendix II, and 19 underAppendix III. Almost two-thirds of the total species recorded

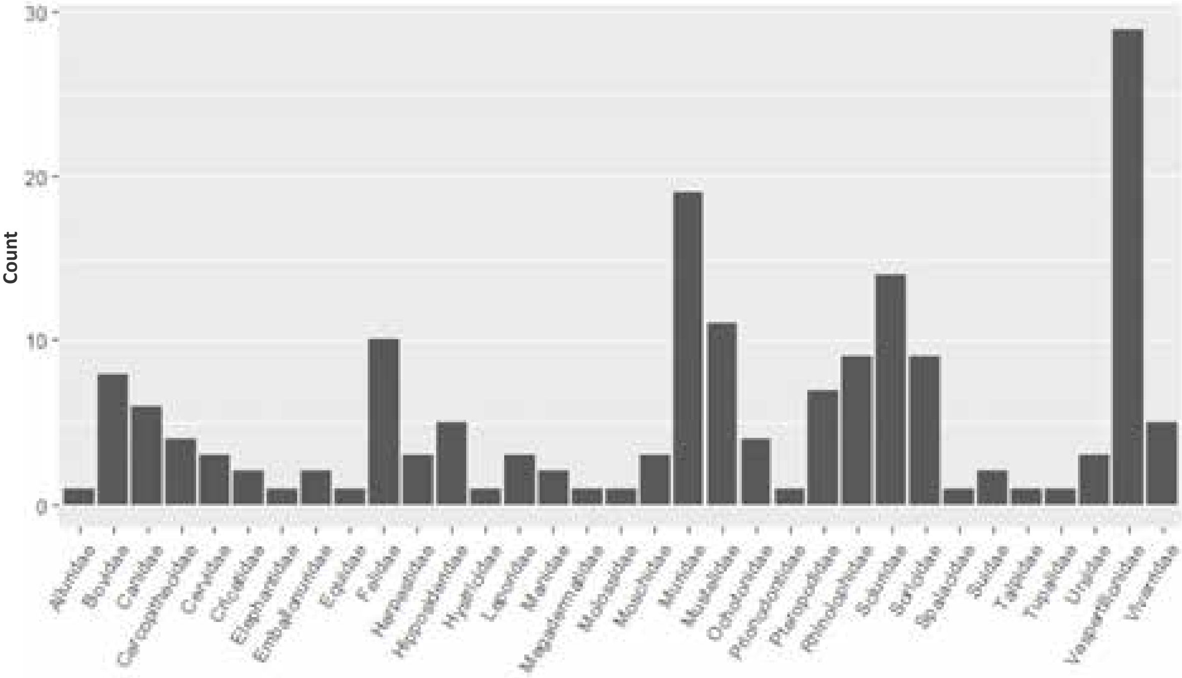

Figure 4. Family-wise representation of mammal diversity in Darjeeling-Sikkim Himalaya.

are protected under the schedules of the Wildlife (Protection) Act, 1972 (WPA, 1972) in India, of which 36 species are listed in Schedule I, 38 in Schedule II, five in Schedule III, four in Schedule IV, and 29 in Schedule V (Appendix 1).

DISCUSSION

The review of biodiversity research trends (Kandel et al. 2016) showed that mammal studies contributed to 45% of total faunal studies in Eastern Himalaya comprising Nepal, Bhutan, and India (Darjeeling-Sikkim). The bulk of mammal documentation in Darjeeling-Sikkim Himalaya was done half a century ago which is likely to have changed in their distribution records and status due to various factors, including the rapidly changing land-use patterns, urbanization, climate change, and other anthropogenic pressures such as hydroelectric projects and road construction (Banerjee et al. 2019)

The resultant checklist from this review is inconsistent with the mammal list of India (Sharma et al. 2014), where the maximum representation is of the orders Chiroptera and Rodentia. This observation could be due to the lack of research in some of the mammal orders like Rodentia in Darjeeling-Sikkim Himalaya. The number of mammal species in Darjeeling and Sikkim also differed, with Sikkim having more number of records than Darjeeling, perhaps due to the considerable altitudinal variation in Sikkim.

This checklist provides for necessary corrections from previous literature, such as the Tarai Gray Langur *Semnopithecus entellus* ssp. *hector,*which is now considered a separate species *Semnopithecus hector,* Greater Hairy-winged Bat *Harpiocephalus mordax* now synonymized with Lesser Hairy-winged Bat *Harpiocephalus harpia* (Matveev 2005) and Rufous Horseshoe Bat *Rhinolophus rouxii* is now synonymized with Chinese Rufous Horseshoe Bat *Rhinolophus sinicus*. New scientific nomenclatures were also incorporated; replacing the old nomenclature such as Cadorna's Pipistrelle *Pipistrellus cadorna* is now *Hypsugo cadornae*(Bates et al. 2019). The present species list also includes a recently upgraded taxon Sikkim Pika *Ochotona sikimaria* (Dahal et al. 2017).

The previous records confirming the presence of Rohu's Bat *Philetor brachypterus* in Sikkim (Molur et al. 2002; Srinivasulu & Srinivasulu 2012) were that of misidentified Joffre's Pipistrelle *Hypsugo joffrei* (Saikia et al. 2017). Previous records of Forrest's Pika *Ochotona forresti* in Sikkim were also merged with records of Large-eared Pika *Ochotona macrotis* in light of the new taxonomic assessment of specimens of Forrest's Pika from Eastern Himalaya (Lissovsky et al. 2017) which considers it as a new subspecies of Large-eared Pika in Eastern Himalaya based on phylogenetic analysis and morphometric measurements. Forrest's Pika was not recorded in subsequent studies as well (Dahal et al. 2020). Therefore, Rohu's Bat and Forrest's Pika are not included in this checklist.

Historical species records based on singular grey literature (Avasthe & Jha 1999) excluded from the species list in Sikkim were Indian Bush Rat *Golunda ellioti*, Hispid Hare *Caprolagus hispidus*, Edward's Rat*Leopoldamys edwardsi*, Hardwicke's Woolly Bat *Kerivoula hardwickii*, Bengal Fox *Vulpes bengalensis*, Smooth-coated Otter *Lutrogale perspicillata*, and Tibetan Antelope/Chiru *Pantholops hodgsonii*. The Bengal Fox although likely present (Gompper & Vanak 2006), is not included in Sikkim species list due to the absence of supporting primary evidence, its distribution range not overlapping as per the extant (resident) shown in the IUCN geographic distribution range and subsequent literature (Menon 2014). The Tibetan Antelope/Chiru was confirmed to be locally extirpatedin Sikkim by Chanchani et al. (2010) as they had assumed the species' presence in the region based on Hooker's account. Joseph Dalton Hooker, however, had not reported the species' sighting in Sikkim and had stated that he "found the horns of this animal on the southern side of Donkia Pass, but (I) never saw a live one except in Tibet" (Hooker 1854, p 157). Hence, there is neither concrete and definitive historical evidence, nor subsequent accounts of this species that suggests its presence in Sikkim (Dawson 1934). Therefore it has been excluded from the species checklist.

Similarly, Tibetan Shrew *Sorex thibetanus* Kastschenko, 1905, and Southeastern Asian Shrew *Crocidura fuliginosa* (Blyth, 1856) were also not included. These species, however, had been mentioned in a non-peer-reviewed report from an ecological study in Teesta Basin (Vijayan et al. 2004). Besides, these species were also not reported in subsequent literature (Molur et al. 2005; Srinivasulu & Srinivasulu 2012), and the IUCN geographic distribution range does not overlap with the study area.

A few species records from singular grey literature from Sikkim (Avasthe & Jha 1999) but whose geographical distribution range are found to overlap with the IUCN distribution range were considered as being present. These include the Northern Tailless Fruit Bat *Megaerops niphanae*, Blyth's Horseshoe Bat *Rhinolophus lepidus*, Trefoil Horseshoe Bat *Rhinolophus trifoliatus*, Greater False Vampire Bat *Megaderma lyra*, European Free-tailed Bat *Tadarida teniotis*, Serotine *Eptesicus serotinus*, Rufous Tube-nosed Bat *Murina leucogaster*, and Crab-eating Mongoose *Herpestes urva*.

Another notable inclusion is the Pygmy Hog *Porcula salvania.* The Pygmy Hog is still included in the checklist, although the current geographic distribution range does not overlap due to empirical research (Hodgson 1847; Sclater 1891) confirming historical presence. Although the Blue Sheep or Bharal *Pseudois nayaur* recorded in Phalut 1955 (Dutt-Mazumdar 1955) is now considered locally extinct in Darjeeling (Mallick 2019), it also is included due to its presence within the landscape.

CONCLUSION

The present review of literature, updated till 2019, for records of mammal species in Darjeeling-Sikkim landscape compiles an updated mammal list which generates an overview of mammals in different taxonomic orders, families, and genera which allows an analysis on areas requiring focus on survey, monitoring, and research in the region.

Small mammals:Three orders of mammalian taxa, namely Rodentia, Scandentia, and Eulipotyphla form the small mammals. Globally, these three orders comprised of more than 2,800 species, of which 437 (15%) of them are considered to be threatened with extinction by the IUCN (IUCN SMSG 2018). The small mammals, however, are also inadequately studied, with many hundreds of species never being photographed in the wild and even their basic ecology unknown (Gomez et al. 2017). Moreover, they also serve as model organisms for a better understanding of ecosystem and landscape processes due to their short life cycles and smaller areas of land use (Barrett & Peles 1999). Pradhan et al. (2018) reported large- and medium-sized mammals from the agroecosystems of Darjeeling but not the small mammals. The recent species inventory of mammals in protected areas (PAs) of Sikkim also does not include small mammals (Lepcha et al. 2017). The fact that small mammals have less representation in recent research studies as compared to large- and medium-sized mammals calls for a priority survey and focus on small mammals in Darjeeling-Sikkim Himalaya.

Bats (Order Chiroptera)

Order Chiroptera has a large number of species in the Darjeeling-Sikkim landscape, but there are minimal systematic surveys and monitoring of bats in the context of changes in land use and agroecosystems.

The most recent study on bats in the region was in 2012 in Kalimpong (Mallick 2012). The species list for bats requires an update for other parts of Darjeeling and Sikkim, and their status needs to be understood for further long term research on bat ecology and monitoring in the region.

Areas outside of protected areas

There is growing recognition of agroecosystems as repositories of significant biodiversity (Altieri 1999; Bali et al. 2007; Bhagwat et al. 2008; Perfecto & Vandermeer 2008; Chazdon et al. 2009; Chettri et al. 2018), which requires serious conservation attention (Perfecto et al. 2005). For instance, there is no record of threatened species such as the Critically Endangered Chinese Pangolin in the recent study by the Forest Department, Sikkim in the protected areas (Lepcha et al. 2017) although there were records of its presence in Sikkim (Avasthe & Jha 1999; Sathyakumar et al. 2011b; The Statesman 2019).

Besides the above three major concerns, the findings from this review also give rise to questions as to what is the current distribution and status of the four Data Deficient species—Hairy-footed Flying Squirrel *Belomys pearsonii,* Millard's Rat *Dacnomys millardi*, Sombre Bat *Eptesicus tatei*, and Joffre's Pipistrelle *Hypsugo joffrei*—one not assessedspecies Sikkim Pika*Ochotona sikimaria,* and 17 endemic mammals in the region. It is also important to know the present status and understand the ecology of mammals in the agroecological matrix, a prerequisite for their conservation and co-existence with humans in the socioecological landscapes. Future research should be directed to address these gaps in the mammal survey and ecological studies in the region.

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Appendix 1. Mammals of Darjeeling-Sikkim Himalaya with their conservation status, present status, and previous records in the landscape.

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
I. ORDER PROBOSCIDEA Illiger, 1811			
1) Family Elephantidae Gray, 1821 (elephants)			
1. *Elephas maximus* Linnaeus, 1758 Asian Elephant	EN, I, (I), Present	Eastern Sikkim, 3657.6m (Elwes 1916), Pangolakha Wildlife Sanctuary (Avasthe & Jha 1999)	Common in Terai and sighting at 1524m (Dalgilesh 1906), Rechila (Shebbeare 1914; Elwes 1916), Rishi La (Dutt-Mazumdar 1955), Neora Valley National Park (Ghose 1984), Sakkam, Gorubathan, Taghera, Tashiding and Mongpong (Mallick 2012)
II. ORDER SCANDENTIA Wagner, 1855			
2) Family Tupaiidae Gray, 1825 (treeshrews)			
2. *Tupaia belangeri* (Wagner, 1841) Northern Treeshrew	LC, II, (II), Present	Rongli (Wroughton 1916a), Gangtok (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Gangtok, Teesta Valley, Tumin (Molur et al. 2005),Sikkim (Chattopadhyay et al. 2006)	Darjeeling (Dalgilesh 1906), Ghoom, Narbong, Sivok (Wroughton 1916a), Nimbong (Wroughton 1917), Mongpu hills (Fry 1923), Mongpoo and Sangsir (Sanborn 1932), Nimbong and Sivok (Agrawal et al. 1992), Kalimpong (Mallick 2012)
III. ORDER PRIMATES Linnaeus, 1758			
SUBORDER: HAPLORRHINI Pocock, 1918			
3) Family Cercopithecidae Gray, 1821 (Old World monkeys)			
Subfamily Cercopithecinae Gray, 1821 (macaques)			
3. *Macaca assamensis* (M'Clelland, 1840) Assam Macaque	NT, II, (II), Present	Chuntang, Dikchu (Wroughton 1916a), Lingtam (Sanborn 1932), Sikkim, between 762–1828.8 m (Maclaren 1949), Khangchendzonga National Park (Avasthe & Jha 1999), Rongli, Chuntang, Melli and Rongli (Molur et al. 2003), Teesta Valley (Vijayan et al. 2004), Geyzing and Singtam (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Fambhonglho Wildlife Sanctuary, Kitam Bird Sanctuary, Khangchendzonga Biosphere Reserve, Maenam Wildlife Sanctuary (Lepcha et al. 2017)	Pashok, Sukhiapokhri, Batasia (Wroughton 1916a), Pashok (Wroughton 1916b), Sangsir and Tarkhola (Sanborn 1932), Tarkhola and Takdah (Khajuria & Ghose 1970), Neora Valley National Park (Ghose 1984), Pashok, Sukhiapokhri, Takdah and Tarkhola (Agrawal et al. 1992), Batasia, Bijanbari, Chitrey, Ghoom, Gopaldhara, Kalijhora, Lepchajagat, Mahanadi, Mirik, Mongpong, Pagaljhora, Pashok, Rumbi, Sevok, Sukhiapokhri, Tarjomjhara, Teesta Bazar, Tindharia, Zero Point (Molur et al. 2003) Neora Valley National Park, Suntalekhola, Lava, Zero Point and Tarkhola (Mallick 2012)
4. *Macaca mulatta* (Zimmermann, 1780) Rhesus Macaque	LC, II, (II), Present	Sikkim, upto 2400m (Avasthe & Jha 1999), Sikkim (Srinivasulu & Srinivasulu 2012)	Darjeeling District (Dalgilesh 1906), Narbong (Wroughton 1916a), Pashok (Wroughton 1916b), Sivok and Mungpoo (Sanborn 1932), Darjeeling, Sepoydhara and Sukhna (Agrawal et al. 1992), Bengdubi, Lava, Mahakal Temple (Molur et al. 2003), Samsing in Neora Valley National Park, Neora river, Ashalary Khola, Sakam Khola, Dhoula Khola and Lava (Mallick 2012)
Subfamily Colobinae Jerdon, 1867 (langurs and leaf-monkeys)			
5. *Semnopithecus hector* (Pocock, 1928) Tarai Gray Langur	NT, II, (II), Present	Khangchendzonga National Park (Avasthe & Jha 1999)	Sevok (Wroughton 1916a; Brandon-jones 2004), Lava (Mallick 2012), Sivok, Pankhabari, Naxalbari (Molur et al. 2003)
6. *Semnopithecus schistaceus* Hodgson, 1840 Nepal Gray Langur	LC, I, (II), Present	Chuntang, Lachen, Sedonchen (Wroughton 1916a), Lingtam, Lachung and Lachen (Sanborn 1932), Khangchendzonga National Park (Avasthe & Jha 1999), Chuntang, Lachen, Lachung, Lingtam, Sedonchen (Molur et al. 2003), Teesta Valley (Vijayan et al. 2004), Yumthang (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Khangchendzonga Biosphere Reserve (Lepcha et al. 2017)	
IV. ORDER RODENTIA Bowdich, 1821			
SUBORDER SCIUROMORPHA Brandt, 1855			
4) Family Sciuridae Hemprich, 1820 (squirrels)			
Subfamily Ratufinae Moore, 1959			
7. *Ratufa bicolor* (Sparrman, 1778) Black Giant Squirrel	NT, II, (II), Present	Rongli and Dikchu (Wroughton 1916a), Ravangla, Damthang and Maenam Wildlife Sanctuary in South; Khangchendzonga National Park and Barsey Rhododendron Sanctuary in West, Tong RF, Chungthang, Dzongu and Shepgyur in North; Fambong Lho, Lagyap RF, Bhusuk, Barapthing RF, Premlakha and Regu in East District (Avasthe & Jha 1999), Temi (Chattopadhyay et al. 2006)	Darjeeling (Dalgilesh 1906), Narbong and Sivok (Wroughton 1916a), Pashok (Wroughton 1916a), Sangser (Wroughton 1917), Sivok, Sangsir and Tarkhola (Sanborn 1932), Tarkhola and Takdah (Khajuria & Ghose 1970), Pashok, Sukhiapokhri, Jaributi, Neora Valley National Park (Ghose 1984; Biswas et al. 1999), Narbong, Rungbee, Sangser, Sivok and Tarkhola (Agrawal et al. 1992), Darjeeling, Mahananda Wildlife Sanctuary and Pashok (Molur et al. 2005), Samsing, Rangpo, Mouchowki, Lava and Jaributi valley (Mallick 2012)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
Subfamily Sciurinae Fischer, 1817			
Tribe Pteromyini Brandt, 1855			
8. *Belomys pearsonii* (Gray, 1842) Hairy-footed Flying Squirrel	DD, (II), Present	East Sikkim (Sclater 1891; Avasthe & Jha 1999; Chattopadhyay et al. 2006), Sombaria (Molur et al. 2005)	Darjeeling, 1828.8 m (Dalgilesh 1906; Molur et al. 2005), Mungpoo (Sanborn 1932), Neora Valley National Park (Ghose 1984)
9. *Eupetaurus cinereus* Thomas, 1888 Woolly Flying Squirrel	EN, (II), Present	Pangdin, Kangarten, Rangit Valley and Bakkhim (Avasthe & Jha 1999), Sikkim (Molur et al. 2005; Chattopadhyay et al. 2006)	
10. *Hylopetes alboniger* (Hodgson, 1836) Particoloured Flying Squirrel	LC, (II), Present	Chuntang and Singhik (Wroughton 1916a), Bakkhim (Avasthe & Jha 1999), Sikkim (Molur et al. 2005; Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	Pashok (Wroughton 1916a; Molur et al. 2005), Pashok and Ambootia (Wroughton 1916b), Rhenok, Neora Valley National Park (Ghose 1984; Biswas et al. 1999), Kurseong, Pashok and Selimbong (Agrawal et al. 1992)
11. *Petaurista elegans* (Müller, 1840) Spotted Giant Flying Squirrel	LC, (II), Present	Sikkim (Avasthe & Jha 1999), Yumthang (Molur et al. 2005), Yumthang and Bakhim (Chattopadhyay et al. 2006)	Manebhanjan (Pal & Dasgupta 1984),Ghoombhanjan, Phalut and Tonglu (Agrawal et al. 1992), Ghoom, Selimbong, Tongsong (Molur et al. 2005)
12. *Petaurista magnificus* (Hodgson, 1836) Hodgson's Giant Flying Squirrel	LC, (II), Present	Sikkim (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Chuntang, Damthang (Molur et al. 2005), Geyzing (Chattopadhyay et al. 2006)	Darjeeling (Dalgilesh 1906; Gurung & Agarwal 1969; Chatterjee et al. 1970; Bandyopadhyay & Dasgupta 1984b; Dey et al. 1984; Banerjee et al. 1996), Ghoombhanjan (Agrawal et al. 1992), Darjeeling and Ghoom (Molur et al. 2005)
13. *Petaurista nobilis* (Gray, 1842) Bhutan Giant Flying Squirrel	NT, (II), Present	Sedonchen (Wroughton 1916a), Zeluk (Sanborn 1932), Sikkim (Avasthe & Jha 1999), Sedonchen, Tumin (Molur et al. 2005), Singhik, Tumin, Rabangla, Ralang, Damthang (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Lepcha et al. 2017)	Batasia and Darjeeling (Wroughton 1916a), Neora Valley National Park (Ghose 1984), Ghoombhanjan and Selimbong (Agrawal et al. 1992), Darjeeling, Ghoom, Manebhanjan, Palmajua, Selimbong (Molur et al. 2005)
14. *Petaurista petaurista* (Pallas, 1766) Red Giant Flying Squirrel	LC, (II), Present	Fambhonglho Wildlife Sanctuary, Khangchendzonga Biosphere Reserve (Lepcha et al. 2017)	Neora Valley National Park (Mallick 2012)
Subfamily Callosciurinae Pocock, 1923			
15. *Callosciurus erythraeus* (Pallas, 1779) Pallas's Squirrel	LC, (II), Present	Sikkim (Thomas 1916a), Sedonchen (Wroughton 1916a; Molur et al. 2005; Chattopadhyay et al. 2006), Lingtam (Sanborn 1932)	
16. *Callosciurus pygerythrus* (I. Geoffroy Saint Hilaire, 1833) Hoary-bellied Squirrel	LC, (II), Present	Sedonchen (Thomas 1916a), Rongli, Gangtok and Dikchu (Wroughton 1916a), Lingtam, Dikchu and Toong (Sanborn 1932), Sikkim, 762–1524 m (Maclaren 1949; Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Chuntang, Gangtok and Lachen (Molur et al. 2005), Tumin, Singtam and Ranipool (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary, Fambhonglho Wildlife Sanctuary, Khangchendzonga Biosphere Reserve (Lepcha et al. 2017)	Pashok, Kurseong, Narbong and Sivok (Wroughton 1916a), Gopaldhara, Pashok and Tong Song (Wroughton 1916b), Nimbong and Sangser (Wroughton 1917), Gopaldhara and Mungpo hills (Fry 1923), Sivok, Sangsir and Mungpoo (Sanborn 1932), Takdah (Khajuria & Ghose 1970), Neora Valley National Park (Ghose 1984; Biswas et al. 1999), Gopaldhara, Mungpo, Narbong, Pashok, Samsing, Sangser, Sivok, Tarkhola and Tindharia (Agrawal et al. 1992; Molur et al. 2005), Rashet and Lava (Mallick 2012)
17. *Dremomys lokriah* (Hodgson, 1836) Orange-bellied Himalayan Squirrel	LC, (II), Present	Sedonchen (Thomas 1916a), Karponang, Sedonchen, Chungtang and Gangtok (Wroughton 1916a), Chungthang, Jeluk, Lachen and Lachung (Sanborn 1932), Sikkim between 1500–2700m, Bakkhim (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Ringin, Sedonchen, Gangtok (Molur et al. 2005), Rabangla and Bakhim (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary, Fambhonglho Wildlife Sanctuary, Khangchendzonga Biosphere Reserve, Maenam Wildlife Sanctuary (Lepcha et al. 2017)	Darjeeling, 1524 m (Dalgilesh 1906), Pashok (Wroughton 1916b), Palmajua (Khajuria & Ghose 1970), Lava, Damdama danda, Thosum and Rechila, Neora Valley National Park (Ghose 1984; Biswas et al. 1999; Mallick 2012), Palmajua and Selimbong (Agrawal et al. 1992), Sukhiapokhri (Molur et al. 2005)
18. *Funambulus pennantii* (Wroughton, 1905) Five-striped Palm Squirrel	LC, (IV), Present	Sikkim (Avasthe & Jha 1999), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	Sivok (Sanborn 1932)
19. *Tamiops macclellandii* (Horsfield, 1840) Himalayan Striped Squirrel	LC, (II) , Present	Sedonchen, Penlong, Gangtok, Chungtang and Ringin (Wroughton 1916a), Lingtam and Chungthang (Sanborn 1932), Sikkim (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Ringin, Sedonchen, Chuntang, Gangtok, Sombaria (Molur et al. 2005)	Darjeeling, 1524m (Dalgilesh 1906), Batasia (Wroughton 1916a), Gopaldhara (Wroughton 1916b), Palmajua (Khajuria & Ghose 1970), Gopaldhara, Palmajua and Selimbong (Agrawal et al. 1992), Lava (Mallick 2012)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
Subfamily Xerinae Osborn, 1910			
Tribe Marmotini Pocock, 1923			
20. *Marmota himalayana* (Hodgson, 1841) Himalayan Marmot	LC, III, (II), Present	Kapup and above Thangu (Wroughton 1916a), Thangu, Gyangong and Ghora la (Sanborn 1932), Cho Lhamu, Lhonak valley, Green Lake, Lasher, Yumesamdong, Kyongnosla Alpine Sanctuary (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Geygong, Yumthang (Molur et al. 2005), Geygong, Lhasar and Thangu (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	
SUBORDER MYOMORPHA Brandt, 1855			
5) Family Spalacidae Gray, 1821			
Subfamily Rhizomyinae Winge, 1887 (bamboo rats)			
21. *Cannomys badius* (Hodgson, 1841) Lesser Bamboo Rat	LC, (V), Present	Sikkim (Sterndale 1884; Avasthe & Jha 1999)	Narbong (Wroughton 1916a, 1916b), Darjeeling (Molur et al. 2005)
6) Family Cricetidae Fischer, 1817			
Subfamily Arvicolinae Gray, 1821 (voles)			
22. *Alticola roylei* Gray, 1842 Royle's Mountain Vole	NT, (V), Present	Changu, Kapup, Gantong, Lachen, Thangu (Wroughton 1916a), Sikkim above 3000m (Avasthe & Jha 1999)	
23. *Neodon sikimensis* (Horsfield, 1841) Sikkim Vole	LC, (V), Present	Lachen and Thangu (Sanborn 1932), Sikkim (Khajuria & Ghose 1970), Sikkim (Avasthe & Jha 1999), Yumthang, Kapup, Lachen, Thangu (Molur et al. 2005), Yumthang, Thangu and Lachen (Chattopadhyay et al. 2006)	Sandakphu (Khajuria & Ghose 1970; Agrawal et al. 1992), Lava and Rechila, Neora Valley National Park (Ghose 1984; Biswas et al. 1999; Mallick 2012)
7) Family Muridae Illiger, 1811			
Subfamily Gerbillinae Gray, 1825 (gerbils, jirds)			
24. *Tatera indica* (Hardwicke, 1807) Indian Gerbil	LC, (V), Uncertain		Darjeeling, among tea at 1524m (Dalgilesh 1906)
Subfamily Murinae Illiger, 1811 (rats and mice)			
25. *Bandicota bengalensis* (Gray, 1835) Lesser Bandicoot Rat	LC, (V), Present	In agricultural lands in Sikkim (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), all over India (Srinivasulu & Srinivasulu 2012)	Pashok, Ghoom, and Narbong (Wroughton 1916a), Pashok (Wroughton 1916b), Kalimpong and Nimbong (Wroughton 1917), Gopaldhara (Fry 1923), Mungpoo (Sanborn 1932), Tarkhola (Khajuria & Ghose 1970), Kalimpong, Nimbong and Pashok (Agrawal et al. 1992), Kalimpong (Mallick 2012)
26. *Bandicota indica* (Bechstein, 1800) Greater Bandicoot Rat	LC, (V), Present	Sikkim (Agrawal et al. 1992; Chattopadhyay et al. 2006), Near Human settlements in Sikkim (Avasthe & Jha 1999)	
27. *Dacnomys millardi* Thomas, 1916 Millard's Rat	DD, (V), Present	Sikkim (Thomas 1916a; Avasthe & Jha 1999)	Gopaldhara and Pashok (Thomas 1916a; Wroughton 1916b), Mungpoo (Sanborn 1932)
28. *Golunda ellioti* Gray, 1837 Indian Bush Rat	LC, (V), Present		Kurseong (Agrawal et al. 1992; Mallick 2019)
29. *Leopoldamys edwardsi* (Thomas, 1882) Edward's Rat	LC, (V), Present		Pashok (Thomas 1916a; Wroughton 1916b), Darjeeling (Agrawal 2000; Molur et al. 2005)
30. *Mus booduga* (Gray, 1837) Little Indian Field Mouse	LC, (V), Uncertain		Gopaldhara (Fry 1923)
31. *Mus cervicolor* Hodgson, 1845 Fawn-colored Mouse	LC, (V), Present	Teesta Valley (Vijayan et al. 2004) Sikkim (Srinivasulu & Srinivasulu 2012)	
32. *Mus musculus* (Linnaeus, 1758) House Mouse	LC, (V), Present	Sedonchen, Rongli, Gangtok, Lachen, Chuntang, Ringin, and Dikchu (Wroughton 1916a), Chungtang (Sanborn 1932), Sikkim (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Tadong and Yuksom (Chattopadhyay et al. 2006)	Darjeeling (Dalgilesh 1906), Ghoom, Darjeeling, Narbong, Sivok, Sukhiapokhri and Batasia (Wroughton 1916a), Gopaldhara, Songma, Pashok, Tong Song (Wroughton 1916b), Gopaldhara and Mongpu hills (Fry 1923), Kalimpong, Nimbong and Pedong (Wroughton 1917), Tarkhola, Takdah and Sandakphu (Khajuria & Ghose 1970), Batasia, Ghoom, Gopaldhara, Kalimpong, Narbong, Tongsong, Pashok, Pedong, Sandakphu, Sukhiapokhri, Takdah and Tarkhola (Agrawal et al. 1992), Neora Valley National Park (Mallick 2012)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
33. *Mus pahari* Thomas, 1916 Gairdner's Shrewmouse	LC, (V), Present	Sikkim (Thomas 1916a), Chuntang (Wroughton 1916a; Ellerman 1961; Chattopadhyay et al. 2006), Lingtam (Sanborn 1932), in the forest of Sikkim below 1650m (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004)	Tonglu, Singalila National Park (Thomas 1916a), Batasia (Thomas 1916a; Wroughton 1916a), Pashok (Wroughton 1916b), Pedong and Sangser (Wroughton 1917), Takdah and Batasia (Khajuria & Ghose 1970), Thosum and Rechila (Ghose 1984; Biswas et al. 1999; Mallick 2012), Pashok and Takdah (Agrawal et al. 1992)
34. *Niviventer eha* (Wroughton, 1916) Smoke-bellied Rat	LC, (V)	Lachen (Thomas 1916a; Sanborn 1932; Khajuria & Ghose 1970), Lachen and Thangu (Wroughton 1916a), Sikkim in Rhododendron forest (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Lachen, Thangu, Yumthang (Molur et al. 2005), Yumthang and Thangu (Chattopadhyay et al. 2006)	Ghoom and Sukhiapokhri (Wroughton 1916a), Palmajua and Sandakphu (Khajuria & Ghose 1970; Agrawal et al. 1992; Molur et al. 2005), Neora Valley National Park (Ghose 1984)
35. *Niviventer fulvescens* (Gray, 1847) Chestnut White-bellied Rat	LC, (V), Present	Chuntang and Lachen (Wroughton 1916a), Lingtam and Chungthang (Sanborn 1932), Lower Eastern Himalayas (Avasthe & Jha 1999), Rabangla, Chuntang, Lachen (Molur et al. 2005), Rabangla (Chattopadhyay et al. 2006)	Ghoom, Sukhiapokhri, Batasia and Narbong (Wroughton 1916a), Gopaldhara, Songma and Pashok (Wroughton 1916b), Nimbong and Pedong (Wroughton 1917), Mongpu hills (Fry 1923), Mungpoo (Sanborn 1932), Palmajua and Takdah (Khajuria & Ghose 1970), Neora Valley National Park (Ghose 1984), Batasia, Nimbong, Palmajua, Pashok, Pedong, Selimbong and Takdah (Agrawal et al. 1992)
36. *Niviventer niviventer* (Hodgson, 1836) Himalayan White-bellied Rat	LC, (V), Present	Chuntang (Thomas 1916a), Chuntang and Lachen (Wroughton 1916a), Lower Himalayas (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Bakhim, Chuntang, Lachen (Molur et al. 2005), Bakhim (Chattopadhyay et al. 2006)	Palmajua and Sandakphu (Khajuria & Ghose 1970; Agrawal et al. 1992), Neora Valley National Park (Ghose 1984), Ghoombhanjan and Selimbong (Agrawal et al. 1992)
37. *Rattus andamanensis* (Blyth, 1860) Indochinese Forest Rat	LC, (V), Present	Pashok, Singhik, Ringin and Rongli (Hinton 1918), Chakung, Rongli and Singhik (Ellerman 1961; Agrawal 2000; Molur et al. 2005), Teesta Valley (Vijayan et al. 2004), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	Gopaldhara (Hinton 1918), Kalimpong, Gopaldhara, Darjeeling, and Pashok (Ellerman 1961; Agrawal 2000; Molur et al. 2005)
38. *Rattus nitidus* (Hodgson, 1845) Himalayan Field Rat	LC, (V), Present	Gangtok, Gnatong, Rongli, Chunthang and Dikchu (Wroughton 1916a), Gnatong and Lingtam (Sanborn 1932), Eastern Himalayas (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Gangtok (Molur et al. 2005)	Ghoom, Sukhiapokhri, Pashok and Batasia (Wroughton 1916a), Gopaldhara, Tong Song and Pashok (Wroughton 1916b), Kalimpong, Nimbong, Pedong and Sangser (Wroughton 1917), Gopaldhara and Mongpu hills (Fry 1923), Mongpoo (Sanborn 1932), Takdah and Sandakphu (Khajuria & Ghose 1970) Neora Valley National Park (Ghose 1984), Batasia, Ghoombhanjan, Gopaldhara, Mongpu, Nimbong, Palmajua, Pashok, Pedong, Sangser, Sukhiapokhri and Takdah (Agrawal et al. 1992), Darjeeling, Pashok and Ghoom (Molur et al. 2005)
39. *Rattus pyctoris* (Hodgson, 1845) Himalayan Rat	LC, (V), Present	Chuntang (Wroughton 1916a; Agrawal et al. 1992), Eastern Himalayas (Avasthe & Jha 1999), Lachen and Chuntang (Molur et al. 2005; Chattopadhyay et al. 2006)	Ghoom and Batasia (Wroughton 1916a), Ghoom (Agrawal et al. 1992; Molur et al. 2005)
40. *Rattus rattus* (Linnaeus, 1758) House Rat	LC, (V), Present	Sedonchen, Rongli, Singhik, Gangtok, Dikchu and Ringin (Wroughton 1916a), Lingtam (Sanborn 1932), Eastern Himalayas (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Tumin (Chattopadhyay et al. 2006)	Darjeeling (Dalgilesh 1906), Pashok, Batasia and Narbong (Wroughton 1916a), Gopaldhara, Songma and Pashok (Wroughton 1916b), Kalimpong, Nimbong, Pedong and Sangser (Wroughton 1917), Mungpoo and Tarkhola (Sanborn 1932), Tarkhola, Palmajua and Takdah (Khajuria & Ghose 1970)
41. *Rattus tanezumi* Temminck, 1844 Oriental House Rat	LC, (V), Present	Lingtam (Sanborn 1932), Rabangla and Yuksom (Chattopadhyay et al. 2006)	Sivok, Sangsir and Mungpoo (Sanborn 1932), Gopaldhara and Mungpo hills (Fry 1923), Gopaldhara, Narbong, Kalimpong, Nimbong, Palmajua, Pashok, Pedong, Sangser, Takdah and Tarkhola (Agrawal et al. 1992)
42. *Vandeleuria oleracea* (Bennett, 1832) Asiatic Long-tailed Climbing Mouse	LC, (V), Present	Common in Lower Himalayas (Avasthe & Jha 1999), Sikkim (Srinivasulu & Srinivasulu 2012)	Pashok (Wroughton 1916b, 1916a; Agrawal et al. 1992), Kalimpong (Wroughton 1917)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
SUBORDER HYSTRICOMORPHA Brandt, 1855			
8) Family Hystricidae G.Fisher, 1817 (Old World porcupines)			
43. *Hystrix brachyura* Linnaeus, 1758 Malayan Porcupine	LC, (II), Present	Foothills (Wroughton 1916a), Sikkim, below 1000m (Avasthe & Jha 1999; Molur et al. 2005; Chattopadhyay et al. 2006), Teesta Valley (Vijayan et al. 2004), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a) Barsey Rhododendron Sanctuary, Fambhonglho Wildlife Sanctuary, Kitam Bird Sanctuary, Khangchendzonga Biosphere Reserve (Lepcha et al. 2017)	Mungpoo (Sanborn 1932), Alubari, Neora Valley National Park (Biswas et al. 1999; Mallick 2012), Darjeeling (Molur et al. 2005)
V. ORDER LAGOMORPHA Brandt, 1855			
9) Family Ochotonidae Thomas, 1897 (pikas)			
44. *Ochotona curzoniae* (Hodgson, 1858) Plateau Pika	LC, Present	Kamparab to Kala (Maclaren 1949), Sikkim (Molur et al. 2005; Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Tso Lhamo plateau (Rawat &Tambe 2011)	
45. *Ochotona macrotis* (Günther, 1875) Large-eared Pika	LC, Present	Teesta Valley (Vijayan et al. 2004), Sikkim (Molur et al. 2005), Lhasar and Thangu (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	
46. *Ochotona roylei* (Ogilby, 1839) Royle's Pika	LC, (IV), Present	Gnatong and Lachen (Wroughton 1916a), Cho Lhamu, Lhonak Valley, Kishongla, Jelep la, Lampokhari, Botang La, Thanggu, Samthong and Dzongri (Avasthe & Jha 1999), East Sikkim (Molur et al. 2005), Gomchen and Thangsing (Chattopadhyay et al. 2006)	
47. *Ochotona sikimaria* Thomas, 1922 Sikkim Pika	NE, Present	Gnatong, Lachen, Thangu (Sanborn 1932), Sikkim-Tibet, Between 2438.4–3657.6 m (Maclaren 1949), Lachen (Khajuria & Ghose 1970), North Sikkim (Avasthe & Jha 1999), Lachung (Molur et al. 2005), Lachen, Lachung, Yumthang, Thang, Dzongri, Menam, Kyongnosla and Tsomgo (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), 2600–4754m (Dahal et al. 2017)	Sandakphu (Khajuria & Ghose 1970; Agrawal et al. 1992), Darjeeling (Molur et al. 2005), Kalimpong, Nimbong, Pedong and Sangser (Wroughton 1917)
10) Family Leporidae Fischer, 1817 (hares and rabbits)			
48. *Caprolagus hispidus* (Pearson, 1839) Hispid Hare	EN, I, (I), Uncertain		Kalimpong and Darjeeling (Wroughton 1916a)
49. *Lepus nigricollis* F. Cuvier, 1823 Indian Hare	LC, (IV), Present	Sikkim, upto 2700m (Avasthe & Jha 1999), Dikling, East Sikkim (Chattopadhyay et al. 2006)	Kurseong (Dalgilesh 1906), Gopaldhara (Wroughton 1916b), Mungpo Hills (Fry 1923), Munsong,Kalimpong (Sanborn 1932), Darjeeling and Tonglu (Agrawal et al. 1992), Samsing, Tarkhola, Neora Valley National Park (Mallick 2012)
50. *Lepus oiostolus* Hodgson, 1840 Wolly Hare	LC, Present	Kongra Lama Pass,above Thangu (Wroughton 1916a), Tangla to Kala, Tang pun sum plain and west of Dochen (Maclaren 1949), Gyagong (Sanborn 1932), Sikkim plateau, usually above 3300m (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Rabangla, South Sikkim and Kongra Lama Pass (Chattopadhyay et al. 2006), Tso Lhamo plateau (Rawat &Tambe 2011)	
VI. ORDER EULIPOTYPHLA Waddell et al., 1999			
11) Family Soricidae Fischer, 1817 (shrews, moles, and hedgehogs)			
Subfamily Crocidurinae Milne-Edwards, 1872			
51. *Crocidura attenuata* Milne-Edwards, 1872 Grey Shrew	LC, Present	Sikkim (Anderson 1877; Ellerman & Morrison-Scott 1966), Sikkim, sub-tropical and temperate regions (Avasthe & Jha 1999)	Narbong (Wroughton 1916a), Takdah (Khajuria & Ghose 1970), Gopaldhara, Mungpo, Pashok and Takdah (Agrawal et al. 1992), Darjeeling and Pashok (Molur et al. 2005)
52. *Suncus etruscus* (Savi, 1822) Pygmy White-toothed Shrew	LC, Present	Lingtam (Sanborn 1932), Sikkim, sub-tropical and temperate regions (Avasthe & Jha 1999)	Mungpu and Darjeeling (Anderson 1881; Agrawal et al. 1992), Narbong (Wroughton 1916a), Pashok (Wroughton 1916b)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
53. *Suncus murinus* Linnaeus, 1766 House Shrew	LC, Present	Gnatong, Rongli, Dikchu (Wroughton 1916a), Lingtam and Rongli (Sanborn 1932), Teesta Valley (Vijayan et al. 2004), Sikkim, tropical, sub-tropical and temperate regions (Avasthe & Jha 1999), Rongli (Chattopadhyay et al. 2006)	Darjeeling (Dalgilesh 1906; Bandyopadhyay and Dasgupta, 1984a), Darjeeling, Ghoom, Narbong, Sivok, Siliguri (Wroughton 1916a), Gopaldhara and Pashok (Wroughton 1916b), Kalimpong, Nimbong, Pedong and Sangser (Wroughton 1917), Mungpoo and Sangsir (Sanborn 1932), Tarkhola (Khajuria & Ghose 1970), Neora Valley National Park (Ghose 1984), Shrubbery Park, Darjeeling (Dasgupta, 1987), Ghoom, Kalimpong, Kurseong, Manibhanjan, Pedong, Rangiroom, Sivok, Ghoombhanjan, Tonglu and Tarkhola (Agrawal et al. 1992)
Tribe: Nectogalini Anderson, 1879			
54. *Chimarrogale himalayica* (Gray, 1842) Himalayan Water Shrew	LC, Present	Rongli (Wroughton 1916a; Molur et al. 2005; Chattopadhyay et al. 2006), Sikkim (Avasthe & Jha 1999)	Darjeeling, near mountain streams 1524m (Dalgilesh 1906), Pashok (Agrawal et al. 1992), Gopaldhara (Molur et al. 2005)
55. *Episoriculus caudatus* (Horsfield, 1851) Hodgson's Brown-toothed Shrew	LC, Present	Sedonchen, Chuntang, Lachen (Wroughton 1916a), Lingtam (Sanborn 1932), Sikkim, sub-tropical and temperate regions (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Chungthang and Lachen (Molur et al. 2005), Lachen and Chunthang (Chattopadhyay et al. 2006)	Ghoom (Wroughton 1916a), Gopaldhara, Songma, and Pashok (Wroughton 1916b), Sangser (Wroughton 1917), Sandakphu (Khajuria & Ghose 1970), Mungpo and Sandakphu (Agrawal et al. 1992), Ghoombangjan (Molur et al. 2005)
56. *Episoriculus leucops* (Horsfield, 1855) Long-tailed Brown-toothed Shrew	LC, Present	Lachen (Molur et al. 2005)	Darjeeling (Agrawal et al. 1992)
57. *Episoriculus macrurus* (Blanford 1888) Long-tailed Mountain Shrew	LC, Present	Chuntang and Lachen (Wroughton 1916a; Chattopadhyay et al. 2006)	Darjeeling (Molur et al. 2005)
58. *Nectogale elegans* Milne-Edwards, 1870 Elegant Water Shrew	LC, Present	Gangtok (Millard et al. 1916b), Chuntang (Wroughton 1916a), Chungthang, Lachung and Lachen (Sanborn 1932), Sikkim (Avasthe & Jha 1999), Yumthang (Molur et al. 2005), Lachung, Chunthang, Yumthang (Chattopadhyay et al. 2006)	Tong Song and Pashok (Wroughton 1916b)
59. *Soriculus nigrescens* (Gray, 1842) Himalayan Shrew	LC, Present	Sedonchen, Gangtok, Chuntang, Lachen (Wroughton 1916a), Lingtam (Sanborn 1932), Sikkim (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), FLachen (Molur et al. 2005), Gnatong, Chunthang, Sedonchen, Lachen (Chattopadhyay et al. 2006)	Darjeeling, 1524m (Dalgilesh 1906), Ghoom, Sukhiapokhri (Wroughton 1916a), Gopaldhara and Pashok (Wroughton 1916b), Palmajua (Khajuria & Ghose 1970), Jaributi, Neora Valley National Park (Ghose 1984; Biswas et al. 1999; Mallick 2012), Ghoom, Gopaldhara and Palmajua (Agrawal et al. 1992)
12) Family Talpidae Fischer, 1817 (desmans, shrew moles and moles)			
Subfamily Talpinae G. Fischer, 1814 (moles)			
Tribe: Talpini G. Fischer, 1814			
60. *Euroscaptor micrura* (Hodgson, 1841) Himalayan Mole	LC, Present	Dikchu (Wroughton 1916a), Zeluk (Sanborn 1932), Sikkim, between 1500–2400m (Avasthe & Jha 1999; Chattopadhyay et al. 2006)	Kurseong and Darjeeling (Dalgilesh 1906), Gopaldhara, Tong Song, Pashok and Songma (Wroughton 1916b), Darjeeling, Batasia, Sivok (Wroughton 1916a), Gopaldhara (Fry 1923), Mungpoo and Tarkhola (Sanborn 1932), Neora Valley National Park (Ghose 1984; Mallick 2012), Gopaldhara, Pashok and Selimbong (Agrawal et al. 1992); Batasia and Gopaldhara (Molur et al. 2005)
VII. ORDER CHIROPTERA Blumenbach, 1779			
13) Family Pteropodidae Gray, 1821 (Old World fruit bats)			
61. *Cynopterus sphinx* (Vahl, 1797) Greater Short-nosed Fruit Bat	LC, (V), Present	Sikkim, upto 2000m (Avasthe & Jha 1999; Das 2003; Chattopadhyay et al. 2006)	Darjeeling (Dalgilesh 1906; Molur et al. 2002), Singla (Wroughton 1916a), Tong Song and Pashok (Wroughton 1916b), Sivok (Sanborn 1932), Neora Valley National Park (Ghose 1984), Chunabhati, Darjeeling, Gorubathan, Kumani and Sukna (Agrawal et al. 1992; Das 2003), Darjeeling, Kumani (Ghosh 2005)
62. *Eonycteris spelaea* (Dobson, 1871) Lesser Dawn Bat	LC, (V), Present	Sikkim, upto 2000m (Avasthe & Jha 1999; Das 2003; Chattopadhyay et al. 2006), Hee Gyathang (Molur et al. 2002)	Pashok (Agrawal et al. 1992), Pashok, Sivok and Sukna (Das 2003; Ghosh 2005)
63. *Megaerops niphanae* Yenbutra and Felten, 1983 Northern Tailless Fruit Bat	LC, (V), Present	Sikkim (Avasthe & Jha 1999)	Pashok (Molur et al. 2002; Das 2003)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
64. *Macroglossus sobrinus* K. Andersen, 1911 Greater Long-nosed Fruit Bat	LC, (V), Present	Sikkim (Avasthe & Jha 1999; Molur et al. 2002; Das 2003)	Darjeeling (Agrawal et al. 1992; Molur et al. 2002; Das 2003; Ghosh 2005)
65. *Pteropus giganteus* (Brünnich, 1782) Indian Flying Fox	LC, II, (V), Present	Melli, Singtam, Rangpo, Tong, Chakung and Ranipool (Avasthe & Jha 1999), Gangtok (Molur et al. 2002)	Darjeeling, warmer valleys at low elevation (Dalgilesh 1906), Siliguri (Wroughton 1916a; Agrawal et al. 1992; Molur et al. 2002; Das 2003; Ghosh 2005)
66. *Rousettus leschenaultii* (Desmarest, 1820) Leschenault's Rousette	LC, (V), Present	Sikkim, upto 2250m (Avasthe & Jha 1999), 17km WSW Mangan (Molur et al. 2002), Hee Gyathang (Ghosh 2005; Chattopadhyay et al. 2006)	Pedong (Wroughton 1917), Tarkhola (Khajuria & Ghose 1970), Neora Valley National Park (Ghose 1984), Gorubathan and Tarkhola (Agrawal et al. 1992; Das 2003; Ghosh 2005), Darjeeling (Molur et al. 2002)
67. *Sphaerias blanfordi* (Thomas, 1891) Blanford's Fruit Bat	LC, (V), Present	Sikkim (Avasthe & Jha 1999; Das 2003), Fambong Lho Wildlife Sanctuary (Molur et al. 2002), Tumin (Ghosh 2005; Chattopadhyay et al. 2006)	Darjeeling, Ghoomti and Palmajua (Agrawal et al. 1992; Das 2003; Ghosh 2005), Darjeeling and Goomti (Molur et al. 2002)
14) Family Rhinolophidae Gray, 1825 (horseshoe bats)			
68. *Rhinolophus affinis* Horsfield, 1823 Intermediate Horseshoe Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Srinivasulu & Srinivasulu 2012)	Kurseong, (Dalgilesh 1906), Pashok (Wroughton 1916b; Agrawal et al. 1992; Das 2003), Darjeeling and Pashok (Molur et al. 2002)
69. *Rhinolophus ferrumequinum* (Schreber, 1774) Greater Horseshoe Bat	LC, Present	Rongli (Wroughton 1916a), Ringin and Rongli (Molur et al. 2002), Lachen (Chattopadhyay et al. 2006; Ghosh 2008)	Darjeeling (Molur et al. 2002)
70. *Rhinolophus lepidus* Blyth, 1844 Blyth's Horseshoe Bat	LC, Present	Sikkim (Avasthe & Jha 1999)	Nimbong, Pedong, and Sangser (Wroughton 1917), Darjeeling (Molur et al. 2002)
71. *Rhinolophus luctus* Temminck, 1834 Great Woolly Horseshoe Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Das 2003)	Singla (Wroughton 1916a), Darjeeling and Nimbong (Agrawal et al. 1992; Das 2003), Kalimpong and Rechila, Neora Valley National Park (Biswas et al. 1999; Mallick 2012), Darjeeling and Singla (Molur et al. 2002)
72. *Rhinolophus macrotis* Blyth, 1844 Big-eared Horseshoe Bat	LC, Present		Lopchu (Molur et al. 2002)
73. *Rhinolophus pearsonii* Horsfield, 1851 Pearson's Horseshoe Bat	LC, Present	Sikkim (Hill 1986; Chattopadhyay et al. 2006), Sikkim, Lower Himalayan range (Avasthe & Jha 1999), Chunthang and Fambong Lho Wildlife Sanctuary (Molur et al. 2002), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	Pashok (Wroughton 1916b), Darjeeling, Mahanadi and Pashok (Agrawal et al. 1992; Das 2003; Ghosh 2008), Darjeeling, Pashok and Lopchu (Molur et al. 2002)
74. *Rhinolophus pusillus* Temminck, 1834 Least Horseshoe Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Das 2003), Fambong Wildlife Sanctuary (Molur et al. 2002), Mangan (Ghosh 2008)	Darjeeling, Nimbong, Pashok and Sangser (Agrawal et al. 1992; Das 2003), Sangser, Pashok and Nimbong (Molur et al. 2002), Nimbong, Sangser (Ghosh 2008)
75. *Rhinolophus sinicus* K. Andersen, 1905 Chinese Rufous Horseshoe Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Das 2003), Tashiding (Molur et al. 2002), Tumin (Chattopadhyay et al. 2006; Ghosh 2008)	Nimbong (Wroughton 1917; Ghosh 2008), Singhmari (Pal & Dasgupta 1982), Kumani and Nimbong (Agrawal et al. 1992; Das 2003), Darjeeling, Nimbong and Pashok (Molur et al. 2002)
76. *Rhinolophus trifoliatus* Temminck, 1834 Trefoil Horseshoe Bat	LC, Present	Sikkim (Avasthe & Jha 1999)	Darjeeling (Agrawal et al. 1992; Molur et al. 2002; Das 2003)
15) Family Hipposideridae Lydekker, 1891 (Old World leaf-nosed bats, trident bats)			
77. *Coelops frithii* Blyth, 1848 Tailless Leaf-nosed Bat	LC, Present		Darjeeling (Blanford 1888; Agrawal et al. 1992; Molur et al. 2002; Das 2003), Gopaldhara, Tongsong, Nimbong, Peshok (Ghosh 2008)
78. *Hipposideros armiger* (Hodgson, 1835) Great Leaf-nosed Bat	LC, Present	Sikkim, upto 1800m (Blanford 1888; Avasthe & Jha 1999; Das 2003; Chattopadhyay et al. 2006); Hee Gyathang and Rongli (Molur et al. 2002)	Gopaldhara, Tong Song and Pashok (Wroughton 1916b), Nimbong (Wroughton 1917), Darjeeling, Goomti, Gopaldhara, Lopchu, Mahandi, Nimbong, Pashok and Tongsong (Agrawal et al. 1992; Molur et al. 2002; Das 2003), Gopaldhara, Tongsong, Peshok, Nimbong (Ghosh 2008)
79. *Hipposideros cineraceus* Blyth, 1853 Least Leaf-nosed Bat	LC, Present		Sangser (Molur et al. 2002), Nimbong, Pashok, Sangser (Das 2003)
80. *Hipposideros lankadiva* Kelaart, 1850 Indian Leaf-nosed Bat	LC, Present		Darjeeling (Anderson 1881; Agrawal et al. 1992; Molur et al. 2002; Das 2003)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
81. *Hipposideros pomona* K. Andersen, 1918 Pomona Leaf-nosed Bat	LC, Present	Rongli (Wroughton 1916b; Molur et al. 2002; Das 2003), Sikkim (Hill et al. 1986; Avasthe & Jha 1999; Chattopadhyay et al. 2006)	Pashok and Narbong (Wroughton 1916a; Ghosh 2008), Pashok (Wroughton 1916b; Agrawal et al. 1992), Nimbong and Sangser (Wroughton 1917), Tongsong (Agrawal et al. 1992), Narbong, Nimbong, Pashok, Sangser and Tong Song (Molur et al. 2002)
16) Family Megadermatidae H. Allen, 1864 (false-vampire bats)			
82. *Megaderma lyra* E. Geoffroy, 1810 Greater False Vampire Bat	LC, Present	Sikkim (Avasthe & Jha 1999)	Terai, Darjeeling (Dalgilesh 1906; Molur et al. 2002), Siliguri (Wroughton 1916a), Sivok (Sanborn 1932), Gyabari, Lopchu, Siliguri, and Sukna (Agrawal et al. 1992; Das 2003)
17) Family Emballonuridae Gervais, 1855 (sheath-tailed bats)			
Subfamily Taphozoinae Jerdon, 1867 (tomb bats)			
83. *Taphozous longimanus* Hardwicke, 1825 Long-winged Tomb Bat	LC, Present		Darjeeling (Blyth 1841; Agrawal et al. 1992; Molur et al. 2002; Das 2003), Peshok, Tongsong (Ghosh 2008)
84. *Taphozous nudiventris* Cretzschmar, 1830 Naked-rumped Tomb Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Molur et al. 2002; Das 2003; Chattopadhyay et al. 2006)	Sivok (Wroughton 1916a; Agrawal et al. 1992; Molur et al. 2002; Das 2003)
18) Family Molossidae Gervais, 1856 (free-tailed bat)			
Subfamily Molossinae Gervais, 1856			
85. *Tadarida teniotis* (Rafinesque, 1814) European Free-tailed Bat	LC, Present	Sikkim, Eastern Himalayas (Avasthe & Jha 1999)	Kurseong (Hill 1963; Molur et al. 2002), Darjeeling (Agrawal et al. 1992; Das 2003)
19) Family Vespertilionidae Gray, 1821 (vesper bats)			
Subfamily Vespertilioninae Gray, 1821			
Tribe: Eptesicini Volleth and Heller, 1994			
86. *Arielulus circumdatus* (Temminck, 1840) Bronze Sprite	LC, Present	Hee Gyathang (Molur et al. 2002)	
87. *Eptesicus serotinus* (Schreber, 1774) Serotine	LC, Present	Sikkim, colder areas (Avasthe & Jha 1999)	Rechila, Neora Valley National Park (Biswas et al. 1999; Mallick 2012)
88. *Eptesicus tatei* Ellerman and Morrison-Scott, 1951 Sombre Bat	DD, Present	Sikkim (Blyth 1863; Avasthe & Jha 1999)	Darjeeling (Blyth 1863; Agrawal et al. 1992; Molur et al. 2002; Das 2003)
Tribe: Nycticeiini Gervais, 1855			
89. *Scotomanes ornatus* (Blyth, 1851) Harlequin Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Molur et al. 2002)	Darjeeling (Blyth 1863), Kurseong (Primrose 1916; Millard et al. 1916b), Singla and Sivok (Wroughton 1916a), Tong Song and Pashok (Wroughton 1916b),Darjeeling, Pashok and Sivok (Agrawal et al. 1992; Das 2003), Pashok, Sivok, Singla, Tongsong (Molur et al. 2002), Tindharia, Peshok, Sivok (Ghosh 2008)
90. *Scotophilus kuhlii* Leach, 1821 Lesser Asiatic Yellow House Bat	LC, Present		Pashok (Agrawal et al. 1992; Das 2003), Darjeeling (Molur et al. 2002)
Tribe: Pipistrellini Tate, 1942			
91. *Nyctalus noctula* (Schreber, 1774) Noctule	LC, Present	Sikkim (Blanford 1888; Avasthe & Jha 1999; Chattopadhyay et al. 2006), Lingtam (Sanborn 1932), Hee Gyathang and Lingtam (Molur et al. 2002)	Tong Song (Wroughton 1916b), Sangser (Wroughton 1917), Darjeeling and Sangser (Agrawal et al. 1992; Das 2003), Sangser and Tongsong (Molur et al. 2002)
92. *Pipistrellus coromandra* (Gray, 1838) Indian Pipistrelle	LC, Present	Rongli and Penlong (Wroughton 1916a), Sikkim (Avasthe & Jha 1999), Mangpu and Rongli (Molur et al. 2002), Penlong (Chattopadhyay et al. 2006; Ghosh 2008)	Siliguri (Wroughton 1916a), Gopaldhara and Pashok (Wroughton 1916b), Nimbong, Pedong, Sangser and Kalimpong (Wroughton 1917), Mungpoo (Sanborn 1932), Takdah (Khajuria & Ghose 1970), Gopaldhara, Nimbong, Pashok, Pedong, Ranichera, Takdah (Agrawal et al. 1992; Das 2003), Gopaldhara, Pashok, Pedong and Siliguri (Molur et al. 2002), Gopaldhara, Pedong, Nimbong, Peshok (Ghosh 2008)
93. *Pipistrellus javanicus* (Gray, 1838) Javan Pipistrelle	LC, Present	Rongli (Sanborn 1932; Molur et al. 2002), Sikkim (Avasthe & Jha 1999; Das 2003)	Pashok (Wroughton 1916b), Darjeeling (Agrawal et al. 1992; Ghosh 2008), Paperkheti, Sukna, Takdah (Das 2003), Darjeeling, Nimbong and Pashok (Molur et al. 2002)
94. *Pipistrellus tenuis* (Temminck, 1840) Least Pipistrelle	LC, Present		Neora Valley National Park (Ghose 1984), Kalijhora (Agrawal et al. 1992; Das 2003), Darjeeling (Molur et al. 2002)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
Tribe: Plecotini Gray, 1866			
95. *Barbastella leucomelas* (Cretzschmar, 1826) Eastern Barbastelle	LC, Present	Sikkim (Avasthe & Jha 1999; Das 2003), Hee Gyathang, Lachung and Mangpu (Molur et al. 2002), Lachung (Chattopadhyay et al. 2006; Ghosh 2008)	Tong Song (Wroughton 1916b), Nimbong (Wroughton 1917; Ghosh 2008), Mungpoo (Sanborn 1932), Darjeeling and Nimbong (Agrawal et al. 1992; Das 2003), Darjeeling, Kurseong, Nimbong, Tongsong (Molur et al. 2002)
96. *Plecotus auritus* (Linnaeus, 1758) Brown Long-eared Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Das 2003), North Sikkim (Molur et al. 2002), Yumthang and Thangu (Chattopadhyay et al. 2006; Ghosh 2008)	Darjeeling (Agrawal et al. 1992; Molur et al. 2002; Das 2003; Chattopadhyay et al. 2006)
Tribe: Vespertilionini Gray, 1821			
97. *Falsistrellus affinis* Dobson, 1871 Chocolate Pipistrelle	LC, Present		Gopaldhara (Wroughton 1916b), Darjeeling (Agrawal et al. 1992; Das 2003), Gopaldhara and Kurseong (Molur et al. 2002)
98. *Hypsugo cadornae* Thomas, 1916 Cadorna's Pipistrelle	LC, Present		Pashok (Thomas 1916a; Wroughton 1916b; Molur et al. 2002), Darjeeling (Agrawal et al. 1992; Das 2003)
99. *Hypsugo joffrei*(Thomas, 1915) Joffre's Pipistrelle	DD, Present	Hee Gyathang (Molur et al. 2002; Saikia et al. 2017; Saikia 2018), Sikkim (Srinivasulu & Srinivasulu 2012)	
100. *Tylonycteris pachypus* (Temminck, 1840) Lesser Bamboo Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Molur et al. 2002; Das 2003)	Sivok (Wroughton 1916a), Pashok (Wroughton 1916b), Kalimpong, Nimbong and Sangser (Wroughton 1917), Darjeeling, Kalimpong, Pashok and Sivok (Agrawal et al. 1992; Das 2003); Darjeeling, Kalimpong, Nimbong, Pashok, Sangser, and Sivok (Molur et al. 2002), Darjeeling, Sivok, Pashok, Kalimpong (Ghosh 2008)
Subfamily Myotinae Tate, 1942			
101. *Myotis annectans* (Dobson, 1871) Hairy-faced Bat	LC, Present		Pashok (Thomas 1920; Topál 1970; Agrawal et al. 1992), Pashok and Teesta Valley (Molur et al. 2002)
102. *Myotis formosus* (Hodgson, 1835) Hodgson's Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Molur et al. 2002; Das 2003)	Darjeeling (Molur et al. 2002; Das 2003)
103. *Myotis muricola* (Gray, 1846) Nepalese Whiskered Bat	LC, Present	Lachung (Anderson 1881), Sedonchen and Lachen (Wroughton 1916a), Lachung and Jeluk (Sanborn 1932), Jeluk, Lachung, Lachen and Sedonchen (Molur et al. 2002), Lachen (Das 2003), Lachung and Lachen (Chattopadhyay et al. 2006)	Darjeeling (Anderson 1881; Agrawal et al. 1992; Das 2003), Neora Valley National Park (Ghose 1984), Gairibas and Ghoom (Molur et al. 2002)
104. *Myotis nipalensis*(Dobson, 1871) Nepal Myotis	LC, Present	Sikkim (Avasthe & Jha 1999), Lachen (Ghosh 2008)	Neora Valley National Park (Ghose 1984), Darjeeling (Agrawal et al. 1992; Molur et al. 2002; Das 2003)
105. *Myotis sicarius* Thomas, 1915 Mandelli's Mouse-eared Myotis	VU, Present	Rongli (Sanborn 1932; Molur et al. 2002), Sikkim (Avasthe & Jha 1999; Das 2003)	Pashok (Wroughton 1916b; Molur et al. 2002; Das 2003)
106. *Myotis siligorensis* (Horsfield, 1855) Himalayan Whiskered Myotis	LC, Present	Sikkim (Avasthe & Jha 1999; Das 2003), Bakhim (Molur et al. 2002), Mangan, Yuksam and Bakhim (Chattopadhyay et al. 2006; Ghosh 2008)	Siliguri (Agrawal et al. 1992; Das 2003), Siliguri and Ghoom (Molur et al. 2002)
Subfamily Murininae Miller, 1904 (tube-nosed bat)			
107. *Harpiocephalus harpia* (Temminck, 1840) Lesser Hairy-winged Bat	LC, Present	Takchom Chu (Maclaren 1949), Sikkim (Avasthe & Jha 1999), Tackchom/Roro river, Ranipool (Molur et al. 2002; Ghosh 2008), Sikkim (Das 2003)	Tong Song (Wroughton 1916b), Neora Valley National Park (Ghose 1984), Darjeeling and Kurseong (Agrawal et al. 1992; Das 2003; Ghosh 2008)(Das 2003; Ghosh 2008), Darjeeling, Ghoom, Kurseong, Teesta Valley and Tongsong (Molur et al. 2002)
108. *Murina aurata* Milne-Edwards, 1872 Little Tube-nosed Bat	LC, Present	Sedonchen (Wroughton 1916a; Molur et al. 2002), Sikkim (Chattopadhyay et al. 2006)	

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
109. *Murina cyclotis* Dobson, 1872 Round-eared Tube-nosed Bat	LC, Present	Sikkim (Avasthe & Jha 1999; Molur et al. 2002; Das 2003), Yumthang (Chattopadhyay et al. 2006; Ghosh 2008)	Singla (Wroughton 1916a), Gopaldhara and Pashok (Wroughton 1916b), Sangser (Wroughton 1917), Takdah (Khajuria & Ghose 1970), Darjeeling, Pashok, Takdah (Agrawal et al. 1992; Das 2003), Darjeeling, Gopaldhara, Tongsong, Singla, Pashok and Teesta Valley (Molur et al. 2002), Darjeeling District (Chattopadhyay et al. 2006), Peshok, Takdah (Ghosh 2008)
110. *Murina huttoni* (Peters, 1872) White-bellied Tube-nosed Bat	LC, Present	Sikkim (Agrawal et al. 1992; Avasthe & Jha 1999; Das 2003)	Darjeeling (Agrawal et al. 1992; Das 2003), Darjeeling, Pashok, Sangser, Teesta Valley, Tong Song (Molur et al. 2002)
111. *Murina leucogaster* Milne-Edwards, 1872 Rufous Tube-nosed Bat	LC, Present	Sikkim (Avasthe & Jha 1999)	Pashok (Thomas 1916b; Wroughton 1916b), Sangser (Agrawal et al. 1992; Das 2003), Pashok and Sangser (Molur et al. 2002)
112.*Murina tubinaris* (Scully, 1881) Scully's Tube-nosed Bat	LC, Present	Chungthang (Sanborn 1932; Molur et al. 2002), Sikkim (Avasthe & Jha 1999)	Gopaldhara and Tongsong (Wroughton 1916b), Sangser (Wroughton 1917), Darjeeling (Agrawal et al. 1992; Das 2003), Darjeeling and Gopaldhara (Molur et al. 2002)
Subfamily Kerivoulinae Miller, 1907 (woolly bats)			
113. *Kerivoula hardwickii* (Horsfield, 1824) Hardwicke's Woolly Bat	LC, Present		Gopaldhara, Pashok and Tong Song (Wroughton 1916b; Molur et al. 2002), Gopaldhara (Fry 1923), Gopaldhara and Pashok (Das 2003)
114. *Kerivoula picta* (Pallas, 1767) Painted Woolly Bat	LC, Present	Sikkim (Blanford 1888; Avasthe & Jha 1999; Molur et al. 2002)	Darjeeling (Anderson 1881; Agrawal et al. 1992; Molur et al. 2002)
VIII. ORDER PHOLIDOTA Weber, 1904			
20) Family Manidae Gray, 1821 (pangolins)			
115. *Manis crassicaudata* E. Geoffroy, 1803 Indian Pangolin	EN, I, (I), Present		Kalimpong (Mallick 2012)
116. *Manis pentadactyla* Linnaeus, 1758 Chinese Pangolin	CR, I, (I), Present	Melli, Kitam, and Manpur (Avasthe & Jha 1999), Yuksam (Sathyakumar et al. 2011a), Sikkim (The Statesman 2019)	Margaret's Hope Tea Estate at 1524 m, Darjeeling (Dalgilesh 1906), Piok Basti, Kalimpong (Mallick 2012)
IX. ORDER CARNIVORA Bowdich, 1821			
21) Family Felidae Fischer, 1817 (cats)			
SUBORDER FELIORMIA Kretzoi, 1945			
Subfamily Felinae Fischer, 1817 (cats)			
117. *Catopuma temminckii* (Vigors and Horsfield, 1827) Asiatic Golden Cat	NT, I, (I), Present	Gangtok (Millard et al. 1916b), Sikkim (Wroughton 1916a), Sikkim (Pocock 1939), Pangdin, Kangarten, Lasher, Thela, Green Lake, Marcopolo camp, Shibringu within Khangchendzonga National Park, Tamzay, Thosa lake, Chimathang, Gochela and Lampokhari (Avasthe & Jha 1999), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Nagdok, Legship and Lachung (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Bashir et al. 2011; Sathyakumar et al. 2011a), Khangchendzonga Biosphere Reserve, Kyongnosla Alpine Sanctuary (Lepcha et al. 2017)	Neora Valley National Park (Ghose 1984; Chatterjee et al. 2018; Mallick 2019)
118. *Felis chaus* Schreber, 1777 Jungle Cat	LC, II, (II), Present	Sikkim (Wroughton 1916a), Sikkim, tropical forest (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Kyongnosla Alpine Sanctuary (Lepcha et al. 2017)	Darjeeling (Dalgilesh 1906; Wroughton 1916a), Nimbong (Wroughton 1917), Kalimpong (Agrawal et al. 1992), Rechila, Jaributi and Lava (Biswas et al. 1999; Mallick 2012)
119. *Lynx lynx* (Linnaeus, 1758) Eurasian Lynx	LC, II, (I), Present	Sikkim-Tibet Border (Ganguli-Lachungpa 1997), Sikkim, plateau region (Avasthe & Jha 1999), Tso Lhamo plateau (Rawat and Tambe 2011)	
120. *Pardofelis marmorata* (Martin, 1837) Marbled Cat	NT, I, (I), Present	Chungthang Bob and Khangchendzonga National Park (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Rabdanche Reserve Forest, Pelling and Rangtalao near Chunthang (Chattopadhyay et al. 2006), Pangolakha Wildlife Sanctuary (Lepcha et al. 2017)	Ghoom (Wroughton 1916a), Jaributi forest, Neora Valley National Park (Ghose 1984; Biswas et al. 1999)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
121. *Prionailurus bengalensis* (Kerr, 1792) Leopard Cat	LC, II, (I), Present	Chuntang and Lachung (Wroughton 1916a), Lingtam (Sanborn 1932), Khangchengzonga National Park and Quite Common throughout Sikkim at an elevation between 2100–2400m (Avasthe & Jha 1999), Yuksum (Chakraborty 2003), Teesta Valley (Vijayan et al. 2004), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary, Fambhonglho Wildlife Sanctuary, Khangchendzonga Biosphere Reserve (Lepcha et al. 2017)	Darjeeling (Dalgilesh 1906; Agrawal et al. 1992), Pashok (Wroughton 1916a), Jaributi, East Nar and Thosum of Neora Valley National Park (Ghose 1984; Biswas et al. 1999; Mallick 2012)
122. *Prionailurus viverrinus* (Bennett, 1833) Fishing Cat	VU, II, (I), Present	East and South Districts, upto 1800m (Avasthe & Jha 1999), Sikkim (Srinivasulu & Srinivasulu 2012)	Aluburi and Jaributi of Neora Valley National Park (Biswas et al. 1999; Mallick 2012)
Subfamily Pantherinae Pocock, 1917			
123. *Neofelis nebulosa* (Griffith, 1821) Clouded Leopard	VU, I, (I), Present	Shot in Sikkim (Wroughton 1916a; Chakraborty 2003), Manpur, Kerabari, Kitam, Dzongu, Rhenock, Barapathing, Sombaria, Bagu, Ranipool and Khangchendzonga National Park (Avasthe & Jha 1999), Kalikhola (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Fambhonglho Wildlife Sanctuary (Lepcha et al. 2017)	Darjeeling (Dalgilesh 1906), Kurseong, Runjeet Valley and Above Rungbee, Teesta Valley (Matthews, 1934), Rungneet Tea Estate (Gabb 1945), Jaributi, Mouchowki, East Nar and West Nar of Neora Valley National Park (Ghose 1984; Biswas et al. 1999; Mallick 2012)
124. *Panthera uncia* (Schreber, 1775) Snow Leopard	VU, I, (I), Present	Thangu (Wroughton 1916a), Sikkim-Tibet border (Ganguli-Lachungpa 1997), Lasher Valley, Yumesamdang, Cho Lhamu, Near Thanggu, Sebu La, Lhonak valley, Youmcho, Seokun, Bhamchona, Dzongri, Sevo, Semchang kha, Sarum, Dudhpokhari and Khangchendzonga National Park (Avasthe & Jha 1999), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Bop, North Sikkim (Chattopadhyay et al. 2006), Tso Lhamo plateau (Rawat &Tambe 2011), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary, Khangchendzonga Biosphere Reserve, Kyongnosla Alpine Sanctuary (Lepcha et al. 2017)	Singalila National Park (Chattopadhyay et al. 2006)
125. *Panthera pardus* (Linnaeus, 1758) Leopard	VU, I, (I), Present	Rishi, Phenock, Manpur, Kitam RF, Sombaria and Khangchengdzonga National Park (Avasthe & Jha 1999), Khangchendzonga Biosphere Reserve, Pangolakha Wildlife Sanctuary (Sathyakumar et al. 2011a)	Darjeeling (Dalgilesh 1906), Neora Valley National Park (Ghose 1984; Biswas et al. 1999), Samsing, Mal, Chunabhati, Rechila, Alubari, Jaributi, Jorepokhri, Mouchowki, West Nar, East Nar and Thosum (Mallick 2012)
126. *Panthera tigris* (Linnaeus, 1758) Tiger	EN, I, (I), Present	Scare in Sikkim (Wroughton 1916a), Rachela, Talkharga, Regu,Phadamchen, Zuluk, Gnathang, Bhusuk yalli, Men-men chu RF, Changu, Lagyap RF, Tamze RF, Kabi, Phensung, Phodong, Ringu, Tong RF, Chyakhung RF, Khudum, Lema, Lachung, Dombangin north-east, and Karchi, Loddang, Phamthey, Maenam and Rumdung (Avasthe & Jha 1999)	Kurseong (Dalgilesh 1906), Darjeeling Terai (Saha, 1955), Neora Valley National Park (Ghose 1984; Biswas et al. 1999) East Nar, West Nar, Thosum), Rhenok, Rechila and East Nar (Mallick 2012)
22) Family Viverridae Gray, 1821 (civets and palm civets)			
Subfamily Paradoxurinae Gray, 1865 (palm civets)			
127. *Arctictis binturong* (Raffles, 1821) Binturong	VU, III, (I), Present	Khangchenzonga National Park, Luing, Parbing, Fombong Lho and West Dentam (Avasthe & Jha 1999), Menshithang and Hee Gyathang (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	
128. *Paguma larvata* (C. E. H. Smith, 1827) Masked Palm Civet	LC, III, (II), Present	Yuksom (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Sosing, Singhik, Naya Bazar and Yuksom (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Fambhonglho Wildlife Sanctuary (Lepcha et al. 2017)	Narbong (Wroughton 1916a), Rechila, Neora Valley National Park (Biswas et al. 1999)
129. *Paradoxurus hermaphroditus* (Pallas, 1777) Common Palm Civet	LC, III, (II), Present	Sikkim (Pocock 1939; Srinivasulu & Srinivasulu 2012), Sikkim, tropical forest (Avasthe & Jha 1999), Kitam Bird Sanctuary (Lepcha et al. 2017)	Darjeeling (Dalgilesh 1906), Narbong and Sivok (Wroughton 1916a), Rechila, Neora Valley National Park (Biswas et al. 1999)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
Subfamily Viverrinae Gray, 1821 (civets)			
130. *Viverra zibetha* Linnaeus, 1758 Large Indian Civet	LC, III, (II), Present	Rongli and Gangtok (Wroughton 1916a), Rangpo (Sanborn 1932), Khangchendzonga National Park and throughout the state upto 2100m (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Singhik, Yuksom, Naya Bazar and Pelling (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Fambhonglho Wildlife Sanctuary (Lepcha et al. 2017)	Ring-Tong Tea Estate (Dalgilesh 1906), Batasia, Tonglu, Narbong and Sivok (Wroughton 1916a), Gopaldhara, Songma and Pashok (Wroughton 1916b), Nimbong (Wroughton 1917), Sivok and Mungpoo (Sanborn 1932), Neora Valley National Park (Ghose 1984), Narbong, Sivok and Sungma (Agrawal et al. 1992), Rechila (Mallick 2012)
131. *Viverricula indica* (E. Geoffroy Saint-Hilaire, 1803) Small Indian Civet	LC, III, (II), Present	Singtam, Sangkhola, and Makha (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Sikkim (Srinivasulu & Srinivasulu 2012), Kitam Bird Sanctuary (Lepcha et al. 2017)	Neora Valley National Park, Jore Pokhri Wildlife Sanctuary, Mahananda Wildlife Sanctuary and Senchel Wildlife Sanctuary (Saha et al. 1992), Kalimpong (Mallick 2012)
23) Family Prionodontidae Pocock, 1933 (linsangs)			
132. *Prionodon pardicolor* Hodgson, 1842 Spotted Linsang	LC, I, (I), Present	Chuntang, Singhik, and Dikchu (Wroughton 1916a), Lingtam, Sedonchen and Jeluk (Sanborn 1932), Sikkim, tropical and sub-tropical forest upto 2100m (Avasthe & Jha 1999), Yuksam and Lima (Chattopadhyay et al. 2006), Barsey Rhododendron Sanctuary (Ghose et al. 2012, 2014)	Neora Valley National Park, upto 2100m (Mallick 2012)
24) Family Herpestidae Bonaparte, 1845 (mongooses)			
133. *Herpestes auropunctatus* (Hodgson, 1836) Small Indian Mongoose	LC, (IV), Present	Sikkim (Avasthe & Jha 1999) Fambhonglho Wildlife Sanctuary, Kitam Bird Sanctuary (Lepcha et al. 2017)	Darjeeling District (Agrawal et al. 1992),Kalimpong (Mallick 2012)
134. *Herpestes edwardsii* (É. Geoffroy Saint-Hilaire, 1818) Grey Mongoose	LC, III, (II), Present	Sikkim, tropical forest edges, scrub jungles and cultivated areas (Avasthe & Jha 1999) Sikkim (Srinivasulu & Srinivasulu 2012)	Darjeeling (Dalgilesh 1906), Suntalekhola (Mallick 2012)
135. *Herpestes urva* (Hodgson, 1836) Crab-eating Mongoose	LC, III, (II), Present	Near hill streams in South and East Districts (Avasthe & Jha 1999)	Pashok and Kurseong (Wroughton 1916a), Sivok (Sanborn 1932)
SUBORDER CANIFORMIA Kretzoi, 1938			
25) Family Canidae Fischer, 1817 (dogs)			
136. *Canis aureus* Linnaeus, 1758 Golden Jackal	LC, III, (II), Present	Rongli and Dikchu (Wroughton 1916a, 1916c), Sikkim, upto 3600m (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Yuksum, Geyzing, Pelling, Kabi, Gangtok, Tumin and Fambong Lho Wildlife Sanctuary (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	Darjeeling (Dalgilesh 1906; Fry 1923), Sukhiapokhri, Narbong and Sivok (Wroughton 1916a), Pedong (Wroughton 1917), Mungpoo and Sivok (Sanborn 1932), Neora Valley National Park (Biswas et al. 1999), Dkyati, Ghoombanjan and Pedong (Agrawal et al. 1992)
137. *Canis lupus* Linnaeus, 1758 Grey Wolf	LC, I, (I), Present	Gnatong, Thangu and above Lachung (Wroughton 1916a), Lachung (Sanborn 1932), Chho Lhamo (Ganguli-Lachungpa 1997), Yumthang valley, Lasher valley, Cho Lhamu, Lhonak valley, Shingba Rhododendron Sanctuary, Tamze, Kyongnosla Alpine Sanctuary, Pangolakha, Rachela, Maenam Wildlife Sanctuary, Lampokhari, Kasturi, Odar, Bhanjyang, Hilley, Barsey Rhododendron Sanctuary, Bamchhona and Sesse la meadows (Avasthe & Jha 1999), Tso Lhamo plateau (Rawat and Tambe 2011), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	Thosum, Neora Valley National Park (Mallick 2012)
138. *Cuon alpinus* (Pallas, 1811) Dhole	EN, II, (II), Present	Gangtok (Millard et al. 1916b), Sikkim (Ellerman & Morrison-Scott 1966; Chattopadhyay et al. 2006), Khangchendzonga National Park, Cho Lhamu, Pangolakha, Tshimthang, Pangdin, Kangarten and Rangit Valley (Avasthe & Jha 1999), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Maenam Wildlife Sanctuary, Pangolakha Wildlife Sanctuary (Lepcha et al. 2017)	Darjeeling (Dalgilesh 1906; Agrawal et al. 1992), Narbong (Wroughton 1916a), Tumsong Tea Estate (Baldry, 1932), Rechila, East Nar, West Nar and Ruka Reserve Forest (Biswas et al. 1999; Mallick 2012)
139. *Vulpes bengalensis* (Shaw, 1800) Bengal Fox	LC, III, (II), Present		Darjeeling (Agrawal et al. 1992), Senchel and Mahanada Wildlife Sanctuaries (Saha et al. 1992), Kalimpong (Mallick 2012)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
140. *Vulpes ferrilata* Hodgson, 1842 Tibetan Fox	LC, (I), Present	Menphu (Katao), Chho Lhamu, Green Lake in North Sikkim, Botang la and Doka la in East Sikkim (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Tso Lhamo plateau (Rawat and Tambe 2011)	
141. *Vulpes vulpes* (Linnaeus, 1758) Red Fox	LC, III, (II), Present	Kapup and Thangu (Wroughton 1916a; Pocock, 1941), Gyam Chohona Lake (5400m), Changri meadow along Chhomu Chu and near Oloten, Khangchendzonga National Park (Avasthe & Jha 1999), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Khangchendzonga Biosphere Reserve, Kyongnosla Alpine Sanctuary, Pangolakha Wildlife Sanctuary, Shingba Rhododendron Sanctuary (Lepcha et al. 2017)	Neora Valley National Park (Biswas et al. 1999)
26) Family Ursidae Fischer, 1817 (bears and pandas)			
142. *Melursus ursinus* (Shaw, 1791) Sloth Bear	VU, I, (I), Present		Neora Valley National Park (Ghose 1984), Darjeeling (Agrawal et al. 1992)
143. *Ursus arctos* Linnaeus, 1758 Brown Bear	LC, II, (I), Present	Phuni in Lachung, Green Lake, Lampokhari and the plateau(Avasthe & Jha 1999) Sikkim (Srinivasulu & Srinivasulu 2012)	
144. *Ursus thibetanus* G.[Baron] Cuvier, 1823 Asiatic Black Bear	VU, I, (II), Present	Gangtok (Millard et al. 1916b), Throughout state at an elevation between 1200–3600 m, Forests below Chewabhanjyang, Uttarey, and Dzongri. Also at Nibe, Nalung, Tinjurey (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Fambong Wildlife Sanctuary, Khangchendzonga National Park and Pangolakha National Park (Sathyakumar 2001), Yuksam and Pelling (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary, Fambhonglho Wildlife Sanctuary, Khangchendzonga Biosphere Reserve, Pangolakha Wildlife Sanctuary (Lepcha et al. 2017)	Serai to Darjeeling (Dalgilesh 1906), Neora Valley National Park (Ghose 1984; Biswas et al. 1999), Neora Valley National Park, Singalila National Park, and Mahananda Wildlife Sanctuary (Sathyakumar 2001), Mouchowki, Rechila, Thosum, East Nar and Jorepokhri (Mallick 2012)
27) Family Mustelidae Fischer, 1817 (otters, weasels, martens, badgers and honey badgers)			
Subfamily Lutrinae Bonaparte, 1838 (otters)			
145. *Aonyx cinereus* (Illiger, 1815) Oriental small-clawed Otter	VU, I, (I), Present	Sikkim (Avasthe & Jha 1999; Srinivasulu & Srinivasulu 2012)	Darjeeling District (Agrawal et al. 1992)
146. *Lutra lutra* (Linnaeus, 1758) Eurasian Otter	NT, I, (II), Present	Chuntang and Dikchu (Wroughton 1916a), Sikkim (Sanborn 1932), Rani-Nampey and Doban, throughout Sikkim 600–3600 m (Avasthe & Jha 1999), Dikchu, Phadong, Chunthang, Hee Gyathang and Melli (Chattopadhyay et al. 2006)	Balasund River (Dalgilesh 1906), Darjeeling (Wroughton 1916a; Agrawal et al. 1992), Pedong (Wroughton 1917)
Subfamily Mustelinae Fischer, 1817 (weasels and martens)			
147. *Arctonyx collaris* F.G. Cuvier, 1825 Hog-badger	VU, (I), Present	Sikkim, tropical and sub-tropical regions (Blanford 1888; Avasthe & Jha 1999)	Darjeeling (Agrawal et al. 1992), Neora Valley National Park (Mallick 2012)
148. *Martes flavigula* (Boddaert, 1785) Yellow-throated Marten	LC, III, (II), Present	Chuntang (Wroughton 1916a), Gangtok, Yumthang and Yumesamdong, throughout Sikkim between 1200–2700m (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Phodong (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary (Ghose et al. 2014), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Barsey Rhododendron Sanctuary, Fambhonglho Wildlife Sanctuary, Khangchendzonga Biosphere Reserve, Kyongnosla Alpine Sanctuary, Maenam Wildlife Sanctuary, Pangolakha Wildlife Sanctuary (Lepcha et al. 2017)	Darjeeling (Dalgilesh 1906),Pedong (Wroughton 1917), Lulegaon, Rishyap, West Nar,Jaributi and Rechila (Ghose 1984; Biswas et al. 1999; Mallick 2012)
149. *Martes foina* (Erxleben, 1777) Beech Marten	LC, III, (II), Present	Ghora la (Sanborn 1932), Cho Lhamu,Lhonak Valley, Kishongla and Samthong, elevations between 1800–3600m (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	Jaributi and Rechila, Neora Valley National park (Ghose 1984; Biswas et al. 1999; Mallick 2012), Darjeeling (Agrawal et al. 1992)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
150. *Melogale personata* I. Geoffroy Saint-Hilaire, 1831 Large-toothed Ferret Badger	LC, III, (II), Present	Sikkim, tropical and sub-tropical forests (Avasthe & Jha 1999) Sikkim (Srinivasulu & Srinivasulu 2012)	
151. *Mustela altaica* Pallas, 1811 Mountain Weasel	NT, III, (II), Present	Sikkim, between 2100–4000m (Avasthe & Jha 1999), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	
152. *Mustela ermine* Linnaeus, 1758 Short-tailed Weasel	LC, III, (I), Present	Teesta Valley (Vijayan et al. 2004), Shingba Rhododendron Sanctuary (Lepcha et al. 2017)	
153. *Mustela kathiah* Hodgson, 1835 Yellow-bellied Weasel	LC, III, (II), Present	Sikkim (Pocock, 1941), Sikkim, sub-tropical and temperate elevations (Avasthe & Jha 1999)	Darjeeling (Dalgilesh 1906; Agrawal et al. 1992), Pashok (Wroughton 1916b), Mungpoo (Sanborn 1932), Neora Valley National Park (Mallick 2012)
154. *Mustela sibirica* Pallas, 1773 Siberian Weasel	LC, III, (II), Present	Lachung and Lachen (Wroughton 1916a), Lingtam (Sanborn 1932), Sikkim, between 1500–4800m (Avasthe & Jha 1999), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Dzongri, Yumthang and Lachen (Chattopadhyay et al. 2006), Tso Lhamo plateau (Rawat and Tambe 2011), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary (Ghose et al. 2014)	Darjeeling (Dalgilesh 1906; Agrawal et al. 1992), Rechila, Neora Valley National Park (Biswas et al. 1999)
155. *Mustela strigidorsa* Gray, 1853 Black-striped Weasel	LC, (I), Uncertain	Sikkim, between 1200–2100m (Sterndale 1884; Blanford 1888; Avasthe & Jha 1999)	
28) Family Ailuridae Gray, 1843 (red panda)			
156. *Ailurus fulgens* F.G. Cuvier, 1825 Red Panda	EN, I, (I), Present	Gangtok (Millard et al. 1916a), Teesta Valley (Vijayan et al. 2004), Chuntang, Lachung, Lachen and Ringin (Wroughton 1916a), Lachung valley, Lachen, Khangchendzonga National Park, Tong RF, Tamze, Kyongnosla Alpine Sanctuary, Zuluk, Phadamchen, Panglokha, Fambong Lho Wildlife Sanctuary, Maenam Wildlife Sanctuary, Hilley-Barsey, Okharey, Rigdee and Chiwabhanjyang (Avasthe & Jha 1999), Chunthang, Menshithang, Lachung and Yuksom (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary (Ghose et al. 2014) Khangchendzonga Biosphere Reserve, Maenam Wildlife Sanctuary, Pangolakha Wildlife Sanctuary (Lepcha et al. 2017)	Darjeeling (Dalgilesh 1906; Agrawal et al. 1992), Sandakphu (Maclaren 1949), Rechila and Pankasari, Neora Valley National Park (Ghose 1984; Biswas et al. 1999), Gairibans, Manebhanjang,Phalut and Sandakphu (Pradhan, 1995), Raschet, Rechila and Thosum (Mallick 2012)
X. ORDER PERISSODACTYLA Owen, 1848			
29) Family Equidae Gray, 1821 (horses, asses, and zebras)			
157. *Equus kiang* Moorcroft, 1841 Kiang	LC, II, (I), Present	North of Gyagong towards Tibetan Plateau (Pinckney 1939), Tuna to Guru and Tang Sun Pum plain (Maclaren 1949), Chho Lhamo (Ganguli-Lachungpa 1997), Chho Lhamu, Gyamchhona, Chulung valley, Yumchho, Kerang, Chhulung La, Bamchho La and Sesse La (Avasthe & Jha 1999), Sikkim (Chakraborty 2003), Tso Lhamo plateau (Chanchani et al. 2010; Rawat and Tambe 2011)	
XI. ORDER CETARTIODACTYLA Owen, 1848			
30) Family Suidae Gray, 1821 (pigs)			
158. *Porcula salvania* Hodgson, 1847 Pygmy Hog	CR, I, (I), Extinct	Sikkim Terai (Hodgson 1847;Sclater 1891; Agrawal et al. 1992; Avasthe & Jha 1999)	Darjeeling Terai (Hodgson 1847;Sclater 1891; Agrawal et al. 1992)
159. *Sus scrofa* Linnaeus, 1758 Wild Boar	LC, (III), Present	Melli RF, Kitam, Soreng RF, Lagyap RF, Tong, Chakung, Rate Chu, Premlakha and Rangpo (Avasthe & Jha 1999), Teesta Valley(Vijayan et al. 2004), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary, Fambhonglho Wildlife Sanctuary, Kitam Bird Sanctuary Khangchendzonga Biosphere Reserve, Pangolakha Wildlife Sanctuary (Lepcha et al. 2017)	Darjeeling, upto moderate elevation (Dalgilesh 1906), East Nar, Thosum and Rechila, Neora Valley National Park (Mallick 2012)

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
31) Family Moschidae Gray, 1821 (musk deer)			
160. *Moschus chrysogaster* (Hodgson, 1839) Alpine Musk Deer	EN, I, (I), Present	Sikkim (Blanford 1888), Lachen and Lachung (Wroughton 1916a; Chattopadhyay et al. 2006), Ridge between Chumbi valley and Sikkim and Gyantse, above 3657.6 m in summers (Wood 1933), All Protected Areas of Sikkim except Fambonglho Wildlife Sanctuary (Sharma & Lachungpa 2002), North Sikkim (Lachungpa 2009), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014; Srivastava & Kumar 2018), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a)	Phalut (Dutt-Mazumdar 1955)
161. *Moschus fuscus* Li, 1981 Black Musk Deer	EN, I, (I), Present	Lachen and Lachung (Wroughton 1916a), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Khangchendzonga Biosphere Reserve, Kyongnosla Alpine Sanctuary, Pangolakha Wildlife Sanctuary (Lepcha et al. 2017)	
162. *Moschus leucogaster* Hodgson, 1839 Himalayan Musk Deer	EN, I, (I), Present	Sikkim between 2500-4000m (Groves & Grubb 2011; Srinivasulu & Srinivasulu 2012; Sharma et al. 2015)	
32) Family Cervidae Goldfuss, 1820 (deer)			
Subfamily Cervinae Goldfuss, 1820			
163. *Axis axis* (Erxleben, 1777) Chital	LC, (III), Present	Areas bordering West Bengal and Sikkim (Avasthe & Jha 1999; Choudhury 2001), Lowland forests (Sharma & Lachungpa 2002)	West of Balasan River, Terai, Darjeeling (Dalgilesh 1906; Dutt-Mazumdar 1955)
164. *Muntiacus vaginalis* (Boddaert, 1785) Northern Red Muntjac	LC, (III), Present	Ringin (Wroughton 1916a), Khangchendzonga National Park, throughout Sikkim between 600-2800m (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Pelling, Melli, Legship and Bakhim (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary, Fambhonglho Wildlife Sanctuary, Kitam Bird Sanctuary, Khangchendzonga Biosphere Reserve, Maenam Wildlife Sanctuary, Pangolakha Wildlife Sanctuary (Lepcha et al. 2017)	Darjeeling, 1828.8 m (Dalgilesh 1906), Sukhiapokhri, Narbong and Sivok (Wroughton 1916a), Rungneet Tea Estate (Gabb 1945), Lopchu Tea Estate (Saha, 1955), Neora Valley National Park (Ghose 1984; Biswas et al. 1999), East Nar, West Nar, Thosum, Rechila, Gorubathan forest, Tempola, Choudapheri (Mallick 2012)
165. *Rusa unicolor* (Kerr, 1792) Sambar	VU, (III), Present		Darjeeling, upto 1066.8m (Dalgilesh 1906; Dutt-Mazumdar 1955), Neora Valley National Park (Ghose 1984) Samsing, Chel Range, Kalimpong Range, East Nar, Thosum, Rechila (Mallick 2012)
33) Family Bovidae Gray, 1821 (cattle, antelope, sheep, and goat)			
Subfamily Antilopinae Gray, 1821 (antelopes)			
166. *Procapra picticaudata* Hodgson, 1846 Tibetan Gazelle	NT, (I), Present	North of Gyagong towards Tibetan Plateau (Pinckney 1939), Between Tuna and Guru (Maclaren 1949), Chho Lhamo, Chhulung La and Kongra La (Ganguli-Lachungpa 1997), Chhomo Chu, meadows near Gyam Chhona(5100m), Chhangri meadow at 4000–4500m (Avasthe & Jha 1999), Tso Lhamo plateau (Chanchani et al. 2010; Rawat and Tambe 2011)	
Subfamily Bovinae Gray, 1821 (cattle)			
167. *Bos gaurus* C.H.Smith, 1827 Gaur	VU, I, (I), Present	Pangolakha, Rache la, and Regu,East Sikkim (Avasthe & Jha 1999; Srinivasulu & Srinivasulu 2012) Pangolakha Wildlife Sanctuary (Lepcha et al. 2017)	Kurseong (Dalgilesh 1906), Sukna Reserve (Dutt-Mazumdar 1955), East Nar, Thosum, Rechila, Tempola and Jorepokhari, Neora Valley National Park (Ghose 1984; Biswas et al. 1999; Mallick 2012), Balason Valley, Sukna and Sevoke (Dasgupta 1991)
Subfamily Caprinae Gray, 1821 (goats and sheep)			
168. *Budorcas taxicolor* Hodgson, 1850 Takin	VU, II, (I), Present	Nimphu, Pangolakha and Rache La, between 2000–3000m (Avasthe & Jha 1999), Menla Reserve Forest (Ganguli-Lachungpa, 2000), Sikkim (Choudhury 2001; Srinivasulu & Srinivasulu 2012)	

	IUCN Status, CITES, (WPA,1972), Present Status	Records in Sikkim	Records in Darjeeling
169. *Capricornis thar* (Hodgson, 1831) Himalayan Serow	NT, I, (I), Present	Khangchendzonga National Park, throughout the state between 2200–3700m (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014; Srivastava & Kumar 2018), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Barsey Rhododendron Sanctuary, Fambhonglho Wildlife Sanctuary, Khangchendzonga Biosphere Reserve, Maenam Wildlife Sanctuary, Pangolakha Wildlife Sanctuary, Shingba Rhododendron Sanctuary (Lepcha et al. 2017)	Darjeeling (Dalgilesh 1906), Rechila (Mallick 2012)
170. *Hemitragus jemlahicus* (C.H. Smith, 1826) Himalayan Tahr	NT, (I), Present	Fimphu, Manandang (Bikmatar), above Rahi Chu (Satdharey), Ruketchu, Ribongthang, Nimphu, Tsingnok, Lingjibok, Khangchendzonga National Park, Aralungchowk and Gomnay (Avasthe & Jha 1999), Chunthang and BOP, North Sikkim (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Khangchendzonga Biosphere Reserve (Lepcha et al. 2017)	Neora Valley National Park (Ghose 1984), Thosum, Rechila, Jorepokhri, Triangular Point (Biswas et al. 1999; Mallick 2012)
171. *Naemorhedus goral* (Hardwicke, 1825) Himalayan Goral	NT, I, (III), Present	Gangtok (Millard et al. 1916b), Khangchenzonga National Park, Kyongnosla, Fimphu and Pentong (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Kyongnosla Alpine Sanctuary (Khatiwara & Srivastava 2014; Srivastava & Kumar 2018), Bop in North Sikkim, Onglakthang and Tolung Gompha in West Sikkim (Chattopadhyay et al. 2006), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Fambhonglho Wildlife Sanctuary, Khangchendzonga Biosphere Reserve, Kyongnosla Alpine Sanctuary, Shingba Rhododendron Sanctuary (Lepcha et al. 2017)	Darjeeling, 1524m (Dalgilesh 1906), Soom Tea Estate Forest (Gabb 1945),Rechila and East Nar, Neora Valley National Park (Ghose 1984; Biswas et al. 1999; Mallick 2012)
172. *Ovis ammon* (Linnaeus, 1758) Argali	NT, II, (I), Present	Sikkim-Tibetan Border (Sanborn 1932), Chhulung La (Ganguli-Lachungpa 1997), Bamchhona, Gyamchhona, Kerang, Chulung valley, Cha La, Lhonak Valley, Giagong area south of Plateau, and Khangchendzonga National park (Avasthe & Jha 1999), Lasser (Chattopadhyay et al. 2006), Tso Lhamo plateau (Chanchani et al. 2010; Rawat &Tambe 2011)	
173. *Pseudois nayaur* (Hodgson, 1833) Bharal	LC, III, (I), Present	Lachen (Wroughton 1916a), Pangdin, Kangarten, Rangit valley, Yumesamdong, Sebu la, Sezum Lava, Lasher, Oloten area, Thela, Green Lake, Marcopolo camp, Shibringu within Khangchendzonga National Park, Tamze, Thosa Lake, Chimathang, Gochela, Lampokhari (Avasthe & Jha 1999), Teesta Valley (Vijayan et al. 2004), Geygong, North Sikkim (Chattopadhyay et al. 2006), Tso Lhamo plateau (Chanchani et al. 2010; Rawat and Tambe 2011), Khangchendzonga Biosphere Reserve (Sathyakumar et al. 2011a), Khangchendzonga Biosphere Reserve (Lepcha et al. 2017)	Phalut (Dutt-Mazumdar 1955)

NE—Not Evaluated | DD—Data Deficient | LC—Least Concern | NT—Near Threatened | VU—Vulnerable | EN—Endangered | CR—Critically Endangered; I,II and III – CITES Appendices; (I), (II), (III), (IV) and (V) – The Wildlife (Protection) Act, 1972 Schedule List.

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Golden Jackal *Canis aureus* Linnaeus, 1758 (Mammalia: Carnivora: Canidae) distribution pattern and feeding at Point Calimere Wildlife Sanctuary, India

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Abstract: Golden Jackal *Canis aureus*, a medium-sized omnivore belonging to the family Canidae, ranges widely from Europe and extends across the middle-east to India. It's adaptable social system according to the distribution of food resources enabling it to range widely from desert to evergreen forests, mangroves, rural, and semi-urban human-agro-ecosystems. Despite its wide distribution, the species has not received adequate scientific attention in much of its southern India range. This study was carried out to assess its distribution pattern, diet composition, and prey preference at Point Calimere Wildlife Sanctuary, a well-known habitat for the jackal and the only predator of the sanctuary. Data on distribution collected through extensive field surveys revealed that the species distribution is uniform in southern and southeastern parts of the sanctuary, in areas where the habitat is more open with grasslands and mudflats and is patch in the tropical dry-evergreen habitat. Analysis of 155 scat samples revealed that the diet comprised 19 species of food items, including mammals, birds, insects, other invertebrates, and plant matter characterizing omnivorous nature. Temporal variation in diet composition—with significantly higher proportion of birds during winter than in summer—coincides with abundance of prey species in relation to season, which indicate the opportunistic foraging and hunting nature of the species. Data on diet preference showed that jackals in the area preferred Black-naped Hare, Spotted Dove and Lapwing followed by Chital, Grey Francolin, Cattle Egret, and Large Egret, while Blackbuck, Bonnet Macaque, and cattle were not preferred, which is discussed under optimal foraging. The jackal being the only large-sized predator of this natural system, more detailed studies and effective measures to conserve the species are vital not only to understand the prey-predator mechanism, but also to conserve the biodiversity of this unique ecosystem.

Keywords: Diet composition and preference, spatio-temporal variation in diet, southern India.

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Author contribution: NB—Study Design, Supervision, Final Analysis and writing part. GK—Data Collection, Preliminary Analysis and helping in writing part. KR—Helping in Data Collection, Preliminary Analysis and in writing part.

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INTRODUCTION

The Golden Jackal *Canis aureus* is an Old-World medium-sized habitat generalist belonging to the family Canidae, similar to the Coyote *Canis latrans* in North America (Bekoff & Gese 2003) and ranges widely from Europe and extends across the middle-east to India and southeastern Asia. The species is currently listed as Least Concern (LC) (Hoffmann et al. 2018) and included in Appendix II of CITES and Schedule III of the Indian Wildlife (Protection) Act 1972. Its tolerance to dry conditions and its omnivorous diet, enable the Golden Jackal to live in a wide variety of habitats, exceeding 2,000m in elevation, ranging from semi-arid environments to forested, mangrove, agricultural, rural, and semi-urban habitats in India and Bangladesh (Clutton-Brock et al. 1976; Poche et al. 1987). The species with omnivorous and opportunistic foraging nature feeds on a wide variety of food that varies in space and time. In Bharatpur, India, rodents, birds, and fruit comprise the bulk of its food (Sankar 1988), and similarly, in Kanha, over 80% of its diet comprises rodents, reptiles, and fruits (Schaller 1967); however, studies on Golden Jackal in Bhal region of Gujarat (Aiyadurai & Jhala 2006) and recently in Bharatpur, Rajasthan, India (Singh et al. 2016) showed higher proportions of large mammals and plant matter in their diet. While in Europe, the slaughter remains and other animal waste from livestock, represents approximately 40% of the jackal diet across the continent (Ćirović et al. 2016).

Golden Jackals are social animals with an extremely flexible social organization that varies upon the availability and distribution of food resources (Macdonald 1979). There is little quantitative information on jackal densities, habitat use, and ranging patterns in relation to food availability. And data on dispersal, survival, and mortality factors of adults, pups, and dispersing individuals are still a major gap in our understanding (Jhala & Moehlman 2004). Despite its wide distribution, the species hasn't received sufficient scientific attention in much of its southern Indian ranges. Point Calimere Wildlife Sanctuary, situated on the southern boundary of the Coromandel Coast, is a well-known habitat for the Golden Jackal (Ali 2005). This study assessed the distribution of jackal, diet composition, and preference estimating the availability of major prey species, at Point Calimere Wildlife Sanctuary.

Image 1. A pair of Golden Jackal *Canis aureus* at Point Calimere Wildlife Sanctury.

MATERIAL AND METHODS

Study Area

This study was carried out between December 2013 and June 2014 at Point Calimere Wildlife Sanctuary located between the geographical coordinates 10.27°N, 79.83°E and 10.33°N, 79.84°E and lies at the confluence of Bay of Bengal and the Palk Strait, near Nagapattinam, Tamil Nadu. The sanctuary derives its name as 'Point Calimere' for the spot inside the sanctuary, where the coast takes a 90° turn from the Bay of Bengal towards Palk Strait (Figure 1). The reserve was declared in 1967 (Ramasubramaniyan 2012) mainly for the conservation of Blackbuck *Antelope cervicapra* and it encompasses an area of 30km^2 of sandy coast fringed by saline swamps and thorny scrub around the backwaters. The coastal area consisting of shore, shallow water, inter-tidal flats, saline lagoons as well as manmade salt pan sites supports >250 species of birds, with about 120 being water birds that include vulnerable species like Spoonbill Sandpiper *Euryhoryhynchus pygnaeus*, Grey Pelicans *Pelecanus philippensis*, and Greater Flamingo *Phoenicopterus roseus*, Lesser Flamingo *P. minor* and is among the 26 wetlands in India designated as wetlands of international importance (pointcalimere.org/overview.htm). The sanctuary consists of unique vegetation types; tropical dry evergreen, open grassland with patches of open scrub (Ali 2005). Its tropical dry evergreen forest is considered as the richest tract in the entire country. The grasslands located on its southern part are the natural habitat of the Blackbuck. Apart from jackal, which is locally called 'kullanary', the sanctuary is also known for Blackbuck , and other mammals like Chital *Axis axis*, Wild Boar *Sus scrofa*, Bonnet Macaque *Macaca radiata* (Muralidharan 1985; Nedumaran 1987; Ramasubramaniyan 2012). A notable feature of the

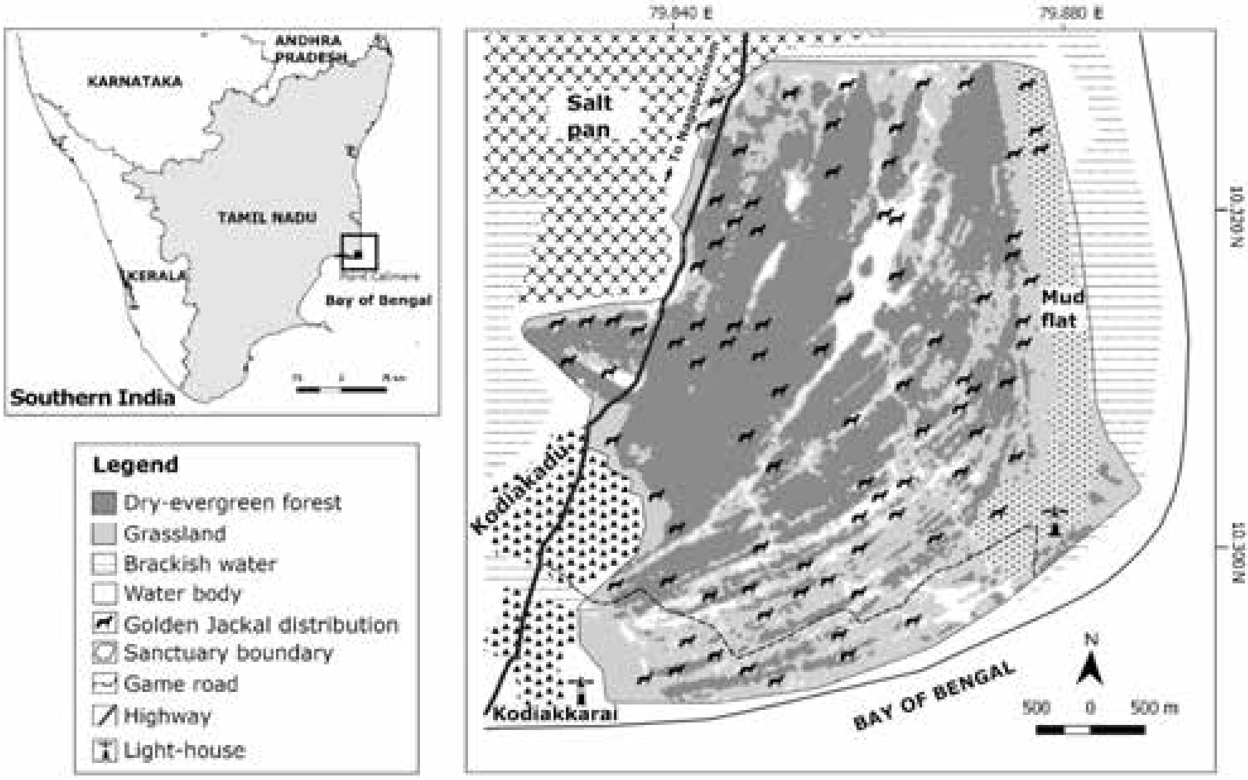

Figure 1. Golden Jackal sightings at Point Calimere Wildlife Sanctuary between December 2013 and June 2014.

sanctuary is the presence of feral horses, an introduced species in the ecosystem. Olive Ridley Turtles have been regularly nesting on the sanctuary beach and during winter, dolphin sighting is common along the sanctuary coast. The natural habitats experience pressure from the invasive feral horse (Baskaran et al. 2016, 2020; Arandhara et al. 2020), anthropogenic pressure from cattle (Nedumaran 1987) and also from the proliferation of *Prosopis juliflora* (Ali 2005), an alien invasive shrub species from Central and South America. With an average density of 14 cattle/km^2, the sanctuary experiences grazing pressure from 300 to 600 cattle/day (Ali 2005).

Distribution pattern

To identify and map the distribution of *C. aureus*, a systematic field survey was carried out on foot covering various administrative units (beats) and forest types of the sanctuary. During the survey, boundaries of administrative units of forest division were marked on a map in consultation with the concerned forest officials and official documents available to record the presence/absence of *C. aureus*. Later, through intensive field surveys covering all the habitats, the distribution of the jackal was identified following direct sightings and indirect evidence (scat). On every sighting of the target species or its evidence, geo-coordinate data were collected using the global positioning system (GPS) besides recording their number. In addition, sighting data recorded during the jackal prey-abundance estimate were also considered. The location data (both direct sighting and indirect evidence) along with other variables (division boundaries) marked on the survey of India topographic map were digitized using the geographical information system (GIS) software (Arc View 3.3, ESRI Inc.) to create the distribution map of the jackal.

Diet composition

The diet composition of jackals was studied following the indirect method, i.e., scat analysis based on frequency occurrence of various undigested food items found in the scat (Schaller 1967). The scat of the jackal can be identified, by size, shape and odour in addition to the nature of feeding and pug marks in the area. Differentiating jackal scat in the field from small carnivore scat requires more experience, however, the absence of most small carnivores excepting mongoose made identification easier in the present study. Similarly, the scat of jackal could be differentiated from domestic/feral dogs based on plant matters like fruits, seeds, pericarp, on which jackal usually feeds unlike dogs. Scats were collected whenever encountered in the study area along the predetermined road and trail surveys. The collected scats were air-dried and sealed in a separate container and numbered serially, and the date and habitat were noted (Joseph et al. 2007). To determine the diet composition, dried scat samples were broken down and washed under running water through a sieve. The scat contents were broken apart and remains of different food items such as hair, feather, scales of reptiles, invertebrate and vegetable matter (grass and fruit seeds) were separated. In case of hair samples, a sample of 20 hairs was picked up randomly from each scat (Mukherjee et al. 1994) to circumvent the possible biases (Karanth & Sunquist 1995). The prey species were identified from the hair structure using a microscope and compared with standard slides. Prey remains in scats were observed microscopically and identified by comparing with standard reference slides (both medullary or epithelial structure prepared using DPX mountant) available at the Department of Zoology, A.V.C. College (Autonomous), and plant materials especially fruit remains such as seeds and pericarp were compared with specimens from natural habitats or collection maintained at the Bombay Natural History Society Field Station at Point Calimere Sanctuary.

Prey abundance

To estimate the prey abundance, line transect (Burnham et al. 1980) direct sighting method was employed. Based on the diet composition data, a list of food items eaten by the jackal was prepared. The abundance of animal species from birds and mammals consumed by the jackal was quantified using the line transect method. To decide about the sampling sites for line transect study, the sanctuary maps were overlaid with 1 × 1 km grid and all the grids were numbered with running serial number resulting in 40 grids. Of these, 37 were selected for sampling. In each grid, a line transect was randomly laid, but aligned to run across drainage patterns and water bodies. From this map, geo-coordinate details were extracted for each line transect start and end points and using them, the transect lines were established in natural habitats of the sanctuary with the help GPS and field compass. These lines were marked with red colour paint or tags. All these transects were sampled at weekly intervals between January and March 2013 during morning (06.00–10.00 h) and evening (16.00–18.00 h). At every sighting of prey item like Black-naped Hare, Palm Squirrel, Chital, Blackbuck, Bonnet Macaque, Wild Boar, feral horse, cattle, and terrestrial birds, besides their group size, sighting angle, and sighting distance were recorded respectively using field compass and range finder.

Data analysis

Using the transect data, the density was estimated following distance-sampling techniques employing the software DISTANCE (version 6.0, Buckland et al. 2004; Thomas et al. 2010). Group and individual density of Blackbuck and feral horse and their standard error (SE) were estimated, evaluating each model of detection probability, viz., uniform, half-normal, and hazard-rate with three different series adjustment terms such as cosine, simple polynomial and hermite polynomial (i.e., detection probability uniform with cosine series adjustment, uniform with simple polynomial and uniform with hermite polynomial and similar combination for half-normal and hazard rate). The best model was selected for estimating the density of each species from nine different combinations of analyses, using the minimum Akaike Information Criteria (AIC) as the standard model selection procedure.

Statistical analyses and prey preference calculation

The diet composition data were quantified in terms of frequency of occurrence, percent of scat containing particular food item out of the total number of scats collected, following traditional scat analysis method (Schaller 1967). The data on the frequency occurrence of various food items recorded in the diet of the jackal between seasons was tested using the Mann–Whitney U test. Prey preference by the jackal was estimated using the % occurrence of various prey items in the diet (as usage rate) and their abundance in the environment (as availability) following Jacob's preference index (Jacobs 1974). Jacob's preference index = $(u - a)/(u + a) - (2 \times u \times a)$, where 'u' is the proportion of a particular category in the diet, and 'a', the proportion of that category in the population.

RESULTS

Distribution pattern of the jackal

In total, the study recorded 41 locations of direct sightings and indirect evidence of jackal between December 2013 and June 2014 and superimposed them on the sanctuary map to produce its distribution map (Figure 1). From the distribution map, though it appears that jackals are distributed throughout the sanctuary, areas in southern and eastern parts, where grassland habitat is dominating, have more uniform distribution

Table 1. Frequency occurrence of various food items recorded from jackal scats (n = 155) at Point Calimere Wildlife Sanctuary.

	Prey item scientific name (common name)	Percent frequency (mean ±SE)
	Mammals	**82.5 ± 3.05**
1	*Antilope cervicapra* (Blackbuck)	20.0 ± 3.22
2	*Axis axis* (Chital)	11.6 ± 2.58
3	*Lepus nigricollis* (Black-naped Hare)	28.4 ± 3.63
4	*Rattus rattus* (House Rat)	9.7 ± 2.38
5	*Sus scrofa* (Wild Boar)	8.4 ± 2.23
6	*Macaca radiata* (Bonnet Macaque)	3.9 ± 1.55
7	*Bos taurus* (Cattle)	4.5 ± 1.67
	Birds	**25.1 ± 3.49**
8	*Francolinus pondicerianus* (Grey Francolin)	3.2 ± 1.42
9	*Vanellus indicus* (Red-wattled Lapwing)	5.2 ± 1.78
10	*Bubulcus ibis* (Cattle Egret)	4.5 ± 1.67
11	*Ardea alba* (Great Egret)	5.2 ± 1.78
12	*Egretta garzetta* (Little Egret)	3.2 ± 1.42
13	*Spilopelia chinensis* (Spotted Dove)	3.9 ± 1.55
	Invertebrate	**15.4 ± 2.91**
14	Beetle (Coleoptera)	11.6 ± 2.58
15	*Pleurroncodes planipes* (Red Crab)	4.5 ± 1.67
	Plant materials	**32.2 ± 3.76**
16	*Hugonia mystax* (Fruits)	5.2 ± 1.78
17	*Manilkara hexandra* (Fruits)	6.5 ± 1.97
18	*Prosophis julifera* (Leaves)	12.3 ± 2.64
19	*Cloris parpata* (Grass)	11.6 ± 2.58
	Unidentified	1.9 ± 1.11

unlike the western and northern parts, where the dry-evergreen habitat predominant.

Overall diet composition

In total, analyses of 155 scats revealed that the jackals' diet comprised 19 different food items including seven species of mammals, six of birds, one each of insect and invertebrate, and four of plants (Table 1). Of the 19 food items, Black-naped Hare and Blackbuck were the most frequent items in ≥20% of the scats collected. The other important items include Chital, and coleopteran insects formed over 10% of the scats indicating the importance of their contribution to jackals' diet. Food items such as leaves of *Cloris parpata* grass and *Prosopis juliflora,* are more likely unintentional consumption, as these are likely ingested along with meat in grasslands or under *Prosopis* cover, as dry leaves stuck to the meat being consumed. Of the five major groups of prey, the contribution of mammalian prey was the highest (53%) followed by plant materials (20%), birds (16%), invertebrates (10%), and unidentified category (1%).

Diet composition between seasons

The diet composition of jackals also varied between the winter and summer. For example, the jackal preyed upon birds significantly more during winter (36%) than during summer (18%) (Man-Whitney-U = 2377.5, p = 0.01) (Figure 2) and all other taxa such as mammals (Man-Whitney-U = 2850.5, p = 0.754), invertebrates (Man-Whitney-U = 2744, p = 0.330), plants (Man-Whitney-U = 2637, p = 0.220), and unidentified (Man-Whitney-U = 2893.5, p = 0.778) appeared in the diet between the two

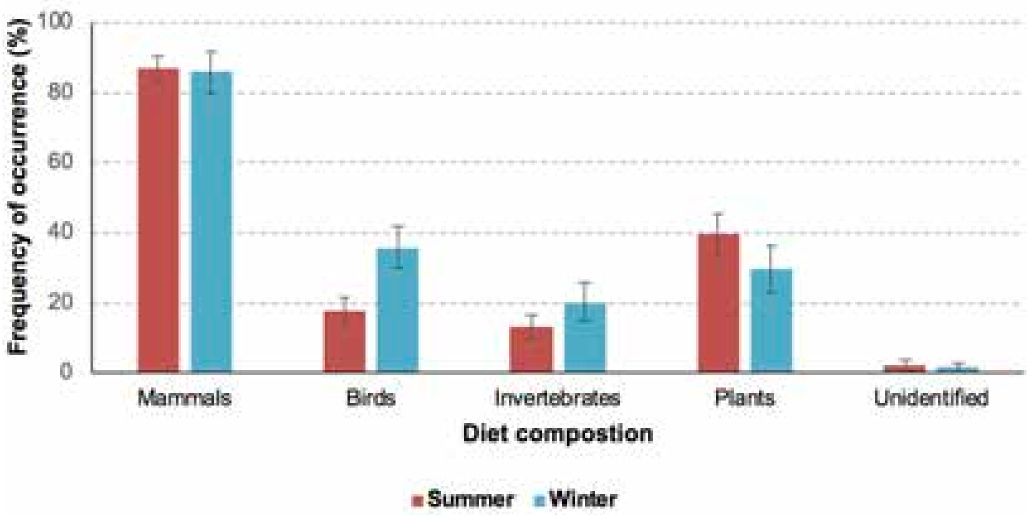

Figure 2. Percent frequency occurrence of various food items identified from Golden Jackal scats in different season at Point Calimere Wildlife Sanctuary between December 2013 and June 2014.

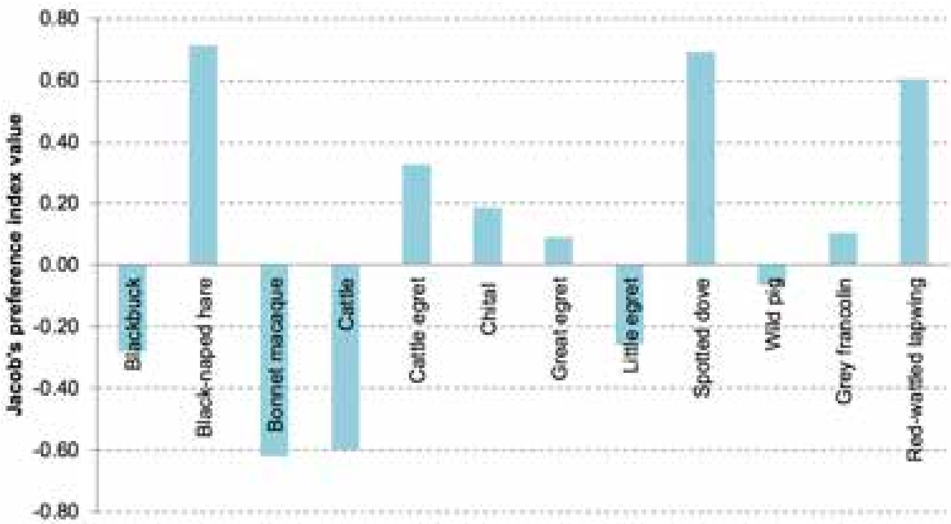

Figure 3. Food preference of the Golden Jackal at Point Calimere Wildlife Sanctuary recorded between December 2013 and June 2014.

Table 2. Prey availability (abundance estimate) and prey use (% frequency occurrence in diet) data to calculate the food preference by the jackal (*due to inadequate sample size instead of density encounter rate arrived; - indicates that abundance data unavailable).

Prey items (scientific name)	Prey species (mean ± SE)	
	Availability (Density/km²)	Use (% frequency in the scat)
Mammals		
Antilope cervicapra	50.2 ± 4.79	20.0 ± 3.22
Axis axis	9.3 ± 2.06	11.6 ± 2.58
Lepus nigricollis	6.2 ±1.18	28.4 ± 3.63
Rattus rattus	-	9.7 ± 2.38
Sus scrofa	14.7±1.86	8.4 ± 2.23
Macaca radiata	34.1±6.67	3.9 ± 1.55
Bos taurus	45.1 ± 6.89	4.5 ± 1.67
Birds		
Francolinus pondicerianus	-	3.2 ± 1.42
Vanellus indicus	-	5.2 ± 1.78
Bubulcus ibis	0.1±0.04*	4.5 ± 1.67
Egretta garzetta	0.2±0.07*	5.2 ± 1.78
Ardea alba	0.2±0.06*	3.2 ± 1.42
Spilopelia chinensis	0.01 ±0.013*	3.9 ± 1.55
Invertebrate		
Insect: Beetle (Coleoptera)	-	11.6 ± 2.58
Red Crab (*Pleurroncodes planipes*)	-	4.5 ± 1.67
Plant materials		
Hugonia mystax (Fruits)	-	5.2 ± 1.78
Manilkara hexandra (Fruits)	-	6.5 ± 1.97
Prosophis julifera (Leaves)	-	12.3 ± 2.64
Cloris parpata (Grass)	-	11.6 ± 2.58
Unidentified	-	1.9 ± 1.11

seasons with similar frequency.

Food preference

Of the 19 food items identified in the jackal's diet, abundance data could be obtained for 12 items only (Table 2). Of these 12 items, Black-naped Hare, Spotted Dove and Red-wattled Lapwing were the most preferred items followed by Cattle Egret, Chital, Grey Francolin, and Large Egret (Figure 3). Although the sanctuary has more biomass of Blackbuck and cattle, jackals did not prefer them.

DISCUSSION

Distribution pattern of the jackal

The present study showed that the distribution of jackal, though not restricted, was uniform in the eastern and southern parts of the sanctuary, where large areas fall under open grasslands and mudflat. The western and northern parts predominantly have tropical dry-evergreen forests, where the jackal sightings and signs were found to be patchy, indicating that this habitat was used relatively lesser than the grassland habitat. This could be an appropriate strategy to optimally use the dry-evergreen habitat, which harbours the food species patchily including fruit bearing trees. Detections of jackals and their signs, however, were likely to be lower in forested habitats, which could also be a reason for the observed higher use of more open habitats. Food availability is one of the most important factors affecting the behaviour, ecology, and evolution of animals. Prey species distribution and their abundance influence the predators' life-history traits like growth, reproduction, and survival (Bilde & Toft 1998; Karanth et al. 2004). Therefore, the prey availability could influence the ecological traits of the predator including movement, distribution patterns and habitat selection (Pyke et al. 1977; Gittleman & Harvey 1982). The reason for the uniform distribution of jackals along open grassland habitat and patchy distribution in dry-evergreen habitat could be the function of its prey distribution. As shown by the diet composition data, Black-naped Hare and Blackbuck, which occupy open grasslands, were the two major prey species that contributed nearly 50% to the jackals' overall diet. Similarly, the jackal's frequent movement in mud-flat habitats could also be due to their dependence on crab and shore birds. The species being omnivorous with a flexible social system can adapt to wide range habitats from Thar Desert of Rajasthan, India to the evergreen forests of Myanmar and Thailand as well as from mangrove to rural and semi-urban human-agro-ecosystems (Clutton-Brock et al. 1976; Poche et al. 1987). In the present study area, however, with its principal diet of Black-naped Hare and Blackbuck being mostly found in the open habitats, it might use the open habitat more uniformly over the wooded forest that is used patchily.

Diet composition

Diet composition identified based on 103 scats analyses revealed that jackals' diet comprised 19 different food items ranging widely from mammals, birds to invertebrates, such as insects and plant part like fruits. Jackal being an omnivorous and opportunistic forager in nature feed on a wide variety of foods that vary in space and time. In Bharatpur, northern India, rodents, birds, and fruit comprise the major bulk (Sankar 1988), and similarly in Kanha, over 80% of the diet comprises rodents, reptiles, and fruit (Schaller 1967). The reason for jackals not depending much on rodents could be the variation in prey availability between the areas. It is likely that the rodent density is lesser in the present study area compared to Bharatpur and Kanha or Black-naped Hare that served as the principal diet of the jackal in the present study area are more abundant in the study area as compared to the other places in India. Besides the above reasons, the difference in study duration and season could also contribute to variation in diet composition between areas. Also, the fact that the rodents being smaller in size compared to Black-naped Hare, given a choice of similar density, the jackal might prefer the Black-naped Hare as it is more optimal. On the other hand, Blackbuck, an ungulate, being much larger than the Black-naped Hare and also with a higher biomass in the study area has not been noticed in the diet as much as the Black-naped Hare, and this may be a trade-off, as the prey is much larger than the predator, and hunting Blackbuck could be more expensive, as it may not able to bring down the prey easily. Nevertheless, the occasional appearance of Blackbuck in the diet of the jackal may be of young ones or calf. Since Blackbucks hide their calves, the jackal hunts them (Jethva & Jhala 2004; Aiyadurai & Jhala 2006).

Of the 19 food items, Black-naped Hare and Blackbuck were the most frequent food items of jackals' diet that appeared in more than 20% of the scats collected during the period. The other important food items include the Red Crab *Pleurroncodes planipes* and coleopteran insects appeared in over 10% of the scats indicating the importance of their contribution to the jackals' diet. Of the five major groups of prey items that constituted the diet of the jackal, mammalian prey contribution was the highest followed by plant materials, birds, insects and invertebrates. Similar to the present study, mammalian species contribution is the most dominant elsewhere in India: in Bhal region, Gujarat (Aiyadurai & Jhala 2006), Pench Tiger Reserve (Majumder et al. 2011), in Sariska Tiger Reserve, India (Chourasia et al. 2012), and abroad; Isreal (Barkowski & Manor 2011), Peljesac Peninsula (Radovic & Darkokovacic 2010). In Hungary, central Europe, the Golden Jackals feed predominantly on animal matter especially small mammals and to a lesser extent on plant matter (Lanszki et al. 2006).

The contribution of plant matter, especially fruit, to the overall diet was lesser in the present study compared to other studies (Kotwal et al. 1991; Gupta 2006). Unlike the present study, greater quantities of vegetable matter are found in the diet of the jackal; during the fruiting season, jackals feed intensively on the fallen fruits of *Ziziphus* sp., *Syzigium cuminii,* and pods of *Prosopis juliflora* and *Cassia fistula* (Kotwal et al. 1991; Gupta 2006). Contrarily, lower proportion of plant matter especially the fruits recorded in the present study could be attributed to the absence of palatable fruit plants in fruiting condition.

Temporal difference in diet composition

The study showed that birds formed the diet of jackal significantly more during winter than in summer. As the present study area is one among the 467 Important Bird Areas of India and one among the 26 RAMSAR sites of India (http://wiienvis.nic.in/Database/IBA_8463.aspx) and also attracts very diverse range of bird species including the migratory water birds in high density during winter than in summer. Therefore, the higher proportion of birds in the diet of jackal coincides with migratory season of water birds in the study area and such shift in diet composition could be a function of optimal foraging (Pyke et al. 1977). The results further indicate the opportunistic foraging and hunting nature of the species, which in turn helps the species to use the heterogenous environment of the study area.

Prey preference

Among the 10 food items available (compared with usage), Black-naped Hare and Spotted Dove were the most preferred diet items followed by Chital, Cattle Egret and Great Egret. Although, the sanctuary has higher number or biomass of Blackbuck and cattle, the jackal did not prefer these species as its principal diet. As discussed earlier, given its smaller size in comparison to blackbuck, it may not be possible for the jackal to bring down the well-grown Blackbuck and thus, it may not be an optimal choice. It may, however, be comparatively easier for the jackals to hunt on the offspring or calf of Blackbuck, which are left behind by females in dense bushes, while going for grazing. During the peak calving time of Blackbuck in Velavadar National Park, India, jackals were observed searching for hiding calves throughout the day with search intensifying during the early morning and late evening (Jhala & Moehlman 2004; Aiyadurai & Jhala 2006). In addition, therefore, the low proportion of blackbuck and cattle in the diet of jackal could be due to the jackal's smaller size. Apart from Black-naped Hare, the jackal also showed preference to Chital, whose population is relatively small in the area.

Conclusions and recommendations

The Golden Jackal population found at Point Calimere Wildlife Sanctuary seems to be a healthy one, although the present study was unable to estimate population given the crepuscular nature of the species. The species is distributed uniformly in the grasslands and patchily in the tropical dry-evergreen habitats. Its ability to exploit a wide spectrum of food, ranges from mammals, birds, invertebrates to plants, which changes temporally, enabling the species to use all the habitats available in the study area. Being the only large-sized carnivore of the sanctuary, effective management of the Golden Jackal is essential for the dynamics of the ecosystem as a predator and may also act as seed disperser, as reported elsewhere and thus, we suggest a long-term study to understand the species ecology and their role in maintaining the ecosystem.

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PLATINUM OPEN ACCESS

COMMUNICATION

Suppression of ovarian activity in a captive African Lion *Panthera leo* after deslorelin treatment

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Abstract: With the intent to evaluate the efficiency of a contraceptive treatment for cyclic ovarian suppression in African Lionesses *Panthera leo* using a Gonadotrophin-Releasing Hormone (GnRH) agonist bioimplant, noninvasive fecal steroid assay associated with the observation of the behavioral estrus were employed for a period of 36 months. Five captive adult females, maintained with a vasectomized male, subcutaneously received a 9.4mg deslorelin acetate implant. The treatment initially stimulated behavioral estrus along with ovarian activity, demonstrated by an estrogen increase in two lionesses. A rise in progesterone concentration in two other animals suggested possible treatment-induced ovulation. After the initial period, deslorelin prevented ovarian activity for at least 22 months. Two females exhibited signs of behavioral estrus after 22 and 31 months. A third lioness with an increased estrogen concentration did not exhibit behavioral estrus signs or a consequent progesterone surge until 33 months after implantation, suggesting a possible resumption of ovarian activity. One female did not exhibit any behavioral estrus signs nor a rise in steroid levels after the "treatment-induced" estrus throughout the entire experiment (36 months). One lioness died after 15 months without exhibiting signs of estrus or an increased progesterone level, however, the estrogen concentration increased 12 months post-implantation, suggesting resumed ovarian activity. The study showed that long-term treatment with a GnRH agonist can be extremely effective as a contraceptive treatment in African lionesses, however, the duration of contraception may vary among individuals and may bear the risk of permanent loss of normal ovarian activity.

Keywords: African Lion, contraception, estrus behavior, fecal assay, GnRH agonist.

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FMVZ USP UFMT FAPESP REPROCON

INTRODUCTION

The reproduction of wild animals in captivity is an important tool for ex situ conservation of endangered species (Jorge Neto et al. 2018b). Some species such as the African Lion *Panthera leo*, however, can adapt to captivity, and thus, are capable of reproducing in such an environment. The abundant reproduction of large carnivores is associated with low adult mortality and increased longevity in captivity. This creates a number of complications as the physical space and financial resources available for their maintenance is limited (Woodroffe & Frank 2005).

The objective of the present study was to use the noninvasive fecal steroid assay associated with behavioral estrus to evaluate the efficiency of chronic treatments with the Gonadotrophin-Releasing Hormone (GnRH) agonist bioimplants to suppress cyclic ovarian activity in African Lionesses.

MATERIALS AND METHODS

Experimental Design

Five adult African Lionesses (L1, L2, L3, L4 and L5) were maintained in captivity with a vasectomized male at the Zoological Park of São Paulo. All females had at least one confirmed pregnancy with a live birth, and none of them had been previously submitted to any kind of contraceptive management, except for physical separation from male lions and time with vasectomized males. L1 (13 years old), L2 (6 y/o) and L4 (6 y/o) were born in the São Paulo Zoo, while L3 (7 y/o) and L5 (7 y/o) came from another captive facility when they were six months old.

The five lionesses received a 9.4mg deslorelin acetate implant subcutaneously. The efficiency of the implant as a contraceptive was evaluated non-invasively using a fecal steroid assay and through observation of the behavioral estrus. The study was approved by the University's Ethics Committee for Use of Animals in Research (CEUAVET-USP).

Gonadotrophin-Releasing Hormone Agonist Bioimplant Formulation and Implantation

The GnRH agonist bioimplants used in the present experiments were supplied by Peptech Animal Health Pty Limited, Australia (Suprelorin 9.4 mg; No. 978; Batch DR023). Each implant contained 9.4mg of GnRH agonist deslorelin acetate ($C_{64}H_{83}N_{17}O_{12}$). Implants were placed subcutaneously under aseptic conditions using a commercial implanting device.

Sample Collection, Hormone Extraction, and Dosage

During the experiment, two fecal samples were collected twice weekly, sealed in plastic bags, labeled with the individual's name/date, and stored at -20°C. From 45 days before to 36 months after implant, fecal aliquots were extracted to quantify estrogen and progestogen metabolites. Fecal hormone metabolites were extracted from the samples, as previously described (Brown et al. 1994). Briefly, each fecal sample was lyophilized, pulverized, and 0.18–0.2 g of dry fecal powder was boiled in 5mL of 90% ethanol for 20min. During boiling, 100% ethanol was added as needed, to maintain approximate pre-boil volumes.

After centrifugation (500g, 20min.), the supernatant was recovered, and the pellet re-suspended in 5mL of 90% ethanol, vortexed for 30 sec, and re-centrifuged (500g, 15min.). The first and second supernatants were combined, air dried, and reconstituted in 1mL methanol. Methanol extracts were vortexed briefly and placed in a sonicator for 15min. Each extract was diluted 1:10 in a steroid dilution buffer and stored in polypropylene tubes at -20°C until further use.

Subsequently, each sample extract was assayed for estradiol and progesterone metabolites following RIA. Estradiol Coat-a-Count RIA kits (Diagnostic Products, Los Angeles, CA, USA) were used to measure the estradiol metabolites, while Progesterone DSL-3900® RIA kits (Diagnostic System Laboratories Inc., Webster, USA) were used to measure the progesterone metabolites. Samples were analyzed in duplicate, and those with a coefficient variation of more than 15% were either re-analyzed (if there was enough sample volume for re-analysis) or discarded.

Estrus Behavior Observation

Animals were observed for 30 min periods twice each day (during the morning and the afternoon), three times a week. The following estrus behavioral patterns were recorded (Schaller 1972): vocalization, restlessness, increased frequency and intensity of rolling, lordosis, male attraction, mating acceptance, and copulation.

RESULTS

Before implant placements, all animals had normal ovarian activity, as confirmed by fecal hormone metabolites dosages (figs. 1–5) and behavioral estrus signs, such as vocalization, restlessness, increased

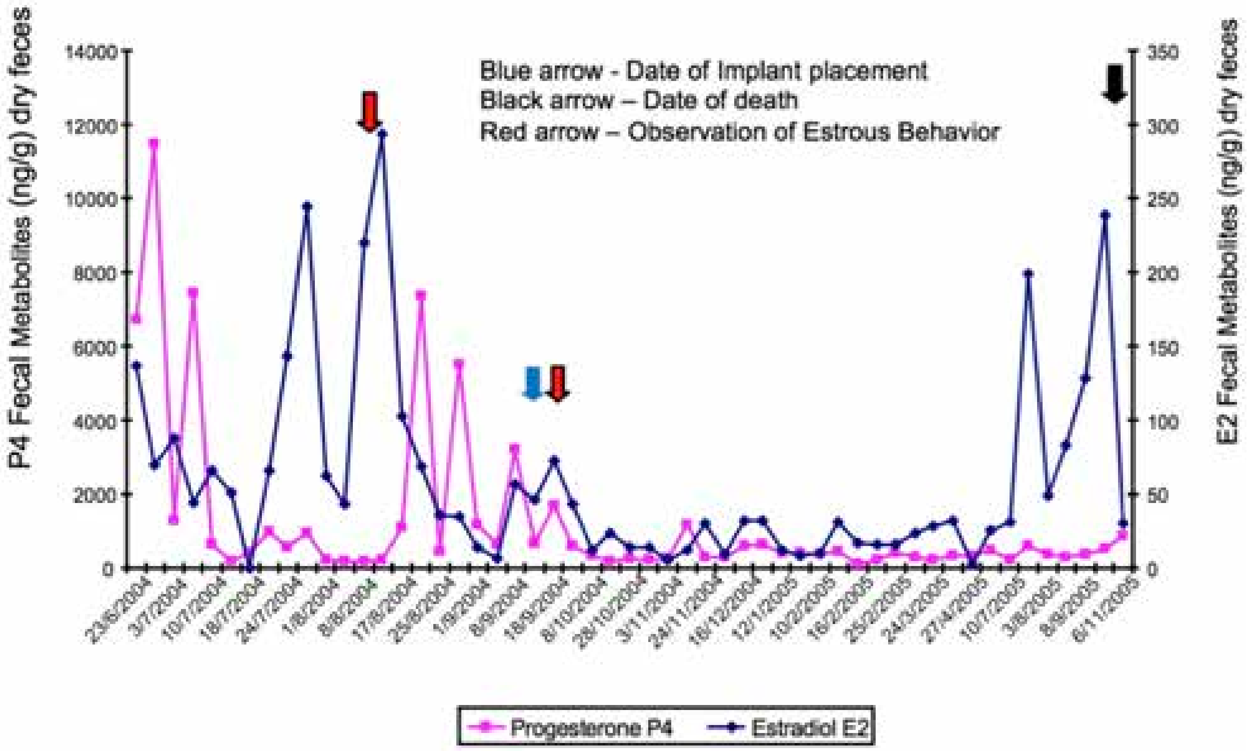

Figure 1. Fecal steroid metabolites profile of the lioness L1 (*Panthera leo*). Blue arrow—date of Implant placement | Black arrow—date of death | Red arrow—observation of estrous behavior.

Table 1. Rise in fecal steroids concentration and/or estrus behavior shortly after implant placements, and period of contraception in African lions treated long-term with GnRH agonist (deslorelin).

Lioness	Estrus behavior shortly after implantation	Rise in fecal progesterone shortly after implantation	Rise in fecal estrogen after downregulation	Estrus behavior after downregulation	Rise in fecal progesterone after downregulation
L1	Yes	No	12 months	Not observed*	Not observed *
L2	No	Yes	No	22 months	Not observed**
L3	Yes	No	No	31 months	Not observed**
L4	No	No	No	33 months	33 months
L5	No	Yes	No	Not observed**	Not observed**

frequency and intensity of rolling, lordosis, male attraction, mating acceptance, and copulation. The average estrus length was 5.8 ± 2.2 days. Treatment with deslorelin initially stimulated a behavioral estrus along with ovarian activity, as demonstrated by increases in the estrogen concentration in two lionesses (L1 and L3, Figs. 1 and 3). We also noted a rise in progesterone concentration in two other females (L2 and L5, Figs. 2 and 5), which suggests possible treatment-induced ovulation (Table 1). After this period, the GnRH agonist prevented ovarian activity for at least 22 months.

Two lionesses exhibited behavioral estrus signs 22 and 31 months after implantation, respectively (L2 and L3, Figs. 2 and 3, respectively). In a third lioness (L4, Fig. 4), behavioral estrus signs and increases in estrogen concentration, as well as a consequent surge in progesterone level was noted 33 months after implant use. The lioness L5 (Fig. 5) did not exhibit any signs of behavioral estrus. Moreover, she only experienced a rise in female sex steroids levels (estrogen and progesterone) after the "treatment-induced" estrus the end of the experiment (36 months). The lioness L1 (Fig. 1) died 15 months after experiment initiation, without demonstrating any estrus signs, nor a rise in progesterone level, however, her estrogen concentration increased 12 months after the placed implant (Table 1).

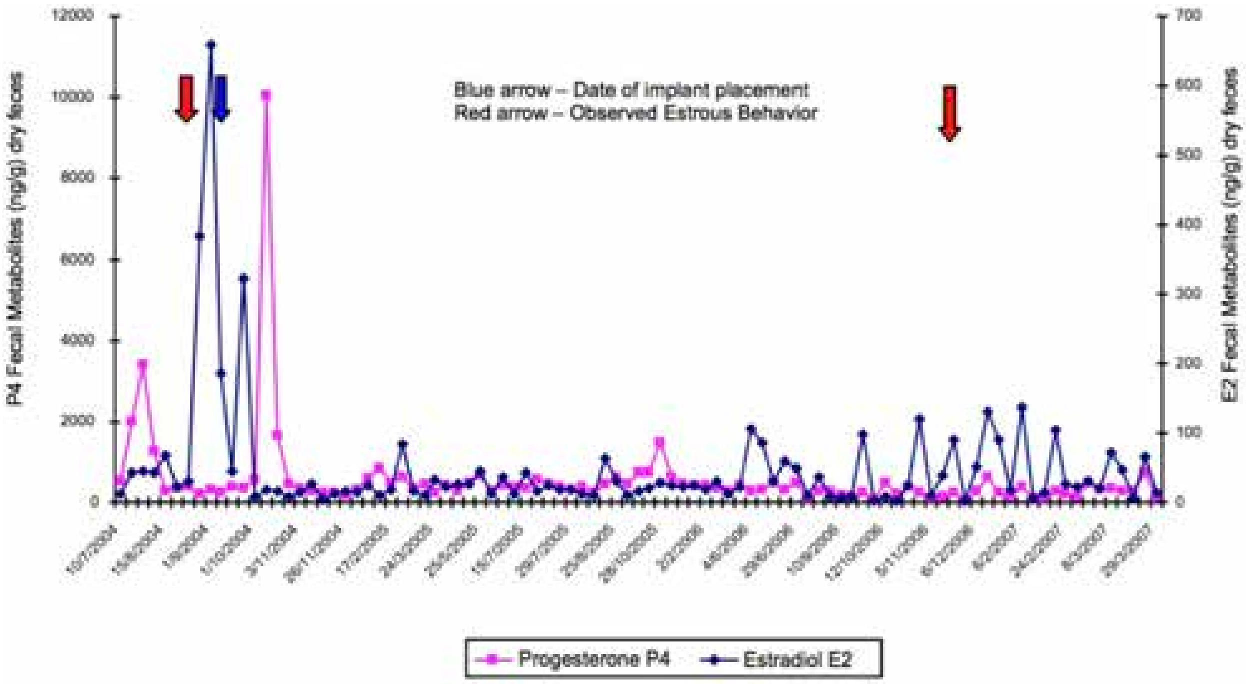

Figure 2. Fecal steroid metabolites profile of the lioness L2 (Panthera leo). Blue arrow—date of implant placement | red arrow—observed estrous behavior.

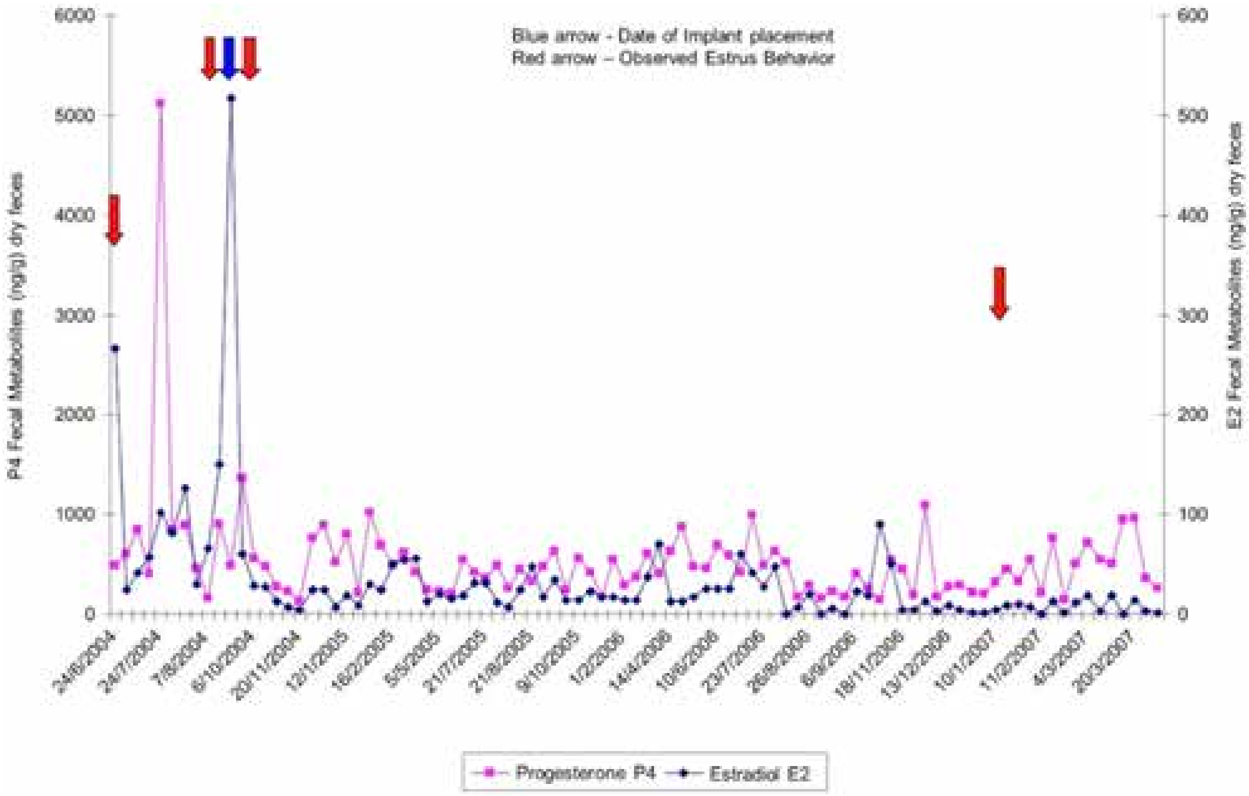

Figure 3. Fecal steroid metabolites profile of the lioness L3 (Panthera leo). Blue arrow—date of implant placement | red arrow—observed estrous behavior.

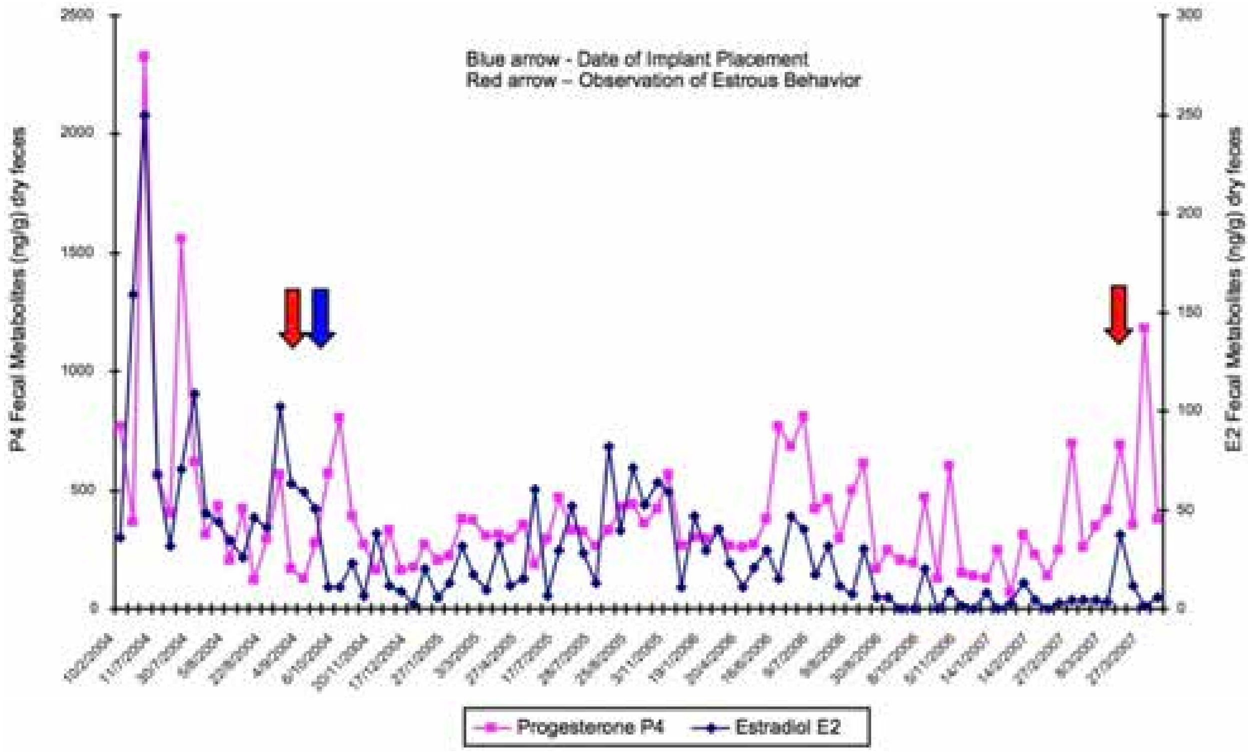

Figure 4. Fecal steroid metabolites profile of the lioness L4 (Panthera leo). Blue arrow—date of implant placement | red arrow—observation of estrous behavior.

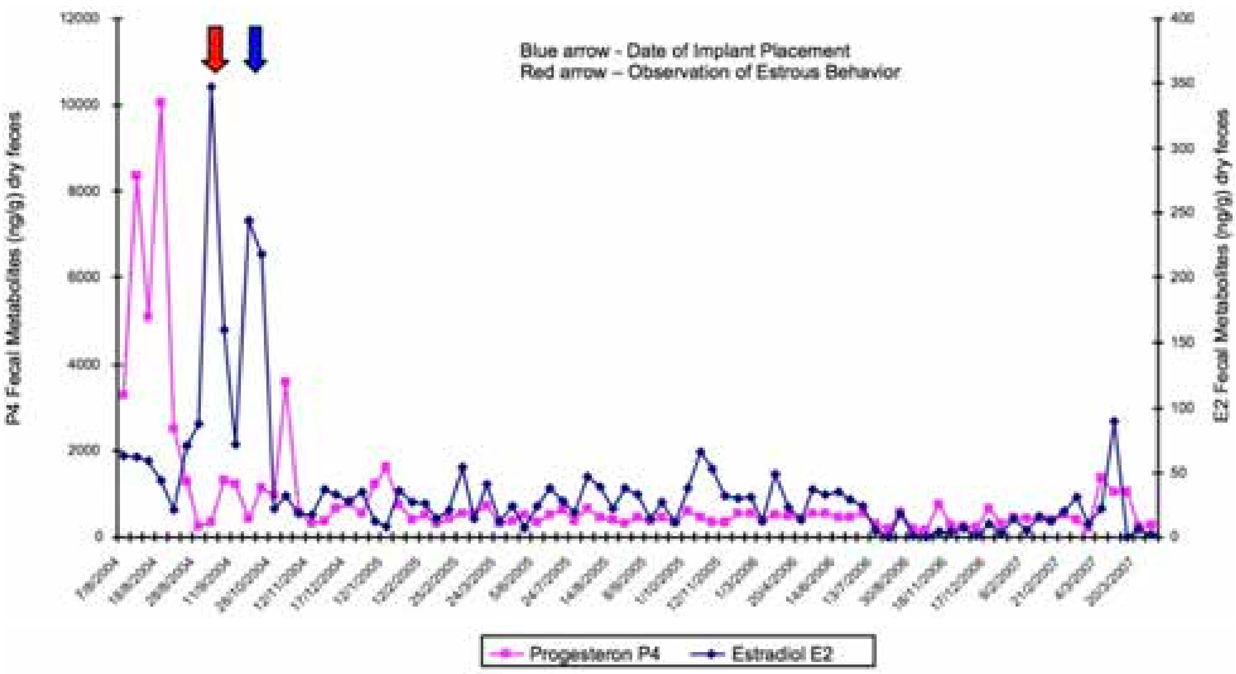

Figure 5. Fecal steroid metabolites profile of the lioness L5 (Panthera leo). Blue arrow—date of implant placement | red arrow—observation of estrous behavior.

DISCUSSION

In the face of the large loss of habitat due to human encroachment and fragmentation, some species become overabundant through human ineptitude. Indeed, humans often attempt to create conditions that favor the proliferation of one species over their competitors. Protected parks and reserves provide animals with an environment that is abundant in resources and predator-free, conditions that allow for unchecked reproduction. As a result, endangered species undergo a localized population explosion that can have detrimental effects on the flora and fauna of the reserve, putting other species at risk; thus, affecting the ecosystem in the same manner as do invasive species (Grandy & Rutberg 2002; Jewgenow et al. 2006).

Wildlife population control by means of contraception has become extremely important, especially for a number of wild carnivores. Population management and alternative noninvasive contraceptive methods have been studied extensively over the last two decades (Rosenfield 2016). Whereas ovariohysterectomy or ovariectomy alone has been the method of choice for most domestic cats (Munson 2006), for reproductive management of threatened or endangered species like the African Lion, a reversible method is desired. While lions can reach high densities inside reserves (Packer et al. 2013), they tend to fare poorly outside protected areas, where they are often the first large carnivore species to disappear (Woodroffe 2001).

The GnRH analog deslorelin, a long-acting biocompatible subcutaneous implant that suppresses specific pituitary functions, has been recommended as reversible contraception (D'Occhio et al. 2002). The increased release of GnRH into the portal vessels which connect the hypophysis to the pituitary gland results in an increased secretion of the follicle stimulating hormone (FSH) and luteinizing hormone (LH), which, in turn, regulate gonadal functions (Conn & Crowley 1994). With continuous exposure to high concentrations of GnRH, the number of cell surface receptors at the portion of the adenohypophysis – responsible for FSH/LH synthesis and release – gradually decreases (Melson et al. 1986) with a concomitant desensibilization effect of gonadotroph cells on GnRH (D'Occhio & Kinder 1995). By this type of mechanism, known as receptor down-regulation, chronic treatment with a GnRH agonist prevents the pulsatile release of FSH, as well as LH (Gong et al. 1995) and the pre-ovulatory surge of LH secretion (D'Occhio & Kinder 1995).

The absence of surge-releases of LH in females treated with a GnRH agonist have led to studies being conducted on the potential long-acting contraceptive effects of the GnRH agonist bioimplant by preventing follicular development and ovulation, and consequently, pregnancies (D'Occhio & Kinder 1995). In addition, the development of a noninvasive fecal steroid assay for assessing the ovarian function of felid species in combination with behavioral studies makes it possible to systematically study various aspects of reproduction (Brown et al. 1994, 2001; Graham et al. 2006). Therefore, the goal of the present study is to use the noninvasive fecal steroid assay associated with behavioral estrus to evaluate the efficiency of chronic treatments with the GnRH agonist bioimplants to suppress cyclic ovarian activity in African lionesses.

The inhibitory effects of ovarian activities, such as the arrest of ovulation caused by desensibilization to endogenous GnRH, provide opportunities to evaluate a GnRH agonist bioimplant as a potential antifertility agent in mammals. In the present experiment, seven lionesses were implanted with a 9.4 mg deslorelin to monitor ovarian function for 36 months. Fecal steroid assay and estrus behavioral observation were the monitoring methods used. Our findings suggest that the GnRH agonist deslorelin suppresses ovarian activity in African lionesses for prolonged periods of time. In fact, no behavioral estrus was noted until 22 months post-implantation. In the 22nd, 31st, and 33rd month, behavioral estrus was noted in three of the lionesses, while the fourth lioness exhibited increased estrogen concentrations and a consequent surge in progesterone level that corresponded to the resumption of ovarian activity, including ovulation, in addition to behavioral estrus.

One lioness died 15 months after the beginning of the experiment without demonstrating any estrus signs nor a rise in progesterone level. On the other hand, the estrogen concentration increased 12 months after the implantation, indicating that the ovarian activity may have re-started. Surprisingly, in a single female, neither estrus behavior nor a rise in fecal progesterone concentration was noted up to the end of the experiment.

Various behavioral activities that characterize estrus in lions appear to be common in several feline species, such as the domestic cat (Graham et al. 2000; Pelican et al. 2005), Jaguar (Wildt et al. 1979; Jorge-Neto et al. 2018a), Siberian Tiger (Seal et al. 1987), Snow Leopard (Schmidt et al. 1993), and Cheetah (Wielebnowski & Brown 1998), possibly serving as indicators of physiological estrus in these animals (Umapathy et al. 2007). It, however, remains unclear why behavioral estrus was observed in two of the lionesses without a rise in fecal estrogen and progesterone metabolites concentration. Ovulation in *Panthera* genus species is triggered by copulation or sensorial stimulation (Jorge-Neto et al. 2020). Therefore, the lack of ovulation observed during this study may demonstrate a estrus detection failure or a compromised ovarian function. It could also be hypothesized that, in these cases, ovarian activity may have re-started and estradiol concentration increased, resulting in the stimulation of behavioral estrus, although, not enough to trigger the cascade of events to reach ovulation.

The fact that neither estrus behavior nor a rise in fecal progesterone concentration was noted in one of the lionesses up to the end of the experiment raises concern. For contraception to be successful for population control, especially in endangered animals, it must not only be safe, effective, and long-acting but also reversible (Castle & Dean 1996).

To date, deslorelin has been used in captive-held wild felines, such as cheetahs (Bertschinger et al. 2001), leopards (Bertschinger et al. 2002) and lions (Bertschinger et al. 2008), without showing any adverse effects. Conversely, in domestic cats, a 6mg implant has been shown to suppress ovarian follicular activity for between four and 14 months, however, until the end of the study period, eight out of ten cats did not fully return to normal ovarian cyclicity (Munson et al. 2001). Moreover, dosages of 12 or 15 mg deslorelin induced contraceptive effects for 12–18 months (Bertschinger et al. 2002). The implant used in this study (9.4mg) has a matrix without sodium acetate anhydrous, that allows slow liberation of the deslorelin, maintaining contraceptive effects for much longer periods, making it impossible to compare the effectiveness of this dosage in relation to the duration of previous products. It has been reported that the effectiveness duration of Suprelorin in wild felids is, on average, twice that prescribed by the manufacturer in dogs, which means that the 9.4mg implant with a minimum effectiveness of 12 months is generally effective for approximately 24 months (Asa et al. 2012). Our findings show a ceasing of ovarian activity of 28.67 ± 5.86 months, which corroborates those found by Bertschinger et al. (2008), in which implants were effectively in lionesses for a period of ~30 months or longer. The reversal time (or duration of efficacy) is variable between species and individuals, probably due to the singularity in the metabolism of deslorelin or the ability to recover from down-regulation (Asa et al. 2012). The findings suggest that long-term treatment with deslorelin may have variability regarding the duration of contraception among individuals due to several factors, including drug/matrix used; genetic and/or environmental influences. The disadvantage of using Suprelorin is the inability to safely predict the duration of effectiveness and the return of ovarian activity, being a problem when there is interest in using these females in conservation programs.

An extensive study using 140 implants (Suprelorin) on 14 species of wild felids, including 59 lionesses, was conducted by the North American Association of Zoos and Aquariums (AZA) and showed no side effects of deslorelin treatment (Asa et al. 2012). Bertschinger et al. (2008) used deslorelin treatment in 23 captive and 40 free-ranging lionesses (*P. leo*) and four captive tigers (*P. tigris*) in South Africa and did not observe any side effects in any females, including some treated four or five times for 5–8 years period. In domestic cat females the use of Suprelorin appears to be a convenient, efficient and safe contraception method, demonstrating female fertile matting after approximately two years post-treatment and no side effects (Fontaine 2015).

Prior to the occurrence of a GnRH agonist antifertility effect, there is an acute phase (D'Occhio et al. 2002; Rosenfield 2016) in which the secretion of LH and FSH increase sharply (Gong et al. 1995, 1996), leading to a corresponding estrus response (Wright et al. 2001). In the present study, shortly after placing the implant, two lionesses exhibited behavioral estrus, and an upsurge of ovarian activity was observed, as demonstrated by increases in the estrogen concentration. A rise in progesterone concentration was noted in two other females. As noted, the treatment-induced behavioral estrus signs without the accompanying rise in progesterone, observed in the first two females could be attributed to a copulation failure rather than compromised ovarian function. As reported in other works, after an initial GnRH treatment, lionesses and cheetahs may exhibit signs of estrus behavior and become attracted to males for a few days, although mating may not occur (Bertschinger et al. 2002).

Conversely, in animals in which a rise in progesterone concentration was noted but no behavioral estrus signs could be observed, a failure in observing estrus signs, a spontaneous ovulation – or sensorial stimuli štriggering ovulation – may have occurred. Spontaneous ovulation has been previously reported in some felines including all *Panthera* species, such as the Leopard (Schmidt et al. 1988), Snow Leopard (Brown et al. 1995), Tiger (Graham et al. 2006), Jaguar (Barnes et al. 2016; Gonzalez et al. 2017) and African Lion (Schramm et al. 1994) while sensorial stimulation has induced ovulation in Jaguars (Jorge-Neto et al. 2020). In one lioness, shortly after placing the implant, no behavioral estrus signs were observed, nor was there a rise in progesterone levels. This may be due to the presence of active luteal tissue from a previous follicular cycle and/or due to individual variations.

Our results reinforce the importance of using non-invasive monitoring as an alternative for hormonal assessment, especially in wild animals. Blood collection is not only a stressful event and can itself cause changes in hormonal concentrations (Sheriff et al. 2011), but also does not allow successive collections for longer studies, such as monitoring of ovarian cyclicity (Sgai et al. 2015). Many studies in several species have been developed and validated for the longitudinal measurement of hormonal metabolites, both for glucocorticoids (Sinhorini et al. 2020) and steroids, enabling effective reproductive monitoring with fecal matrix (Monfort et al. 1997; Van Meter et al. 2008). These studies demonstrated efficient results without the need to perform a serum endocrine evaluation.

In conclusion, long-term treatment with a GnRH agonist has been shown to be extremely effective in inhibiting the synthesis and liberation of FSH and LH from the pituitary, and as a result, ceasing ovarian activity in female African lions for 28.67 ± 5.86 months. The duration of contraception, however, may vary among individuals, with the added risk of some females not returning to normal ovarian activity, rendering that female infertile. It is strongly suggested that further studies investigate the long-term antifertility effects of GnRH agonists in this species.

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Resumo: Com o objetivo de avaliar a eficiência de um tratamento contraceptivo para a supressão cíclica ovariana em leoas africanas (*Panthera leo*) usando um bioimplante com agonista GnRH, foram utilizados ensaios não invasivos de esteroides fecais associados à observação de comportamento estral pelo período de 36 meses. Cinco fêmeas adultas em cativeiro, mantidas com um macho vasectomizado, receberam subcutaneamente um implante de 9,4mg de acetato de deslorelina. O tratamento inicialmente estimulou o comportamento estral, juntamente com a atividade ovariana, demonstrada pelo aumento de estrogênio em duas leoas. Um aumento na concentração de progesterona em outros dois animais sugeriu uma possível ovulação induzida pelo tratamento. Após o período inicial, a deslorelina impediu a atividade ovariana por pelo menos 22 meses. Duas fêmeas exibiram sinais de estro comportamental após 22 e 31 meses. Uma terceira leoa com aumento da concentração de estrogênio não apresentou sinais comportamentais de estro ou consequente aumento de progesterona até 33 meses após o implante, sugerindo uma possível retomada da atividade ovariana. Uma fêmea não exibiu nenhum sinal de estro comportamental nem um aumento nos níveis de esteroides após o estro "induzido pelo tratamento" durante todo o experimento (36 meses). Uma leoa morreu após 15 meses sem exibir sinais de estro ou um aumento no nível de progesterona. No entanto, a concentração de estrogênio aumentou 12 meses após o implante, sugerindo a retomada da atividade ovariana. O estudo mostrou que o tratamento a longo prazo com um agonista da GnRH pode ser extremamente eficaz como tratamento contraceptivo em leoas africanas; no entanto, a duração da contracepção pode variar entre os indivíduos e pode assumir o risco de perda permanente da atividade ovariana normal.

Author contributions: DPAF Braga, CS Pizzutto and MABV Guimarães conceived, designed, and directed the study. DPAF Braga, CS Pizzutto and PF Viau performed the experiments. SHR Correa, CA Oliveira, DPAF Braga, CS Pizzutto and MABV Guimarães analyzed and interpreted the data. DPAF Braga wrote the manuscript. CS Pizzutto, DA Rosenfield and PN Jorge-Neto critically revised the manuscript. All authors approved the manuscript for publication.

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COMMUNICATION

Spatial aggregation and specificity of incidents with wildlife make tea plantations in southern India potential buffers with protected areas

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Abstract: Many wildlife species survive in human-modified landscapes and understanding the opinions of those who share space with wildlife will aid conservation efforts. Using a questionnaire, we assessed the presence of 12 mammal species in 78 tea plantations in the Nilgiris, southern India. We obtained data on (i) plantation size, location, and elevation, (ii) species presence over a year, (iii) type and number of wildlife incidents caused, (iv) financial cost of wildlife damage, and (v) support for wildlife conservation. We used a generalized linear model to assess whether the distance to protected areas, elevation, and plantation size influenced species presence and the effect of these variables and wildlife incidents on support for conservation. Among all species reported, Bonnet Macaque, Wild Boar, and Porcupine were the most widespread, and the former two and the Gaur reportedly caused >50% of damages. Crop damage was the most frequent (74%, n = 244), whereas livestock predation, attacks on people, and infrastructure damage constituted <10% of incidents reported. The cost of wildlife damage was negligible for 72 estates and significant for six. The number of species increased with proximity to protected areas, with increasing elevation and plantation area. Plantation management (62%) supported wildlife conservation, and support increased with decreasing plantation size, increasing distance to protected areas, and with a higher number of species reported, but decreased with increasing incidents of wildlife damage. Mitigating impacts of a few widely distributed species that cause disproportionate damage and compensating those that incur disproportionately high costs could increase support for conservation. Education and awareness programs for the plantation community can further help increase support and participation in wildlife conservation activities. Plantations can thus serve as supplementary habitats for wildlife in regions where hard boundaries between protected areas and human settlements prevail.

Keywords: Conservation attitudes, human-wildlife coexistence, Nilgiri Biosphere Reserve, wildlife damage.

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For **Author details** & **Author contribution** see end of this article.

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INTRODUCTION

The transformation of terrestrial ecosystems into human use areas has driven global biodiversity loss (Vitousek et al. 1997; Johnson et al. 2017) and has forced many species into human-modified landscapes. Although protected areas (PA) safeguard remnant habitats and wildlife, the current global PA network which comprises 14.9% of Earth's land area (UNEP-WCMC et al. 2018) is inadequate for the long-term conservation of several species, particularly those that are wide-ranging (Woodroffe & Ginsberg 1998; Jenkins & Joppa 2009; Di Minin et al. 2016). On the other hand, certain human-modified landscapes such as coffee and tea plantations can provide refuge, foraging grounds, and enable wildlife movement between reserves (Bal et al. 2011; Rathod & Rathod 2013; Guzmán et al. 2016; Kumar et al. 2018). In landscapes that lack intact or protected forests, such plantations can provide supplemental habitats for wild animals (Bhagwat et al. 2008; Krishnan et al. 2019). The survival of many species, however, will ultimately depend on their ability to persist and be tolerated in human-modified landscapes.

Wild animals that are displaced by habitat loss and fragmentation may harm humans, their properties, and their livelihoods (Torres et al. 2018). For instance, in Cameroon, 12 different mammal species damaged cocoa pods in cocoa plantations (Arlet & Molleman 2010). In India, damage by Asian Elephants *Elephas maximus* to a variety of crops causes economic loss to farmers (Ramkumar et al. 2014; Govind & Jayson 2018); and Leopards *Panthera pardus* reportedly attack people and livestock in tea plantations (Sidhu et al. 2017; Kshettry et al. 2020). Such incidents can reduce tolerance for wildlife, lead to retaliatory killing of wild animals, and can also affect ongoing conservation efforts (Nyhus et al. 2000; Marchal & Hill 2009; Kalam et al. 2018); however, under certain circumstances, humans are tolerant of wild animals. For instance, in Africa, farmers tolerated Chimpanzees *Pan troglodytes verus* as they would eat the fruit of the cashew nut and pile the nuts, thereby facilitating harvest by farmers (Hockings & Sousa 2012). In Indonesia, farmers tolerated Orangutans *Pongo abelii* in oil palm plantations and agricultural farms as they were considered harmless (Campbell-Smith et al. 2010); and Islamic religious beliefs protected crop-raiding macaques (*Macaca tonkeana* and *M. ochreata brunnescens*) (Riley & Priston 2010).

Identifying the extent of human tolerance for wildlife, and the factors that reduce and promote tolerance, is crucial for the conservation of wildlife in human-modified landscapes (Treves & Bruskotter 2014). Interviews and surveys are widely employed to assess tolerance to wildlife presence among local communities. For instance, they have been used to assess tolerance towards (i) wildlife presence, (ii) economic loss to wildlife, and (iii) responses towards conservation initiatives (Fulton et al. 1996; Arjunan et al. 2006; Kansky & Knight 2014). In this study, we used questionnaire surveys to assess wildlife presence and support for wildlife conservation in tea plantations in the Nilgiri Biosphere Reserve (NBR), which is part of the Western Ghats (a global biodiversity hotspot) of India.

The NBR comprises of six critical PAs and is an important region globally for the conservation of the Asian Elephants, Bengal Tiger *Panthera tigris*, Nilgiri Tahr *Nilgiritragus hylocrius*, and the Critically Endangered White-rumped Vulture *Gyps bengalensis*. Since the British colonization in the 19th century, however, montane evergreen forests (known locally as 'sholas') and montane grasslands in the NBR have been transformed into agricultural fields, monoculture plantations, and other land uses (Prabhakar & Gadgil 1995). As a result, many monoculture plantations adjoin PAs and include open grassy expanses, swamps, patches of forest along streams, fuel-wood plantations, and degraded forest fragments that support rich flora and fauna (Shankar & Mudappa 2003; Kumara et al. 2004). A critical shortcoming of the NBR is that it has been designed without a transition zone, which is mandatory as per UNESCO guidelines for biosphere reserves (Daniels 1996; Puyravaud & Davidar 2013; UNESCO 2019). Hard boundaries affect both humans and wildlife. Therefore, a transition zone, where human activities are more compatible with conservation, may help reduce these impacts. Assessing wildlife presence in tea plantations and human tolerance of wildlife in the NBR would help understand whether plantations can act as transition zones in this region. Moreover, tea is a non-edible crop and can thus reduce economic losses caused by wildlife.

We conducted our survey in the Nilgiris District (henceforth Nilgiris) in the NBR. We surveyed 78 small and large tea plantations to assess (i) wildlife presence in each plantation, (ii) estimate damages caused by wildlife and its financial costs, and (iii) assess support for wildlife conservation among plantation managers. We tested the hypotheses that support for wildlife conservation would be positively associated with increasing (a) plantation size, and (b) distance to PA, and negatively associated with (c) higher incidents of damage, and (d) their increasing costs.

METHODS AND MATERIALS

Study area

The Nilgiris (2,452km^2) lies between 11.6–11.91 ^{0}N and 76.21–77.03 ^{0}E in the state of Tamil Nadu (Figure 1). This region is mountainous with elevations ranging from 900–2,500 m. The heterogeneous landscape and climate (von Lengerke 1977) support diverse vegetation types including lowland tropical rainforests, deciduous forests, thorny scrub vegetation, upper montane shola forests, and grasslands (Prabhakar & Pascal 1996). Forests cover 1,426km² (Department of Economics and Statistics 2016) constituting 58% of the total area and several important PAs such as Mudumalai Tiger Reserve (321km²) and Mukurthi National Park (78km²) are located here.

The district has a human population of around 700,000 (Census of India 2011). There are six administrative subdivisions called taluks, of which we surveyed three: Gudalur (726km²), Kotagiri (397km²), and Coonoor (229km²). Gudalur lies on the western side of the Nilgiri Plateau at a lower elevation (≈1,000m) and receives an annual rainfall of around 2,300mm. Kotagiri and Coonoor lie on the upper plateau (>1500m). Kotagiri is situated along the northern slopes and receives an annual rainfall of 800–1,500 mm, whereas Coonoor lies east of the plateau and receives 1,200–1,500 mm annual rainfall.

The Nilgiris District is also an important tea growing region in southern India, and plantations of tea and coffee have replaced a high proportion of native grasslands and montane forests (Kumar & Bhagavanulu 2008). Today, the plantations range from smallholdings (<10ha) to over 400ha (Tea Board India 2003) and cover about 23% (560km²) of the district area (Department of Economics and Statistics 2016). Several tea plantations in the Western Ghats are also next to PAs, and they provide a permanent or transitory habitat for many species, including those that are endangered (Shankar & Mudappa 2003; Kumara et al. 2004).

Methods

We surveyed 78 small and large tea plantations in the three regions mentioned earlier, from January to

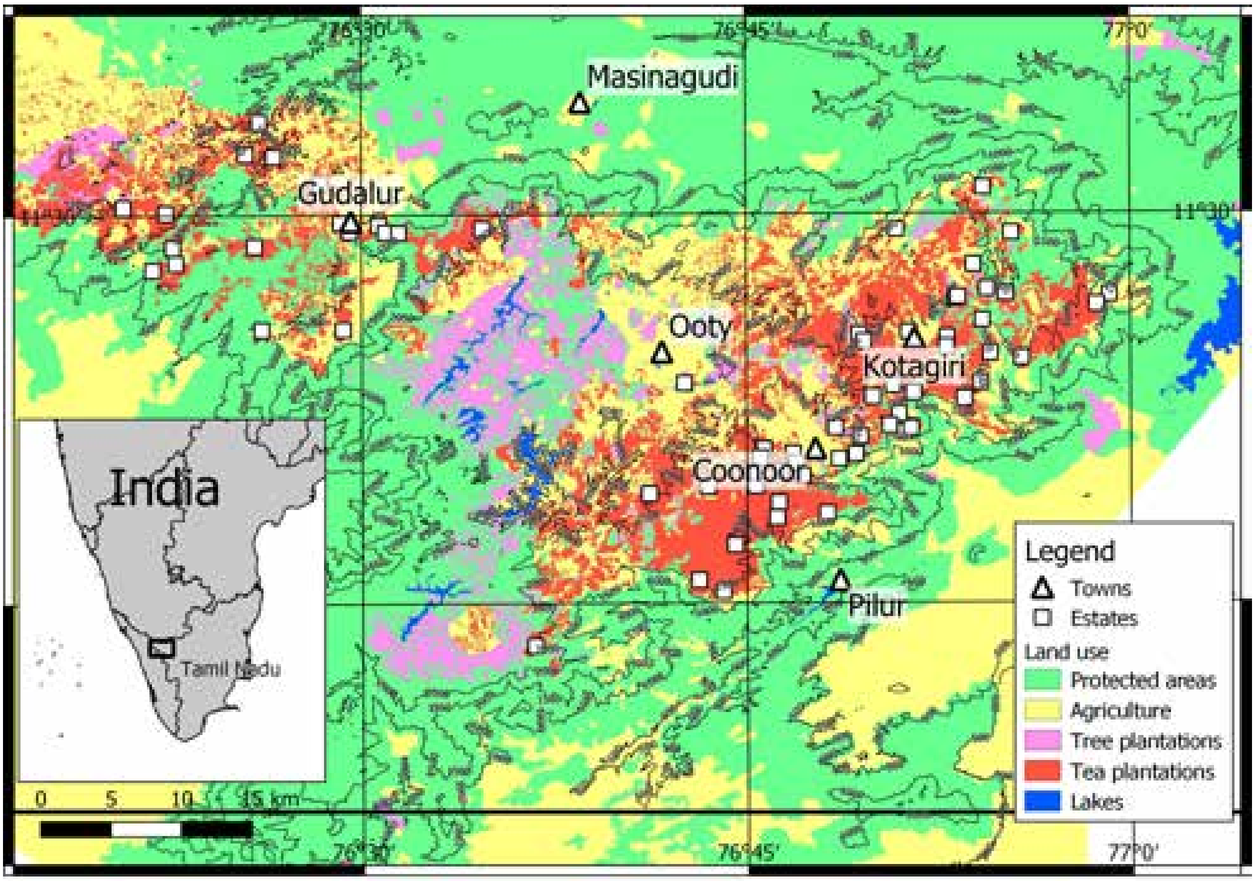

Figure 1. Map of the study area indicating location of all plantations surveyed in Nilgiris District.

March 2011. We first obtained a list of tea plantations from the offices of the United Planters Association of Southern India (UPASI) in Gudalur and Coonoor. During our survey, we came across many plantations that were not members of UPASI, that we also included. We categorized all reserved forests that have a lower level of protection, tiger reserves, and national parks that are strict nature reserves, as PAs in this study.

Questionnaire Survey

We used a structured questionnaire (Appendix A1 in supplementary data) which focused on: (i) location of the plantation office, (ii) size of plantation, and (iii) distance to PAs. Using a global positioning system (GPS), we recorded the location of each plantation office and used this as the point for geo-referencing. We then calculated the distance to PAs using a GRASS geographic information system (GRASS GIS). Further, we asked about the (iv) sighting frequency of 12 mammalian species, (v) incidents of crop and infrastructure damage, livestock depredation, and attacks on humans, and (vi) financial costs of wildlife damage over one year (January 2010 to January 2011). Last, we inquired about (vii) the management's support for wildlife conservation (positive/negative).

We selected 12 species that could cause different types of damage: Asian Elephant, Gaur, Wild Boar *Sus scrofa*, Sambhar *Rusa unicolor*, Muntjak *Muntiacus muntjak*, Sloth Bear *Ursus ursinus*, Bonnet Macaque *Macaca radiata*, Crested Porcupine *Hystrix indicus*, and Indian Giant Squirrel *Ratufa indica* that could raid crops and cause infrastructure damage; Bengal Tiger, Leopard, and Dhole or Asiatic Wild Dog *Cuon alpinus* that could prey on livestock. Photographs of these mammals were shown to interviewees to reduce error in identifying the wildlife in question. We did not carry out any independent field survey to verify the presence or absence of these species.

We initiated the survey by first contacting and interviewing plantation managers to ascertain wildlife present on their premises and to gauge whether their company supported wildlife conservation or not. We then interviewed one ground-level supervisor to corroborate wildlife presence and damages. Wherever possible, we verified wildlife presence by going through records of wildlife sightings maintained by plantation staff under the Rainforest Alliance Certification. We also interacted with villagers living around the periphery of the plantations to crosscheck and verify the data collected from the plantations we surveyed.

Wildlife presence and species richness

When a species was reported to be present in a plantation, we coded it as 1 and its absence as 0. All the species presence were summed up in a plantation, to get an estimate of the total number of species (species richness) reported. If present, we asked for sighting frequency, which was also coded: never = 0, daily/weekly = 1, regular monthly = 2, occasionally once a year = 3.

Wildlife incidents

We categorized the reported crop and infrastructure damage, livestock depredation, and attacks on humans, as 'wildlife caused incidents' and not as 'human-wildlife conflict' for reasons mentioned by Davidar (2018). We used a binary score for each type of incident reported in a plantation, 1 if reported and 0 if not reported. We summed up all the incidents reported over the year, by species and for each plantation.

Financial costs of wildlife damages

Plantation managers provided financial data on wildlife damage over a year (January 2010 to January 2011). If the cost of wildlife damage was negligible, they were not recorded by the management team and hence not provided to us. Besides documenting the financial cost of wildlife damage, comparing them with other components can help determine the actual cost incurred and how significant the financial loss can be to those affected. We used the cost of preventing insect pest damage (pesticide usage) in tea plantations as a baseline of financial cost control to compare the damage caused by wildlife. The estimated cost of wildlife damage and pesticide usage per hectare over the year in each plantation was noted in Indian Rupees and converted to United States Dollar (USD) using the rates prevalent during the study period.

Support for wildlife conservation

We coded the responses towards support for wildlife conservation as 0 if negative and 1 if positive, however, many plantation managers did not provide a response, which we recorded as 'no response'. Hence during the analysis, we recoded the responses as 0 if negative, 1 if positive, and 2 if 'no response'. We ran two sets of analysis, one with the negative responses and another where we merged the 'no response' category with negative response category. We did so because negative opinions may have repercussions if the results of the survey were placed in the public domain (Newmark et al. 1993; Gillingham & Lee 1999; Liu et al. 2011).

Data analyses

We used the software R 3.2.3 (R Core Team 2016) for statistical analysis. We conducted exploratory analysis on the size, distribution of plantations, elevation, and proximity to a PA. We calculated the distance from the point of geo-referencing (plantation office) to the nearest PA using the v.distance module of GRASS-GIS 7.2 (GRASS Development Team 2017).

We used a generalized linear model (GLiM) with Poisson link to analyze whether the distance to a PA, elevation, and size of a plantation influenced species richness. One assumption of the GLiM is the independence of observations, and since plantations that are close to each other may have the same issues, we tested whether the response variable was spatially autocorrelated. The Moran's I indicated no spatial autocorrelation ($p = 0.18$) of the response variable. We also used a GLiM but this time with quasi-Poisson distribution (due to overdispersion of data), with the same explanatory variables to analyze their effects on wildlife damage incidents. In both cases, we included all variables and interactions and then simplified by stepwise deletion comparing models with the AIC and ANOVA. We stopped the model simplification when the AIC was lowest, or the ANOVA became significant. We eliminated two estates, one for which we could not obtain geographic coordinates and another with an exceptionally large area (8,000ha).

We examined a few potential causes that could prompt individuals to approve or disapprove of wildlife conservation efforts. We named the dependent variable as "Attitude," and our explanatory variables were (i) distance to PA from plantation office, (ii) size of the plantation, (iii) species richness (of the studied species), and (iv) number of incidents of wildlife damage.

We used a GLiM to determine the association between the four explanatory variables and support for wildlife conservation. We used the binomial link function as the dependent variable was binomial. We conducted two logistic regression analysis using two sets of variables. The first set excluded all the 'no response' answers and included only positive and negative responses. The second set combined 'no response' answers with the negative responses. The first logistic regression started with all variables but no interactions, due to lack of power. The second logistic regression started with all variables and interactions. Both were simplified by stepwise deletion as above.

We analyzed data of those estates that reported costs of pesticide usage and those that also reported wildlife damage. We first used log-transformation to obtain a normal distribution. We then performed a Shapiro-Wilk normality test to confirm normality. Because one sample was small, we compared the log-transformed arithmetic means with a t-test to verify whether wildlife damage costs were similar to insect pest-control costs.

RESULTS

Location, plantation size, and distance to protected areas

The 78 plantations surveyed ranged in area from 5 to 8,094 ha and occurred at elevations between 700 to 2,300 m (Figure 1). Of these, 20 were in Gudalur, 22 in Kotagiri, and 36 in Coonoor (Appendix A2 in supplementary data). Tea was the primary crop in all plantations: 57 cultivated only tea, 21 grew coffee in addition, and 23 grew spices. The average distance to a PA was 2.4km, and the maximum distance was 10 km. Twenty-one plantations were situated less than one kilometer from different PAs and 56 further away (Appendix A2 in supplementary data). We were unable to obtain the GPS coordinates for one plantation.

Wildlife presence and species richness

There was a median of eight species reported per plantation with a range from 0 to 12. The most widely distributed species were the Bonnet Macaque (across 91% of the plantations), followed by Wild Boar (85%) and Porcupine (78%) (Figure 2). On the other hand, the Tiger (33%), Dhole (32%), and Muntjak (13%) were rarely reported (Figure 2). There was a significant positive correlation between the total number of species in a plantation and proportion of charismatic species, such as the Tiger and Dhole (Spearman rank correlation S_r = 0.350116, p = <0.01).

GLiM simplification produced the most parsimonious model with three variables that were correlated with species richness (Table 1): distance to a PA, elevation, and interaction between distance to a PA and plantation size. Species richness was significantly and negatively correlated with distance to a PA ($p = 0.00104$) (Table 1), tended to increase with increasing elevation, and was weakly and positively associated with the interaction between increasing distance to a PA and larger area, therefore larger plantations further away tended to have more species (Table 1).

Wildlife incidents

A total of 244 wildlife-related incidents were reported over one year, with an average of three incidents per

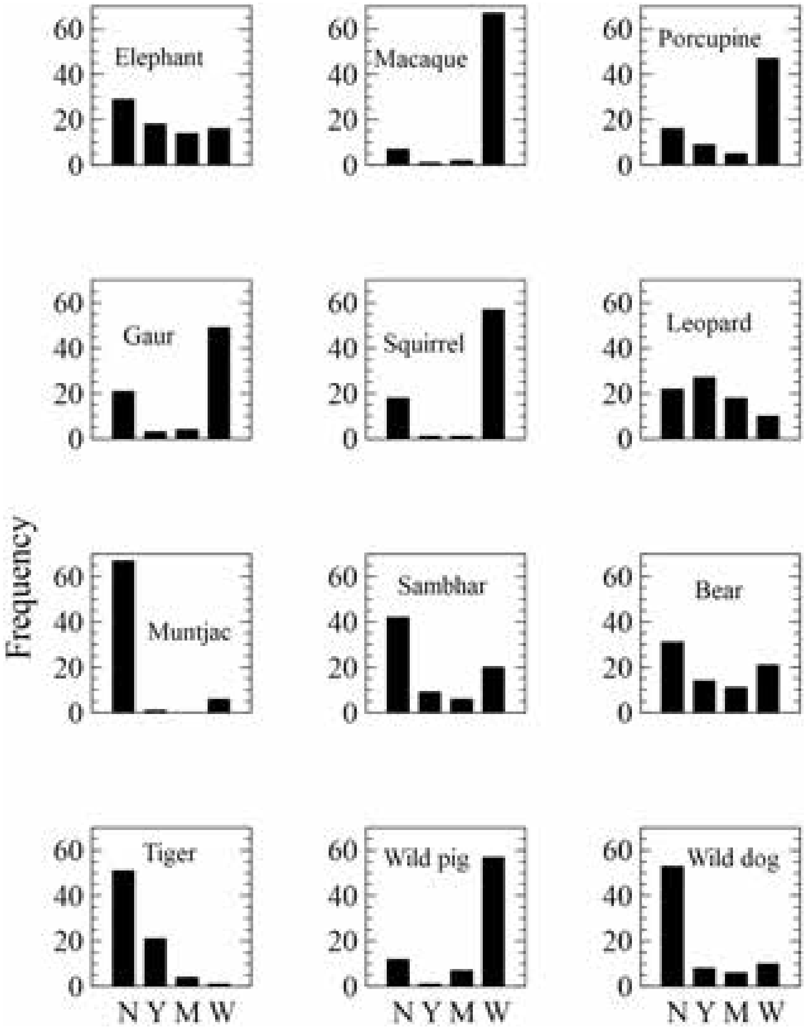

Figure 2. Frequency (%) of wildlife sightings of the 12 species surveyed across 78 tea plantations
X axis labels: N=Never, Y=Yearly, M=Monthly and W=Weekly

Table 1. Results from GLiM analysis of variables associated with species richness across 76 plantations.

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	1.5220585	0.2295756	6.630	3.36e-11
Distance	-0.0842639	0.0257034	-3.278	0.00104
Elevation	0.0003574	0.0001399	2.555	0.01061
Distance: Area	0.0001418	0.0000453	3.130	0.00175
Null deviance: 70.896 on 75 degrees of freedom **Residual deviance: 55.537 on 72 degrees of freedom** **AIC: 345.97**				

year per plantation (Appendix A2 in supplementary data). There was no significant effect of distance to a PA, elevation, or plantation size on the number of wildlife incidents reported. Overall, the Bonnet Macaque, Wild Boar, and Gaur were implicated in over 50% of the total incidents. Crop damage, such as uprooting tea bushes, damage to trees, and raiding vegetable gardens, caused mostly by the Gaur (20%), Bonnet Macaque (19.4%), and Wild Boar (18.3%) were reported in 74% of plantations (Figure 3). The other incidents were less frequent: livestock predation by Leopard or Tiger constituted 9%; infrastructure damage mostly by Bonnet Macaques

Table 2. Support for wildlife conservation across 76 tea plantations in the Nilgiris.

Region	Responses n (%)			Total
	Negative	Positive	No Response	
Gudalur	1 (5.2)	9 (47.4)	9 (47.4)	19
Kotagiri	2 (9)	13 (59)	7 (32)	22
Coonoor	2 (5.7)	25 (71.4)	8 (22.9)	35
Total	**5 (6.5)**	**47 (62)**	**24 (31.5)**	**76**

The differences between the three regions were not significant (Log likelihood chi square = 6.592, df = 4, p = 0.159).

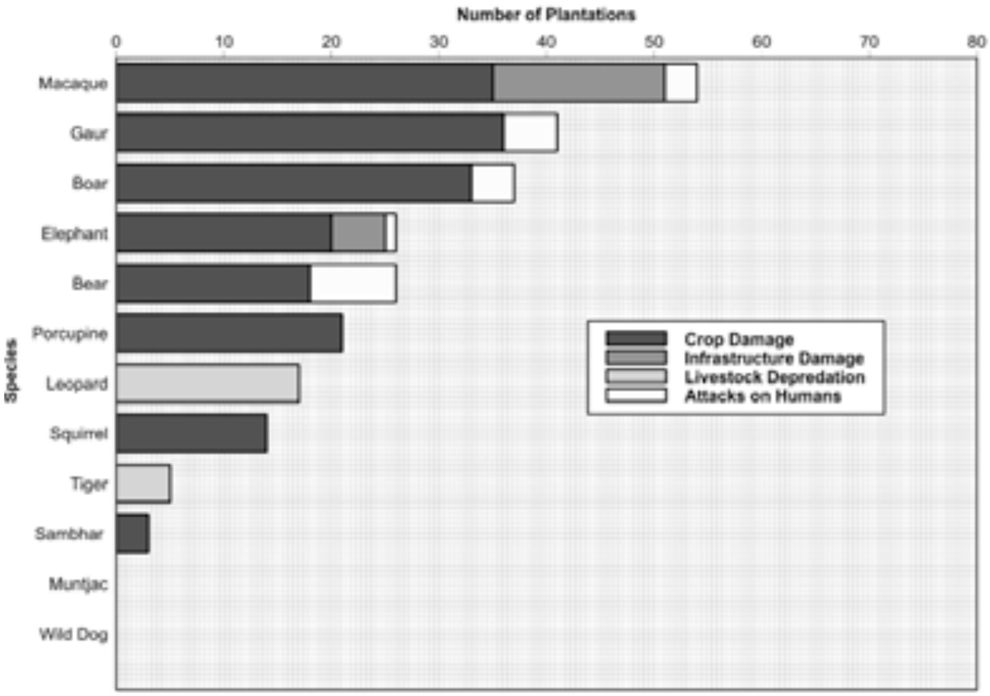

Figure 3. The number and type of wildlife incidents reported per species over a year (January 2010 to January 2011) by the 78 plantations.

and occasionally by Elephants was 8.5%, and attacks on people mostly by the Sloth Bear and Gaur was 8.5% (Figure 3).

Financial costs

A total of 37 estates provided financial data on pesticide usage and had an average (exponentiated log-transformed average) INR 1,682 $ha^{-1}yr^{-1}$ (1 USD= 45 INR during the study period; USD 37.4) (Appendix A2 in supplementary data). On the other hand, the cost of wildlife damage was nil or negligible for 72 estates (Appendix A2 in supplementary data). The six estates that reported a loss due to wildlife had an average (exponentiated log-transformed average) cost of INR 243 $ha^{-1}yr^{-1}$ (USD 5.4) (Appendix A2 in supplementary data). The cost of pesticide usage was significantly higher than the cost incurred due to wildlife damage (Welch two-sample T-test = 3.6, df = 7.3, p < 0.01).

Support for wildlife conservation

Overall, 62% of respondents supported conservation, 6.5% did not, and 31.5% did not respond (Table 2). There was no significant difference between the responses across the three regions, possibly because there were too few negative responses (log-likelihood chi-square = 6.592, df = 4, p = 0.159). Plantation managers in Gudalur, however, had the lowest percentage of positive and no responses among the three taluks, indicating ambiguous attitudes towards conservation.

The first GLiM, which included only negative and positive responses, indicated that plantation managers supported wildlife conservation when there were more

Table 3. Results of GLiM analyses on variables associated with support for wildlife conservation among 76 plantations in the Nilgiris.

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-5.955607	2.203375	-2.703	0.00687
Distance	1.130861	0.560615	2.017	0.04368
Area	-0.013464	0.006077	-2.216	0.02672
Species richness	1.174853	0.380301	3.089	0.00201
Incidents	-0.982413	0.458589	-2.142	0.03217
Distance: Area	0.016226	0.007016	2.313	0.02073
Distance: Species richness	-0.382859	0.153184	-2.499	0.01244
Area: Incidents	0.004312	0.002351	1.834	0.06660
Distance: Area: Incidents	-0.003560	0.001859	-1.915	0.05555
Distance: Species richness: Incidents	0.061742	0.024890	2.481	0.01312
Null deviance: 101.054 on 75 degrees of freedom **Residual deviance: 65.263 on 66 degrees of freedom** **AIC: 85.263**				

species present on their premises (p = 0.0401). The second GLiM where the 'no response' answers were merged with the negative responses increased the significance of this relationship (p = 0.00201, Table 3, also Appendix A3 in supplementary data).

Conservation support increased with an increasing number of species reported in a plantation; with increasing distance from PA, and among larger plantations situated further away (Table 3). Although incidents generally decreased support, it was modulated by greater wildlife presence in larger plantations further away (Table 3). Plantations opposed to, or ambiguous about conservation were generally larger, and/or with a higher number of incidents reported (Table 3). The last three interactions between (i) area and incidents, (ii) distance, area and incidents, and (iii) distance, species, and incidents were marginally significant and/or complex.

DISCUSSION

Human-wildlife 'conflict' is a global issue that encompasses a wide range of species, events, and settings, many of which have the potential to harm both humans and wildlife (Dickman 2010). Incidents with wildlife are often presented with synthetic variables such as economic loss to farmers and livestock owners, human injuries and mortalities, and loss of human livelihoods (e.g., Acharya et al. 2016; Acha et al. 2018; Govind & Jayson 2018). Although these variables help us understand the intensity and extent of incidents with wildlife, it would be incorrect to infer or depict human-wildlife conflict as a uniform and pervasive threat, from which anyone and everyone may suffer. Moreover, such views can diminish support for wildlife conservation and make conflict management even harder.

On the other hand, several studies reveal key patterns/differences in human-wildlife conflict events. For instance, human-wildlife interactions are limited in developed countries due to lower dependency on forest ecosystems but are far greater in developing countries because there is a higher dependency on forests, particularly for rural livelihoods, agriculture production and development (Anand & Radhakrishna 2017). Similarly, only a few species are known to cause extensive damage. For instance, 32 species caused damage across 11 protected regions in India, but only six were responsible for most incidents (Karanth & Kudalkar 2017). In Zimbabwe, of five carnivorous species, the Lion *Panthera leo* and Spotted Hyaena *Crocuta crocuta* were held responsible for most livestock depredation events (Loveridge et al. 2017). In Nepal, four (out of 12 species) caused maximum damage to human property and life (Lamichhane et al. 2018). Similarly, in our study, we show that (i) most of the damages are created by species that are not dangerous, (ii) incidents of damage to human property and life are spatially clustered and can probably be avoided, (iii) economic cost due to wildlife damage is in general low when compared to other costs such as that of preventing insect pest damage, and (iv) support for conservation is relatively high.

About 50% of wildlife-related incidents, mostly crop damage, were caused by a few species such as the Bonnet Macaque, Wild Boar, and Gaur. Whereas counter-intuitively, increased diversity of wildlife increased support for conservation. This could be because plantations supporting a higher proportion of the 12 species selected for this survey, significantly reported the presence of charismatic species such as the Tiger and Dhole. Moreover, economic costs were disproportionately borne by a few plantations and higher costs were mostly because of wild Elephants destroying fences and infrastructure. Therefore, reducing impacts of a few pest species, and perhaps mitigation of Elephant damages in a few plantations, could have disproportionate effects on conservation attitudes in this region.

Many plantations with significant wildlife species were not adjacent to PAs, indicating that these plantations support resident populations of widespread generalist species such as Bonnet Macaques and Wild Boar. These species were also considered chronic pests. The abundance of Bonnet Macaques in forests in peninsular India is very low, and the species is fast disappearing from its original habitats owing to expanding ranges of the Rhesus Macaque *Macaca mulatta* (Erinjery et al. 2017); however, it is ubiquitous in human settlements due to its adaptability to human food and refuse (Pillay et al. 2011).

The presence of charismatic species such as the Tiger and Dhole were reported in estates with more wildlife. The aesthetic value of several wildlife species could elicit favorable responses. For instance, de Pinho et al. (2014) reported that several species perceived as beautiful garnered more conservation support by agro-pastoralist communities living around Amboseli National Park, in southern Kenya.

There was considerable support for wildlife conservation among plantation managers. Surprisingly, support was lower in larger-sized plantations, especially those located closer to PAs. Studies have however shown that in general, wealthy farmers with larger agricultural holdings are better able to buffer the economic costs of wildlife damage (Naughton-Treves & Treves 2005; Zimmermann et al. 2005). In this case, however, large industrial plantations were less tolerant of wildlife. The reason for this is not clear. Perhaps surveillance by protected area managers creates resentment among more powerful plantation groups, or as in some cases, they have encroached upon reserved forests.

Although non-significant across regions, a higher proportion of plantations in Gudalur preferred not to state whether or not they supported wildlife conservation. Gudalur is an important region for wildlife, as it lies between major PAs, and is an important Elephant corridor connecting Mudumalai Tiger Reserve and Wynaad Wildlife Sanctuary that run through this region (Puyravaud et al. 2017). There are, however, many conflicts over forest leases and land tenure in this region (Krishnan 2009).

Land tenure insecurity is widely observed in tropical and developing regions and often overlaps with areas that have high conservation value (Bruce et al. 2010). There was a distinct land tenure system called the ‘janmum’ tenure in Gudalur which the Tamil Nadu State Government sought to abolish in 1969 through the “Gudalur Janmum Estates” (Abolition and Conversion into Ryotwari) Act, 1969. Litigation over implementing this Act has been dragging on, and this uncertainty has resulted in large scale encroachment of forest land (Davidar et al. 2012). Out of the 32,375ha of disputed land in the taluk that falls under janmum system of hereditary proprietary rights, 11,736ha have been identified as forests, and 6,475ha have been leased to local communities (Ravichandran 2019a). Among the remaining 14,164 unsettled hectares, 12,140ha has been encroached upon by plantations (Ravichandran 2019b).

Land tenure insecurity can create resentment towards conservation. For instance, Romañach et al. (2007) found that land “squatters” were not as positive towards the presence of carnivores when compared to those who held a title deed to communal land. Similarly, Guinness (2016) also found that land ownership significantly influenced local perceptions of crop-raiding. Hence, it is possible, this could be among the reasons for antagonism towards conservation among many plantation managers in Gudalur. Targeted education and awareness programs for the plantation community in general are thus necessary, as they can help increase support for wildlife conservation and encourage participation in ongoing conservation efforts in the region.

Our study shows that plantations provide a supplementary habitat for many endangered and iconic species. Support for conservation was high, although the ubiquitous presence of some species such as the Bonnet Macaque and Wild Boar, considered ‘pests’ by the respondents, caused a high proportion of damages. Overall, a few species caused most of the problems, and a few plantations suffered high costs. Mitigation attempts should, therefore, focus on these species and plantations to increase conservation support. With adequate mitigation of negative impacts, plantations can serve as a ‘transition’ zone for the Nilgiri Biosphere Reserve, to soften the hard boundaries between protected areas and the human-dominated mosaic, and to facilitate the movement of wildlife between reserves.

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Appendix 1. Sample questionnaire

Name of plantation
Corporate/family/others
Year of establishment
Total area of plantation
Region
Plantation crops (tick one) tea coffee cardamom rubber others
Total area (if multiple crops)
Geographical coordinates latitude longitude altitude
Presence of forests in your plantation yes/no type of forest
Area or % of forest cover
Nearest protected area to estate **Approximate distance (km)**

Wildlife		**Frequency of sightings in plantation**				
Species	**Impact ±**	**Daily**	**Weekly**	**Monthly**	**Annually**	**Not Sighted**
Asian Elephant						
Bengal Tiger						
Leopard						
Gaur						
Sloth Bear						
Wild Dog						
Wild Boar						
Bonnet Macaque						
Sambar Deer						
Muntjak						
Crested Porcupine						
Malabar Giant Squirrel						

Wildlife	Number of damage incidents in plantation					
Species	**Crop damage**	**Infrastructure damage**	**Livestock attack**	**Human attack**	**Financial loss (INR)**	**Comments**
Asian Elephant						
Bengal Tiger						
Leopard						
Gaur						
Sloth Bear						
Wild Dog						
Wild Boar						
Bonnet Macaque						
Sambar Deer						
Muntjak						
Crested Porcupine						
Malabar Giant Squirrel						

Amount spent on insect pest control per year

Do you (as a management) support wildlife conservation?
Yes/No Why?

How can you help conserve wildlife?

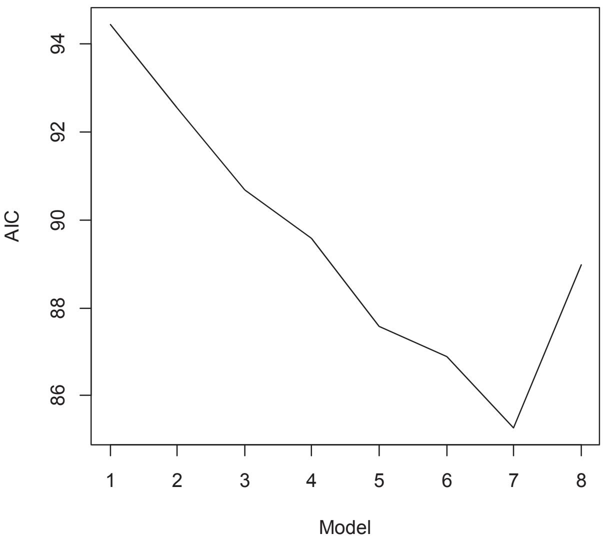
Appendix 2. General description of the 78 tea plantations surveyed across Gudalur, Kotagiri, and Coonoor taluks of Nilgiris District, India.

Taluk	Estate	Distance to PA (km)	Elevation (m)	Area (ha)	Number of species reported	Number of incidents over a year	Wildlife damage cost (INR)	Cost of insect pest control (INR)	Support for wildlife conservation
Gudalur (n=20)	1	3.44	960	61	6	3	0	100000	0
	2	2.83	943	7	0	0	0	24000	2
	3	2.84	940	7	0	0	0	0	2
	4	0.16	1257	7	3	3	10000	10000	2
	5	6.18	1939	40	8	5	0	0	1
	6	4.71	943	12	3	2	0	0	2
	7	3.29	1064	853	9	0	0	0	1
	8	1.73	941	243	7	4	0	0	2
	9	2.76	1093	61	7	3	0	123600	2
	10	1.82	1061	896	4	1	350000	3200000	1
	11	4.42	1036	648	9	0	0	160000	1
	12	0.5	1935	1457	7	2	0	100000	2
	13	0.03	1475	24	5	0	0	10000	2
	14	1.9	1230	8094	9	5	0	0	1
	15	4.99	959	1214	8	0	0	0	1
	16	3.36	960	1012	10	2	0	0	1
	17	1.89	955	360	7	3	0	0	1
	18	0.84	700	81	7	2	28000	0	2
	19	4.57	971	1214	9	4	0	0	1
	20	0.69	1156	1012	7	5	0	0	1

Taluk	Estate	Distance to PA (km)	Elevation (m)	Area (ha)	Number of species reported	Number of incidents over a year	Wildlife damage cost (INR)	Cost of insect pest control (INR)	Support for wildlife conservation
Kotagiri (n=22)	21	3.43	1842	243	10	3	35000	3000000	1
	22	6.18	1939	28	4	1	0	0	2
	23	1.17	1461	61	9	2	0	0	2
	24	1.66	1924	24	7	2	0	0	0
	25	3.54	1793	27	6	4	0	0	2
	26	5.51	1980	36	7	6	0	700000	1
	27	1.4	1487	166	8	8	0	500000	1
	28	0.14	1487	29	8	6	0	216000	0
	29	6.56	2006	89	7	3	0	0	1
	30	0.17	1302	210	6	3	0	290625	2
	31	0.66	1288	625	9	6	25500	3437500	1
	32	0.52	1718	263	8	4	0	30000	1
	33	1.67	1502	202	5	2	0	0	1
	34	0.86	1415	192	10	6	0	1000000	2
	35	4.03	1966	202	8	4	0	90000	2
	36	4.62	1879	133	8	6	0	0	1
	37	3.82	1585	133	9	6	0	0	1
	38	4.55	1890	10	7	5	0	30000	1
	39	1.02	1837	250	9	5	0	236000	1
	40	0.46	1921	359	7	1	0	681681	1
	41	0.36	1538	24	6	2	5000	40000	2
	42	2.71	1792	118	6	0	0	0	1

Taluk	Estate	Distance to PA (km)	Elevation (m)	Area (ha)	Number of species reported	Number of incidents over a year	Wildlife damage cost (INR)	Cost of insect pest control (INR)	Support for wildlife conservation
Coonoor (n=36)	43	2.84	1935	49	9	10	0	300000	1
	44	0.8	1688	185	8	3	0	500000	1
	45	1.78	2057	151	6	4	0	150000	1
	46	4.08	1663	134	7	2	0	0	1
	47	3.8	1649	61	8	6	0	0	2
	48	2.62	1810	20	8	2	0	0	2
	49	0.5	1005	259	7	0	0	100000	1
	50	1.08	1349	384	10	3	0	200000	1
	51	1.22	1612	61	9	4	0	0	1
	52	4.64	1756	61	2	1	0	0	0
	53	*	*	19	9	3	0	0	1
	54	2.62	1810	5	6	0	0	0	2
	55	1.45	1679	607	8	5	0	200000	1
	56	1.08	1350	1063	7	6	0	400000	1
	57	2.45	1579	18	9	5	0	270000	1
	58	4.04	1885	36	7	5	0	50000	2
	59	4.17	1840	32	7	4	0	0	2
	60	1.92	1754	50	6	1	0	0	0
	61	0.1	1867	1498	12	3	0	0	1
	62	10.04	2230	21	3	0	0	0	1
	63	1.06	1572	101	8	5	0	0	2
	64	0.49	2050	270	11	4	0	300000	1
	65	3.56	1863	101	8	4	0	0	1
	66	0.16	1599	164	9	3	0	380000	1
	67	0.4	1545	69	7	5	0	0	2
	68	1.04	1856	207	8	5	0	0	1
	69	0.7	2047	176	8	3	0	200000	1
	70	7.33	2132	147	4	3	0	0	1
	71	3.38	1727	12	9	3	0	120000	2
	72	1.5	1936	52	4	0	0	220000	1
	73	1.4	1969	48	9	4	0	0	1
	74	2.26	1624	45	8	3	0	0	1
	75	1.98	1920	70	8	2	0	500000	1
	76	0.6	1739	427	10	0	0	0	1
	77	0.86	1604	600	10	3	0	500000	1
	78	2.54	2074	47	6	1	0	0	1

* Could not obtain data
Wildlife incidents, cost of wildlife damage and insect pest control over a one-year period (January 2010 to January 2011)
Support for wildlife conservation: 0- Negative, 1- Positive and 2- No Response



Appendix 3. Change of the Akaike's information criterion (AIC) with model simplification with all variables and interactions.

Author details: Ms. Tamanna Kalam holds a Master's degree in ecology and environmental sciences from Pondicherry University. She has over 7 years of experience in wildlife conservation. Her research focusses on understanding human-wildlife interactions in human-modified landscapes, Asian elephants (their behaviour, distribution and threats), and the impact of anthropogenic activities on wildlife. Ms. Tejesvini A.P. has over 7 years of experience in sustainable development and corporate social responsibility. She holds a Master's degree in ecology and environmental science. She currently works as a sustainability developer. Previously she has worked in several wildlife conservation projects and is now finding ways to bridge business sustainability and wildlife conservation. Dr. Rajeev K. Srivastava has served the Indian Forest Service for over 32 years. He was the former Principal Chief Conservator of Forests (PCCF) for the Tamil Nadu Forest Department. Currently, he is the director for the Tamil Nadu Women Development Corporation and is also a Senior Advisor at Wildlife Conservation Society (WCS), India. Dr. Priya Davidar retired as a Professor in ecology and environmental sciences, Pondicherry University, India. She received her PhD in Zoology (Ornithology) from Bombay University in 1979 under the guidance of Dr. Salim Ali. She was a post-doctoral fellow at the Smithsonian Institution and Harvard University, USA. She is active in the field of conservation advocacy and research. Dr. Jean-Philippe Puyravaud is the director of the Sigur Nature Trust. He received his PhD in ecology from University Pierre and Marie Curie, Paris, France. He works in landscape ecology and conservation.

Author contributions: TK and TAP carried out the field work. PD and JPP secured funding, helped with study design, statistical analysis, preparation of study area map and editing. All authors contributed to the literature review and writing.

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PLATINUM OPEN ACCESS

COMMUNICATION

Innovative way of human-elephant competition mitigation

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Abstract: The negative interaction between humans and elephants is often referred to as conflict, however it is also seen as competition. Human-elephant competition (HEC) is a major protection threat in the fringe villages of the Jaldapara National Park (JPNP) of West Bengal, India. JPNP is facing challenges from the highly populated fringe villages, which exist in elephant corridors. Between 2015 and 2018 there were 12 elephant deaths. During the same period elephants caused 34 human deaths. As per data, most of the elephant interactions occurred in the fringe villages of Madarihat and Jaldapara North Range. Per reports of human deaths, Chekamari and Khairbari villages of Madarihat Range are in the most vulnerable list. Most of the human deaths occurred in the early morning (05.00–06.00 h) and in the evening, when people are going outside for open defecation (OD). On a pilot basis Chekamari and Khairbari villages of Madarihat Range were selected for a door to door household survey with the objective to develop an innovative strategy as a mitigation measure of HEC. The results of the survey show that both villages are tribal and minority population, the socio-economic condition of the people is very poor, on an average 5–6 members are in each household, the source of drinking water is a community well for most of the households, and 50 households are devoid of toilet facilities so automatically the members of those households go outside for OD. Out of the total human deaths, 16 occurred in the Madarihat area; out of these 16 cases, six were from the Chekamari and Khairbari villages. For this reason, between April 2019 to September 2019, with available funds 20 toilets with tube-well were built in the 20 neediest households of these two villages. Due to the communication with the community, behavioural changes were made and their participation for 100% usage of those toilets was assured. After the construction of the toilets until now, no human death cases have been reported.

Keywords: Behavioural changes, communication, mitigation, open defecation, toilets.

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Competing interests: The author declares no competing interests.

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INTRODUCTION

The interaction between humans and elephants is often referred to as conflict, however, it is also seen as competition. Human-elephant competition (HEC) (Davidar 2018) is a negative interaction between the two species, resulting in crop loss, property damage, and can lead to the loss of life of both humans and elephants. Competition may be direct and indirect. Loss of property, crops, and lives is the result of direct competition. In indirect competition people live in fear of elephants, which restricts free movement and day to day activities of people in forest fringe areas. The forest department promotes coexistence through different means with the help of local joint forest protection committees (JFPCs) in the forest fringe villages. In southern Bengal, in the adjacent forest fringe areas of Jhargram, Medinipur, Rupnarayan, and Kharagpur a special team "Hulla Party" drives the elephants from the village towards the forest. But in recent times there has been a total ban of the usage of "spike and fire balls, i.e. Hulla" by a recent Supreme Court order. In northern Bengal the concept of Hulla Party does not exist, but JFPC members are provided with crackers and searchlights from the forest department to drive elephants to the forest. So, at present, the forest department in both northern and southern Bengal solely depend on high beam searchlights and crackers to mitigate the elephant depredation problem. Apart from this direct action in the field, the forest department also compensates the loss of crop, property, livestock, and human life which occur from HEC (Davidar 2018), per the order of the Government of West Bengal. A person who is affected by an elephant attack as specified in the government order (No. 195-For/11M-95/2011 pt-I dated 30.i.2015), whose crop and/or house is damaged by wild animals, and if any domestic animal is injured/died due to a wild animal attack, is eligible to claim ex-gratia compensation (West Bengal Forest Department 2015). Ex-gratia compensation for injuries and loss of human life is duly and promptly paid within 24 hours of the incident. In present times, the government order (No.1805-For/O/11M-95/2011 (Pt.I) Kolkata, 29 October 2018) regarding payment of compensation for the loss of life and property due to elephant depredation has been revised by the Government of West Bengal. The family of the deceased should receive four lakh rupees for loss of life subject to certification regarding the cause of death from the appropriate authority. Ex-gratia payment for the loss of a limb or eye(s) is INR 59,100 per person, when the disability is between 40–60%, and when the disability is more than 60% that amount is increased to INR two lakh (INR 200,000) per person, subject to certification by a doctor from a government hospital or dispensary regarding the extent and cause of disability (West Bengal Forest Department 2018). Ex-gratia payments regarding grievous injury requiring hospitalization are between INR 12,700 and INR 4,300 per person when requiring hospitalization for more than a week and less than a week, respectively (West Bengal Forest Department 2018). So, this background information is clear enough to understand that the forest department is adopting all sorts of strategies to mitigate HEC in the forest fringe villages. No mitigation measures, however, are found to be 100% successful in avoiding competition between elephants and forest fringe villages. Where a JFPC exists as per the government norms, local people receive 40% of the revenue generated from eco-tourism activity and timber operation for community infrastructure development from the forest department. This provides a platform to the department to address elephant conservation and to tackle HEC. But the problem is massive in villages where no JFPCs exist and the forest department is unable to support community infrastructure work by providing JFPC share money and other benefits. This study mainly focused on assessing the problem and adopting other innovative strategies to mitigate and tackle HEC in the areas of non JFPC villages in elephant corridors, where the issue of elephant depredation is significant.

MATERIALS AND METHODS

Study Area

Jaldapara Wildlife Division of West Bengal, India (Figure 1) covers an area of 306.96km² with the national park area of 216.53km². The Chekamari and Khairbari villages of Madarihat Range of Jaldapara Wildlife Division (Figure 2) lies between 26.700–26.718N & 89.243–89.264E. The study area is a non-forest elephant corridor in between the forest land of Dhumchi and Jaldapara (Figure 1, 2). The average normal annual rainfall of the area is about 293cm. The southwest monsoon starts from the middle of May and lasts until the end of September. The heaviest rainfall occurs during the month of June, July, and August. During the rainy season humidity is high. The approximate water table position of Madarihat Range and locality in summer is 2.80m (Conservator of Forest & Divisional Forest Officer 2012). People are working in agriculture mainly for subsistence; maize, paddy, potato are principal crops, which are also the preferred food crops for the elephants.

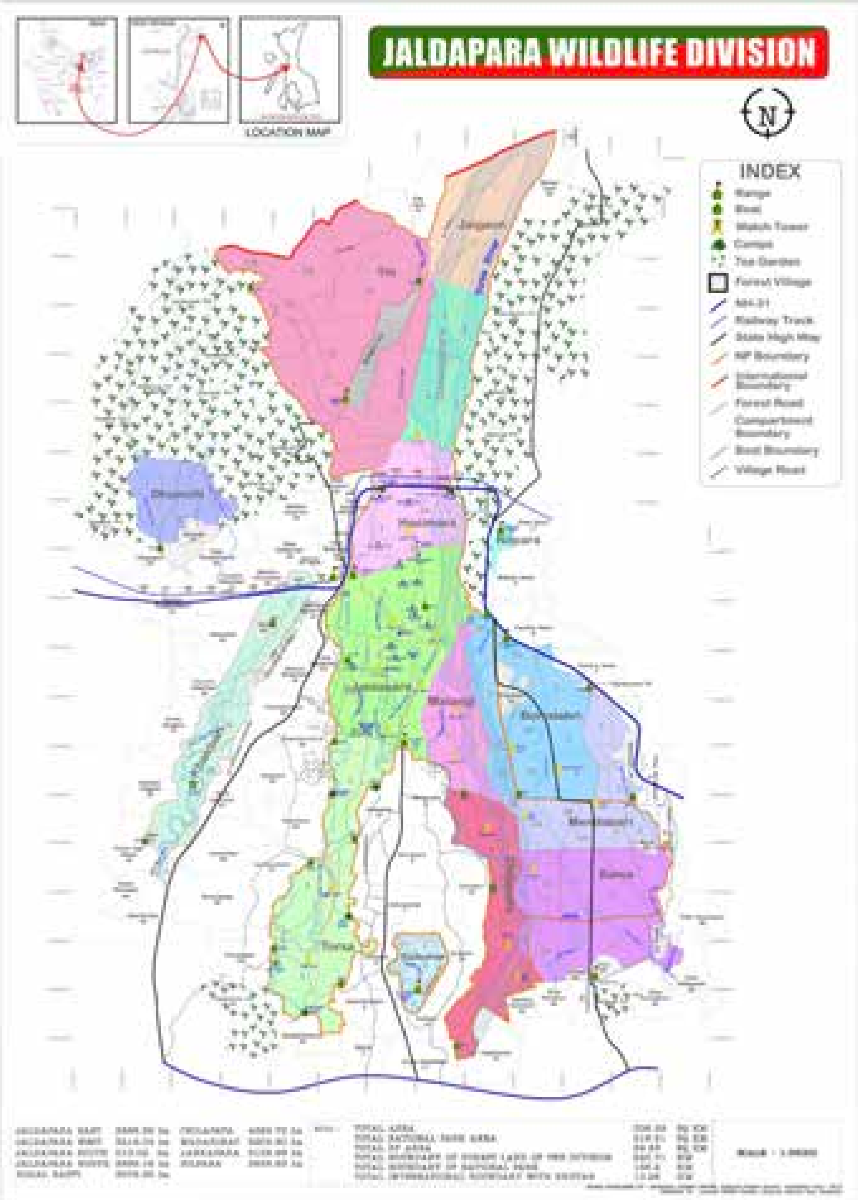

Figure 1. Jaldapara Wildlife Division.

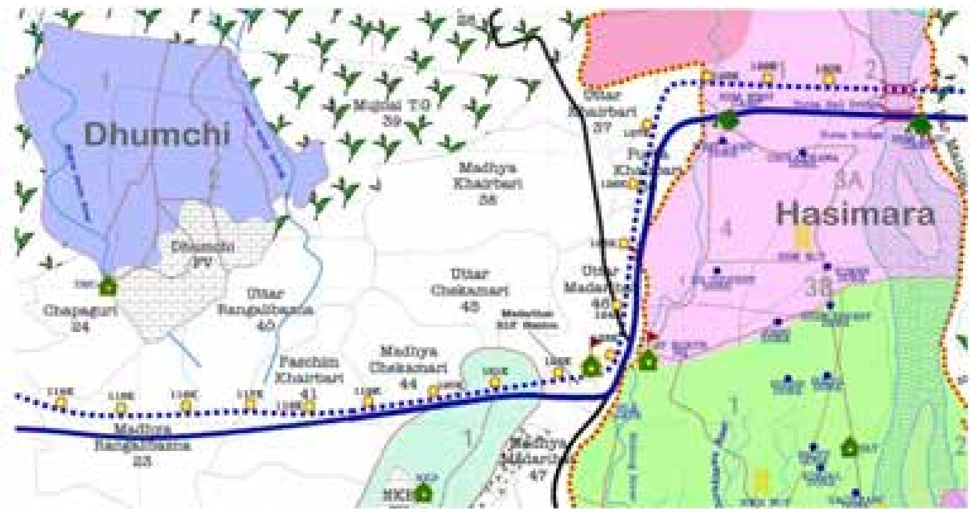

Figure 2. Chekamari and Khairbari villages.

Data collection and analysis

To understand the background of human-elephant antagonism a preliminary study was conducted to collect primary data from Jaldapara Wildlife Division through a prepared questionnaire. Primary data analysis provided the estimated number of wild elephants in the Jaldapara Wildlife Division, season-wise maximum and minimum group size of elephants during crop raids, area of common habitat shared by elephants and humans, total number of elephants and human deaths during three years (2015–2018), details on age and gender of elephant and human death cases, causes of elephant and human deaths (Tables 1, 2), level of aggression of local people, methods used for driving away lone elephants/herds, total cases of crop-damage between 2015–2018, season of intensive crop damage, type of crop damage, total cases of property damages between 2015–2018, total compensation paid in cases of human-death, crop-damage and cases of property-damage between 2015–2018. The primary data analysis helped to identify the most vulnerable site of human and elephant deaths (Tables 1, 2). With this basic information field foresters of Madarihat Range, led by the author, went to the community platform of competition prone villages and through consecutive meetings by the author and field staff of Madarihat Range, awareness was created in the schools and other village institutions. The objective to mitigate HEC was communicated to the local people through audio-visual aids and door to door visits. These visits helped the local people to communicate their problem, livelihood, and socio-economic status. Based on the communication, the specific time of incidences of human death was assessed and this provided the incentive to adopt an innovative strategy to build toilets with tube-well on a priority basis to avoid the chance of HEC.

RESULTS

Primary data from the Jaldapara Wildlife Division, West Bengal collected through the Questionnaire Method by the following questionnaire.

1. What is the name of the division?

Jaldapara Wildlife Division, Coochbehar.

2. How many forest-ranges are there in the division?

14.

3. How many elephants are there in the wild?

100–130 (Last estimation)

4. What is the maximum group size of elephants observed?

a) 60 to 70 individuals in a herd during monsoon.

b) The herd divides into maximum 25 to 35 individuals during rest of the year.

5. What is the minimum group size of elephants observed?

Minimum 2 to 3 adults in a small group during crop raids.

6. What is the total area (in km^2) of the Division?

306.96km^2.

7. How many elephants died in past three years from 2015 to 2018?

12

8. Is any data available regarding the age and gender of elephant death cases? (For example: How many females or males? How many adults/sub adults/juveniles/calves?) Data Available in Table 1

9. Are GPS locations available where these cases happened?

Not Available

10. What were the causes of elephant death?

a) Electrocution- 4

b) Cardiorespiratory failure- 3.

c) Rail Accident- 1

d) Infighting- 2

e) Natural Death- 2

11. How many cases of human deaths by wild elephant attack occurred in past three years from 2015 to 2018?

34

12. Is any data available regarding the age and gender of human death cases? (For example: How many females or males? How many of them were old/young?)

Year wise Detail Data available in Table 2

Year	Male		Female	
	Old Age	Young	Old age	Young
2015–16	2	2	1	-
2016–17	-	9	-	2
2017–18	8	1	1	3
2018–19	3	2	-	-

13. Is GPS locations available of where these cases happened?

Not Available

14. Generally what is time of elephant depredation in the villages?

In the evening and night for raiding in the crop fields.

15. What were the causes of human deaths?

Injury through direct interaction with elephants.

16. Generally what was the time of injury or direct interaction with elephants?

In most of the cases in the early morning when elephant herds returned back to the forest from the villages, and in a few cases in the evening at the time of elephant depredation during crop raiding.

17. What was the level of aggression of local people (high, moderate or low)?

Moderate

18. What are the methods used for driving away lone elephants/herds of elephants from the villages?

Elephant driving by using high beam searchlights and crackers.

19. How much crop area damaged in between 2015–2018?

Year	Crop damaged Area (in ha)
2015–16	100.84
2016–17	166.39
2017–18	49.31
2018–19	293.15

19. Which seasons (months), more crops was damaged? Is any specific timing or months of raiding observed?

Throughout the year.

20. What crops were damaged most?

Maize, paddy, potato.

22. How many hut damages between 2015–2018?

Year	Huts damaged (number)
2015–16	619
2016–17	308
2017–18	193
2018–19	827

23. How much compensation paid in cases of human death (2015–2018)?

Year	Compensation paid (IN Rs.)
2015–16	7,90,000.00
2016–17	18,00,000.00
2017–18	13,92,500.00
2018–19	8,25,000.00 (Current year-5 cases) +11,70,000.00 (Old cases-11 cases)

24. How much compensation paid in cases of crop damage (2015–2018)?

Year	Compensation paid (IN Rs.)
2015–16	2,65,000.00
2016–17	15,41,506.00
2017–18	6,05,000.00
2018–19	38,40,870.00

25. How much compensation paid in cases of hut damage (2015–2018)?

Year	Compensation paid (Rs.)
2015–16	40,800.00
2016–17	8,80,355.00
2017–18	6,38,200.00
2018–19	36,05,950.00

RESULTS OF PRIMARY DATA ANALYSIS

From the preliminary data available in Table 2 it is known that most human deaths occurred in the fringe villages of the Madarihat Police Station (Madarihat PS) and Range, which shares a boundary with Jaldapara National Park. The data of the site of human deaths of Table 2 shows that Chekamari and Khairbari villages of Madarihat are very vulnerable. The questionnaire data shows that deceased included both old and young. The questionnaire shows that elephants raid mainly in the crop season of maize, paddy, and potato. In northern Bengal, farmers grow maize in summer, then paddy in the monsoon, then potato in the winter. As a result, local farmers are attracting elephant raids throughout the year. The questionnaire data shows that elephant depredation in the villages occurred in the evening and night mainly during raiding in the crop fields, and cause of human death is direct Injury or interaction with elephants. But as a follow up door to door communication, it appeared that in most cases the time of injury or direct interaction with elephants occurred early in the morning when elephant herds returned to the forest from the villages, and in a few cases in the evening at the time of elephant depredation during crop raiding.

Through preliminary data analysis, we understand that Chekamari and Khairbari villages of Madarihat Range and PS are vulnerable areas (Table 2) and, for that reason, a second phase of field study was conducted by the author and his field foresters of Madarihat Range in that area through door to door communication. Door to door communication was made by onsite visits and discussion with every household for the purpose of assessing the primary reason of HEC, to know the reason for open defecation (OD), to get the data of availability of toilets in those households, to know the education status of the family members of those households, and, most importantly to communicate the mitigation measures of HEC. The main result of this communication was learning the fact that 50 households were devoid of toilet facilities in these two villages, and the members of those households were going outside for OD in the early morning and in the evening. On an

Table 1. List of elephant deaths.

Year	Site	Age (in years)	Gender	Assigned cause	Remarks
2015	Tulsipara Das Ghar Village, P.S. Birpara	4	Female	Electrocution	Accidental
	Tulsipara Bara Line, P.S. Birpara	30	Female	Electrocution	Accidental
	Satali Nakadala Village area	-	Male	Electrocution	Accidental
	BD-8 Compartment of Jaldapara National Park	Adult	Female	Cardio respiratory failure	Natural
	JP-5 Compartment of Jaldapara National Park	15	Female	Cardio respiratory failure	Natural
	Railway track near Haripur, Madarihat, Alipurduar District	-	Male Tusker	Railway accident	Accidental
2016	BD-4 Compartment of Jaldapara National Park	Adult	Male	Cardio respiratory failure	Natural
	BN-4 Compartment of Jaldapara National Park	4	Male	Cardio respiratory failure	Natural
	Gopalpur Tea Garden	-	Male Tusker	Electrocution	Accidental
	BN-4 Compartment of Jaldapara National Park	25	Male	Infighting	Natural
2017	Titi-4 Compartment of Jaldapara National Park, near Torsa river bed.	2	Male Calf	-	Natural Death
2018	BD-3(a) Compartment of Kodalbasti Range, Jaldapara	40	Male	In fighting	Natural

average, 5–6 members live in each household of those villages. So, approximately 250–300 people were going outside for OD, with the fear of direct competition with elephants and other wild animals at that specific time. As per the objective of our study, we were searching for an innovative strategy to mitigate competition in the villages of non JFPC areas. Interestingly, these two villages, Chekamari and Khairbari, do not have JFPCs. Middle-aged adult men and women were, to some extent, more cautious to avoid interaction with elephants at that specific time. Young and older people by nature are less concerned with the interactions and some lost their life with the direct competition at the time of OD outside. The community and the relatives of the deceased confirmed the fact that almost all of the cases of human deaths by wild elephant attack occurred when the deceased went for OD outside.

DISCUSSION

Based on the interpretation of the survey and communication results, and the availability of CAMPA (Compensatory Afforestation Fund Management Planning Authority), 20 toilets with tube-well were constructed on a priority basis for the 20 neediest households of those villages. These households are unable to construct a toilet due to poor socio-economic condition. After construction, the toilets were handed over to those beneficiaries and behavioural changes were made to assure 100% usage of toilets through consecutive household visits, meetings, and seminars. Villagers also adopted the good practice of toilet usage instead of OD, and as a result direct confrontation with elephants was avoided. No human death has occurred to date in that area. All the toilets with tube-well were tagged with their GPS location and a beneficiary list is kept in the Madarihat Range Office and with the Jaldapara Wildlife Division. After seeing the success of the pilot project, the CAMPA authority sanctioned funds for those remaining 30 households devoid of toilet facilities. Construction is ongoing and very soon we will be able to officially distribute those toilets to make the Chekamari and Khairbari villages OD free. In the meantime, people are using community toilets and the toilets of relatives. To date no human deaths have been reported from those areas where toilets were constructed and usage was assured among the people through community participation.

CONCLUSION

By constructing toilets with tube-well as an innovative strategy a big problem of human-elephant competition and elephant conservation was addressed through door to door communication and with community participation. For the first time a protected area has

Table 2. List of human deaths.

Year	Site	Age (in years)	Gender	Possible Cause	Compensation Paid (IN Rupees)
2015–16	Jaldapara Village near forest boundary, Alipurduar	-	Male	Attacked by wild elephant	2,50,000.00
	Near house premises, Uttar Rangalibazna, Madarihat, Alipurduar.	98	Female	Attacked by wild elephant	2,50,000.00
	Near house premises, Madhya Chekamari, Madarihat, Alipurduar.	56	Male	Attacked by wild elephant	2,50,000.00
	Near house premises, Purba Khairbari, Madarihat, Alipurduar.	55	Male	Attacked by wild elephant	Part payment 20,000.00
	Near house premises, Uttar Khairbari, Madarihat, Alipurduar.	40	Male	Attacked by wild elephant	Part payment 20,000.00
2016–17	Sidhabari Village area, Alipurduar	42	-	Attacked by wild elephant	2,50,000.00
	Inside Khairbari Forest, Paschim Salkumar, Madarihat	40	Male	Attacked by wild elephant	Not eligible for compensation in forest land
	Kalikhola, Ballalguri, Totopara, Alipurduar	45	Male	Attacked by wild elephant	2,50,000.00
	Near house premises, Gopalpur Tea Garden, Madarihat	6	Female	Attacked by wild elephant	2,50,000.00
	Near house premises, Chapaguri, Madarihat	27	Male	Attacked by wild elephant	2,50,000.00
	In national park (on duty), Alipurduar	25	Male	Attacked by captive elephant	1,87,500.00
	Near house premises, Paschim Khairbari, Madarihat	35	Male	Attacked by wild elephant	1,75,000.00
	Ranbahadur Basti, village, Dalsingpara, Alipurduar	-	-	Attacked by wild elephant	1,87,500.00 (75% payment)
	Satali Mandalpara, Madhya Satali Village, Jaigaon, Alipurduar	46	Male	Attacked by wild elephant	2,50,000.00
	Inside Jaldapara National Park (on duty)	23	Male	Attacked by captive elephant	-
	Moiradanga (inside forest), Mairadanga Village, Falakata, Alipurduar	40	Female	Attacked by wild elephant	-
2017–18	Totopara Road, Hollapara village, Ballalguri, Totopara, Madarihat, Alipurduar	59	Male	Attacked by wild elephant	1,87,500.00
	Inside Jaldapara National Park in JP-1 Compartment, NWC Beat, Madarihat, Alipurduar	45	Female	Attacked by wild elephant	-
	Inside National Park in JP-1 Compartment, NWC Beat, Madarihat, Alipurduar	44	Female	Attacked by wild elephant	Not eligible to get compensation inside the national park
	Inside the Forest land of BD-3 Compartment, Kodalbasti Beat under Kodalbasti Range, Jaldapara National Park, Alipurduar	65	Male	Attacked by wild elephant	Not eligible to get compensation inside forest land.
	Madhya Madarihat, Madhya Khairbari village, Madarihat, Alipurduar	68	Male	Attacked by wild elephant	80,000.00
	Purba Khairbari, Torsa Tea Garden, Dalsingpara, Alipurduar	45	Female	Attacked by wild elephant	1,25,000.00
	In Jaldapara National Park (On duty), Madarihat, Alipurduar	47	Male	Attacked by captive elephant	2,50,000.00
	River side of Bhangri river, Garganda Tea Garden, Madarihat, Alipurduar	-	Female	Attacked by wild elephant	1,25,000.00
	In Jaldapara National Park (On duty), Falakata, Alipurduar	-	Male	Attacked by captive elephant	1,25,000.00
	Purba Deogaon, Falakata, Alipurduar	29	Male	Attacked by wild elephant	1,25,000.00
	Subhasini Nadi Line, Hasimara Outpost, Alipurduar	52	Male	Attacked by wild elephant	1,25,000.00
	Ramjhora Tea Garden, Birpara, Alipurduar	66	Male	Attacked by wild elephant	1,25,000.00
	StaliMandal Para, P.S. : Jaigaon, Alipurduar	54	Male	Attacked by wild elephant	1,25,000.00
2018–19	Lankapara, Madarihat,	-	-	Attacked by wild elephant	2,50,000.00
	Near House premises, Madarihat Range, Uttar Chakamari, Madarihat, Alipurduar	-	-	Attacked by wild elephant	1,25,000.00
	Near House premises, Paschim Madarihat Village, Madarihat, Alipurduar			Attacked by wild elephant	1,25,000.00
	Near house premises, Mujnai Tea Garden, Madarihat, Alipurduar	-	-	Attacked by wild elephant	1,25,000.00
	Near house premises, Chilapata Range, Uttar Mendabari, Kalchini, Alipurduar	-	-	Attacked by wild elephant	2,00,000.00

Image 1. Beneficiaries with toilets & tube-wells at Chhekamari and Khairbari villages, Madarihat, Alipurduar District, West Bengal. © Divisional Forest Officer, Jaldapara Wildlife Division.

adopted this sort of innovative strategy to mitigate human-elephant competition by promoting coexistence; as an added advantage the issue of open defecation is also addressed. So this project is a win-win situation for both the community people and the forest department towards elephant conservation.

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COMMUNICATION

New locality records and call description of the Resplendent Shrub Frog *Raorchestes resplendens* (Amphibia: Anura: Rhacophoridae) from the Western Ghats, India

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Abstract: The Resplendent Shrub Frog, *Raorchestes resplendens* Biju, Shouche, Dubois, Dutta, & Bossuyt, 2010 is a Critically Endangered species endemic to the Western Ghats and was considered to be restricted to a three-square kilometer patch atop Anamudi summit. In this study, we report 36 new locations of the species from the Anamalai massif of the southern Western Ghats. Niche-based prediction modelling suggests that the species is restricted to Anamalai massif. The call description of this frog is also provided for the first time. The preferred microhabitat of the frog is *Chrysopogon* grass clumps in the marshy/swampy montane grassland ecosystem. Restricted to a small area with controlled burning management practiced in its habitat, *R. resplendens* needs immediate attention.

Keywords: Anamalai, Critically Endangered, ground-dwelling bush frog, new distribution record, vocalization.

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Author contribution: PSE & SD conceived the study; SD, KPR carried out field work; all authors equally contributed to the data compilation, analysis and writing the manuscript

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INTRODUCTION

There are currently 8,134 described species of amphibians (Frost 2020) and an average of 144 species described every year starting from 2004–2015 (Tapley et al. 2018). At the same time, amphibians are the most threatened group of vertebrates with 41% of the total assessed species under threatened categories (IUCN 2016). Considering the total number of new species described between 2004 and 2016, India ranks second globally with 155 species (Tapley et al. 2018). Of these, 75% are from the Western Ghats and Sri Lanka Biodiversity Hotspot (Myers et al. 2000; Mittermeier et al. 2004). One of the most diverse groups of frogs in India with the greatest number of species described since 2004 is the genus *Raorchestes* known to be a genus of direct developing rhacophorid frogs (Biju et al. 2010).

Raorchestes resplendens Biju, Shouche, Dubois, Dutta, & Bossuyt, 2010 is a Western Ghats endemic, medium-sized, ground-dwelling bush frog. Its prominent orange colouration and large glands, bordered with black make it distinct from other species of *Raorchestes*. The species belongs to the *beddomii* clade (Vijayakumar et al. 2014) and is restricted to the Anamalai massif of Western Ghats. The species is known from only from its type locality, a three square kilometer patch of habitat on the Anamudi summit, the highest peak (2,695m) in Western Ghats in Eravikulam National Park (ENP) and a site approximately 20km north-east of Anamudi summit (Joseph et al. 2012). Joseph et al. (2012) suggested the possibility of a wider distribution of the species within ENP. *Raorchestes resplendens* is assessed as Critically Endangered (IUCN SSC Amphibian Species Specialist Group 2011).

In this study, we provide information on the distribution of the species inside and outside the protected area network based on surveys undertaken in 2015–2018. In addition, we also predict the probable distribution of the species using niche-based modelling. We also provide the first ever description of the vocalization of *R. resplendens.*

STUDY AREA

Eravikulam National Park (ENP, 10.083–10.333 ^{0}N & 77.00—77.166 ^{0}E) in Kerala, India. This 97km^2 national park is one of the few remaining undisturbed patches of the montane shola-grassland ecosystem in the Western Ghats. The high elevation protected area located in the Kannan Devan Hills of Idukki District has a base elevation of approximately 2,000m. ENP experiences tropical montane climate with average annual rainfall of 5,000–6,500 mm. More than 60% of the park area is dominated by grasslands with shola patches in the valleys.

MATERIALS AND METHODS

A combination of survey methods including visual encounter surveys, call surveys, and scan searches (Heyer et al. 1994; Krishnamurthy 2003; Halliday 2006) were used between January 2015 and December 2018 to document the distribution of *R. resplendens*. During the breeding season (May−September), surveys were undertaken from 18.00–02.00 h, as bush frogs are known to be most active at night (Biju et al. 2010). Morning and evening surveys were conducted from 08.00–13.00 h and 14.00–17.00 h to record diurnal activity, if any. Surveys were done in shola-grassland ecosystems above 1,700m especially inside ENP from where the species was first described and reported. To avoid repeated count and getting maximum distribution range of the species the surveys were spatially replicated.

Calls of *R*. *resplendens* were recorded at approximately 0.5m distance using ZOOM H4nSP Handy Recorder from four locations in ENP, including Anamudi, Kolukan, Bheemanoda, and Sambamala area. Ten to 20 calls were recorded for each individual (n=10 males). Ambient temperature and snout vent length (SVL) was taken immediately after the recording using Kestrel 3500 hand-held weather station and a Mitutoyo digital vernier caliper. Analyses of the calls were done using Raven v1.4 software (Cornell Laboratory of Ornithology, Ithaca, NY, USA) (Bee et al. 2013a,b; Thomas et al. 2014). Temporal and spectral parameters of calls were measured following definitions of Bee et al. (2013a,b). Six call properties: call duration (ms)—time between the beginning of first pulse and the end of last pulse in a call; call rise time (ms)—time between the beginning of first pulse and the peak of pulse of maximum amplitude; call fall time (ms)—time between the peak of pulse of maximum amplitude and end of last pulse; inter-call interval—time between end of a call to the beginning of the next call; call rate—number of calls delivered per minute; and overall dominant frequency were analyzed for the current study.

Prediction of distribution and calculation of extent of occurrence (EOO): Maximum entropy species distribution modelling software (Maxent) version 3.4.1 was used to predict the distribution of *R. resplendens* in Anamalai Hills. We used approximately 30 arc seconds of data for altitude, precipitation, average temperature and 19 bioclimatic variables available at the WorldClim website (http://www.worldclim.org/); 30-m resolution raster dataset layers were georectified to WGS 1984 43 North Zonation. Geographical coordinates and elevation of each location were recorded using Garmin Montana 680 and a map with sight records and the potential distribution was plotted using ArcGIS. The EOO and area of occupancy (AOO) (IUCN 2012) were calculated using the geospatial conservation assessment tool, GeoCAT (Bachman et al. 2011). The EOO was also calculated from species distribution model by overlaying fishnet squares over the prediction map. Each square covered an area of $4km^2$. Squares with medium, high, and very high prediction values were included to calculate the EOO since there were no records of the species from areas of medium to very low prediction even after intensive surveys.

RESULTS AND DISCUSSION

Prior to our study the Critically Endangered (CR) *R. resplendens* (Image 1) was known to occur only inside ENP from two locations, Anamudi summit and Poovar. The present study reports 36 new locations for the species including four from outside ENP (Table 1 and Image 2). The four new locations outside ENP are Njandalamala of Chinnar Wildlife Sanctuary, a location south-east of ENP in Munnar Forest Division, a location near the south-west boundary of ENP in Munnar Forest Division, and one location in the adjacent Anamalai Tiger Reserve of Tamil Nadu lying close to the north-west boundary of ENP. The record from near Konalar, Anamalai Tiger Reserve is the lowest elevational record (1,896m) for the species whereas Anamudi Peak (2,695m) is the highest. The previously reported lowest elevational record was from Poovar (2,522m).

During the three-year study period from within ENP limits *R. resplendens* was encountered 637 times. This makes the species the second most encountered *Raorchestes* species in the grasslands of ENP after *Raorchestes dubois* (1,438 times). The unique ground-dwelling habit favored by *R. resplendens* could be the reason they evaded researchers for such a long time. They seem to be very sensitive to light and retreat into grass clumps whenever there is an artificial source of light. Contrary to the tiny bamboo thicket (*Arundinaria densifolia*) habitat preferred by the *R. resplendens* recorded on Anamudi summit, the majority of the individuals observed elsewhere were found actively calling and breeding in marshy/swampy grasslands (Image 3) alongside a water source in the valleys of the montane grasslands rather than on peaks.

At 21.20h on 28 May 2015, a single male was observed calling within a grass clump (*Chyrsopogon* sp.), 5cm above the ground at a marshy area on the base of Sambamala Hill (Image 1). Further investigation resulted in reporting 21 individuals (14 calling males and 7 females) on the same day from the same habitat patch. A single male specimen was collected and preserved in the wildlife museum of Kerala Forest Research Institute,

Image 1. *Raorchestes resplendens* in its habitat.

Table 1. Sighting locations of *Raorchestes resplendens* from southern Western Ghats.

	Location	Area	Lat.	Long.	Elevation
1	Njandalamala	Chinnar WS, KL	10.313642°	77.141561°	2346m
2	Munnar Division	Munnar Forest Division, KL	10.093747°	77.202883°	2587m
3	Rajamala Tourism Zone	Eravikulam, KL	10.143794°	77.037753°	1905m
4	Naaykollimala	Eravikulam, KL	10.142961°	77.036047°	1909m
5	Wireless Station Rajamala	Eravikulam, KL	10.149767°	77.044744°	2238m
6	Umayamala	Eravikulam, KL	10.163153°	77.072042°	2169m
7	Mesthirikettu	Eravikulam, KL	10.184550°	77.088272°	2174m
8	Range Point	Eravikulam, KL	10.187094°	77.085794°	2203m
9	Bheemanoda	Eravikulam, KL	10.195603°	77.084517°	2228m
10	Kallupaalam	Eravikulam, KL	10.194811°	77.077353°	2243m
11	Kallupaalam 2	Munnar Forest Division, KL	10.190761°	77.072839°	2173m
12	Bheemanoda 2	Eravikulam, KL	10.196908°	77.086600°	2204m
13	Bheemanoda 3	Eravikulam, KL	10.192550°	77.090950°	2200m
14	Varayattumala 1	Eravikulam, KL	10.204817°	77.085856°	2212m
15	Varayattumala 2	Eravikulam, KL	10.208128°	77.088392°	2237m
16	Kambipaalam Mala	Eravikulam, KL	10.217369°	77.081100°	2216m
17	Eravikulam	Eravikulam, KL	10.209414°	77.075336°	2199m
18	Eravikulam 2	Eravikulam, KL	10.218831°	77.078683°	2178m
19	Eravikulam 3	Eravikulam, KL	10.221906°	77.079378°	2156m
20	Sambamala Base	Eravikulam, KL	10.216506°	77.071711°	2200m
21	Sambamala	Eravikulam, KL	10.213450°	77.065103°	2266m
22	Anamudi View Near Kolukan	Eravikulam, KL	10.218089°	77.059017°	2229m
23	Kolukkan	Eravikulam, KL	10.227481°	77.047964°	2110m
24	Campamala	Eravikulam, KL	10.225033°	77.074289°	2329m
25	Erumapetti	Eravikulam, KL	10.231128°	77.089286°	2269m
26	Turners Valley	Eravikulam, KL	10.222319°	77.089286°	1901m
27	Chinna Mannumudi	Eravikulam, KL	10.228486°	77.094269°	2247m
28	Kudimala	Eravikulam, KL	10.215919°	77.109719°	2049m
29	Near Varattukulam	Eravikulam, KL	10.236183°	77.100469°	2182m
30	Kaatumala	Eravikulam, KL	10.254211°	77.097894°	2526m
31	Kaatumala 1	Eravikulam, KL	10.258489°	77.101667°	2271m
32	Kaatumala 2	Eravikulam, KL	10.267222°	77.090308°	2050m
33	Poovar 1	Eravikulam, KL	10.286419°	77.084633°	1984m
34	Konalar	Grass Hills, TN	10.321906°	77.070497°	1896m
35	Border Grass Hills	Eravikulam, KL	10.309903°	77.092350°	2096m
36	Border Chinnar	Eravikulam, KL	10.299444°	77.113611°	2092m
37	Poovar (Previous record)	Eravikulam, KL	10.273414°	77.086064°	2040m
38	Anamudi (Previous record)	Eravikulam, KL	10.168367°	77.059954°	2695m

KL—Kerala | TN—Tamil Nadu | WS—Wildlife Sanctuary.

Peechi, Kerala (KFRI/WLM/A0035). The size was small in comparison with the details given in published information and from those field-measured earlier during the study. The measurements of the preserved specimens are as follows: snout vent length (SVL) 20.76mm small; head slightly wider than long (HW) 7.88mm, (HL) 7.44mm; snout length (SL) 2.63mm larger than horizontal diameter of the eye (EL) 2.43mm; snout

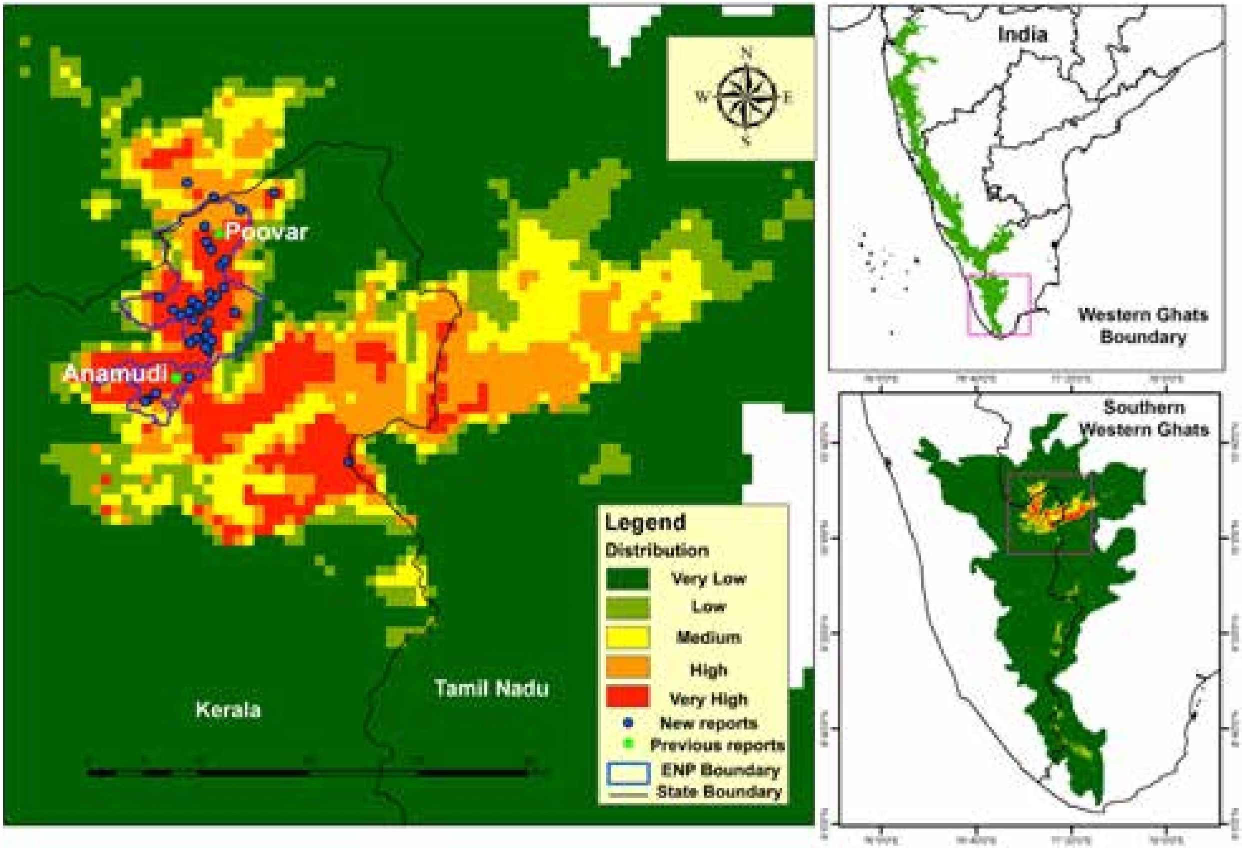

Image 2. Distribution of the *Raorchestes resplendens* and prediction based on niche-modelling.

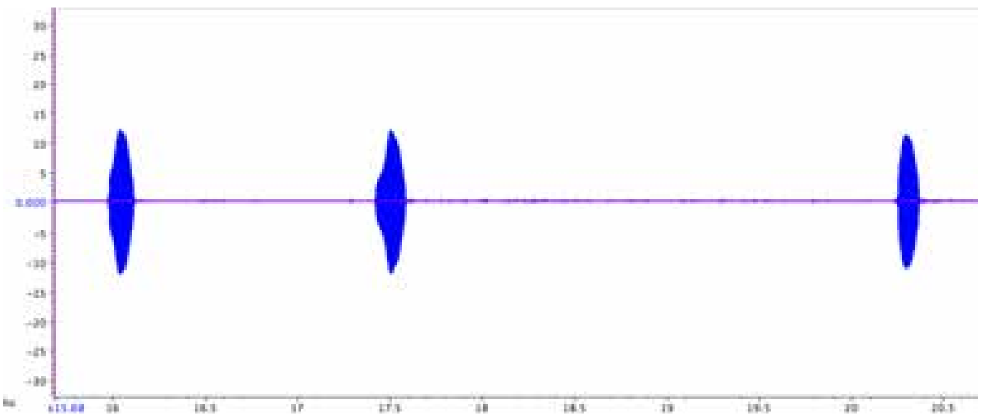

Figure 1. Wave form of *Raorchestes resplendens* call in 5s time frame.

rounded in dorsal view; minimum distance between upper eyelids (IUE) is 2.82mm and maximum width of upper eyelid (UEW) is 1.43mm. Distinct and rounded tympanum. Forelimb (FLL) 4.44mm shorter than hand length (HAL) 4.733mm; fingers with discs and distinct circum-marginal grooves; webbing absent on fingers and absence of nuptial pads. Unlike many of the species in the genus *Raorchestes*, the hind limbs are moderately short for this species; shank length (ShL) 5.37mm shorter than thigh length (TL) 7.01mm; foot length (FOL) 7.06mm shorter than distance from the base of inner metatarsal tubercle to the tip of toe IV. Toes with discs and distinct circum-marginal grooves and reduced webbing. Dorsum with large orangish glands whereas the creamy white ventrum is granular.

Call Description

Raorchestes resplendens males were observed

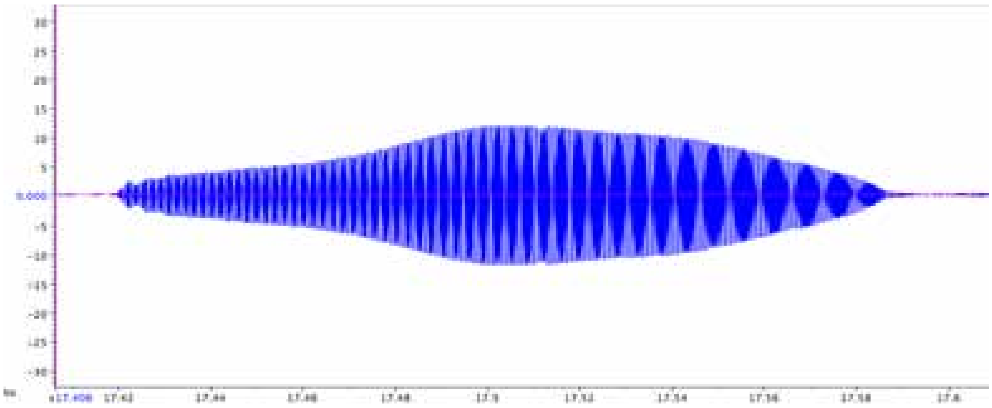

Figure 2. Wave form of *Raorchestes resplendens* call in 2s time frame

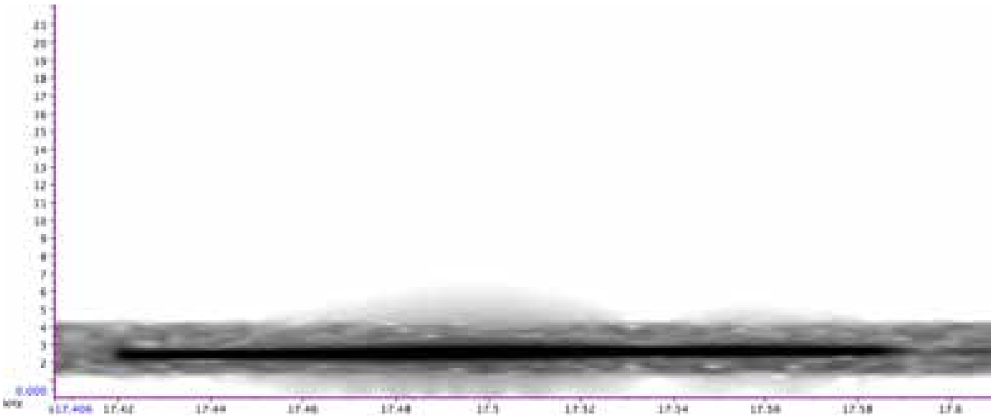

Figure 3. Spectrogram of *Raorchestes resplendens* call

actively calling from 18.00–02.00 h, during their peak breeding season in May–September. A total of 141 calls from 10 males were analyzed for the description of vocalization. Temperature ranged between 16–20 °C during all recordings. Calls were relatively simple (Figure 1 & 2). The advertisement call (https://doi.org/10.6084/m9.figshare.12781229.v1) had non-pulsatile temporal structure unlike published calls of other bush frogs including *Raorchestes graminirupes*, *R. flaviocularis, R. silentvalley, R. lechiya, R. travancoricus*, and *Pseudophilautus kani* (Bee et al. 2013a,b; Vijaykumar et al. 2014; Rajkumar et al. 2016; Zachariah et al. 2016). Advertisement calls typically ranged between 58.9–148.8 ms in duration (Table 2). On an average, the interval between two calls was 2.9 ± 3.6 s, and these intervals were uncorrelated with SVL or mass (Table 2). The call rise time ($\overline{X}$ = 46.3 ms ± 29.4 ms; Table 2) was slightly shorter than call fall time ($\overline{X}$ = 56.7 ms ± 16.8 ms; Table 2). The calls were typically delivered at rate of 21.5 calls/minute (Table 2).

The spectrum was characterized by single broad peak with mean dominant frequency of 2.5 KHz (Figure 3, Table 2).

Distribution

The niche-based prediction model of distribution in the southern Western Ghats suggests that the species is restricted to montane grasslands of Munnar-Valparai area of Anamalai massif. The EOO and AOO calculated using GeoCAT are 289km^2 and 84km^2, respectively. The approximate EOO calculated based on the prediction using minimum convex polygon was ~272km^2 with the majority of the area being within ENP and the calculated EOO does not include areas where our model suggested a low, very low likelihood of occurrence as there were no actual observations of the species in these areas (Image 2). The species habitat is well-protected as its distribution largely occurs within protected areas. The areas outside the protected area network owned by the Kerala Forest Department where the species occurs could be further designated as eco-sensitive zones to prevent management-based habitat modifications

Table 2. Call characteristics of 141 calls of *Raorchestes resplendens* from 10 males.

Call character	Mean	SD	Minimum	Maximum
Call duration (ms)	103	37.3	58.9	148.8
Call rise time (ms)	46.3	29.4	11.9	80.5
Call fall time (ms)	56.7	16.8	39.9	69.8
Intercall interval (s)	2.9	3.6	1.4	4.9
Overall dominant frequency (KHz)	2.5	0.1	2.4	2.8
Call rate (calls/min)	21.5	7.9	16.1	41.4

Image 3. Marshy grassland habitat of *Rarochestes resplendens*.

(Kanagavel et al. 2018). The absence of the species at Anamudi National Park and adjacent areas could be due to the absence of grassland habitats.

The report of the species from areas other than Eravikulam National Park including Chinnar Wildlife Sanctuary, grass hills of Anamalai Tiger Reserve, and areas of Munnar Forest Division ensures better conservation possibilities as these areas are under protection by the Kerala and Tamil Nadu forest departments. Controlled cold burning of grasslands in November–February months before the grass gets dry (Image 4), practiced as a part of habitat management programme in Eravikulam National Park (Kerala Forests & Wildlife Department 2013), is observed to be detrimental to slow-moving reptiles and amphibians due to mortality during the fire and exposed habitat without thick grasses (Image 5) after fires. It was also observed that the mortality is

Image 4. Control burning in montane grasslands.

Image 5. *Raorchestes resplendens* moving through burnt grassland.

comparatively less and recolonization in smaller animals is faster in areas where mosaic pattern is followed while burning (Bhaskar et al. 2019). A further reduction in the size of the burnt areas in mosaic pattern would ensure better protection to the herpetofauna. More sampling efforts and systematic approach is required to understand more about the specific threats faced by the *Raorchestes resplendens*. The management practice of controlled burning, however, might be a threat that needs immediate attention which is specific to ENP, one of its major habitat.

Information on the call of the species will be helpful in further studies as the species is very hard to detect which might be the possible reason for detecting the species from only two locations after the initial description of species in 2010 and the knowledge of the distribution extent can lead to proper conservation action plans for the Critically Endangered species.

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COMMUNICATION

First record of a morphologically abnormal and highly metal-contaminated Spotback Skate *Atlantoraja castelnaui* (Rajiformes: Arhynchobatidae) from southeastern Rio de Janeiro, Brazil

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Abstract: This paper reports the first record of a morphologically abnormal and highly metal-contaminated Spotback Skate *Atlantoraja castelnaui* (Ribeiro, 1907) (Elasmobranchii, Rajidae) in Rio de Janeiro, Brazil. Incomplete fusion of the right pectoral fin with the head was observed, while a radiography indicated muscle sheaf discontinuity near the rostrum. Extremely high contamination by several elements, including teratogenic As, Hg and Cd in the individual was detected. The observed morphological deformity may be due to high concentrations of teratogenic elements in the environment, possibly playing a role in abnormal embryonic development in egg cases exposed to high environmental concentrations of these contaminants. *Atlantoraja castelnaui* is the least biologically understood member of the genus *Atlantoraja*, and this paper furthers both morphological observations and ecotoxicological assessments on this species.

Keywords: Altered embryonic development, Arhynchobatidae, food safety, metal contamination, morphological abnormality,

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Ethics statement: Elasmobranch sampling is permitted under SISBIO license 70078-1. All samples were bought from local artisanal fishers and no animals required sacrifice.

Competing interests: The authors declare no competing interests.

For **Author details, Author contribution** and **Acknowledgements** see end of this article.

INTRODUCTION

The Spotback Skate *Atlantoraja castelnaui* (Ribeiro, 1907), Arhynchobatidae, is endemic to the southwestern Atlantic Ocean, between Rio de Janeiro, Brazil, and northern Argentina (Hozbor et al. 2004; Figueiredo & Menezes 2015). *A. castelnaui* can reach 1.5m and occurs between 10 and 500 meters in depth, with benthic habits, oviparous reproduction mode and feeds on teleost fish, cephalopods, decapods and other elasmobranchs (Moreira et al. 2011; Barbini & Lucifora 2012; Figueiredo & Menezes 2015). It is especially vulnerable to trawl fisheries due to its benthonic habits (Ebert & Sulikowski 2009). In addition, owing to its large size, this taxon achieves high commercial values and trawl experiences along the coast of Uruguay and Argentina have indicated a 75% drop in biomass between 1994 and 1999 (Hozbor et al. 2004). As such, many populations are overexploited throughout their distribution, *A. castelnaui* is listed as "Endangered" by the IUCN and currently undergoing decreasing population trend (Hozbor et al. 2004). In fact, the vulnerability of large skates and rays to overexploitation and, consequently, stock depletion, is well documented (Dulvy & Reynolds 2002). Given this scenario, alongside the fact that this species is the least biologically understood member of the *Atlantoraja* genus (Moreira et al. 2011), information on the basic biology of *A. castelnaui* is required to support fisheries management and conservation actions (Ribeiro-Prado et al. 2008).

The most common morphological abnormality in skates (order Rajiformes) is the non-fusion of the pectoral fins to the head or rostrum (Mejía-Falla et al. 2011) (Figure 1), and some studies have reported such abnormalities for the Arhynchobatidae family (Casarini et al. 1996; Ribeiro-Prado et al. 2008).

In order to contribute towards biological knowledge on *A. castelnaui*, the aim of this study was to describe a morphological abnormality in a very young specimen captured in southeastern Brazil, where no conservation measures are in place for this species (Hozbor et al. 2004), through morphometric measurements, radiography and chemical analyses.

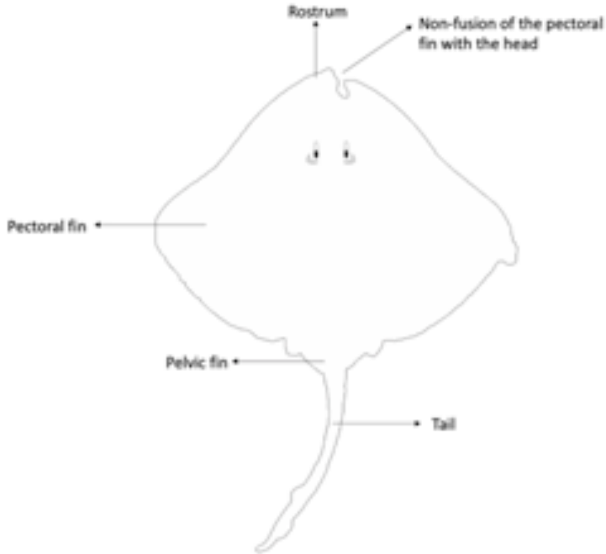

Figure 1. Schematic example of the non-fusion of the pectoral fins to the head in skates and rays.

MATERIAL AND METHODS

An abnormal and very young male *A. castelnaui* specimen was collected during regular field studies of elasmobranchs caught by artisanal fishing gillnets at Tamoios, Cabo Frio, southeastern Brazil (Image 1) on 12 October 2019.

The ray specimen is deposited at the Fish, Chelonian, Seabird**,** and Marine Mammal Tissue Collection, at the Instituto Oswaldo Cruz, Fiocruz, under identification code CTPQAMM #01-2019. At the laboratory, the following morphometric measurements were taken: total length (TotL); disk length (DL); disk width (DW); total weight (TW); tail length (TailL). Bilaterally symmetric structures were also measured on the right and left sides, as follows: gill length (GL); eye height (EH); eye diameter (ED), spiracle height (SH); spiracle diameter (SD); pelvic fin length (PFL); pectoral fin length (PectFL). All measurements were taken to the nearest mm using a caliper.

The abnormal specimen was then submitted to a radiography for further abnormality assessments.

A ventral muscle sample was removed with the aid of a stainless-steel scissors and metals, metalloids and rare earth elements were determined by inductively coupled plasma mass spectrometry (ICP-MS). Briefly, approximately 150mg of the sample were placed in a 15mL screw-capped polypropylene tube and mixed with concentrated sub-boiled bidistilled nitric acid (Merck, Rio de Janeiro). This mixture was then left to stand overnight at room temperature in the closed tube. After 12 hours, the acid decomposition was completed by heating the sample at 100°C, for 4h in the closed vessel, avoiding volatilization of volatile elements, such as Hg and Se. The sample was then diluted with ultra-pure water (resistivity > 18.0 MΩ cm) obtained from a Merck Millipore purifying system (Darmstadt, Germany) to

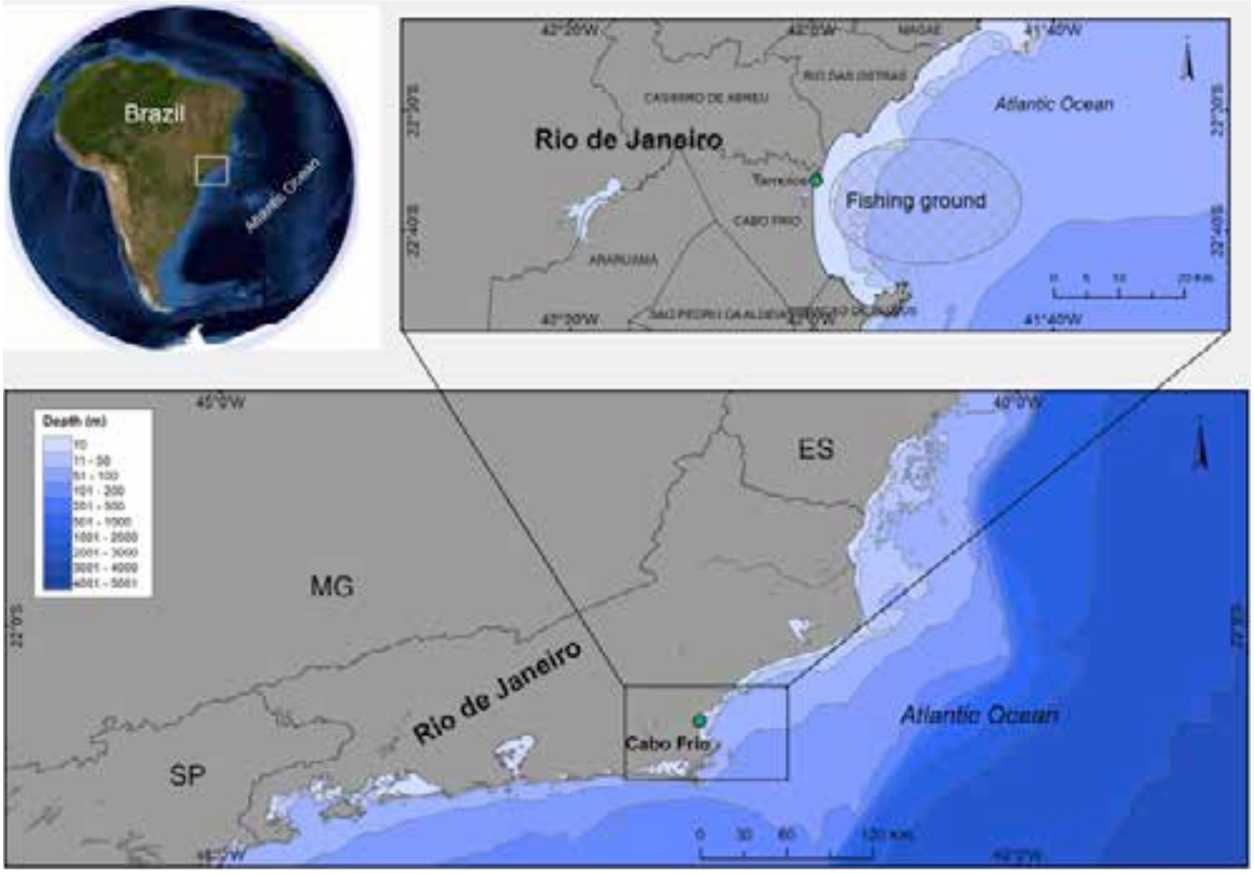

Image 1. The sampling location of the *A. castelnaui* specimen, at Tamoios, Cabo Frio, southeastern Brazil.

10mL. Metals, metalloids and rare earth elements were determined, in quintuplicate, using multi-elemental external calibration, by appropriate dilutions of a mixed standard solution (Merck IV) and using ^{102}Rh as the internal standard at 20 mg L^{-1}. The determinations were conducted on a NexIon 300 Perkin Elmer ICP-MS (Norwalk, CT, USA). Method accuracy was verified with procedural blanks and by the parallel analysis of the certified reference material (CRM) ERM®- BB422 (fish muscle) in triplicate. All CRM recovery values were within acceptable Eurachem standards (Eurachem 1998).

RESULTS

The *A. castelnaui* abnormality consisted of the incomplete fusion of the right pectoral fin with the head, resulting in cleft between the pectoral fin and the rostrum (Image 2). No anophthalmia was observed.

The morphometric measurements of the *A. castelnaui* specimen are displayed in Table 1.

Bilaterally symmetric structures were also measured, in order to assess possible variations, displayed in Table 2.

The radiography image of the specimen is displayed in Image 3. Muscle sheaf discontinuity is noted near the rostrum, while a very discrete radio-opacity, possibly indicative of arthrosis, is also observed.

The metal, metalloid and rare earth element concentrations detected in the muscle tissue sample are displayed in Table 3.

The metals Bi, Cd, In, Nb and Re were all below their respective LQ of 0.024, 0.035, 0.008, 0.029 and 0.0005 mg kg^{-1} wet weight, while the rare Earth elements Nd, Pr and Th were below their LQ of 0.0001, 0.0003 and 0.014 mg kg^{-1} wet weight, respectively.

DISCUSSION

It appears that pectoral fins non-adherent to the head are the most frequently recorded abnormality in Rajidae species worldwide (Ribeiro-Prado et al. 2008), where the pectoral fin fails to fuse together at the front of the head during early development stages (Ahlstrom

Image 2. Incomplete fusion of the right pectoral fin with the head in a very young *A. castelnaui* specimen from Cabo Frio, Rio de Janeiro, southeastern Brazil. © Salvatore Siciliano and Catarina Amorim Lopes.

Table 1. Morphometric body measurements of a very young *A. castelnaui* specimen from Cabo Frio, Rio de Janeiro, southeastern Brazil.

Morphometric body measurements	
Total length (cm)	34.50
Total weight (g)	115.00
Disk length (cm)	15.00
Disk width (cm)	20.90
Tail length (cm)	16.50

Table 2. Bilaterally symmetric structure measurements of the assessed *A. castelnaui* specimen from Cabo Frio, Rio de Janeiro, southeastern Brazil.

Measurement	Right	Left
Length of the 1st gill arch	3.80	3.80
Length of the 2nd gill arch	2.90	3.30
Length of the 3rd gill arch	3.20	3.36
Length of the 4th gill arch	3.00	3.30
Gill arch length means	2.20	2.40
Eye diameter	6.37	6.00
Eye height	10.03	10.53
Spiraculum diameter	4.66	6.13
Spiraculum height	4.43	4.06
Pectoral fin width	105.6	106.83
Pelvic fin width	40.80	38.66

& Bigelow 1963). Records of such abnormalities are available for *Atlantoraja cyclophora, A. platina, Raja asterias*, *R. brachyura*, *R. clavate*, *R. miraletus*, *R. radiata*, *R. radula*, *R. richardsoni, Rioraja agassizi and Rostroraja alba* (see Ribeiro-Prado et al. 2008 for more details). For *A. castelnaui,* a previous record of incomplete pectoral fin fusion is noted for the state of São Paulo, also located in southeastern Brazil, in one sub-adult specimen (total length and disk width of 87.5cm and 61cm, respectively), albeit for the left pectoral fin (Ribeiro-Prado et al. 2008).

Fluctuating asymmetry, defined as random deviations from perfect bilateral symmetry due to developmental disturbances during early life, is a valuable tool to quantify stress during early developmental stage (Jagoe & Haines 1985). In the present study, most right-side structures were slightly smaller compared to the left-side structures, with the exception of the 1st gill arch (same size), eye diameter (larger), spiraculum height (higher) and pelvic fin width (larger). Although the sample size is of only one individual, the observed differences in bilaterally symmetric structure may be indicative of developmental disturbances, and future studies in the study area should also carry out this analysis in order to build a fluctuating asymmetry database for this and other species.

It has been postulated that unfavorable environmental conditions, such as high pollutant loads, probably play a role in occurrence of abnormalities (Casarini et al.

Table 3. Metal, metalloid and rare earth element concentrations (mg kg^{-1} wet weight) in the muscle of the assessed *A. castelnaui* specimen from Cabo Frio, Rio de Janeiro, Southeastern Brazil. LQ – Limit of Quantification (mg kg^{-1} wet weight), defined as the lower limit that elements can be accurately quantified.

Metals and metalloids					
Element	**LQ**	**Sample**	**Element**	**LQ**	**Sample**
Ag	0.003	0.178	**Pb**	0.010	2.288
Al	0.101	82.74	**Pd**	0.003	0.113
As	0.015	61.64	**Rb**	0.002	4.626
Au	0.001	0.006	**Sb**	0.002	0.052
Ba	0.014	2.442	**Sc**	0.087	0.82
Br	1.022	265.55	**Se**	0.428	7.951
Co	0.002	0.17	**Sn**	0.007	0.149
Cr	0.034	13.59	**Sr**	0.018	635.162
Cs	0.001	0.098	**Ta**	0.003	0.007
Cu	0.018	5.45	**Ti**	0.163	39.40
Fe	2.642	378.24	**Tl**	0.001	0.002
Ga	0.002	0.12	**U**	0.006	0.022
Ge	0.020	0.12	**V**	0.006	3.39
Hg	0.009	0.487	**W**	0.019	0.046
Mn	0.022	8.17	**Y**	0.001	0.352
Mo	0.009	0.197	**Zn**	0.206	256.37
Ni	0.010	4.19	**Zr**	0.014	0.076
Rare earth elements					
Element	**LQ**	**Sample**	**Element**	**LQ**	**Sample**
Ce	0.004	0.176	**La**	0.001	0.085
Dy	0.001	0.012	**Lu**	0.001	0.001
Er	0.000	0.007	**Sm**	0.001	0.015
Eu	0.001	0.032	**Tb**	0.000	0.001
Gd	0.001	0.028	**Tm**	0.000	0.001
Ho	0.000	0.001	**Yb**	0.001	0.005

1996; Ribeiro-Prado et al. 2008), especially during early developmental fish stages, which are considered particularly sensitive to water pollution toxicity (Osman et al. 2007; Jezierska et al. 2009; Zhang et al. 2012). *In vitro* exposure to metals, in particular, has been proven as responsible for increasing the frequency of several types of body malformations of fish embryos (Cheng et al. 2000; Flik et al. 2002; González-Doncel et al. 2003; Hallare et al. 2005; Jezierska et al. 2009), confirming the teratogenic and genotoxic properties of metals in fish. In addition, several field studies have also been carried out and have associated the genotoxic potential of these compounds to morphological abnormalities in fish (Ferrante et al. 2017; Braga et al. 2019). This shall be further discussed ahead.

This hypothesis was assessed by a screening of metals, metalloids and rare earth elements in the muscle tissue of this individual prior to fixation in alcohol.

The specimen assessed herein was a very young individual. *A. castelnaui* juveniles and females have been reported as inhabiting more coastal areas in Brazil (Oddone et al. 2008). This leads to high exposure to environmental contamination from anthropogenic activities in these individuals. In addition, *A. castelnaui* feeds mainly on bony fish, followed by decapods, elasmobranchs, mollusks, and cephalochordates, with crustaceans present in this species diet in greater amounts in smaller individuals, while cephalopods, elasmobranchs, and echinoderms predominate in higher class sizes (Barbini & Lucifora 2012). Therefore, this skate is at high risk for the bioaccumulation of several contaminants, including metals, through the dietary route.

Morphological deformities in several fish species

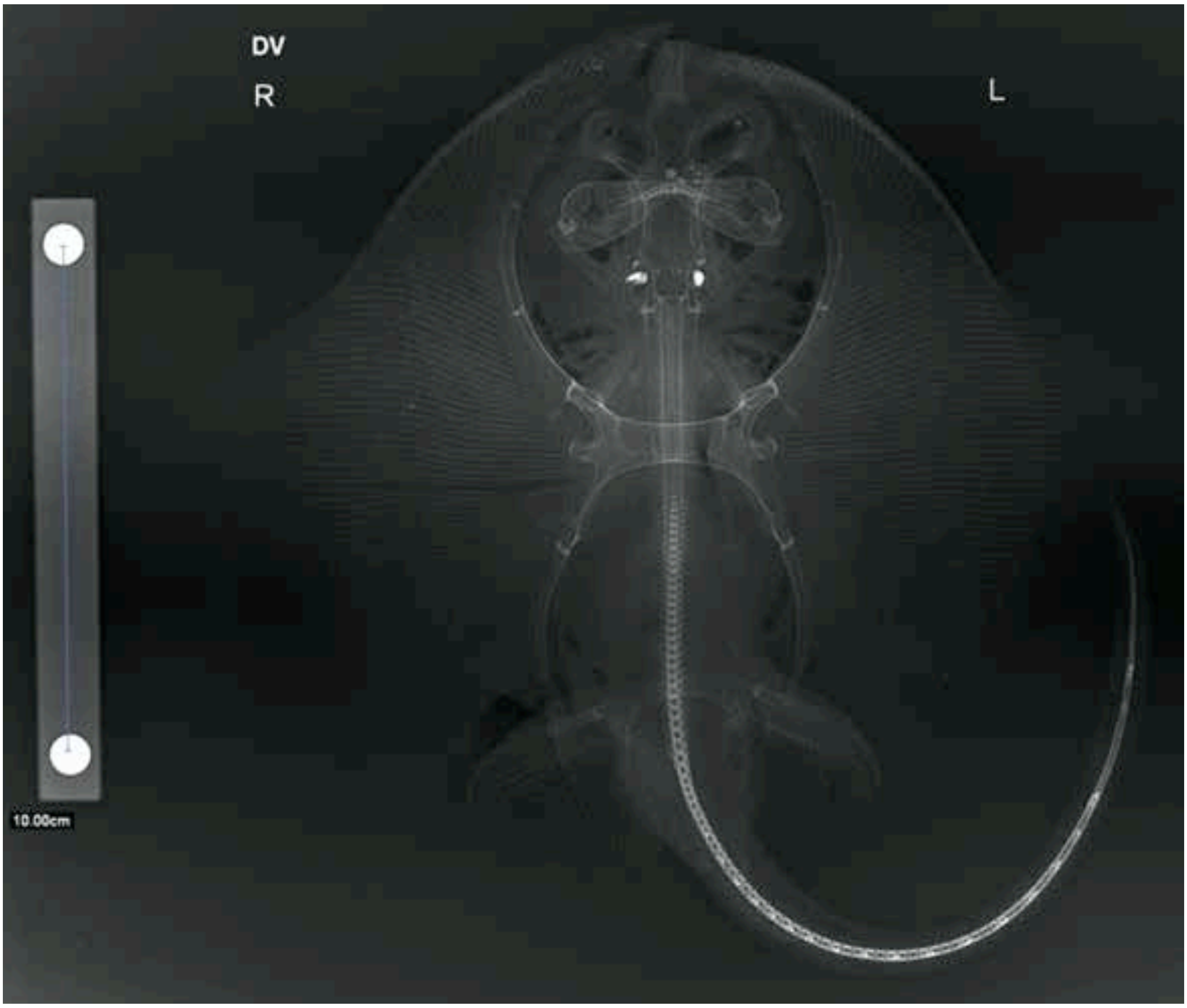

Image 3. Dorsal view radiography image of the assessed *A. castelnaui* specimen from Cabo Frio, Rio de Janeiro, southeastern Brazil.

have been related to water quality and contamination, including metal concentrations (Hiraoka & Okuda 1983; Sun et al. 2009; Alavi-Yeganeh et al. 2019). For example, altered spinal curvatures in Rainbow Trout *Oncorhynchus mykiss* larvae hatched from Cd-incubated eggs has been reported (Woodworth & Pascoe 1982), as well as spinal and cranial malformations and jaw underdevelopment in common carp larvae exposed to Cu during embryonic development (Stouthart et al. 1995). Other assessments have verified various types of vertebral deformities and two-headed morphological abnormalities in Cu- and Zn-exposed White Sucker *Catostomus commersoni* larvae (Munkittrick & Dixon 1989), skeletal kinking, improperly formed mouth, head and eyes and reduced brain size, among others, in Zn-exposed Fatthead Minnow *Pimephales promelas* embryos (Dawson et al. 1988), eye and optic capsules malformations and jaw and branchial arch deformities in Zn-exposed Atlantic Herring *Clupea harengus* eggs who hatched into larvae (Somasundaram et al. 1984), and several spinal cord deformations in Cu-exposed common carp embryos (Flik et al. 2002). In addition, Zebrafish *Danio rerio*, widely applied as a model bioindicator species concerning metal effects, assessments concerning Cd exposure in embryos have reported several morphological alterations, such as head and eye hypoplasia, altered axial curvature and tail malformations (Cheng et al. 2000), helical bodies, hooked tails, tail degeneration and abnormal body posture (Hallare et al. 2005), and severe stunting, ocular deformities (microphthalmia, anisophthalmia and anophthalmia) and dystrophic jaws (synarthrosis) (González-Doncel et al. 2003).

Besides *in vitro* assessments, real environmental scenarios have also indicated that metals are most likely causative of morphological abnormalities in fish. For example, spinal deformities in natural Grass Goby

Zosterisessor ophiocephalus populations from the Gulf of Gabès in Tunisia have been associated to metal (Cd, Cu and Zn) accumulation, as higher frequencies of deformities were observed in metal-contaminated areas compared to non-contaminated areas (Messaoudi et al. 2009); a high frequency of vertebral deformities in Fourhorn Sculpin *Myoxocephalus quadricornis* exposed to heavy metal pollution in the Gulf of Bothnia (Baltic Sea) has been verified (Bengtsson & Lithner 1988), and higher frequencies of skeletal anomalies (deformed fins, the lack of one or more fins and pelvic girdle, pugheadedness, asymmetric cranium, shortened operculae, fused and deformed vertebrae and spinal curvatures) were observed in Bream *Abramis brama* sampled from a polluted area (River Rhine) compared to a control area (Lake Braassem) (Slooff 1982). In addition, one assessment carried out on Mediterranean Killifish, *Alphanius fasciatus*, from different unpolluted and polluted areas off the coast of Tunisia reported deformed specimens only from the polluted sampling areas, presenting higher Cd concentrations in their livers and spinal columns when compared to normal specimens, also indicating significantly higher Cd bioaccumulation factors in the former (Kessabi et al. 2009). In another study carried out by the same group also associated skeletal deformities in the vertebral column of Mediterranean Killifish from the Tunisian coast to high concentration of heavy metals (Cd, Cu and Zn) (Kessabi et al. 2013). In another study, many different skeletal deformities in the vertebral column, cranium, operculum, fins and jaws of tilapia (*Oreochromis* spp.) sampled from different rivers in Taiwan were correlated to Hg, Zn, Pb, Cu and Cr concentrations (Sun et al. 2009).

In addition, some assessments have evaluated genotoxicity effects of several metals comparing polluted and non-polluted sites and associated this with morphological abnormalities in fish. For example, an assessment carried out concerning the ichthyofauna from polluted and non-polluted/protected estuaries located on the São Paulo coast, Brazil, reported several genotoxic alterations (nuclear abnormalities in erythrocytes) in two teleosts, *Centropomus paralelus* and *Diapterus rhomneus* due to high Zn, Co, Cr, and As concentrations (Braga et al. 2019), while another assessment observed a clear and significant correlation between two genotoxic biomarkers of effect (micronuclei and nuclear abnormalities) and Cd, Cr, Hg and Pb, as well as to an overall degree of metal pollution index, in a benthic teleost species, the Rusty Blenny *Parablennius sanguinolentus* (Ferrante et al. 2017).

These assessments, however, have all been carried out in teleosts, and studies in this regard for elasmobranchs are severely lacking. To the best of our knowledge, no assessments in this regard are available in the literature concerning this group, indicating a significant knowledge gap that must be bridged.

Furthermore, morphological abnormalities are more frequently observed in oviparous species compared to viviparous species (Ribeiro-Prado et al. 2008), as embryos developed in egg cases maintain direct contact with environmental conditions, including contaminants, while embryos that develop inside the womb are protected from external influence up to a certain extent. Feeding solely only on yolk, as *A. castelnaui* embryos do (Dulvy & Reynolds 1997), produced through lipid mobilization from the mother's liver during vitellogenesis (Rossouw 1987), also allows for high maternal transfer of several contaminants, including metals.

Regarding the contaminant concentrations observed herein, almost no studies regarding rare Earth elements (REE) in elasmobranchs are available. This group of elements, comprising scandium, yttrium, lanthanum and the 14 chemical elements following lanthanum, termed lanthanoids (Redling 2006), consists of non-essential elements for living systems and have been reported as presenting low to moderate toxicity, including substitution of bone calcium by certain REE, due to their same oxidation state, carcinogenic properties (Rim et al. 2013) and the ability to result in cytotoxicity and genetic damage through oxidative stress (Huang et al. 2011; Jha & Singh 1995). In addition, long-term REE intake has been postulated as resulting in chronic poisoning (Hirano & Suzuki 1996). The sum of the Rare Earth Elements (ΣREE) detected herein did not reach the only maximum permissible concentration available worldwide, of 0.7 mg kg^{-1} (China 2005), although this has been established only for animal feeds and no other limits are available for other matrices. REE are found in the geological composition of sediments (Hu et al. 2006; Laveuf & Cornu 2009) and, as *A. castelnaui* is a benthic species, it may ingest sediment during feeding, accounting for the levels detected in muscle tissue. Higher REE concentrations have, in fact, been previously reported as being higher in benthic species (Guo et al. 2003; Mayfield & Fairbrother 2015), suggesting that they experience higher REE exposure due to their feeding habits, as REEs in aquatic environments are preferentially adsorbed to sediments and to fine suspended sediment particulates compared to the dissolved water column phase (Yang et al. 1999; Moermond et al. 2001; Taylor et al. 2012).

Although certain essential elements, such as Cu, Fe, Mn, Se and Zn, when present in high amounts can also lead to negative biota and consumer effects, three of the most noteworthy environmental contaminants, As, Hg and Pb were observed at extremely high concentrations in the evaluated specimen. Thus, we shall focus on these elements, as they are known carcinogenic and teratogenic compounds.

Arsenic, a dangerous teratogen (Eisler 1988a) at almost 62mg kg^{-1} w.w., was astonishingly high. This element, however, is usually present in its non-toxic form arsenobetaine, which comprises over 90% of total As, in fish (Gao et al. 2018; Ruelas-Inzunza et al. 2018). This demonstrates the need to carry out arsenic speciation analyses, in order to quantify both the toxic inorganic fractions and nontoxic organic fractions in fish. Nevertheless, even when taking this percentage into account, about 6mg kg^{-1} w.w. would still be present in the toxic inorganic form, over the threshold for adverse aquatic organism effects reported as ranging from 1.3 to 5 mg kg^{-1} w.w. (Eisler 1988a). Arsenic exposure has been directly associated to skeletal abnormalities in fish. In one study, adult Mummichog *Fundulus heteroclitus* were exposed to 230mg kg^{-1} of arsenic, an environmentally relevant in drinking water and aquatic environments in several areas worldwide, resulting in an average arsenic body burden of 74.6µg kg^{-1} (one order of magnitude lower than the observed value of 6mg kg^{-1} in toxic form calculated herein, albeit for muscle only) for 10 days immediately prior to spawning, and the hatchlings of exposed fish presented significantly increased incidence of curved or stunted tails (Gonzalez et al. 2006). In addition, this is also six-fold higher the maximum amount stipulated by the Brazilian ANVISA and the Codex Alimentarius (1.0 and 0.5 mg kg^{-1} w.w., respectively), indicating significant consumer health risks for humans who consume this species (Codex Alimentarius Commission 2009; ANVISA 2013).

Concerning Hg, a potent neurotoxin, concentrations as low as 0.008mg kg^{-1} w.w. in muscle have been reported as enough to alter biochemistry and gene expression, while the threshold for negative reproductive, histological and growth effects is of about 0.135mg kg^{-1} w.w. in muscle (Sandheinrich & Wiener 2011). Morphological abnormalities have been previously reported in Hg-exposed fish. For example, one study assessed Hg-exposed Mummichog *Fundulus heteroclitus* and reported various eye vesicle malformations, ranging from partially fused eyes with two separate lenses to cyclopia and severe gross malformation of the craniofacial, cardiovascular and skeletal systems (Weis & Weis 1977), indicating the direct effect of this element on embryo development. Therefore, the concentration observed herein indicates significant biota health effects, as well as potential consumer risks, since the maximum amount stipulated by the Brazilian ANVISA and the Codex Alimentarius for total mercury amounts in fish is of 0.5mg kg^{-1} (Codex Alimentarius Commission 2009; ANVISA 2013), almost the same as the 0.487mg kg^{-1} detected in the present study.

Regarding Pb, there is no safe threshold for exposure to this carcinogen and neurotoxin for any organism (ATSDR 2017). Dietary levels as low as 0.1 to 0.5 mg kg^{-1} have been linked to learning deficits in vertebrates (Eisler 1988b), and Pb effects range from neurotoxic and immunological to physiological and behavioral (ATSDR 2017). Pb exposure in fish has also been directly linked to diverse embryonic organogenesis malformations. For example, one study carried out in Pb-treated Common Carp *Cyprinus carpio* reported craniofacial anomalies, yolk sac malformation, vertebral shortening and curvatures and cardiac malformations (Jezierska et al. 2009), while another verified scoliosis in Pb-exposed brook trout (*Salvelinus fontinalis*) eggs who hatched into larvae (Holcombe et al. 1976). Regarding human consumption, the FAO/WHO permissible level for Pb of 0.3 mg kg^{-1} (Codex Alimentarius Commission 2009) was exceeded almost 100 times in the present study, indicate severe human consumption risks for this toxic element.

On a side note, Ti, although not considered a classic environmental contaminant, has emerged in recent decades as a contaminant of increasing concern in the form of titanium dioxide nanoparticles applied to many personal care products. These compounds have been reported as eliciting deleterious effects in marine trophic webs, although scarce data is available for either Ti or its nanoparticle forms in the marine environment (Frenzilli et al. 2014). In the present study, it is noteworthy that Ti concentrations were an order of magnitude higher than observed in marine mammal muscle, liver, and kidneys (Holsbeek et al. 1998, 1999), which are long-lived animals highly exposed to metals through the dietary route and expected to bioaccumulate more contaminants than a very young skate. Thus, Ti contamination is probable, and should be further assessed in future studies.

Other assessments concerning pollutant concentrations for elasmobranchs carried out in only one specimen are available in the literature. For example, one study assessed metals, persistent organic pollutants and polonium in the muscle and liver of a rare filter-feeding shark specimen, the Megamouth *Megachasma pelagios*, found stranded on the central-north coast of the Rio de Janeiro, Southeastern Brazil (de Moura et al. 2015), while another assessment was carried out in one shortfin Mako Shark *Isurus oxyrinchus* specimen and one Big-eye Thresher *Alopias superciliosus* specimen, also from Brazilian waters, concerning persistent organic pollutant concentrations in muscle (Azevedo-Silva et al. 2009), although the studies did not aim to verify the causes of morphological abnormalities. Another report verified metal concentrations in the liver of one specimen from three marine mammal species (one Orca, one Pygmy Killer Whale and one Franciscana Dolphin) (Lemos et al. 2013). Thus, even though discussion with the literature is hampered, reports concerning only one specimen of threatened species are also important to create baseline data for threatened species.

CONCLUSIONS

Atlantoraja castelnaui is an endangered species displaying a current decreasing population trend and especially vulnerable to trawl fisheries due to its benthonic habits. In addition, no conservation measures are in place for this species in Brazil. This study is the first record of a specimen displaying incomplete pectoral fin fusion with the head in Rio de Janeiro, southeastern Brazil. A radiography indicated disordered muscle sheafs near the rostrum, while a metal, metalloid and rare-earth screening indicated extremely high contamination by teratogenic elements such as As, Hg, and Cd. The observed morphological deformity may in fact be due to the high concentrations of these elements in the Cabo Frio environment, also indicating high environmental contamination and significant human health risk concerns for populations who consume this species regularly in southeastern Brazil. It should be noted that this coastal environment undergoes under a strong influence of the so-called Cabo Frio upwelling system, an oceanographic anomaly that significantly enriches these waters, yielding locally higher fish catches. This paper furthers both morphological observations and ecotoxicological assessments on this relatively biologically unknown species in Brazil, paramount for future conservation measures. Although only one specimen was assessed herein, environmental contamination cannot be discarded as a possible cause for the observed deformity, and the extremely high contaminant levels observed indicate the need for further assessments for the species, both with regard to deleterious effects on the species itself and in a public health context.

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COMMUNICATION

Butterfly diversity in an organic tea estate of Darjeeling Hills, eastern Himalaya, India

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Abstract: The study was undertaken from March–May 2019 to explore the butterflies in the human-modified tea dominated landscape of Darjeeling Hills and understanding the diversity, community structure, habitat specialization, and conservation status of butterflies in an organic tea estate. Sampling was done in the two representative ecosystems of tea plantation and secondary forest within the study area. Altogether 71 species and sub-species across 43 genera belonging to five families were recorded during this study, of which seven are protected under the Wildlife (Protection) Act of India, 1972.

Keywords: Lepidoptera, secondary forest, species richness, tea plantation.

Abbreviations: TP—Tea Plantation, SF—Secondary Forest, FI—Forest Interior, FE—Forest Edge, OL—Open Land.

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INTRODUCTION

Tea plantation is one of the important agro-ecosystems based on agroforestry practices in tropical landscapes (Tscharntke et al. 2008). Tea estates in Darjeeling practice shade tea cultivation which includes diverse shade trees of native species (Chettri et al. 2018a). This with surrounding forest patches have a high potential of maintaining biodiversity (Lin et al. 2012; Sreekar et al. 2013; Ahmed & Dey 2014) than monoculture tea plantations (Soh et al. 2006) or abandoned tea plantations (Subasinghe & Sumanapala 2014). Some studies conducted in monoculture tea plantations have shown that tea plantations have lower potential to maintain biodiversity when compared to forests (Ahmed & Dey 2014) and other agroforestry ecosystems such as home gardens (Yashmita-Ulman et al. 2016) but higher than Eucalyptus plantation monocultures (Kottawa-Arachchi & Gamage 2015) and agro-silviculture systems (Yashmita-Ulman et al. 2016).

In Darjeeling, tea plantation started in 1841 (Darjeeling Tea 2020). The first tea garden was established in 1856 by the Kurseong and Darjeeling Tea Company. Currently, there are 87 tea estates covering an area of 17,542 hectares of land (Datta 2010) or 20% of the land of Darjeeling Hills; 51 of the 87 tea estates in Darjeeling have been certified organic (data collected from Tea Research Association, Darjeeling). While a few studies have been undertaken to explore the diversity of birds in the tea landscapes of the region (Ahmad & Yahya 2010; Chettri et al. 2018a), no studies on butterflies has been undertaken till date.

Butterflies play an important role in supporting global food supply as pollinators (Losey & Vaughan 2006; Lindström et al. 2018) and are considered to be good indicators of ecosystem health, as they are very sensitive to small environmental variations and changes in forest structures (Pollard 1977). This taxon is vulnerable due to their response to changing habitat, climatic conditions, land-use patterns, and management intensity (Thomas 2005; Rundolf et al. 2008; Zingg et al. 2018).

Butterflies of Darjeeling-Sikkim Himalaya has attracted eminent naturalists and entomologists since the 19th century. In recent years, systematic studies on butterflies have increased in Sikkim (Acharya & Vijayan 2011, 2015; Chettri 2015; Chettri et al. 2018b; Sharma et al. 2020), however, only a few studies (Roy et al. 2012; Sengupta et al. 2014) have been conducted in Darjeeling hills (including Kalimpong). A total of 689 species have been reported to occur in Darjeeling-Sikkim Himalaya (Haribal 1992), which is 51.76% of total butterfly species recorded in India (Varshney & Smetacek 2015; Kehimkar 2016).

The organic tea estates of Darjeeling are expected to maintain a higher richness of butterflies as lower use of chemical insecticides and weedicides have been reported to have a positive impact on the diversity and abundance of butterflies (Rands & Sotherton 1986; Rundlof et al. 2008; Muratet & Fontaine 2015). Thus, the study aims to explore the conservation potential of butterflies in the human-modified tea dominated landscape by understanding the diversity, community structure, habitat specialization, and conservation status of butterflies in an organic tea estate of Darjeeling Hills. The study makes an effort to compare the species richness of tea plantation with that of the secondary forest, thus providing insights on species assemblages within the two representative ecosystems of a typical tea estate in Darjeeling, West Bengal. The study further adds to the limited existing literature on butterflies of Darjeeling Hills, Eastern Himalaya.

MATERIALS AND METHODS

Study Area

This study was conducted in Makaibari Tea Estate in the Kurseong sub-division of Darjeeling District, West Bengal, India (Figure 1A–C). It has an area of 248 hectares, of which 70% is covered by forest, which acts as a barrier to the scorching winds from the plains of Bengal (Makaibari 2020). The tea estate was established in 1859 and became the first tea estate to be certified organic in 1988 (Makaibari 2020). The entire tea estate located in an elevation range of approximately 400–1,100 m practices organic tea cultivation and is one of the lowest elevation tea estates of Darjeeling hills.

Two representative ecosystem types were selected for the present study (Image 1–6):

Tea Plantation (TP): Tea plantation represents an area where small-leaved Chinese variety of tea, *Camelia sinensis* var. *sinensis* that reaches a height of 0.5–1 m are grown (Datta 2010) with uniformly interspaced shade trees that include *Schima wallichii*, *Cryptomeria japonica*, *Albizia procera*, *Alnus nepalensis*, *Syzygium nervosum*, *Exbucklandia populnea*, *Eurya japonica*, *Ficus religiosa*, and *Ficus benghalensis* (Chettri et al. 2018a).

Secondary Growth Forest (SF): Makaibari Tea Estate has areas covered with a semi evergreen forest where tea is not planted. This forest acts as a barrier/wind break and also has numerous water bodies. Vegetation in these areas is dominated by species consisting of *Acer*

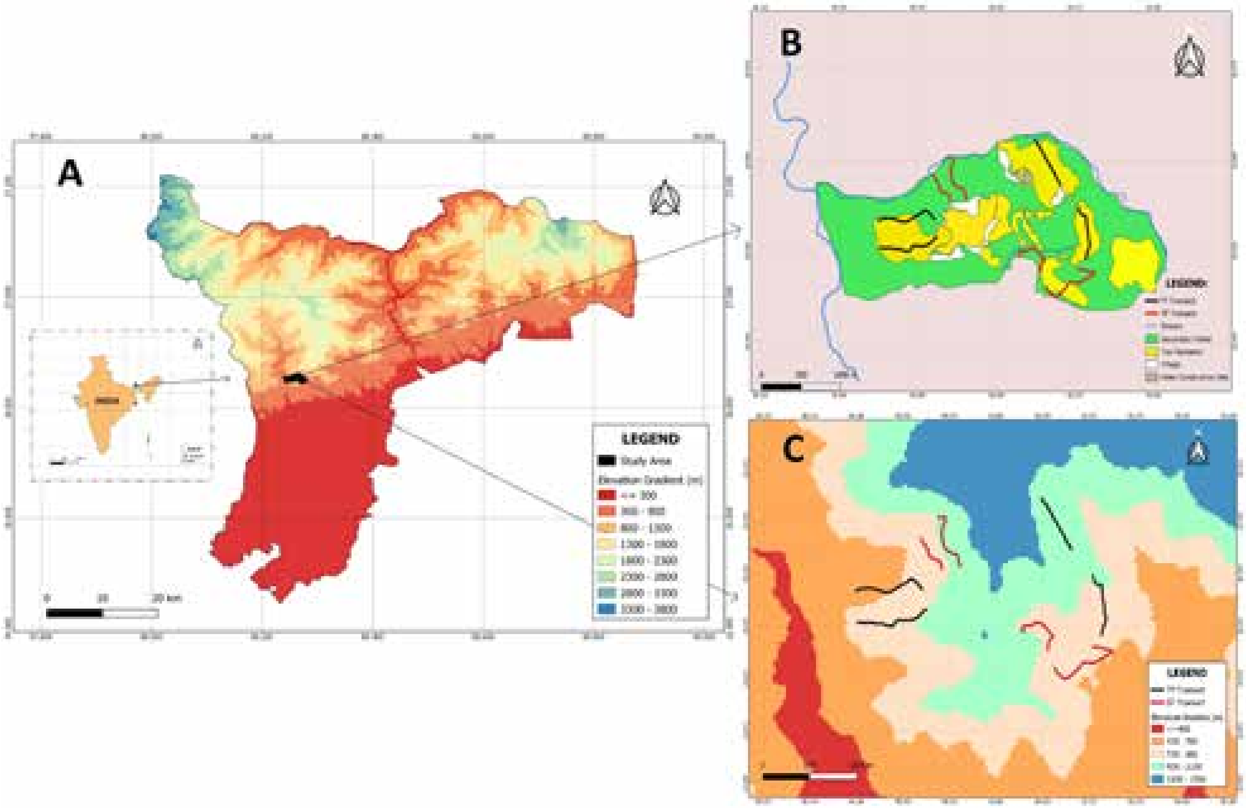

Figure 1. A—the location of Darjeeling and the study area within, along an elevation gradient | B—the study area showing Secondary Forest (SF), Tea Plantation (TP), SF Transects, TP Transects, Streams, and Villages of Makaibari Tea Estate, Darjeeling Hills, Eastern Himalaya, India | C—the study area showing SF Transects, TP Transects along an elevation gradient.

oblongum, Schima walichi, Shorea robusta, Terminalia myriocarpa, Eriobotrya bengalensis, Magnolia pterocarpa, Acer campbelli, Tetrameles nudiflora, Prunus nepalensis, Bombax ceiba, and mixed bamboo groves.

Study Design and Sampling

Eight trails were selected as transects (four each) in two representative ecosystem types (Figure 1B–C). The transects were approximately 1km in length and approximately 3m in width. Sampling was carried out twice in each transect during the pre-monsoon season from March to May 2019 on clear sunny days mostly between 09:00–15:00 h when butterfly activity is at its highest. Butterflies were sampled using the transect walk method (Pollard 1977; Acharya & Vijayan 2015) along the selected transects.

Following Kitahara (2004), points along transects were divided into three habitat classes: Forest Edge (FE), Open land (OL), and Forest Interior (FI). Points with forest on both sides were considered as FI sites, points with forest on one side and open land on the other as FE sites, and a point with open land on both sides as OL sites. Here open land refers to areas which do not have canopy cover in both TP and SF transects, and these represented either tea plantation sites or degraded forest sites.

Butterflies were photographed and identified using standard field guide (Kehimkar 2016), and online web resources (www.ifoundbutterflies.org). Species that could not be identified were photographed and shown to experts for identification. An effort was made to use the latest nomenclature and common names as far as possible as per Varshney & Smetacek (2015), Kehimkar (2016), and website on Indian butterflies (www.ifoundbutterflies.org).

RESULTS

A total of 71 species across 43 genera belonging to five families, were recorded in the Makaibari Tea Estate during this study (Table 1). The observed butterflies belonged to five families (Figure 2) namely, Hesperiidae (five genera, seven species), Papilionidae (three genera, nine species), Lycaenidae (seven genera, eleven species), Pieridae (nine genera, 12 species) and Nymphalidae (20

Image 1. Landscape view of the study area.

Image 2. Non-perennial stream within the secondary forest.

Image 3. Tea plantation site.

Image 4. Tea plantation and surrounding secondary forest.

Image 5. Secondary forest.

Image 6. Tea plantation site with interspersed shade trees.

genera, 32 species). As shown in Table 1, Nymphalidae (40.81%) with 20 species, Lycaenidae (20.40%) with 10 species, Pieridae (12.24%) with six species, Papilionidae (6.12%) with three species, and Hesperiidae (12.24%) with six species were observed in TP. In the SF, Nymphalidae (53.48%) with 23 species, Lycaenidae

(4.65%) with two species, Pieridae (18.60%) with eight species, Papilionidae (20.93%) with nine species and Hesperiidae (2.32%) with one species were observed (Images 7–16).

The species richness was higher in TP area (49 species, 69.01%) than in SF (43 species, 60.56%). Among the 71 species recorded, 21 species were common to both the habitats, while the rest were exclusively observed either in TP or SF (Figure 3). Among the 21 common species, 11 belonged to family Nymphalidae, six to Pieridae, three to Papiloinidae, and one to Lycaenidae.

Based on habitat classification along each transect, butterflies were observed to utilize all the three habitat classes, with the highest diversity recorded in forest edges (44 species), followed by open land (38 species), and forest interior (29 species). A number of recorded species (26 out of 71 species) , however, were observed to utilize more than one habitat class (Table 1).

Out of the 71 species of butterflies observed in the present study, seven (one species under Schedule I, three species under Schedule II, and three species under Schedule IV) species, namely, *Jamides caerulea*, *Lampides boeticus*, *Euploea klugii klugii*, *Euploea mulciber*, *Neptis sankara*, *Melanitis zitenius gokala*, and *Papilio bootes* are protected in India under the Wildlife (Protection) Act, 1972 (Table 1). Two among these were observed in both TP and SF, while the remaining five were observed only in one of the two representative ecosystem types (two each in TP and SF). Among the protected species four species belonged to Nymphalidae, two to Lycaenidae, and one to Papilionidae (Table 1).

Based on the categorization of Kehimkar (2016), four of the 71 species observed in the present study were rare (Table 1).

Himalayan Spotted Flat *Celaenorrhinus munda*

This species was observed in a FE site (26.856°N & 88.254°E) in SF-transect at an elevation of 870m in March. The site is close to human settlements, and the observed individual was seen feeding on the nectar of Azalea flowers. These butterflies are known to prefer forests at elevations of up to 2,000m (Kehimkar 2016).

Scarce Banded Flat *Celaenorrhinus badia*

This species was observed in an OL site (26.851°N & 88.248°E) in TP-transect at an elevation of 790m in May. The observed individual was perched on the underside of a leaf of a shrub within the tea plantation area. These butterflies have been observed in forests of up to 500m (Kehimkar 2016).

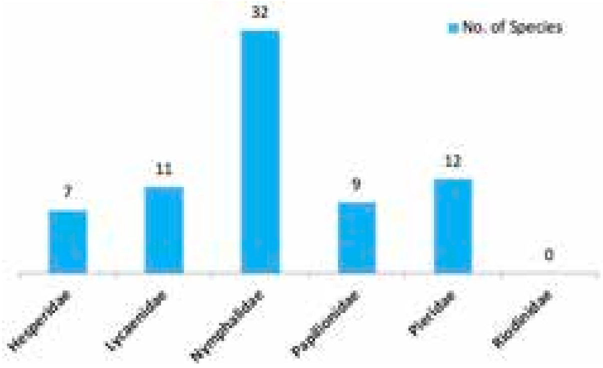

Figure 2. Family-wise distribution and the number of recorded species in Makaibari Tea Estate, Darjeeling Hills.

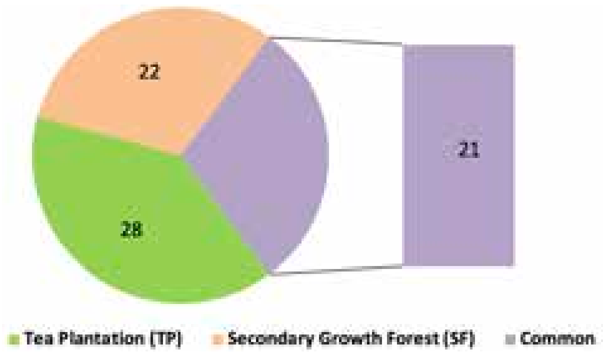

Figure 3. Number of species encountered exclusively in the two ecosystem types (namely, Tea Plantation and Secondary Forest) and the number of species that were common to both the ecosystem types.

Royal Cerulean *Jamides caerulea*

This species was observed in an OL site (26.851°N & 88.246°E) in TP-transect at an elevation of 780m in April. The observed individual was seen feeding on the nectar of a flowering herb within the tea plantation area. These butterflies have been observed in forests of up to 500m (Kehimkar 2016).

Krishna Peacock *Papilio krishna*

This species was observed in a FI site (26.857°N & 88.255°E) in SF-transect at an elevation of 920m in May. The observed individual was seen basking on a leaf within the forest. These butterflies have been observed in forests of up to 900–3,000 m (Kehimkar 2016).

DISCUSSION

During this study, 10.30% of the total butterflies reported from Darjeeling-Sikkim Himalaya (Haribal 1992) were recorded from the two representative

Table 1. Checklist of butterflies recorded in Makaibari Tea Estate.

Common name	Scienntific name	Family	*Ecosystem type	#Habitat	Wildlife (Protection) Act, 1972	Status category (Kehimkar 2016)
Chestnut Bob	*Iambrix salsala*	Hesperiidae	TP	FE		Common
Common Red Eye	*Matapa aria*	Hesperiidae	TP	FE		Common
Common Small Flat	*Sarangesa dasahara*	Hesperiidae	TP	FE		Common
Common Spotted Flat	*Celaenorrhinus leucocera*	Hesperiidae	TP	FE		Common
Detached Dart	*Potanthus trachala*	Hesperiidae	TP	FE		Common
Himalayan Spotted Flat	*Celaenorrhinus munda*	Hesperiidae	SF	FE		Rare
Scarce Banded Flat	*Celaenorrhinus badia*	Hesperiidae	TP	OL		Rare
Royal Cerulean	*Jamides caerulea*	Lycaenidae	TP	OL	Schedule II	Rare
Silver Forget-me-not	*Catochrysops panormus*	Lycaenidae	TP	OL		Uncommon
Forget-me-not	*Catochrysops strabo*	Lycaenidae	TP	OL		Common
Purple Sapphire	*Heliophorus epicles*	Lycaenidae	TP, SF	OL + FE + FI		Common
Common Cerulean	*Jamides celeno*	Lycaenidae	TP	FE		Common
Pea Blue	*Lampides boeticus*	Lycaenidae	TP	OL	Schedule II	Common
Bhutya Lineblue	*Prosotas bhutea*	Lycaenidae	SF	OL		Uncommon
Tailless Lineblue	*Prosotas dubiosa*	Lycaenidae	TP	OL		Common
Common Lineblue	*Prosotas nora*	Lycaenidae	TP	OL		Common
Pale Grass Blue	*Pseudozizeeria maha*	Lycaenidae	TP	OL		Common
Dark Grass Blue	*Zizeeria karsandra*	Lycaenidae	TP	OL		Common
Banded Treebrown	*Lethe confusa*	Nymphalidae	SF	FE + FI		Common
Blue King Crow	*Euploea klugii klugii*	Nymphalidae	SF	FI	Schedule IV	Uncommon
Striped Blue Crow	*Euploea mulciber*	Nymphalidae	SF	FI	Schedule IV	Common
Broad-banded Sailer	*Neptis sankara*	Nymphalidae	TP	OL + FE	Schedule I	Uncommon
Brown King Crow	*Euploea klugii kollari*	Nymphalidae	SF	FE + FI		Common
Chestnut Tiger	*Parantica sita*	Nymphalidae	TP, SF	OL + FE + FI		Uncommon
Chocolate Pansy	*Junonia iphita*	Nymphalidae	TP	OL + FE		Common
Chocolate Tiger	*Parantica melaneus*	Nymphalidae	TP, SF	OL + FE + FI		Common
Clear Sailer	*Neptis clinia susruta*	Nymphalidae	TP, SF	FE		Uncommon
Common Crow	*Euploea core*	Nymphalidae	TP, SF	OL + FE + FI		Common
Common Jester	*Symbrenthia lilaea*	Nymphalidae	SF	FE		Common
Common Lascar	*Pantoporia hordonia*	Nymphalidae	SF	FI		Common
Common Sailer	*Neptis hylas*	Nymphalidae	TP, SF	OL + FE + FI		Common
Common Three Rings	*Ypthima asterope*	Nymphalidae	TP, SF	OL + FE + FI		Common
Dark Evening Brown	*Melanitis phedima*	Nymphalidae	TP, SF	FE + FI		Uncommon
Glassy Tiger	*Parantica aglea*	Nymphalidae	TP, SF	OL + FE + FI		Common
Great Evening Brown	*Melanitis zitenius gokala*	Nymphalidae	TP	FE	Schedule II	Uncommon
Himalayan Sailer	*Neptis mahendra*	Nymphalidae	TP, SF	FE		Uncommon
Indian Fritillary	*Argyrnnis hyperbius*	Nymphalidae	TP	OL + FE		Common
Indian Tortoiseshell	*Aglais caschmirensis*	Nymphalidae	TP	OL		Common
Large Yeoman	*Cirrochroa aoris*	Nymphalidae	SF	FI		Common
Lemon Pansy	*Junonia lemonias*	Nymphalidae	TP	OL + FE		Common
Leopard Lacewing	*Cethosia cyane*	Nymphalidae	SF	FI		Common
Autumn Leaf	*Doleschallia bisaltide*	Nymphalidae	TP	FE		Uncommon
Orange Staff Sergeant	*Athyma cama*	Nymphalidae	SF	FI		Uncommon

Common name	Scienntific name	Family	*Ecosystem type	#Habitat	Wildlife (Protection) Act, 1972	Status category (Kehimkar 2016)
Plain Tiger	*Danaus chrysippus*	Nymphalidae	SF	FI		Common
Popinjay	*Stibochiona nicea*	Nymphalidae	TP, SF	OL + FE + FI		Common
Powdered Baron	*Euthalia monina*	Nymphalidae	SF	FE		Common
Small Jewel Four-Ring	*Ypthima singala*	Nymphalidae	TP	OL		Uncommon
Straight-banded Treebrown	*Lethe verma*	Nymphalidae	SF	FE		Common
Yellow Coster	*Acraea issoria*	Nymphalidae	TP, SF	OL + FE + FI		Common
Black Prince	*Rohana parisatis*	Nymphalidae	TP	OL		Common
Common Birdwing	*Troides helena*	Papilionoidae	SF	FE		Uncommon
Common Bluebottle	*Graphium sarpedon*	Papilionoidae	SF	OL		Common
Common Mormon	*Papilio polytes*	Papilionoidae	SF	FE		Common
Common Peacock	*Papilio bianor*	Papilionoidae	TP, SF	FE + FI		Uncommon
Krishna Peacock	*Papilio krishna*	Papilionoidae	SF	FI		Rare
Paris Peacock	*Papilio paris*	Papilionoidae	SF	FE		Uncommon
Red Helen	*Papilio helenus*	Papilionoidae	TP, SF	OL + FE		Common
Tailed Redbreast	*Papilio bootes*	Papilionoidae	TP, SF	OL + FE + FI	Schedule II	Uncommon
Yellow Helen	*Papilio nephelus*	Papilionoidae	SF	FI		Uncommon
Chocolate Albatross	*Appias lyncida*	Pieridae	TP, SF	OL + FE + FI		Uncommon
Common Grass Yellow	*Eurema hecabe*	Pieridae	TP	OL		Common
Common Gull	*Cepora nerissa*	Pieridae	TP	OL		Common
Great Orange Tip	*Hebomoia glaucippe*	Pieridae	TP	FE		Common
Indian Cabbage White	*Pieris canidia*	Pieridae	TP, SF	OL + FE + FI		Common
Large Cabbage White	*Pieris brassicae*	Pieridae	TP, SF	OL + FE		Common
Lesser Gull	*Cepora nadina nadina*	Pieridae	TP, SF	OL + FE + FI		Uncommon
Psyche	*Leptosia nina*	Pieridae	TP	OL		Common
Red Base Jezebel	*Delias pasithoe*	Pieridae	SF	FE + FI		Uncommon
White Orange Tip	*Ixias marianne*	Pieridae	TP, SF	OL + FE		Common
Yellow Jezebel	*Delias agostina*	Pieridae	SF	FI		Uncommon
Yellow Orange Tip	*Ixias pyrene*	Pieridae	TP, SF	OL + FE + FI		Common

*Ecosystem type: TP = Tea Plantation; SF = Secondary Forest.
#Habitat specialization: FI (Forest interior only), FI+FE (Forest interior + Forest edge), FE (Forest edge only), FE + OL (Forest edge+ Openland), OL (Openland only), OL + FE + FI (Open Land + Forest interior + Forest edge).

ecosystems in Makaibari Tea Estate, Darjeeling Hills. Moreover, the present study only provides pre-monsoon diversity of butterflies and did not cover the monsoon and post-monsoon seasons when the butterflies are most abundant in India (Kunte et al. 1999; Acharya & Vijayan 2015; Chettri 2015). Thus the total number of butterflies found in the area may be much higher than what is reported in this study.

The highest number of encountered species belonged to Nymphalidae, which is the most dominant family in the tropical region, including the forests and human-modified systems of Darjeeling-Sikkim Himalaya (Acharya & Vijayan 2015; Chettri 2015; Chettri et al. 2018b; Sharma et al. 2020). This suggests that the trend is followed even in tea estates.

The study conducted in the pre-monsoon season showed a rich diversity of butterflies within a small spatial gradient. This was expected as shade-tea cultivation with surrounding forest patches are reported to have the potential to maintain biodiversity (Lin et al. 2012; Sreekar et al. 2013; Ahmed & Dey 2014; Bora & Meitei 2014), as is the case with the present study area. Furthermore, the study area is a certified organic tea estate, uses no chemical pesticides or insecticides (Makaibari 2020), and was thus expected to maintain a higher richness of butterflies owing to its organic farming strategy (Rands & Sotherton 1986; Rundlof et al. 2008; Muratet & Fontaine 2015). Thus the findings of the study add to the existing literature on retention of high biodiversity, and conservation potential of butterflies in organic agroecosystems of the region (Rundlof et al. 2008; Sharma et al. 2020).

The results showed that the butterfly communities in the two representative ecosystems showed assemblage of different species with low similarity, with approximately 70.42% of the total recorded species (22 in SF and 28 in TP) being recorded exclusively in either of the two systems. This suggests that the two systems are unique from one another in terms of quality and resource availability (Blair & Launer 1997), and are equally important for the conservation of butterflies.

Species richness of butterfly was slightly higher in the tea plantation system than the secondary forest system. It was not expected as forest systems provide favorable habitat to the butterflies (Chettri et al. 2018b). Makaibari Tea Estate, however, practices shade-tea cultivation, along with surrounding forest which covers a major portion (70%) of total area (Makaibari 2020). Thus, tea plantation sites in the study area are enclosed by forests on all sides, allowing easy entry to forest specialist species into the tea plantation system. This was further highlighted by the fact that a number of recorded species (26 out of 71 species) were observed to utilize more than one habitat class. Moreover, it should be noted that tea plantation systems have more open areas, which allow more butterflies to bask around, perch, patrol, and perform mud-puddling.

SF and TP both harbored habitat specialist species (63.38% of all species recorded), of which 28 species were either forest edge or forest interior species (Table 1), suggesting the importance of secondary forest for conservation of butterflies in a tea landscape, which is in line with the findings of other similar studies (Lin et al. 2012; Sreekar et al. 2013; Ahmed & Dey 2014). In India, a similar trend has been reported from other human-modified landscapes in the Himalaya (Chettri et al. 2018b; Sharma et al. 2020) and forests of Western Ghats (Kunte et al. 1999). The number of specialists is inversely proportional to the level of disturbance in forest habitats (Mayfield et al. 2005; Vu 2013; Chettri et al. 2018b), which suggests that the forest habitat in the study area has experienced very less disturbance over the years.

The study also shows that seven of the 71 encountered butterflies are protected under the Wildlife Protection Act of India, 1972, thus Makaibari Tea Estate can be considered to be an important site for the conservation of butterflies.

CONCLUSION

The study highlighted the potential of an organic tea estate surrounded by forest in the conservation of butterflies in Darjeeling Hills, Eastern Himalaya. The study showed that tea plantation systems and secondary forest systems near natural forest area of Darjeeling are equally important in the conservation of butterflies along with natural forest. In the Darjeeling-Sikkim Himalaya, few recent studies have provided information on butterflies from different parts of Sikkim (Acharya & Vijayan 2011, 2015; Kunte 2010; Rai et al. 2012; Chettri et al. 2018b; Dewan et al. 2018; Sharma et al. 2020), however, very few studies have been conducted in Darjeeling (including Kalimpong) Hills (Roy et al. 2012; Sengupta et al. 2014). Thus, the findings of the study add to the limited existing literature on butterflies of Darjeeling Hills, especially in a tea estate area. Further studies are needed to establish baseline data of butterflies in present-day Darjeeling Hills, and our study is an attempt to understand the butterfly diversity in a tea estate of Eastern Himalaya.

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Image 7. Bhutia Lineblue

Image 8. Common Bluebottle

Image 9. Common Jester

Image 10. Common Mormon

Image 11. Glassy Tiger

Image 12. Himalayan Spotted Flat

Image 13. Lemon Pansy

Image 14. Yellow Coster

Image 15. Yellow Orange Tip

Image 16. Purple Sapphire

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PLATINUM OPEN ACCESS

COMMUNICATION

Freshwater decapods (Crustacea: Decapoda) of Palair Reservoir, Telangana, India

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Abstract: Recent surveys conducted in 2016–2018 from the Palair Reservoir of the Indian state of Telangana resulted in the collection of 153 specimens of freshwater decapods. These specimens are assigned to 10 species: seven prawns in three genera and three families; three crabs in two genera of one family. Among these, four species are recorded here as new records to Telangana: *Penaeus semisulcatus* De Haan, 1844, *Caridina gracilipes* De Man, 1892, *Barytelphusa guerini* (H. Milne Edwards, 1853), and *Oziotelphusa* sp.

Keywords: Brachyura, Caridea, crabs, Dendrobranchiata, freshwater, prawns, systematics.

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Author contribution: SM—collector, Identifier of specimens and coresponding author; JD—guide in the project; AN & CSS—aissisting in field collection and photography.

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INTRODUCTION

The Palair Reservoir is located near Palair Village in the Khammam District of Telangana (17.199°–17.249° N & 79.868°–79.922° E), which is about 30km from the district headquarters (Fig. 1). Palair is a large man-made reservoir that is up to 16m in depth and covers an area of 1, 748ha. It has considerable economical, ecological and biological significance, being home to many freshwater invertebrate and vertebrate populations that support local fisheries which take fin-fish and macro crustaceans like prawns and crabs (Roy et al. 2015). While ichthyofaunal resources have been properly documented, the Decapoda (crustaceans with 10 legs) are poorly known. Surveys were conducted in the Palair Reservoir between from 2016 to 2018 in order to document the diversity of decapods.

Decapoda are highly diverse, with an estimated 15, 000 species worldwide, 1, 669 recorded from freshwater. One-hundred-and-eighteen species of freshwater prawns (Valarmathi 2017) and 122 species of freshwater crabs (Pati & Thackray 2018) have been documented from India. In a recent ongoing project started in August 2016 on "Taxonomic Studies on Freshwater Decapods of Telangana", a total of 153 specimens of Decapoda have been collected from Palair Reservoir. One species of penaeoid prawn belonging to family Penaeidae, five species of caridean prawns belonging to Palaemonidae and Atyidae families and two species of brachyuran crabs (family Gecarcinucidae) have been identified from recent collections. The earlier studies had reported two species of caridean prawns (Palaemonidae) and three brachyuran crabs (Gecarcinucidae) among 82 examples of Decapoda collections (Roy et al. 2015).

MATERIAL AND METHODS

Four surveys were conducted in the Palair Reservoir during December 2016, February 2017, July 2017 and August 2018. A total of 153 specimens of freshwater decapod crustaceans (131 prawns and 22 crabs) were collected from running waters, submerged vegetation, and muddy/rocky habitats of 10 localities surrounding the Palair Reservoir (Figure 1, Table 1).

Crabs were either handpicked from beneath stones

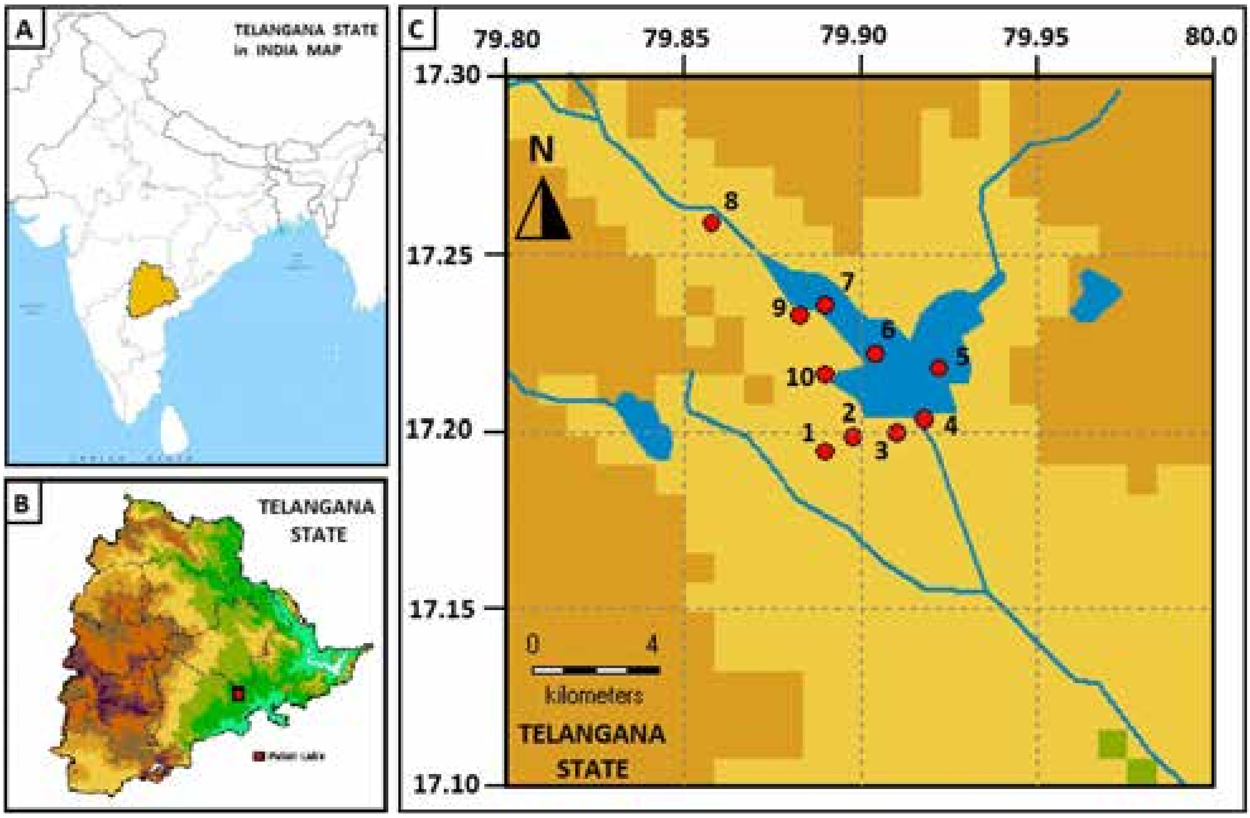

Figure 1. A—Telangana location map | B—Location of Palair in Telangana map | C—Map of the Palair Reservoir showing surveyed localities made by DIVA-GIS: 1—Naikangudem | 2—J.C. Boating and Waterpark | 3—Palair Reservoir near S.H. 42 | 4—Palair Park | 5—Kattamaisamma Temple, Palair | 6—Kotturu | 7—Neradavai | 8—Thammagudem | 9—Urlugonda | 10—Annarigudem.

Table1. Details of the surveyed localities surrounding the Palair Reservoir.

Locality code	Localityt	Nature of water body	Latitude (°N)	Longitude (°E)
1.	Naikangudem	Canal	17.195	79.890
2.	J.C. Boating and Waterpark	Reservoir	17.199	79.898
3.	Palair Reservoir near S.H. 42	Reservoir	17.200	79.910
4.	Palair Park	Reservoir	17.204	79.918
5.	Kattamaisamma Temple, Palair	Reservoir	17.218	79.922
6.	Neradavai	Canal	17.236	79.890
7.	Thammagudem	Small stream	17.259	79.858
8.	Urlugonda	Small stream	17.222	79.904
9.	Annarigudem	Reservoir	17.233	79.883
10.	Kotturu	Reservoir	17.216	79.890

and small rocks or dug out from burrows. Prawns were gathered from shallow waters using a D-shaped hand-net. Large-sized crabs and prawns were caught with cast nets. Collected specimens with proper collection data were preserved in 70–80 % ethyl alcohol (Ng 2017). The identification of penaeid, palaemonid, and atyid prawns was achieved by following Holthuis (1980), Jalihal et al. (1984), Chace & Bruce (1993), Wowor & Choy (2001), Mariappan & Richard (2006), and Jose (2013) whereas the crab identification was confirmed from Pati & Sharma (2014). An unknown species of crab, here referred as *Oziotelphusa* sp., has no affinities with the congeners (see Bahir & Yeo 2005; Pati & Sharma 2012; Raj et al. 2017). Confirmation of the species distribution has done from The IUCN Red List 2020.

All the identified specimens were deposited in the collections of the Zoological Survey of India, Freshwater Biology Regional Centre, Hyderabad, India (ZSI-FBRC). In addition, the previously collected material (six prawns and 15 crabs) from ZSI-FBRC was also examined. These specimens were collected between 2009 and 2011.

RESULTS

From the present study, a total of 10 species of decapods were recognized from the Palair Reservoir; seven species of prawns in three genera of three families (Penaeidae, Palaemonidae, and Atyidae); three species of crabs in two genera of the family Gecarcinucidae. A systematic account is provided on the decapods of the Palair Reservoir.

Systematics
Order Decapoda Latreille, 1802
Suborder Dendrobranchiata Spence Bate, 1888
Superfamily Penaeoidea Rafinesque, 1815
Family Penaeidae Rafinesque, 1815

1. Penaeus semisulcatus De Haan, 1844 [in De Haan, 1833–1850] (Image 1)

1844. *Penaeus semisulcatus* De Haan, in Von Siebold, Fauna Japonica, Crustacea (6/7): Pl. 46.

1900. *Penaeus ashiaka* Kishinouye

Material examined: FBRC/ZSI/INV/1810, 16.ii.2017, 6 specimens, Palair, coll. S. Mandal.

Diagnostic characters: Total length (TL) 130–132 mm, Rostrum length (RL) 27–30 mm, Carapace length (CL) 27–29 mm; rostral formula 7–8(5)/2, rostrum straight, rostral length is more or less equal to the carapace; carapace smooth, antennal spine and hepatic spine present, adrostral carina reaching almost posterior margin of carapace, gastrofrontal carina present; antennal carina meets with hepatic carina, hepatic carina inclined at an angle of 20° anteroventrally; cervical sulcus present, branchiocardiac carina shallow, postorbital carapace margin is oval-shaped; 3rd maxilliped is extending up to the half of the antenular scale. First 3 pairs of legs forming pincer, 3rd pair is comparatively larger than 1st and 2nd pair; spine on Ischia of 1st and 2ndperiopod; 5th pereopod with small exopodite. Copulatory organ on First pair of pleopod in male (petasma) and on posterior thoracic sternites in female (thelycum); abdomen with posterior part of pleura (lateral plates) covering anterior part of succeeding pleura; pleopods are with two branches.

Remarks: In India, *P. semisulcatus* occurs along both the coasts of India, including Andaman & Nicobar Islands (Samuel et al. 2016). *Penaeus semisulcatus*is is predominantly marine. The species, however, is known to exist in freshwater environments. The present specimens of *P. semisulcatus* constitute a new record to Telangana.

Suborder Pleocyemata Burkenroad, 1963
Infraorder Caridea Dana, 1852
Superfamily Atyoidea De Haan, 1849 [in De Haan, 1833-1850]
Family Atyidae De Haan, 1849 [in De Haan, 1833-1850]

2. Caridina gracilipes De Man, 1892 (Image 2)

1892. *Caridina Wyckii*var. *gracilipes* De Man: 387 Pl. 24 Fig. 29–29e [type localities: Sulawesi (Celebes), and Selajar, Indonesia].

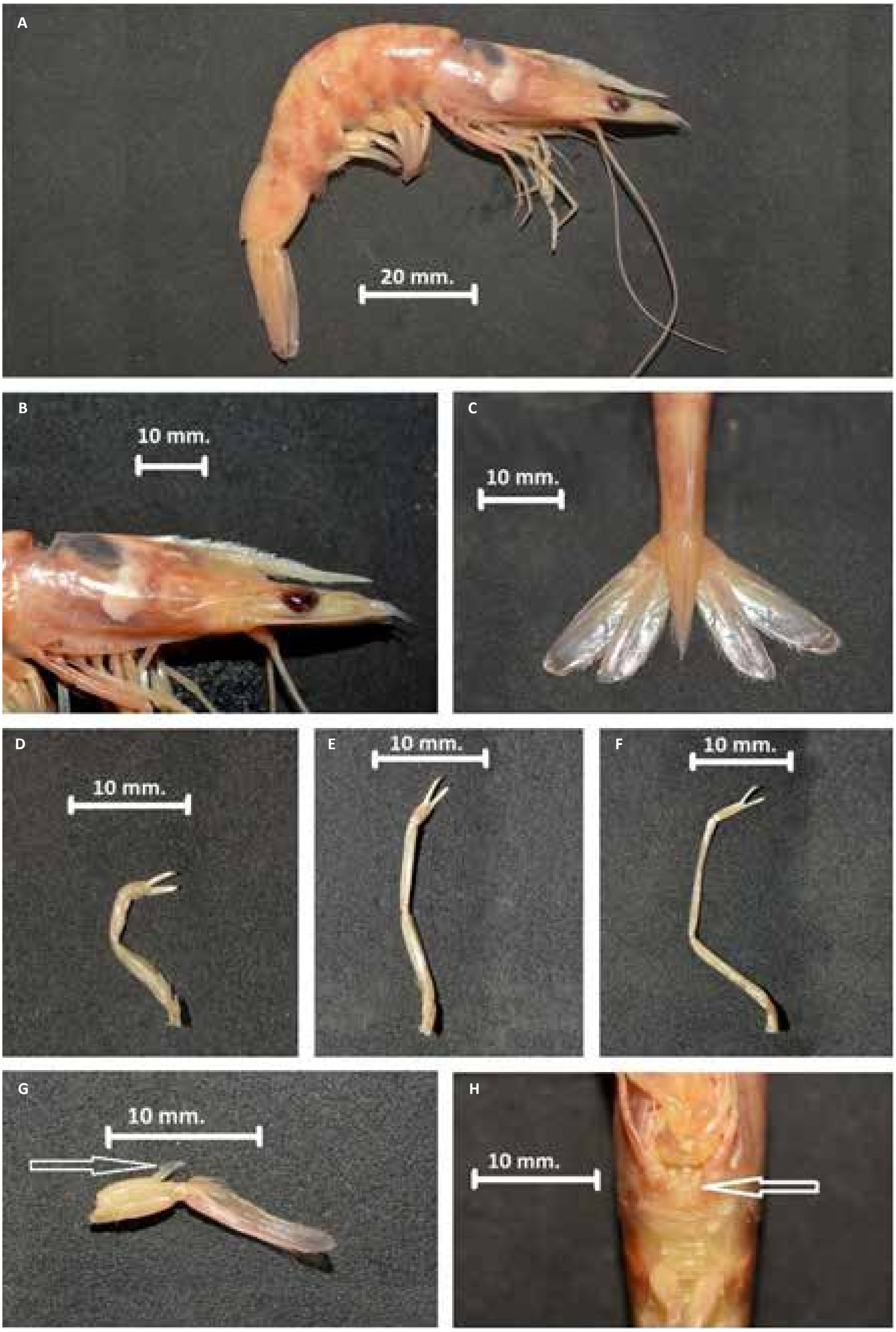

Image 1. *Penaeus semisulcatus* De Haan, 1844 from the Palair Reservoir: (FBRC/ZSI/INV/1810) A—whole animal, lateral view (female) | B—lateral view of cephalothorax | C—telson with uropods | D—first cheliped | E—second cheliped | F—third cheliped | G—petasma (male) | H—thelycum (female). Scale bars: 20mm (A), 10mm (B–H). © Sudipta Mandal.

2004. *Caridina gracilipes* - Wowor et al.: 341, Fig. 6D; Cai & Shokita 2006a: 250.

Material examined: FBRC/ZSI/INV/1979, 64 specimens, 31.viii.2018, Nayakulgudem, coll. S. Mandal.

IUCN Status: Least Concern.

Diagnostic characters: TL 18.0–19.3 mm, RL 3.5–3.8 mm and CL 3.2–3.7 mm. Rostrum formula 16–23(3)/8–11, rostrum is straight, slightly upturned distally, dorsal teeth interrupted by gap in the anterior side, rostrum longer than 3rd segment of antennal peduncle but shorter than antennal scale, carapace and rostrum equal in length; 3rd maxilliped crosses half of the antennal scale; 1st chelipeds stout, palm equal to finger, a tuft of hair with finger, carpus is half of chela and merus shorter than chela, carpus with deep anterior excavation, ischium very short and stout; 2nd chelipeds longer than 1st chelipeds, finger longer than palm with tuft of hair at the end, carpus longer than chela but sub equal to merus; 3rd to 5th periopods similar in structure with simple dactyls, longer than 1st and 2nd periopods; abdomen smooth, 6th segment two times as long as 5th and sub equal to telson in length, berried females carry around 120–130 eggs measuring 0.33×0.46 mm; endopod of 1st pleopod of male acutely triangular; 5–7 pairs of movable spines, terminal pair flanking the posterior-lateral angles of telson, posterior margin 'V' shaped posses 6 long plumose setae; uropods are exceeding tip of the telson, endopod is smaller than exopod, lateral margin of exopod straight, suture in exopod is across the middle with 7–9 movable spines.

Remarks: In India, *C. gracilipes* is known from Tamil Nadu, Kerala, Andhra Pradesh, and West Bengal states. The present specimen from the Palair Reservoir is a new record to Telangana. This species is exclusively a freshwater species found in lakes and rivers.

3. Caridina shenoyi Jalihal & Sankolli in Jalihal, Shenoy & Sankolli, 1984 (Image 3)

1984. *Caridina shenoyi* Jalihal & Sankolli Rec. Zool. Surv. India. Occ. Paper No. 69**:** 1–40.

2013. *Caridina shenoyi* Jalihal & Sankolli Zool. Surv. India. State Fauna Series, 21**:** 63–72.

IUCN Status: Least Concern.

Material examined: FBRC/ZSI/INV/1823, two specimens, 13.vii.2017, J.C. Boating & Water Park, Palair, coll. S. Mandal.

Diagnostic characters: TL 14.4–19 mm, RL 2.8mm and CL 7.2mm; rostrum formula 18–22(6–7)/6–7, rostrum is straight, slightly downward distally, dorsal teeth are placed equally, rostrum reaches up to the end of 2nd segment of antennal peduncle but not reaches up to the end of the antennal scale, carapace 1.8 times as long as rostrum; 3rd maxilliped reaches up to the end of the antennal scale; 1st cheliped is stout, palm is sub equal to finger, carpus is half of palm and merus, merus is equal to palm, a tuft of hair with chela, chela 2.2–2.5 times as long as broad, carpus 1.8–2.0 times as long as broad, carpus with deep anterior excavation; 2nd cheliped is also stout and more or less equal to 1st cheliped, reaches end of antennal peduncle by chela, carpus is sub equal to merus and longer than chela, a tuft of hair with chela; finger is 1.5–1.8 times as palm; 3rd to 5th periopods similar in structure with short and stout dactyls, longer than 1st and 2ndperiopod; abdomen smooth without any abdominal hump, 6th segment 1.48 times as long as 5th and 0.76 times as long as telson, berried females carries around 350–370 eggs measuring 0.6×0.4 mm, 6th abdominal segment less than half of carapace length; endopod of 1st pleopods of male acutely triangular, appendix masculine 0.3 times as long as endopod; six pairs of movable spines, terminal pair flanking the posterior-lateral angles of telson. Posterior margin 'V' shaped posses six long plumose setae; uropods are exceeding tip of the telson, endopod is smaller than exopod, lateral margin of exopod straight, suture in exopod is across the middle with 22 movable spines.

Remarks: In India, *C. shenoyi* is known from Kerala, Karnataka, and Telangana states. This species is generally found in submerged vegetations in shallow water.

Superfamily Palaemonoidea Rafinesque, 1815
Family Palaemonidae Rafinesque, 1815

4. Macrobrachium equidens (Dana, 1852)

Material examined: Reported by Roy et al. (2015).

Diagnostic Characters: Body robust, rostrum formula 10–11(2–4)/4–7, rostrum strong, reaching at end of antennal scale, dorsal teeth placed at regular interval; ridge of antennal spine extending in the direction of hepatic spine; 2nd cheliped sub equal in length, fingers covered with soft dense pubescence, not dentate on opposable margins, not gaping; out of two postereo-lateral spines of telson, lower one over-reaching the telson tip.

Remarks: In India, *Macrobrachium equidens* has been reported from Kerala, Odisha, Karnataka, Andhra Pradesh, and Goa.

5. Macrobrachium malcolmsonii (H. Milne Edwards, 1844) (Image 4)

1844. *Palaemon malcolmsonii* H. Milne Edwards, In: Jacquemont Voyage, Inde, 4(2): 8.

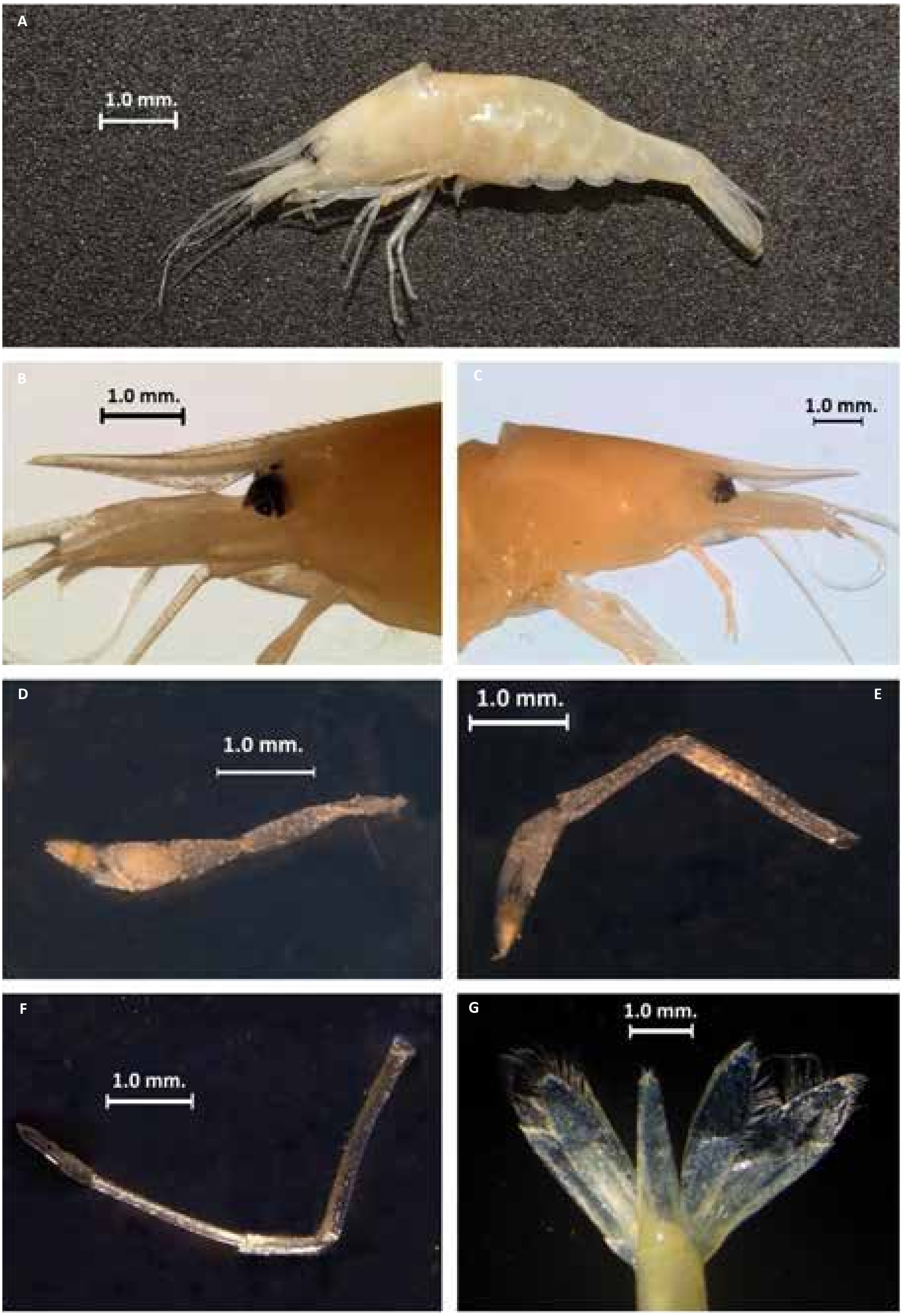

Image 2. *Caridina gracilipes* De Man, 1892 from the Palair Reservoir: (FBRC/ZSI/INV/1979) A—whole animal, lateral view | B—rostrum | C—lateral view of cephalothorax | D—first cheliped | E—second cheliped | F—fifth periopod | G—telson with uropods. Scale bars: 1.0mm (A–G). © Sudipta Mandal.

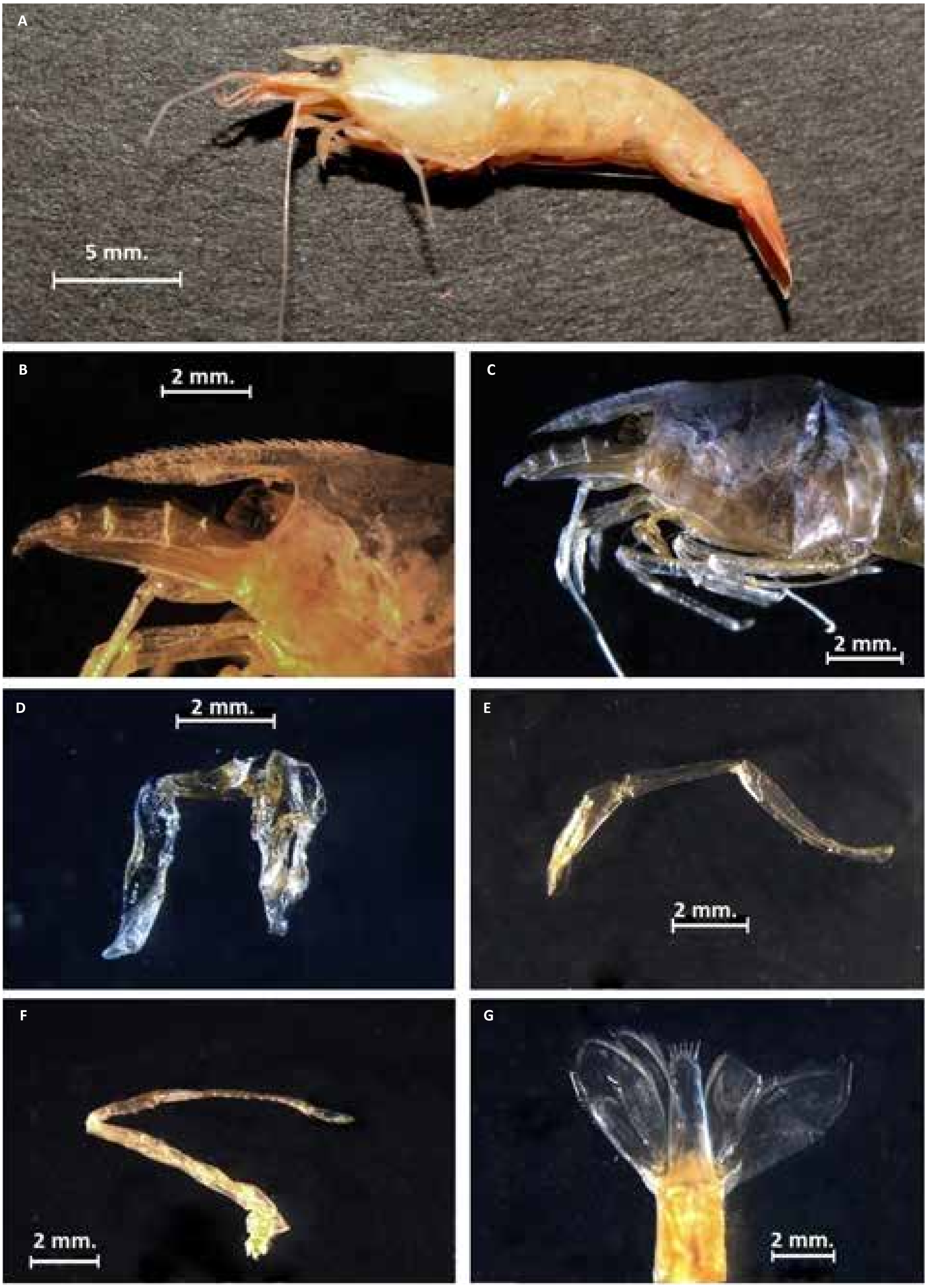

Image 3. *Caridina shenoyi* Jalihal & Sankolli, 1984 from the Palair Reservoir: (FBRC/ZSI/INV/1823) A—whole animal, lateral view | B—rostrum | C—lateral view of cephalothorax | D—first cheliped | E—second cheliped | F—fifth periopod | G—telson with uropods. Scale bars: 5mm (A), 2mm (B–G). © Sudipta Mandal.

2007. *Macrobrachium malcolmsonii* (H. M. Edwards, 1844) Rec. zool. Surv. India: 107(Part 2): 93–101.

IUCN Status: Least Concern.

Material examined: FBRC/ZSI/INV/1495, 1 specimen, 15.vii.2010, Neredvai, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1497, 2 specimens, 14.viii.2010, Palair, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1500, 1 specimen, 14.viii.2010, Annarigudem, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1524, 1 specimen, 16.viii.2010, Kottura, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1525, 1 specimen, 16.viii.2010, Uralakonda, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1368, 23 specimens, 7.xii.2016, J.C. Boating & Water park, Palair, coll. S. Mandal; FBRC/ZSI/INV/1405, 7 specimens, 7.xii.2016, Palair, coll. S. Mandal; FBRC/ZSI/INV/1439, 7 specimens, 13.vii.2017, Palair, coll. S. Mandal; FBRC/ZSI/INV/1886, 3 specimens, 30.viii.2018, Palair Park, Palair, coll. S. Mandal; FBRC/ZSI/INV/1891, 4 specimens, 31.viii.2018, near S.H. 42, Palair, coll. S. Mandal.

Diagnostic characters: TL 140–180 mm, RL 38–59 mm, CL 38–60 mm; rostral formula 9–11(2–4)/5–6, rostrum slightly upturned distally, proximal portion convex; two sub distal teeth present in dorsal arm, rest are evenly placed, rostrum more or less equal to antennal scale but longer than 3rdantenular peduncle; carapace smooth, antennal spine and hepatic spine present, post antenular carapace margin evenly rounded; 3rd maxilliped does not reach up to half of antenular scale; 1st cheliped very short, equal and slender, palm equal to fingers, a dance row of setae in the lower side of palm, carpus 2.5 times as long as chela and 1.3 times as long as merus; 2nd cheliped strong, equal and well developed, movable finger covers with velvety pubescence in adults, fingers are longer than half of the palm, palm not swollen, carpus 0.8 as long as chela, 1.3 as long as merus; 3rd to 5th periopod in structure with simple dactylus; abdomen smooth, 6th segment 1.5 as long as 5th and 0.63 as long as to telson; telson with two pairs of dorsal movable spines and two pairs of posterior spines with 12–14 plumose setae, posterior apex exceed the tips of longer posteriolateral spines; uropods are exceeding tip of telson, endopod shorter than exopod in length, lateral margin of exopod straight, overreached by blunt angular lamellar end. The mobile mesial spine of exopod is absent.

Remarks: In India this species is distributed in Andhra Pradesh, Karnataka, Kerala, Maharashtra, Odisha, Tamil Nadu, Tripura, and West Bengal. Apart from India it has been reported from Indonesia, Kenya, Madagascar, Mozambique, and Sri Lanka. This species is collected from the deep water of large reservoirs or rivers.

6. Macrobrachium rosenbergii (de Man, 1879) (Image 5)

1879. *Palaemon rosenbergii* de Man: 167.

1950a *Macrobrachium rosenbergii* Holthuis: 111. Fig. 25.-Kuris, Ra'anan, Sagi, and Cohen, 1987: 219.

IUCN Status: Least Concern.

Material examined: FBRC/ZSI/INV/1420, 3 specimens, 16.ii.2017, Palair, coll. S. Mandal.

Diagnostic characters: TL 132–145 mm, RL 48–51 mm, CL 35–40 mm; rostral formula 12–16(3–4)/10–11, rostrum upturned distally, proximal portion convex, all teeth are evenly placed; rostrum longer than antennal scale and antenular peduncle; carapace smooth, antennal spine and hepatic spine present, post antenular carapace margin evenly rounded; 3rd maxilliped reaches half of antenular scale; 1st chelipeds equal, slender, shorter than 2nd cheliped, palm equal to fingers, carpus two times as long as chela and 1.3 times as long as merus; 2nd chelipeds strong, equal and well developed, carpus shorter than chela but longer than merus, palm swollen, fingers longer than half of the palm, legs entirely covered with very small dense spinules; 3rd to 5th periopod in structure with simple dactylus; abdomen smooth, 6th segment 1.85 times as long as 5th and equal to telson; telson with two pairs of dorsal movable spines and two pairs of posterior spines with 14–16 plumose setae, posterior apex exceed the tips of longer posteriolateral spines; uropods are exceeding tip of telson, endopod shorter than exopod in length, lateral margin of exopod straight, overreached by blunt angular lamellar end, mobile mesial spine of exopod is absent.

Remarks: *M. rosenbergii* has been reported from all over India. This species is also collected from the deep water of large reservoirs or rivers along with *M. malcolmsonii*.

7. Macrobrachium scabriculum (Heller, 1862) (Image 6)

1862a. *Palaemon scabriculum* Heller: 527 [type locality: Sri Lanka].

1950a. *Macrobrachium scabriculum.* - Holthuis: 224.

IUCN Status: Least Concern.

Material examined: FBRC/ZSI/INV/1887, 5 specimens, 30.viii.2018, Palair Park, Palair, coll. S. Mandal; FBRC/ZSI/INV/1890, 7 specimens, 31.viii.2018, near S.H. 42, Palair, coll. S. Mandal.

Diagnostic characters: TL 9.8cm.; rostrum formula 12–15(2–3)/2–3, rostrum straight, long as 3rd segment of peduncle and 0.75 times as long as carapace; carapace rough posteriorly, antennal spine and hepatic spine present, post antenular carapace margin evenly

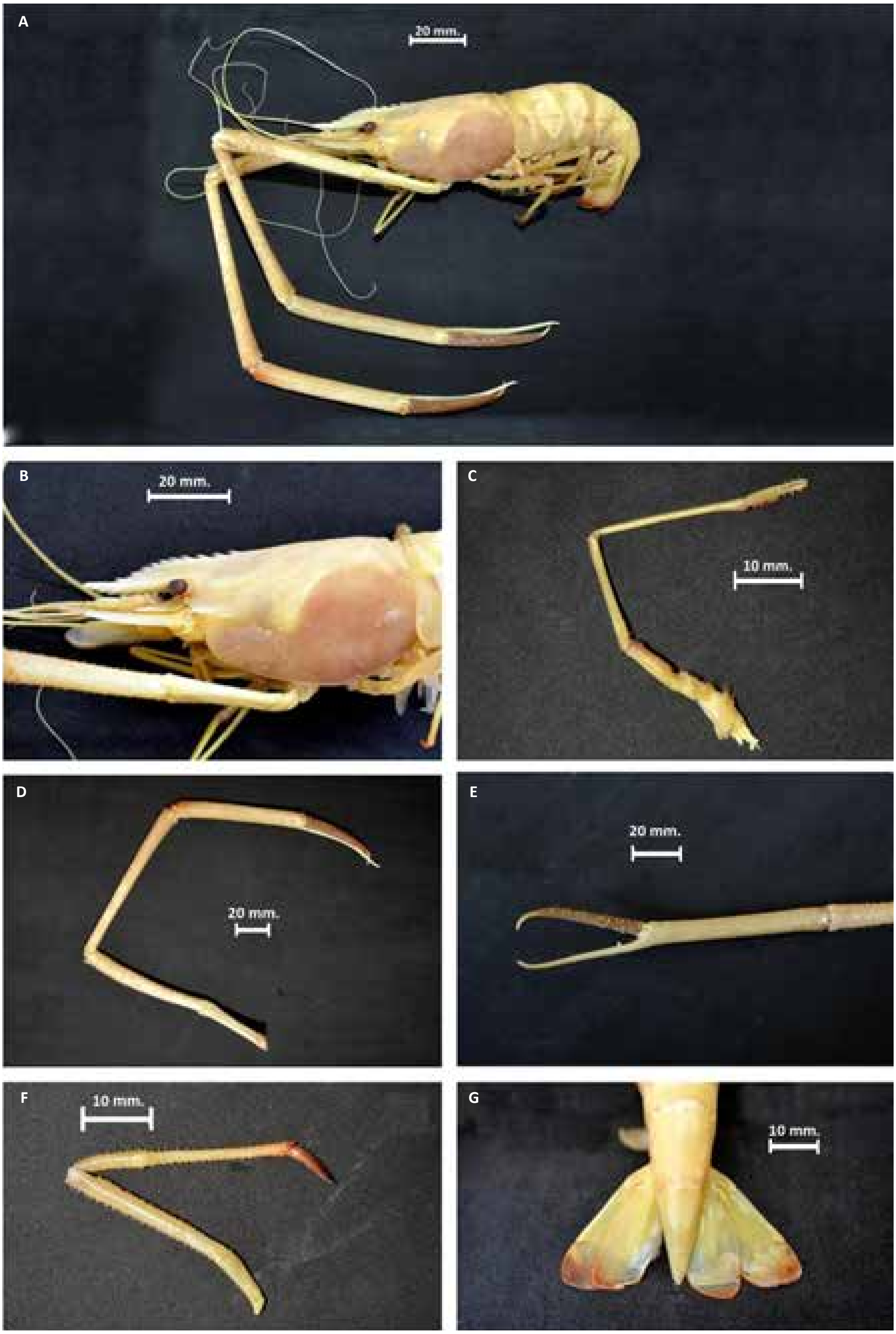

Image 4. *Macrobrachium malcolmosonii* (H.M. Edwards, 1844) from the Palair Reservoir: (FBRC/ZSI/INV/1891) A—whole animal, lateral view | B—lateral view of cephalothorax | C—first cheliped | D—second cheliped | E—chela of second cheliped | F—fifth periopod | G—telson with uropods. Scale bars: 20mm (A, B, D , E), 5mm (C, F, G).

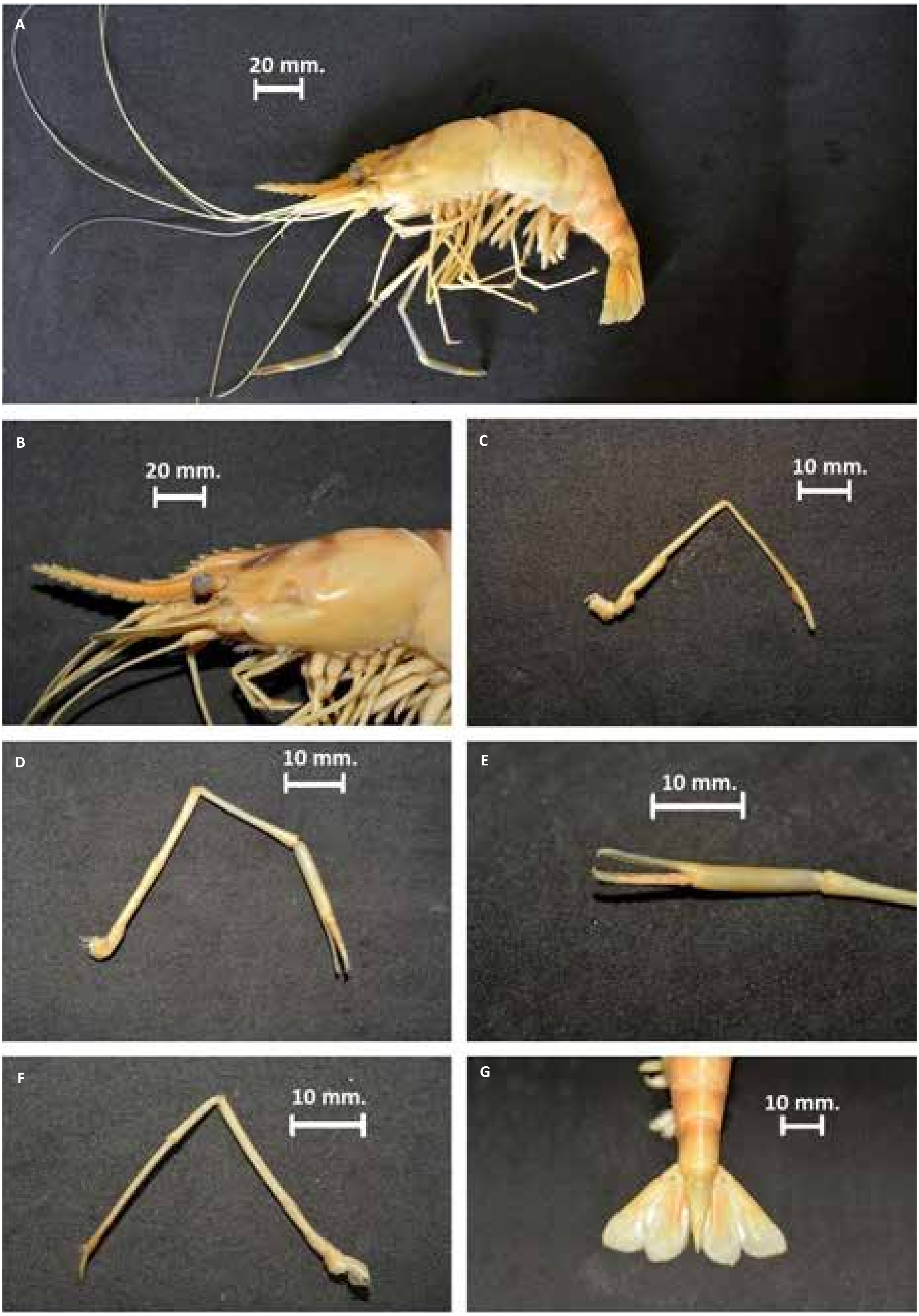

Image 5. *Macrobrachium rosenbergii* (De Man, 1879) from the Palair Reservoir: (FBRC/ZSI/INV/1420) A—whole animal, lateral view | B—lateral view of cephalothorax | C—first cheliped | D—second cheliped | E—chela of second cheliped | F—fifth periopod | G—telson with uropods. Scale bars: 20mm (A, B), 10mm (C–G). © Sudipta Mandal.

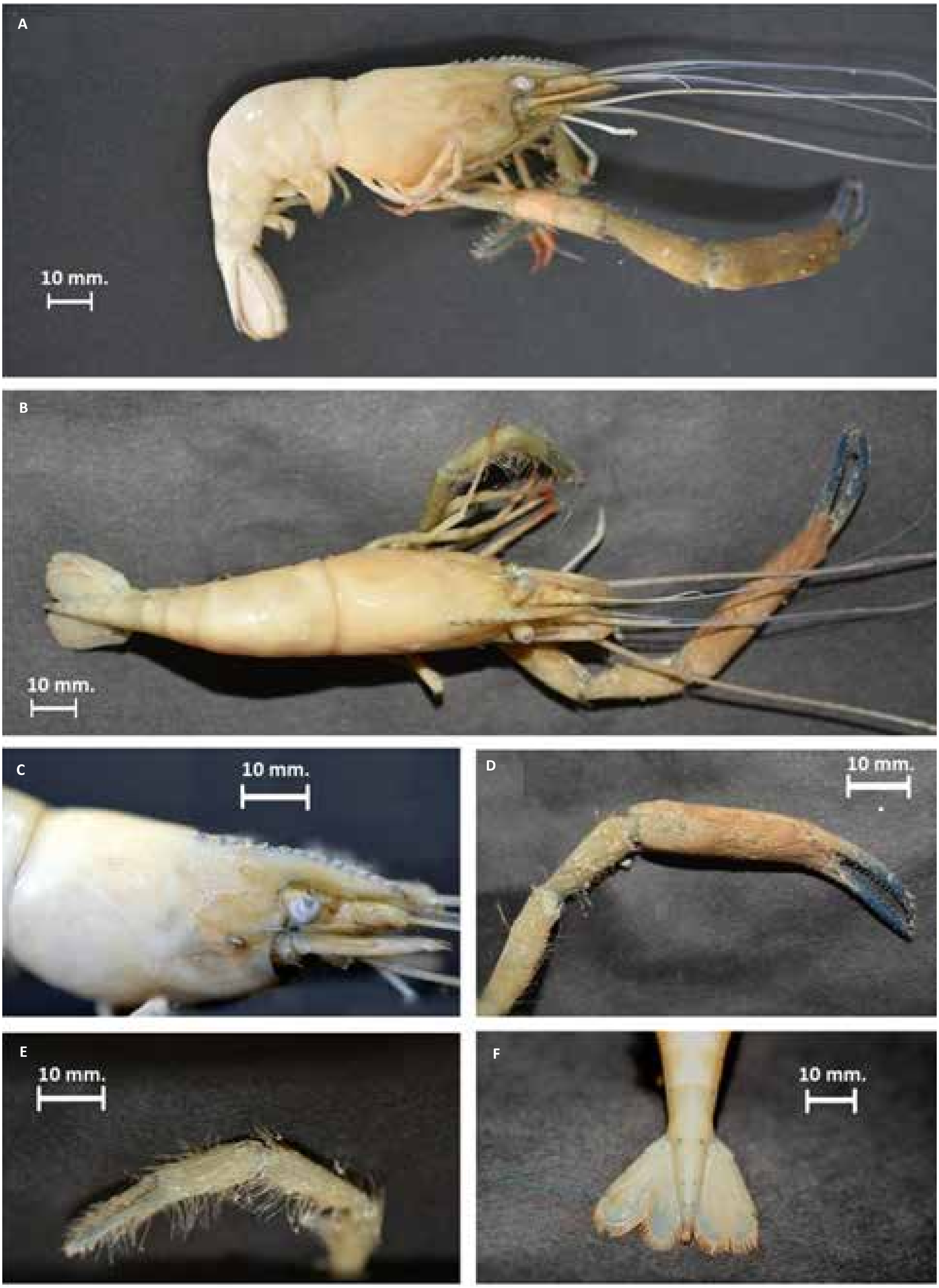

Image 6. *Macrobrachium scabriculum* (Heller, 1862) from the Palair Reservoir: (FBRC/ZSI/INV/1890) A—whole animal, lateral view | B—whole animal, dorsal view | C—lateral view of cephalothorax | D—larger 2nd cheliped | E—smaller 2nd cheliped | F—telson with uropods. Scale bars: 10mm (A–F). © Sudipta Mandal.

Image 7. ***Barytelphusa cunicularis*** **(Westwood in Sykes, 1836) from the Palair Reservoir: (FBRC/ZSI/INV/1365) A—whole animal, dorsal view | B—whole animal, frontal view | C—whole animal, ventral view (male) | D—whole animal, ventral view (female) | E—third maxillipeds | F—male first gonopod (G1) | G—left male second gonopod (G2). Scale bars: 10mm (A–D), 5mm (E, F), 2mm (G). © Sudipta Mandal.**

rounded; 3rd maxillipeds cross half of antenular scale; 1st cheliped is slender, equal and extending over the tip of the antennal scale; 2nd Cheliped stout, exhibiting sexual dimorphism in adult, in male unequal in size and shape, larger one longer than the body, much stouter than the smaller Cheliped and characterized by the presence of velvety pubescence on palm, palm longer than fingers with equal thickness, cutting edge of the fingers armed with a row of tubercles which gradually decreased in size distally, Carpus shorter than both palm and merus; smaller Cheliped shorter than the body and less pubescent, fingers longer than palm, cutting edges plane, palm shorter than Carpus, Carpus sub equal to merus; 3rd to 5th periopods similar in structure with simple dactylus; abdomen smooth, 6th segment 1.25 as long as 5th and 0.55 as long as to telson; telson with two pairs of dorsal movable spines and 2 pairs of posterior spines with 6–7 plumose setae, posterior apex do not exceed the tips of longer posteriolateral spines; uropods are exceeding tip of telson, endopod equal to exopod in length, lateral margin of exopod straight, overreached by blunt rounded lamellar end, mobile mesial spine of exopod present.

Remarks: In India *M. scabriculum* is known from Andhra Pradesh, Karnataka, Kerala, Maharashtra, Odisha, Tamil Nadu, Tripura, Telangana, & West Bengal; Indonesia; Kenya; Madagascar; Mozambique; and Sri Lanka. This species is generally found in crevices or beneath the stones and small rocks in shallow water.

Infraorder Brachyura Latreille, 1802
Superfamily Gecarcinucoidea Rathbun, 1904
Family Gecarcinucidae Rathbun, 1904

8. Barytelphusa cunicularis (Westwood in Sykes, 1836) (Image 7)

1836. *Thelphusa cunicularis* Westwood, in Sykes & Westwood: 183; H. Milne Edwards, 1853: 209.

1970a. *Barytelphusa* (*Barytelphusa*) *cunicularis*– Bott: 335; 1970b: 31; Srivastava, 2005: 118, Pl. 1 Fig. 3.

IUCN Status: Least Concern.

Material examined: FBRC/ZSI/INV/1413, 1 specimen, Annarigudem, 14.viii.2010, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1455, 1 specimen, Urlakonda, 16.viii.2010, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1465, 1 specimen, Kotturu, 16.viii.2010, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1493, 15.viii.2010, 3 specimens, Neredvai, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1498, 2 specimens, Neredvai, 12.iv.2011, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1572, 2 specimens, Narasimhulugudem, 11.iv.2011, Coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1365, one specimen, J.C. Boating & Water park, Palair, 7.xii.2016, coll. S. Mandal; FBRC/ZSI/INV/1383, 4 specimens, J.C. Boating & Water park, Palair, 16.ii.2017, coll. S. Mandal; FBRC/ZSI/INV/1889, 1 specimen, near S.H. 42, Palair, 31.viii.2018, Coll. S. Mandal.

Diagnostic characters: Carapace width 76–95 mm, CL 57–70 mm, Carapace height 19–38 mm; carapace wider than long, dorsal surface is slightly convex anteriorly and flat posteriorly; anteriolateral borders of carapace convex and cristiform, posteriolateral borders ill-defined and convergent posteriorly, cervical groove is distinct, meets with postorbital crest, H-groove is clear; frontal width 16–20 mm. Anteriolateral margin and branchial region raised in frontal view, frontal median triangle incomplete, epistome bilobed, without median tooth; post orbital and epigastric cristae strongly developed, fused with latter slightly anterior to former, forming gentle concave ridge in dorsal view, external orbital tooth blunt and not separated from the lower border of the orbit, external orbital angle broadly triangular with outer margin, ca. 2–3 times length of inner margin, epibranchial tooth broad, blunt, separated from external orbital angle with visible cleft; 3rd maxilliped exopod with long flagellum; suture between thoracic sternites 2–3 distinct and suture between 3–4 slightly visible as grooves; Chelipeds unequal in both the sexes, carpus has a strong sharp spine with a small accessory cusp at its inner angle, one big tooth in the middle of the immovable finger, rest of all apposed moderately; ambulatory legs smooth, compressed dorsoventrally, more or less same size with the chelipeds, dactylus subequal in length with propodus narrowly triangular, 6th segment broader than long with concave lateral margin, telson is tongue-shaped, equal to 6th segment in length, abdominal cavity deep, female pleon broadly tongue-shaped, vulvae oval-shaped, situated just beside the margin with thoracic sternite 5; G1 long, narrow, curving slightly outwards, terminal segment long with pointed tip; G2 short, distal segment short.

Remarks: *Barytelphusa cunicularis* was so far known from the states of Maharashtra, Kerala, Karnataka, Tamil Nadu and West Bengal as well as Andhra Pradesh and Telangana. This species is generally found in small pit at the bank of river or lake or reservoir.

9. Barytelphusa guerini (H. Milne Edwards, 1853) (Image 8)

1853. *Thelphusa guerini* H. Milne Edwards, Ann. Sci. Nat. Zool., 1853: 210.

1970a. *Barytelphusa (Barytelphusa) guerini* Bott, Abh. senckenb. naturforsch. Ges.: 33.

IUCN Status: Least Concern.

Material examined: FBRC/ZSI/INV/1411, 2 specimens, Annarigudem, 14.viii.2010, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1464, 1 specimen, Erragaddathanda, 16.viii.2010, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1496, 1 specimen, Nayakangudem, 14.viii.2010, coll. Dr. S.V.A. Chandrasekhar; FBRC/ZSI/INV/1499, 1 specimen, Neredvai, 12.iv.2011, coll. Dr. S.V.A. Chandrasekhar; ZSI/INV/1406, 3 specimens, J.C. Boating & Water park, Palair, 13.vii.2017, coll. S. Mandal, FBRC/; FBRC/ZSI/INV/1888, 7 specimens, Canal 1, beside Palair

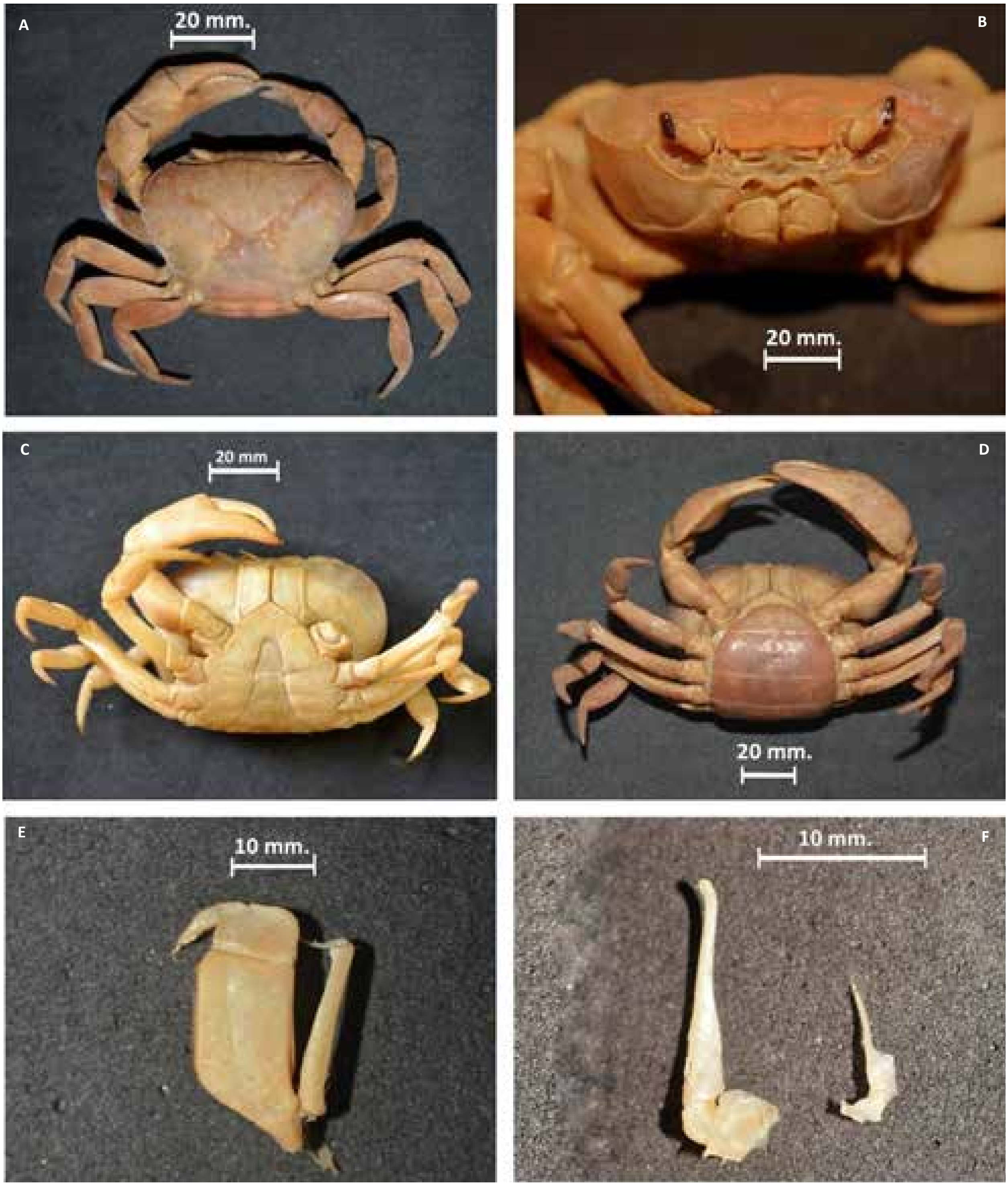

Image 8. *Barytelphusa guerini* (H. Milne Edwards, 1853) from the Palair Reservoir: (FBRC/ZSI/INV/1406) A—whole animal, dorsal view | B—whole animal, frontal view | C—whole animal, ventral view (male) | D—whole animal, ventral view (female) | E—third maxilliped | F—male first gonopod (G1) | G—left male second gonopod (G2). Scale bars: 20mm (A–D), 10mm (E–F). © Sudipta Mandal.

Park, 30.viii.2018, coll. S. Mandal; FBRC/ZSI/INV/1911, 1 specimen, Katta Maisamma temple, Palair, 31.viii.2018, coll. S. Mandal; FBRC/ZSI/INV/1885, 5 specimens, Small stream near agricultural field, Thammagudem, 31.viii.2018, coll. S. Mandal.

Diagnostic characters: Carapace width 49–56 mm, CL 39–43 mm, Carapace height 12–19 mm; carapace wider than long, dorsal surface is convex; anteriolateral borders

Image 9. *Oziotelphusa* sp. from the Palair Reservoir: (FBRC/ZSI/INV/1696) A—whole animal, dorsal view | B—whole animal, ventral view (male) | C—whole animal, frontal view. Scale bars: 10mm (A–C). © Sudipta Mandal.

of carapace convex and cristiform, posteriolateral borders ill-defined and convergent posteriorly; cervical groove is distinct, meets with post orbital crest (does not touch the antereo lateral line); H-groove is clear; frontal width 12–16mm, frontal median triangle incomplete, epistome bilobed, without median tooth; post orbital and epigastric cristae strongly developed, fused as a continuous line, post-orbital crests trenchant, sinuous and separated from Epibranchial tooth by clearly visible cleft, external orbital tooth blunt and not separated from the lower border of the orbit, external angle of frontal median triangle cristiform, epibranchial tooth well formed but blunt, postereo-lateral borders ill-defined and convergent posteriorly; 3rd maxilliped exopod with long flagellum; suture between thoracic sternites 2–3 distinct, between 3–4 slightly visible as shallow grooves on sides; chelipeds unequal in both the sexes, Carpus has a strong sharp spine with a small accessory cusp at its inner angle, 2/3 bigger teeth in both movable and immovable fingers, rest of all apposed moderately; ambulatory legs smooth, compressed dorsoventrally, more or less same size with the chelipeds; male abdomen broad-based triangular, 6th segment broader than long, trapezoidal in shape with straight lateral margin, telson tongue-shaped, equal to 6th segment in length, abdominal cavity deep; female pleon oval-shaped, vulvae oblong, situated attached with the margin of thoracic sternite 5; G1 long, narrow, curving slightly outwards, terminal segment very long with bulged tip; G2 short, distal segment short.

Remarks: *Barytelphusa guerini* was so far only known from the states of Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Rajasthan, and Uttar Pradesh (Pati & Thackeray 2018). The species is reported herein for the first time from Telangana based on the material from the Palair Reservoir. This species is collected from beneath the stones and small rocks in shallow water.

10. Oziotelphusa sp. (Image 9)

Material examined: FBRC/ZSI/INV/1696, 1 specimen, 15.viii.2010, Palair Reservoir, Neradavai, coll. Dr. S.V.A. Chandrasekhar.

Diagnostic characters: Carapace greatest width 30.2mm, CL 21.4mm, carapace height 12.7mm, carapace wider than long. Dorsal surface strongly convex, surface very smooth; anteriolateral borders of carapace convex, smooth and sheet-like without serration; the cervical groove distinct, disappears in a distance behind post-orbital crest, H-groove clear; frontal median triangle complete but not as broad as frontal margin, epistome trilobed, epistomal medial tooth sharp; orbit broad, external orbital tooth blunt and not separated from the lower border of the orbit, external orbital angle triangular; epigastric crest sub-trenched and slightly in advance and separated from post-orbital cristae; post-orbital crests trenchant, sinuous, separated from epibranchial tooth with visible cleft. Epibranchial tooth blunt; 3rd maxilliped exopod with strong flagellum; abdomen of the male T-shaped, suture between anterior thoracic sternites 2–3 visible as shallow, narrow groove not reaching lateral margins, but suture between sternite 3–4 indiscernible.

Remarks: The present lone male specimen from the Palair Reservoir is here referred to *Oziotelphusa* sp., and it has no affinities with the congeners *Oziotelphusa aurantia* and *Oziotelphusa kerala* (Bahir & Yeo 2005; Pati & Sharma 2012; Raj et al. 2017); and this unknown species are found to be new records from Telangana (cf. Pati & Thackeray 2018).

DISCUSSION

Decapods of Palair Reservoir were poorly studied until the present work. In total, 10 decapod species are currently known from the Palair Reservoir as a result of present and previous collections. Among these, four species stand as new state records: *P. semisulcatus*, *C. gracilipes*, *B. guerini*, and *Oziotelphusa* sp. Previous researchers reported 82 examples of Decapoda collected from the reservoir during the survey period of July 2009 to April 2011 (Roy et al. 2015). Among them there were two species of caridean prawns of Palaemonidae family *Macrobrachium malcolmsonii* (H. Milne Edwards, 1844) and M. *equidens* (Dana, 1852), along with three species of brachyuran crabs of Gecarcinucidae family, namely, *Barytelphusa cunicularis* (Westwood in Sykes, 1836), *B. guerini* (H. Milne Edwards, 1853), and *Barytelphusa jacquemnotii* (Rathbun, 1905). *B. jacquemnotii,* which had a different species identity in the paper of Roy et al. (2015), has been synonymised with *B. cunicularis* (Pati & Sharma 2014).

In the present study, one species of Penaeid prawn and five species of caridean prawn were encountered along with two brachyuran crabs. One of the previously reported species *Macrobrachium equidens* has not been found in the current study period. In addition to the earlier reported prawn species *Macrobrachium malcolmsonii*, two other species of Palaemonidae family, i.e., *M. scabriculum* (Heller, 1862) and *M. rosenbergii* (De Man, 1879) have been encountered this time. Two species of Atyidae family, i.e., *Caridina gracilipes* De Man, 1892 and *C. shenoyi* Jalihal, Shenoy & Sankolli, 1984 have also been recorded this time. Further discussion on Genus *Caridina* will be provided elaborately in near future. Importantly, none of the species of *Oziotelphusa* were present in the current sampling, however, one specimen of the previous collections identified up to the genus level (*Oziotelphusa* sp.), barely has affinities with the congeners *Oziotelphusa aurantia* and *Oziotelphusa kerala*. Further identification up to the species level of this *Oziotelphusa* specimen requires further collections from the location, which will be conducted in the near future.

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PLATINUM OPEN ACCESS

COMMUNICATION

Diversity and distribution of figs in Tripura with four new additional records

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Abstract: The genus *Ficus* L., commonly known as Fig plays an important role in the forest ecosystem, being a keystone species. Taxonomic revision, habitat assessment, and floristic study of the genus *Ficus* of northeastern region are scanty and still lacking. As the genus is rich in diversity, this region possesses tremendous scope for utilisation of its members, as many species belonging to this genus carry good properties for diverse uses for the benefit of mankind. Therefore, the present study has been undertaken for identification of the collected taxa, diversity assessment of the wild as well as planted species, distribution throughout the state and preparation of a comprehensive checklist along with measures of diverse functions and ecological role of the genus *Ficus* in Tripura, North-East India. Field survey was conducted between April 2017–August 2018 throughout Tripura and all the locations were marked with GPS which is given in the present distribution map of *Ficus* in Tripura. This study is based on extensive field survey and specimen collection. Key taxonomic description, both accepted and vernacular names, phenology, and diverse habitat function of all species have been provided. Based on the available literatures, distribution information of the present records were calculated. Evaluation of diverse ecological role were scored based on the published literature and field observations. In the present study, 23 taxa of *Ficus* have been reported from the study area including four new distribution records. Most of the *Ficus* species recorded in this study were from moist mixed deciduous and secondary forests. Out of 23 species of *Ficus* recorded in the present study, seven (7) species belong to evergreen small tree to shrub (*F. benghalensis*, *F. drupacea*, *F. elastica*, *F. microcarpa*, *F. racemosa*, *F. sarmentosa* and *F. semicordata*); three (3) species recorded are large deciduous tree (*F. racemosa*, *F. religiosa* and *F. rumphii*). Fleshy fruited trees are the most preferable option for survival of frugivores over diverse habitats and thus, plays major role for entire ecosystem restoration. The present work will be useful to understand the critical interactions between plants and frugivore at different trophic levels. Further, *Ficus* groups tend to have multiple ecological roles, and as a result there exists huge scope to understand the mechanisms of plant functional traits for conservation of threatened frugivore diversity.

Keywords: Conservation, ecological roles, Ficus, frugivore, northeastern India.

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Author contribution: All authors have contributed equally. This is a collaborative work and have been modified by authors from time to time wherever required.

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INTRODUCTION

The genus *Ficus* L. (commonly known as Fig; Moraceae) or fig trees are being considered as keystone species and ecologically important because they sustain populations of the many seed-dispersing animals that feed on their fruits throughout the year (Chaudhary et al. 2012; Krishnan & Borges 2018). *Ficus* is considered the most conspicuous and elusive genus due to its minute flowers present inside the closed fleshy receptacle (scyconium). The genus comprises about 750 species throughout the world (Corner 1965; Berg 1989; Berg & Corner 2005; Ronsted et al. 2008; Pederneiras et al. 2015). Furthermore, Adebayo et al. (2009) reported occurrence of 800 species in tropical and subtropical regions of the world and about 115 species in India (Chaudhary et al. 2012). *Ficus* is one of the largest genera of angiosperms comprising terrestrial trees (deciduous and evergreen trees), shrubs, hemi-epiphytes, climbers, and creepers occurring in the tropics and subtropics of the world (Frodin 2004; Berg & Corner 2005).

The first systematic account of the Indian *Ficus* L. is available in King (1887–88,1888); therein he recorded 113 species and 47 infraspecific taxa from whole of the then British India out of which only 75 species and 16 infraspecific taxa were reported from present-day political boundary of the country. There are many published works on the genus by various authors who have contributed in the field of identification, classification, and nomenclature (Corner 1961, 1965, 1969, 1975, 1981; Berg 1986, 2003, 2006, 2007, 2010, 2012; Chantarasuwan & Kumton 2005; Whitfeld & Weiblen 2010; Kumar et al. 2011; Murugan et al. 2013; Dhungana et al. 2015) and new records from different regions of the world have contributed to the knowledge on taxonomy and distribution of this genus.

Ficus is readily distinguished by the highly characteristic fruits and has often been recognized by the milky juice, the prominent stipule that leaves a scar on falling and the minute unisexual flowers often arranged on variously shaped receptacles (Hutchinson & Dalziel 1958). *Ficus* includes a large number of indoor ornamental plants and garden and roadside trees such as *F. benjamina, F. elastica, F. pumila, F. religiosa*, and *F. microcarpa*. The genus has followed several curious lines of evolution (Weiblen 2001). The main concentration of the species lies in Asian-Australian region with about 500 species which is about 66% of the world species. Ficus is also considered one of the most diversified genera with regard to its habits and life forms (free standing tree, epiphytes, semi-epiphytes in the crevices, Rheophytes, and Lithophytes). Some of the species of Ficus are used as food (e.g., *F. auriculata, F. semicordata*), fodder (e.g., *F. hispida*), and as medicine (e.g., *F. elastica*, *F. religiosa*). Moreover, *F. religiosa* and *F. benghalensis* are considered sacred to Buddhists and Hindus (Wilson & Wilson 2013).

It was reported that globally biodiversity is changing at an unprecedented rate as a complex response to several human-induced changes (Vitousek et al. 1997) and forest restoration is an increasingly important tool to offset and indeed reverse global deforestation rates (Cottee-Jones et al. 2016). One low cost strategy to accelerate forest recovery is conserving scattered native trees that persist across disturbed landscapes. Ficus trees, which are considered to be critically important components of tropical ecosystems, may be particularly attractive to seed dispersers in that they produce large and nutritionally rewarding fruit crops (Cottee-Jones et al. 2016) and in case of forest restoration studies seed dispersal has been frequently referred (Cole et al. 2010; Holl et al. 2013; Zahawi et al. 2013).

Fleshy-fruited trees are believed to be the most effective species at attracting frugivores over disturbed habitats and thus prove to be more effective restoration nuclei than other species (Slocum 2001). *Ficus* in particular is believed to be a very important genus of fleshy-fruited tree for a wide range of frugivores (Leighton & Leighton 1983; Terborgh 1986; Janzen 1988; Lambert & Marshall 1991; Shanahan et al. 2001; Kinnaird et al. 2005). Within intact forests, the unusual asynchronous fruiting cycle, large crop sizes, and pan-tropical availability of Ficus means that over 1,200 tropical birds and mammals have been recorded consuming Ficus fruit (Shanahan et al. 2001).

Taxonomic revision, habitat assessment, and floristic study of the genus *Ficus* of northeastern region are scanty and still lacking; however several studies were conducted from the region, viz.: Cottee-Jones et al. (2016) evaluated importance of Ficus trees for tropical forest restoration; medicinal uses *Ficus* by Sharma & Pegu (2011); figs as wild vegetables by Dutta (2012); a rare and lesser known species of India by Buragohain et al. (2012); and fig morphological characters and distribution by Dhungana et al. (2015). In Tripura such type of study and analysis was not done until date except for a few new reports (Majumdar et al. 2012a); however, efforts were made to quantify some Ficus tree species along with other trees in the forests of Tripura (Majumdar et al. 2012b; Majumdar & Datta 2014). As the genus is rich in diversity, this region possesses tremendous scope for utilisation of its members, as many species belonging to this genus carry good properties for use for the benefit of mankind. Therefore, the present study has been undertaken for identification of the collected taxa, diversity assessment of the wild as well as planted species, distribution throughout the state and preparation of a comprehensive checklist along with measures of diverse functions and ecological role of the genus *Ficus* in Tripura, North-East India.

MATERIALS AND METHODS

Study area

Tripura is a state of northeastern India. It is the third-smallest state in the country bordered by Bangladesh to the north, south, west, and the Indian states of Assam and Mizoram to the east. There are five hill ranges in Tripura, these are, Baramura, Atharamura, Longtarai, Sakhan, and Jampui run north to south, parallel to each other. Forests cover more than half of the area, in which bamboo and cane tracts are common. Like most of the Indian subcontinent, Tripura lies within the Indo-Malaya eco-zone. According to the bio-geographic classification of India, the state is in the North-East bio-geographic zone (Champion & Seth 1968). The state has a geographical area of 10,491km^2. As per the report of the Forest Survey of India (FSI 2015) total forest and tree cover in the state is 8,044km^2, i.e., 76.71 % of the total state's geographical area.

Field survey, data collection and species identification

Field survey was conducted between April 2017–August 2018 throughout Tripura and all the locations were marked with GPS which is given in the present distribution map of Ficus in Tripura (Fig. 1). Survey was also conducted in each locality including discrete forest area. The occurrences of the Ficus plants were recorded and specimens were collected from the field for taxonomical study as well as made into standard mounted herbarium sheets following the standard procedure (Jain & Rao 1977). As far as possible, specimens were collected with reproductive parts for the morphological studies and preparation of herbarium sheets. Reproductive parts were preserved in FAA solution for further microscopic studies in the laboratory.

The taxonomic identification of tree species and their geographic distribution ranges were based on the information of Hooker (1890), Kanjilal et al. (1940), Haridasan & Rao (1987), and Deb (1981). The identity of collected specimens was also determined by study of detailed taxonomic descriptions in different e-floras. The voucher specimens were deposited in the herbarium of the Department of Botany, Tripura University.

Species distribution

Based on the available literatures, distribution information of the present records were calculated on a scale of 1–6 (smaller to larger) to derived geographic distribution ranges score from numerical scale by slightly modified methods of Spitzer et al. (1993), i.e., (1) Eastern Himalaya, Yunnan and northern Indochina, (2) Bangladesh, northeastern India and northern Myanmar, (3) Indo-Burma (India including Andaman Island, Burma, Thailand and up to Vietnam), (4) Indo-Australian (India including Western Ghats, Sri Lanka, Indonesia and up to Australasian tropics), (5) Paleotropic (up to Baluchistan), (6) Cosmopolitan (Majumdar et al. 2012a).

Data analysis

Local occurrence and distribution in different forest habitat as well as non-forest land was typically recorded based on Frequency classes (Raunkiaer 1934), indicates the number of sampling units in which a given species occurs (Mishra 1968). Frequency of *Ficus* species in different locations of refers to the degree of dispersion of individual species in an area and is usually expressed in terms of percentage of occurrence.

Frequency and relative frequency of species in the study area are measured by using the formulae of Curtis & McIntosh (1950), which are given below.

Frequency = (No. of occurrences of a species × 100) / Total No. of site samples taken

Relative Frequency = (No. of occurrence of particular species × 100) / Total no. of occurrences of all the species

The values of relative frequency are calibrated on a 10-point scale to assign a status to the species in each region, however in this study we have not laid any quadrat and in this concern availability of a species was ranked based on their occurrence throughout the state Tripura. Four distinct groups are derived from this 10-point scale and each group in each region is designated as follows: 7–10 Very Frequent, 5–7 Frequent, 3–5 Less Frequent, <3 Rare.

Evaluation of diverse ecological role

Major uses of *Ficus* species found in Tripura were scored based on the published literature and field observations, which were prioritized for their various medicinal uses and diverse ecological role.

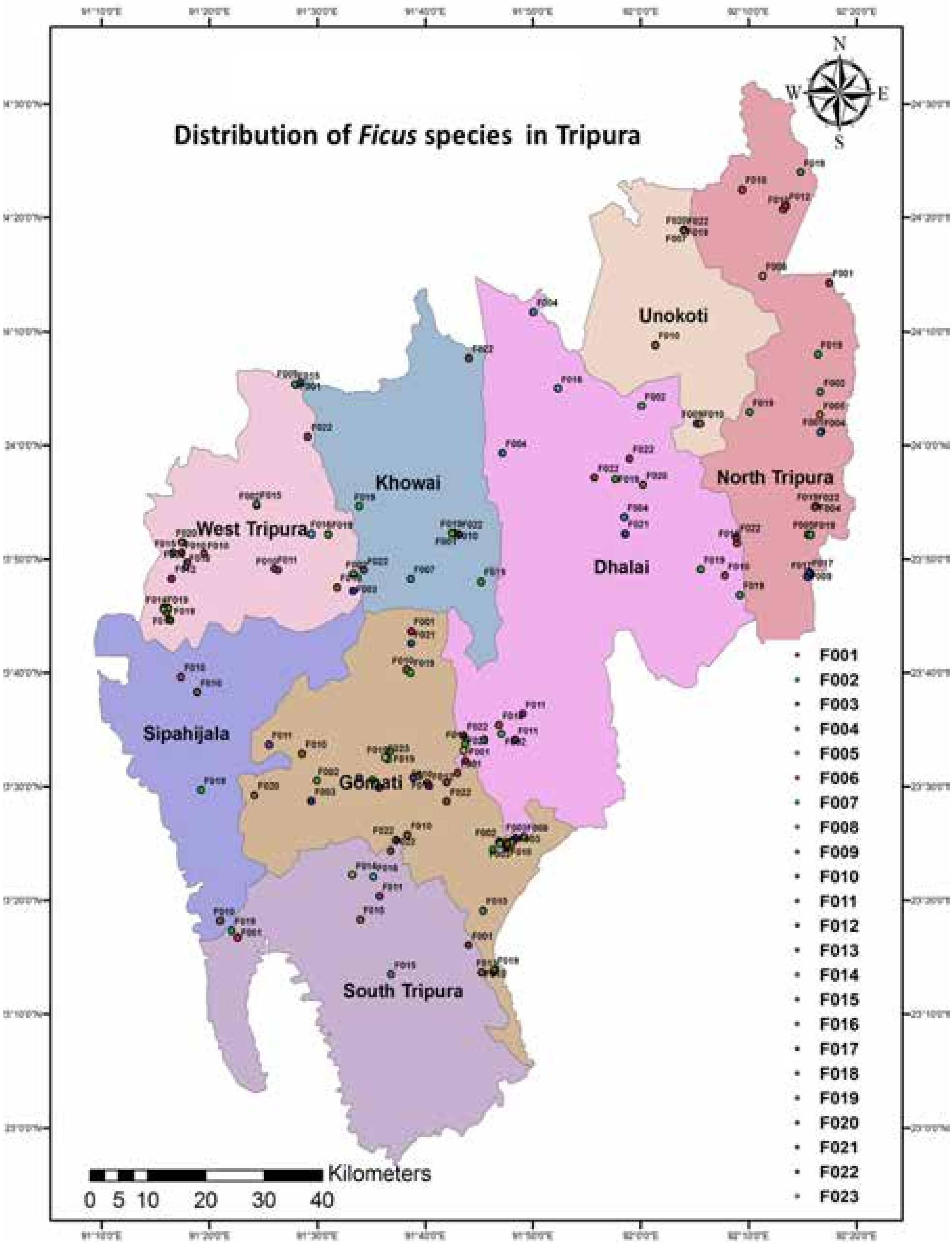

Figure 1. The location of field study and distribution of 23 Ficus species in Tripura.

RESULTS

Taxonomic treatment and species enumeration

Ficus auriculata Lour.

Fl. Cochinch. 2: 666. 1790; Kanjilal et al. Fl. Assam 4: 263. 1940; Deb, FI. Tripura State 1:217.1981. (Image 1; F001).

Vernacular name: Durumpui (Kokborok), Elephant Ear Fig, Theibal.

Trees small, evergreen, young parts pubescent. *Leaves*7.8–22 × 2.7–7.7 cm, elliptic or ovate-elliptic, serrate, subcoriaceous, glabrescent, lateral nerves 3–7 on each side, base subcuneate, 3–5 nerved; petiole 2.5–7.5 cm long; stipule ovate-lanceolate. Figs peduncled, subglobose, pyriform, red when ripe. Male flowers: perianth segments 3, stamens 2. Gall flowers: perianth 3 toothed, style short, stigma dilated. Female flowers: perianth 3 toothed, style long ,stigma clavate.

Flowering & fruiting: August–March.

Global distribution: India, Bangladesh, Malesia, Myanmar, Pakistan to southern China, Thailand.

Distribution in India: Outer Himalaya ascending up to 2,000m, Arunachal Pradesh, Assam, Bihar, Jammu & Kashmir, Jharkhand, Maharashtra, Manipur, Meghalaya, Mizoram, Odisha, Sikkim, southern India, West Bengal

Distribution in Tripura: Taidu, Simna, Vanghmun. Baramura-Debtamura R.F., Atharamura R.F.,Trishra R.F., Damcherra, Paschim Kalajari R.F. part.

Uses: Fruit is edible.

Ecology: Frequently found in evergreen forest, and mostly occur along the hill tract.

Ficus benghalensis L.

Sp. Pl. 1059. 1753; Kurz, For. Fl. Brt. Burma 2:440. 1877; King in Ann. Roy. Bot. Gard. Calcutta. 1: 18, t. 13 & 81c.1887 & in Hook.f., Fl. Brit. India 5: 499. 1888; Brandis, Indian Trees 600. 1906; Kanjilal et al., Fl. Assam 4:240.1940; Corner, Gard. Bull. Singapore 17: 381. 1960; Deb, Fl. Tripura State 1:211. 1981; Harridasan & Rao,For. Fl. Megh.2:820. 1987; (Image 1; F002).

Vernacular name: Bargad, Banyan, Bor.

Trees large, evergreen. Leaves 12–20 × 7–12 cm elliptic to ovate, apex mucronate, coriaceous, base rounded, sub-cordate or slightly narrowed at the base, green and glossy above, glabrescent or pubescent beneath, lateral nerves 4–7 on each side, looped near the margin, base 3–7 nerved, petiole 1.2–5 cm long; stipules deltoid. Figs in auxiliary pairs, 1.5cm, with three large rounded basal bracts, red when ripe. Male flowers: numerous near the mouth of the receptacle; perianth segments 3; stamen one. Gall flowers: similar with a short style. Female flower: with smaller perianth and longer style.

Flowering & fruiting: April–July.

Global distribution: Bangladesh, India, Malaysia, Nepal, Pakistan, Sri Lanka, widely cultivated in tropics.

Distribution in India: Throughout India, northeastern region, sub-Himalayan forest, Andaman Islands

Distribution in Tripura: Tripura University Campus, G.B. Bazar, Paschim Kalajari R.F. part, Jatanbari, Dumbur, and scattered throughout the state.

Uses: Wood moderately hard, used as timber for miscellaneous purposes (Deb 1981). *F. benghalensis* is considered greatly sacred to Hindu as well as to the Buddhists and worshiped in diverse ways at a variety of occasions. *F. benghalensis* is also reported to cure many diseases ethnomedicinally such as leucorrhoea, anti-emetic, cutsand wounds, joint pains.

Ecology: Naturally scattered in the state and planted on road side as an avenue tree. The aerial root is styptic and aphrodisiac. Tips of the hanging roots are given for obstinate vomiting.

Ficus benjamina L.

Mant. Pl. 1: 129. 1767; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 43, t. 52, 83h. 1887 & in Hook. F., Fl. Brit. Lndia 5: 508. 1888; Brandis, Indian Trees 604. 1906; Deb, Fl. Tripura State 1:212. 1981. (Image 1; F003).

Vernacular name: Biriphang topsi (kokborok), Golden Fig, Weeping Fig, Java Fig, Pukar.

Trees large, main branches producing aerial roots which can develop into new trunks. Leaves 3.7–10 × 1.3–5 cm, leaf blade ovate to broadly elliptic, entire, coriaceous, glabrous, lateral nerves numerous, slender, anastomosing into an intramarginal nerve; petiole 1–2 cm long; stipules lanceolate. Figs axillary, often in pairs, globose or ovoid, about 2.2cm across. Male flowers few, scattered, pedicellate. Perianth segments 2, spathulate. Gall flowers: perianth 3–4 segmented. Female flowers: sessile. Perianth spathulate, stigma enlarged.

Flowering & fruiting: January–March

Global distribution: India (cultivated, avenue plants), China, Malaysia to the Solomon Islands and northern Australia.

Distribution in India: Throughout the north-eastern region, sub-Himalayan forest, Andaman Islands.

Distribution in Tripura: Balipur chhara, Tirthamukh, Dumboor; Purba Kalajhari R.F.

Uses: Milky juice and leaves are medicinal and trees are ceremonial and used as fodder (Rijal 1994; Thapa et al. 1997; Panthi & Chaudhary 2002).

Ecology: Sacred tree and mostly occurrs on the roadside.

Ficus curtipes Corner

Gard. Bull. Singapore 17: 397. 1960 & 21 (1): 22. 1965; Roy et al., J. Econ. Taxon. Bot. Vol 22: 49-63. 1998; Deb, Fl. Tripura State 1:212. 1981; (Image 1; F004).

Vernacular name: Eastern Laurel Fig

Trees large, epiphytic when young. Branchlets green, glabrous. Leaves 6.2–19 × 3–3.7 cm oblong-elliptic or obovate-elliptic, entire, obtuse, coriaceous, lateral nerves 10–12 on each side; base 3–7 nerved, cuneate; petiole 0.8–1.7 cm long, stout; stipules ovate-lanceolate, acuminate. Figs axillary on leafy branchlets, paired, dark red to purplish red when mature, globose to depressed globose, 1–1.5 cm across, inside without bristles. Male flowers: numerous, scattered, perianth segments 3; Gall flowers: perianth segments; style subterminal. Female flowers: sessile, style lateral, stigma funnel shaped.

Flowering & fruiting: August–October

Global distribution: Bangladesh, Bhutan, India, Indonesia, Malaysia, Malay Peninsula (Langkawi Island), Myanmar, Nepal, Sikkim, Thailand, Vietnam.

Distribution in India: Northern and northeastern India.

Distribution in Tripura: Hmonpui, Tlakchi, Tlangsang, Jampui Hills, Kamalpur.

Uses: Yields an inferior rubber (Deb, 1981), used as an ornamental tree.

Ecology: Found in moist deciduous forest.

Ficus drupacea Thunb.

Diss. *Ficus* 6, 11. 1786; Miq., Ann. Mus. Bot. Lugd.-Bat. 3: 286. 1867; Corner, Gard. Bull. Singapore 17: 380. 1960 & 21 (1): 13. 1965; Deb, Fl. Tripura State 1:213. 1981; (Image 1; F005).

Vernacular name: Mysore Fig, Brown Woolly Fig, Paras Peepal.

Trees large. Bark grayish-white. Branches without aerial roots; densely yellowish-brown woolly. Leaves 14.8–25 × 6–13 cm elliptic to ovate-elliptic, entire bluntly acuminate, coriaceous, glabrous, dotted above, glabrescent beneath, lateral nerves 12–20 on each side, anastomosing into an intramarginal nerve, tertiaries very finely reticulate, base slightly cordate or rounded, 3–7 nerved, petiole 2–3.5 cm long; stipules deltoid, rusty tomentose. Figs axillary, 3.5cm across, globose, rusty tomentose when young, glabrous, orange when ripe. Male flowers: long pedicellate, perianth segments 4, stamen 1. Gall flowers: with 4 perianth lobes. Female flowers: perianth lobes 4, style lateral.

Flowering & fruiting: January–March.

Global distribution: India, Bangladesh, China, Indonesia, Malesia, Myanmar, Nepal, Sri Lanka, Thailand, Vietnam, Laos, Bhutan.

Distribution in India: Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, northeastern India.

Distribution in Tripura: Hmonpui, Sabual, Jampui Ranges.

Uses: The figs are edible but rather tasteless.

Ecology: Found mostly in evergreen and rarely in deciduous forests.

Ficus elastica Roxb.

(Hort. Beng. 65. 1814, nom. Nud.) ex Hornem., Hort. Bot. Hafn. Suppl. 7. 1819; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 45, t. 54. 1887 & in Hook. F., Fl. Brit. Lndia 5: 508. 1888; Brandis, Indian Trees 603. 1906; Deb, Fl. Tripura State 1:213. 1981 (Image 1; F006).

Vernacular name: Indian Rubber Tree, Rabar Gach, Atha bor

Trees large, evergreen, epiphytic when young. Bark pale gray, smooth.

Leaves 12–28 × 5–14 cm elliptic to oblong, entire, coriaceous, caudate at apex, rounded at base, glabrous; lateral nerves many, inconspicuous, petiole 1.3–6 cm long; stipules large, lanceolate, flaccid, reddish. Figs axillary on leafless branchlets, paired, yellowish-green, ovoid-ellipsoid, about 1.2cm long, sub-sessile, involucral bracts hood like at an early stage, caducous, scar conspicuous. Male flowers: scattered among other flowers, pedicellate, perianth lobes, anther ovoid-ellipsoid. Gall flowers: perianth lobes 4; style subterminal. Female flowers: style long; stigma subcapitate.

Flowering & fruiting: Fl. March–April, Fr. June–October.

Global distribution: Bhutan, Indonesia, Myanmar, Nepal, native to tropical Asia, India, and Malaysia and has been introduced in several countries.

Distribution in India: Assam, Meghalaya, Sikkim, Tripura, Karnataka, eastern Himalayas, and also widely cultivated throughout the country.

Distribution in Tripura: Planted at MBB College garden, growth is luxuriant

Uses: Yields the India rubber of commerce. Bark is astringent and used as styptics for wounds. Latex used for parasitic worms. Decoction of aerial rootlets used for wounds, cuts and scores.

Ecology: Planted in garden and luxuriant growth was found to very prominent. The species is not wind-tolerant and tends to break apart in strong winds.

Ficus hederacea Roxb.

Fl. Ind., ed. 1832, 3: 538. 1832. *F. scandens* Roxburgh

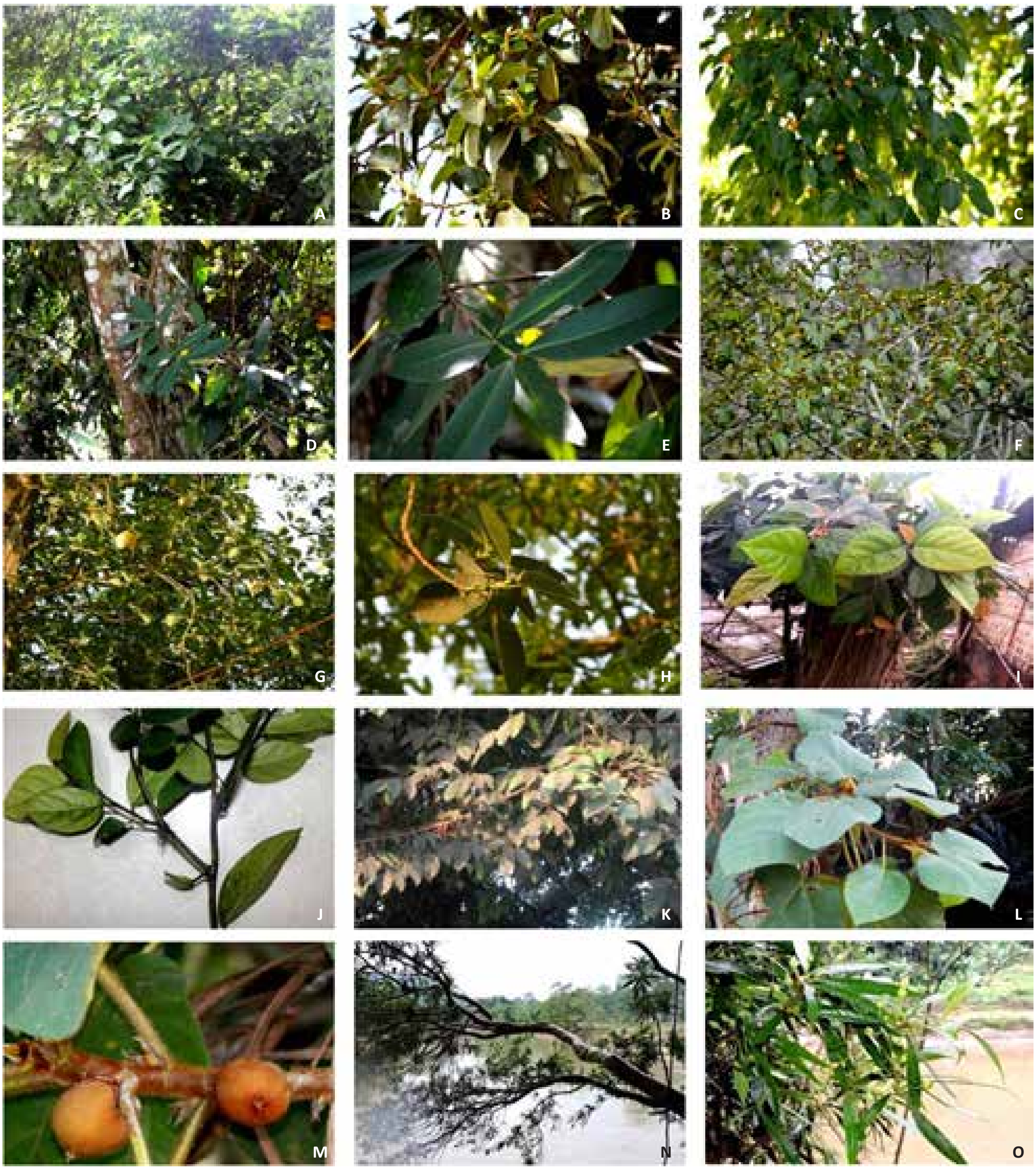

Image 1. A—Habitat of *Ficus auriculata* Lour. (F001) | B—*F. benghalensis* L. (F002) | C—drooping branches of *F. benjamina* L. (F003) | D–E—habitat and twig showing apical bud of *F.curtipes* Corner (F004) | F—*F. drupacea* Thumb. (F005) | G–H—complete tree of *F. elastica* Roxb. ex Homem. (F006) | I–J—habitat and twig with aerial adventitious root on branches of *F. hederacea* Roxb. (F007) | K—complete tree of *F. heteropleura* Blume. (F008) | L–M—habitat and fig bearing twig of *F. hirta* Vahl. (F009) | N–O—habitat of *F. ischnopoda* Miq. (F011).

(1832); Deb, Fl. Tripura State 1:214. 1981; King in Hook. F. Fl. Brit. Ind. 5: 526. 1888; Kanjilal et al. Fl. Assam 4: 260. 1940. (Image 1; F007).

Vernacular name: Climbing Fig, Ivy Fig, Dudhe lahari (Nepali).

Shrubs, scandent. Stems and branchlets with aerial roots at nodes. Stipules caducous, ovate. Leaves 5–7 × 3–4.8 cm, alternate, ovate or elliptic, thickly leathery, entire, acute at apex, rounded at base, scabrid above, pubescent beneath; lateral nerves 5–6 on each side, base 3 nerved, petiole 0.8–1.2 cm long; stipules ovate, acuminate. Figs axillary on leafy or on leafless branchlets, solitary or paired, yellowish green to red when mature, globose, 0.8–1.2 cm across., with thick and short hairs when young, inside without bristles, apical pore navel-like, slightly convex. Male flowers: few, scattered, sessile; perianth lobes 4; lanceolate, style subterminal, stamens 2. Gall flowers: pedicellate; calyx lobes 4, lanceolate; ovary obovate, hard, black; style subapical, short; stigmas curved. Female flowers: flowers on separate figs, perianth 4, style elongate, stigma subcapitate, linear.

Flowering & fruiting: August–March.

Global distribution: Myanmar, India, southern China, Tonkin, Laos, Annam, and northern Thailand

Distribution in India: Northern India, Andaman Islands, Mizoram.

Distribution in Tripura: Uttar Unakuti R.F., Khasiamangal, Teliamura R.F. part.

Ficus heteropleura Blume

Bijdr. Fl. Ned. Ind. 9: 466. 1825 Kanjilal et al. Fl. Assam 4: 239. 1940; Deb, FI. Tripura State 1:214.1981; (Image 1; F008).

Vernacular name: Unknown.

Erect Shrubs or small trees. Leaves 5–10.2 x 3–6.8 cm, elliptic or ovate, undulate, abruptly caudate, attenuated at the base, coriaceous, glabrous; lateral nerves 2–4 on each side, more prominent beneath; stipules minute, subulate. Figs pedunculate, axillary, subglobose, 0.5–8 cm, scabrid, reddish-yellow when ripe; peduncle short, hispid. Male flowers: perianth segments 4, stamen one, joined to a pistilode. Female flowers: perianth 3 fid, style short.

Flowering & fruiting: January–August.

Global distribution: Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Malaysia, Myanmar, Philippines, Thailand, Vietnam.

Distribution in India: Andaman & Nicobar Islands, Arunachal Pradesh, Assam, Bengal, Tripura.

Distribution in Tripura: Purba Kalajhari R.F., Suryamaninagar, Shilachari, Panisagar.

Uses: Unknown.

Ecology: Found in evergreen forest and hilly tract.

Ficus hirta Vahl

Enum. Pl. 2: 201. 1805; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 149, t. 188, 189. 1888 & in Hook. F., Fl. Brit. Lndia 5: 531. 1888; Brandis, Indian Trees 608. 1906; Deb, Fl. Tripura State 1:215. 1981; (Image 1; F009).

Trees or Shrubs, branches hollow; young parts pubescent. Leaves 12–30 x 10–20 cm, suborbicular, ovate or ovate-elliptic, serrate, acuminate, sometimes 3–5 lobed, scabrid above, hirsute or tomentose beneath, lateral nerves 4–7 on each side, base cordate or rounded, 3–7 nerved, petiole 2.4–16 cm long, hirsute, stipules ovate-lanceolate, acuminate. Figs axillary, in pairs, globose, 0.7–2.5 cm across, covered with long rufescent hairs. Male flowers: perianth segments 4; stamens 2. Gall flowers: perianth segments 4; style lateral, stigma funnel shaped. Female flowers: perianth segments 4, linear, lanceolate, style filiform.

Flowering & fruiting: August–September.

Global distribution: Asia: Bhutan, China, India, Indonesia, Myanmar, Nepal, Thailand, Vietnam.

Distribution in India: Arunachal Pradesh, Assam, Meghalaya, Sikkim, Tripura, West Bengal.

Distribution in Tripura: Betlingshib, Deo Reserve Forest part, Manu, Purba Simna.

Uses: Edible (Manandhar 2002).

Ecology: Scattered in moist deciduous mixed forest.

Ficus hispida L. f.

Suppl. Pl. 442. 1782; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 116, t. 154, 155. 1888 & in Hook. F., Fl. Brit. India 5: 522. 1888; Brandis, Indian Trees 606. 1906; Kumar et al., American J. Pl. Sci. 2: 83, f. 4. 2011.Kanjilal et al. Assam 4:253.1940; Deb, FI. Tripura State1:215.1981. (Image 2; F010).

Vernacular name: Domur, Daduri, Khohota dimoru, Hairy Fig, Devil Fig, Khamta (kokborok), Kagsha, Kala umbar, Kharvoti.

Trees small, with fistular branches. Leaves 10–28 × 5.4–10 cm, opposite, obovate, obovate-oblong, elliptic or oblong, acute or acuminate, serrate or dentate, subcoriaceous, scabrid above, hispid, pubescent beneath, lateral nerves 6–10 on each side, petiole hispid, 1.2–5 cm long; stipules ovate-lanceolate, pubescent outside. Figs in pairs or clusters on short tubercles from old wood or on long branches, obovoid or turbinate, narrowed to a short stalk, hispid, greenish yellow and faintly ribbed when ripe, basal bract 3. Male flowers: perianth lobes 3; stamen one. Gall flowers: pedicellate, perianth rudimentary, style short, stigma dilated. Female flowers: perianth rudimentary, style one, hairy.

Flowering & fruiting: April–September.

Global distribution: India, Bhutan, China, Indochina, Malesia, Nepal, Sri Lanka, Australia.

Distribution in India: Andaman Islands, throughout northeastern India.

Distribution in Tripura: Scattered throughout the state.

Uses: Leaves are used as fodder; immature

Image 2: A–B—Habitat of *F. hispida* L.f. (F010) | C–D—a complete tree and fig bearing twig of *F. microcarpa* L.f. (F013) | E–F—Habitat of *F. nervosa*.and fig bearing twig(F014) | G—habitat of *F. pumila* L. (F016) | H—*F. rumphii* Blume (F019) | I—a complete tree of *F. racemosa* L. (F017) | J—*F. religiosa* L. (F018) | K—habitat of *F. lamponga* Miq. (F012) | L—*F. obscura* Blume (F015) (Source: Majumdar et al. 2012a) | M—habitat of *F. sarmentosa* Buch.-Ham.ex (F020) | N—habitat of *F. semicordata* Buch.-Ham.ex (F021) | O—habitat of *F. squamosa* Roxb. (F022) | P—*F. virens* Aiton. (F023).

inflorescence is used as a vegetable. Fruits are prescribed for diabetic patients. Ethno-medicinally, fruits, leaves and sticky latex are used for the treatment of lever ailments, urinary diseases and inflammatory conditions. In diabetes rootexudates is taken even as for curing jaundice, curry prepared from leaf is taken (Borah et al. 2012). Young shoots, leaves and green fruits are eaten as vegetable and even the ripe receptacle is also eaten which is considered as food for liver (Dutta 2012). Fruits are also eaten cooked or pickled, leaves are used for making dishes and twigs are lopped for fodder (Chhetri 2010).

Ecology: Mostly found in deciduous forest.

Ficus ischnopoda Miq.

Ann. Mus. Bot. Lugd.-Bat. 3: 229, 294. 1867; Kurz, Fl. Burma 2: 456. 1877; Kanjilal et al. Assam 4:257.1940; Deb, Fl. Tripura State 1:216.1981. (Image 1; F011).

Trees small, bark gray, with winglike ridges. Branchlet internodes red, short. Leaves clustered apically on branchlets, base cuneate, margin entire, apex acuminate, lateral nerves 6–12 on each side, base 3 nerved, petiole hispid, 1.5–2.2 cm long, reddish-brown; stipules ovate-lanceolate, pubescent outside. Figs pedunculate, axillary, solitary, pyriform, 1–2 cm across, constricted at the base into a strip, reddish-brown when ripe. Male flowers: perianth segments 3; stamen 2. Gall flowers: pedicellate, perianth segments 4, style short, lateral. Female flowers: on separate figs, perianth segments 5, style long, , subterminal, persistent.

Flowering & fruiting: May–August.

Global distribution: India, Bangladesh, Bhutan, China, Indochina, Malesia, Myanmar, Thailand.

Distribution in India: Arunachal Pradesh, Assam, Meghalaya, Tripura, West Bengal.

Distribution in Tripura: Deb Bari, Silachari.

Ecology: River banks, scrub.

Ficus lamponga Miq.

Fl. Ind. Bat. Supple. 431. 1861 & Ann. Mus. Bot. Lugd.-Bat. 3: 294. 1867; Kurz, For. Fl. Brit. Burma 2: 451. 1877; (Image 2; F012).

Vernacular name: Lampung Fig, Dimoru, Dieng-kajapo, Dieng-thalliang, Mumukichok

Tree. Bark brownish-grey, faintly reticulately fissured. Leaves ovate to ovate-elliptic, 10–24 by 4–12 cm long, margin entire, acute or acuminate at apex, membranous, glabrous above, lateral nerves 8–12 on each side, reticulation fine, distinct, petiole 1–2.5 cm long, stipules lanceolate. Figs axillary on leafless and leafy branchlets, solitary or paired, peduncled, ellipsoid, globose or sub-pyriform, reddish orange when ripe about 1 cm across. Male flowers calyx lobes 4, stamens 1, filament adnate. Gall flowers ovary smooth, globose, style lateral, stigma tubular. Female flowers calyx lobes 4–5, style sub-terminal, stigma cylindric.

Flowering & fruiting: October–January.

Global distribution: Bangladesh, Bhutan, India, Indonesia, Myanmar.

Distribution in India: Andaman Islands, Arunachal Pradesh, Cachar in Assam, Manipur, Meghalaya, West Bengal.

Distribution in Tripura: Agartala, Suryamani nagar.

Remarks: This taxon was recorded as new distribution of extensions in Tripura based on specimens collected from the field. The detailed description of the species with photographs and collection number are provided here to authenticate the record.

Ficus microcarpa L. f.

Suppl. Pl. 442. 1782; Kanjilal et al. Fl. Assam 4 : 245. 1940; Deb, FI. Tripura State 1:216.1981. (Image 2; F013).

Vernacular name: Pakar, Laurel Fig, Chinese Banyan, Indian Laurel, Curtain Fig

A large evergreen tree. Leaves 3.7–13 x 2.2–6.1 cm, ovate or rhomboid, bluntly acute or obtuse at the apex, cuneate at the base, entire, coriaceous, glabrous; lateral nerves 8–10 on each side, 3 nerved at the base, stipules lanceolate. Figs 0.5–0.9 cm across, globose, sessile, in axillary pairs, yellowish when ripe. Male flowers numerous; perianth segments 3, stamen one. Gall flowers numerous; perianth segments 3, stamen one. Female flowers: perianth minute, style short, stigma clavate.

Flowering & fruiting: February-March.

Global distribution: India, Australia, Bhutan, China, Indochina, Japan, Malesia, Nepal, Sri Lanka, Taiwan.

Distribution in India: Andaman & Nicobar Islands, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Peninsular region, Punjab, Rajasthan, Sikkim, Karnataka, Tamil Nadu, Kerala, Tripura, Assam.

Distribution in Tripura: Abhicharan bazaar, Krishna Nagar, Agartala, Purba Simna, Jalaya Bazaar, Ichhachhari, Jolaibari.

Uses: Its figs are consumed by several frugivorous vertebrate species, primarily birds, but also bats, rodents, other small mammals, and ants, which act as secondary dispersal agents (Kaufmann et al. 1991; Shanahan et al. 2001).

Ecology: Mostly grown in roadside and designated as sacred tree, however it was also found in moist deciduous mixed forest with very low species density.

Ficus nervosa B. Heyne ex Roth in Nov. Pl. Sp. 388. 1821; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 53, t. 65A. 1887 p. p. & in Hook. F., Fl. Brit. Lndia 5: 512. 1888 p. p.; Brandis, Indian Trees 600. 1906; Lakshminarasimhan & Roy, J. Econ. Taxon. Bot. 20: 373. 1996. (Image 2; F014).

Vernacular name: Mai-hong, Nyaung-peinne

Trees. Branchlets wrinkled when dry. Leaves elliptic, oblong, or obovate-lanceolate, leathery, glabrous, abaxially dark coloured with small scattered tubercles, adaxially dark green but brown when dry and shiny, base rounded to cuneate and with two glands, margin entire, apex obtuse and mucronate; basal lateral veins short, with axillary glands, secondary nerves 7–12 on each side and abaxially prominent, petiole 1–2 cm. Figs axillary on normal leafy stem, paired or solitary, globose, 1–1.2 cm in diameters, tuberculate when young, base attenuate

Image 3: A–B—Clusters of figs and LS of Fig of *F. auriculata* Lour. | C–D–E—figs, LS of figs and magnified view (LS) of fig of *F. benghalensis* L. | F—LS of Fig *F. benjamina* L. | G—Figs of *F. heteropleura* Blume. | H—LS of figs of *F. hirta* Vahl. | I–J—Figs and TS of fig of *F. hispida* L.f. | K—LS of fig of *F. ischnopoda* Miq. | L—Figs of *F. lamponga* Miq.

into an apparent stalk, sessile, pubescent. Male, gall, and female flowers within same fig. Male flowers: near apical pore, pedicellate; calyx lobes 2, spatulate, unequal in size; stamen 1. Gall flowers: pedicellate or sessile; calyx lobes 3, elongated, apex acuminate; style lateral; stigma clavate.

Flowering & fruiting: January–August.

Global distribution: China (Fujian, Guangdong, Guangxi, Guizhou, Sichuan, Yunnan), Taiwan, Bhutan, India, Myanmar (Bago, Kachin, Sagaing, Taninthayi), Sikkim, Sri Lanka, Vietnam, Nicobars, Nepal, Laos, Thailand.

Distribution in India: Andaman & Nicobar Islands, Arunachal Pradesh, Assam, Bihar, Jharkhand, Meghalaya, Peninsular region, Sikkim.

Distribution in Tripura: Mandai, Purba Kathalia and scattered in Dhalai District of Tripura.

Uses: Bark contains Secondary metabolites and they are responsible for therapeutic effects (Devi et al. 2013).

Ecology: Canopy trees in evergreen forests.

Remarks: This taxon was recorded as new distribution of extensions in Tripura, Northeast India; based on specimens collected from the field. The detailed description of the species with photographs and collection number are provided here to authenticate the record.

Ficus obscura Blume.

Bijdr. Fl. Ned. Ind. 9: 474. 1825; King, Ann. i.t. 102, 103. *F. microtus* Miq. Var. *borneensis* Miq., Ann. Mus. Bot. Lugd.-Bat. 3: 273. 1867. *F. pisifera* Wall. Ex Voight, Hort. Suburb. Calc. 285. 1845; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 3, t. 1. 1887 & in Hook. F., Fl. Brit. India 5: 496. 1888. (Image 2; F015).

Small tree, branchlets rough with short stiff hairs and scales; leaves 3.4–25 x 2.7–8.8 cm thinly membranous, very unequal- sided, unequally serrate and rough with raised dots and minute stiff hairs, chiefly along the nerves; stipules 1.2–1.4 cm long. Figs 0.7–1.2 cm across, flower with 1 or 2 bract-like warts on the outer surface, reddish or orange when ripe.

Flowering & fruiting: May–September.

Global distribution: India and Myanmar.

Distribution in India: Northeastern India.

Distribution in Tripura: Betlingshib, Jampui Hills.

Ecology: Evergreen Forest and rare.

Remarks: This taxon was also recorded as new addition to the flora of Tripura by Majumdar et al. (2012a). The detailed description of the species with photographs and collection number are provided here to authenticate the record.

Ficus pumila L.

Sp. Pl. 1060. 1753; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 124, t. 158. 1888; (Image 2; F016).

Vernacular name: Creeping Fig, Climbing Fig.

Shrubs, climbers or scandent. Rooting branchlets sterile. Leaves distichous, leaf blade on fertile branchlets different in shape than ones on sterile branches, ovate-cordate, ovate-elliptic, abaxially pubescent, margin entire, apex obtuse, acute, or acuminate; lateral nerves conspicuous, honeycomblike; basal nerves elongated, secondary nerves 3 or 4, abaxially prominent, and adaxially impressed; stipules lanceolate, with yellow brown silk like hairs. Figs axillary on normal leafy branches, solitary, yellowish green to pale red when mature, pear-shaped to globose or cylindric, shortly yellow pubescent when young, basally attenuate into a short stalk, apical pore truncate, densely covered with long pubescence, persistent. Male flowers: many, in several rows near apical pore, pedicellate; calyx lobes 2 or 3, linear; stamens 2; filaments short. Gall flowers: pedicellate; calyx lobes 4, linear; style lateral, short. Female flowers: pedicel long; calyx lobes 4.

Flowering & fruiting: May–August.

Global distribution: India, China, Japan, Korea, Malesia, Taiwan, Vietnam (Cultivated).

Distribution in India: Cultivated.

Distribution in Tripura: Cultivated.

Uses: Used for the production of jams and jellies. The fruits and the leaves are considered to be galactagogue and tonic. They are used in cases of impotence, lumbago, rheumatism, anaemia, haematuria, chronic dysentery and haemorrhoids. The latex is reported to have anthelmintic properties.

Ecology: Cultivated outdoors, this plant is a popular cover for stone walls or rock outcroppings. Grow as a houseplant or garden annual.

Remarks: This taxon was also recorded as new addition to the flora of Tripura. In Tripura it is known as an ornamental plant and is used widely for covering walls, somewhere introduced, however edible fruits are not consumed by local people. The detailed description of the species with photographs and collection number are provided here to authenticate the record.

Ficus racemosa L.

Sp. Pl. 1060. 1753; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 183. 1888; Deb, Fl.Tripura State 1:217.1981. (Image 2; F017).

Vernacular name: Cluster Fig, Gular Fig, Redwood Fig, Udumbara, Janja dumur.

A large deciduous tree; young parts pubescent, bark greyish brown. Leaves 10–17.5 x 3.8–8 cm, ovate-elliptic, ovate-oblong or oblong-lanceolate, entire, bluntly acuminate, membranous, glabrous, with minute dots on the lower surface; lateral nerves 4–10 on each side; base 3 nerved; petiole 1.4–2.4 cm long; stipules small ovate-lanceolate. Receptacles peduncled, in short panicled fascicles from the trunk and larger branches, sometimes axillary, subglobose or pyriform, 2.5–3.8 cm across, reddish when ripe; basal bracts 3. Male flowers: perianth 3–5 lobed; stamens of gall flowers pedicellate. Female flowers: perianth 4–5 toothed, style subterminal, stigma clavate.

Flowering & fruiting: March–May and again September–November.

Global distribution: India, Australia**,** Bangladesh, China, Indochina, Malesia, Myanmar, Nepal, Pakistan, Sri Lanka.

Distribution in India: Almost throughout from the outer Himalaya to plains and low hills.

Distribution in Tripura: Throughout the state.

Uses: The fruit is edible, the leaves are used as fodder (Chaudhary et al. 1999), and the bark is used for tanning. Latex is aphrodisiac and vulnerary, useful in inflammations, piles, diarrhea and in combination with sesamum oil in cancer. The mature fruits are astringent, stomachic and carminative. They are eaten by local communities. A decoction of the bark is used as a wash for wounds. Fruits are edible when ripe. Ethno-medicinally, boiled fruits are given in diabetes (Buragohain 2011).

Ecology: Moist areas, beside rivers and streams, and scattered throughout the state.

Ficus religiosa L.

Sp. Pl. 2: 1059. 1753; King, Ann. Roy. Bot. Gard. (Calcutta) 1:55. 1888; Hook f., Fl. Brit. India 5:513.1888; Kanjilal et al., Fl.Assam.4:246.1940; Brandis, Indian Trees. 601.1906; Deb, Fl. Tripura State 1:218. 1981. (Image 2; F018).

Vernacular name: Pipal Tree

A large deciduous tree; bark greyish with brownish specks. Leaves 10–18 x 8–12 cm, orbicular-ovate, undulate, caudate, long acuminate, coriaceous, glabrous, tubercled beneath, lateral nerves 6–8 on each side, tertiaries closely reticulate; base 5–7 nerved, shallow cordate, rounded or truncate, petiole 7–10 cm long, slender, stipules minute. Receptacle sessile in axillary pairs, 1.3–1.5 cm across, subglobose, bark purple when ripe; basal bracts 3, pubescent. Male flowers very few, sessile, perianth segments 3, ovate, stamen one, filament short. Gall and female flowers: perianth segments 5, lanceolate, style short.

Flowering & fruiting: Mar–April, and again May–June.

Global distribution: India, Burma, Ceylon, Bangladesh, China, Myanmar, Pakistan and Thailand; introduced and cultivated in southeastern Asia, Middle East, northern Africa (Egypt, Libya), USA and elsewhere.

Distribution in India: Kerala, Assam, Tripura, Odisha.

Distribution in Tripura: Kunjaban, G.B. Bazar, Uttar Unakuti R.F., Kakraban and mostly scattered throught the state.

Uses: This is considered as a highly sacred tree in Hindu & Buddha religions since ancient time and worshiped in different ways at various occasions. The juice of bark is used for the treatment of ulcer, liver, spleen and skin diseases. The wood is moderately hard and durable so used in packing materials; the leaves are used as a fodder and it is planted as an avenue or road side tree.

Ecology: Roadside as sacred tree.

Ficus rumphii Blume

Bijdr. Fl. Ned. Ind. 437. 1825; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 54, t. 67b, 84t. 1887 & in Hook. F., Fl. Brit. India 3: 512. 1888; Watt., Dict. Ec. Prod. Ind. 3: 361. 1890; Brandis, Indian Trees 601. 1906; Deb, Fl. Tripura State 1:218. 1981; (Image 2; F019).

Vernacular name: Pilkhan, Khabar, Gajhar.

A large deciduous tree; bark greyish, smooth. Leaves 7.4–15 x 3.5–7.8 cm ovate or ovate-oblong, entire, shortly acuminate, glabrous, lateral nerves 3–6 on each side, base3-5b nerved, cordate, truncate or narrowed into the petiole; petiole 3.8–7.5 cm long, jointed with the blade; stipules small, ovate-lanceolate, black when ripe, basal bracts 3, orbicular. Male flowers few near the osteole, perianth segments 3, stamen one. Gall and female flowers: perianth segments 3, lanceolate, style elongate, stigma clavate.

Flowering & fruiting: April–July and again December–January

Global distribution: Nepal, Bhutan, China, Myanmar, Indochina, Malaysia, India.

Distribution in India: North-west to north-east & central states, Andaman and Nicobar Island. From sub Himalayan tract and outer hills.

Distribution in Tripura: Bagafa, Bagma, Amarpur, Jirania, Maharani Bazar, Kalajhari Bazar, Gandachhara.

Uses: Used as fodder tree (Manandhar 2002). Foot and mouth disease of cattle is treated by feeding *F. rumphii* (Manandhar 1992, 2002).

Ecology: Mostly grows as an epiphytic while young.

Ficus sarmentosa Buch.-Ham. ex. J.E.Sm.,

Rees. Cyclop. 14: *Ficus* no. 45. 1810; King, Ann. Roy. Bot. Gard. (Calcutta) 1: 184. 1888(Image 2; F020).

Shrubs or woody vines. Branchlets grayish-white when dry, rugose, glabrous, subglabrous, or densely white-hairy. Leaves 7.5–15 × 2.3–4.5 cm, distichous, subglabrous leaf blade ovate, ovate-elliptic, elliptic-lanceolate, both surfaces glabrous, base rounded to broadly cuneate, margin entire, apex acute to acuminate; secondary nerves 4–12 on each side of midvein, tertiary veins honeycomblike, petiole 1.2cm long, hairy; stipules lanceolate-ovate. Figs axillary on leafy or on leafless branchlets, solitary, glabrous, sparsely pubescent, or densely covered with brown hairs, inside with bristles, apical pore slightly concave, sessile. Male flowers: pedicellate; calyx lobes 3 or 4, oblanceolate; stamens 2; filaments very short; anthers mucronate. Gall flowers: pedicellate; calyx lobes 4, obovate-spatulate; ovary elliptic; style short; stigma shallowly funnelform. Female flowers: pedicellate; calyx lobes spatulate; ovary obovate; style subapical; stigma thin and long.

Flowering & fruiting: May–July.

Global distribution: Bangladesh, Pakistan, China, Bhutan, Indochina, Japan, Korea, Myanmar, Nepal, Taiwan.

Distribution in India: Arunachal Pradesh, Assam, Jammu & Kashmir, Himachal Pradesh, Mizoram, Meghalaya, Punjab, Sikkim, Tripura, Uttar Pradesh, West Bengal.

Distribution in Tripura: Gandhari, Dakshin Taidu, Sadhujan Para.

Ecology: This taxon naturally spread their branches along the ground, but readily takes advantage of any shrub or tree in their path over which they can ascend. Evergreen species and traced in several semi evergreen forest patches.

Ficus semicordata Buch.-Ham. ex J.E.Sm.

Rees Cyclop. 14: *Ficus* no. 71. 1810; Corner, Gard. Bull. Singapore 17: 449. 1960 & 21 (1): 62.1965; Deb, Fl. Tripura State 1:219. 1981; (Image 2; F021).

A small tree, young parts hirsute. Leaves 10–25 x 6–18 cm, alternate, oblong or elliptic-lanceolate, serrate or crenate, acute or acuminate, scabrid; nerves 7–14 on either side, base unequal semi-sagittate or subcordate; petiole short, 0.5–1.5 cm long, scabrid; stipules lanceolate. Receptacles in pairs or in clusters on drooping mostly leafless branches, sometimes near the base of the tree or from larger branches, 1-2 cm across, globose or pyriform, hispid, reddish brown when ripe. Male and gall flowers in short peduncled set.

Flowering & fruiting: May–September.

Global distribution: Nepal, Bhutan, China, Bangladesh, Myanmar, Thailand, Vietnam, Pakistan, Malaysia, India.

Distribution in India: Jammu & Kashmir, Uttar Pradesh, Jharkhand, Madhya Pradesh, Sikkim, Assam, Meghalaya, Manipur.

Distribution in Tripura: Atharamura R.F., Subal singh, Hawaibari, Uttar Unakuti R.F., Tlangsang, Shakhan Sermon, Manu Chhailengta R.F., Longtarai R.F., Paschim Daluma, Dakshin Baramura Deotamura R.f., Uttar Debipur, Paschim Kalajari R.F. part.

Uses: The figs are sweet and eaten by locals as fruit. The juice from the roots is given in bladder complaints and visceral obstructions (Kirtikar & Basu 2001). The leaves are use as fodder for cattle.

Ecology: Characteristics species of semi evergreen forests and mostly occurring in hilly tract of Tripura. Furthermore moist mixed deciduous forest at comparatively higher elevation also supports this taxon.

Ficus squamosa Roxb.

Fl. Ind. 3: 531. 1832; Harridasan & Rao, 2:833.1987; Kanjilal *et al*., Fl. Assam 4:252.1940; Deb, Fl. Tripura State 1:220.1981. Joseph, Fl.Nongpoh Vicinity 251.1982; Image 2; F022).

Vernacular name: Dimoru, Jamynrei, Phukhu-jhola.

Shrubs bushy, young shoots rusty hirsute. Leaves 2.5–12 x 0.8–2.8 cm, opposite, crowded at the ends of branches, lanceolate or oblanceolate, acuminate, entire or serrate along the upper half, membranous when young, subcoriaceous when mature, glabrous above, scabrid beneath, strigose along midrib and nerves, lateral nerves 6–8 on each side, base acute, 3 nerved; petiole upto 2.5cm long ; stipules scarious, glabrous. Receptacles pedunculate, solitary, axillary or in cluster on old stem, pyriform, globose, 2–2.5 cm across, hispid, verrucose, ribbed, brown when ripe. Male flowers: perianth segments 3–4; stamen one. Gall flowers: perianth hyaline, style lateral. Female flowers: style hairy, long, slender.

Flowering & fruiting: Almost throughout the year.

Global distribution: India, Nepal, Bhutan, China, Myanmar, Thailand.

Distribution in India: Arunachal Pradesh, Assam, Bihar, Meghalaya, Odisha, Tripura, Uttarakhand, West Bengal.

Distribution in Tripura: Paschim Kalajari R.F. part, Dumbur, Debbari.

Ecology: Key species of riparian habitat and restricted in specific areas of Tripura.

Ficus virens Aiton

Hort. Kew. 3: 451. 1789; Kanjilal et al. Fl. Assam 247.1980; Deb, FI. Tripura State 1:216.1981. (Image 2; F023).

Key to the species

1a. Male, female and gall flowers in the same receptacle, male flowers without rudimentary pistil
1b. Male, female and gall flowers not in the same receptacle, male flowers with a rudimentary pistil, monandrous

2a. Leaves coriaceous, 10–20 × 7–12 cm, ovate, base cordate, 3–7 nerved
2b. Leaves 6–18 × 3–3.8 cm, coriaceous, elliptic or oblanceolate, glabrous; base 3 nerved, cuneate; lateral nerves 10–12 on each side

3a. Receptacle globose, pubescent; lateral nerves 4–7 on each side of the leaf .... ***F. benghalensis***
3b. Receptacle oblong or ovoid, tomentose; lateral nerves 12–20 on each side .... ***F. drupacea***

4a. Bark smooth, leaves coriaceous, secondary nerve less than 12; figs warty, orange or reddish... ***F. curtipes***
4b. Bark brownish-grey, fissured reticulate, inside yellowish-brown, leaves membranous, lateral nerves less than 14 on each side. Figs globose, smooth, red .... ***F. lamponga***

5a. Leaves more or less coriaceous
5b. Leaves membranous on long slender petiole; leaves cordate, acuminate

6a. Lateral nerves closely parallel, inconspicuous, numerous, nearly at right angles to the midrib, anastomosing little except at the margin
6b. Lateral nerves conspicuous, 5–8 on each side of midvein, nervules and reticulations minute but distinct .... ***F. virens***

7a. Stipules large, sub-persistent; receptacles greenish-yellow when ripe .... ***F. elastica***
7b. Stipules small, caduceus; receptacle yellow or red when ripe .... ***F. benjamina***

8a. Leaves leathery, glabrous; basal veins conspicuously raised; base truncate or rounded, 3-5 nerved; figs purplish-red when mature
8b. Leaves leathery, not glabrous; basal veins not raised; cuneate at the base; base 3 nerved; figs yellow to slightly red when mature...***F. microcarpa***

9a. Leaves 7.5–15 × 3.8–7.5, shortly acuminate .... ***F. rumphii***
9b. Leaves 10–18 × 7–12, long acuminate ... . ***F. religiosa***

10a. Male flowers monandrous
10b. Male flowers diandrous

11a. Receptacles mostly axillary
11b. Receptacle mainly in fascicles from stem or branches

12a. Erect shrubs or trees; rooting branched fertile, stipule without hair, 4–8 nerved; receptacles 7.5mm or more across
12b.Climber or scandent shrubs, rooting branchlets sterile, stipule with yellow brown silky hair; 3–4 nerved .... ***F. pumila***

13a. Leaves mostly opposite
13b. Leaves mostly alternate

14a. Leaves narrow, linear, oblanceolate, cuneate at the base .... ***F. squamosa***
14b. Leaves ovate-oblong or elliptic-oblong; base sub-cordate orrounded .... ***F. hispida***

15a. Receptacle globose, glabrous, 1.5–2.5 cm across; leaves granulate beneath
15b. Receptacle hispid and verrucose when ripe, 1–1.8 cm across; leaves unequally subauriculate .... ***F. semicordata***

16a. Receptacle mostly axillary
16b. Receptacles mostly in fascicles from stem or branches

17a. Erect shrubs or trees
17b. Creeping or epiphytic

18a. Young parts sparsely hairy; leaves entire or nearly so; receptacle pedunculate, lengthening out into a stalk, gradually constricted .... ***F. ischnopoda***
18b. Young parts densely tomentose; leaves not entire; receptacle sessile with long rufescent hairs, globose .... ***F. hirta***

19a. Leaves ovate .... ***F. hederacea***
19b. Leaves oblong .... ***F. sarmentosa***

20a. Leaves unequal at the base, margin serrate, style lateral, persistent, fruit orange .... ***F. obscura***
20b.Leaves cuneate base margin entire, style terminal, caudacous, fruit reddish .... ***F. nervosa***

21a. Leaves ovate-elliptic, serrate, subcoriaceous .... ***F. auriculata***
21b. Leaves ovate, ovate-oblong, entire, membranous .... ***F. racemosa***

22a. Stipules long, ovate-lanceolate; leaves unequilateral, lanceolate to elliptic ovate; female sepals 4
22b. Stipules minute; leaves broadly ovate or ovate elliptic; female sepals 3 .... ***F. heteropleura***

Image 4: A—LS of fig of *F. lamponga* Miq. B–C—fig bearing twig and magnified view (LS) of fig of *F. racemosa* L. | D–E–F—Figs, LS of figs and magnified view (LS) of fig of *F. religiosa* L. | G—Figs of *F. rumphii* Blume | H–I–J—fig bearing twigs and TS of fig of *F. semicordata* Buch.-Ham. ex | K—LS of fig of *F. squamosa* Roxb. | L—Figs on twig of *F. virens* Aiton.

Vernacular name: White Fig, Sandpaper Fig, Pilkhan, Ching Heibong

Trees large, with buttress or prop roots, deciduous or semideciduous. Leaves 7.5–20 × 3.6–8 cm, leaf blade ovate to elliptic, oblong ovate or ovate narrowly, base bluntly rounded, cuneate, or cordate, margin entire, apex acuminate to shortly acuminate; lateral nerves 6–9 on each side, base 3 nerved, cuneate, petiole up to 7.8cm long; stipules ovate, pubescent. Figs axillary on leafy branchlets, paired or solitary or in clusters on leafless older branchlets, subglobose, 6–8 cm across, with conspicuous interfloral bristles. Male flowers: few, near apical pore, sessile; perianth segments 4, lanceolate; stamen 1; filament short; anther broadly ovoid. Gall flowers: pedicellate; perianth segments 4; style lateral, shorter than ovary. Female flowers: similar to gall flowers; style longer than ovary.

Flowering & fruiting: April–August.

Global distribution: Bhutan, Bangladesh, Pakistan, China, Cambodia, India, Indonesia, Japan, Laos, Malaysia, Myanmar, New Guinea, Philippines, Sikkim, Sri Lanka, Thailand, Vietnam; northern Australia.

Distribution in India: India (Throughout up to 1,700m, also frequently planted), Uttar Pradesh, Punjab.

Distribution in Tripura: Paschim Daluma, Amarpur Rangtang Bari, Ramthakur College, Agartala.

Uses: Foliage buds are eaten as vegetable and pickle.

Ecology: Roadside.

DISCUSSIONS

Most recently, 115 taxa of *Ficus* have been recorded from India out of which 89 are species and remaining 26 taxa fall under different infra-specific categories (six subspecies and 20 varieties), with maximum diversity in the north-east (61 spp.) and peninsular regions and Andman & Nicobar Islands with ca. 35 species each (Chaudhary et al. 2012). Kanjilal et al. (1940) reported 42 species of Ficus from undivided Assam in "Flora of Assam". In Meghalaya alone about 43 species of Ficus are found and considered as the hotspot region for the genus in India (Chaudhary et al. 2012).

In the present study, 23 taxa of *Ficus* have been reported from the study area including four new distribution records (Table 1). The increase in the number of species has been observed in the present study when compared to the earlier report of 23 taxa including one variety in the "Flora of Tripura State" from the same geographical extent (Deb 1981), which was based on survey of literature, author's own collection and consultation of herbaria, however, while working on the morpho-taxonomy of figs in Tripura, we could collect only 19 species out of 23 species reported by Deb (1981).

Out of 23 species of Ficus recorded in the present study, seven species belong to evergreen small tree to shrub (*F. benghalensis*, *F. drupacea*, *F. elastica, F. microcarpa, F. racemosa, F. sarmentosa* and *F. semicordata*); three (3) species recorded are large deciduous tree (*F. racemosa*, *F. religiosa* and *F. rumphii*). Among all species *F. hispida* and *F. racemosa* show a wide range of distribution in all the eight districts of the study area and variations in its habit which range from small shrub to medium-sized tree, however, *F. hispida* has been found more commonly especially in lowland and moist areas in mixed deciduous forest. The most common is the *F. hispida* which is present throughout except inside the deep forest. Apart from forest areas, *F. benghalensis* and *F. religiosa* are commonly visible on walls, temples and old buildings. *F. benjamina*, *F. religiosa, F. curtipes, F. virens* are epiphytic when young and free standing later. The *Ficus* species recorded occurs in mixed deciduous forest, moist deciduous forest, tropical semi-evergreen forest, and secondary forest.

Species distribution and conservation status

The information on geographic extensions of *Ficus* species is important from taxonomical and phytogeographical point of view and will also contribute towards the conservation of those restricted species. Although, it is difficult to quantify the total number of additional species that still exist in different forests of Tripura without comprehensive reassessments of the flora. Furthermore, present effort has been focussed on geographical distribution of collected species (Fig.2) with their regional distribution. Tripura possesses special significance in the biogeography of the North-eastern region due to its unique location and habitat heterogeneity. This region is part of Indo-Burma hotspot which is one of the 35 biodiversity hotspots in the world (Myers et al. 2000). The undulating topography, high rainfall and varied altitudes are main factors that have contributed to its rich hilly ecosystem and habitat diversity (Majumdar et al. 2012b). Many *Ficus* species are fast declining in the wild due to habitat changes, forest fragmentation, road construction and clearance of virgin forests for shifting cultivation, plantation and due to other developmental activities. Out of the present checklist, *F. drupacea* was assigned as Least Concern (ver. 3.1) in the IUCN Red List of Threatened Species (https://www.iucnredlist.org). Besides *Ficus*

Table 1. Checklist of *Ficus* species along with their current status on availability, distribution ranking and collection number/field number deposited at Tripura University Herbarium (TUH) with their voucher specimens at Central National Herbarium (CAL).

Sp. Id	Name of species	Species abbreviation	Species Code	Habit	Status	Distribution Range Score	Collection number (TUH)	Voucher specimens (CAL)
1.	*Ficus auriculata* Lour.	*Fau*	F001	Small evergreen tree	Less Frequent	5	Banik & Datta, TUH-2301	Deb 27103.
2.	*Ficus benghalensis* L.	Fbe	F002	Evergreen tree	Very Frequent	4	Banik & Datta, TUH-2000	–
3.	*Ficus benjamina* L.	Fben	F003	Large tree, with drooping branches.	Frequent	4	Banik & Datta, TUH-2302	Deb 1174.
4.	*Ficus curtipes* Corner	Fcu	F004	Large tree (epiphytic when young)	Rare	4	Banik & Datta, TUH-2074	Biswas 5047; Deb 1207; Deb 2336; Deb 2786
5.	*Ficus drupacea* Thunb.	Fdr	F005	Evergreen tree (sometimes epiphytic)	Less Frequent	5	Banik & Datta, TUH-2306	Biswas 5077.
6.	*Ficus elastica* Roxb. ex Hornem.	Fel	F006	Large evergreen tree (sometimes epiphytic when young)	NA (Cultivated)	3	Banik & Datta, TUH-2311	Deb Burman 832.
7.	*Ficus hederacea* Roxb.	Fhe	F007	Shrub scandent, often rooting at the nodes, sometimes climbing.	Rare	4	Banik & Datta, TUH-2317	Deb 2339; Deb 2582.
8.	*Ficus heteropleura* Blume	Fhet	F008	Shrub or small trees.	Less frequent	4	Banik & Datta, TUH, 1995	Deb 2062.
9.	*Ficus hirta* Vahl	Fhir	F009	Tree/Shrub	Less Frequent	3	Banik & Datta, TUH-2318	Deb 2671; Deb 27302.
10.	*Ficus hispida* L.f.	Fhis	F010	Small tree with fistular branches.	Very Frequent	5	Banik & Datta, TUH-1999	Deb Burman 23,835 ; Deb 1968; Deb 2271.
11.	*Ficus ischnopoda* Miq.	Fis	F011	Small tree, young parts pubescent.	Frequent (restricted to riparian habitat)	4	Banik & Datta, TUH-1994	Deb 2059.
12.	*Ficus lamponga*	Fla	F012		Less Frequent	4	Debbarma & Datta, TUH2325	–
13.	*Ficus microcarpa* L.f.	Fmi	F013	Large evergreen tree	Less Frequent	3	Banik & Datta, TUH-2001	Deb 2095.
14.	*Ficus nervosa*	Fne	F014	Small tree	Less Frequent	4	Banik & Datta, TUH-2094	–
15.	*Ficus obscura* Blume	Fob	F015	Shrubby or subarboreous	Rare	2	Banik & Datta, TUH-1996	–
16.	*Ficus pumila*	Fpu	F016	Evergreen, climber.	NA (Cultivated)	3	Banik & Datta, TUH-2095	–
17.	*Ficus racemosa* L.	Fra	F017	Large deciduous tree	Very Frequent	6	Debbarma & Datta, TUH-1992	Deb 2447.
18.	*Ficus religiosa* L.	Fre	F018	Large deciduous tree	Very Frequent	5	Banik & Datta, TUH-1993	–
19.	*Ficus rumphii* Blume	Fru	F019	Large deciduous tree	Very Frequent	4	Banik & Datta, TUH-2326	Deb Burman 424.
20.	*Ficus sarmentosa* Buch.-Ham. ex Sm.	Fsa	F020	Evergreen shrub	Very Frequent	5	Debbarma & Datta TUH 1997	Deb Burman 1152.
21.	*Ficus semicordata* Buch.-Ham. ex Sm.	Fse	F021	Small tree	Frequent	5	Banik & Datta, TUH-2327	Deb 1317; Deb 26895; Deb 27433
22.	*Ficus squamosa* Roxb.	Fsq	F022	Shrub	Rare (restricted in riparian habitat)	3	Banik & Datta, TUH-2334	Deb 1259; Deb 2009.
23.	*Ficus virens* Aiton	Fvi	F023	Large tree	Frequent	5	Banik & Datta, TUH -1998	Deb Burman 869.

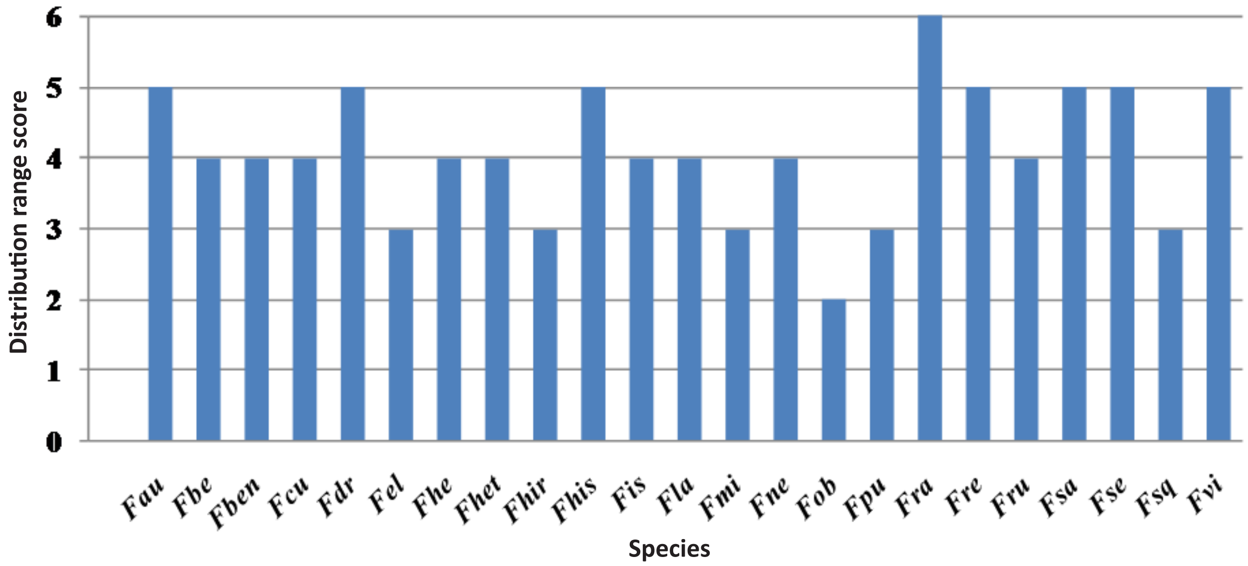

Figure 2. Geographical distribution of selected *Ficus* species based on distribution range score.

drupacea, very recently few more species have been assigned as "Least Concern" and these are *F. auriculata*, *F. benjamina*, *F. hispida*, *F. ischnopoda*, *F. microcarpa*, *F. racemosa*, *F. semicordata*, and *F. virens*.

Distribution of species in different habitats reveals that forests ecosystems are the main habitat of recorded species broadly distributed in moist deciduous forest, riparian cover and semi-evergreen forest. In the recent exploration of *Ficus* species in Tripura, we did not find any occurrence of four species which may be due to the current rate of deforestation and habitat loss some of these species may have altered distribution and may no longer exist in a particular area (Krupnick & Kress 2003). The uneven distribution of these species and the absence of these species in many parts of the state can be attributed to various factors.

Review on potential ecological role by Ficus

Ficus is the most important plant genus for tropical frugivores. Ficus forms a uniquely important group within the subset of plants with bird-eaten fruit because of their numerical abundance, intra-crown synchrony of fruit ripening, relatively short intervals between fruiting, large crop sizes and intrapopulation fruiting asynchrony. These characteristics combined with their availability at times when other fruits are scarce, makes *Ficus* a most important keystone plant resource (Lambert & Marshall 1991). Worldwide, a large number of animals are known to feed on the syconia, including pigeons, parrots, hornbills, toucans, bats, monkeys, and squirrels (Shanahan et al. 2001). According to Shanahan et al. (2001) 1,274 bird and mammal species in 523 genera and 92 families are known to eat figs. Figs are known to be eaten by 54 species but feature especially heavily in the diet of Asian hornbills. Brockelman (1982) noted that hornbills were the only birds capable of eating *Ficus drupacea* figs whole. *Ficus virens* ranks as one of the top 10 Ficus species that attract the most number of frugivorous species (Shanahan et al. 2001) and further can lead to improve frugivore biodiversity (Lee et al. 2013). Figs are among the most important food of specialized frugivores in Africa, southeastern Asia and Australia (Snow 1981). Khan & Ahsan (2015) reported that *Ficus benghalensis* was the top most preferred food plant. This plant species supported the diet of 13 (44.8%) species of birds. The birds have been shown to make long-duration feeding visits to fruiting trees and defecate fig seeds intact (Compton et al. 1996). The pigeon family (Columbidae) has a worldwide distribution and, after the parrots, has more fig-eaters than any other frugivore family which comprises 125 species in 25 genera (Shanahan et al. 2001). Invertebrates, including ants, dung beetles, snails and hermit crabs are known to consume fig fruits or seeds, thereby having impacts on *Ficus* seed dispersal. About 750 species of *Ficus* and the pollinating wasps resulted significant ecological interactions to complete their life cycle (Wiebes 1979; Grison-Pige et al. 2002; Harrison 2003; Castro et al. 2015). The figs (syconia) are pollinated entirely by specific wasps from the family Agaonidae (Chalcidoidea), which in turn reproduce by laying eggs in the fig's flowers, where the larvae feed and expand

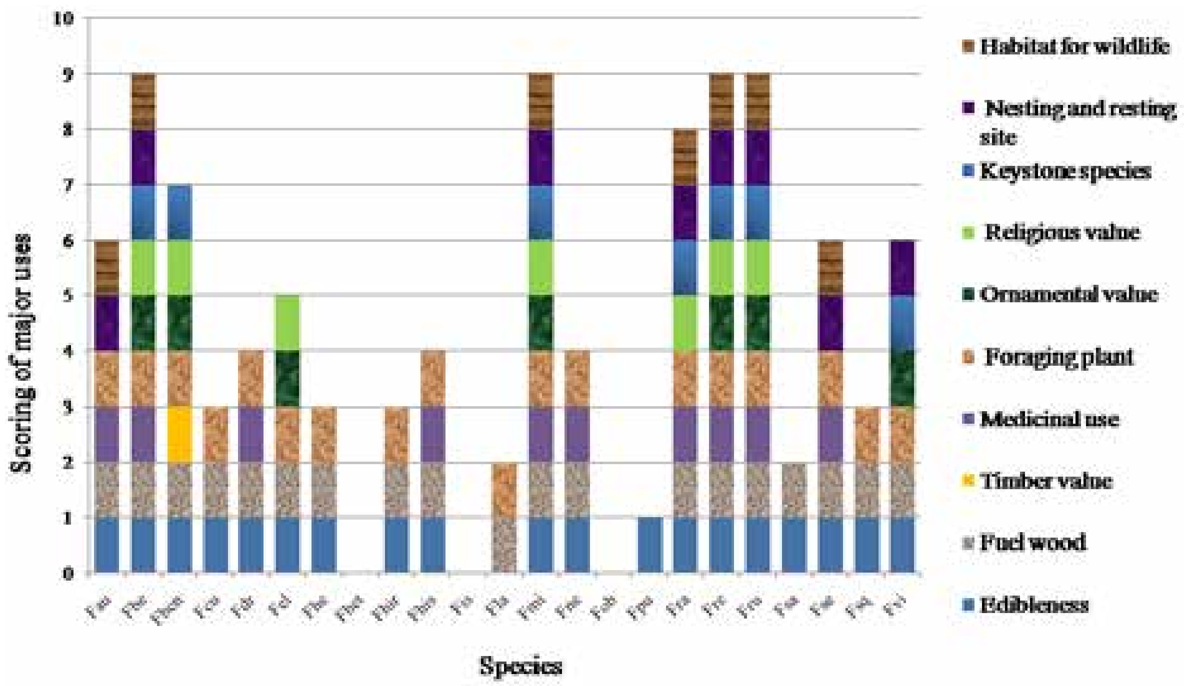

Figure 3. Scoring of major uses and ecosystem services of selected *Ficus* species.

their life cycle (Cook & Segar 2010). Such mutualism is exploited by a number of other parasitic non-pollinating wasps (Wiebes & Compton 1990) and by numerous species of ants, Homoptera, Coleoptera, Lepidoptera and Diptera (Bain et al. 2012).

Major uses of *Ficus* species found in Tripura were scored based on their earlier report and species were prioritized for their ecosystem services and medicinal uses (Fig. 3). Several species of Ficus, viz., *F. microcarpa, F. religiosa,* F.*auriculata*, *F. benjamina, F. racemosa*, *F. bengalensis* have been used in daily diet for nutrition as well as for medicinal usage and medicinal plants in the treatment of different diseases (Khan et al. 2011). Several species are indigenously used as food, fodder, fuel wood, vegetable, medicine, etc. They provide good fodder and various ecological services. They provide nectar, refuge habitat for several bird species and a wide variety of insects, and host orchids and mistletoes (Kunwar & Bussman 2006). *F. benghalensis, F. benjamina, and F. religiosa* have been reported as common host plants for orchids (Subedi & Paudyal 2001). *Ficus* is also important species in tropical forest restoration (Cottee-Jones et al. 2016). Higher species richness in Moraceae was recorded for all community types due to local availability of *Artocarpus chama, A. lacucha* and several other *Ficus* spp; their local adaptability and strong dispersal capability facilitated by several frugivorous birds and animals (Majumdar et al. 2012b). Due to high FIV (Family Important Value) of Moraceae particularly in secondary Teak forest may shift the secondary Teak population by native species richness of Moraceae. In such cases, species of Moraceae may contribute maximum for both IVI (Importance Value Index), FIV and ultimately to be the top predominant family over the existing species of other families especially in case of Teak dominated community. Such competitions among the families may alter the present forest dynamics and simultaneously may increase with changing of disturbance intensity; which partially may be boosted by several seed dispersal agents during secondary forest formations (Majumdar et al. 2012b). Because, species belonging to Moraceae have the advantages of attractive colored figs, sweet taste, high seed production and stock, small achene, universally eaten by frugivore and high germination ability even on unsuitable habitat viz., tree hole, dead wood, stone and barren land. Especially Capped Langur *Trachypithecus pileatus*, (Red List status - Vulnerable A2cd+3cd ver 3.1) (Das et al. 2008) was observed feeding on tender leaves of *Aartocarpus chama*, *A. lacucha*, *Bombax ceiba*, *Garuga pinnata, Ficus glumerata*, and *Albizia lucida* during field study in *Shorea* dominated community. *Ficus* trees scored low in terms of economic value, and the main reason for them remaining in the landscape was because of religious attributes endowed upon them. Trees that had shrines were significantly larger than those that did not. *Ficus* have been described as keystone species (Bleher et al. 2003; Eshiamwata et al. 2006) and provide connectivity for both tree and animal populations over a landscape scale (Manning et al. 2006). Further, figs often survive in human-dominated landscapes because of their cultural significance. *F. benghalensis*, *F. religiosa* have considerable religious associations in Hinduism and Buddhism and are also used as sites of worship (Barua 2009) and these cultural factors contribute to the safeguarding mature trees. They may be considered sacred groves at very local scales, and are working examples of how cultural practices might influence the existence of biodiversity outside protected areas.

With agricultural intensification, however, the number of mature *Ficus* trees declined and people cut down trees when they interfered with their daily activities. Extensive conversion of forests for cash crop plantation in this region has resulted in the emergence of landscape tracts that are a heterogeneous mixture of agriculture, human-settlement and forest fragments. Increased structural complexity and habitat for animals at local scales, and connectivity for both tree and animal populations over a landscape scale may result in ecosystem stability. It has been suggested that the establishment of Ficus is a critical phase in the reassembly of forests. Thus, they are an important resource for maintaining biodiversity outside protected areas, and their loss may result in undesirable ecological regime shifts. This account of Ficus diversity and distribution in the forest ecosystem may provide knowledge to the researchers about wildlife occurrence and their resource utilization in these subtropical regions.

CONCLUSION

The present study highlighted the taxonomy and diversity of the genus *Ficus* L. in Tripura, northeastern India, based on extensive field survey and exploration. The increase in the number of species has been observed in the present study when compared to the earlier report of 23 taxa including one variety in the "Flora of Tripura State" from the same geographical extent. As the genus is rich in diversity, this region possesses tremendous scope of exploitation of its members, as many species belonging to this genus have carried good properties beneficial to mankind as well as sustaining wildlife. Their importance for sustaining wildlife and the stability of interactions with several biological groups is an issue of considerable concern for conservation. Figs are tropical keystone resource and paramount to sustain wildlife and the stability of interactions with several biological groups is an issue of considerable concern for conservation.

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SHORT COMMUNICATION

Open garbage dumps near protected areas in Uttarakhand: an emerging threat to Asian Elephants in the Shivalik Elephant Reserve

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Abstract: Waste dumping sites near protected areas are a growing issue, which may affect the activities and behaviour of wildlife, more than what we notice. Here, we present two of our case studies, where Asian Elephants were found feeding at garbage dumps in Haridwar and Ramnagar forest divisions in the Shivalik Elephant Reserve in Uttarakhand State. Since garbage dumps may spread bacterial infection and induce adverse changes in the health conditions of the elephant population, we draw the attention of planners to develop a plan of action for proper disposal of the garbage through these preliminary observations, without affecting protected areas and wildlife species, including elephants. Moreover, collection of data on the presence of garbage dumps across the reserve and a study on the behavioural responses of scavenging and non-scavenging animals visiting the dumps would give us a better understanding of the level of impact of garbage dumps for disposal planning. It is to emphasize that garbage does not constitute a part of natural food for elephants. There are restrictions and guidelines in the Indian Wildlife (Protection) Act 1972, Solid Waste Management Rules, 2016 and Guidelines for Declaration of Eco-Sensitive Zones around National Parks and Wildlife Sanctuaries.

Keywords: Elephants, garbage dumps, protected areas, Shivalik Elephant Reserve.

Protected areas play a key role in maintaining biodiversity and services provided by natural systems (Kolahi et al. 2013). Dumped garbage that is nondegradable or contain harmful chemicals, may cause negative impact on the regeneration of vegetation, ground water reservoirs, and adversely affect the life and behaviour of wildlife anywhere, including protected areas.

Protected areas defined under the Wildlife (Protection) Act, 1972 and its amendments, are carefully delineated habitats for wildlife conservation. Of late, waste dumping sites near protected areas have become a serious issue, which may be affecting the activities and behaviour of wildlife, more than what we readily notice. The food waste generated by humans is often accessible to wildlife, which not only affects wildlife ecology and behaviour but also affects the ecological processes and community dynamics (Newsome & van Eeden 2017). One of the most significant threats in the protected areas in Asia is inappropriate waste management, which is related with the practice of land filling or combustion of waste and low environmental awareness (Przydatek 2019). The congregation of animals at rubbish dumps near human settlements may increase negative human-animal interactions like animal attacks on people, livestock depredation, and the risk of aircraft collision with scavenging birds (Plaza & Lambertucci 2017).

In the last few years, there have been reports of wild animals straying to the outskirts of protected habitats, near the garbage dumps. Such garbage around the protected forests is usually dumped unknowingly by tourists or thrown on the road side by the people living adjacent to the forests. Garbage dumps normally

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comprise of both the residual organic and inorganic waste from the cities. Contrary to all this, it is also true that these temporary garbage dumps attract wild animals and among several adverse possibilities, it may pose threat for premature death as well. It is now widely acknowledged that the attraction of wildlife to the dumping sites is also changing the behavior of individuals, particularly in making them opportunistic feeders. Wild animals feeding on the garbage in the outskirts of forests may have drastic impacts on their behaviour; it may affect their activity pattern and even made them the carriers of pathogenic infections.

A recent study carried out on the foraging behavior of some vertebrates near garbage dumps and the risk of plastic consumption indicated that the garbage dumps are resulting in a shift in food habits of some wild animals (Katlam et al. 2018).

In this note, we report on two case studies in which elephants were feeding on the garbage dumps lying across Haridwar and Ramnagar forest divisions in the state of Uttarakhand, India (Image 1). These divisions are among the crucial habitats for elephants, as these habitats are endowed with the natural water reservoirs and food plant species of elephants. Both the study areas fall under the Shivalik Elephant Reserve in northern India and are adjacent to Rajaji and Corbett national parks.

Study sites and observation of cases

In the year 2002, one of the northwestern elephant range was designated as the 11th elephant reserve in the country, naming it as the Shivalik Elephant Reserve (henceforth Reserve), covering an area of 5,405km^2. The reserve mainly consisted of three protected areas in the state of Uttarakhand, namely, the Jim Corbett National Park, Rajaji National Park, and Sonanadi Wildlife Sanctuary, apart from some other reserve forests. As per the recent estimates carried out by the state government in the year 2015, it was revealed that the state harbours nearly 1,800 elephants (Uttarakhand Forest Department 2015). The estimation also reveals that the Reserve has been maintaining a viable population of elephants for the last two decades, and it averaged at 1,572 ±319 (range 1,346–1,797). In the Shivalik Elephant Reserve, the male-female ratio of elephants in Rajaji and Corbett national parks was recorded as 1:1.8 and 1:1.5–2.1, respectively (Williams 2002), however, another study

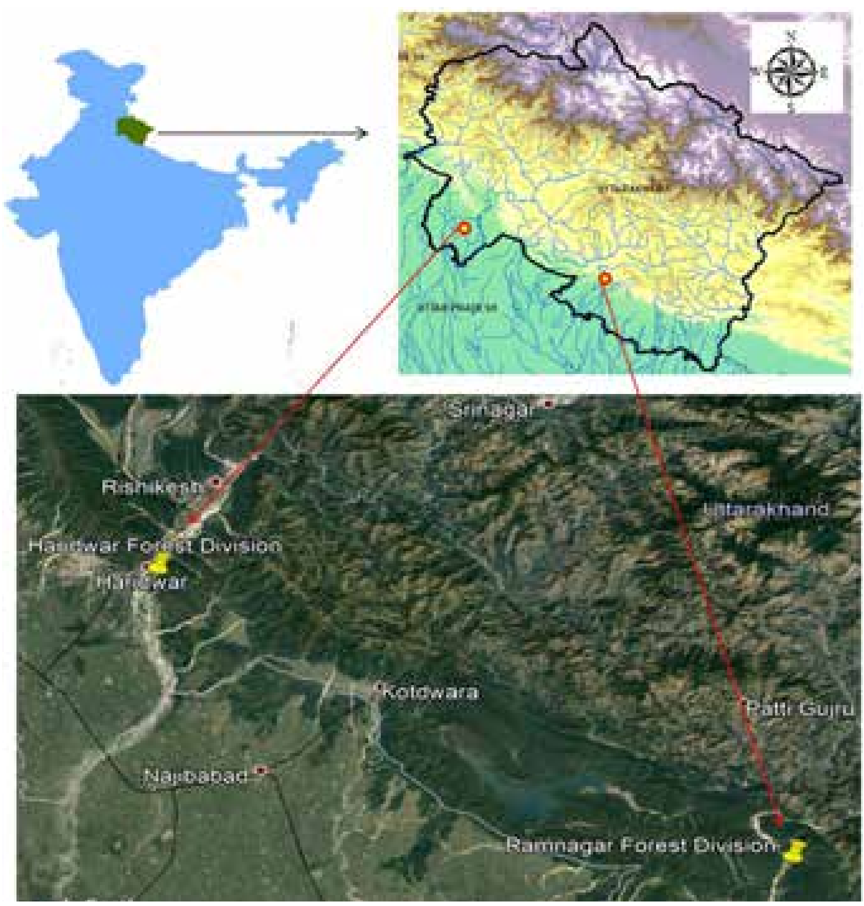

Image 1. Location of the study area in India, with the sites pinned from where the elephants were recorded feeding on the garbage (map prepared using Google Earth).

carried out in Rajaji National Park indicated that the male-female ratio of the elephants is 1:4.4 (Joshi et al. 2007). All these figures, if taken into account, reveal that the Reserve consists of a healthy population of elephants.

Unfortunately, the Reserve is suffering from the consequences of negative man-elephant interactions. Rapidly increasing demand for land for habitation, agriculture, industries, and unsustainable land-use practices have overarching negative impacts on the large migratory corridors of the elephants. Incidences of straying of elephants in crop fields and habitations, human encroachments into forest areas, and killing of humans by the elephants are increasing. Linear infrastructure developments in the form of roads, railway lines, power lines, and canals add to the problems in some of the habitats across the Reserve.

Image 2. An adult male Asian Elephant feeding from the waste near Shyampur forest of Haridwar Forest Division in the year 2007 (now is a part of Rajaji Tiger Reserve).

Case Study-1: Shyampur Forest in Haridwar Forest Division

The first observation of concern was made during the year 2007 from Shyampur Forest Range of the Haridwar Forest Division, now a part of the Rajaji Tiger Reserve, wherein a bull elephant was found feeding on a garbage dump lying along the east Ganga canal (29.92^{0}N, 78.17^{0}E; Image 2). This garbage belonged to the city of Haridwar and was being thrown at the site for about two decades (from the year 1995 to 2015) in about 0.32km^2 of the land. The garbage consisted of both biodegradable and non-biodegradable solid wastes, including the waste generated at Har-ki-Pauri from the tourist aggregation, hospitals, and industries. The dumping site was being used mainly for land filling. Since the garbage contained leftover food and the remains of flowers and leaves, the elephants were found attracted towards the dump. This garbage not only affects the environment but also exposes the wild animals to an unpredictable threat.

An inspection done by the state forest department during the year 2015 at Shyampur forest indicated that at a few places, the biodegradable and non-biodegradable waste, originating from Haridwar City, was not being disposed-off properly (Anonymous 2015). Between the years 1995 and 2015, more than 100,000 ton of garbage has been dumped in this site every year, including 300 tons of garbage every day from the Haridwar Municipal Corporation (Sharma 2015). Fortunately, in the year 2015–2016, the Corporation started dumping of the city's garbage in a piece of government land near Sarai Village in Haridwar. Since the year 2016, any kind of garbage is not being thrown at the east Ganga canal site. Elephants use this track to visit the river Ganga crossing the Haridwar-Bijnor National Highway. This forest is also a connecting chain for elephant movement in between Rajaji and Corbett tiger reserves.

Case Study-2: Kosi Forest in Ramnagar Forest Division

The second observation was made during the year 2017 in the Kosi Forest Range of the Ramnagar Forest Division, wherein some pieces of plastic bags were found in the dung piles of an elephant (29.45^{0}N, 79.15^{0}E; Image 3). This division is adjacent to Corbett Tiger Reserve and is a potential tourism zone. Though any permanent garbage dumping site was not found in and adjoining areas of the division, it was assumed that the elephants probably ate plastic bag either from the garbage being thrown by the pilgrims in Sitabani Temple or from the Chhoi Village near Ramnagar City. The Sitabani Temple is situated in Kota Forest Range, and is well connected to the Kosi Forest Range (7–8 km from the spot from where the observation was made). Every year thousands of tourists and local villagers visit the temple and notably the waste from anthropogenic activities and the remains of the offerings along with the plastic bags are scattered in the surroundings. In order to minimize the use of plastic bags, the forest department started distributing jute carrybags to the tourists in the year 2017.

Similarly, Chhoi Village is located about five kilometers from Ramnagar City, wherein garbage was observed being thrown by the local people along the Ramnagar-Haldwani motor road. This area is a connecting corridor for elephant movement across Ramnagar and Terai West forest divisions. The presence of Kosi River further

Image 3. The remains of plastic bag recorded from the dung-piles of elephant in Kosi forest of the Ramnagar Forest Division.

facilitates the frequent movement of elephants across the area. The garbage accumulated at both the sites (in Sitabani Temple and Chhoi Village) was found temporary. On examining the garbage, it was found that the garbage mainly consisted of leftover food, vegetable residues, wrappers of chips, etc.

Discussion

Impacts of garbage-feeding on elephant

Improper management of waste can lead to substantial and irreversible environmental, economic, and social impacts (Dunjic et al. 2017). Though there are only a few reports of elephants feeding on garbage, observations made from the Haridwar and Ramanagar forest divisions indicates that the garbage dumping sites near elephant habitat may pose a threat to them. On several occasions, species like Spotted Deer, Barking Deer, Sambar Deer, Wild Boars, and Rhesus Macaques have also been observed feeding on garbage lying across protected areas. Even several birds like house crow, babblers, doves, little egrets, and black kites were also recorded hovering and feeding on garbage dumps.

Selective feeders with specialized feeding apparatus (mouth or hand parts) such as primates or insectivorous birds may be less susceptible to plastic ingestion and phthalate accumulation (Hardesty et al. 2015) compared to elephants, ruminants or carnivores, which are incapable of selectively retrieving food contained in plastic (Katlam et al. 2018). Plaza & Lambertucci (2017) pointed out that the species that take advantage of feeding in the garbage dumps consisting of organic waste can produce negative impacts on other species, which do not use to feed on the dumping sites. They also indicated that the probability of pathogen infections, poisoning, foreign body ingestion may be high and such feeding may also change the pattern of movement, migration, home ranges size, and behaviours of the individuals. This change in the movement patterns can have different ecological consequences as well, like changes in pathogen distribution, which the species carry (Mc Kay & Hoye 2016).

Such reports were also received from Mudhumalai Tiger Reserve, southern India, wherein elephants were found feeding in the dump yards, which were in the middle of an elephant corridor (Ganesan 2016). Even male elephants were found breaking the electric fence to enter garbage dump areas in Silver Clouds in the Gudalur area in the Nilgiris (Oppili 2016). Open garbage dumps have also been recorded as a prevalent problem in Sri Lanka. A detailed study carried out by Fernando & Pastorini (2006) on the elephants in and around Wasgamuwa National Park of Sri Lanka revealed that elephants use garbage dumps to feed on edible items on a regular basis; even plastic bags were recorded in the dung piles of elephants during the study in the year 2005. The death of an elephant was also recorded in Sri Lanka in March 2017, which was found regularly eating garbage at Manampitiya (Rodrigo 2017). In this context, the study and comments by Katlam et al. (2018) is of significance about the risks resulting from garbage dumps and the shift in food habits of some wild animals.

Legal provisions and recommendations

In the year 2011, the Ministry of Environment and Forests prepared draft guidelines for ecotourism in and around protected areas (MoEF 2011) in which the emphasis was on banning of burning or disposing non-biodegradable waste within the protected area or in surrounding eco-sensitive zone or buffer area. Since garbage dumps may spread bacterial infection and induce behavioural changes in elephants, it is recommended that a plan of action is needed to be prepared for proper dumping and disposing-off of garbage, especially across protected areas.

Rajaji and Corbett national parks lie in the Shivalik Elephant Reserve in northern India, wherein a large number of tourists arrive to observe wildlife in their natural habitats. Considering that the number of tourists is increasing every year, improper waste disposal practices across the protected habitats may affect wildlife significantly. In order to minimize the impact of garbage on elephants, formulation of an action plan for solid waste management (with adoption of at-source segregation approach) for the Shivalik Elephant Reserve needs to be developed. Besides, tourists and local people need to be sensitized about the harmful impacts of garbage dumps, especially plastic bags, using nature education, and awareness tools.

Garbage dump and landfill sites should be shifted away from the out skirts of protected habitats and wildlife corridors; this approach will be helpful in minimizing the exposure of wildlife to harmful wastes. Likewise, by collecting data on existence of garbage dumps across the protected habitats of elephants and initiating a study to better understand the level of impact of garbage dumps on the behaviour of elephants, we would be able to know whether these dumps are changing the behaviour and activities of elephants or not.

To achieve the objectives contained in the Indian Wildlife (Protection) Act 1972, Solid Waste Management Rules, 2016 and Guidelines for Declaration of Eco-Sensitive Zones around National Parks and Wildlife Sanctuaries, there is a need to sensitize people about effective ways of waste management and about the functional role of species in maintaining the ecosystem and biodiversity. Moreover, ensuring local community and stakeholder participation in conservation initiatives and habitat monitoring would be an effective management and conservation strategy.

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SHORT COMMUNICATION

A preliminary checklist of spiders (Araneae: Arachnida) in Jambughoda Wildlife Sanctuary, Panchmahal District, Gujarat, India

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Abstract: Studies relating to spiders in Gujarat have been sporadic and most of the spider documentation have been done from agriculture fields, wetlands and few from protected areas. One such undocumented area was Jambughoda Wildlife Sanctuary, Panchmahal District, Gujarat. Therefore, a study to document the spider diversity was carried out in Jambughoda Wildlife Sanctuary from July 2012 to October 2015. A combination of four sampling methods namely, belt transect along with hand-pick method, pitfall sampling, vegetation beating and leaf litter extraction were used for collection of spiders from different strata. During the study, a total of 138 species belonging to 90 genera and 29 families were recorded from the study area. Of which, 21 species and 17 genera were recorded for the first time from Gujarat State. The theridiid genus *Cephalobares* O. Pickard-Cambridge, 1870 was recorded for the first time from India. The families Araneidae, Salticidae, Theridiidae and Oxyopidae were found to be dominant in the area. We recognized seven feeding guilds namely ambushers, foliage runners, ground runners, orb weavers, sheet web-builders, space web-builders and stalkers. Amongst these, orb-weavers, stalkers and ground runners were dominant. This documentation, however, forms the baseline information for spiders of Jambughoda WLS, suggesting the great diversity of the spider fauna in this protected area, which can be further explored.

Keywords: Araneidae, orb-weavers, Oxyopidae, Panchmahal District, Salticidae, stalkers, Theridiidae, Vadodara District.

Spiders, in general, being chiefly entomophagous play an important ecological role in the terrestrial ecosystem (Marc et al. 1999; Skerl & Gillespie 1999). Due to their ability of aerial ballooning they can readily disperse into different habitats and being generalist predators they are abundant in all terrestrial habitats (Coddington & Levi 1991). They also play a significant role in controlling the insect populations in the agricultural fields (Riechert & Bishop 1990). They also play an important role in the food chain by being abundant food source for birds, lizards, wasps, and other animals. Over 48,643 valid species of spiders belonging to more than 4,173 genera and 128 families have been reported throughout the world (World Spider Catalog 2019). Out of which, over 1,700 species belonging to more than 450 genera and 61 different families have been reported from India (World Spider Catalog 2019).

Though in the past, spider documentation from Gujarat have been sporadic but is relatively better recorded as compared to other states in the country. Major contribution to the spider fauna of the Gujarat

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was done by Patel and team by describing 47 species from 18 families (Patel 1971, 1973, 1988, 1989, 2003; Patel & Patel 1972, 1975; Patel & Reddy 1990; Parasharya & Vyas 2013). Apart from these reports, several other sporadic checklists from agricultural fields (Kumar & Shivakumar 2006; Trivedi 2009) and habitats in Gujarat contributed to addition of new species and new distribution records (Siliwal & Kumar 2001; Kumar & Shivakumar 2006; Trivedi 2009; Parasharya et al. 2011; Vachhani et al. 2012; Parmar & Patel 2015; Vasava et al. 2015; Prajapati et al. 2016a,b,c). So far, over 400 species of spiders have been reported from Gujarat (Kumar 2015; Yadav et al. 2017).

In Gujarat State, most of the spider documentation has been done from nonprotected areas like agriculture fields, wetlands etc. and very few from protected areas. A total of 27 regions are deemed as protected areas in Gujarat from which, only 10 areas areas have a documentation of spiders, viz., Barda WS (62 species) (Singh et al. 2000a), Hingolgadh Nature Education Sanctuary (56 species) (Singh et al. 2000b; Patel & Vyas 2001), Jessore WS (157 species) (Pandey et al. 2004a), Narayan Sarovar WS (24 species) (Singh et al. 2001), Purna WS (116 species) (Siliwal et al. 2003; Pandey et al. 2004b), Rampara WS (21 species) (Singh & Tatu 1999), Ratanmahal Sloth Bear Sanctuary (42 species) (Patel et al. 2012), Shoolpaneshwar WS (147 species) (Pandey & Raval 2010), Vansda NP (124 species) (Singh et al. 2000c, Patel 2003), and Wild Ass WS (27 species) (Singh et al. 1999).

The Jambughoda Wildlife Sanctuary (WS) is one such unstudied protected area in central Gujarat located between Panchmahal and Vadodara districts known for its relatively rich biodiversity including flagship species like Sloth Bear and Leopard. Studies in the past in Jambughoda WS from this protected area were restricted to flora and higher vertebrates like mammals, birds, reptiles and fishes (Padate et al. 2003; Vyas 2006; Devkar et al. 2013). Moreover, invertebrate documentation from this area was restricted only to lepidopteran and few insect species (Padate et al. 2003). Therefore, in the present study, we initiated documentation of spider diversity from Jambughoda WS.

Materials and Methods

The study was conducted in the Jambughoda WS, which is located between 22.333–22.550 ^{0}N and 73.583–75.750 ^{0}E in Panchmahal and Vadodara districts of Gujarat State, India (Figure 1). The sanctuary area extends over 130.38km^2 and is covered by three forest ranges, viz., Halol, Jambughoda, and Vadodara. Altitudes ranges from 230 to 354 m. Jambughoda WS

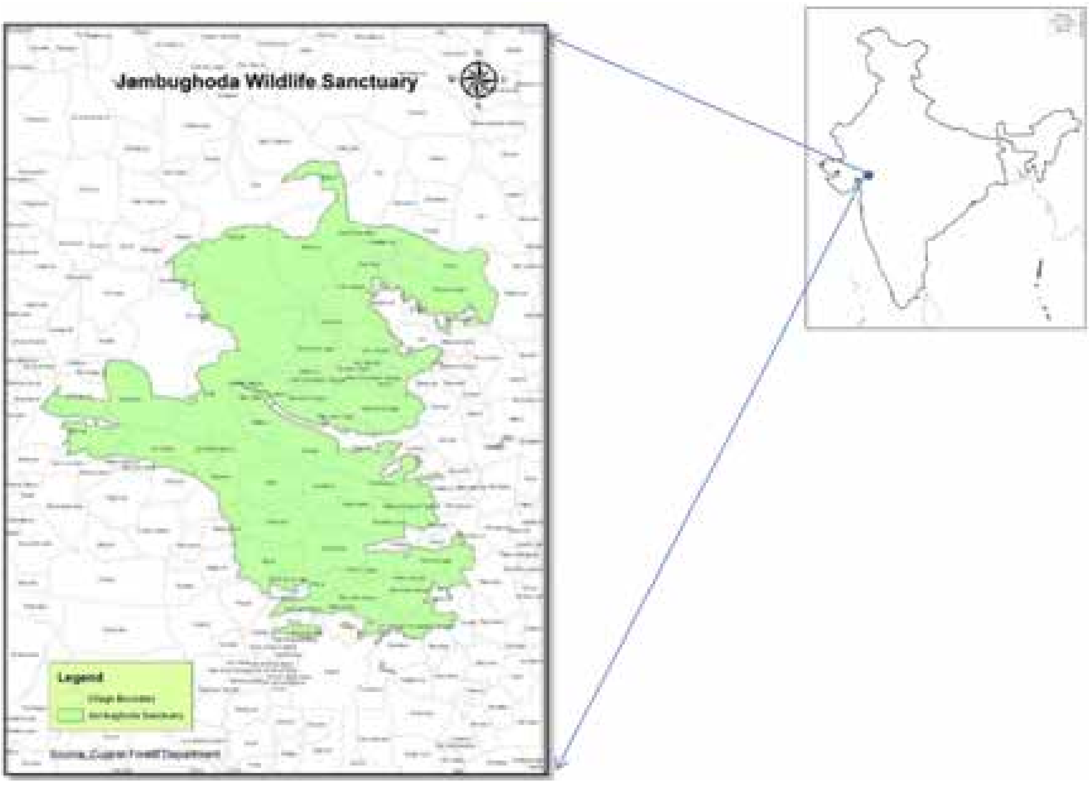

Figure 1. Jambughoda Wildlife Sanctuary, Panchmahal District, Gujarat, India.

consists of southern tropical dry deciduous type forest, further classified into four sub-types, i.e., 5A/ C 1b dry teak forest, 5A/C 2 southern dry mixed deciduous forest, 5/E 9 dry bamboo brakes, and 3B/C 2 southern moist mixed deciduous forest (Champion & Seth 1968). The sanctuary has both natural forest and plantations. The mean annual temperature in the sanctuary is 25.5˚C, with a maximum of 45˚C and a minimum of 7˚C and the area receives an average annual rainfall, which ranges 800–1,200 mm (Pandya & Oza 1998).

To explore the spider diversity of Jambughoda WS, the sampling was carried out from July 2012 till October 2015. A combination of four sampling methods namely, belt transect (Kapoor 2006) was applied for overall diversity count; pitfall sampling (Curtis 1980; Green 1999) was done for ground-dwelling spiders; vegetation beating was done for spiders inhabiting in vegetation; leaf litter extraction (Crossley & Hoglund 1962; Kapoor 2006) was used for spider taxa associated with moisture and sheltered areas. All the collected specimens were preserved in 70–80% ethanol (ethyl alcohol) and stored separately in clear tarsons polypropylene (PP) sampling containers (50ml). Each specimen was labeled which that included the date of collection, locality of collection and the name of collector. Further, these preserved specimens were identified under a using stereomicroscope (WILD™). Spiders were identified up to the species level using the standard monographs (Levi & Levi 1962; Tikader 1977, 1980, 1982, 1987; Tikader & Biswas 1981; Tikader & Malhotra 1980; Pocock 1900; Majumder & Tikader 1991; Gajbe 2008; Javed & Tampal 2010; Vankhede et. al. 2013; Keswani & Vankehede 2014). Whereas, immature spiders were classified up to the genus or family level. For species level identification epigyne was dissected and cleaned in concentrated lactic acid for 15–20 minutes. All specimens are deposited in the museum of Department of Zoology, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, and curated by DK; later on these specimens will be deposited in a national repository.

Results and Discussion

The present study resulted in the record of 138 spider species belonging to 90 genera and 29 families from Jambughoda WS along with their natural history notes (Table 3; Image 1–138). Of these 29 families, the most dominant family was Araneidae (26 species) followed by Salticidae (17 species), Theridiidae (11 species), and Oxyopidae (10 species), however, families with high generic diversity were Araneidae and Salticidae (14 genera each), followed by Theridiidae (11 genera), and Gnaphosidae (six genera). Whereas, 15 families, viz., Clubionidae, Corinnidae, Ctenidae, Eresidae, Cheiracanthiidae, Liocranidae, Oecobiidae, Palpimanidae, Philodromidae, Prodidomidae, Scytodidae, Sicariidae, Stenochilidae, Titanoecidae, and Zodariidae were represented by a single genus.

Table 1. List of genera recorded for the first time from Gujarat, India.

	Families	List of genera
1	Araneidae	*Gea* C.L. Koch, 1843
2	Araneidae	*Lipocrea* Thorell, 1878
3	Araneidae	*Singa* C.L. Koch, 1836
4	Gnaphosidae	*Megamyrmaekion* Reuss, 1834
5	Hersiliidae	*Murricia* Simon, 1882
6	Oonopidae	*Brignolia* Dumitrescu & Georgescu, 1983
7	Oxyopidae	*Hamadruas* Deeleman-Reinhold, 2009
8	Pisauridae	*Hygropoda* Thorell, 1894
9	Pisauridae	*Nilus* O. Pickard-Cambridge, 1876
10	Prodidomidae	*Prodidomus* Hentz, 1847
11	Salticidae	*Portia* Karsch, 1878
12	Salticidae	*Stenaelurillus* Simon, 1886
13	Theridiidae	*Cephalobares* O. Pickard-Cambridge, 1870*
14	Theridiidae	*Euryopis* Menge, 1868
15	Theridiidae	*Meotipa* Simon, 1894
16	Theridiidae	*Yaginumena* Yoshida, 2002
17	Uloboridae	*Zosis* Walckenaer, 1841

*This genus is recorded for the first time from India.

Out of the 90 genera identified from the Jambughoda WS, 17 genera were recorded for the first time from Gujarat State (Table 1). The genus *Cephalobares* O. Pickard-Cambridge, 1870 belonging to family Theridiidae is documented for the first time from India during the present study. This genus was previously reported only from two countries, i.e., China and Sri Lanka, and comprise of only two species, namely, *Cephalobares globiceps* O. Pickard-Cambridge, 1870 reported from both the countries and *Cephalobares yangdingi* Gao & Li, 2010 reported only from type locality in China (World Spider Catalog 2017).

Amongst the recorded 138 species of spiders, 21 spider species were recorded for the first time from Gujarat (Table 2) wherein *Poltys* cf. *columnaris* of the family Araneidae and *Zosis* cf. *geniculata* of the family Uloboridae were juveniles; because of their peculiar external characteristics of abdominal shape and pattern they were identified easily till species level.

Out of the eight feeding guilds described by Uetz et al. (1999), we found seven feeding guilds based on

Table 2. List of species recorded for the first time from Gujarat, India.

	Families	List of species
1	Araneidae	*Gea subarmata* Thorell, 1890
2	Araneidae	*Lipocrea fusiformis* (Thorell, 1877)
3	Araneidae	*Poltys bhabanii* (Tikader, 1970)
4	Araneidae	*Poltys* cf. *columnaris* Thorell, 1890
5	Araneidae	*Poltys nagpurensis* Tikader, 1982
6	Clubionidae	*Clubiona foliata* Keswani & Vankhede, 2014
7	Ctenidae	*Ctenus narashinhai* Patel & Reddy, 1988
8	Gnaphosidae	*Scopoides kuljitae* (Tikader, 1982)
9	Gnaphosidae	*Zelotes mandae* Tikader & Gajbe, 1979
10	Hersiliidae	*Murricia hyderabadensis* Javed & Tampal, 2010
11	Oxyopidae	*Hamadruas sikkimensis* (Tikader, 1970)
12	Oxyopidae	*Peucetia yogeshi* Gajbe, 1999
13	Pisauridae	*Hygropoda* cf. *mahendriensis* Vankhede, Keswani & Rajoria, 2013
14	Pisauridae	*Nilus phipsoni* (F. O. Pickard-Cambridge, 1898)
15	Sicariidae	*Loxosceles rufescens* (Dufour, 1820)
16	Tetragnathidae	*Tetragnatha extensa* (Linnaeus, 1758)
17	Tetragnathidae	*Tylorida ventralis* (Thorell, 1877)
18	Theridiidae	*Coleosoma blandum* O. Pickard-Cambridge, 1882
19	Theridiidae	*Meotipa picturata* Simon, 1895
20	Theridiidae	*Yaginumena maculosa* (Yoshida & Ono, 2000)
21	Uloboridae	*Zosis* cf. *geniculata* (Olivier, 1789)

foraging behaviour of spiders from Jambughoda WS namely, ambushers, foliage runners, ground runners, orb weavers, sheet web-builders, space web-builders, and stalkers. From all these seven functional groups the dominant guild was of orb weavers (39 species) followed by stalkers (27 species), ground runners (25 species), foliage runners (19 species), space web-builders (14 species), ambushers (11 species), and sheet web builders (3 species) (Figure 2). The dominance of orb weavers could be due to mixed vegetation found in the forest, which provides enough space to build their webs of different sizes and also provide protection from their predators (Siliwal et al. 2003; Patel et al. 2012).

In addition to this, during the present study we also came across six spiders which are probably new to science (*Singa* sp., *Brignolia* sp., *Prodidomus* sp., *Epocilla* sp., *Euryopis* sp., & *Storena* sp.) and will be published separately after comparative taxonomic work.

Conclusion

A preliminary checklist of spiders from Jambughoda WS, Panchmahal District, Gujarat is provided in this paper which is the first ever documentation of the spiders of Jambughoda from this sanctuary. Data presented here may aid future initiatives to build a biodiversity database of spider fauna in this region. The presence of 138 species of spiders in a dry deciduous forest like Jambughoda WS indicates that, to sustain such rich biodiversity the habitat has to be ecologically balanced and this southern tropical dry deciduous forest is one of them as it has capability to sustain such diverse number of flora and fauna including spiders. And, therefore, it was possible to get interesting first records of genus and species from this area. This documentation, however, is by no means inclusive but forms the baseline information for spiders of Jambughoda WS suggesting the great diversity of the spider fauna in this protected area.

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Table 3. List of spider species documented from Jambughoda Wildlife Sanctuary, Panchmahal District, Gujarat, India.

	Family	Scientific name	No. of specimens collected & sex	Voucher no. 12,13,14,15	Natural history notes	Image no.
1.	Araneidae	*Araneus mitificus* (Simon, 1886)	3F, 1M	ZOL-13-ARA-61 ZOL-13-ARA-62 ZOL-13-ARA-63 ZOL-14-ARA-125	Found resting in the retreat of folded leaf which was attached to the one end of its orb web	Image 1
2.	Araneidae	*Argiope aemula* (Walckenaer, 1841)	2F, 1M	ZOL-12-ARA-1 ZOL-12-ARA-2 ZOL-12-ARA-3	Observed resting in upside down position at the center (Hub) of its orb web	Image 2
3.	Araneidae	*Argiope anasuja* Thorell, 1887	2F, 1M	ZOL-12-ARA-4 ZOL-12-ARA-5 ZOL-12-ARA-6	Observed feeding on moths, grasshoppers entangled in its web	Image 3
4.	Araneidae	*Chorizopes* sp.	1F	ZOL-14-ARA-126	Collected from underside of leave resting in its mesh web	Image 4
5.	Araneidae	*Cyclosa confraga* (Thorell, 1892)	1F	ZOL-14-ARA-127	Collected from its web, decorated with a longitudinal line of debris passing through the hub were the spider camouflages itself	Image 5
6.	Araneidae	*Cyclosa hexatuberculata* Tikader, 1982	1F	ZOL-13-ARA-64	Collected from its web, decorated with a longitudinal line of debris passing through the hub were the spider camouflages it self	Image 6
7.	Araneidae	*Cyclosa moonduensis* Tikader, 1963	1F, 1M	ZOL-12-ARA-7 ZOL-12-ARA-8	Observed hanging by a single strand of silk over the lower vegetation	Image 7
8.	Araneidae	*Cyclosa spirifera* Simon, 1889	1F	ZOL-13-ARA-65	Collected from its web, decorated with a longitudinal line of debris passing through the hub were the spider camouflages it self	Image 8
9.	Araneidae	*Cyrtophora cicatrosa* (Stoliczka, 1869)	2F	ZOL-12-ARA-9 ZOL-12-ARA-10	Observed resting in upside down position at the center of its tent shape web	Image 9
10.	Araneidae	*Cyrtophora citricola* (Forsskål, 1775)	2F, 1M	ZOL-13-ARA-66 ZOL-13-ARA-67 ZOL-14-ARA-128	Observed resting in upside down position at the center of the tent shape web	Image 10
11.	Araneidae	*Eriovixia excelsa* (Simon, 1889)	2F, 1M	ZOL-12-ARA-11 ZOL-12-ARA-12 ZOL-14-ARA-129	Nocturnal spider, during day time hides in their retreat (rolled leaf) attached at one end of its web	Image 11
12.	Araneidae	*Eriovixia laglaizei* (Simon, 1877)	1F	ZOL-14-ARA-130	Nocturnal spider, collected from its orb web	Image 12
13.	Araneidae	*Eriovixia poonaensis* (Tikader & Bal, 1981)	1F	ZOL-15-ARA-174	Nocturnal spider, found resting during day time in its retreat (rolled leaf)	Image 13
14.	Araneidae	*Gasteracantha kuhli* C.L. Koch, 1837	1F	ZOL-15-ARA-175	Collected from its orb web	Image 14
15.	Araneidae	*Gea subarmata* Thorell, 1890	1F	ZOL-15-ARA-176	Small orb web with uniformly circular radii constructed between blades of grass. Spider was found resting in the centre of the web. New record from Gujarat	Image 15
16.	Araneidae	*Larinia chloris* (Audouin, 1826)	1F	ZOL-12-ARA-13	Observed resting in upside down position at the center (Hub) of the orb web	Image 16
17.	Araneidae	*Lipocrea fusiformis* (Thorell, 1877)	1F	ZOL-12-ARA-14	Observed resting in upside down position at the center (Hub) of the orb web	Image 17
18.	Araneidae	*Neoscona mukerjei* Tikader, 1980	3F, 2M	ZOL-12-ARA-15 ZOL-12-ARA-16 ZOL-12-ARA-17 ZOL-13-ARA-68 ZOL-13-ARA-69	Observed resting in upside down position at the center (Hub) of its orb web	Image 18
19.	Araneidae	*Neoscona nautica* (L. Koch, 1875)	1F	ZOL-14-ARA-131	Observed resting in upside down position at the center (Hub) of its orb web	Image 19

	Family	Scientific name	No. of specimens collected & sex	Voucher no. 12,13,14,15	Natural history notes	Image no.
20.	Araneidae	*Neoscona theisi* (Walckenaer, 1841)	3F, 1M	ZOL-13-ARA-70 ZOL-13-ARA-71 ZOL-14-ARA-132 ZOL-14-ARA-133	Observed resting in upside down position at the center (Hub) of its orb web	Image 20
21.	Araneidae	*Neoscona vigilans* (Blackwall, 1865)	1F	ZOL-13-ARA-72	Observed resting in upside down position at the center (Hub) of its orb web	Image 21
22.	Araneidae	*Poltys bhabanii* (Tikader, 1970)	1F	ZOL-14-ARA-134	Nocturnal spider, observed resting in upside down position at the center (Hub) of its orb web	Image 22
23.	Araneidae	*Poltys* cf. *columnaris* Thorell, 1890	1J	ZOL-15-ARA-177	Nocturnal spiders, looks like dry broken twig of plant. At night they were found resting in the centre of their large orb web	Image 23
24.	Araneidae	*Poltys nagpurensis* Tikader, 1982	1F	ZOL-15-ARA-178	Nocturnal spider, collected from its orb web constructed between two lower branches of *Tectona grandis*	Image 24
25.	Araneidae	*Singa* sp.	2F, 1M	ZOL-15-ARA-179	Observed hanging with a single strand of silk attached on one side to a leave and other side to a shrub branch	Image 25
26.	Araneidae	*Thelacantha brevispina* (Doleschall, 1857)	1F	ZOL-15-ARA-180	Observed resting in upside down position at the center (Hub) of its orb web	Image 26
27.	Clubionidae	*Clubiona drassodes* O. Pickard-Cambridge, 1874	1F	ZOL-12-ARA-18	Found resting on the underside of leaf	Image 27
28.	Clubionidae	*Clubiona filicata* O. Pickard-Cambridge, 1874	1F	ZOL-13-ARA-73	Found resting on the underside of leaf	Image 28
29.	Clubionidae	*Clubiona foliata* Keswani & Vankhede, 2014	1F	ZOL-13-ARA-74	Observed wandering on the foliage	Image 29
30.	Clubionidae	*Clubiona pashabhaii* Patel & Patel, 1973	1F	ZOL-12-ARA-19	Found resting on the underside of leaf	Image 30
31.	Corinnidae	*Castianeira zetes* Simon, 1897	1F	ZOL-14-ARA-135	Found running in the leaf litter	Image 31
32.	Ctenidae	*Ctenus narashinhai* Patel & Reddy, 1988	1F	ZOL-13-ARA-75	Found running in the leaf litter	Image 32
33.	Eresidae	*Stegodyphus pacificus* Pocock, 1900	1F	ZOL-15-ARA-181	Colonial spider, collected from its web which was having many entrances	Image 33
34.	Eresidae	*Stegodyphus sarasinorum* Karsch, 1892	2F, 1M	ZOL-13-ARA-76 ZOL-13-ARA-77 ZOL-14-ARA-136	Colonial spider, collected from its web which was having many entrances	Image 34
35.	Cheiracanthiidae	*Cheiracanthium inornatum* O. Pickard-Cambridge, 1874	1F, 1M	ZOL-13-ARA-78 ZOL-13-ARA-79	Collected resting on the grass blade	Image 35
36.	Eutichuridae	*Cheiracanthium melanostomum* (Thorell, 1895)	1F	ZOL-14-ARA-137	Collected while it was resting on the underside of leaf	Image 36
37.	Eutichuridae	*Cheiracanthium triviale* (Thorell, 1895)	1F	ZOL-14-ARA-138	Collected while it was resting on the underside of leaf	Image 37
38.	Eutichuridae	*Cheiracanthium* sp.	1F	ZOL-15-ARA-182	Collected while it was resting on the underside of leaf	Image 38
39.	Gnaphosidae	*Drassodes* sp.	1J	ZOL-15-ARA-183	Found under the bark of palm tree	Image 39
40.	Gnaphosidae	*Haplodrassus* sp.	1J	ZOL-15-ARA-184	Collected by pitfall method	Image 40
41.	Gnaphosidae	*Megamyrmaekion ashae* Tikader & Gajbe, 1977	1F	ZOL-15-ARA-185	Collected by pitfall method	Image 41
42.	Gnaphosidae	*Scopoides kuljitae* (Tikader, 1982)	1F	ZOL-15-ARA-186	Collected by applying litter sampling	Image 42
43.	Gnaphosidae	*Scopoides* sp.	1J	ZOL-15-ARA-187	Collected by applying litter sampling	Image 43
44.	Gnaphosidae	*Trachyzelotes jaxartensis* (Kroneberg, 1875)	1F	ZOL-15-ARA-188	Collected by pitfall method	Image 44
45.	Gnaphosidae	*Zelotes mandae* Tikader & Gajbe, 1979	1F	ZOL-14-ARA-139	Collected by pitfall method	Image 45

	Family	Scientific name	No. of specimens collected & sex	Voucher no. 12,13,14,15	Natural history notes	Image no.
46.	Hersiliidae	*Hersilia savignyi* Lucas, 1836	3F, 2M	ZOL-12-ARA-20 ZOL-12-ARA-21 ZOL-13-ARA-80 ZOL-12-ARA-22 ZOL-13-ARA-81	Found camouflaged on the bark of trees. Observed feeding on *Camponotus compressus*	Image 46
47.	Hersiliidae	*Murricia hyderabadensis* Javed & Tampal, 2010	1F	ZOL-15-ARA-189	Found camouflaged on the bark of trees	Image 47
48.	Liocranidae	*Oedignatha* sp.	1M	ZOL-14-ARA-140	Collected by applying litter sampling	Image 48
49.	Lycosidae	*Evippa* sp.	1F	ZOL-12-ARA-23	Collected by pitfall method	Image 49
50.	Lycosidae	*Hippasa lycosina* Pocock, 1900	1F	ZOL-12-ARA-24	Collected by pitfall method	Image 50
51.	Lycosidae	*Lycosa poonaensis* Tikader & Malhotra, 1980	1F	ZOL-12-ARA-25	Collected by pitfall method	Image 51
52.	Lycosidae	*Lycosa* sp.	1F	ZOL-12-ARA-26	Collected by pitfall method	Image 52
53.	Lycosidae	*Pardosa birmanica* Simon, 1884	1F	ZOL-12-ARA-27	Collected by pitfall method	Image 53
54.	Lycosidae	*Pardosa sumatrana* (Thorell, 1890)	1F, 1M	ZOL-13-ARA-82	Collected by pitfall method	Image 54
55.	Oecobiidae	*Oecobius putus* O. Pickard-Cambridge, 1876	2F, 1M	ZOL-12-ARA-28 ZOL-12-ARA-29 ZOL-12-ARA-30	Collected from its web, constructed at the corner of huts in the village	Image 55
56.	Oonopidae	*Brignolia* sp.	1F	ZOL-14-ARA-141	Collected by pitfall method	Image 56
57.	Oonopidae	Unidentified species 1	1F	ZOL-14-ARA-142	Collected by pitfall method	Image 57
58.	Oxyopidae	*Hamadruas sikkimensis* (Tikader, 1970)	1F	ZOL-15-ARA-190	Collected from the underside of leaf	Image 58
59.	Oxyopidae	*Oxyopes ashae* Gajbe, 1999	1F	ZOL-14-ARA-143	Found resting on grass blades	Image 59
60.	Oxyopidae	*Oxyopes bharatae* Gajbe, 1999	1F	ZOL-14-ARA-144	Collected from the underside of leaf	Image 60
61.	Oxyopidae	*Oxyopes birmanicus* Thorell, 1887	2F	ZOL-12-ARA-31	Found resting on grass blades	Image 61
62.	Oxyopidae	*Oxyopes pankaji* Gajbe & Gajbe, 2000	1F	ZOL-14-ARA-145	Collected from the underside of leaf	Image 62
63.	Oxyopidae	*Oxyopes* sp.	1F	ZOL-12-ARA-32	Collected from the underside of leaf	Image 63
64.	Oxyopidae	*Peucetia akwadaensis* Patel, 1978	1M	ZOL-14-ARA-146	Collected from the underside of leaf	Image 64
65.	Oxyopidae	*Peucetia viridana* (Stoliczka, 1869)	1F	ZOL-14-ARA-147	Collected from the underside of leaf	Image 65
66.	Oxyopidae	*Peucetia yogeshi* Gajbe, 1999	1F, 1M	ZOL-14-ARA-148	Collected from the underside of leaf	Image 66
67.	Oxyopidae	*Peucetia* sp.	1F	ZOL-12-ARA-33	Collected from the underside of leaf	Image 67
68.	Palpimanidae	Unidentified species 2	1F	ZOL-13-ARA-83	Collected by pitfall method	Image 68
69.	Philodromidae	*Tibellus elongatus* Tikader, 1960	1F	ZOL-15-ARA-	Collected from the branch of tree where it was fully camouflaged	Image 69
70.	Pholcidae	*Crossopriza lyoni* (Blackwall, 1867)	2F, 2M	ZOL-12-ARA-34	Collected from tangled web constructed between the lower vegetation in the forest	Image 70
71.	Pholcidae	*Pholcus fragillimus* Strand, 1907	2F, 2M	ZOL-12-ARA-35 ZOL-13-ARA-84 ZOL-12-ARA-36 ZOL-13-ARA-85	Collected from its tangled untidy web constructed between the lower vegetation in the forest	Image 71
72.	Pholcidae	*Pholcus phalangioides* (Fuesslin, 1775)	2F	ZOL-13-ARA-86 ZOL-13-ARA-87	Collected from its tangled web constructed between the lower vegetation in the forest	Image 72

	Family	Scientific name	No. of specimens collected & sex	Voucher no. 12,13,14,15	Natural history notes	Image no.
73.	Pisauridae	*Hygropoda* cf. *mahendriensis* Vankhede, Keswani & Rajoria, 2013	3F, 2M	WILD-14-ARA-1277, WILD-14-ARA-1278, WILD-14-ARA-1279, WILD-14-ARA-1276, WILD-14-ARA-1293	Found near the streams of water, resting at periphery of stream and waiting for its prey (Hunting position)	Image 73
74.	Pisauridae	*Nilus phipsoni* (F.O. Pickard-Cambridge, 1898)	2F, 1M	ZOL-14-ARA-149 ZOL-14-ARA-150 ZOL-14-ARA-151	Found near the streams of water, resting on stones at the periphery of streams	Image 74
75.	Pisauridae	*Perenethis venusta* L. Koch, 1878	1M	ZOL-15-ARA-191	Found on the vegetation near the stream of water	Image 75
76.	Pisauridae	*Pisaura podilensis* Patel & Reddy, 1990	1F, 1M	ZOL-14-ARA-152 ZOL-15-ARA-192	Collected from the upper side of leaf near its nursery web	Image 76
77.	Prodidomidae	*Prodidomus* sp.	1M	ZOL-15-ARA-193	Accidentally found moving in the leaf litter and collected by handpick method	Image 77
78.	Salticidae	*Epocilla* sp.	1M	ZOL-14-ARA-153	Found in the underside of leaf	Image 78
79.	Salticidae	*Harmochirus brachiatus* (Thorell, 1877)	1M	ZOL-14-ARA-154	Found under the bark of Palm tree	Image 79
80.	Salticidae	*Hasarius adansoni* (Audouin, 1826)	2F, 1M	ZOL-13-ARA-88 ZOL-13-ARA-89 ZOL-13-ARA-90	Found underside of leaf	Image 80
81.	Salticidae	*Hyllus semicupreus* (Simon, 1885)	1F, 1M	ZOL-13-ARA-91 ZOL-13-ARA-92	Found underside of leaf	Image 81
82.	Salticidae	*Marpissa tigrina* Tikader, 1965	1F	ZOL-14-ARA-155	Found underside of leaf	Image 82
83.	Salticidae	*Marpissa* sp.	1F	ZOL-14-ARA-156	Collected from the lower vegetation by handpick method	Image 83
84.	Salticidae	*Menemerus bivittatus* (Dufour, 1831)	1F, 1M	ZOL-12-ARA-37 ZOL-12-ARA-38	Found underside of leaf	Image 84
85.	Salticidae	*Myrmarachne tristis* (Simon, 1882)	1F, 1M	ZOL-13-ARA-93 ZOL-13-ARA-94	Found underside of leaf	Image 85
86.	Salticidae	*Myrmarachne* sp.	1F	ZOL-12-ARA-39	Collected from its retreat constructed in a rolled leaf	Image 86
87.	Salticidae	*Phintella vittata* (C.L. Koch, 1846)	3F, 1M	ZOL-12-ARA-40 ZOL-13-ARA-95 ZOL-13-ARA-96 ZOL-12-ARA-41	Found underside of leaf	Image 87
88.	Salticidae	*Plexippus paykulli* (Audouin, 1826)	1F, 1M	ZOL-13-ARA-97 ZOL-13-ARA-98	Found wandering on the walls of huts in the village	Image 88
89.	Salticidae	*Plexippus petersi* (Karsch, 1878)	1F, 1M	ZOL-14-ARA-157 ZOL-13-ARA-99	Found wandering on the walls of huts in the village	Image 89
90.	Salticidae	*Portia* sp.	1M	ZOL-15-ARA-194	Observed wandering on the ground within the leaf litter	Image 90
91.	Salticidae	*Rhene albigera* (C.L. Koch, 1846)	1M	ZOL-15-ARA-195	Found underside of leaf	Image 91
92.	Salticidae	*Stenaelurillus* sp.	1F, 1M	ZOL-14-ARA-158 ZOL-14-ARA-159	Collected wandering on the ground and in the dry leaf litter	Image 92
93.	Salticidae	*Telamonia dimidiata* (Simon, 1899)	2F, 1M	ZOL-12-ARA-42 ZOL-13-ARA-100 ZOL-12-ARA-43	Found underside of leaf	Image 93

	Family	Scientific name	No. of specimens collected & sex	Voucher no. 12,13,14,15	Natural history notes	Image no.
94.	Salticidae	*Thyene imperialis* (Rossi, 1846)	2F, 2M	ZOL-12-ARA-44 ZOL-13-ARA-101 ZOL-12-ARA-45 ZOL-13-ARA-102	Found underside of leaf	Image 94
95.	Scytodidae	*Scytodes fusca* Walckenaer, 1837	2F	ZOL-13-ARA-103 ZOL-13-ARA-104	Found underside of leaf	Image 95
96.	Scytodidae	*Scytodes pallida* Doleschall, 1859	1F	ZOL-14-ARA-160	Found inside the folded leaf probably resting during day time	Image 96
97.	Scytodidae	*Scytodes thoracica* (Latreille, 1802)	1F	ZOL-15-ARA-196	Found inside the folded leaf probably resting during day time	Image 97
98.	Scytodidae	*Scytodes* sp.	1F	ZOL-15-ARA-197	Found underside of leaf	Image 98
99.	Sicariidae	*Loxosceles rufescens* (Dufour, 1820)	2F, 1M	ZOL-13-ARA-105 ZOL-13-ARA-106 ZOL-14-ARA-161	Collected from the leaf litter and also from its web constructed in the crevices of mines walls	Image 99
100.	Sparassidae	*Heteropoda bhaikakai* Patel & Patel, 1973	1F	ZOL-12-ARA-46	Collected from the inner & outer walls of huts in the village, also seen in the leaf litter of *Tectona grandis*	Image 100
101.	Sparassidae	*Heteropoda venatoria* (Linnaeus, 1767)	1F	ZOL-12-ARA-47	Collected from the outer walls of huts in the village, also seen in the leaf litter of *Tectona grandis*	Image 101
102.	Sparassidae	*Olios bhavnagarensis* Sethi & Tikader, 1988	1F	ZOL-13-ARA-107	Collected from the underside of leaf	Image 102
103.	Sparassidae	*Olios gravelyi* Sethi & Tikader, 1988	1F	ZOL-13-ARA-108	Collected from the underside of leaf	Image 103
104.	Sparassidae	*Olios milleti* (Pocock, 1901)	1F	ZOL-12-ARA-48	Collected from the folded leaf	Image 104
105.	Sparassidae	*Olios wroughtoni* (Simon, 1897)	1M	ZOL-12-ARA-49	Collected from the underside of leaf	Image 105
106.	Sparassidae	*Olios* sp.	1F	ZOL-12-ARA-50	Collected from the underside of leaf	Image 106
107.	Stenochilidae	*Stenochilus hobsoni* O. Pickard-Cambridge, 1871	1M	ZOL-15-ARA-198	Collected by pitfall method. Probably inhabits in leaf litter	Image 107
108.	Tetragnathidae	*Guizygiella indica* (Tikader & Bal, 1980)	1F, 1M	ZOL-13-ARA-109 ZOL-13-ARA-110	Collected from its orb web constructed between lower branches of tree	Image 108
109.	Tetragnathidae	*Guizygiella melanocrania* (Thorell, 1887)	2F, 1M	ZOL-13-ARA-111 ZOL-14-ARA-162 ZOL-14-ARA-163	Collected from its orb web constructed between lower branches of tree	Image 109
110.	Tetragnathidae	*Guizygiella shivui* (Patel & Reddy, 1990)	2F, 1M	ZOL-13-ARA-112 ZOL-13-ARA-113 ZOL-13-ARA-114	Collected from its orb web constructed between lower branches of tree	Image 110
111.	Tetragnathidae	*Leucauge decorata* (Blackwall, 1864)	3F, 1M	ZOL-12-ARA-51 ZOL-12-ARA-52 ZOL-12-ARA-53	Collected from its web near the water stream	Image 111
112.	Tetragnathidae	*Tetragnatha extensa* (Linnaeus, 1758)	1F, 1M	ZOL-12-ARA-54 ZOL-12-ARA-55	Found resting on the leaves of lower branches of *Pongamia pinnata* tree near water stream	Image 112
113.	Tetragnathidae	*Tetragnatha mandibulata* Walckenaer, 1841	2F, 1M	ZOL-12-ARA-56 ZOL-13-ARA-115 ZOL-13-ARA-116	Found resting on the leaves of lower branches of *Pongamia pinnata* tree near water stream	Image 113
114.	Tetragnathidae	*Tetragnatha maxillosa* Thorell, 1895	1F, 1M	ZOL-14-ARA-164 ZOL-14-ARA-165	Found resting on the leaves of lower branches of *Pongamia pinnata* tree near water stream	Image 114
115.	Tetragnathidae	*Tylorida ventralis* (Thorell, 1877)	1F, 1M	ZOL-14-ARA-166 ZOL-14-ARA-167	Found resting at the periphery of streams on twigs of plants with their legs stretched longitudinally	Image 115

	Family	Scientific name	No. of specimens collected & sex	Voucher no. 12,13,14,15	Natural history notes	Image no.
116.	Theridiidae	*Argyrodes argentatus* O. Pickard-Cambridge, 1880	1F, 1M	ZOL-13-ARA-117 ZOL-13-ARA-118	Observed hanging on a single strand of silk attached to nearby vegetation or twigs	Image 116
117.	Theridiidae	*Cephalobares* sp.	3F, 1M	WILD-14-ARA-1299, WILD-14-ARA-1300, WILD-14-ARA-1301, WILD-14-ARA-1298	Collected from the web of *Guizygiella* shivui, kleptoparasitic	Image 117
118.	Theridiidae	*Coleosoma blandum* O. Pickard-Cambridge, 1882	1M	ZOL-12-ARA-57	Collected from the base of dried palm tree leaf by handpick method	Image 118
119.	Theridiidae	*Euryopis* sp.	1F	ZOL-15-ARA-199	Observed hanging by a single strand of silk attached to the leaves/branch of tree from both the sides	Image 119
120.	Theridiidae	*Latrodectus hasselti* Thorell, 1870	1F	ZOL-14-ARA-168	Collected from the underside of rock by uplifting it. Female was observed guarding the egg-sac	Image 120
121.	Theridiidae	*Meotipa picturata* Simon, 1895	1F	ZOL-14-ARA-169	Observed hanging on a single strand of silk attached to the leaves/branch of tree from both the sides	Image 121
122.	Theridiidae	*Nihonhimea mundula* (L. Koch, 1872)	3F	ZOL-12-ARA-58 ZOL-13-ARA-119 ZOL-14-ARA-170	Collected from mesh web. In which it was resting in the conical shaped folded dry leaf	Image 122
123.	Theridiidae	*Rhomphaea projiciens* O. Pickard-Cambridge, 1896	2F, 1M	ZOL-12-ARA-59 ZOL-13-ARA-120 ZOL-13-ARA-121	Mostly seen hanging on a single strand of silk attached from both the sides on either leaf/branch of tree/shrub	Image 123
124.	Theridiidae	*Steatoda* sp.	1F	ZOL-15-ARA-200	Found in the crevices and holes of the trees	Image 124
125.	Theridiidae	*Yaginumena maculosa* (Yoshida & Ono, 2000)	1M	ZOL-15-ARA-201	Collected from small untidy mesh web constructed underside of large leaves	Image 125
126.	Thomisidae	*Amyciaea forticeps* (O. Pickard-Cambridge, 1873)	2F, 1M	ZOL-14-ARA-171 ZOL-14-ARA-172 ZOL-15-ARA-202	Collected from the trail of red weaver ants on tree branches. They were also observed feeding on these ants	Image 126
127.	Thomisidae	*Camaricus* sp.	1F	ZOL-13-ARA-122	Collected from the lower foliage by handpick method	Image 127
128.	Thomisidae	*Indoxysticus minutus* (Tikader, 1960)	1F	ZOL-13-ARA-123	Found on lower branches of tree, fully camouflaged with the background	Image 128
129.	Thomisidae	*Runcinia* sp.	1F	ZOL-15-ARA-203	Collected from the underside of leaf	Image 129
130.	Thomisidae	*Thomisus* sp.	1F	ZOL-13-ARA-124	Found on and underside of lower foliage/shrubs	Image 130
131.	Titanoecidae	*Pandava* sp.	2F, 1M	WILD-14-ARA-1268, WILD-14-ARA-1269, WILD-14-ARA-1267	Collected from the underside of loose barks of tree and can be easily located by the outline of cribellate silk at the periphery of loose bark	Image 131
132.	Uloboridae	*Miagrammopes* sp.	1J	ZOL-15-ARA-204	Collected from leaf litter by handpick method	Image 132
133.	Uloboridae	*Uloborus danolius* Tikader, 1969	1F	ZOL-15-ARA-205	Collected from its web constructed in between dry twigs	Image 133
134.	Uloboridae	*Uloborus krishnae* Tikader, 1970	1F	ZOL-15-ARA-206	Observed resting underside of the leaf in its web	Image 134
135.	Uloboridae	*Uloborus* sp.	1F	ZOL-14-ARA-173	Found hanging on a single strand of silk attached underside of leaf	Image 135
136.	Uloboridae	*Zosis* cf. *geniculata* (Olivier, 1789)	1J	ZOL-15-ARA-207	Collected from its web constructed attached to the walls of mines	Image 136
137.	Zodariidae	*Storena gujaratensis* Tikader & Patel, 1975	1M	ZOL-12-ARA-60	Leaf litter dwelling spider; collected by pitfall method	Image 137
138.	Zodariidae	*Storena* sp.	1F	ZOL-15-ARA-208	Leaf litter dwelling spider; collected by pitfall method	Image 138

ARA—Araneae | F—female | J—Juvenile | M—male | WILD—Wildlife Information Liaison Development Society | ZOL–Zoology

Image 1. *Araneus mitificus*

Image 2. *Argiope aemula*

Image 3. *Argiope anasuja*

Image 4. *Chorizopes* sp.

Image 5. *Cyclosa confraga*

Image 6. *C. hexatuberculata*

Image 7. *Cyclosa moonduensis*

Image 8. *Cyclosa spirifera*

Image 9. *Cyrtophora cicatrosa*

Image 10. *Cyrtophora citricola*

Image 11. *Eriovixia excelsa*

Image 12. *Eriovixia laglaizei*

Image 13. *Eriovixia poonaensis*

Image 14. *Gasteracantha kuhli*

Image 15. *Gea subarmata*

Image 16. *Larinia chloris*

Image 17. *Lipocrea fusiformis*

Image 18. *Neoscona mukerjei*

Image 19. *Neoscona nautica*

Image 20. *Neoscona theisi*

Image 21. *Neoscona vigilans*

Image 22. *Poltys bhabanii*

Image 23. *Poltys cf columnaris*

Image 24. *Poltys nagpurensis*

Image 25. *Singa* sp.

Image 26. *Thelacantha brevispina*

Image 27. *Clubiona drassodes*

Image 28. *Clubiona filicata*

Image 29. *Clubiona foliata*

Image 30. *Clubiona pashabhaii*

Image 31. *Castianeira zetes*

Image 32. *Ctenus narashinhai*

Image 33. *Stegodyphus pacificus*

Image 34. *Stegodyphus sarasinorum*

Image 35. *Cheiracanthium inornatum*

Image 36. *C. melanostomum*

Image 37. *Cheiracanthium triviale*

Image 38. *Cheiracanthium* sp.

Image 39. *Drassodes* sp.

40. *Haplodrassus* sp.

Image 41. *Megamyrmaekion ashae*

Image 42. *Scopoides kuljitae*

Image 43. *Scopoides* sp.

Image 44. *Trachyzelotes jaxartensis*

Image 45. *Zelotes mandae*


Image 46. *Hersilia savignyi*


Image 47. *Murricia hyderabadensis*


Image 48. *Oedignatha* sp.


Image 49. *Evippa* sp.


Image 50. *Hippasa lycosina*


Image 51. *Lycosa poonaensis*


Image 52. *Lycosa* sp.


Image 53. *Pardosa birmanica*


Image 54. *Pardosa sumatrana*


Image 55. *Oecobius putus*


Image 56. *Brignolia* sp.


Image 57. Unidentified sp. 1


Image 58. *Hamadruas sikkimensis*


Image 59. *Oxyopes ashae*


Image 60. *Oxyopes bharatae*

Image 61. *Oxyopes birmanicus*

Image 62. *Oxyopes pankaji*

Image 63. *Oxyopes* sp.

Image 64. *Peucetia akwadaensis*

Image 65. *Peucetia viridana*

Image 66. *Peucetia yogeshi*

Image 67. *Peucetia* sp.

Image 68. Unidentified sp. 2 (Palpimanidae)

Image 69. *Tibellus elongates*

Image 70. *Crossopriza lyoni*

Image 71. *Pholcus fragillimus*

Image 72. *Pholcus phalangioides*

Image 73. *Hygropoda* cf. *mahendriensis*

Image 74. *Nilus phipsoni*

Image 75. *Perenethis venusta*


Image 76. *Pisaura podilensis*


Image 77. *Prodidomus* sp.


Image 78. *Epocilla* sp.


Image 79. *Harmochirus brachiatus*


Image 80. *Hasarius adansoni*


Image 81. *Hyllus semicupreus*


Image 82. *Marpissa tigrina*


Image 83. *Marpissa* sp.


Image 84. *Menemerus bivittatus*


Image 85. *Myrmarachne tristis*


Image 86. *Myrmarachne* sp.


Image 87. *Phintella vittata*


Image 88. *Plexippus paykulli*


Image 89. *Plexippus petersi*


Image 90. *Portia* sp.


Image 91. *Rhene albigera*


Image 92. *Stenaelurillus* sp.


Image 93. *Telamonia dimidiata*


Image 94. Thyene *imperialis*


Image 95. *Scytodes fusca*


Image 96. *Scytodes pallida*


Image 97. *Scytodes thoracica*


Image 98. *Scytodes* sp.


Image 99. *Loxosceles rufescens*


Image 100. *Heteropoda bhaikakai*


Image 101. *Heteropoda venatoria*


Image 102. *Olios bhavnagarensis*


Image 103. *Olios gravelyi*


Image. 104. *Olios milleti*


Image 105. *Olios wroughtoni*


Image 106. *Olios* sp.


Image 107. *Stenochilus hobsoni*


Image. 108. *Guizygiella indica*


Image 109. *Guizygiella melanocrania*


Image 110. *Guizygiella shivui*


Image 111. *Leucauge decorata*


Image 112. *Tetragnatha extensa*


Image 113. *Tetragnatha mandibulata*


Image 114. *Tetragnatha maxillosa*


Image 115. *Tylorida ventralis*


Image 116. *Argyrodes argentatus*


Image 117. *Cephalobares* sp.


Image 118. *Coleosoma blandum*


Image 119. *Euryopis* sp.


Image 120. *Latrodectus hasseltii*


Image 121. *Meotipa picturata*


Image 122. *Nihonhimea mundula*


Image 123. *Rhomphaea projiciens*


Image 124. *Steatoda* sp


Image 125. *Yaginumena maculosa*


Image 126. *Amyciaea forticeps*


Image 127. *Camaricus* sp.


Image 128. *Indoxysticus minutes*


Image 129. *Runcinia* sp.


Image 130. *Thomisus* sp.


Image 131. *Pandava* sp.


Image 132. *Miagrammopes* sp.


Image 133. *Uloborus danolius*


Image 134. *Uloborus* sp.


Image 135. *Uloborus* sp.

Image 136. *Zosis* cf. *geniculata*

Image 137. *Storena gujaratensis*

Image 138. *Storena* sp.

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SHORT COMMUNICATION

Preliminary checklist of spider fauna (Araneae: Arachnida) of Chandranath Hill, Goa, India

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Abstract: The present investigation is a very first attempt to generate the checklist of spiders from Chandranath Hill, Paroda, Quepem, Goa. A preliminary study was conducted from June 2018 to March 2020 to document the spider diversity from the region. In all, 125 species of spiders belonging to 102 genera from 19 families were identified. The dominant families were Salticidae followed by Araneidae. Guild structure analysis revealed six feeding guilds, namely, orb weavers, foliage runners, ground runners, stalkers, space-web builders and ambushers. This study has not only highlighted the need for conservation of this ecosystem due to the significant species diversity and endemic species but has also filled the lacuna of spider study in Goa to form the foundation for further investigation. Extensive research on the spiders from Chandranath Hill in the future can certainly expect further new discoveries.

Keywords: Chandreshwar, diversity, guild structure, Salticidae, spiders.

Currently, the world list of spiders comprises over 48,000 species belonging to more than 4,000 genera and 128 families (World Spider Catalog 2020), of which, 1,843 species from 472 genera and 60 families are reported from India (Caleb & Sankaran 2020). In Goa, a total of 11 families belonging to 28 genera and 39 species have been documented till date (Bastawade & Borkar 2008).

The present study aims to generate a primary report documenting the spider diversity of Chandranath Hill, thereby highlighting the ecological aspect of this ecosystem.

Materials and Methods

Study area

The Chandranath Hill (15.213⁰N & 74.037⁰E) situated in Paroda, Quepem Taluka of South Goa District stands at a height of approximately 350m. Commonly known as Chandreshwar, this Hill has an area of approximately 2km^2. This heavily wooded hill commands a panoramic view and its surroundings are enchanting accompanied with thick vegetation with riparian patches. The speciality of this hill is that it is geographically not connected to the Western Ghats yet it is rich in biodiversity. Despite this, no study on spiders has been carried out in this area till date, thus making it an important reason for conducting this exploration which will in-turn generate primary data with the help of this documentation. The study was conducted for a period of 22 months, from June 2018 till March 2020, covering all the seasons.

Climate and vegetation

The study area being close to the Arabian Sea

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Image 1A–B. A—location of Chandranath Hill | B—most recent satellite view of the Hill.

experiences warm and humid climate for most of the year with atmospheric temperatures ranging from 21°to 36°C. The humidity ranges from 71 to 89%.

Teak is a common occurrence which is found in association with *Macaranga peltata* (Chandada), *Mangifera indica* (Wild mango), *Garcinia* (Kokum). Shrubs like *Mussaenda frondosa* (Dhobi tree), *Ixora coccinea* (Jungle geranium) are common along with orchids like *Eria* and climbers like *Begonia* spp. Seasonal wild balsams (*Impatiens sp.)*, *Sida rhombifolia* (Arrow Leaf Sida), *Sonerila rheedii* (Rheed's Sonerila) and *Melastoma malabathricum* (Malabar Melastome) are abundant. As one moves to a higher elevation through dense foliage and small streams of cascading water, breath-taking glimpses of the vegetation and the landscape can be witnessed.

Methods

Spiders were visually searched in their microhabitats such as ground, litter, bushes, flowers, leaves, branches, in cracks and crevices. Webs and web lines were traced to locate the spiders. Logs and stones after being upturned to search for spiders were placed back in their original position. Spiders were photographed in their natural habitat itself as soon as they were sighted using Canon EOS 500D DSLR mounted with 18–55 mm lens attached with Raynox DCR-250 magnifying lens.

Random active search was employed to capture spiders. Whenever possible, the spiders were handpicked. The lid-container method was used to trap the spiders. Vegetation beating was done using a wooden stick with an inverted umbrella placed below the vegetation to collect the spiders that were out of reach. Sweep net method was used to collect spiders that dwell in the foliage. The collected specimens were preserved in 70% alcohol. Spiders were examined under a stereo-zoom microscope (Weswox STM-80) and identified with the help of taxonomic keys and illustrations provided by Gajbe (2007, 2008), Gravely (1921a,b, 1924, 1931) Pocock (1900, 1901), Tikader (1960, 1963, 1970, 1971, 1980, 1981, 1982a,b), Tikader & Bal (1981), Tikader & Malhotra (1980), Sethi & Tikader (1988), Proszynski (1992) and other relevant literature. Nomenclature and taxonomy is according to the World Spider Catalog (2020). All the specimens were identified up to family and generic level and some to specific level. Spiders that could not be identified are not included in the checklist.

Results and Discussion

The study at Chandranath Hill, Goa from June 2018 to March 2020 resulted in the documentation of 125 species belonging to 102 genera of 19 families (Table 1).

Spiders from family Salticidae proved to be the most dominant constituting 26.40% of the total species (33). Further, 22.40% of the species (28) belonged to Araneidae making it the second dominant family. The families with least number of species (01) were Cheiracanthiidae, Ctenidae, Gnaphosidae, Hersiliidae, Philodromidae and Scytodidae.

Guild structure

Six feeding guilds, namely, orb weavers, foliage runners, ground runners, stalkers, space-web builders, and ambushers were identified based on the foraging behaviour (Uetz et al. 1999).

The most dominant guild was of the stalkers with 40 species followed by orb weavers (39), ambushers (16), space-web builders (14), ground runners (10) and foliage runners (06).

Vegetation architecture plays a major role in the species composition found within a habitat (Greenstone

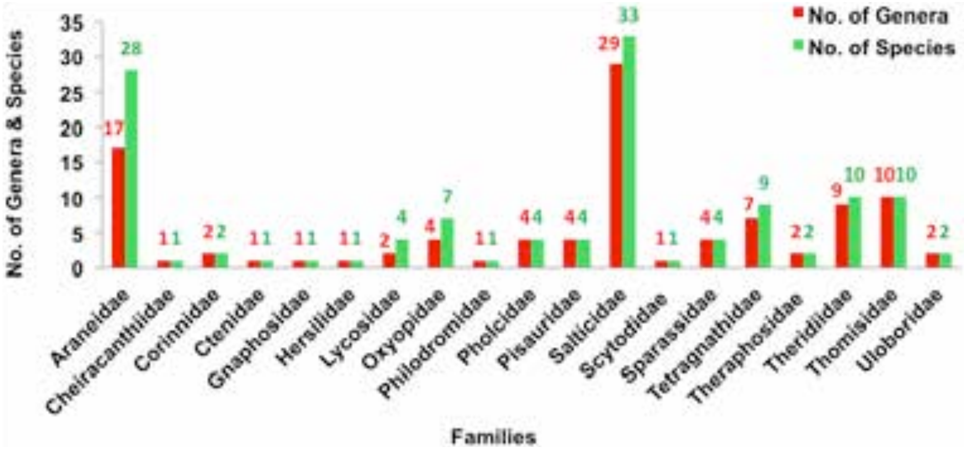

Figure 1. Comparative distribution of genera and species in different families.

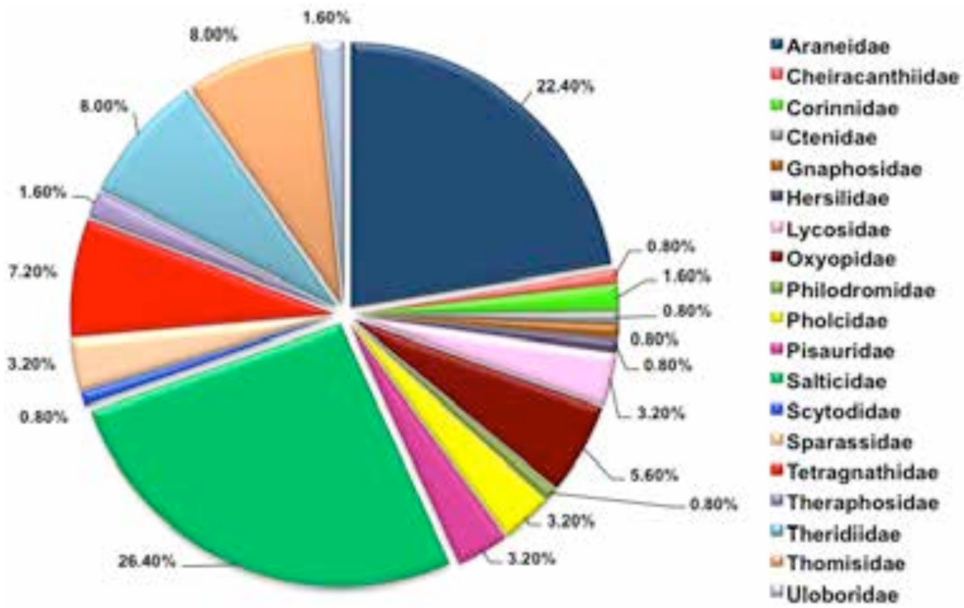

Figure 2. Percentage distribution of spider families of Chandranath Hill, Goa.

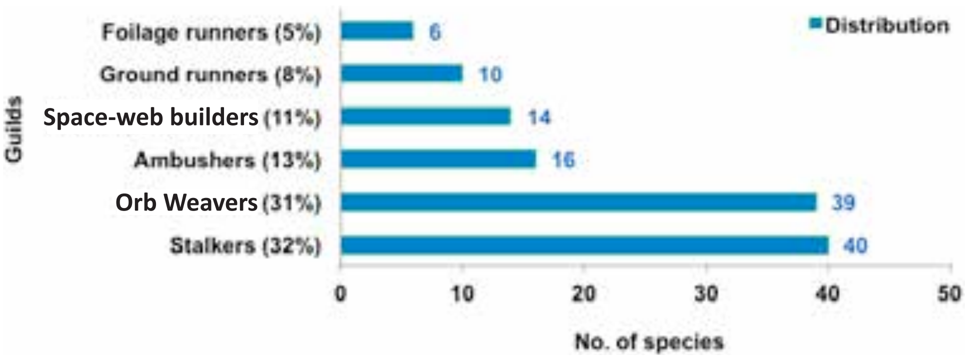

Figure 3. Guild structure of spiders at Chandranath Hill, Goa.

Table 1. Checklist of spider species recorded at Chandranath Hill, Goa.

Family		Species	Guild
Araneidae	1	*Anepsion maritatum* (O. Pickard-Cambridge, 1877)# (Image 2)	Orb Weavers
	2	*Arachnura angura* Tikader, 1970#	
	3	*Araneus mitificus* (Simon, 1886)#	
	4	*Araneus viridisomus* Gravely, 1921# (Image 3)	
	5	*Argiope aemula* (Walckenaer, 1841)	
	6	*Argiope anasuja* Thorell, 1887#	
	7	*Argiope pulchella* Thorell, 1881	
	8	*Chorizopes* sp#	
	9	*Cyclosa bifida* (Doleschall, 1859)#	
	10	*Cyclosa spirifera* (Simon, 1889)#	
	11	*Cyrtophora cicatrosa* (Stoliczka, 1869)	
	12	*Cyrtophora unicolor* (Doleschall, 1857)# (Image 4)	
	13	*Eriovixia* sp. 1#	
	14	*Eriovixia* sp. 2#	
	15	*Gasteracantha geminata* (Fabricius, 1798) (Image 5)	
	16	*Gasteracantha hasselti* C.L.Koch, 1837	
	17	*Gasteracantha kuhli* C.L.Koch, 1837#	
	18	*Gea spinipes* C.L.Koch, 1843# (Image 6)	
	19	*Herennia multipuncta* (Doleschall, 1859)	
	20	*Larinia* sp.#	
	21	*Neoscona bengalensis* Tikader & Bal, 1981	
	22	*Neoscona mukerjei* Tikader, 1980	
	23	*Neoscona theisi* (Walckenaer, 1841)#	
	24	*Nephila kuhli* (Doleschall, 1859)#	
	25	*Nephila pilipes* (Fabricius, 1793)	
	26	*Parawixia dehaani* (Doleschall, 1859) (Image 7)	
	27	*Poltys* sp.# (Image 8)	
	28	*Thelacantha brevispina* (Doleschall, 1857)#	
Cheiracanthiidae*	29	*Cheiracanthium* sp#	Foliage runners
Corinnidae*	30	*Castianeira zetes* Simon, 1897#	Ground runners
	31	*Echinax panache* Deeleman-Reinhold, 2001 (Image 9)#	
Ctenidae	*32*	*Ctenus* sp.	Ground runners
Gnaphosidae	*33*	*Zelotes* sp.#	Ground runners
Hersiliidae	*34*	*Hersilia savignyi* Lucas, 1836	Ambushers
Lycosidae	35	*Hippasa pisaurina* Pocock, 1900#	Ground runners
	36	*Hippasa agelenoides* (Simon, 1884)	
	37	*Hippasa greenalliae* (Blackwall, 1867)#	
	38	*Pardosa* sp.	
Oxyopidae*	39	*Hamadruas* sp.# (Image 10)	Stalkers
	40	*Hamataliwa* sp.#	
	41	*Oxyopes birmanicus* Thorell, 1887#	
	42	*Oxyopes shweta* Tikader, 1970#	
	43	*Oxyopes javanus* Thorell, 1887#	
	44	*Oxyopes* sp.#	
	45	*Peucetia viridana* (Stoliczka, 1869)# (Image 11)	
Philodromidae*	46	*Tibellus elongatus* Tikader, 1960# (Image 12)	Ambushers

Family		Species	Guild
Pholcidae	47	*Artema atlanta* Walckenaer, 1837	Space-web builders
	48	*Crossopriza lyoni* (Blackwall, 1867)[#]	
	49	*Leptopholcus* sp.[#]	
	50	*Pholcus* sp.	
Pisauridae*	51	*Dendrolycosa gitae* (Tikader, 1970)[#]	Ambushers
	52	*Hygropoda* sp.[#] (Image 13)	
	53	*Nilus* sp.[#]	
	54	*Polyboea* sp.[#] (Image 14)	
Salticidae	55	*Asemonea tenuipes* (O. Pickard-Cambridge, 1869)[#] (Image 15)	Stalkers
	56	*Bianor* sp.[#]	
	57	*Brettus cingulatus* Thorell, 1895[#] (Image 16)	
	58	*Bristowia* sp.[#] (Image 17)	
	59	*Carrhotus viduus* (C.L.Koch, 1846)[#]	
	60	*Chrysilla volupe* (Karsch, 1879)[#]	
	61	*Cyrba ocellata* (Kroneberg, 1875)[#]	
	62	*Epeus indicus* Prószyński, 1992[#] (Image 18)	
	63	*Harmochirus brachiatus* (Thorell, 1877)[#]	
	64	*Hasarius adansoni* (Audouin, 1826)[#]	
	65	*Hyllus semicupreus* (Simon, 1885)[#] (Image 19)	
	66	*Icius vikrambatrai* Prajapati, Malamel, Sudhikumar & Sebastian, 2018[#] (Image 20)	
	67	*Indopadilla insularis* (Malamel, Sankaran & Sebastian, 2015)[#] (Image 21)	
	68	*Langona* sp.[#]	
	69	*Marengo* sp.[#] (Image 22)	
	70	*Menemerus bivittatus* (Dufour, 1831)[#]	
	71	*Menemerus* sp.[#]	
	72	*Myrmaplata plataleoides* (O. Pickard-Cambridge, 1869) (Image 23)	
	73	*Myrmarachne melanocephala* MacLeay, 1839[#]	
	74	*Myrmarachne prava* (Karsch, 1880)[#]	
	75	*Phaeacius* sp.[#]	
	76	*Phanuelus* sp.[#]	
	77	*Phintella vittata* (C.L.Koch, 1846)[#]	
	78	*Piranthus* sp.[#]	
	79	*Plexippus paykulli* (Audouin, 1826)[#]	
	8	*Plexippus petersi* (Karsch, 1878)[#]	
	81	*Plexippus* sp.[#]	
	82	*Portia albimana* (Simon, 1900)[#] (Image 24)	
	83	*Rhene flavicomans* Simon, 1902[#]	
	84	*Stenaelurillus* sp[#] (Image 25)	
	85	*Telamonia dimidiata* (Simon, 1899)[#] (Image 26)	
	86	*Thiania bhamoensis* Thorell, 1887[#] (Image 27)	
	87	*Vailimia* sp.[#]	
Scytodidae*	88	*Scytodes* sp.[#]	Foliage runners
Sparassidae*	89	*Heteropoda* sp.[#]	Foliage runners
	90	*Olios milleti* (Pocock, 1901)[#]	
	91	*Palystes* sp.[#] (Image 28)	
	92	*Pandercetes* sp.[#]	

Tetragnathidae	93	*Dolichognatha longiceps* (Thorell, 1895)#	Orb Weavers
	94	*Guizygiella* sp.#	
	95	*Leucauge decorata* (Blackwall, 1864)#	
	96	*Mesida* sp.#	
	97	*Opadometa fastigata* (Simon, 1877)# (Image 29)	
	98	*Tetragnatha mandibulata* Walckenaer, 1841	
	99	*Tetragnatha viridorufa* Gravely, 1921#	
	100	*Tylorida striata* (Thorell, 1877) (Image 30)#	
	101	*Tylorida* sp.	
Theraphosidae	102	*Chilobrachys fimbriatus* Pocock, 1899	Ground runners
	103	*Thrigmopoeus* sp.	
Theridiidae*	104	*Ariamnes* sp.#	Space-web builders
	105	*Argyrodes flavescens* O. Pickard-Cambridge, 1880# (Image 31)	
	106	*Chikunia nigra* (O. Pickard-Cambridge, 1880)# (Image 32)	
	107	*Chrysso angula* (Tikader, 1970)# (Image 33)	
	108	*Chrysso urbasae* (Tikader, 1970)# (Image 34)	
	109	*Coleosoma blandum* O.Pickard-Cambridge, 1882# (Image 35)	
	110	*Episinus* sp.#	
	111	*Meotipa sahyadri* Kulkarni, Vartak, Deshpande & Halali, 2017#	
	112	*Propostira ranii* Bhattacharya, 1935# (Image 36)	
	113	*Thwaitesia* sp.#	
Thomisidae	114	*Amyciaea forticeps* (O. Pickard-Cambridge, 1873)# (Image 37)	Ambushers
	115	*Angaeus* sp.# (Image 38)	
	116	*Camaricus formosus* Thorell, 1887	
	117	*Massuria* sp.# (Image 39)	
	118	*Oxytate* sp.# (Image 40)	
	119	*Stiphropus* sp.#	
	120	*Strigoplus netravati* Tikader, 1963 (Image 41)	
	121	*Synema revolutum* Tang & Li, 2010#	
	122	*Thomisus* sp.#	
	123	*Xysticus* sp.#	
Uloboridae*	124	*Miagrammopes* sp.# (Image 42)	Orb Weavers
	125	*Uloborus* sp.# (Image 43)	

*—Families newly recorded in Goa | #—Species newly recorded in Goa

1984; Scheidler 1990; Sudhikumar et al. 2005) and vegetation which is structurally more complex can sustain higher abundance and diversity of spiders (Hatley & Macmahon 1980; Sudhikumar et al. 2005). Additionally, good vegetation along with floral diversity houses a number of insect species, this in turn results in hosting a high diversity of spiders as insects happen to be their main prey (Chetia & Kalita 2012).

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Image 2. *Anepsion maritatum*

Image 3. *Araneus viridisomus*

Image 4. *Cyrtophora unicolor*

Image 5. *Gasteracantha geminata*

Image 6. *Gea spinipes*

Image 7. *Parawixia dehaani*

Image 8. *Poltys* sp.

Image 9. *Echinax panache*

Image 10. *Hamadruas* sp.

Image 11. *Peucetia viridana*

Image 12. *Tibellus elongatus*

Image 13. *Hygropoda* sp.

Image 14. *Polyboea* sp.

Image 15. *Asemonea tenuipes*

Image 16. *Indopadilla insularis*

Image 17. *Brettus cingulatus*

Image 18. *Bristowia* sp.

Image 19. *Epeus indicus*

Image 20. *Hyllus semicupreus*

Image 21. *Icius vikrambatrai*

Image 22. *Marengo* sp.

Image 23. *Myrmaplata plataleiodes*

Image 24. *Portia albimana*

Image 25. *Stenaelurillus* sp.

Image 26. *Telamonia dimidiata*

Image 27. *Thiania bhamoensis*

Image 28. *Palystes* sp.

Image 29. *Opadometa fastigata*

Image 30. *Tylorida striata*

Image 31. *Argyrodes flavescens*

Image 32. *Chikunia nigra*

Image 33. *Chrysso angula*

Image 34. *Chrysso urbasae*

Image 35. *Coleosoma blandum*

Image 36. *Propostira ranii*

Image 37. *Amyciaea forticeps*

Image 38. ***Angaeus*** **sp.**

Image 39. ***Massuria*** **sp.**

Image 40. ***Oxytate*** **sp.**

Image 41. ***Strigoplus netravati***

Image 42. ***Miagrammopes*** **sp.**

Image 43. ***Uloborus*** **sp.**

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SHORT COMMUNICATION

Butterfly (Lepidoptera: Rhopalocera) fauna of Jabalpur City, Madhya Pradesh, India

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Abstract: The present study was carried out to reveal the butterfly species diversity in the Jabalpur City, Madhya Pradesh, India. Study was carried out from January 2008 to 2018. A total of 112 species were recorded, with an addition of 41 new species for Jabalpur district and one species for the state of Madhya Pradesh. Of the total, 42 species were very common, five were frequent common, 18 were rare, and four were very rare. Nymphalidae was dominant with 39 species, followed by Lycaenidae with 38, Pieridae with 15 species, Hesperiidae with 14, Papilionidae with eight and Riodinidae with one species. About six species of the recorded ones come under the protection category of the Indian Wildlife (Protection) Act, 1972. The study illustrated the value of Jabalpur City area in hosting valuable resources for butterflies.

Keywords: Butterflies, central India, diversity, new records.

Among insects, butterflies are sensitive biota severely affected by the environmental variations and changes in the forest structure as they are closely dependent on plants (Pollard 1991). Butterflies are generally regarded as one of the best taxonomically studied groups of insects; they have been studied systematically since the early 18th century and about 18,000 species are documented worldwide (Martinez et al. 2003). This figure is not constant because of the continuous addition of new butterflies and also due to ongoing disagreements between taxonomists over the status of many species.

The Indian subcontinent with a diverse terrain, climate, and vegetation hosts about 1,504 species of butterflies (Tiple 2011) of which peninsular India hosts 351, and the Western Ghats 336. Butterflies enable sustenance of ecosystem services through their role in pollination and serving as important food chain components. Being potential pollinating agents of their nectar plants as well as indicators of the health and quality of their host plants (Tiple et al. 2006) and the ecosystem as a whole, exploration of butterfly fauna thus becomes important in identifying and preserving potential habitats under threat.

In central India the butterfly species diversity was reported earlier by Forsayeth (1884), Swinhoe (1886), Betham (1890, 1891), Witt (1909), and D'Abreu (1931) who documented a total 177 species occurring in the erstwhile Central Provinces (now Madhya Pradesh and Vidarbha). Subsequent monumental works and fauna volumes include several species from Madhya Pradesh and Chhattisgarh (Evans 1932; Talbot 1939, 1947; Wynter-Blyth 1957). In the recent past, several

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workers have studied butterflies from some districts and conservation areas of Madhya Pradesh and Chhattisgarh (Singh 1977; Gupta and Shukla 1987; Chaudhury 1995; Chandra et al. 2000 a,b, 2002; Singh & Chandra 2002; Siddiqui & Singh, 2004; Chandra 2006). Chandra et al. (2007) recorded 174 species of butterflies belonging to 100 genera under eight families from Madhya Pradesh and Chhattisgarh. Singh & Koshta (2008) reported 39 species of butterflies from Jabalpur District, Madhya Pradesh. Recently, Tiple (2012) recorded 62 species of butterflies belonging to 47 genera and five families from TFRI Campus, Jabalpur.

The present study was started with a view to examine the diversity of butterflies from Jabalpur City. Since there is no published checklist of butterfly from Jabalpur city prior to this, the present work could be the baseline for further research.

Materials and Methods

The findings presented in the article are based on opportunistic sampling and photo documentation was carried out on a biweekly basis from 2008 to 2018 in and around Jabalpur City. Identification of the butterflies was primarily made directly in the field. In critical condition specimens were collected only with handheld aerial sweep nets and subsequently released without harm. Each specimen was placed in plastic bottles and carried to the laboratory for further identification with the help of field guides (Wynter-Blyth 1957; Kunte 2000). The species were categorized on the basis of their abundance in Jabalpur City. The butterflies were categorized as VC—Very common (> 100 sightings), C—Common (51–100 sightings), FC—Frequent common (16–50 sightings), R—Rare (2–15 sightings), VR—Very rare (< 2 sightings) (Tiple 2012). The species recorded for the first time from the Jabalpur district are marked with asterisk (*), and those which were previously unrecorded in Madhya Pradesh are marked with #.

Study Sites

Jabalpur is one of the largest and the most crowded cities in Madhya Pradesh and located in the centre of India at 23.16°10’7.57’’N and 79.93°55’54.64’’E. Jabalpur City has a humid subtropical climate having three main seasons: the wet monsoon season from June to October, the cool dry winter from October to March, and the hot dry season from April till the onset of the rains in the beginning of June. The temperature of the city ranges from a minimum of 10°C to a maximum of 45°C with a relative humidity 10–15% to 60–95%. Annual precipitation is 1,386mm.

All the study sites were within and around Jabalpur City within a radius of 20km. Butterflies were surveyed in Dumna Nature Reserve, Dhobi Reserve Forest, Lower Gaur Reserve Forest, city gardens, Tropical Forest Research Institute (TFRI), Airport Road, Medical College

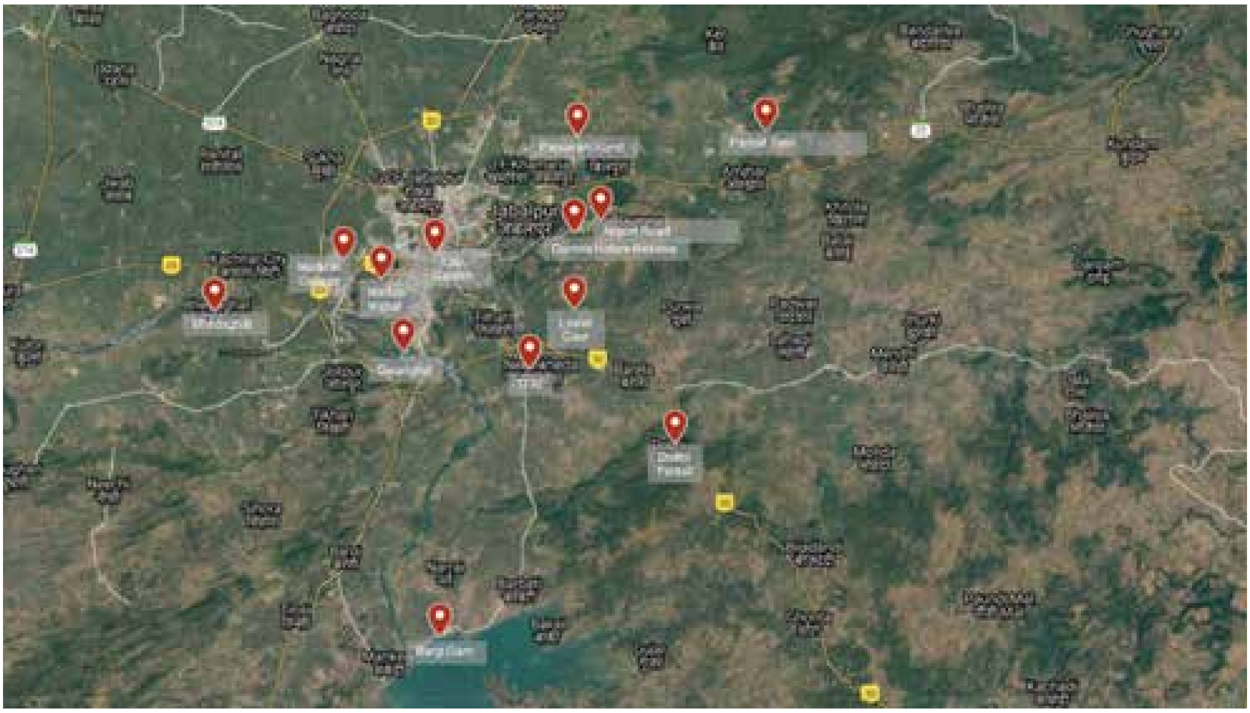

Image 1. Jabalpur City. Source: Google Earth

Campus, Bhedaghat, Pariyat Tank, Parashuram Kund, Madan Mahal Hills, areas adjacent to river Narmada and Bargi dam during the monsoon and post monsoon period (Image 1).

Results and Discussion

During the course of study 112 species of butterflies referable to 71 genera, belonging to six families were recorded. This study added 41 species as new records for Jabalpur District and one species for Madhya Pradesh. The highest number of butterflies belonged to the family Nymphalidae (39 species) with nine new records (viz.: *Athyma selenophora*, *Byblia ilithyia*, *Charaxes psaphon*, *Euploea klugii*, *Mycalesis visala*, *Phaedyma columella*, *Neptis jumbah*, *Ypthima sterope*, and *Ypthima indica*). This was followed by the Lycaenidae with 38 species and19 new records (viz.: *Acytolepis puspa*, *Amblypodia anita*, *Anthene lycaenina*, *Azanus ubaldus*, *Chilades lajus*, *Everes lacturnus*, *Iraota timoleon*, *Jamides celeno*, *Prosotas dubiosa*, *Rapala manea*, *Spindasis ictis*, *Spindasis schistacea*, *Tajuria cippus*, *Talicada nyseus*, *Tarucus balkanicus*, *Tarucus callinara*, *Zizeeria karsandra*, *Azanus gesous*, and *Caleta decidia*). In Pieridae, 15 species with four new records were recorded (*Colotis fausta*, *Colotis danae*, *Colotis etrida*, and *Ixias marianne*). A total of 15 hesperiid species were recorded with five new records (*Baoris farri*, *Parnara naso*, *Sarangesa dasahara*, *Suastus gremius*, and *Udaspes folus*). Nine species were recorded from the family Papilionidae with two new records (*Graphium doson* and *Papilio clytia*) and *Abisara bifasciata* new species recorded from the family Riodinidae (Figure 1). *Euploea klugii* was recorded for the first time from Madhya Pradesh (Image 2). Formerly, *E. klugii*, a very widely distributed species was recorded only from northeastern India, Western Ghats, and Odisha.

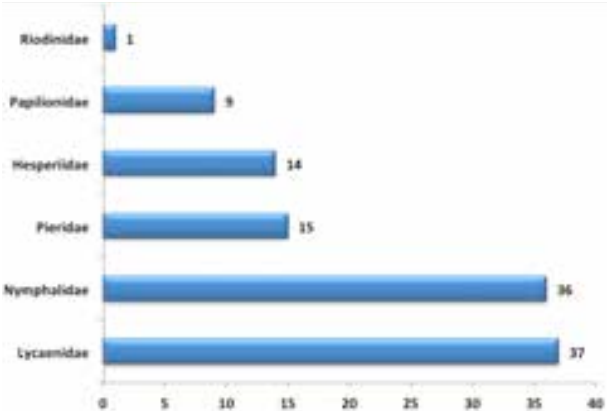

Figure 1. The number of butterfly species encountered in different families in the Jabalpur City, Madhya Pradesh.

Image 2. *Euploea klugii,* a new record for Madhya Pradesh State.

Among the 112 species of butterflies about 38% (43) were common, 38% (42) species were very common, 4% (five) were frequent common, 16% (18) were rare, and 4% (four) were very rare (*Papilio clytia*, *Byblia ilithyia*, *Neptis jumbah*, and *Iraota timoleon*). The observed and identified species, their status in and around the city of Jabalpur are listed in Table 1.

Among the 112 butterflies recorded, six species (*Pachliopta hector, Euploea core, Hypolimnas misippus, Euchrysops cnejus Ionolyce helicon*, and *Baoris farri*) are protected under the Indian Wildlife (Protection) Act, 1972. Interestingly, butterflies (*Neptis soma*, *Melanitis phedima*, *Abisara echerius*) which were recorded earlier from Jabalpur city were not seen during the present study. The probable causes of this could be the loss of habitats due to ever-expanding urbanization along with the broader climatic changes. As reported by Kunte (2000), an objective revision of the scheduled list is necessary to provide appropriate and adequate legal protection to Indian butterflies.

Wynter-Blyth (1957) had identified two seasons as peaks, March–April and October for butterfly abundance in India. The abundance of diverse species was positively affected by approaching summer, high relative humidity and more rainfall. In the present investigation most butterfly species were observed from the monsoon (hot/wet season) to early winter (cool/wet season) months but subsequently declined in early summer (March). Among the 112 species of butterflies, *Papilio demoleus*, *Pachliopta aristolochiae*, *Catopsilia pomona*, *Eurema hecabe*, *Danaus chrysippus*, *Tirumala limniace*, *Acraea violae*, *Euploea core*, *Junonia lemonias*, *Catochrysops strabo*, and *Chilades putli* were found throughout the year (January–December), whereas the remaining 101 species of butterflies were prominently observed only

Table1. List of butterflies recorded from Jabalpur city together with common name and status. [*: new record in Jabalpur district; #: new record for Madhya Pradesh state; abundance acronyms: VC—Very common (> 100 sightings) | C—Common (51–100 sightings) | FC—Frequent common (16–50 sightings) | R—Rare (2–15 sightings) | VR—Very rare (< 2 sightings)]

	Scientific name	Common name	Status
	Family Papilionidae		
1	*Graphium agamemnon* (Linnaeus, 1758)	Tailed Jay	C
2	*Graphium doson* (C. & R. Felder, 1864)*	Common Jay	R
3	*Graphium nomius* (Esper, 1799)	Spot Swordtail	C
4	*Pachliopta aristolochiae* (Fabricius, 1775)	Common Rose	C
5	*Pachliopta hector* (Linnaeus, 1758)	Crimson Rose	C
6	*Papilio clytia* Linnaeus, 1758*	Common Mime	VR
7	*Papilio demoleus* Linnaeus, 1758	Lime Butterfly	VC
8	*Papilio polymnestor* Cramer, [1775]	Blue Mormon	FC
9	*Papilio polytes* Linnaeus, 1758	Common Mormon	VC
	Family Pieridae		
10	*Belenois aurota* (Fabricius, 1793)	Pioneer	C
11	*Catopsilia pomona* (Fabricius, 1775)	Common or Lemon Emigrant	VC
12	*Catopsilia pyranthe* (Linnaeus, 1758)	Mottled Emigrant	VC
13	*Cepora nerissa* (Fabricius, 1775)	Common Gull	VC
14	*Colotis fausta* (Olivier, 1804) *	Large Salmon Arab	R
15	*Colotis danae* (Fabricius, 1775) *	Crimson Tip	R
16	*Colotis etrida* (Boisduval, 1836) *	Small Orange Tip	R
17	*Delias eucharis* (Drury, 1773)	Common Jezebel	VC
18	*Eurema blanda* (Boisduval, 1836)	Three-Spot Grass Yellow	R
19	*Eurema brigitta* (Stoll, [1780])	Small Grass Yellow	C
20	*Eurema hecabe* (Linnaeus, 1758)	Common Grass Yellow	VC
21	*Eurema laeta* (Boisduval, 1836)	Spotless Grass Yellow	VC
22	*Ixias marianne* (Cramer, [1779]) *	White Orange Tip	C
23	*Leptosia nina* (Fabricius, 1793)	Psyche	C
24	*Pareronia hippie* (Fabricius, 1787)	Common Wanderer	C
	Family Nymphalidae		
25	*Acraea terpsicore* (Linnaeus, 1758)	Tawny Coster	VC
26	*Ariadne merione* (Cramer, [1777])	Common Castor	C
27	*Ariadne ariadne (Linnaeus)*	Angled Castor	C
28	*Athyma selenophora* (Kollar, [1844]) *	Staff Sergeant	R
29	*Byblia ilithyia* (Drury, [1773]) *	Joker	VR
30	*Charaxes psaphon* Westwood, 1847*	Tawny Rajah	R
31	*Charaxes solon* (Fabricius, 1793)	Black Rajah	C
32	*Vanessa cardui* (Linnaeus, 1758)	Painted Lady	C
33	*Danaus chrysippus* (Linnaeus, 1758)	Plain Tiger	VC
34	*Danaus genutia* (Cramer, [1779])	Striped Tiger	VC
35	*Euploea core* (Cramer, [1780])	Common Indian Crow	VC
36	*Euploea klugii* Felder & Felder, 1865 *#	Brown King Crow	R
37	*Euthalia aconthea* (Cramer, [1777])	Common Baron	R
38	*Hypolimnas bolina* (Linnaeus, 1758)	Great Eggfly	C
39	*Hypolimnas misippus* (Linnaeus, 1764)	Danaid Eggfly	C
40	*Junonia almana* (Linnaeus, 1758)	Peacock Pansy	VC

	Scientific name	Common name	Status
41	*Junonia atlites* (Linnaeus, 1763)	Grey Pansy	C
42	*Junonia hierta* (Fabricius, 1798)	Yellow Pansy	C
43	*Junonia iphita* (Cramer, [1779])	Chocolate Pansy	VC
44	*Junonia lemonias* (Linnaeus, 1758)	Lemon Pansy	VC
45	*Junonia orithya* (Linnaeus, 1758)	Blue Pansy	VC
46	*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown	VC
47	*Moduza procris* (Cramer, [1777])	Commander	C
48	*Mycalesis mineus* (Linnaeus, 1758)	Dark Branded Bushbrown	C
49	*Mycalesis perseus* (Fabricius, 1775)	Common Bushbrown	VC
50	*Mycalesis visala* Moore, [1858] *	Long-brand Bushbrown	R
51	*Phaedyma columella* (Cramer, [1780]) *	Short-banded Sailer	C
52	*Neptis hylas* (Linnaeus, 1758)	Common Sailer	VC
53	*Neptis jumbah* Moore, [1858] *	Chestnut-Streaked Sailer	VR
54	*Phalanta phalantha* (Drury, [1773])	Common Leopard	VC
55	*Charaxes agrarius* (Swinhoe, 1887)	Anomalous Nawab	C
56	*Symphaedra nais* (Forster, 1771)	Baronet	C
57	*Tirumala limniace* (Cramer, [1775])	Blue Tiger	VC
58	*Ypthima asterope* (Klug, 1832) *	Common Threering	VC
59	*Ypthima baldus* (Fabricius, 1775)	Common Fivering	R
60	*Ypthima inica* (Hewitson, 1865) *	Lesser Threering	C
	Family Riodinidae		
61	*Abisara bifasciata* Moore, 1877*	Double-banded Judy	R
	Family Lycaenidae		
62	*Acytolepis puspa* (Horsfield, [1828]) *	Common Hedge Blue	VC
63	*Amblypodia anita* Hewitson, 1862*	Leaf Blue	C
64	*Anthene lycaenina* (Felder, 1868) *	Pointed Ciliate Blue	C
65	*Arhopala amantes* (Hewitson, 1862)	Large Oakblue	C
66	*Azanus jesous* (Lederer 1855) *	African Babul blue	C
67	*Azanus ubaldus* (Stoll, [1782]) *	Bright Babul Blue	R
68	*Castalius rosimon* (Fabricius, 1775)	Common Pierrot	VC
69	*Catochrysops strabo* (Fabricius, 1793)	Forget-Me-Not	VC
70	*Chilades lajus* (Stoll, [1780]) *	Lime Blue	C
71	*Luthrodes pandava* (Horsfield, [1829])	Plains Cupid	VC
72	*Chilades parrhasius* (Fabricius, 1793)	Small Cupid	R
73	*Freyeria putli* (Kollar, [1844])	Eastern grass Jewel	VC
74	*Virachola isocrates* (Fabricius, 1793)	Common Guava Blue	C
75	*Euchrysops cnejus* (Fabricius, 1798)	Gram Blue	VC
76	*Everes lacturnus* (Godart, [1824]) *	Indian Cupid	C
77	*Iraota timoleon* (Stoll, [1790]) *	Silverstreak Blue	VR
78	*Jamides bochus* (Stoll, [1782])	Dark Cerulean	C
79	*Jamides celeno* (Cramer, [1775]) *	Common Cerulean	VC
80	*Lampides boeticus* (Linnaeus, 1767)	Pea Blue	VC
81	*Leptotes plinius* (Fabricius, 1793)	Zebra Blue	VC
82	*Prosotas dubiosa* (Semper, [1879]) *	Tailless Lineblue	C
83	*Prosotas nora* (Felder, 1860)	Common Lineblue	C

	Scientific name	Common name	Status
84	*Psuedozizeeria maha* (Kollar, [1844])	Pale Grass Blue	C
85	*Rapala iarbus* (Fabricius, 1787)	Common Red Flash	C
86	*Rapala manea* (Hewitson, 1863) *	Slate Flash	C
87	*Spindasis ictis* (Hewitson, 1865) *	Common Shot Silverline	C
88	*Spindasis schistacea* (Moore, [1881]) *	Plumbeous Silverline	R
89	*Spindasis vulcanus* (Fabricius, 1775)	Common Silverline	VC
90	*Tajuria cippus* (Fabricius, 1798) *	Peacock Royal	R
91	*Talicada nyseus* (Guérin- Menéville, 1843) *	Red Pierrot	FC
92	*Tarucus balkanicus nigra* Bethune-Baker, [1918] *	Black-spotted Pierrot	C
93	*Tarucus callinara* Butler, 1886*	Spotted Pierrot	C
94	*Tarucus nara* (Kollar, 1848)	Rounded Pierrot/ Striped Pierrot	VC
95	*Zizeeria karsandra* (Moore, 1865) *	Dark Grass Blue	VC
96	*Zizina otis* (Fabricius, 1787)	Lesser Grass Blue	VC
97	*Zizula hylax* (Fabricius, 1775)	Tiny Grass Blue	VC
98	*Caleta decidia* (Hewitson 1876) *	Angled Peirrot	FC
	Family Hesperiidae		
99	*Badamia exclamationis* (Fabricius, 1775)	Brown Awl	VC
100	*Baoris farri* (Moore, 1878) *	Paintbrush Swift	R
101	*Borbo cinnara* (Wallace, 1866)	Rice Swift	VC
102	*Caltoris kumara* (Moore, 1878)	Blank Swift	VC
103	*Coladenia indrani* (Moore, [1866])	Tricolour Pied Flat	FC
104	*Hasora chromus* (Cramer, [1780])	Common Banded Awl	VC
105	*Parnara naso* (Fabricius, 1798) *	Straight Swift	C
106	*Pelopidas mathias* (Fabricius, 1798)	Small Branded Swift	VC
107	*Sarangesa dasahara* Moore, [1866] *	Common Small Flat	R
108	*Spialia galba* (Fabricius, 1793)	Indian Skipper	C
109	*Suastus gremius* (Fabricius, 1798) *	Indian Palm Bob	C
110	*Telicota bambusae* (Moore, 1878)	Dark Palm Dart	VC
111	*Telicota colon* (Fabricius, 1775)	Pale Palm Dart	FC
112	*Udaspes folus* (Cramer, [1775]) *	Grass Demon	C

after June–July till the beginning of summer (April–May). Increasing species abundance from beginning of monsoon (June–July) till the early winter (August–November) and decline in species abundance from late winter (January–February) up to the end of summer have also been reported by Tiple et al. (2007) and Tiple (2012) in similar climatic conditions in this region of central India. They further demonstrated that most species were noticeably absent in the disturbed and human-impacted sites (gardens, plantations, and grasslands) and there was no occurrence of unique species in moderately disturbed areas comparable to those of less-disturbed wild areas. Jabalpur City is always disturbed and stressed by human actions, which may be the reasons for overall reduction of unique species from human-disturbed sites as compared to the other sites. The cause of this decline might be non-availability of nectar and larval host plants, scarcity of water, and cutting of grasslands (Tiple et al. 2007).

We are rapidly losing greenery in the name of development. There has also been an alarming rise in industrial and automobile pollution in Indian cities. With the shrinking of greenery and increase in pollution, butterflies, birds and all our wildlife are fast disappearing. The net result is a complete imbalance of the ecosystem and extinction of many species. In spite of the fast growth, Indian cities still have diverse serene habitats such as the traffic island gardens in the middle of busy roads, parks or urban forest areas with mixed deciduous and non-deciduous trees and scrubland serving as ideal habitats for various types of insects, especially butterflies.

The findings of the present study underline the importance of the city as a preferred habitat for butterflies. If the landscaping and maintenance of gardens are carefully planned, the diversity of butterflies may increase in Jabalpur City providing a rich ground for butterfly conservation as well as for research. This study will also add to our future attempts in understanding the complex nature of mutualistic interaction between butterflies and flowering plants that is essential for continuity of ecosystem services. The present list of butterfly species is not conclusive and exhaustive and future exploration will be continued to update this checklist.

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SHORT COMMUNICATION

Evaluating threats and conservation status of South African *Aloe*

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Abstract: South Africa is one of the biodiversity hotspots for *Aloe* in Africa. This makes it important to evaluate the conservation status and threats to this genus. The South African National Biodiversity Institute (SANBI) Red List was employed to evaluate these two factors. Results revealed that 44% of all species in this genus are of conservation concern with the majority of them facing threats. This study recommends that more attention such as strengthening the protection of these species and controlling the threats identified in this study should be given to species in this genus in terms of conservation management to reduce their risk of extinction.

Keywords: Asphodelaceae, biodiversity loss, extinction risk, hotspot, threatened species.

The genus *Aloe* belongs to the Asphodelaceae family (Cousins & Witkowski 2012). Biodiversity hotspots for this genus in Africa are located in Ethiopia, Madagascar and southern Africa (Grace 2009), which coincide with Africa's main biodiversity hotspots (Daru et al. 2013).

Aloes are important to any ecosystems where they are found (Cousins & Witkowski 2012). Their nectar is a source of food for many insects (Nicolson & Nepi 2005; Botes et al. 2009a,b) and avians (Symes et al. 2008; Forbes et al. 2009). They also modulate harsh environmental conditions, which facilitate colonization of the environment by other plant taxa (Wabuyele & Kyalo 2008). Their mat-like root that is dense assist in preventing soil erosion (Smith & Van Wyk 2009).

Some species of this genus are traded commercially as cosmetics (Grace et al. 2015) and medicine (Bjorå et al. 2015). This has led *Aloe* to become threatened, with the majority of species in this genus being included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Grace 2011). This implies that conservation of the species in this genus should be given a high priority, especially in areas that are hotspots of this genus (Klopper & Smith 2013).

This study evaluated the conservation status and threats of *Aloe* in South Africa to determine which species in this genus are threatened, and to determine factors responsible for their risk of extinction. Unlike some previous studies that mentioned the overall conservation status of the genus *Aloe* (e.g., Grace et al. 2009; Cousins & Witkowski 2012), this study showed the conservation status and threats each species of *Aloe* is facing using the South African National Red List, and also quantified in percentages species in this genus under different Red List categories and threat categories.

Methods

This study used the SANBI Red List 2017 version to evaluate threats and conservation status of South

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African *Aloe*. The following percentages were calculated: the species that are highly threatened, threatened and of conservation concern (Critically Endangered, Endangered, Vulnerable, Near Threatened, Rare, and Data Deficient); *Aloe* species that fall under different categories of threats (Habitat destruction, individual's collection, invasive species occurrence, fire occurrence, overgrazing, and insect attack); species endemic and non-endemic to South Africa; threatened endemic species; and endemic species that are of conservation concern and different categories of threats (habitat destruction, individual's collection, invasive species occurrence, fire occurrence, overgrazing, and insect attack) to endemic species.

Results and Discussion

Endemic and non-endemic species of the genus *Aloe* in South Africa

A total of 125 taxa belonging to the genus *Aloe* were listed in the South African National Red List; 61.6% of species in the genus *Aloe* found in the South African National Red List are endemic, while 38.4% are non-endemic. Species endemism is an important factor to be considered in conservation because the loss of endemic species is of high significant impact in biodiversity loss in any geographic areas that they occur (Moraswi et al. 2019). A population survey of endemic taxa should be encouraged to determine their population size, density, and distribution in order to reveal their current population trend. This information will inform appropriate conservation measures, which are adaptive to local conditions.

Highly threatened, threatened, and species of conservation concern in South African *Aloe*

The various threat status categories of South African *Aloe* are: 52.8% (Least Concern), 10.4% (Rare), 2.4% (Data Deficient), 3.2% (Data Deficient, taxonomically problematic), 10.4% (Near Threatened), 11.2% (Vulnerable), 4% (Endangered), 5.6% (Critically Endangered), 44% are of conservation concern (Critically Endangered, Endangered, Vulnerable, Near Threatened, Rare, and Data Deficient). Species that are highly threatened are referred to as Critically Endangered (Williams et al. 2013) because they are at the brink of extinction. *Aloe* species in this study that falls into this category (Table 1) should be given quick conservation intervention such as preventing further collection by people, minimizing habitat loss, and improving on their regeneration potentials to prevent complete extirpation of their populations. Some plant species are not threatened, but can be flagged and given priority in terms of conservation, and thus be referred to as species of conservation concern (Victor & Keith 2004). Species of conservation concern in this study that are not threatened should be monitored to determine if they have become threatened (Table 1). For instance Data deficient taxa could possibly be threatened (Moraswi et al. 2019). This is why further efforts is required to obtain sufficient information about them in order to determine if they are threatened or not.

Threats to South African endemic and non-endemic *Aloe* species

Percentages of taxa in the genus *Aloe* in South Africa facing different types of threats are as follows: 41.6% are threatened by habitat destruction, 16.8% are threatened due to individual's collection, 14.4% threatened by occurrence of invasive species, 5.6% are threatened because of fire occurrences, 11.2% are threatened by overgrazing, 0.8% threatened due to insect attack, while there are no threats found for 42.4% of the taxa. *Aloe* species are generally threatened by habitat destruction and collection by people (Klooper et al. 2009), a situation also reflected in this study. The collection by people are majorly due to medicinal uses and horticultural uses which might be affecting the wild population of these taxa (Grace 2011). Enforcement of regulation restricting the collections of these taxa should be more encouraged. It must be noted that a thorough assessment of those species for which their threats are unknown can significantly change the results pattern in the threat categories as presented above.

Threats to endemic species of South African *Aloe*

The results of the percentages of endemic species of South African *Aloe* facing different kind of threats are as follows: 57% are affected by habitat destruction, 23.4% affected by Individual's collection, 17% are affected by invasive species, 9% by fire occurrence, 13% by overgrazing, while there are no threats found for 26% of the endemic species. Habitat destruction and collection by people still stood out among the threats to endemic South African *Aloe* species. It is recommended that species for whom their threats are not known (Table 1) be further assessed. Thus, it is possible that a reassessment of these species can alter the results presented above.

Conservation status of endemic species in South African *Aloe*

The results of the percentages of endemic *Aloe*

Table 1. List of *Aloe* species in South Africa, their SANBI Red List Status, their endemism status and their threats on SANBI Red List.

Species	SANBI Red List status	Endemism status	Threats
Aloe aculeata Pole-Evans	Least Concern	Not endemic	No threat
Aloe affinis A.Berger	Least Concern	Not endemic	Habitat destruction
Aloe africana Mill.	Least Concern	Endemic	Habitat destruction
Aloe albida (Stapf) Reynolds	Near Threatened	Not endemic	Habitat destruction
Aloe alooides (Bolus) Druten	Least Concern	Endemic	Habitat destruction
Aloe ammophila Reynolds	Least Concern	Endemic	No threat
Aloe angelica Pole-Evans	Least Concern	Endemic	Habitat destruction
Aloe arborescens Mill.	Least Concern	Not endemic	No threat
Aloe arenicola Reynolds	Near Threatened	Endemic	No threat
Aloe barbara-jeppeae T.A.McCoy & Lavranos	Near Threatened	Endemic	Habitat destruction
Aloe bergeriana (Dinter) Boatwr. & J.C.Manning	Data Deficient	Not endemic	Habitat destruction
Aloe bowiea Schult. & J.H.Schult.	Critically Endangered	Endemic	Habitat destruction
Aloe braamvanwykii Gideon F.Sm. & Figueiredo	Endangered	Endemic	Habitat destruction
Aloe branddraaiensis Groenew.	Least Concern	Endemic	Habitat destruction
Aloe brevifolia Mill. var. brevifolia	Vulnerable	Endemic	Habitat destruction, invasive presence, individual's collection
Aloe brevifolia Mill. var. depressa (Haw.) Baker	Data Deficient taxonomically problematic	Endemic	Habitat destruction
Aloe broomii Schönland var. *broomii*	Least Concern	Not Endemic	No threat
Aloe broomii Schönland var. *tarkaensis* Reynolds	Rare	Endemic	No threat
Aloe buhrii Lavranos	Vulnerable	Endemic	Individual's collection, habitat destruction
Aloe castanea Schönland	Least Concern	Endemic	No threat
Aloe chabaudii Schönland var. *chabaudii*	Least Concern	Not endemic	No threat
Aloe challisii Van Jaarsv. & A.E.van Wyk	Vulnerable	Endemic	Individual's collection, invasive presence
Aloe chlorantha Lavranos	Vulnerable	Endemic	Insect attack
Aloe chortolirioides A.Berger var. chortolirioides	Vulnerable	Not endemic	Habitat destruction, invasive presence, fire occurrences,
Aloe chortolirioides A.Berger var. *woolliana* (Pole-Evans) Glen & D.S.Hardy	Least Concern	Endemic	Habitat destruction, fire occurrences
Aloe claviflora Burch.	Least Concern	Not endemic	No threat
Aloe comosa Marloth & A.Berger	Least Concern	Endemic	Individuals collection, habitat destruction
Aloe condyae Van *Jaarsv*. & P.Nel	Vulnerable	Endemic	Invasive presence
Aloe cooperi Baker	Least Concern	Not endemic	Habitat destruction, overgrazing, invasive presence
Aloe craibii Gideon F.Sm.	Critically Endangered	Endemic	Individual's collection, fire occurrences, invasive presence, habitat destruction
Aloe cryptopoda Baker	Least Concern	Not endemic	No threat
Aloe dabenorisana Van *Jaarsv.*	Rare	Endemic	Individual's collection
Aloe dewetii Reynolds	Least Concern	Not endemic	No threat
Aloe dominella Reynolds	Near Threatened	Endemic	Habitat destruction, overgrazing, fire occurrences, invasive presence
Aloe dyeri Schönland	Least Concern	Not endemic	No threat
Aloe ecklonis Salm-Dyck	Least Concern	Not endemic	Habitat destruction, invasive presence
Aloe excelsa A.Berger var. *excelsa*	Least Concern	Not endemic	No threat
Aloe falcata Baker	Least Concern	Not endemic	Individual's collection, overgrazing
Aloe ferox Mill.	Least Concern	Not endemic	Individual's collection, habitat destruction, overgrazing
Aloe fosteri Pillans	Least Concern	Endemic	No threat

Species	SANBI Red List status	Endemism status	Threats
Aloe fouriei D.S.Hardy & Glen	Data Deficient taxonomically problematic	Endemic	Habitat destruction, overgrazing
Aloe framesii L.Bolus	Near Threatened	Endemic	Habitat destruction
Aloe gariepensis Pillans	Least Concern	Not endemic	No threat
Aloe gerstneri Reynolds	Vulnerable	Endemic	Habitat destruction, Overgrazing
Aloe glauca Mill.	Least Concern	Endemic	No threat
Aloe globuligemma Pole-Evans	Least Concern	Not endemic	No threat
Aloe graciliflora Groenew.	Least Concern	Endemic	No threat
Aloe grandidentata Salm-Dyck	Least Concern	Not endemic	No threat
Aloe greatheadii Schönland var. *davyana* (Schönland) Glen & D.S.Hardy	Least Concern	Not endemic	No threat
Aloe greatheadii Schönland var. *greatheadii*	Least Concern	Not endemic	No threat
Aloe greenii Baker	Least Concern	Not endemic	No threat
Aloe hahnii Gideon F.Sm. & R.R.Klopper	Near Threatened	Endemic	Habitat destruction
Aloe hardyi H.F.Glen	Rare	Endemic	No threat
Aloe hereroensis Engl. var. hereroensis	Least Concern	Not endemic	No threat
Aloe humilis (L.) Mill.	Least Concern	Endemic	Habitat destruction, individual's collection
Aloe inconspicua Plowes	Endangered	Endemic	Habitat destruction, overgrazing
Aloe integra Reynolds	Vulnerable	Not endemic	Habitat destruction, invasive presence, fire occurrences
Aloe jeppeae Klopper & Gideon F.Sm.	Least Concern	Endemic	No threat
Aloe kamnelii Van Jaarsv.	Rare	Endemic	No threat
Aloe karasbergensis Pillans	Least Concern	Not endemic	No threat
Aloe knersvlakensis S.J.Marais	Rare	Endemic	No threat
Aloe kniphofioides Baker	Vulnerable	Endemic	Habitat destruction, fire occurrences
Aloe komaggasensis Kritzinger & Van Jaarsv.	Vulnerable	Endemic	Individual's collection, habitat destruction, overgrazing
Aloe komatiensis Reynolds	Endangered	Not endemic	Habitat destruction, invasive presence
Aloe kouebokkeveldensis Van Jaarsv. & A.B.Low	Rare	Endemic	No threat
Aloe krapohliana Marloth	Data Deficient	Endemic	Individual's collection, habitat destruction, overgrazing
Aloe lettyae Reynolds	Endangered	Endemic	Habitat destruction, invasive occurrence, overgrazing, fire occurrences
Aloe linearifolia A.Berger	Near Threatened	Endemic	Habitat destruction, overgrazing
Aloe lineata (Aiton) Haw. var. *lineata*	Least Concern	Endemic	Habitat destruction
Aloe lineata (Aiton) Haw. var. *muirii* (Marloth) Reynolds	Least Concern	Endemic	No threat
Aloe littoralis Baker	Least Concern	Not endemic	No threat
Aloe longistyla Baker	Data Deficient	Endemic	Individual's collection, habitat destruction, overgrazing
Aloe lutescens Groenew.	Least Concern	Not endemic	No threat
Aloe maculata All.	Least Concern	Not endemic	No threat
Aloe marlothii A.Berger subsp. *marlothii*	Least Concern	Not endemic	No threat
Aloe marlothii A.Berger subsp. *orientalis* Glen & D.S.Hardy	Least Concern	Not endemic	No threat
Aloe melanacantha A.Berger	Least Concern	Not endemic	No threat
Aloe meyeri Van Jaarsv.	Rare	Not endemic	No threat
Aloe micracantha Haw.	Near Threatened	Endemic	Habitat destruction, invasive presence
Aloe microstigma Salm-Dyck	Least Concern	Not endemic	No threat
Aloe minima Baker	Least Concern	Not endemic	Habitat destruction
Aloe modesta Reynolds	Vulnerable	Endemic	Habitat destruction, Invasive presence

Species	SANBI Red List status	Endemism status	Threats
Aloe monotropa I.Verd.	Vulnerable	Endemic	Individual's collection
Aloe mudenensis Reynolds	Least Concern	Endemic	Habitat destruction
Aloe myriacantha (Haw.) Schult. & J.H.Schult.	Least Concern	Not endemic	Invasive occurrences
Aloe neilcrouchii R.R.Klopper & Gideon F.Sm.	Endangered	Endemic	Habitat destruction
Aloe neilcrouchii R.R.Klopper & Gideon F.Sm.	Critically Endangered	Endemic	Habitat destruction
Aloe nubigena Groenew.	Rare	Endemic	Habitat destruction
Aloe parvibracteata Schönland	Least Concern	Not endemic	No threat
Aloe pearsonii Schönland	Vulnerable	Not endemic	Overgrazing
Aloe peglerae Schönland	Critically Endangered	Endemic	Habitat destruction, individual's collection
Aloe perfoliata L.	Least Concern	Endemic	No threat
Aloe petricola Pole-Evans	Least Concern	Endemic	Habitat destruction
Aloe petrophila Pillans	Rare	Endemic	No threat
Aloe pictifolia D.S.Hardy	Rare	Endemic	No threat
Aloe pluridens Haw.	Least Concern	Endemic	No threat
Aloe pratensis Baker	Least Concern	Not endemic	Habitat destruction, individual's collection
Aloe pretoriensis Pole-Evans	Least Concern	Not endemic	Habitat destruction
Aloe prinslooi I.Verd. & D.S.Hardy	Near Threatened	Endemic	Individual's collection and invasive presence
Aloe pruinosa Reynolds	Vulnerable	Endemic	Habitat destruction, individual's collection, invasive occurrence
Aloe reitzii Reynolds var. *reitzii*	Near Threatened	Endemic	No threat
Aloe reitzii Reynolds var. *vernalis* D.S.Hardy	Critically Endangered	Endemic	Individual's collection
Aloe reynoldsii Letty	Rare	Endemic	Individual's collection
Aloe rupestris Baker	Least Concern	Not endemic	No threat
Aloe saundersiae (Reynolds) Reynolds	Critically Endangered	Endemic	Habitat destruction, overgrazing, fire occurrences
Aloe sharoniae N.R.Crouch & Gideon F.Sm.	Least Concern	Not endemic	Habitat destruction
Aloe simii Pole-Evans	Critically Endangered	Endemic	Habitat destruction, Invasive presence
Aloe soutpansbergensis I.Verd.	Rare	Endemic	Individual's collection
Aloe speciosa Baker	Least Concern	Endemic	No threat
Aloe spectabilis Reynolds	Least Concern	Endemic	No threat
Aloe spicata L.f.	Least Concern	Not endemic	No threat
Aloe striata Haw.	Least Concern	Endemic	No threat
Aloe succotrina Lam.	Least Concern	Endemic	No threat
Aloe suffulta Reynolds	Least Concern	Not Endemic	No threat
Aloe suprafoliata Pole-Evans	Least Concern	Not Endemic	No threat
Aloe thompsoniae Groenew.	Rare	Endemic	No threat
Aloe thorncroftii Pole-Evans	Near Threatened	Endemic	Habitat destruction, invasive presence
Aloe thraskii Baker	Near Threatened	Endemic	Habitat destruction, individual's collection
Aloe vanbalenii Pillans	Least Concern	Not endemic	No threat
Aloe vanrooyenii Gideon F.Sm. & N.R.Crouch	Least Concern	Endemic	No threat
Aloe verecunda Pole-Evans	Least Concern	Endemic	Habitat destruction
Aloe vogtsii Reynolds	Near Threatened	Endemic	Habitat destruction
Aloe vossii Reynolds	Data Deficient taxonomically problematic	Endemic	Habitat destruction, fire occurrences, Invasive presence
Aloe vryheidensis Groenew.	Data Deficient taxonomically problematic	Endemic	Habitat destruction
Aloe zebrina Baker	Least Concern	Not endemic	No threat

taxa in South Africa on SANBI Red List threat status categories are as follows: 32.4% (Least Concern), 5.2% (Data Deficient taxonomically problematic), 2.6% (Data Deficient), 15.6% (Rare), 15.5% (Near Threatened), 14.3% (Vulnerable), 5.2% (Endangered) and 9.1% (Critically Endangered); 28.6% of the endemic species in this genus are threatened (Critically Endangered, Endangered, Vulnerable); 62.3% of the endemic species are of conservation concern (Critically Endangered, Endangered, Vulnerable, Near Threatened, Rare, and Data Deficient). Endemic plant species are more vulnerable to extinction (Williams et al. 2013) because they are restricted to certain geographic regions and the total extirpation of their populations in that region automatically result in total extinction of the species (Bamigboye 2019). This is also being clearly revealed in this study as all the Critically Endangered *Aloe* species in this study are endemic species, which further supports the notion that a more proactive conservation intervention should be given to these species.

Conclusion

This study presents the current conservation status, endemic status and threats that each species of *Aloe* in South African Red List are facing. It also quantifies the percentages of species in this genus that fall into different SANBI Red List categories, threat categories, and endemism categories. This study provides information on the species of *Aloe* in South Africa that need more conservation attention. For instance the Critically Endangered species in this study that are all endemic species (Table 1) can be given higher priorities for conservation. Conservation status of species changes over time (Bamigboye et al. 2016). It is recommended that South African *Aloe* should be further evaluated to see if they have become more threatened in recent times or not. A recent evaluation will also reveal if the ones that are not threatened on SANBI Red List are now threatened.

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NOTE

The first record of Montagu's Harrier *Circus pygargus* (Aves: Accipitridae) in West Bengal, India

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India is the second largest home for harriers (Aves: Accipitridae: Circus) globally and harbors six harrier species of the 16 found across the world (Verma 2007). Harriers are slender, long naked-legged, long wing, and long tailed raptors with an owl-like facial ruff. The key characters to identify harriers are: under wing pattern, facial pattern, axillary pattern, body streaking, tail features and mode of flight (soaring and gliding). Montagu's Harrier *Circus pygargus* (Image 1a,b) is widespread in India and the smallest of the country's harriers. There are, however, no previous photographic records from West Bengal. There have also been some unsubstantiated records without photographs.

On 30 December 2019, we started birding in Bonpatna Village, in Kesiyari block, West Midnapore, West Bengal, India. While birding we noticed a harrier and a Black Kite *Milvus migrans* gliding over the marshes and bushes with several dead snakes (killed by a fisherman during netting) behind a local dam (used for fishing). This area (near a wetland and cultivated field) was a perfect fit as Montagu's favorite habitat (Image 1c,d). This bird species is often found at night in the open, frequently in sizeable congregations and in company with other harrier species in grassy swamp or fallow land (Ali & Ripley 2002).

The Montagu's Harrier can be confused with many harrier species that exist within the same range, e.g., Pallid Harrier *C. macrourus*, Pied Harrier *M. melanoleucos*, and Hen Harrier *C. cyaneus*. Distinguishing sub adults and juveniles is most confusing. We have undertaken a comparative analysis to elucidate proper identification.

On identification we found real difficulties between Pallid Harrier and Montagu's Harrier. A paper by Svensson in 1971 is still considered the most comprehensive treatment to elucidate the subject. Identification of juvenile is most difficult. Lewington also added few important aspects regarding identification (Lewington 1991). Ali & Ripley in 2002 noted underparts with chestnut shaft-stripes and a grayish rump. The juveniles of both species undergo a partial body moult in the winter, which varies between within species (Forsman 1995). Characters like underwing primaries, head pattern, upper tail coverts, rump and collar are the most important features. At the time of migration, they have acquired a slim outline and their flight is more like adults. Montagu's juveniles are identified by dark finger tips, and grayish base to outer primaries. Amount of white around eye and distinctiveness and shape of collar are other features (Forsman 1995). Forsman also supported the difference between Montagu's, Pallid and Hen Harrier with wing formula, In addition Forsman (1995) pointed out the rufous underparts and darker adult female secondaries in Montagu's Harrier (Forsman 1995). Identification is easier

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Image 1. a–b— Montagu's Harrier *Circus pygargus* | c—grassy swamp land perfect for roosting | d—a wetland beside the roosting site. © Suman Pratihar and Niloy Mandal.

if the bird is aged first. When recognizing adult female Pallid with Montagu's Harrier, one must remember that female Hen Harrier is a more likely to be confusing, rather than Montagu's (Forsman 1995; Grimmett et al. 2011). The lack of white in the upper tail coverts, and white in the rump; pale lores, prominent white above the eye and presence of white collar in our specimen confirmed that it was not Pied Harrier *Circus melanoleucos*.

We have compiled ten points which confirm the identification of our specimen as follows:

1. Flat owl-like face, oval head shape, long wing and tail, small body.
2. More white round the prominent eye, though restricted not well developed dark ear-coverts patch.
3. Crescent-shaped pale collar with tapered end.
4. Ear covert extended up to the eye.
5. Under wing outer primaries with uniform grayish bases and not evenly barred. Secondary pattern is variable so less reliable.
6. Broad supercilium (narrow in case of *Circus macrourus*) with clear face.
7. No white in the upper tail covert (white upper tail covert is character of Pied Harrier).
8. Grayish-white rump present (from field note).
9. Long outermost primary p1 number and roughly equalling p5, all broad dark fingertips.
10. A very distinct, unique pattern similar to sub adult female Montagu's Harrier.

We revisited the place, in the hope of finding more individuals, and a roosting site, but were unsuccessful. As this is the first report of the species from the state, it is difficult to conclude whether it is a passage migrant, or a vagrant in West Bengal.

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NOTE

An account of snake specimens in St. Joseph's College Museum Kozhikode, India, with data on species diversity

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Kerala State, southwestern India harbors rich and diverse snake fauna yet it is one that has been little studied (Beddome 1863; Theobald 1876; Ferguson 1895; Wall 1905, 1919; Constable 1949; Gans 1966; Inger et al.1984; Murthy 1981,1990; Das & Whitaker 1990; Das 1991; Zacharias 1997; Kumar et al. 2012: Palot 2015; Aengals et al. 2018; Jayakumar & Nameer 2018). A few studies conducted on snakes in Kerala were mostly in the Western Ghats. Little information is available from the low elevation areas of the state especially northern Kerala (Malabar). There are records and specimens from Kannur (Wall 1905) but not much from Kozhikode. Recent studies on the herpetofauna in Malabar coastal plains reveal a good deal of endemics and even new species. Examples: Dussumier's Smooth Water Snake *Dieurostus dussumierii*, (Chandramouli et al. 2012), Striped Coral Snake, *Calliophis nigrescens* (Kumar et al. 2010) Beypore Skink *Chalcides pentadactyla* (Aengals et al. 2018) and the recently described Fanthroated Lizard *Sitana attenborough* (Sadasivan et al. 2018).

The national repositories of reference collections in ZSI (Das et al. 1998; Chanda et al. 2000) and in BNHS (Das & Chaturvedi 1998) are well known. But the holdings of the herpetofauna collections in many local zoological museums are poorly known. Ganesh & Asokan (2010) have documented the collections in the Madras museum. The occurrence of the enigmatic frog *Nasikabatrachus* sp. was revealed from the holdings of three college museums in Kerala and Tamil Nadu (Dutta et al. 2004). Museum of Jahangir Nagar University in Bangladesh is also an example of smaller collections providing important biodiversity information (Mahony et al. 2009). A cursorial glance through St. Josephs College (Kozhikode) museum in Kerala, revealed a small holding of snakes and other biological diversity. These specimens collected by students, faculty members or local people have been overlooked or not properly catalogued and hence remain unstudied. A study on such collections is hence undertaken to fill this lacuna.

This study is based on the snakes in the collections in

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the Zoology Department of St. Josephs College; Devagiri, Kozhikode. The collection focuses on the period between 1957and 1970 and derives mostly from the effort of late Mr. Cyril Edwards, a taxidermist and snake enthusiast in the Zoology Department. All specimens except two species were collected within a 10km radius of Devagiri at 11.26^{0}N & 75.83^{0}E. No scientific studies have been carried out on this collection other than Adiyodi (1960, 1961, 1963). This paper is aimed at presenting a check list of snakes in the college museum, collected from Devagiri and the surrounding areas in Kozhikode, between 1957 and 1970 with special attention on rare and restricted range species. We compared this data with the collections from Kerala in the North American museums and the British Museum which hold the largest holdings of Indian species outside India, to obtain information on the status and distribution of these species in Kerala. Though the snakes were not collected systematically to study their abundance, the frequency of different snake species in the collection can offer an approximate estimate of their relative abundance in the area, while also considering the inherent complexities such as detection probability and seasonal dynamics, to name a few. (Miller & Zug 2016)

Area of collection

Most areas around Devagiri, (8km from Kozhikode city towards east) from where the specimens were collected, consisted of open secondary scrub jungle and stretches of laterite, sparsely covered with grass intermixed with a few groves of cashew on hilltops and hillsides, with valleys in between, mostly under paddy cultivation. Coconut is grown on many slopes. Menon (1962) has given a detailed description of the area. Secondary vegetation including scrubby trees and bushes also occur in some areas, between the hilltop and the low lying paddy fields. The terrain is undulating with an average elevation of 60m. Weather is hot and humid, with summer season from March to May followed by the southwest monsoon from June to September. Rains may continue till December. The area is an ideal habitat for snakes such as the Sawscaled Viper *Echis carinatus* and Sand Boa *Eryx conicus*. There has been an increase in human settlements over the last 60 years though there are several Sacred Groves/ snake groves in the area supporting wildlife including snakes. (Menon 1962)

The following list mentions the snake species of Kozhikode vouchered in the St. Josephs College collection. The specimens were reexamined recently (August 2017) by the authors to confirm their species identity.

Systematic list

Family Typhlopidae

1. Grypotyphlops acutus (Dum & Bibr.): One specimen (SJC 011). It was collected in 1969 at Kozhikode. A species found in peninsular India (Whitaker & Captain 2004). There is a specimen from Kannur in the Museum of Comparative Zoology (MCZ) Cambridge (Constable 1949).

Family Pythonidae

2. *Python molurus* (Linnaeus): One specimen (SJC 012) It was collected in 1967 at Kozhikode. It is a southern Asian species common in lowlands, close to densely populated areas of the city and regularly prey on poultry in the country side.

Family Erycidae

3. *Eryx conicus* (Schneider): One specimen (SJC 013): It was collected in 1972 at Devagiri. It occurs in drier parts of India. There is a specimen from Kottayam in the United States National Museum,(USNM) Washington, D.C. (USNM 193291 date of collection and name of collector not known) and in the Cornell University Museum of Vertebrates, (CUMV) Ithaca, collected from Kottayam (CUMV 0009191) on 3 August 1970 by S Ranganathan and from Kollam (CUMV 0009303) collected on 21 August 1970 by Ram S. Singh. Its occurrence at Kottayam, a heavy rainfall area is noteworthy.

Family Colubridae

4. *Dryocalamus nympha* (Daudin): One specimen (SJC 014): It was collected in1969 at Devagiri. The species occurs in Indian peninsula and Sri Lanka.

5. *Ptyas mucosa* (Linne): Two specimens (SJC 015,16): It was collected in1956 at Devagiri. Once widespread across South and Southeast Asia today declining in numbers. There is a specimen in USNM from Nelliampathy, Palakkad District (USNM 42468 date of collection and name of collector not known) and one from Ponmudi, Trivandrum District in Carnegie Museum, Pittsburgh (CM 115060) collected on 30 June 1984 by Carl, Gans.

6. *Oligodon arnensis* (Shaw): One specimen (SJC 017): It was collected in 1969 at Devagiri. It is a south Asian species. CM has two specimens from Kottayam. (CM 69181, 69183) collected on 26 May 1970 by F.H. Rahmani.

7. *Oligodon taeniolatus* (Jerdon): One specimen (SJC 018) It was collected in 1969 at Devgiri and is a South Asian species. There are specimens in MCZ collected from Taliparamba, Kannur District by Wall (1905).

California Academy of Sciences (CAS) San Francisco, has three specimens collected from Malabar (CAS Herp 17240, 171241, 17242) by R.H. Beddome, date of collection is not known.

8. *Dendrelaphis tristis* (Daudin): One specimen (SJC 019): It was collected in 1960 at Devagiri. It is a widespread species in South Asia. There are specimens in CM from Sholiar, Thrissur District. (CM 122116) collected on 27 July 1986 by Carl Gans and in CAS from Trivandrum (CAS 14921) collected on January 1941 by A.W.C.T. Herre. A live specimen was kept in the Zoology Department for a year.

9. *Lycodon aulicus* (Linnaeus): One specimen (SJC 020): It is collected in1959 at Devagiri and found in South Asia. One specimen in CAS from Kozhikode (CAS 15946) was collected on 13 January 1941 by A.W.C.T. Herre, one from Ponmudi in CM (CM115061) collected on 30 June 1984 by Carl Gans) and one from Taliparamba in MCZ. (Constable 1949).

10. *Lycodon travancoricus* (Beddome): One specimen (SJC 021): It was collected in 1995 at Kozhikode and occurs in southern India, Madhya Pradesh and Odisha. It is reported from Laccadives (Adiyodi 1963) where it was probably introduced. There are specimens from Ernakulum in CAS, (CAS 15967) collected on 17 January 1941 by A.W.C.T. Herre, from Kottayam in Louisiana State University Museum of Zoology, Baton Rouge (LSUMZ 24708) collected on 26 April 1970 by F. H. Rahmani, in USNM from Travancore (USNM 129726 date of collection and name of collector not known) and from Ponmudi in Field Museum of Natural History, Chicago (FMNH 217705) collected on 23 May 1982 by R. F. Inger and H. B. Shaffer.

11. *Lycodon flavomaculatus* (Wall): One specimen (SJC 022): It was collected in 1960 at Devagiri and is also found in the Western Ghats of Maharashtra, Karnataka and Kerala at an altitude range of 550–650 m (Wallach et al. 2014).

12. *Amphiesma stolatum* (Linne.): One specimen (SJC 023): It was collected in1959 at Kozhikode and occurs in South and Southeast Asia. There is one specimen in FMNH from Travancore (FMNH 171766) collected on 20 September 1969 by S.R. Ranganathan

13. *Boiga cf. thackerayi* Giri, Deepak, Captain, Pawar & Tillack, 2019: One specimen (SJC 024). It was collected in May 1961 from Kozhikode. It also occurs in southwestern India (Ganesh et al. 2020). There is a specimen from Nelliampathy, Palakkad District, in USNM (USNM 42469 date of collection and name of collector not known) two from Periyar Tiger Reserve in the Wildlife division, Thekkady (Zacharias 1997) and two from Ponmudi in (FMNH 217701, 217702) collected on 4 June 1982 and 2 June 1982 respectively by R.F. Inger and H.B. Shaffer.

14. *Boiga trigonata* (Schneider): One specimen (SJC 025) It was collected in 1959 at Devagiri. It also occurs in South Asia. Wall (1905) collected it from Taliparamba. There are two specimens in CAS from Malabar (CAS 17245,17246) collected by R.H. Beddome date of collection not known) three from Kottayam; two in LSUMZ (LSUMZ 24702 and 45546) collected on 21 April 1970 by S.R. Ranganathan and on 5 July 1978 B. Sinha) and one in CM (CM 68862) collected on 21April 1968 by S.R. Ranganathan.

15. *Ahaetulla. nasuta* (Lacepede): One specimen (SJC 026): It was collected in 1959 at Devagiri and is fairly common in South and Southeast Asia. There are five specimens in FMNH from Ponmudi, Trivandrum District (FMNH 217689-217693) collected on May/June 1982 by R.F. Inger and H.B. Shaffer) and one in CM from Peppara Dam, in Trivandrum District (CM 114960) collected on 29 June 1984 by Carl Gans.

Family Elapidae

16. *Bungarus caeruleus* (Schneider): One specimen (SJC 027): It was collected in 1959 at Kozhikode. It is fairly common in the Indian subcontinent.

17. *Calliophis melanurus* (Shaw): One specimen (SJC 028). It was collected in 1960 at Kozhikode. It is found in western and southern India, Uttar Pradesh, Sri Lanka. It is common in the plains of Kozhikode (Kumar et al. 2010)

18. *Calliophis nigrescens* (Gunther): One specimen (SJC 029): It was collected in. 1959 at Nilambur. It is a Western Ghats endemic (McDiarmid et al. 1999). There is a specimen in USNM from Nelliampathy (USNM 42467) name of collector and date of collection not known) and Travancore in CAS (CAS 17265 collected by R.H. Beddome date of collection not known). Recently collected from Periyar Tiger Reserve (Radhakrishnan 1999) and Kozhikode near sea coast (Kumar et al. 2010).

19. *Naja naja* (Linn.): Four specimens (SJC 030,31,32,33): It was collected in 1958 at Devagiri. It is a widespread species and is fairly common in the Indian subcontinent.

20. *Hydrophis schistosus* (Daudin): One specimen (SJC 034): It was a common sea snake and was caught from the Kozhikode Coast.

Family Viperidae

21. *Daboia russellii* (Shaw & Nodder): Three specimens (SJC 035,36,37): It was collected in 1957 at Devagiri. It is a widespread species in the area and occurs in South

Asia. There are three specimens from Kottayam, one in CM (CM 69425) collected on 27 July 1962 by S. Perveen; two in LSUMZ (LSUMZ 79887, 79888) collected on 18 April 1969 by B. Sinha and S.R. Ranganathan. There are two specimens in FMNH; one each from Travancore and Kerala (FMNH 171564, 171769) collected on 26 August 1965 and 5 August 1966 by Ranganathan).

22. *Echis carinatus* (Schneider):Two specimens (SJC 038,39): It was collected in 1959 at Devagiri. It occurs throughout India in semidesert and arid tracts and is found in Malabar region but not in southern Kerala (Adiyodi 1961, Daniel 2002). There are two specimens collected from Kozhikode in the college museum. The first author has observed several in 1970's in the Calicut University Campus where two persons died of the bite of this species. Vidal (1890) mentions the influence of *Echis carinatus* in the death rate in Northern Kanara during the last century. Museum of Natural History, University of Florida (UF), Gainesville has specimens from Kottayam (UF 766745) collected by Mahajan on 3 November 1977, Kollam (UF 74270, 74271, 74272) collected by S. Shantaraman on 4 August 1971, and Trivandrum (UF 74269) by Raman Venket on 28 May 1971. LSUMZ has two specimens from Trivandrum (LSUMZ 24719, 24720) collected by Raman Venkat on 28 May 1971 and CAS has a specimen from Malabar (CAS 17277 collected by R.H. Beddome date of collection not known). Its occurrence at Kottayam a heavy rainfall area needs further investigation. The species appears to have a wide distribution in northern and southern Kerala; mostly in the south.

23. *Hypnale hypnale* (Merrem): One specimen (SJC 040): It was collected in 1969 at Kozhikode. It occurs in the Western Ghats as far north as Lat. 16^0 and Sri Lanka. (Murthy 1990, McDiarmid et al. 1999). In India it is found in the Western Ghats (Smith 1943, McDiarmid et al. 1999). The species occurs at an elevation ranges of 300–600 m in India but from sea level to 1,524m in Sri Lanka (Whitaker & Captain 2004). It has been recorded from Annamalai's, Palani Hills and New Amarambalam, Nilambur (Murthy 1990). Recently two specimens were collected from Idukki Wildlife Sanctuary (Radhakrishnan 1999) and two from Periyar (Zacharias 1997). One was caught from decaying litter an agricultural landscape at Mevada, Kottayam District, Kerala at about 50m, in May 2001. The specimen was, about 20cm in length unfortunately was killed by a farm worker, while clearing weeds at the base of a pepper vine.

There are four specimens of the Humpnosed Pit viper in the MCZ, collected from Taliparamba at 55m, (Constable 1949) a low elevation area not that far from the sea coast. CM has one specimen from Vazhachal near Thrissur (CM 151746) collected by Gans et al. on 15 June 1990, FMNH has six specimens from Ponmudi (FMNH 217683-217688) collected by R.F. Inger and H.B. Schaffer in May/June 1982 and CAS has one specimen each from Malabar and Travancore (CAS 12269,12270). There is a specimen from Nelliampathy, Palakkad District in the Natural History Museum London (NHMUK ZOO 1911.5.4.5) . Seems to have a wide distribution in Kerala in the low lands and hills. The Humpnosed Pit Viper is very common in Kannur, northern Kerala as evidenced by the number of humans bitten by this species (Roshnath et al.2018)

24. *Trimeresurus malabaricus* (Jerdon): One specimen (SJC 041): It was collected from Pulloorampara, about 300m, Kozhikode District, on 30.iii. 1960. Smith (1943) and McDiarmid et al. (1999) reported the species to occur at a range of 600–2,000 m elevations in southern and western India. It is not widespread but reasonably common in its range (Whitaker & Captain 2004). USNM and Natural History Museum, London, UK (NHMUK) have specimens from Nelliampathy (USNM 42470 and NHMUK 1936.9.10.3). CAS has two from Ponmudi (CAS 125400 , 124089) collected by J.C. Daniel on 9 May 1965 and May 1969 respectively and one from Travancore (CAS 17274 name collector and date of collection not known) CM has two specimens from Sholiyar collected at 450m (CM122112, 122113) by Gans et al. on 27July 1986. There are 25 specimens from Ponmudi; 20 in FMNH (FMNH 217663 217682) collected at altitudinal range of 110–920 m by R.F. Inger and B.S. Shaffer in May/June 1982 and five in CM (CM 114910,115037,115132, 115133, 115195) collected by Gans et al. in July 1983 and June 1984. MCZ has a specimen from Kannur at an elevation of 900m (MCZ 119447) collected by W.L. Brown, Wildlife Division, Thekkady has one from Periyar (Zacharias 1997) and Natural History Museum London has two from Wayanad (NHMUK 1874.4.29.1 and 1955.1.3.6971). *T. trimeresurus* seems to be the most abundant species in the hills of Kerala. Wall (1919) collected 163 specimens from Wayanad in 1917.

Relative abundance

With twentytwo species, (excluding the sea snake and the two species collected from Nilambur and Pulloorampara) the suburb of Kozhikode once harbored a diverse snake fauna. The study was not conducted to obtain abundance data but the frequency of vouchering different snake species in the collection of the Zoology Department, offers an approximate estimation of potential relative abundance (Miller & Zug 2016). The number of individuals of each species in the zoology museum collection might potentially provide an approximate measure of snake abundance at Kozhikode during that time period. Obviously, a species' size and ease of sighting and collecting will influence the preponderance of any individual species' presence in the collection, but nevertheless it might also imply what is rare and common (Zug pers comm, vide email dated 28.ix.2016). For example, the Common Worm Snake *Indotyphlus braminus* a very common and widespread species (Whitaker & Captain 2004) is not present in this collection, but would be present in Kozhikode area. There are two specimens of this species from Malabar in MCZ. The well collected species in the collection was the Common Cobra *Naja naja* (4) which is followed by the Russell's Viper *Daboia russellii* (3). The relative abundance of the Common Cobra nearly doubles that of the third and fourth most abundant species; *Ptyas mucosa* (2) and *Echis carinata* (2), two species that have completely contrasting ecological and natural history traits. All the other species were represented by one specimen each. Random field observation during the years 1997–2000 supported this finding though people live in the area believed the Russell's Viper, is the most abundant species in the area.

Conclusion

This study highlights the often hidden resources housed in museum collections in colleges and other unassuming and modest natural history holdings that can be leveraged for studies on poorly known species (e.g. *Nasikabatrachus* sp. and *Dieurostus dussumuerii*). Our paper suggests that the distribution of several species of snakes as already known and their habitats may not be accurate. Records show that the criteria of collection are generally biased towards representation of a few species or sites leaving majority without any representation in a biodiversity document. College museums are important in this context. We hope our study may stimulate others to collect information on snake species in more college museums in the state. The habitats from where the specimens were collected have undergone drastic changes during the last 50 years. Koshy et al. (1987) found that the number of amphibian and reptiles caught in a southern Indian riparian habitat, were higher than expected and very few were caught under rock and logs. It would be interesting to conduct a survey on the current status and distribution of snakes from various habitats in the Devagiri and surrounding areas in the Kozhikode District. Most reptiles show strong seasonal occurrence (Wall 1905; Zug et al. 1998; Akani et al. 2013; Rahman et al. 2013; Roshnath et al. 2018) though Hofer & Bersier (2001) believed that high annual rainfall and the lack of a pronounced dry season should minimize potential effects of climatic properties. A yearround survey in the area, may yield comprehensive information on the current status and ecology of this fascinating group of animals.

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NOTE

Notes on the occurrence of a rare pufferfish, *Chelonodontops leopardus* (Day, 1878) (Tetraodontiformes: Tetraodontidae), in the freshwaters of Payaswini River, Karnataka, India

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The pufferfish genus *Chelonodontops* Smith, 1958 distinguishes itself from other genera of pufferfishes through the combination of the following characters: presence of two lateral lines on the flanks of the body, nasal organ with two flat skin flaps in appearance and a weakly developed skin fold that extends in the ventrolateral part of the body from the chin to the caudal fin base (Matsuura 2002; Psomadakis et al. 2018). The genus *Chelonodontops* currently consists of six valid species, viz.,: *Chelonodontops patoca* (Hamilton, 1822) widely distributed in the Indo-Pacific*, C. leopardus* (Day, 1878) known from India and Myanmar, *C. pleurospilus* (Regan, 1919) found in the eastern coast of South Africa, *C. laticeps* (Smith, 1948) also occurs along the eastern coast of South Africa to Madagascar, *C. alvheimi* Psomadakis, Matsuura & Thein 2018 reported off Myanmar, the Andaman Sea and the Bay of Bengal, and *C. bengalensis* Habib, Neogi, Oh, Lee & Kim 2018 described from Bangladesh (Fricke et al. 2019).

From India, only two species of *Chelonodontops* have been recorded till date, viz., *C. patoca* (mostly recorded as *Chelonodon patoca*) and *C. leopardus* (reported as *Arothron leopardus*). Day (1878) described a pufferfish species *Tetrodon leopardus* and stated its locality as 'seas of India', but no specific locality mentioned. Furthermore, it has been listed/reported from the state of Kerala (Bijukumar & Deepthi 2009; Zeena & Beevi 2012), from Pulicat Lake (Raj et al. 2002) and Tamil Nadu coast (Krishnan et al. 2007; Ramesh et al. 2008; Barman et al. 2011) on the southeastern coast.

This study reports *Chelonodontops leopardus* from the Payaswini River located in the state of Karnataka, India about 65km upstream from the estuary.

Material: Six specimens of the species were collected from the Payaswini River (12.568^{0}N & 75.382^{0}E) near Sullia, Dakshina Kannada District of the state of Karnataka, southwestern India. The specimens were fixed in 10% formalin and preserved in 70% ethanol and deposited to the marine fish section of Zoological Survey of India, Kolkata and catalogued with no. ZSI F 13527/2. All measurements and counts follow Dekkers (1975). The measurements were made point to point using digital vernier callipers.

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***Chelonodontops leopardus* (Day, 1878)**
Image 1–2

Tetrodon leopardus Day, 1878, *The fishes of India*, (4): 706, Pl. 180 (fig. 2) (type locality: seas of India)

Chelonodontops leopardus Psomadakis et al. 2018, Ichthyological Research, 66(1): 52. (India and Myanmar).

Material examined: ZSI F 13527/2, 6 ex., 66.7–85.5 mm SL, Payaswini River (12.568^{0}N & 75.382^{0}E) near Sullia, Dakshina Kannada District, Karnataka, 16.v.2018, Priyankar Chakraborty.

Description: Selected morphometric measurements are provided in Table 1. Dorsal surface covered with spinules that originate from the interorbital region and extends to a midpoint between pectoral and dorsal fin origin. Ventrally extended from the throat to the anterior portion of the anus. Two lateral lines, one extending from caudal fin base right up to the posterior region of the eye and the second one branching out from the mainline near the caudal peduncle and continues ventrolaterally posterior to the pectoral fin. Nasal organ with equal-sized flat skin flaps. The body is moderately elongated. Dorsal fin rays 11; anal fins rays 8–9; pectoral fin rays 16–18; caudal fin rays 10–11. Dorsal fin origin slightly anterior to vertical through that of the anal fin. Caudal fin truncate. Olive green dorsally with a multitude of iridescent yellow spots which turns white on the ventro-lateral part of the body. Ventral side of the body white in color. Anal fin dusky, caudal fin dark brown with several rows of white spots, pectoral and dorsal fins pale. Three cross bands across the body with the one over the head shaped like a V followed by a thinner interorbital band. The second above the pectoral fin and the third one from the base of the dorsal fin.

Image 1. *Chelonodontops leopardus* live (dorsum) coloration photographed soon after collection.

Image 2. *Chelonodontops leopardus*: coloration under preservation (85.5mm SL)

Discussion

Francis Day described *Tetrodon leopardus* from the 'Seas of India' and no specific type locality was mentioned (Day, 1878). Ferraris et al. (2000), however, mentioned that the syntype of this species at the Australian Museum (AMS B.7722) was from Madras (=Chennai). As observed from a specimen catalogue at Zoological Survey of India, another specimen with catalogue number ZSI F2260 (currently lost) was purchased from Day and supposedly collected from Canara (=Karnataka). This species was long treated under the genus *Arothron* until Psomadakis et al. (2018) considered it as a member of the genus *Chelonodontops* and redescribed with detailed diagnostic features. It has been listed/reported as *Arothron leopardus* by many researchers across India (Jisha et al. 2004; Krishnan et al. 2007; Ramesh et al. 2008; Barman et al. 2011; Zeena & Beevi 2012). Psomadakis et al. (2018) examined materials of *C. leopardus* and placed them in the genus *Chelonodontops* with the redescription of the species based on only two specimens. They further mentioned that the syntype (AMS B.7722) from Chennai(?) is a smaller individual and hence ontogenical and geographical differences maybe indicative of variation among populations.

It is interesting to note that the fish presently under discussion were collected from inland freshwater body roughly 65km from the nearest estuarine zone. Mastsuura (2017) suggested that 'many marine dwelling pufferfishes enter estuaries and rivers'. Among the pufferfishes occurring in India, few species such as *Carinotetraodon imitator* Britz & Kottelat 1999, *C. travancoricus* (Hora &

Image 3. 'Yellow-spotted Pufferfish' in aquarium trade.

Table 1. Morphomerticcharacters of examined *Chelonodontops leopardus* from Payaswini River, Sullia, Karnataka.

Characters	Percentage of SL/HL
Standard length (SL)	-
Head length (HL) in % of SL	33.9–42.5
Predorsal length in % of SL	66.5–78.3
Dorsal fin length in % of SL	17.8–22.3
Pectoral fin length in % of SL	13.2–17.1
Anal fin length in % of SL	16.3–19.1
Caudal fin length in % of SL	25.3–30.2
Caudal peduncle depth in % of SL	13.6–14.3
Eye diameter in % of HL	29.8–35.7
Interorbital width in % of HL	54.9–61.1

Nair 1941), *C. patoca* (Hamilton 1822), *Dichotomyctere fluviatilis* (Hamilton 1822), *D. nigroviridis* (Marion de Procé 1822), *Leiodon cutcutia* (Hamilton 1822), and *Pao palembangensis* (Bleeker 1851), are known from freshwater regions.

Chelonodontops patoca have been reported from the freshwaters of Karnataka and Kerala (Arunachalam et al. 1999, 2009). In both these reports, the diagnosis of species does not include any information about spinules on back, which is a major distinguishing character from *C. leopardus*. While *C. patoca* has spinules on the dorsal surface of head and body extending from behind inter-orbital space nearly to dorsal fin origin, in *C. leopardus* that extends from interorbital region to midpoint between pectoral fin and dorsal fin origin (Psomadakis et al. 2018). The original delineation of *C. patoca* by Hamilton (1822) does not have any spot on the caudal fin, while both the figures provided by Arunachalam et al. (1999, 2009) have caudal fin bearing spots similar to the body which is a character close to that of *C. leopardus*. Further examination of *C. patoca* materials, mentioned in Arunachalam et al. (1999, 2009), are needed to clarify the taxonomic status or morphological variant. Also, a similar species dubbed as the Yellow-spotted pufferfish (Image 3) sometimes occur in the aquarium trade. It adheres to the description of *C. leopardus* in possessing spots in the caudal fin region. The Payaswani River originates from Patti Ghat Hills in Coorg District of Karnataka, which flows through Sullia Town (Dakhin Karnataka), enters Kerala, and finally reaches Kasaragod Town where it drains into the Arabian Sea. The present material obtained near Sullia Town is far away in upland than those of Arunachalam et al. (2009) collected from the same river.

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NOTE

New records of hoverflies of the genus *Volucella* Geoffroy (Diptera: Syrphidae) from Pakistan along with a checklist of known species

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The genus *Volucella* Geoffroy, 1762 belongs to the tribe Volucellini of the subfamily Eristalinae, which appears to mimic bumblebees or wasps. The adults are characterized by their large, broad and robust body, extended downward face and plumose arista, feathered with long hairs and cell R1 closed before the wing border (van Veen 2010). This genus comprises of three species groups—Bombylans, Pellucens, and Zonaria—based on their colouration and external body appearance (Barkalov 2003). The members of bombylans group are long-haired bumblebee mimic hoverflies, the pellucens group are mostly black species with short hair that have their second abdominal tergites completely pale or with at least a pair of yellow to pale brown spots, and the zonaria group have striped abdomens (wasp mimics). So far known, their larvae have different modes of feeding: first those larvae obtained from wounds caused by goat moths on old deciduous trees feed on wet material accumulated by the action of moths. The second type inhabit the nests of social wasps and bumble bees and are detritivores and larval predators, (except *Volucella inflata*, that appears to live in tunnels made by other insects in which sap and insect faeces/tree humus provide a sub-aqueous mix). The third type are scavengers and facultative or obligatory predators or ectoparasitoids (Rotheray 1999; Speight 2003).

In the process of compiling the checklist of the family Syrphidae, 81 species under 42 genera of hoverflies are recorded from Pakistan (Shehzad et al. 2017; Hassan et al. 2018a,b, 2019, 2020) in comparison with Indian hoverflies which are 357 species in 69 genera (Ghorpadé 2015). The genus *Volucella* Geoffroy, 1762 is recently reported from Pakistan (Shehzad et al. 2017) and the current study aims to update the list of known and new records of this genus.

Material and Methods

The adult specimens of the new country records were collected from the flowers of *Buddleja davidii* at Kuldana, Murree, Punjab, Pakistan. The photographs of the previously known species (*V. ruficauda*) were obtained from the National Insect Museum, Islamabad, Pakistan. The collected specimens were identified by using Choi et al. (2006) and further details are provided in remarks. The specimens were photographed using Olympus SZX7 stereomicroscope attached with a Sony CCD digital

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camera. The identified specimens are deposited in the insect collection at National Insect Museum, Islamabad and Laboratory of Biosystematics, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan. The list of all known species is compiled from Ghorpadé (2015) and Shehzad et al. (2017).

Results

The present study was conducted to update the genus *Volucella* from Pakistan based on previous literature. As a result, *Volucella pellucens tabanoides* Motschulsky, 1859 is a new record.

Taxonomy

Genus *Volucella* Geoffroy, 1762

Diagnostic characters: *Volucella* are large, broad-bodied hoverflies. They can easily be diagnosed by the downwardly extended face, with moderately long third antennal segment with basal arista, arista plumose; abdomen oval in shape; legs simple; wings with marginal cell closed, anterior cross-vein distinctly before middle of discal cell; apical portion of fourth vein distinctly recurrent; second vein bristle at base.

Volucella peleterii (Macquart, 1834) (Image 1A–C)

Material examined: #103, 1 male, PMAS-Arid Agriculture University, Rawalpindi, Punjab, Pakistan (33.647^{0}N & 73.083^{0}E, 511m).

Diagnostic characters: Pubescence on the body usually short, not dense; antennae and head wholly orange; epistome produced with short yellowish, with some black hairs, central bump distinct (Image 1C); thorax brownish-orange, scutellum orange with golden hairs sometime mixed with black hairs; wings brownish (Image 1A); legs orange with short orange pubescence (Image 1B); abdomen with tergite 1 and base of second grey livid, tergite with three largely triangular spot in the centre, tergite 4 with a little tinged with brown towards the tip (Image 1A).

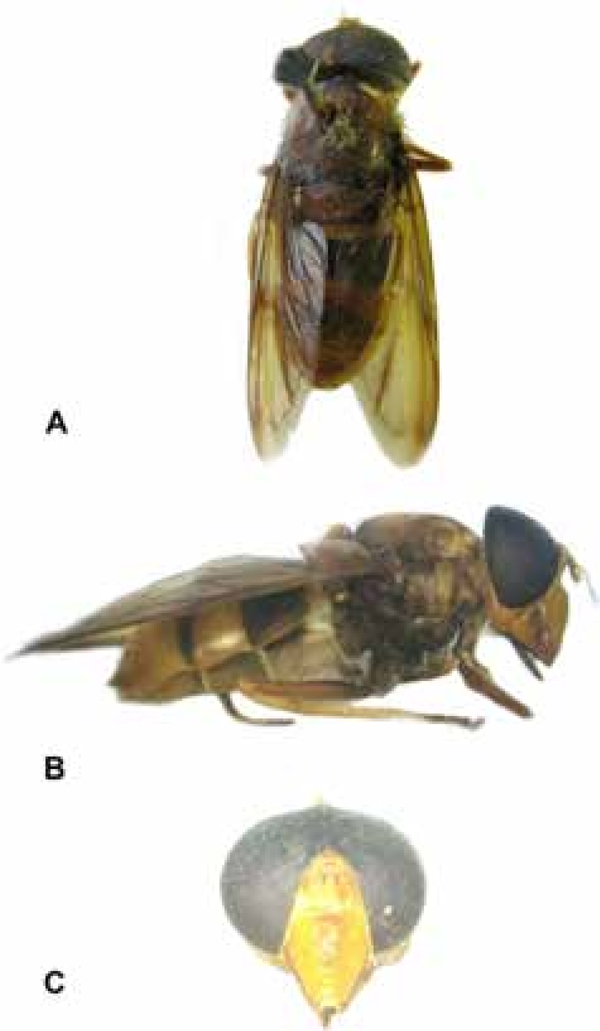

Image 1. *Volucella peleterii*: A—dorsal habitus | B—lateral habitus | C—frontal view. © Shakeel Ahmed

Distribution: Pakistan: Azad Jammu & Kashmir: Muzaffarabad; Gilgit-Baltistan: Gilgit; Punjab: Murree (Shehzad et al. 2017). India: Jammu & Kashmir (Ghorpadé 2015). A single male specimen of this species at Department of Entomology, PMAS-Arid Agriculture University and possibly collected from Punjab province of Pakistan [deposited at Department of Entomology, PMAS-Arid Agriculture University].

Key to the species of genus *Volucella* for Pakistan

1. Body densely pubescent (Image 3A–B); face black (Image 3C) .... *ruficauda*
- Body bare; face yellowish-orange 2
2. Abdominal tergite 2 wholly yellowish-white (Image 2A); thoracic dorsum shining black, brownish along humeri and along the side margins (Image 2A) .... *pellucens*
- Abdominal tergite 2 almost entirely black (Image 1A); thoracic dorsum brownish-orange (Image 1A) .... *peleterii*

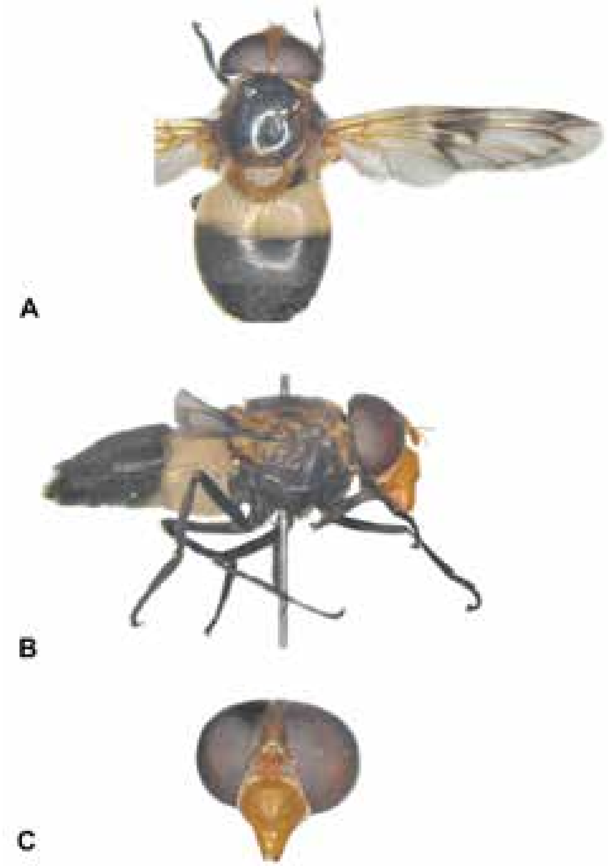

Image 2. *Volucella pellucens tabanoides*: A—dorsal habitus | B—lateral habitus | C—frontal view. © Imran Bodlah

Volucella pellucens tabanoides Motschulsky, 1859 (Image 2A–C)

Material Examined: #104, 2 males, 1 female, 18.vii.2018, Kuldana, Murree, Rawalpindi, Punjab, Pakistan (33.925^{0}N & 73.405^{0}E, 1,928m), leg. M.A. Hassan.

Diagnostic characters: Pubescence on the body usually short, not dense; head tawny, frons little produced, antennae orange (Image 2C). Thorax shining black, brownish along humeri and along the side margins, scutum posteriorly with distinct brown triangular macula (*V. pellucens tabanoides* Motschulsky); scutellum tawny with long black bristles along margin (Image 2A); pleuron black; legs black, knees a little brownish-orange (Image 2A-B). Abdomen short-ovate, second segment wholly yellowish-white remaining black, pubescence on abdomen black except along the basal margin of second abdominal segment white; wings, veins on basal half pale orange, a distinct black marks in middle and at tip, the veins along hind margins blackish, squamae brownish with orange margins and fringe, halter brown (Image 2A).

Remarks: Coi et al. (2006) remarked that there is a clear difference between Far Eastern and European subspecies of *V. pellucens* especially in females. Females of *V. p. tabanoides* (Russian far east, Mongolia, China, Korea, and Japan; Oriental region can be distinguished from those of *V. p. pellucens* (widespread in western Palaearctic region) by their scutum with distinct brown triangular prescutellar macula. Based on this remarks about *V. p. tabanoides* on distribution probably present in the Oriental region and scutum posteriorly with distinct brown triangular macula; the Pakistani *V. pellucens* species should be *V. p. tabanoides*. We are, however, not sure about the subspecies status of the Indian *V. pellucens* reported from Jammu & Kashmir and Uttarakhand.

Host plant: *Buddleja davidi* Franch.

Volucella ruficauda Brunetti, 1907 (Image 3A–C)

Diagnostic characters: This species can easily be diagnosed by body with densely covered pubescence

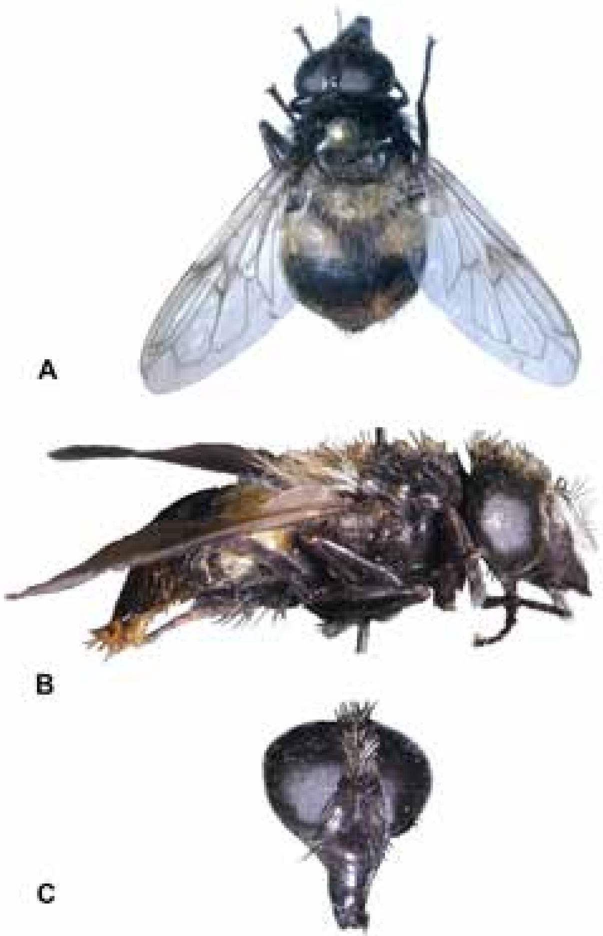

Image 3 . *Volucella ruficauda*: A—dorsal habitus | B—lateral habitus | C—frontal view. © Anjum Shehzad

(Image 3A–B); head black, vertex in female with yellow bristles, epistome produced with short black pubescence (Image 3C); thorax black with mixed yellowish and black bristles, scutellum orange with long yellowish bristles; wings yellowish grey with brownish suffusion in middle (Image 3A); legs brownish (Image 3B); abdominal tergite 2 with large triangular spots on lateral sides, remaining black (Image 3A), abdominal tergite 3–5 with red hairs (Image 3B).

Distribution: Pakistan: Gilgit-Baltistan, Deosai (Shehzad et al. 2017). India: Jammu & Kashmir and Sikkim (Ghorpadé 2015).

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NOTE

A new species of *Dillenia* (Angiosperms: Dilleniaceae) from the Eastern Ghats of Andhra Pradesh, India

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The genus *Dillenia* L. is represented by ca. 60 species distributed from Madagascar and Seychelles to the Fiji Islands and India to southeastern Asia and Australia (Hoogland 1952; Mabberley 2008). In India the genus is represented by seven species (Majumdar 1993), of which four are reported from Andhra Pradesh (Pullaiah et al. 2018). *Dillenia andamanica* C.E. Parkinson and *D. bracteata* Wight are strictly endemic to the Andaman & Nicobar Islands and the Western Ghats, respectively (Singh et al. 2015). Initially, *D. bracteata* Wight was also reported from Sri Lanka based on Wight collections, but, while revising the family, Wadhwa (1996) ruled out the distribution in Sri Lanka and stated that 'both specimens are wrongly labelled'.

While working on the project 'Non Detrimental Finding Studies (NDFs) on Red Sanders (*Pterocarpus santalinus* L.f.) tree in India', a *Dillenia* species with white flowers was collected from the Chittoor District of Eastern Ghats, Andhra Pradesh. After critical studies and comparison with all known species, the material is recognized as a novelty that markedly differs from all known species of *Dillenia*. Hence, it is described here as a new species.

Dillenia tirupatiensis J. Swamy & Rasingam sp. nov.
(Image 1; Figure 1 & 2)

Type: 8858 (Holotype CAL; Isotypes BSID), 09.v.2018, Musalipedu Beat, 13.617222°N & 79.647778°E, 802m, Papanaidupet Section, Tirupati Range, Chittoor East Forest Division, Chittoor District, Andhra Pradesh, coll. J. Swamy.

Diagnosis: *Dillenia tirupatiensis* is allied to *D. hookeri* by its inflorescence, bracteoles, and shape of seeds but differs by its elliptic-obovate leaves (oblong-oblanceolate in *D. hookeri*), crenate margins (entire to slightly dentate in *D. hookeri*), 8–10 mm long pedicel (15–40 mm in *D. hookeri*), 8mm long bracteoles (20–35 mm in *D. hookeri*), white flowers (yellow in *D. hookeri*), ovules that are in four rows at the base and two rows at the apex of the placenta (two rows in *D. hookeri*) and styles that are erect and parallel for up to 3mm before spreading (spreading from the base in *D. hookeri*) (Table 1).

Description: Deciduous tree 2–5 m high; bark grayish; branches sympodial, younger ones 3.5–8 mm thick, densely tomentose, the hairs on older branchlets appressed, glabrescent. Leaf scars clasping about half of branch, subfalcate, with emarginate upper margin,

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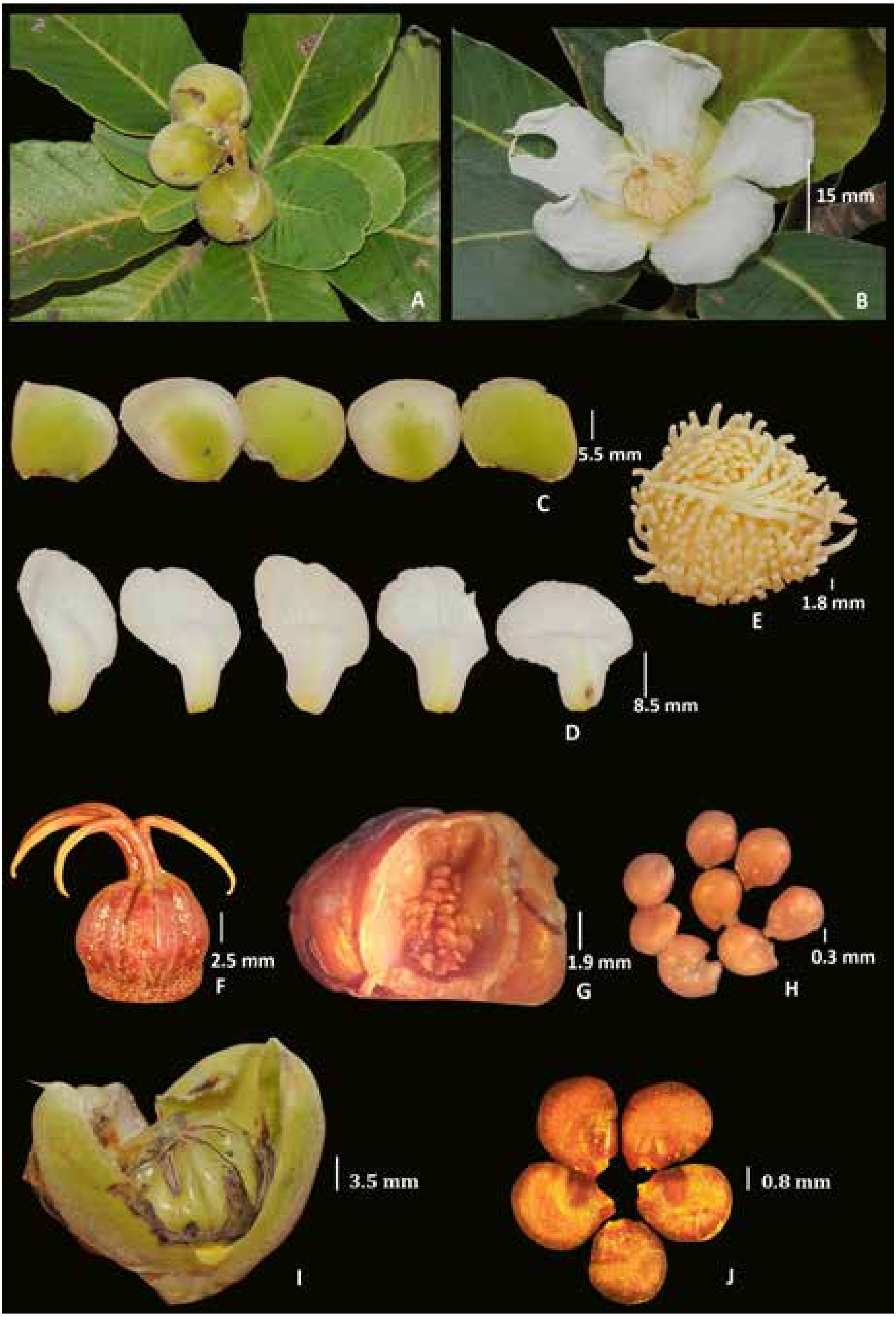

Image 1. *Dillenia tirupatiensis* J. Swamy & Rasingam sp. nov. A—inflorescence| B—flower | C—sepals | D—petals | E—stamens & pistil | F—pistil | G—carpel with 2–4 rows of ovules | H—ovules | I—pseudocarp | J—seeds. Photos by J. Swamy

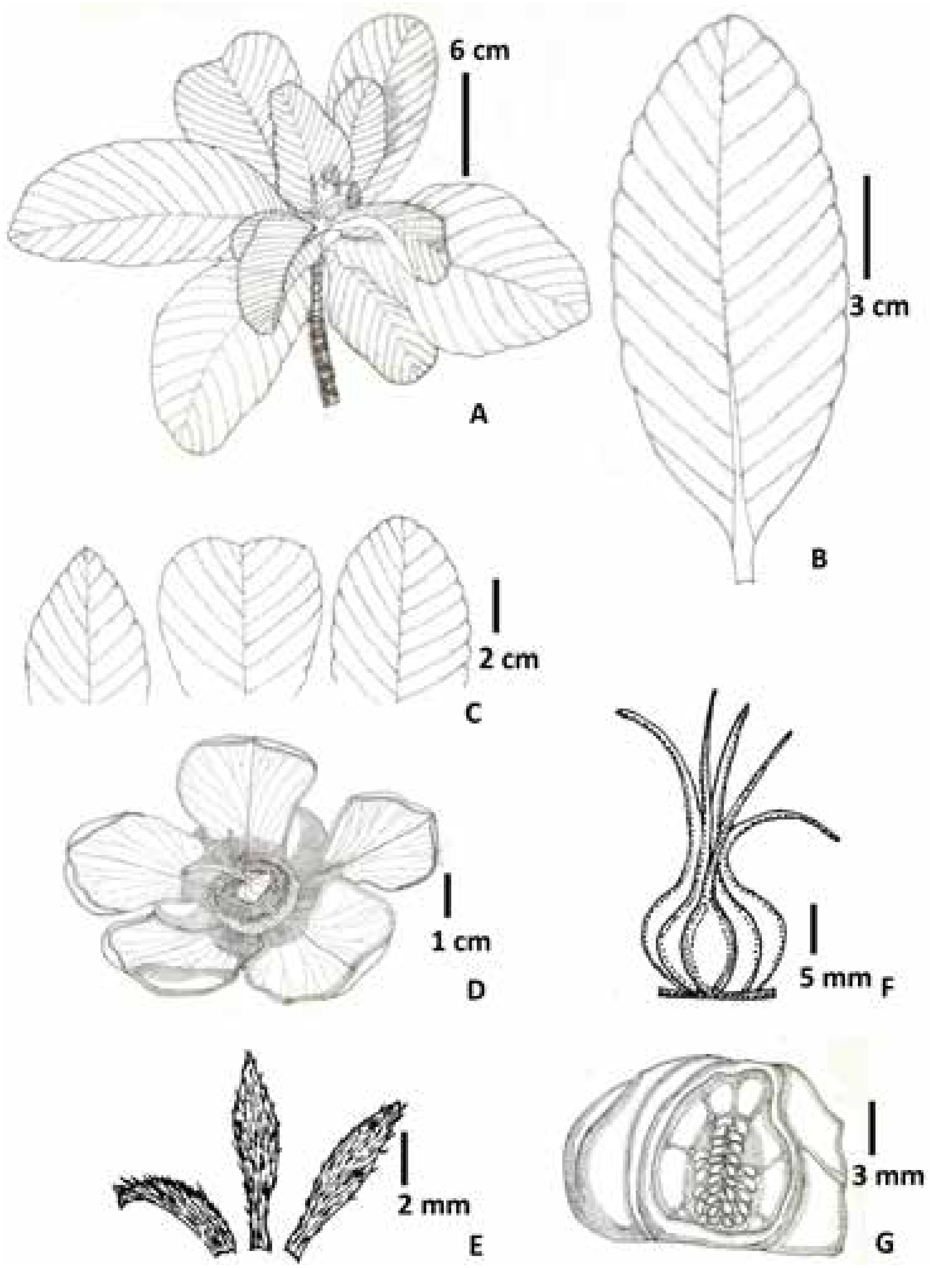

Figure 1. *Dillenia tirupatiensis* J. Swamy & Rasingam sp. nov. A—flowering branch | B—leaf | C—apices of leaves | D—flower | E—bracteoles | F—gynoecium | G—carpel with 2–4 rows of ovules. Illustration by Pooja R. Mane

with 10–13 leaf traces about middle. Leaves elliptic, obovate, 4–13 (–22) × 3–7 (–12) cm, cuneate or acute at base, crenate along margin, rounded, obtuse, retuse, emarginate, acute, rarely acuminate at apex, glabrescent above, densely tomentose beneath; lateral nerves slightly curving upward, ending in margin, 13–32 on either side of midrib, more densely tomentose and with hairs on nerves. Petiole 8–20 mm long, 1–4 mm broad, densely sericeous. Flowers terminal, solitary (rarely 2–3-flowered), up to 6cm across, on racemes 8–16 mm long. Pedicel 4–10 mm long, 1.5–2 mm broad, thickened to 3mm at apex in bud, densely sericeous. Bracteoles 3, sessile, lanceolate, ca. 8 × 3 mm, decurrent at base, ciliate along margin, truncate or acute at apex, densely sericeous. Sepals 5, oblong-oval, 22–28 × 8–15 mm, rounded at apex, densely sericeous on upper surface, glabrous on lower surface, faintly 11–14-nerved from base. Petals 5, white, 25–45 × 14–40 mm, obovate, narrowed towards base, entire along margin, rounded at apex, glabrous, 9–12 nerved from base. Stamens ca.

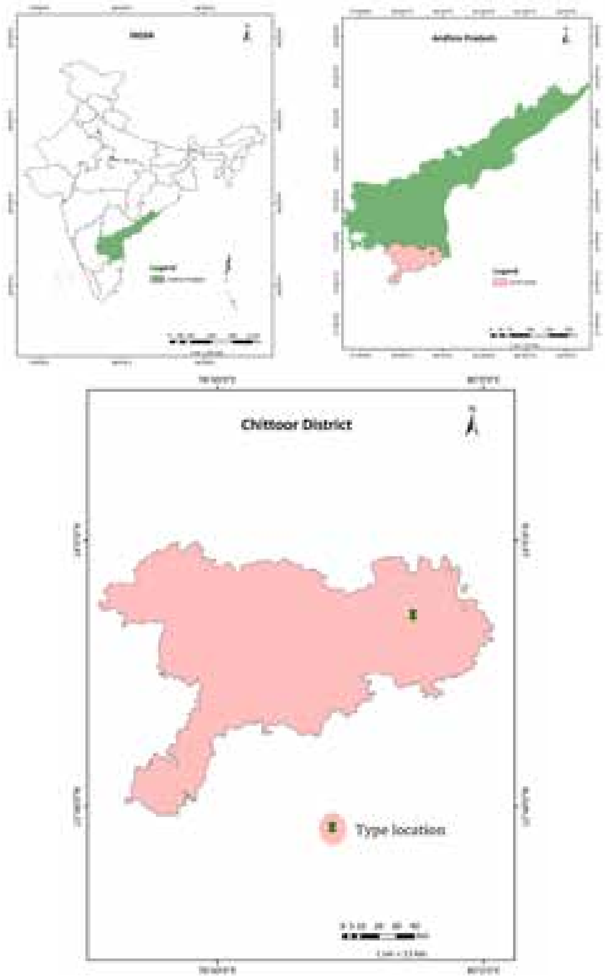

Figure 2. Type locality of *Dillenia tirupatiensis* J. Swamy & Rasingam sp. nov. in India.

Table1. Morphological comparison of *Dillenia hookeri* and *D. tirupatiensis* J. Swamy & Rasingam sp. nov.

Characters	***Dillenia hookeri***	***Dillenia tirupatiensis***
Leaves	Oblong to oblanceolate	Elliptic, obovate
Leaf base	Acute	Cuneate, acute
Leaf margin	Entire to slightly dentate	Crenate
Leaf apex	Rounded, sometimes slightly acuminate	Rounded, obtuse, retuse, emarginate, acute and rarely acuminate
Flower	Yellow	White
Pedicel	15–40 mm	8–10 mm
Bracteoles	20–35 × 7–10 mm	8 × 3 mm
Sepals	15mm long	22–28 mm long
Carpels	6–7, 5 × 1.5 mm, glabrous in each with 18 ovules in two rows	5, 7.5 × 5.5 mm, glabrous, in each with ca. 12–24 ovules in basally four rows and apically two rows
Style	Spreading, cylindric, ca. 11 × 4 mm	Lower 2.5–3 mm parallel, above this spreading, ca. 6 × 0.5 mm

180 arranged in rows, slightly curved in bud, all of about same length, 6.6–7 mm long; filaments ca. 2mm long, ca. 0.3 mm broad; anthers 4.6–5 mm long, ca. 0.8mm broad, rounded or slightly emarginate at apex, the thecae linear and opening by a pore near apex. Carpels 5, 5–7.5 × 3.5–5.5 mm, arranged around a conical receptacle, globular, ca. 10 × 12 mm, glabrous, each with 12–24 ovules; ovules obovoid to reniform, ca. 1 × 0.7 mm, glabrous, arranged in lower parts in 4 rows and in the upper part always in two rows; styles 5, parallel-jointed for lower 2.5–3 mm then spreading, ca. 6mm long, ca. 0.5mm broad. Pseudocarps indehiscent, globular, 12–16 × 16–18 mm (excluding enclosing sepals). Carpels 10–12 × 4–5 mm, 1–3 seeded. Seeds obovoid to reniform, 3–4 mm diam., smooth, dark reddish-brown.

Flowering and fruiting: March–August.

Habitat: Rare in dry deciduous forest, growing from 600–900 m elevation in association with *Phoenix loureiroi*, *Pterocarpus santalinus*, *Syzygium alternifolium*, *Chloroxylon swietenia*, *Anogeissus latifolia* etc.

Distribution: India, Andhra Pradesh, Chittoor District, Chittoor East Forest Division, Tirupati Range, Papanaidupet Section, Musalipedu Beat (Figure 2).

Etymology: The specific epithet is derived from the type locality Tirupati, a famous temple town in the Chittoor district of Andhra Pradesh.

Conservation status: This species is so far known only from the type locality and a total of five mature individuals in the surrounding areas. Extensive explorations, however, are needed in nearby locations and similar habitats to know the exact extent of occurrence of this species, for an accurate evaluation of its threat status. Therefore, the threat status is provisionally evaluated here as "Data Deficient (DD)" using the IUCN Red List Categories and Criteria Version 3.1 (IUCN 2012).

Notes: *Dillenia bracteata* is related to *D. tirupatiensis* by its leaf shape and size, equal stamens and arrangement of styles but differs by having 0–2 small bracteoles, 2–6-flowered racemes, yellow flowers, and ovules arranged in 2 rows in the carpels. *Dillenia retusa* reported from Karnataka, Tamil Nadu, and Sri Lanka, is also similar to the new species by its inflorescence, and flower colour but differs by its fewer lateral nerves in the leaves, ebracteolate flowers, unequal stamens, and styles spreading from the base.

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Key to the *Dillenia* species in India

1a. Flowers white 2
1b. Flowers yellow 4
2a. Flowers more than 12cm across .... *D. indica*
2b. Flowers less than 12cm across 3
3a. Bracteoles absent; innermost stamens distinctly larger than outer ones, with apical part reflexed outward over the later...*D. retusa*
3b. Bracteoles present; stamens all about same length, only slightly curved in bud .... *D. tirupatiensis*
4a. Anther thecae opening with longitudinal slit; flowers up to ca. 5cm across 5
4b. Anther thecae opening with apical pore; flowers ca. 10–12 cm across 6
5a. Flowers up to 3cm across; pedicels without bracteoles .... *D. pentagyna*
5b. Flowers 4–5 cm across; pedicels with bracteoles .... *D. scabrella*
6a. Stamens equal; styles parallel up to 3mm at base, above spreading; carpels 5 .... *D. bracteata*
6b. Stamens unequal; styles spreading from base; carpels 6–12 7
7a. Petiole up to 2cm long; outer sepals ca. 15 × 12 mm, inner ones ca. 18 × 14 mm; carpels 6–8 .... *D. andamanica*
7b. Petiole 3–6.5 cm long; outer sepals 25 × 18 mm, inner ones 30 × 20 mm; carpels 10–12 .... *D. aurea*

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NOTE

Reinstatement of *Pimpinella katrajensis* R.S.Rao & Hemadri (Apiaceae), an endemic species to Maharashtra with notes on its taxonomy and distribution

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Pimpinella L. is one of the largest genus of the subfamily Apioideae (Family: Apiaceae) having 200 species, distributed in Asia, Europe, and Africa (Mabberly 2008). Only a few species of the genus are reported from South America and one occurs in North America (Pimenov & Leonov 1993). In India, the genus is most speciose by having about 20 species (Mukherjee & Constance 1993).

De Candole (1827) divided the genus *Pimpinella* into three sections: *Tragoselinum*, characterized by its glabrous fruits and perennial roots; *Tragium*, with hairy fruits, perennial (rarely biennial) roots and pinnate to bipinnate radical leaves with ovate segments; and *Anisum*, which included species with down-covered annual fruits. Bentham & Hooker (1867) reported 65–70 species of the genus *Pimpinella* and classified it into six sections according to the habitat of the plant, leaf & fruit morphology, and petal colour. *Pimpinella* can be distinguished from other genera by mainly perennial herbs, cordate-ovoid or oblong-ovoid, slightly laterally compressed fruits constricted at their commissures, each with five filiform ribs (Pu & Watson 2005).

During floristic survey of Satara District of Maharashtra State, some specimens belonging to the genus *Pimpinella* were collected from Ajinkyatara Fort. Initially, we identified the unknown *Pimpinella* species as *P. wallichiana* Gandhi. But after critical examination of specimens through perusal of literature (Hooker 1879; Rao & Hemadri 1976) and consultation of type and other specimen from BSI and SUK the specimens were identified as *Pimpinella katrajensis* Rolla Rao & Hemadri.

Mukherjee & Constance (1993) subsumed *P. katrajensis* into *P. wallichiana* without any reason while Almeida (1998) treated it as a variety of *P. wallichiana* based on leaf characters; however, both species are very distinct (Table 1). Thus, in this communication we have provided morphological description, images, and distinguishing characters of *P. katrajensis* for correct identification and distribution note in Maharashtra State as also help resolve the name on the PlantList.

Pimpinella katrajensis **Rolla Rao & Hemadri**

Indian Forester 102(4): 232–234; 1976. (Image 1)

Perennial erect aromatic herbs; root fusiform, about 10cm long; stem terete striate, pubescent to glabrous, leaves pinnately trifoliate, petiole 12–15 cm long, sheathing at base, puberulous, ovate-orbiculate, cordate to truncate, acute at apex, margins coarsely

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Table 1. Distinguishing characters between Pimpinella katrajensis and P. wallichiana

Characters	*P. katrajensis*	*P. wallichiana*
Stem	White tomentose	Glabrous to sparsely hairy
Upper leaf	Tomentose, trifid	Glabrous, many dissected lobes
Basal leaflet margin	Crenate to crenulated	Serrate
Basal lateral leaflet base	Not oblique	Oblique
Bracts and bracteoles	Absent	Present, caducous
Rays	Tomentose	Glabrous to sparsely hairy
Ovary	Covered with white tomentose	Covered with hyaline tubercles
Fruit	Oblong, 2.2–3 mm long	Orbicular to oblong, 1.8–2 mm long
Out growth on fruit epidermis	Yellow pointed hairs with thick base	Hyaline tubercles present

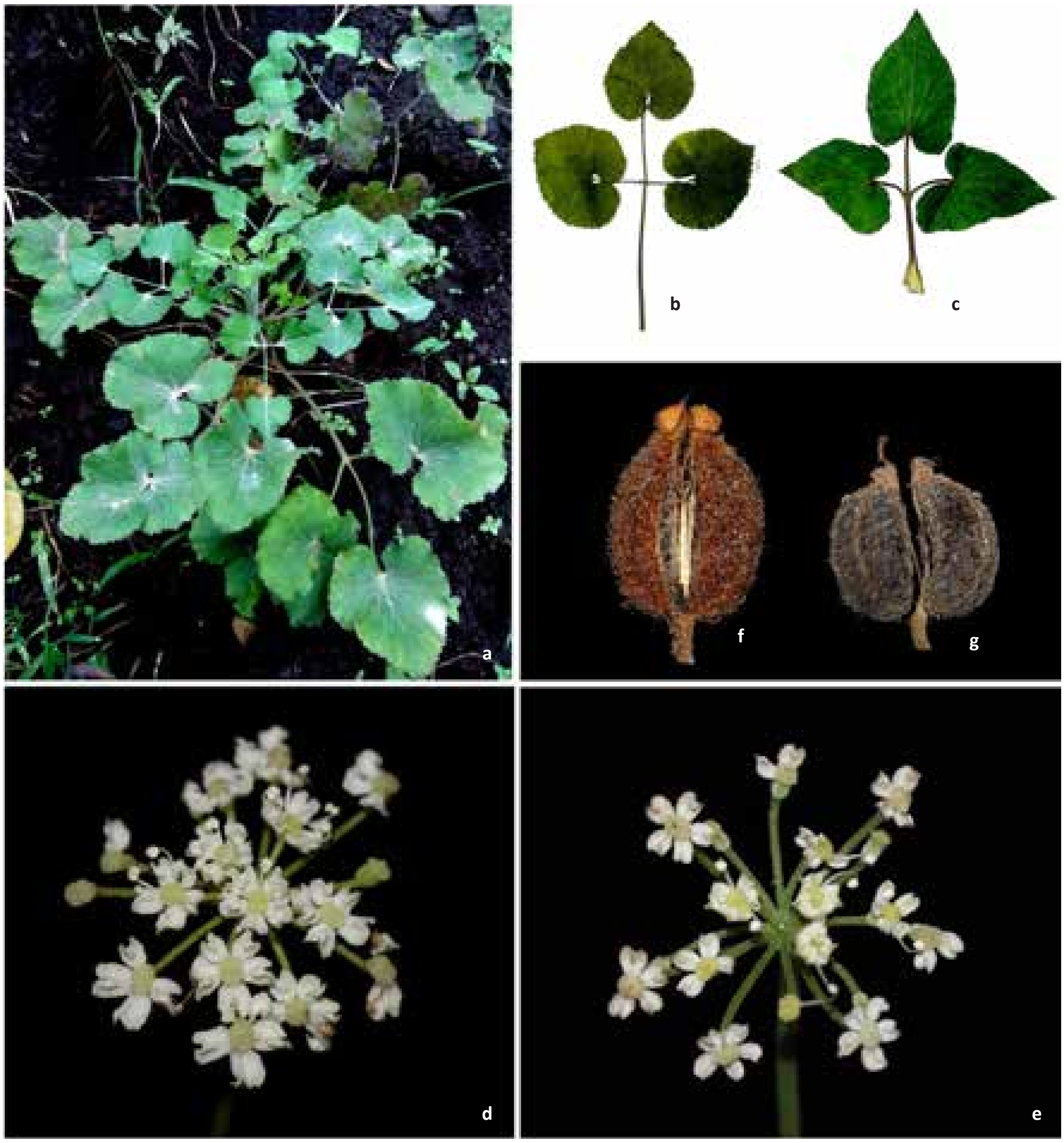

Image 1. Comparison between *Pimpinella katrajensis* Rolla Rao & Hemadri and *P. wallichiana* Gandhi: *P. katrajensis*: a—Habit, b—Leaf, d—Umbellets and f—fruit; *P. wallichiana*: c—Leaf, e—Umbellets and g—fruit. © K.V.C. Gosavi & S.D. Kulkarni.

Image 2. A. Holotype - *Pimpinella katrajensis* Rolla Rao & Hemadri.

toothed and cartilaginous, lower surface minutely pubescent, sparsely pubescent on upper surface; uppermost leaves smaller. Inflorescences terminal compound umbels, large, tall, bisexual, puberulous, primary rays c. 5cm long, secondary rays 6–7 in number, 1–2.5 cm, long, puberulous, ebracteate. Flowers 6–15 per umbel, ebracteolate, unequal pedicellate, pedicels pubescent. Calyx teeth not distinguished. Corolla white, hairy outside, petals 5, broadly ovate, with notch at tip, stamens 5, anthers 0.3–0.4 mm long. Stylopodium distinct, conical shaped, styles very short. Fruit laterally compressed, ovoid, 2.2–3 mm long, pubescent to tomentose. Carpophore bifid.

Flowering & fruiting: September–December.

Habitat: Grows on rocky crevices on slopes at high altitude.

Distribution note: *Pimpinella katrajensis* is endemic to Maharashtra and only reported from two localities, Katraj Ghat near Pune and Pachgani in Satara District, however it is also distributed at Ajinkyatara, Vasota, Ambedare and Pateshwar in Satara District.

Specimens examined: *K.* 108794 (BSI) (holotype), 20.ix.1971, Katraj Ghat, Pune District, Maharashtra, India, coll. Hemadri (Image 2A; 002367 (NGCPR, SUK), 11.x.2018, Ajinkyatara Fort, Satara District, Maharashtra, India, coll. S.D Kulkarni & S.M. Deshpande (Image 2B).

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NOTE

Puccinia duthiei Ellis & Tracy: a new host record on *Chrysopogon velutinus* from India

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Dicaeoma duthiei (Ellis & Tracy) Sydow [as '*duthiae*'], Annls mycol. 20(3/4):117 (1922)

Uredo duthiei (Ellis & Tracy) Pardo-Card. [as '*duthiae*'], Revista, Facultad Nacional de Agronomia Medellin 56(2): 2080 (2003)

Chrysopogon (Trin.) belongs to (Family Poaceae) and is represented by 23 species in India (Sunil et al. 2017). Rust disease is caused by pathogenic fungi of the order Pucciniales, which comprises about 168 genera and approximately 7,000 species of rusts (Mohanan 2010). An attempt has been made to establish new host record of rust fungus, *Puccinia duthiei* (Ellis and Tracy, 1897) on *Chrysopogon velutinus* (Hook.f.) Bor from India.

The rust infected leaves of *C. velutinus* were collected on January 2018, from Surali Ghat in Karad Tehsil of Satara District, (MS) India, situated at altitude of about 710m. It is geographically located at 17.738^{0}N & 74.462^{0}E. The leaves with early, mature and late stages of disease were examined and symptoms were noted (Image 1 a & b).

A number of tiny, elevated, globulous to elongated, elliptic, dark brown to yellowish-brown powdery rust pustules were noticed on lower surface of leaves. Later on, these pustules converted in to blackish color at maturity (Image 1c). With the help of razor, several thin transverse sections passing through pustule were cut and taken on the glass slide. The sections were stained with cotton blue, mounted in lacto phenol and observed under digital microscope (Olympus CX21Iledfs1). Microphotographs of different morphological features were taken using the software Magvision equipped with MIPS-3 MP Camera. With the help of fine needle, scrape mount slides of urediniospores and teliospores were prepared and dimensions of the same were measured by software with an inbuilt tool in the system at different magnifications viz., 10, 40 and 100 X (Image 1. d) & by using mm and µm scale under digital microscope.

A voucher specimen was deposited in Ajrekar Mycological Herbarium (AMH), MACS' Agharkar Research Institute, Pune, India under the accession number (AMH-10144).

Puccinia duthiei Ellis & Tracy, 1897

Dicaeoma duthiei (Ellis & Tracy) Sydow [as '*duthiae'*], Annls mycol. 20(3/4):117 (1922)

Uredo duthiei (Ellis & Tracy) Pardo-Card. [as '*duthiae'*], Revista, Facultad Nacional de Agronomia Medellin 56(2): 2080 (2003)

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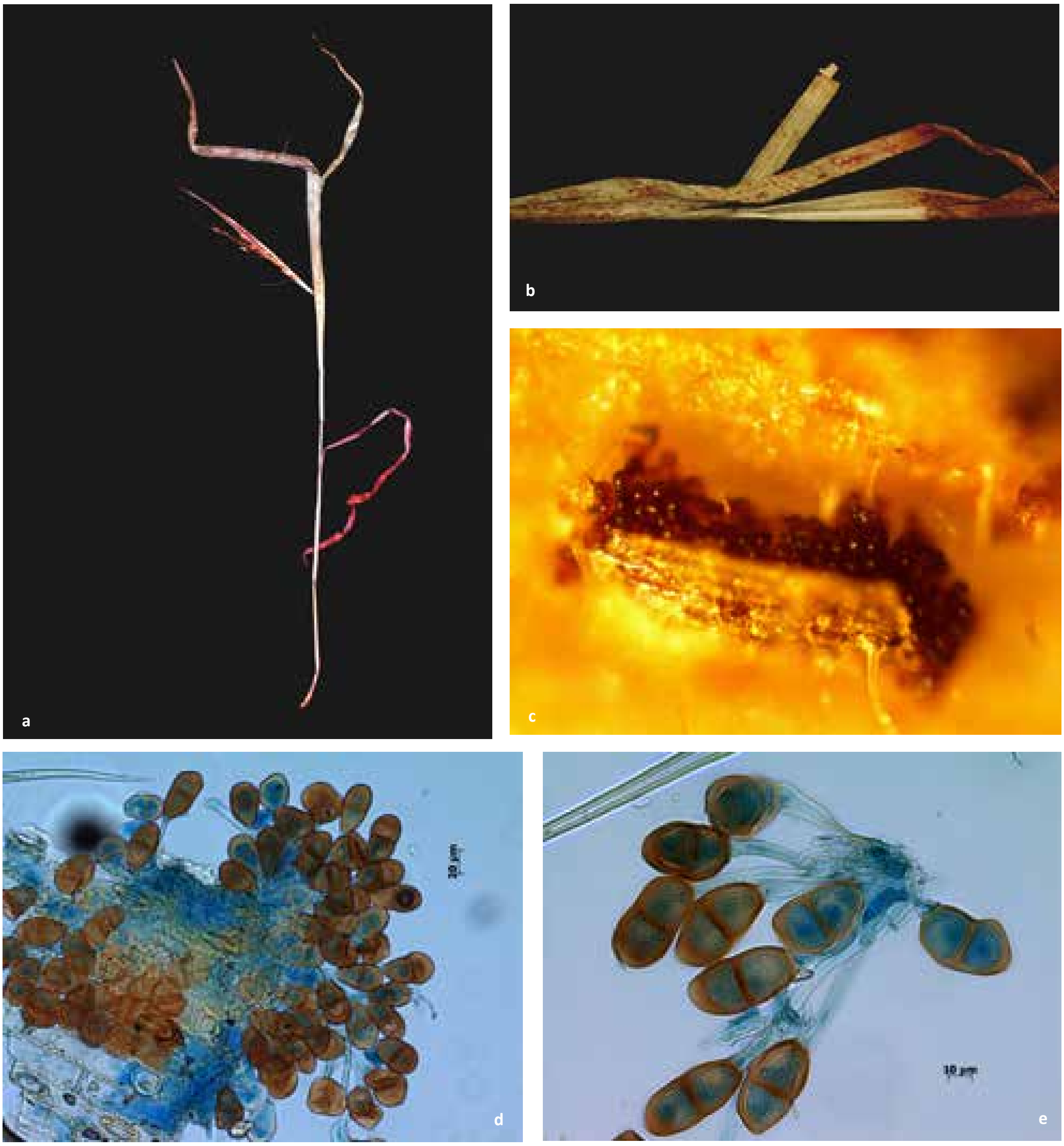

Image 1. *Puccinia duthiei*: a—rust infected plant | b—rust pustules on leaves | c—enlarged view of rust pustule | d—section passing through rust pustule (showing numerous stalked teliospores) | e—stalked septate teliospores in higher magnification. Scale d=20µm, e=10µm.

***Puccinia duthiei* Ellis & Tracy**

Rust pustules (infection spots) are rounded to elliptic, elongated, hypophyllous, dark brown to yellowish-brown, about 0.16–0.67 mm. *Urediniospores*- oval, echinulate, yellowish to brown, darker at apex, unicelled, 24.76–35.32 x 15.96–24.16 µm, wall- dark brown between 1.3–2.35 µm thick, germ pores, 4–6. *Teliospores*- unicelled to bicelled, broadly ellipsoidal, dark yellow to yellowish-brown, constricted near septa, up to 24.18–48.34 x 24.54– 28.30 µm, thick walled 2.56–7.94 µm. Teliospore stalk gradually increasing towards length, hyaline to light olivaceous, aseptate, smooth walled, up to 97.71–114 x 5–6.75 µm.

Material examined: On living leaves of *Chrysopogon velutinus* (Hook.f.) Bor (Poaceae), Karad, Satara (MS) India, January 2018, Type Duthie, on *Andropogon* *pertusus* (=*Bothriochloa pertusa* (L.) A. Camus), Saharanpur, India (NY; isotype PUR).

Discussion: *P. chrysopogi* (Barclay, 1889) was reported on *Chrysopogon echinulatus* (Steud.) W. Wats. and *C. gryllus* (L.) Trin. from India by Cummins (1971). *P. chrysopogi* was recently listed in fungal flora of Swat District in Pakistan (Usman et al. 2016). *Puccinia duthiei* (Ellis & Tracy, 1897) was reported new to India on *Dichanthium foveolatum* by Pawar et al. (2018). The crucial review of literature indicates that, there are previous evidences about incidence of *P. duthiei* in India on another host. Therefore, it confirms new host record of *P. duthiae* on *Chrysopogon velutinus* from India.

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