ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

26 February 2019 (Online & Print)
Vol. 11 | No. 3 | 13251–13418

10.11609/jott.2019.11.3.13251-13418
www.threatenedtaxa.org

Journal of Threatened Taxa

PLATINUM
OPEN
ACCESS

Building evidence for conservation globally

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road, Saravanampatti,
Coimbatore, Tamil Nadu 641035, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

continued on the back inside cover

Caption: ***Rattus satarae*** **Sahyadri Forest Rat, a canopy specialist of the Western Ghats forests. Shot at Palthope Estate, Kutta, Karnataka by Sanjay Molur, ZOO / WILD.**

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13251–13260

'Non-protected' primates as bushmeat, pets and pests in southeastern Democratic Republic of Congo

Paul Kaseya Kazaba

Ecology, Ecological Restoration and Landscape (EREP) Research Unit, Faculty of Agricultural Sciences, University of Lubumbashi, B.P. 1825 Lubumbashi, D.R. Congo.
Pan African University Life and Earth Sciences Institute (PAULESI), University of Ibadan, Ibadan, Nigeria.
paulkazaba@gmail.com

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

Abstract: This article reports the uses of primates in a fast-expanding city, and human-primate interactions in the vicinity of a protected area in southeastern Democratic Republic of Congo (DRC). Surveys in markets, households and restaurants suggested that primate meat is frequently sold and consumed in the city of Lubumbashi. Carcasses of diurnal monkeys accounted for almost 10% of the total weight of smoked bushmeat sold between March and July 2016 in urban markets, and in 21% of households the last bushmeat consumed prior the date of the survey was of a primate species. Kinda Baboons *Papio kindae*, Malbrouck Monkeys *Chlorocebus cynosuros* and Blue Monkeys *Cercopithecus mitis* were found illegally kept as pets. Occasional observations and questionnaire surveys carried out in both the Sector North of Upemba National Park and its neighboring areas, indicated wild populations of these species which were mentioned as "pest primates" by 73% of respondents. There is no compensation scheme for damages caused by wildlife to crops, and culling problematic animals was listed by a majority (70%) of respondents as the most effective way to repel crop-raiding primates. Given the current population growth, and considering the increasing spatial overlap between human activities and wildlife, wild populations of these primates are no doubt at risk, but all the three species belong to the Least Concern category on the latest version of the IUCN Red List. The Blue Monkey is a 'partially protected' species in DRC, while the two other benefit from less strict conservation measures and their legal status of 'non-protected' remains. This situation illustrates the necessity of updating legal status and establishing a Red List of species at the country level.

Keywords: Cercopithecine monkeys, human-wildlife interactions, poaching, wildlife conservation.

French Abstract: Cet article décrit les utilisations des primates dans une ville en expansion et les interactions humains-primates à proximité d'une aire protégée dans le sud-est de la République démocratique du Congo (RDC). Des enquêtes conduites au niveau des marchés, des ménages et des restaurants ont suggéré que la viande des primates est fréquemment vendue et consommée dans la ville de Lubumbashi. En effet, les carcasses des primates représentaient près de 10% du poids de la viande de brousse vendue entre mars et juillet 2016 sur les marchés communaux. Dans 21% des ménages, la dernière viande consommée avant la période de l'enquête était d'une espèce de primate. Des babouins (Papio kindae), des singes de Malbrouck (Chlorocebus cynosuros) et singes bleus (Cercopithecus mits) ont été trouvés illégalement détenus comme animaux de compagnie. Des observations occasionnelles et des enquêtes réalisées dans le Parc national de l'Upemba et ses environs ont indiqué la présence de ces trois espèces, qui ont été qualifiées de «primates nuisibles» par 73% des répondants. Il n'existe aucun système de compensation des dommages causés par les animaux sauvages, et l'abattage des animaux à problèmes a été mentionné par la majorité (70%) des répondants comme le meilleur moyen de répulsion des primates ravageurs des cultures. Etant donné le rythme actuel de croissance démographique et le chevauchement croissant entre les activités humaines et la faune, ces primates sont sans doute en péril. Ils restent néanmoins dans la catégorie « Préoccupation mineure » sur la Liste rouge de l'UICN; le singe bleu est une espèce «partiellement protégée», tandis que les deux autres espèces conservent leur statut juridique «animaux non encore protégés». Cette situation illustre la nécessité de mettre à jour le statut juridique et d'établir une liste rouge des espèces au niveau des pays.

DOI: https://doi.org/10.11609/jott.4669.11.3.13251-13260

Editor: Mewa Singh, University of Mysore, Mysuru, India. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4669 | Received 02 November 2018 | Final received 21 December 2018 | Finally accepted 22 January 2019

Citation: Kazaba, P.K. (2019). 'Non-protected' primates as bushmeat, pets and pests in southeastern Democratic Republic of Congo. *Journal of Threatened Taxa* 11(3): 13251–13260; https://doi.org/10.11609/jott.4669.11.3.13251-13260

Funding: Académie de Recherche et d'Enseignement supérieur (ARES), Rue Royale 180, 1000 Bruxelles, Belgium.

Competing interests: The author declares no competing interests.

Author Details: Paul Kaseya Kazaba currently works at the Department of Natural Resources Management, University of Lubumbashi, D.R. Congo. Paul does research in wildlife management, primatology and forest ecology.

Acknowledgements: We warmly thank Professor D. Tshikung (University of Lubumbashi, D.R. Congo) and Dr. R.C. Beudels-Jamar (Royal Belgian Institute for Natural Sciences) for their precious comments and suggestions on surveys of the bushmeat trade; Dr. M.-C. Huynen (University of Liège, Belgium) for her help in the identification of primates kept as pets in Lubumbashi, and Mr. R. Katembo (Congolese Institute for the Conservation of Nature) for his collaboration during data collection in Upemba National Park.

INTRODUCTION

The latest (2018-19) Red List published by the International Union for Conservation of Nature (IUCN) suggests that more than 60% of the 440 species of primates (hereafter used in reference to non-human primates) evaluated are threatened with extinction (listed Vulnerable, Endangered or Critically Endangered). Indeed, the status of the majority of primates is worsening (Schwitzer et al. 2014), mainly because of habitat loss and fragmentation (Roberts et al. 2016) and poaching (Cheyne 2009; Ceballos-Mago et al. 2010; Oates 2013; Mallon et al. 2015; Estrada et al. 2017) across the world.

In Africa, primates are poached for bushmeat (Fa et al. 1995; Refisch & Koné 2005; Mossoun et al. 2015) and for multiple uses in traditional medicine (Carpaneto & Germi 1989; Alves et al. 2010; Svensson et al. 2015). In addition, the illegal keeping and trafficking of live primates has been mentioned in several articles (Gambalemoke et al. 2000; van Lavieren 2008; Kabasawa 2009; Ebua et al. 2014; van Uhm 2016). Poaching and illegal trade are among the major impediments to the survival of many primate species in several countries across the continent.

The Democratic Republic of Congo (DRC) has a significant role to play in primate conservation (Chapman et al. 2006; Estrada et al. 2017). This country is characterized by a large diversity of habitats and a considerable variety of primates, represented by more than 30 species, including three of the four types of great apes (Rainer et al. 2014) and the recently described Lesula (*Cercopithecus lomamiensis*) (Hart et al. 2012). Overall, Congolese wildlife is protected by a set of legal instruments and a large network of protected areas (Inogwabini 2014). Unfortunately, challenges in managing parks and reserves (IUCN, 2010) and the lack of local evaluation and updates of both conservation and legal status of species, make wildlife increasingly vulnerable to anthropogenic threats.

Primates are threatened across all ecoregions of the DRC; for example in the west, center and east of the country characterized by diverse types of rainforests, endangered great apes (Bonobos, Chimpanzees and Gorillas) as well as smaller primates are poached for the consumption of their meat, and for trade as pets (Hart et al. 2008; Hicks et al. 2010; Stiles et al. 2013). In the south-east Zambezian part of the country (White 1983), which, is covered mainly by savannas and Miombo woodlands (Malaisse 2010; Kabulu et al. 2008; Munyemba & Bogaert 2014), some primates deemed opportunistic and less-threatened to date are also hunted (Tshikung & Pongombo 2009) and survive in human-disturbed areas.

This study examines the use of primates in Lubumbashi, a fast-expanding city in the south-east of the DRC, and presents a preliminary appraisal of their situation in the wild. This was done by analyzing data on: (i) the bushmeat trade and consumption, (ii) primates kept as pets in Lubumbashi, and (iii) the presence of primates and human-primate conflicts in the vicinity of Upemba National Park.

MATERIALS AND METHODS

Study Area

The study was conducted in seven municipalities of Lubumbashi (11.450–11.783 ^{0}S & 27.327–27.667 ^{0}E) and at three locations in rural areas: Lusinga Station (8.933^{0}S & 27.205^{0}E) in the Sector North of Upemba National Park, and Kasungeshi (8.938^{0}S & 27.380^{0}E) and Mumbolo (9.109^{0}S & 27.258^{0}E), two villages neighboring the park (Fig. 1). With an estimated population of 2.088 million in 2018 (UN-Habitats 2014), Lubumbashi, the second largest city of DRC, is connected to other cities by railway and a number of roads, some of which cross both Upemba and Kundelungu National Parks in southeastern DRC.

The major part of the study area is under a tropical climate coded Cw, according to the Köppen's Classification (Malaisse 2010), with a rainy season lasting from November to March, and a dry season from May to September; October and April are considered as transitional months (Assani 1999). With an annual average of 20°C, temperatures vary from 16 to 33°C; the annual mean rainfall is 1300mm (Saad et al. 2012). Around both Lubumbashi and the Sector North of Upemba National Park, open forests (Miombo woodlands), the main forest type of the south of the DRC, are human-dominated and highly fragmented (Kabulu et al. 2008; Munyemba & Bogaert 2014).

Surveys on the Trade and Consumption of Primate Meat

Data on the trade of primate meat were collected in the major markets of the seven municipalities of Lubumbashi. To avoid bias due to the possible negative perception of the consumption or trade of primate meat, surveys were extended to all types of bushmeat, which were grouped into four categories for statistical analyses: reptiles and three orders in mammals (rodents,

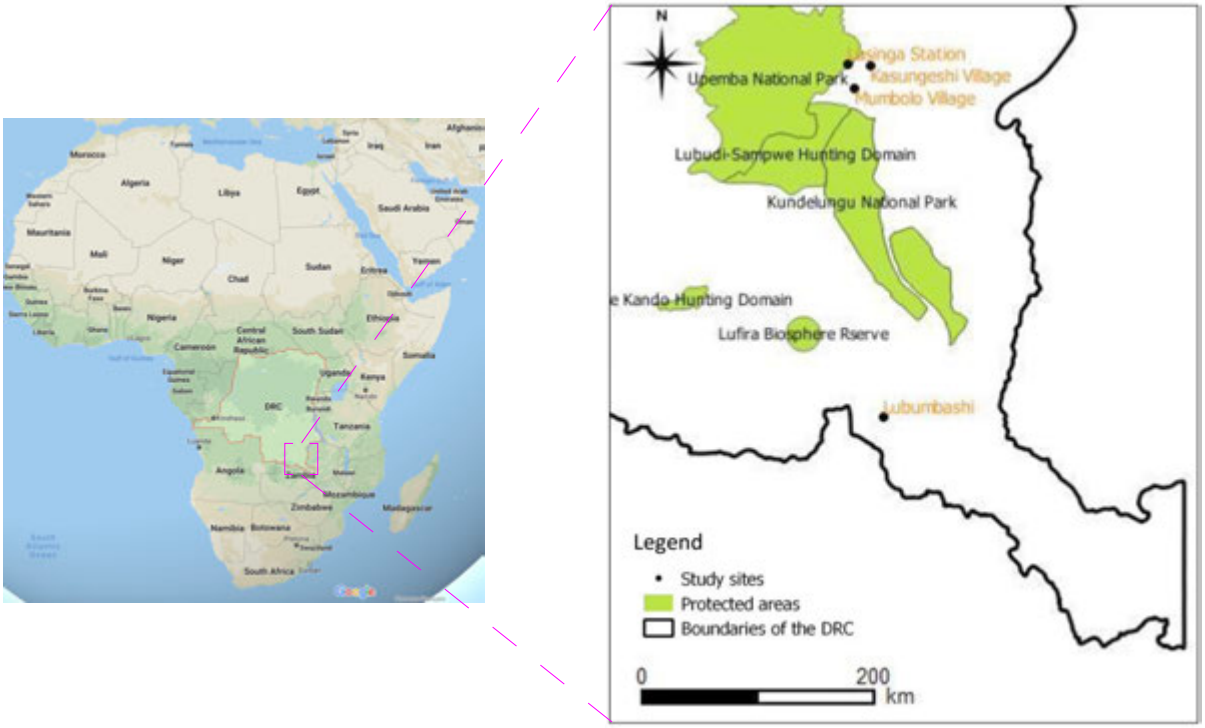


Figure 1. Lubumbashi City and the three villages surveyed in the vicinities of Upemba National Park, southeastern Democratic Republic of Congo (DRC).

artiodactyls and primates). A total of 30 vendors who regularly sell bushmeat were selected for the first part of the survey. Questionnaires consisted of both open-ended and close-ended questions formulated in order to collect and collate information on characteristics of the trade, quantities of carcasses, sites of origin, and trends in the availability of bushmeat.

Eighteen of the 30 selected vendors agreed to participate in the second part of the survey and to provide qualitative and quantitative data on arrivals of bushmeat during the five months (March–July 2016) of repeated surveys. Throughout this period, carcasses were counted and weighed at a two-week interval and each time vendors reported new arrivals of bushmeat. This interval was fixed based on data from previous surveys (Tshikung & Pongombo 2009) on bushmeat trade in Lubumbashi.

Carcasses were preliminarily identified by macroscopic observation. Although smoked, many primates were clearly visible and readily recognizable by body parts such as hands, feet and heads. Local names used by respondents were linked with results of molecular identification of the bushmeat frequently sold in Lubumbashi (Didier Tshikung pers. comm. 25.vi.2016) and served to confirm two species of primates which were traded during the survey period.

With respect to the preference and consumption of primate meat, surveys were carried out in all the seven municipalities of Lubumbashi and were focused on a total of 140 households and 20 restaurants selected randomly. Questionnaires were addressed to household members who usually purchase and/or prepare food. For the same reason as in surveys at the market level, we collected information on the consumption of bushmeat without any particular emphasis on primate meat.

Surveys on Primates Kept as Pets

This part of the study took place in three stages. First, information from veterinarian services of the seven municipalities and occasional observations served for identifying pet primates' owners in Lubumbashi. Second, the purpose of the study was presented to the 74 pet primate owners identified, and only 34 of them consented to participate in the survey. Third, interviews were conducted between August 2015 and February 2016.

Respondents provided information on local names, sites of origins, acquisition, uses and living conditions of captive primates. Additional information and photographs were subsequently collected in March and April 2016 in order to identify these animals at the species level. Species' range data on the IUCN Red List

(Butynski 2008; Kingdon 2008; Kingdon et al. 2016) and pictorial identification guides (Rowe 1996; Mittermeier et al. 2013), as well as the verification by an expert (Marie-Claude Huynen, pers. comm. 02.viii.2016) were used to confirm the identification of these primates.

Collection of Data on Primates in the Wild

In order to gather preliminary information on the status of primates in the wild, surveys targeted human settlements in the Sector North of the Upemba National Park and were conducted in August and September 2017. Questions were addressed to a sample of 117 respondents randomly selected at the three study locations (Fig. 1).

Questionnaires were used to obtain preliminary information on abundance and distribution of the three diurnal primates identified at Lubumbashi. Data on human-wildlife interactions, as well as respondents' appreciations of the trends in wild populations of these species in the area were also collected. Both park managers and rangers were also contacted for verification purposes.

Data Synthesis and Analysis

Data from surveys were encoded on MS Excel spreadsheets for descriptive statistics. Quantitative variables such as age, income of bushmeat vendors and purchase prices of primates were described mainly on the basis maximum, minimum, mean and standard deviation. For most close-ended questions, frequency distributions of responses were plotted and presented by bar charts and pie chart. Also, we performed a chi-square test of independence in order to examine the relationship between the geographic location of respondents (within or out of the protected area) and their perception of primates as crop-raiders.

Bushmeat vendors and pet primate owners mentioned a number of sites around which primates were captured. Geographic coordinates of these sites were found in the Google Earth application and then exported as shapefiles to Quantum GIS software (version 2.10.1) as a layer of points, each representing one site. The final map (Fig. 2) was obtained by overlapping this layer on four other data layers presenting cities (points), the road network (lines) and, protected areas and boundaries of DRC (polygons).

RESULTS

Hunting Sites of Primates Used as Food and Pets

A majority (almost 80%) of the 30 vendors declared they buy primate carcasses (and other bushmeat) directly from hunters, who take specimens from a number of sites located more than 200km north of Lubumbashi. This information was used for mapping purposes and helped locate these sites (Fig. 2).

Almost two-third of the 36 primates kept as pets in surveyed households were captured in the vicinities of Kyubo (9.529^{0}S & 27.043^{0}E), Sampwe (9.353^{0}S & 27.438^{0}E) and Bunkeya (10.398^{0}S & 26.968^{0}E). These villages are in the neighborhood of the Upemba-Kundelungu complex of protected areas. The rest of the sites are located in different landscapes of four provinces in southeastern DRC: Upper Katanga, Upper Lomami, Lualaba and Tanganyika.

Trade of Primate Meat in Markets

In surveyed markets of Lubumbashi, data on socio-demographic characteristics of respondents indicated that bushmeat is sold only by women, aged 18–60 (38.2 ± 10.6 years). About 70% of the 30 respondents declared that monthly profits generated by the bushmeat trade, ranging from 100 to 300 United States Dollars (USD), represent more than half of the total income of their households. Also, 50% of the vendors declared that these profits are primarily spent for schooling children. Paying rent, purchasing food and savings were mentioned by 26%, 13% and 10%, respectvely.

The choice of primate meat is motivated mainly by supply: almost all (90%) vendors claimed they sell primate meat because when compared to other bushmeat it has been the most available in recent years. Few vendors mentioned the preferences of their customers. Notable quantities of bushmeat were weighed throughout the five months covered by the surveys in markets. We recorded 6,773kg of smoked meat of many species. In this set, artiodactyls (buffaloes, warthogs and antelopes) are the most represented, with carcass weights accounting for almost 70% of the total. Primates (diurnal monkeys found in the area) accounted for about 10% of the total carcasses recorded during the same period (Fig. 3).

Consumption of Primate Meat in Households and Restaurants

Respondents estimated the average weight of smoked bushmeat consumed monthly was less than 3kg for two out of three households. For almost 28%

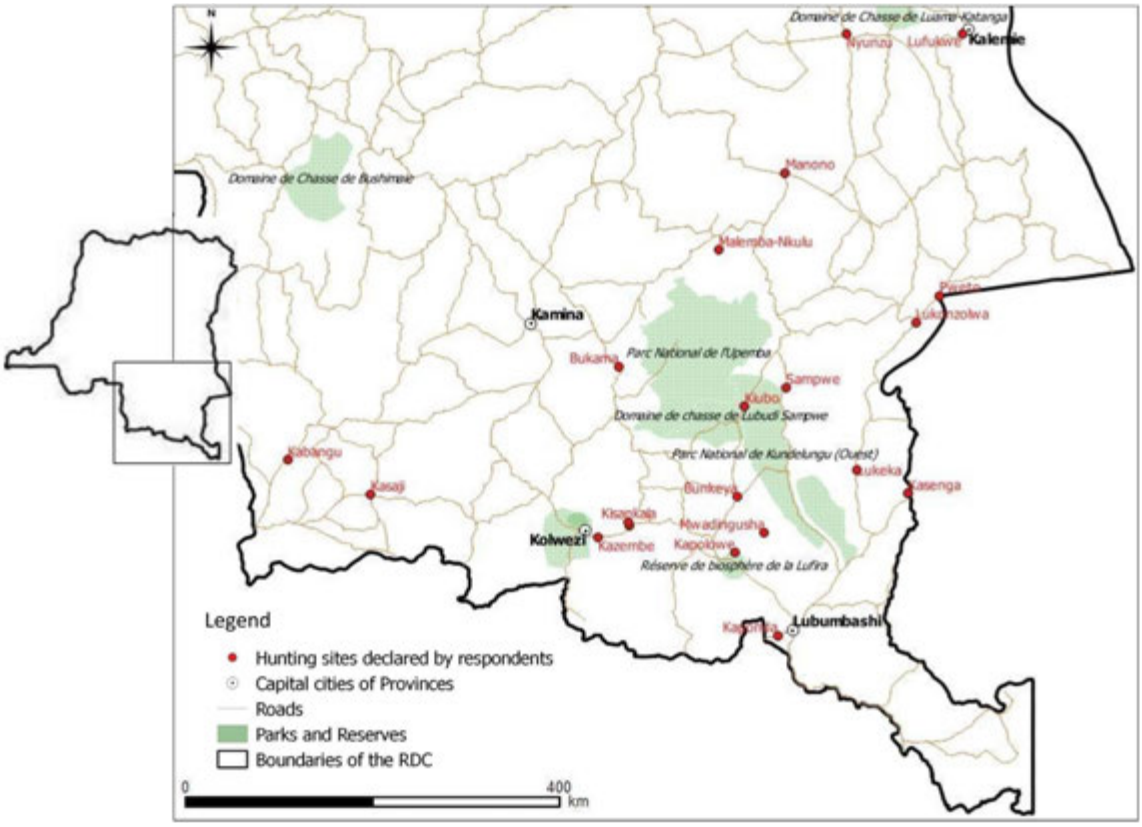


Figure 2. Sites where primates are hunted in the southern Democratic Republic of Congo. Parks and reserves are presented as: 'Parc National' (French: National Park), 'Domaine de Chasse' (hunting domains) and 'Réserve de la Biosphère' (biosphere reserve).

of 140 households, respondents listed "monkey meat" among the main three types of bushmeat consumed frequently (more than once a month). Further, in 21% of the households, the last bushmeat consumed prior to the date of the survey was of a primate species.

The main reasons provided for primate meat consumption included availability (46% of 140 respondents) and preferences of household members (37%). However, in 14% of households, the meat of primates, especially that of great apes, was listed among the three types of bushmeat never consumed. To justify such a choice, a number of reasons, mainly cultural beliefs, were mentioned.

Primate meat was served frequently in only two of the surveyed restaurants. Profitability (for 45% of the 20 respondents) and preferences of consumers (35%) were the main factors influencing the choice of bushmeat served in restaurants. In half of the surveyed restaurants, as well as in 21% of households, bushmeat was directly ordered from hunters rather than purchased in urban markets.

Primates Used as Pets

In the 34 households surveyed, a total of 36 monkeys including 19 Kinda Baboons (*Papio kindae*), 16 Malbrouck Monkeys (*Chlorocebus cynosuros*) and a Blue Monkey (*Cercopithecus mitis*) were identified as pets in the study area (Image 1). All three species are found in the south-east of the DRC. Bought from hunters (nearly 44%), third persons (31%) or offered by a relative (25%), all of the 36 pet primates were owned illegally. Indeed, all the respondents declared not to possess any official document authorizing either the acquisition or the keeping of a wild animal in captivity. For bought animals, respondents mentioned a wide range of purchase prices (21 ± 13 USD). The cheapest monkey, a male Baboon, had been purchased for the equivalent of 3 USD in 2008, and the most expensive one, a juvenile Malbrouck Monkey had cost 50 USD in 2014. Nearly half of the primates used as pets were acquired within a one-year period prior the survey (Fig. 4). Eighty percent were infants when captured in the wild.

The knowledge of the status of wild populations of primates in the area was assessed. About 70% of respondents estimated that the populations of these

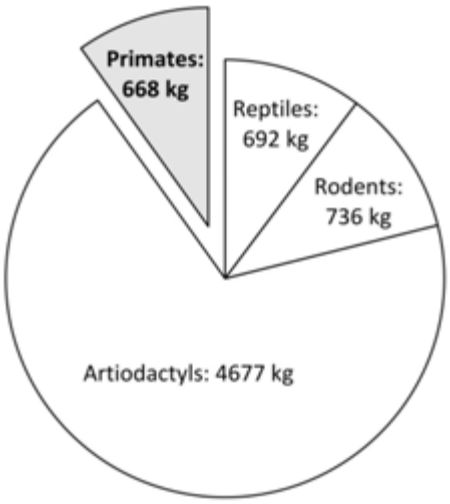


Figure 3. Proportion of primates' meat (10%) in the batch of 6,773kg of smoked bushmeat carcasses sold by 18 vendors between March and July 2016 in Lubumbashi. Artiodactyls included species of warthogs, antelopes and buffaloes found in the region.

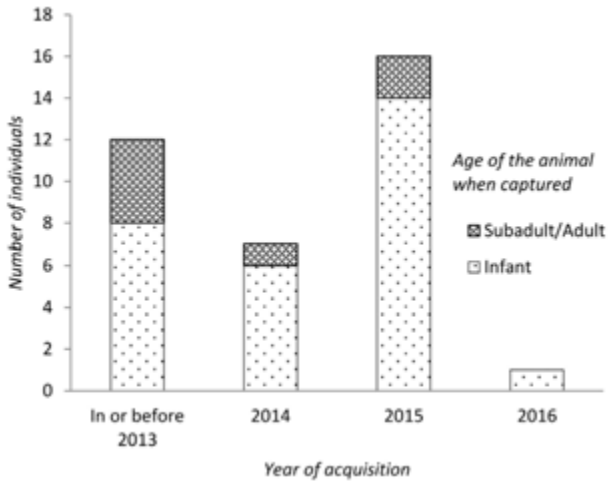


Figure 4. Distribution of the 36 primates used as pets per date of acquisition and age classes when they were captured in the wild. Data have been collected between August 2015 and February 2016.

species were decreasing. According to the others, primate populations were stable (6%) or increasing (24%). Respondents also considered that keeping primates as pets was: beneficial (44% of the 34); with no influence (32%), and a form of threat to wild populations (24%). In addition, for 58% of respondents who claimed that primate populations were decreasing, among the types of threats listed, trade of live primates ranked the third after primate meat consumption and habitats loss. More than 75% of the pet primate owners affirmed not to be aware of the existence of any law regulating the detention of wild animals in DRC.

Image 1. Photos of primates used as pets in some households surveyed in Lubumbashi City. (A) an adult and (B) an infant Baboon *Papio kindae*; (C) a subadult Malbrouck Monkey *Chlorocebus cynosuros*. © P. Kazaba.

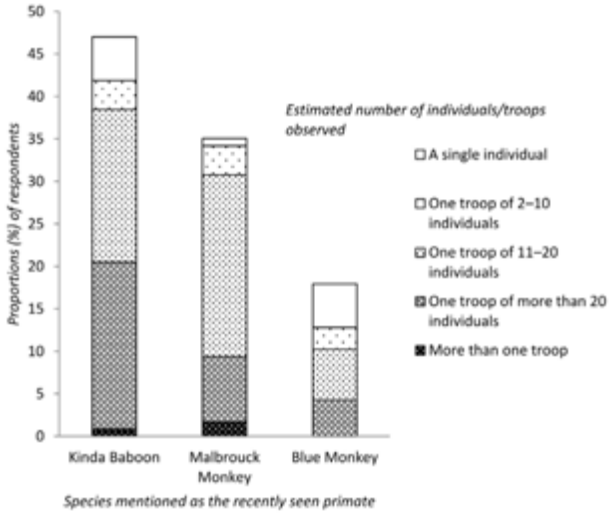


Figure 5. Species and estimated number of individuals/troops of primates declared to be seen more recently in the Sector North of Upemba National Park by the 117 respondents. Overall, the last sighting of these species was: less than one month (for 33% of respondents); between one and three months (22%), and more than three months (45%) before the survey period.

Primates in the Sector North of Upemba National Park

Occasional observations and survey data suggest the existence of all the three primate species in the Sector North of Upemba National Park and its vicinities. The Kinda Baboon was mentioned by 47% of the 117 respondents as the diurnal primate seen more recently (this was less than a month before the survey period for 33% of respondents) in the area. In fact, troops of baboons are frequently reported (Vanleeuwe 2008, Rodrigue Katembo pers. comm. 21 December 2016) and have been observed during our fieldwork. Malbrouck Monkeys and Blue Monkeys were mentioned by 35% and 18% of the respondents, respectively (Fig. 5). Overall, these animals were reported to occur in a variety of environments: dense forests galleries (for 26% of respondents), Miombo woodlands (27%), savannas (38%) and human settlements, including cultivated lands (9%).

All three species were listed as crop-raiding primates. More than 85% of the respondents mentioned "damage to crops" as the main problem caused by these primates in the area. Rangers reported several cases of human-wildlife conflict involving Kinda Baboons and Malbrouck monkeys, which are apparently more frequent outside of protected areas. According to the management of the park, dialogue with local people is often used as a way of addressing these conflicts, and there is no compensation scheme for damage caused by wildlife in the area. Culling problematic animals was listed by the majority (70%) of respondents as the most effective way to repel crop-raiding primates.

Although most respondents (30 out of the 37) living within the protected area (at the Lusinga Station) listed agriculture among their livelihood activities, only a small proportion (38%) of them showed a perception of these species as "pest primates" at first glance, unlike in the two villages neighboring the park (almost 90%, N=80). Results of a chi-square test confirmed that mentioning a fact related to crop-raiding when questioned "what do you know about this primate?" significantly depended on where respondents lived, X^2 (1, N =117) = 33, P < 0.001. This is probably due to the fact that most of the respondents settled at Lusinga are relatives of staff members of the Upemba National Park, and thus rely one way or another on wildlife conservation, or are more aware of conservation-related benefits such as ecotourism.

DISCUSSION

Illegality and Complexity in the Trade of Primates

Geographic data presented in Fig. 2 reflects the illegal nature of the trade of both bushmeat and live primates. In fact, it is shown that primates are captured out of the sites (hunting domains) clearly defined by the Congolese legislation. Moreover, the sites mentioned the most are located in proximity or at junction points of main roads, some of which cross protected areas such as Upemba and Kundelungu national parks. A number of studies have pointed out the impact of road networks on wildlife. In the Congo Basin, Wilkie et al. (2000) noted that the road density was closely linked with natural resources exploitation and the disappearance of wildlands and wildlife, among others. Poulsen et al. (2009) suggested that the road network facilitated access to remote areas and accelerated the exploitation of wildlife by creating markets to wildlife products in the Northern Congo. This situation has also been raised in the specific case of logging in DRC (Ngabinzeke et al. 2014), in the Congo Basin (Kleinschroth et al. 2015) and in tropical Africa as a whole (Laurance et al. 2017). In the study area, it is frequent to observe wildlife products being sold along roadsides.

From the results of the surveys carried out in Lubumbashi, it can be noted that quantities of bushmeat sold in markets are far lower than those observed in the north-east (van Vliet et al. 2012) and the west of DRC (Ngabinzeke et al. 2014), however, similar trends are observed in terms of proportions of weight of carcasses

when grouped per taxonomic groups: like in this study, carcasses of artiodactyls accounted for about 70% of bushmeat sold in markets of Kisangani city (van Vliet et al. 2012) and around a forest concession (Ngabinzeke et al. 2014). Monkeys were ranked the second taxonomic group, representing nearly 30% (van Vliet et al. 2012) and 15% (Ngabinzeke et al. 2014) of bushmeat carcasses. Like the aforementioned studies, we support the view that consuming primate meat reflects the scarcity of animals usually and mostly consumed such as artiodactyls. From this point of view, and considering the increase in hunting pressure reported in DRC, primates will certainly be increasingly targeted and threatened across the country.

Results also indicate that almost all live primates, as well as a notable proportion of the bushmeat consumed in households and restaurants (21%), are purchased and sometimes ordered directly from hunters. Therefore, data from formal markets are not sufficient to represent the whole extent of the bushmeat trade, and should not be considered the only way to determine quantities of bushmeat consumed locally. Also, as an illustration, certain food items such as sugar, rice, corn flour, vegetables, fishes and meats are commonly sold in a kind of informal market starting around 5 p.m in downtown Lubumbashi and called 'marchés de nuit' (literally, night markets) (Kesonga et al. 2016). It is possible that bushmeat is also sold in these markets, but for logistical reasons data from them was not collected.

Globally Evaluated 'Least Concern' but Locally at Risk?

Trends observed in both the city and the wild raise concerns about the fate of affected species. Apart from being consumed as bushmeat, used as pets or regarded as pests, Kinda Baboons, Malbrouck Monkeys and Blue Monkeys are all found in the Miombo ecoregion, where increasing fragmentation of natural habitats has been reported (Kabulu et al. 2008). For example, in the hinterland of Lubumbashi, Miombo woodlands (occupying 85% of the area in 1956) experienced a decline of 76% between 1956 and 1984 and 40% between 1984 and 2009 (Munyemba & Bogaert 2014). Adding the hunting pressure to the increasing spatial overlap between human activities and wildlife, due to (among others) the current population growth (UN-Habitats 2014; Useni et al. 2017), wild populations of these primates are no doubt at risk in that area.

In addition, all the three species are not sufficiently protected from the legal point of view. Indeed, unlike great apes such as Bonobos, Chimpanzees and Gorillas listed as 'Fully Protected' species (Appendix I) by the Congolese Hunting Act (Mpoyi 2012), many diurnal monkeys are still 'Partially Protected' (Appendix II) or 'Non-Protected' (Appendix III) and thus may be hunted under less strict conditions. These include the Blue Monkey (Appendix II), and the Kinda Baboon and the Malbrouck monkey (Appendix III). According to this Act, except under a scientific license, capturing, trading and possessing specimens of 'Fully Protected' species are strictly prohibited and severely punished. Like in Lubumbashi (Tshikung & Pongombo 2009; this study), Kisangani (van Vliet et al. 2012) and Oshwe (Ngabinzeke et al. 2014), several monkey species are part of the bushmeat commonly sold and are kept as pets (Gambalemoke et al. 2000) across the country.

The IUCN has a key role to play in raising awareness about the conservation status of species and thus guiding conservation efforts (Rodrigues et al. 2006; Hermoso et al. 2017). As in many countries, DRC relies on the IUCN evaluations and many other international instruments for defining conservation priorities and strategies. It should be highlighted, however, that the three species of diurnal monkeys sold as bushmeat, kept as pets or considered as pest animals remain part of the Category 'Least Concern' on the IUCN Red List, the latest evaluation being published in 2008 for both the Malbrouck Monkey (Butynski 2008) and the Blue Monkey (Kingdon et al. 2008), and in 2016 for the Kinda Baboon (Kingdon 2016) . Considering the results of this study and the insufficient level of legal protection for these species, their conservation status resulting from a global evaluation does not reflect their true conservation status in DRC. A similar contrast has also been raised by many scholars (Gärdenfors et al. 2001; Maes et al. 2015; Erinjery et al. 2017; Thakur et al. 2018) for several taxa worldwide.

CONCLUSION

This study presents a preliminary appraisal of the extent of human-driven threats to the remaining primate populations in the south-east of DRC. Results revealed that three Cercopithecine monkeys: Kinda Baboons, Malbrouck monkeys and Blue Monkeys, account for a significant part of the bushmeat frequently sold and consumed; are illegally kept as pets in Lubumbashi, and are regarded as pests because of their crop-raiding behavior in the Sector North of Upemba National Park and its vicinities. The uses of primates as studied in Lubumbashi are likely to undergo a rapid evolution, and considering the increasing trends in spatial overlap

between human activities and wildlife, the three species are likely at risk in the area. It is obvious that putting in relation the dynamic of habitats, levels of hunting and data on the abundance and distribution of these species in the wild is the best path towards the prediction of human-driven threats and their impacts on these species. This study provides an overview of these threats, from which two main lessons emerge:

1. Data from markets may not suffice to reflect the extent of a phenomenon such as the illegal bushmeat trade, given that significant quantities of wildlife products may be directly delivered to households by hunters.

2. The decline in wild populations of artiodactyls, which account for most of the bushmeat currently being traded and consumed, may increase hunting pressure on other taxa such as primates. Thus addressing the bushmeat crisis will require predicting changes in the availability of bushmeat and the resulting trends in consumer preferences for taxonomic wildlife groups. This will identify potentially threatened taxa and help to judiciously guide conservation strategies.

The fact that the majority of the respondents depending (directly or not) on the Upemba National Park do not perceive the three primate species as pests supports the idea that sharing wildlife-related benefits can improve the attitudes of populations neighboring protected areas towards wildlife, and thus facilitate the implementation of conservation tools. Conversely, the perception of wild animals as pests may hinder conservation efforts, as highlighted in many studies.

Finally, this study illustrates the problem of evaluating species without considering local and rapidly-changing threats. The necessity of local and country-level Red Lists of threatened taxa should be emphasized. In this respect, there is also a need for updating the legal status of species based on fresh data on trends in both wild populations and anthropogenic threats.

REFERENCES

Alves, R.R.N., W.M.S. Souto & R.R.D. Barboza (2010). Primates in traditional folk medicine: World overview. *Mammal Review* 40(2): 155–180; https://doi.org/10.1111/j.13652907.2010.00158.x

Assani, A.A. (1999). Analyse de la variabilité temporelle des précipitations (1916-1996) à Lubumbashi (Congo-Kinshasa) en relation avec certains indicateurs de la circulation atmosphérique (oscillation australe) et océanique (El Niño/La Niña). *Sécheresse* 10(4): 245–252.

Butynski, T.M. (2008). *Chlorocebus cynosuros*. The IUCN Red List of Threatened Species 2008: e.T136291A4270290; dowloaded on 10 October 2018; http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T136291A4270290.en

Carpaneto, G. & F. Germi (1989). The mammals in the zoological culture of the Mbuti Pygmies in north-eastern Zaire. *Hystrix the Italian Journal of Mammalogy* 1: 1–83; https://doi.org/10.4404/hystrix-1.1-3888

Ceballos-Mago, N., C. González & D. Chivers (2010). Impact of the pet trade on the Margarita Capuchin Monkey *Cebus apella margaritae*. *Endangered Species Research* 12(1): 57–68; https://doi.org/10.3354/esr00289

Chapman, C.A., M.J. Lawes & H.A.C. Eeley (2006). What hope for African primate diversity? *African Journal of Ecology* 44(2): 116–133; https://doi.org/10.1111/j.1365-2028.2006.00636.x

Cheyne, S.M. (2009). Challenges and opportunities of primate rehabilitation - Gibbons as a case study. *Endangered Species Research* 9: 159–165; https://doi.org/10.3354/esr00216

Ebua, V.B., T.E. Agwafo, M. Mbida & J. Vaughan (2014). Rehabilitating captive wild-born yellow Baboons (*Papio cynocephalus*) for re-introduction into the wild. *International Journal of Biodiversity and Conservation* 6(2): 159–170; http://dx.doi.org/10.5897/IJBC2013.0660

Erinjery, J., S. Kumar, H.N. Kumara, K. Mohan, T. Dhananjaya, P. Sundarraj, R. Kent & M. Singh (2017). Losing its ground: A case study of fast declining populations of a 'least-concern' species, the Bonnet Macaque (*Macaca radiata*). *PlosOne*; https://doi.org/10.1371/journal.pone.0182140.

Estrada, A., P.A. Garber, A.B. Rylands, C. Roos, E. Fernandez-Duque, A. Di Fiore, Nekaris K.A.I., V. Nijman, E.W. Heymann, J.E. Lambert, F. Rovero, C. Barelli, J.M. Setchell, T.R. Gillespie, R.A. Mittermeier, L.V. Arregoitia, M. de Guinea, S. Gouveia, R. Dobrovolski, S. Shanee, N. Shanee, S.A. Boyle, A. Fuentes, K.C. MacKinnon, K.R. Amato, A.L.S. Meyer, S. Wich, R.W. Sussman, R. Pan, I. Koné & B. Li (2017). Impending extinction crisis of the world's primates: Why primates matter. *Science Advance* 3: e1600946; https://doi.org/10.1126/sciadv.1600946

Fa, J.E., J. Juste, J. Pérez de Val & J. Castroviejo (1995). Impact of market hunting on mammal species in Equatorial-Guinea. *Conservation Biology* 9(5): 1107–1115; https://doi.org/10.1046/j.1523-1739.1995.951107.x

Gambalemoke, M., K. Kitambala, N. Tshikaya & K. Nyebone (2000). Les animaux sauvages détenus dans la cité de Bunia (R.D. Congo): Inventaire et application des lois relatives à la détention. *Tropicultura* 18 : 8–88.

Gärdenfors, U., C. Hilton-Taylor, G.M. Mace & J.P. Rodríguez (2001). The application of IUCN Red List criteria at regional levels. *Conservation Biology* 15(5): 1206–1212; https://doi.org/10.1111/j.1523-1739.2001.00112.x

Hart, J.A., F. Grossmann, A. Vosper & J. Ilanga (2008). Human hunting and its impact on bonobos in the Salonga National Park, Democratic Republic of Congo, pp. 245–271. In: Furuichi, T. & J.M. Thompson (eds.). *The Bonobos: Behavior, Ecology and Conservation*. Springer, New York, 336pp.

Hart, J.A., K.M. Detwiler, C.C. Gilbert, A.S. Burrell, J.L. Fuller, M. Emetshu, T.B. Hart, A. Vosper, E.J. Sargis A.J. & Tosi (2012). Lesula: a new species of *Cercopithecus* monkey endemic to the Democratic Republic of Congo and implications for conservation of Congo's Central Basin. *PLoS ONE* 7(9): e44271; https://doi.org/10.1371/journal.pone.0044271

Hermoso, V., S.R. Januchowski-Hartley, S. Linke, D. Dudgeon, P. Petry & P. McIntyre (2017). Optimal allocation of Red List assessments to guide conservation of biodiversity in a rapidly changing world. *Global Change Biology* 23(9): 3525–3532; https://doi.org/10.1111/gcb.13651

Hicks, T.C., L. Darby, J. Hart, J. Swinkels, N. January & S. Menken (2010). Trade in orphans and bushmeat threatens one of the Democratic Republic of the Congo's most important populations of eastern chimpanzees (*Pan troglodytes schweinfurthii*). *African Primates* 7(1): 1–8; http://hdl.handle.net/11245/1.332289

Inogwabini, B.I. (2014). Conserving biodiversity in the Democratic Republic of Congo: a brief history, current trends and insights for the future. *Parks* 20(2): 101–110; https://doi.org/10.2305/IUCN.

CH.2014.PARKS-20-2.BI.en

Kabasawa, A. (2009). Current state of the chimpanzee pet trade in Sierra Leone. *African Study Monographs* 30(1): 37–54.

Kabulu, D.J., I. Bamba, K.F. Munyemba, P. Defourny, C. Vancutsem, N.S. Nyembwe, L.M. Ngongo & J. Bogaert (2008). Analyse de la structure spatiale des forêts au Katanga. *Annales de la Faculté des Sciences Agronomiques* 1(2): 12–18.

Kingdon, J. (2016). *Papio kindae*. The IUCN Red List of Threatened Species 2016: e.T136848A92251482; dowloaded on 10 October 2018; https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T136848A92251482.en

Kingdon, J., S. Gippoliti, T.M. Butynski, M.J. Lawes, H. Eeley, C. Lehn & Y. De Jong (2008). *Cercopithecus mitis*. The IUCN Red List of Threatened Species 2008: e.T4221A10676022; dowloaded on 10 October 2018; https://doi.org/10.2305/IUCN.UK.2008.RLTS.T4221A10676022.en

Kleinschroth, F., S. Gourlet-Fleury, P. Sist, F. Mortier & J.R. Healey (2015). Legacy of logging roads in the Congo Basin: How persistent are the scars in forest cover? *Ecosphere* 6(4): 1–17; https://doi.org/10.1890/ES14-00488.1

Laurance, W.F., M.J. Campbell, M. Alamgir & M.I. Mahmoud (2017). Road expansion and the fate of Africa's tropical forests. *Frontiers in Ecology and Evolution*, 5: 75; https://doi.org/10.3389/fevo.2017.00075

Maes, D., N.J. Isaac, C.A. Harrower, B. Collen, A.J. Van Strien & D.B. Roy (2015). The use of opportunistic data for IUCN Red List assessments. *Biological Journal of the Linnean Society* 115(3): 690–706; https://doi.org/10.1111/bij.12530

Malaisse, F. (2010). *How to Live and Survive in Zambezian Open Forest (Miombo Ecoregion).* Presses Agronomiques de Gembloux, Gembloux, 422pp.

Mallon, D.P., M. Hoffmann, M.J. Grainger, F. Hibert, N. van Vliet & P.J.K. McGowan (2015). Analyse de situation de l'UICN concernant la faune terrestre et d'eau douce en Afrique centrale et de l'Ouest. Document occasionnel de la Commission de la sauvegarde des espèces de l'UICN nº 54. UICN, Gland, 162pp.

Mittermeier, R.A., A.B. Rylands & D.E. Wilson (Eds.) (2013). *Handbook of the Mammals of the World: Primates.* Lynx Edicions, Spain, 952pp.

Mossoun, A., M. Pauly, C. Akoua-Koffi, E. Couacy-Hymann, S.A. Leendertz, A.E. Anoh, A.H. Gnoukpoho, F.H. Leendertz & G. Schubert (2015). Contact to non-human primates and risk factors for zoonotic disease emergence in the Taï region, Côte d'Ivoire. *EcoHealth* 12(4): 580–591; https://doi.org/10.1007/s10393-015-1056-x

Mpoyi, M.A. (2012). *Les Codes Verts: Textes légaux et réglementaires de la République Démocratique du Congo en matière de l'environnement et des ressources naturelles. Tome I textes juridiques en matière des forêts, 2ème édition revue et augmentée*. CODELT, Kinshasa, 574pp.

Munyemba, K.F. & J. Bogaert (2014). Anthropisation et dynamique spatiotemporelle de l'occupation du sol dans la région de Lubumbashi entre 1956 et 2009. *E-Revue UNILU* 1: 3–23 ; http://www.unilu.ac.cd/pressesuniversitaires/wp-content/uploads/2015/05/Munyemba-et-Bogaert.pdf

Ngabinzeke, J.S., J.B. Masamba, R.N. M'Vubu & C. Vermeulen (2014). Consommation de produits d'origine animale dans la concession forestière 039/11 de la SODEFOR à Oshwe. *Tropicultura* 32: 147–55.

Oates, J.F. (2013). Primate conservation: Unmet challenges and the role of the International Primatological Society. *International Journal of Primatology* 34(2): 235–45; https://dx.doi.org/10.1007/s10764-013-9664-1

Poulsen, J.R., C.J. Clark, G. Mavah & P.W. Elkan (2009). Bushmeat supply and consumption in a tropical logging concession in northern Congo. *Conservation Biology* 23(6): 1597–1608; https://doi.org/10.1111/j.1523-1739.2009.01251.x

Rainer, H., A. White & A. Lanjouw (eds.) (2014). *State of the Apes 2013. Extractive Industries and Ape Conservation.* Cambridge University Press, Cambridge, 367pp.

Refisch, J. & I. Koné (2005). Impact of commercial hunting on monkey populations in the Taï Region, Côte d'Ivoire. *Biotropica* 37(1): 136–144; https://doi.org/10.1111/j.1744-7429.2005.03174.x

Roberts, P., N. Boivin, J. Lee-Thorp, M. Petraglia & J. Stock (2016). Tropical forests and the genus *Homo*. *Evolutionary Anthropology* 25(6): 306–317; https://doi.org/10.1002/evan.21508

Rodrigues, A.S.L., J.D. Pilgrim, J.F. Lamoreux, M. Hoffmann & T.M. Brooks (2006). The value of the IUCN Red List for conservation. *Trends in Ecology & Evolution* 21 (2): 71–76.

Rowe, N. (1996). *The Pictorial Guide to the Living Primates*. Pogonias Press, East Hampton, N.Y., 263pp.

Saad, L., I. Parmentier, G. Colinet, F. Malaisse, M.-P. Faucon, P. Meerts & G. Mahy (2012). Investigating the vegetation–soil relationships on the copper–cobalt rock outcrops of Katanga (D.R. Congo), an essential step in a biodiversity conservation plan. *Restoration Ecology* 20: 405–415; http://dx.doi.org/10.1111/j.1526-100X.2011.00786.x

Schwitzer, C., R.A. Mittermeier, A.B. Rylands, L.A. Taylor, F. Chiozza, E.A. Williamson, J. Wallis & F.E. Clark (2014). *Primates in peril: The world's 25 most endangered primates 2012–2014*. IUCN SSC Primate Specialist Group (PSG), International Primatological Society (IPS), Conservation International (CI), and Bristol Zoological Society, Arlington, 87pp.

Stiles, D., I. Redmond, D. Cress, C. Nellemann & R.K. Formo (2013). Stolen apes: The illicit trade in Chimpanzees, Gorillas, Bonobos and Orangutans. A Rapid Response Assessment. United Nations Environment Programme, GRID-Arendal, Nairobi, 56pp.

Svensson, M.S., D.J. Ingram, K.A. Nekaris V. & Nijman (2015). Trade and ethnozoological use of African Lorisiforms in the last 20 years. *Hystrix the Italian Journal of Mammalogy* 26(2): 153–161; https://doi.org/10.4404/hystrix-26.2-11492

Thakur, M., E.W. Schättin & W.J. McShea (2018). Globally common, locally rare: revisiting disregarded genetic diversity for conservation planning of widespread species. *Biodiversity and Conservation*: 27(11): 3031–3035; https://doi.org/10.1007/s10531-018-1579-x

Tshikung, K.M. & S.E.W. Pongombo (2009). Identification et détermination de statut des populations fauniques commercialisées et consommées dans la ville de Lubumbashi, R.D. Congo. Rapport préliminaire. *Annales de la Faculté de Médecine Vétérinaire* 20: 54–59.

UN-Habitat (2014). The State of African Cities 2014. Re-imagining Sustainable Urban Transitions. United Nations Human Settlements Programs, Nairobi, 273pp.

Useni, Y.S., S.K. Cabala, C.K. Nkuku, Y.M. Amisi, F. Malaisse, J. Bogaert & F.K. Munyemba (2017). Vingt-cinq ans de monitoring de la dynamique spatiale des espaces verts en réponse à l'urbanisation dans les communes de la ville de Lubumbashi (Haut-Katanga, RD Congo). *Tropicultura* 35(4): 300–311.

van Lavieren, E. (2008). The illegal trade in Barbary Macaques from Morocco and its impact on the wild population. *Traffic Bulletin* 21: 81–88.

van Uhm, D.P. (2016). Monkey business: the illegal trade in Barbary macaques. *Journal of Trafficking, Organized Crime and Security* 2(1): 36–49.

van Vliet, N., C. Nebesse, S. Gambalemoke, D. Akaibe & R. Nasi (2012). The bushmeat market in Kisangani, Democratic Republic of Congo: implications for conservation and food security. *Oryx* 46(2): 196–203; https://doi.org/10.1017/S0030605311000202

Vanleeuwe, H. (2008). Large mammals and human impact surveys. Upemba and Kundelungu National Parks, Democratic Republic of Congo. WCS/U.S. Fish and Wildlife Service, 30pp.

White, F. (1983). *La végétation de l'Afrique : Mémoire accompagné de la carte de la végétation de l'Afrique*. ORSTOM-UNESCO, Paris, 384pp.

Wilkie, D., E. Shaw, F. Rotberg, G. Morelli & P. Auzel (2000). Roads, development, and conservation in the Congo Basin. *Conservation Biology* 14(6): 1614–1622; https://doi.org/10.1111/j.1523-1739.2000.99102.x

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13261–13277

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM
OPEN ACCESS

Diversity, structure and natural history of amphibians in the upper Claro River basin, a buffer zone of the National Natural Park Los Nevados, Central Cordillera of Colombia

Julián Andrés Rojas-Morales [1] & **Mateo Marín-Martínez** [2]

[1] Postgrado en Ecología Tropical, Instituto de Ciencias Ambientales y Ecológicas, Facultad de Ciencias, Universidad de Los Andes, Núcleo La Hechicera, 5101, Mérida, Venezuela.
[1] Associate researcher Museo de Historia Natural, Centro de Museos, Universidad de Caldas, Calle 58 # 21-50, A. A. 275, Manizales, Colombia.
[2] Grupo de Ecología y Diversidad de Anfibios y Reptiles, Facultad de Ciencias Exactas y Naturales, Universidad de Caldas, Calle 65 # 26-10, A. A. 275, Manizales, Colombia.
[1] julian.herpetologia@gmail.com (corresponding author), [2] mateo2805@hotmail.com

Abstract: We present an assessment on composition, diversity and structure of amphibians in three zones along an elevation gradient (2,400–3,000 m) in the Central Cordillera of Colombia. For this purpose, we carried out two field trips in November 2014 and February 2015, covering rainy and dry seasons, respectively. Diurnal (08:00–12:00 h) and nocturnal (18:00–22:00 h) visual encounter surveys were made without spatial restrictions. The diversity for each zone (alpha) and for the entire landscape (gamma) was evaluated by the effective number of species, and the structure of the communities was analyzed by range-abundance curves. The inequality factor for each of the sampling zones was also calculated. A total of 15 species belonging to seven genera and three families were recorded, all of the order Anura. Craugastoridae with 11 species (73.3% of richness) and *Pristimantis* (eight species) were the most diverse family and genus, respectively. The average alpha diversity per zone was 6.6 effective species, with zone A being the most diverse with eight species. In terms of beta diversity we found 2.5 effective communities at the landscape level, and differences between zones are given by the rare species, while the most abundant ones (e.g., *Pristimantis uranobates*) are shared between them. It is presumed that the greater diversity of zone A is due to the lower elevation and better state of conservation if compared to the other two zones. Of the total species recorded, three are threatened with extinction: Endangered (*Hypodactylus latens*, *Osornophryne percrassa*), and Critically Endangered (*Niceforonia adenobrachia*). The finding of three yet undescribed species is highlighted.

Keywords: Andean landscapes, diversity, endemic species, threatened amphibians.

DOI: https://doi.org/10.11609/jott.4075.11.3.13261-13277 | **ZooBank:** urn:lsid:zoobank.org:pub:0E9C1E7D-CC3E-45DA-A250-4970233C1168

Editor: Mirco Solé, Universidade Estadual de Santa Cruz, Salobrinho, Brazil. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4075 | Received 12 February 2018 | Final received 24 January 2019 | Finally accepted 02 February 2019

Citation: Rojas-Morales, J.A. & M. Marin-Martinez (2019). Diversity, structure and natural history of amphibians in the upper Claro River basin, a buffer zone of the National Natural Park Los Nevados, Central Cordillera of Colombia. *Journal of Threatened Taxa* 11(3): 13261–13277; https://doi.org/10.11609/jott.4075.11.3.13261-13277

Funding: Central Hidroeléctrica de Caldas S.A. E.S.P (CHEC); Universidad de Caldas.

Competing interests: The authors declare no competing interests.

Author Contribution: Both authors made an equal contribution to this research.

For **Spanish abstract** and **Author Details** see end of this article.

Acknowledgements: Special thanks to Alexandra Jaramillo (La Laguna Hostel) for providing lodging, food and work space during our field work periods. Thanks to Daniela Gómez and Camilo Morales for supporting us in the field work during the first outing, to César Duque Castrillón for providing us with some of his photographs, to Julián Adolfo Salazar (MHN-UCa) for the work space in the laboratory of the Natural History Museum of the University of Caldas, to Sergio Escobar for his help with the preparation of the study area map. This work is the product of the project "Línea base biótica para el proyecto geotérmico del valle de Nereidas-CHEC", supported by the Central Hidroeléctrica de Caldas S.A. E.S.P (CHEC) and developed by the University of Caldas. Thanks to Nancy Aydeé Rojas, Fernando Vargas Salinas (University of Quindío), Aldemar Acevedo (University of Pamplona), and Cristina Aristizábal (National Natural Parks of Colombia) for their observations and comments on the manuscript.

INTRODUCTION

The study of biodiversity in the mega-diverse countries is a condition without which development models could not be implemented in a sustainable manner (Erhlich & Wilson 1991; Adams et al. 2004; Greene et al. 2005). Therefore, to carry out research that generates knowledge about diversity, distribution, uses and threats to biodiversity, it is an obligation to delineate these models at different scales. Colombia is characterized by its high biodiversity, highlighting a considerable richness of anuran amphibians (757 species with 354 endemics; Acosta & Cuentas 2018), being the second richest amphibian country in the world after Brazil (Frost 2017). Contrary to this, near to 28% of Colombian amphibian species are threatened with extinction (Acosta & Cuentas 2018) due to different factors, such as climate change, habitat transformation, chytridiomycosis, and introduction of exotic species (Stuart et al. 2008). The highest proportion of threatened species is concentrated in the Andean region, where the greatest diversity occurs with more than 400 species (Lynch et al. 1997; Acosta 2000; Kattan et al. 2004; Bernal & Lynch 2008; Acosta & Cuentas 2018).

Located in Central Cordillera and delimited from east to west by the basins of the Magdalena and Cauca rivers, respectively, the department of Caldas is one of the smallest departments (geographic political units) of Colombia. Despite having a small geographic area (7888km^2), its amphibian fauna represents approximately 14% of the known richness for Colombia (Acosta 2009; Rojas-Morales et al. 2014a). Such diversity can be attributed to its location within the north Andean region, which represents the global Hotspot (Myers et al. 2000) with the highest amphibian diversity in the world (Hutter et al. 2017). In some areas above 2,500m of elevation and up to the Páramo level (3,200–3,700 m), there is still an information gap regarding composition and diversity of amphibians. At this area, landscape configuration has been modified since the mid-nineteenth century to expand livestock farms, and subsequently extensive potato crops (*Solanum tuberosum*). This has considerably transformed the original habitat of this mountain region (Valencia 1985; Márquez 2001).

Although in recent years there have been numerous studies to quantify the amphibian's diversity at different spatial scales in Colombia particularly to compare between natural and modified habitats (e.g., Arroyo et al. 2003; Urbina & Londoño 2003; Cadavid et al. 2005; García et al. 2007; Cáceres-Andrade & Urbina-Cardona 2009; Osorno et al. 2011), the metrics used are not the most appropriate because they do not represent the diversity per se of the communities. Indexes such as Shannon or Simpson dominance are measures of entropy, but do not correspond with the number of effective elements that make up a biological community. For that reason it is difficult to interpret and compare results from different studies with this mathematical application (Ricotta 2003; Jost 2006; Moreno et al. 2011). Only until very recent years, a different approach has been used to measure the diversity (including amphibians), taking into account the conversion of indexes into values of number of effective species, to represent the species diversity (Jost 2006; Rös et al. 2012; Acevedo et al. 2016; Méndez-Narváez & Bolívar-G 2016; Vargas-Salinas & Aponte-Gutierrez 2016; Casas-Pinilla et al. 2017). The approach proposed by Jost (2006) is more effective to account diversity, because results are given in number of species, which facilitates interpretation of results.

In this paper we present an analysis of amphibian diversity and structure, between three zones of an Andean river in the Central Cordillera of Colombia. We follow Jost's proposal (Jost 2006) for the analysis of species diversity, assuming the effective number of species as the diversity measurement. In addition, we provide information on natural history, distribution, and identification of the threatened species encountered in the study.

MATERIALS AND METHODS

Study area

The study was carried out in the area of the geothermal project of the "Nereidas Valley", located in the upper Claro River basin, Playa Larga Village, municipality of Villamaría, department of Caldas, Colombia, on the western slope of the Central Cordillera. This area occupies approximately 8km^2 of extension, and is located within the buffer zone of Los Nevados National Natural Park (Fig. 1). Fieldwork was carried out specifically in the farms "La Laguna" (zone A), "Playa Larga" (zone B) and "Laguna Alta" (zone C). The sampling zones are between 2,400–3,000 m of elevation, with a temperature and a relative humidity ranging between 8–16 ^{0}C and 78–93%, respectively. The average annual rainfall reaches 2,076mm, with two rainy periods between March–May and October–November (Acosta-Galvis 2009). Two life zones are recognized in this area (sensu Holdridge 1982), which correspond to the very humid low montane forest (bmh-MB) from

2,400–2,600 m, and the pluvial montane forest (bp-M) above this elevation, in the Zone B.

Landscape at this area is dominated by pastures for livestock (> 70% of the landscape) with introduced grass species such as *Pennisetum clandestinum*, *Holcus lanatus*, and *Paspalum* sp. (Poaceae). Secondary forests are the main natural coverage, restricted to the hilltops and stream borders that normally do not exceed 100m in width. All this area is drained by the Claro River, and Molinos and Nereidas streams, which make up the upper Claro River basin (Image 1).

Zone A - "La Cadena": (4.919^{0}N & -75.455^{0}W, WGS84, 2,420m). This is a secondary forest fragment in advanced state of succession with low anthropic intervention located in a narrow canyon with a steep slope (> 50%). The forest shows four differentiable strata with trees that reach up to 50m height (*Ceroxylon quindiuense*) (Image 2a). Highest strata are represented by species such as *Weinmannia pubescens, W. elliptica* (Cunoniaceae), *Brunellia comocladifolia* (Brunelliaceae), *Faramea flavicans* (Rubiaceae), *Guarea kunthiana* (Meliaceae), *Lippia schlimii* (Verbenaceae), *Drimys granadensis* (Winteraceae), *Oreopanax floribundus* (Araliaceae), *Turpinia occidentalis* (Staphyleaceae), *Ficus gigantosyce* (Moraceae) and *C. quindiuense* (Arecaceae). The understory is rich in herbaceous and growing trees, mainly of the genus *Piper* spp. (Piperaceae) and *Miconia* spp. (Melastomataceae), covered prolifically by mosses and lichens, as well as epiphytes such as bromeliads (*Mezobromelia capituligera*, *Guzmania multiflora*), and orchids (*Odontoglossum* spp., *Cyrtochilum diceratum*). This zone has a thick layer of leaf litter that remained humid during the two field trips. Inside the forest runs "La Cadena", a 2.5–3 m wide and 15–60 cm deep stream, which flows into the Claro River almost 300m downstream from this zone.

Zone B - "Playa Larga": (4.911^{0}N & -75.428^{0}W, WGS84, 3,000m). This area corresponds to a farm dedicated exclusively to cattle raising for milk production, whose forest fragments are characterized by presenting early stages of succession, dominated by species such as *Chusquea* spp. (Poaceae), *Erato vulcanica*

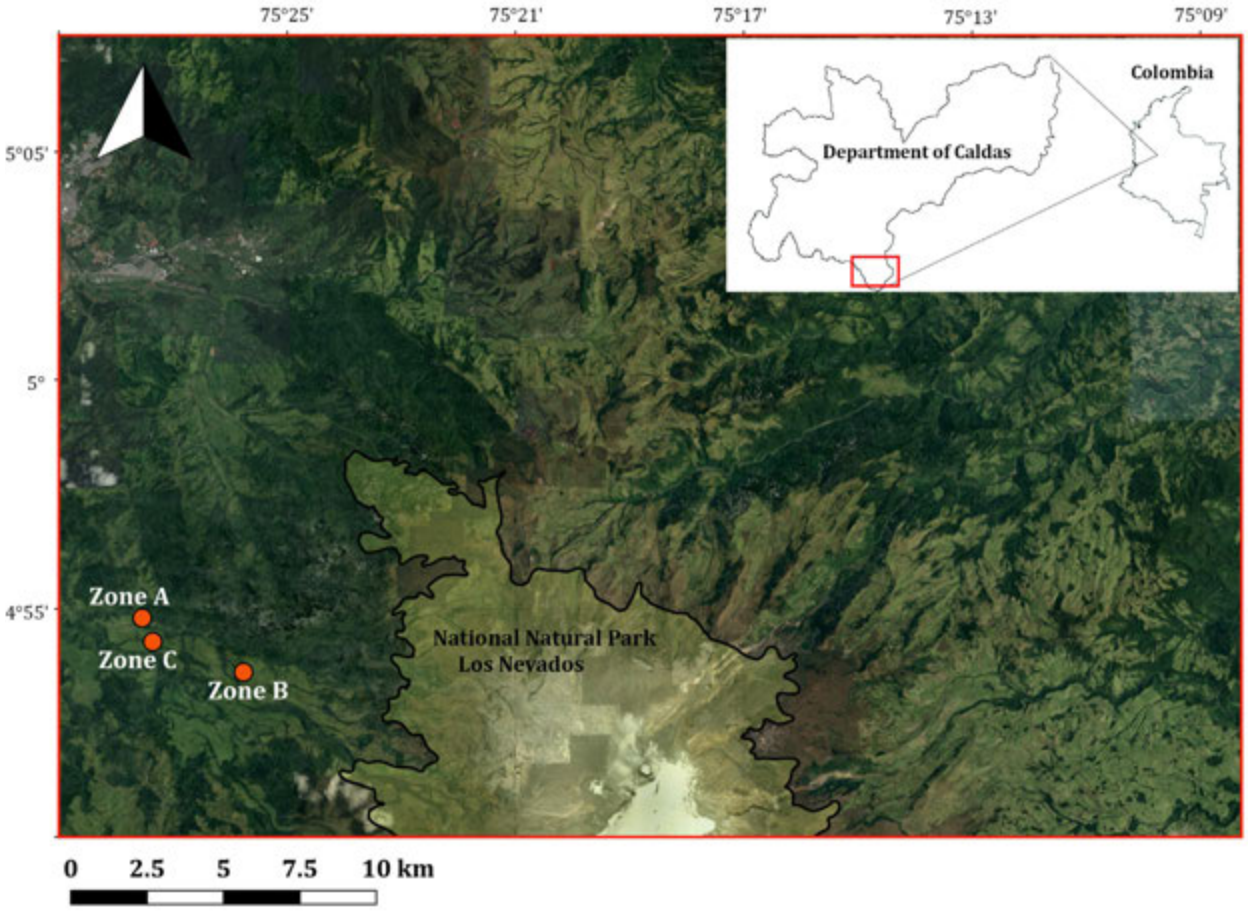


Figure 1. Study area indicating the sampling zones (red dots). Los Nevados National Natural Park is highlighted in light yellow.

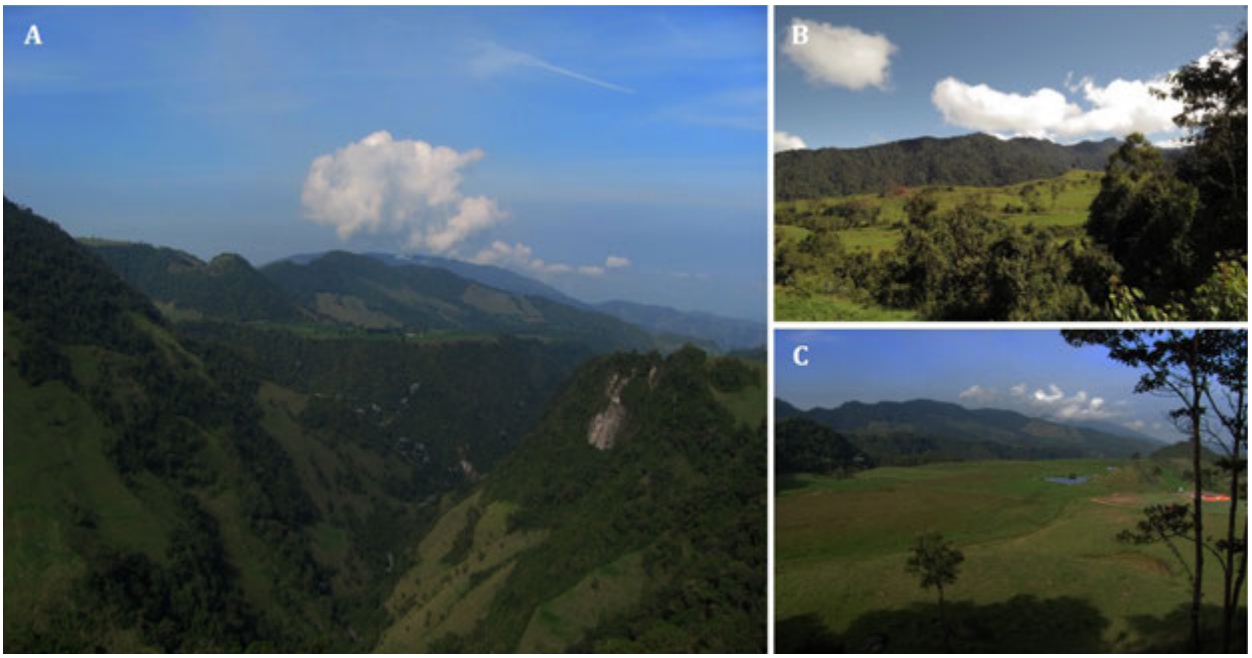


Image 1. Study area in the upper Claro River basin, municipality of Villamaría, department of Caldas, Colombia.
(A) Canyon of the Claro River at 2,500m elevation, showing the abrupt geomorphology in this area. (B) Zone B at 3,000m, evidencing the dominance of pastures for livestock; on the background there is a block of forest corresponding to the Forest Protective Reserve of the CHEC. (C) Zone C at 2,400m, showing the transformation of the natural forest to pastures and crops of potatoes (*Solanum tuberosum*) and onion (*Allium fistulosum*). © Julián Andrés Rojas.

(Asteraceae), *Solanum* spp. (Solanaceae), *Iresine* spp. (Amaranthaceae), *Gunnera* spp. (Gunneraceae), with a low presence of arboreal and shrub species; however, in the surroundings there are considerable forested areas restricted to the hilltops of the mountains, with slopes greater than 70% (Image 2b) crossed by streams that fall in cascades into the Claro River.

Zone C - "Laguna Alta": (4.925^{0}N & -75.458^{0}W, WGS84, 2,380m). This area also corresponds to a cattle farm for milk production, comprising a homogeneous matrix of introduced pastures. The forests are associated with the edge of the Claro River canyon.

Fieldwork

We carried out two field trips between November 11–17, 2014, and February 1–6 in 2015, covering rainy and dry periods, respectively. During each field trip the three zones were sampled, investing two consecutive days/night for each one. For the observation and capture of amphibians, diurnal (08:00–12:00 h) and nocturnal (18:30–22:00 h) samplings were carried out by two people, using the methodology of visual encounters surveys (VES) (Crump & Scott 1994), covering all possible habitats such as streams, inside forest, and open areas. The samplings were made from the ground to 2.5m above, being therefore an understory herpetofaunal research.

Amphibians were manually captured, and kept in plastic bags with vegetation inside to maintain humidity. For all individuals we registered their snout-vent length (SVL) (mm) and weight (g). In addition to this, the specific microhabitat was recorded classified as bare soil, litter, rock, trunk, leaf and water. Height of the perch and the distance to the nearest water body (m), besides temperature (°C) and relative humidity (%) for each register point, were registered too. We follow Frost (2017) for the taxonomic arrangement and for species identification we used the works of Cochran & Goin (1970), Lynch (1975, 1989, 1991), Lynch et al. (1994), Ardila-Robayo et al. (1996), Kaplan (1997), and Rivera-Correa & Faivovich (2013). Individuals were identified in the field as far as possible, but some specimens with taxonomic uncertainty were collected with the permission granted by the environmental authority (Corporación Autónoma Regional de Caldas - Resolution 1166 of 09 October 2014). Collected individuals were euthanized and prepared following the animal care protocol (Cortés et al. 2006). Specimens were deposited in the Herpetological Collection of the Museo de Historia Natural of the Universidad de Caldas (MHN-UCa), Colombia.

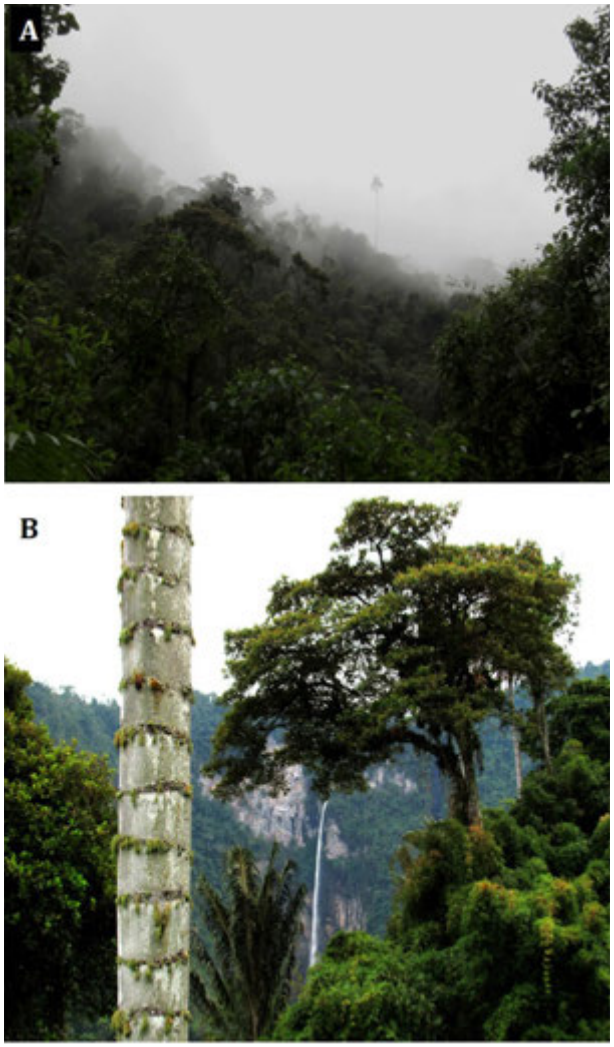


Image 2. Natural habitats sampled in the upper basin of the Claro River, municipality of Villamaría, department of Caldas, Colombia. (A) Interior of the forest in zone A. A semi-permanent fog covered the forest (cloud forest). (B) Zone B showing the beauty of the landscape characterized by the forest, steep slopes and waterfalls.

Data analysis

Diversity was evaluated in terms of the effective number of species "^{q}D" (Jost 2006), an approach that is equivalent to Hill's numbers (Hill 1973). ^{q}D is an ecological measure to quantify and compare the diversity expressed in biologically interpretable units (effective number of species) (Jost 2006). Three orders of diversity q were taken into account: order 0 (^{0}D, species richness), 1 (^{1}D, Shannon's entropy exponential) and 2 (^{2}D, Simpson's inverse). Exponent q determines the influence of the species abundance on the values of diversity. In this way the species richness (^{0}D) is not sensitive to the abundance of species and gives disproportionate weights to the rare species (Jost 2006). In ^{1}D (Diversity of Shannon), the contribution of each species is commensurate with its abundance in the community, and thus can be interpreted as the typical diversity or the number of common species in the community (Jost 2006). Finally, ^{2}D can be interpreted as the number of "very abundant" or "dominant" species in the community (Jost 2006). The completeness was evaluated as percentage of the community represented in the total of captured individuals (Chao & Jost 2012). The sampling coverage varies between 0% (low completeness) to 100% (high completeness). The estimation of the sampling coverage and diversity were made with the iNEXT package for R (Hsieh et al. 2016).

The structure of communities was analyzed through range-abundance graphs using the relative abundances of each species. This is to observe dominant and rare species and the equity of the sampled communities. The inequality value for each one of the sampling zones was also calculated using the inequality factor $IF_{0,q}$, using in this case the values of ^{2}D (Jost 2010):

$$IF_{0,2} = {}^{0}D/{}^{2}D$$

Where ^{0}D corresponds to the values of species richness and ^{2}D to the values of the second order diversity. A scale that oscillates between zero and one was standardized, where zero corresponds to low values of inequality and one to high values. For this the standardized formula (RI0, q) was used for the value previously calculated (IF0, q) and the number of species (S):

$$IR0, q = (IF0,q - 1) (S - 1)$$

To check whether the species showed any preference for a given geographical zone a chi-square based test of association was performed on the contingency matrix containing the species with their respective abundance in a given zone (Table 1). Correspondence analysis was performed to visualize the distribution of species in the three zones. Statistical analysis was performed in PAST 3.19 (Hammer et al. 2001). As the threatened species that were recorded are poorly represented in literature, we also present a description with useful characteristics for their identification in the field, and specific annotations about their distribution and natural history (Appendix II, Images 5–8).

RESULTS

Richness and species composition

After 96 hours/man in general for all sites (32h/site), 77 individuals were recorded, belonging to 15 species, seven genera and three families, all of the order Anura (Table 1). Craugastoridae was the best represented family, with 73.3% (11 species) of the records, and *Pristimantis* was the richest genus with eight species (Image 3); one of them represents a new species in the process of taxonomical description (González-Durán pers. comm.). The Hylidae family was represented by two species: *Dendropsophus bogerti* (Cochran & Goin 1970) and *Colomascirtus larinopygion* (Duellman 1973), as well as the family Bufonidae with *Osornophryne percrassa* Ruiz & Hernández, 1976 and *Rhinella* sp. The species *Rhinella* sp. and *Niceforonia* sp. also represent undescribed taxa (Image 4). The most abundant species in all sites was *Pristimantis uranobates* (n = 19), followed by *P. paisa* (n = 15) and *P. permixtus* (n = 14). The less abundant species were *Hypodactylus latens* (Lynch 1989), *P. thectopternus* (Lynch 1965), *Niceforonia* sp., *Pristimantis* sp. 1 (Image 3F) and *Pristimantis* sp. 3 (Image 3H), which had a single register during the entire study.

Sampling coverage and structure of the community

For zone A, sampling coverage reached 89%, with a total of 29 individuals, belonging to eight species, four genera and three families. Craugastoridae family was the most representative (75% of the species); *P. uranobates* (n = 11) was the most abundant species followed by *C. larinopygion* (n = 8) and *P. paisa* (n = 4). Species such as *H. latens* and *P. permixtus* had a single record (Fig. 2A, B). The value of the inequality factor for this zone was 0.08, being the site with the lowest value (Table 2). At this zone, *P. uranobates* and *C. larinopygion* accounted for 27% of the total abundances, followed by *P. paisa* representing 13%, *Rhinella* sp. and *P. boulengeri* 10%, and the rest of the species 3.4% (Fig. 2). For zone B, 93% sampling coverage was obtained, with 31 individuals represented by seven species, three genera and two families (Table 1). The most abundant species was *P. permixtus* (n = 13), followed by *P. uranobates* (n = 8) and *Pristimantis* sp. 2 (n = 4). The species that had a single record in this site were *Niceforonia* sp. and *P. paisa* (Fig. 2). The value of the inequality factor for this site was 0.15 (Table 2). In zone C, a total of 17 individuals were found distributed in five species, two genera and two families. The most abundant species was *P. paisa*

Table 1. Anuran species and number of individuals by zone in the upper Claro River basin, municipality of Villamaría, department of Caldas, Colombia. Threat categories are according to IUCN 2017 (International Union for Conservation of Nature). Categories represent Not evaluated (NE); Least Concern (LC); Near Threatened (NT); Endangered (EN); Critically Endangered (CR).

Taxa	Zone A	Zone B	Zone C	Total	Code	IUCN Red List
Bufonidae						
Osornophryne percrassa	-	2	-	2	A	EN
Rhinella sp.	3	-	-	3	B	
Craugastoridae						
Hypodactylus latens	1	-	-	1	C	EN
Niceforonia sp.	-	1	-	1	D	
Niceforonia adenobrachia.	-	2	-	2	E	CR
Pristimantis boulengeri	3	-	-	3	F	LC
Pristimantis paisa	4	1	10	15	G	LC
Pristimantis permixtus	1	13	-	14	H	LC
Pristimantis sp. 1	1	-	-	1	I	
Pristimantis sp. 2	-	4	-	4	J	
Pristimantis sp. 3	-	-	1	1	K	
Pristimantis thectopternus	-	-	1	1	L	LC
Pristimantis uranobates	8	8	3	19	M	LC
Hylidae						
Dendropsophus bogerti	-	-	2	2	N	LC
Colomascirtus larinopygion	8	-	-	8	O	NT
Total	29	31	17	77		

Image 3. Species of the genus *Pristimantis* (Craugastoridae) recorded during this study. (a) *P. boulengeri* SVL 23,4mm; (b) *P. paisa* SVL 25,6mm; (c) *P. permixtus* SVL 25,5 mm; (d) *P. thectopternus* SVL 24,3mm; (e) *P. uranobates* (green morph) SVL 20,3mm; (f) *Pristimantis* sp. 1 SVL 22,7mm; (g) *Pristimantis* sp. 2 SVL 26mm; (h) *Pristimantis* sp. 3 SVL 58mm. © Julián Andrés Rojas.

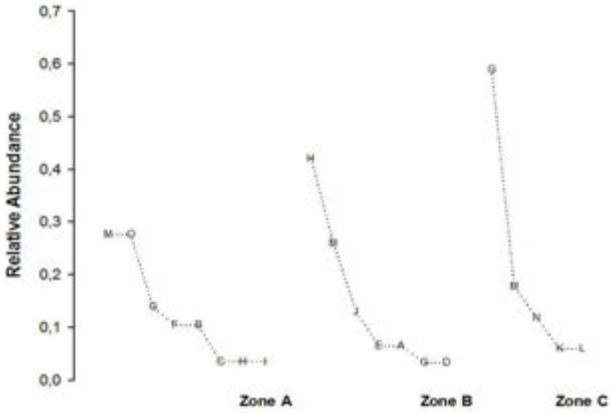


Figure 2. Range-abundance amphibian curves for each zone in the upper Claro River basin, municipality of Villamaria, department of Caldas, Colombia. Letters represent species code, see Table 1.

(n = 10) followed by *P. uranobates* (n = 3) and *D. bogerti* (n = 2). *Pristimantis thectopternus* and *Pristimantis* sp. 3 had a single record (Fig. 2). The sampling coverage for this site was 88% and the inequality value was 0.25, this being the highest value among all sites (Table 2).

Diversity profiles

The species richness (^0D) shows that zone A has a greater number of effective species (8), followed by zone B (7) and finally zone C (5) (Fig. 3). In the same way, the diversity of order ^1D indicates that zone A presents a greater number of effective species with respect to the other two zones with 6.1, followed by zone B with 4.7 and zone C with 3.3 effective species (Fig. 3). When expressing this results in equivalences, zone B may contain 77% of the diversity found for zone A. On the other hand, it is observed that zone A presented almost twice the diversity of species with respect to zone C, and when comparing zones B and C, it was found that the latter may contain 70% of the diversity recorded for zone B. With the order ^2D measure of diversity, all the sites result with a lower number of effective species (Fig. 3), since this measure focuses only on the most abundant species (Jost 2006). With this measure of diversity zone A reached 5.1 effective species, being the most diverse zone followed by zone B with 3.7 effective species, and finally zone C with 2.5 effective species. This is due to the fact that in zone A (which presented the lowest values of inequity, see Table 2), the most abundant species represent 27% of the total of individuals, while for zone B the most abundant species represent 41% of the total, and in zone C 58%; this leads to greater equity in the distribution of abundances among the species common to zone A compared to the other two sites.

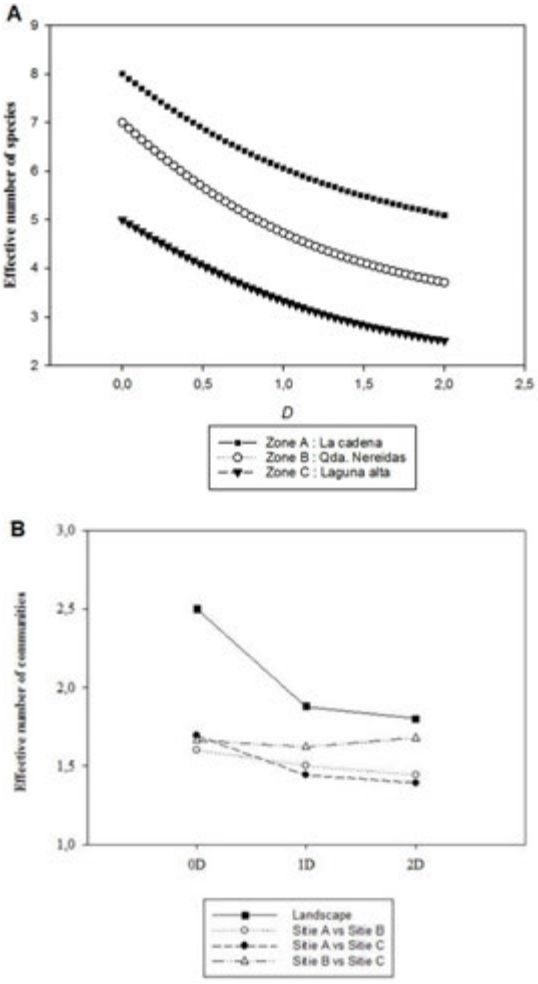


Figure 3. Amphibian diversity profiles for three zones in the upper Claro River basin, municipality of Villamaria, department of Caldas, Colombia. (A) Diversity in effective number of species; (B) Diversity in terms of communities.

Table 2. Values of the inequality factor for the three sampled zones in the upper Claro River basin, municipality of Villamaría, department of Caldas, Colombia.

Factor of inequality	$IF_{0,2}$	$RI_{0,2}$
Zone A-La Cadena	1.57	0.08
Zone B-Playa Larga	1.89	0.15
Zone C-Laguna Alta	1.99	0.25

With respect to beta diversity, it was found that there are 2.5 effective communities at the landscape level (^0D), 1.9 according to the diversity ^1D, and 1.8 according to ^2D, respectively. These results indicate that the differences between the sampled areas are given for the rare species, while some abundant species are shared, as *P. uranobates*, which was the most

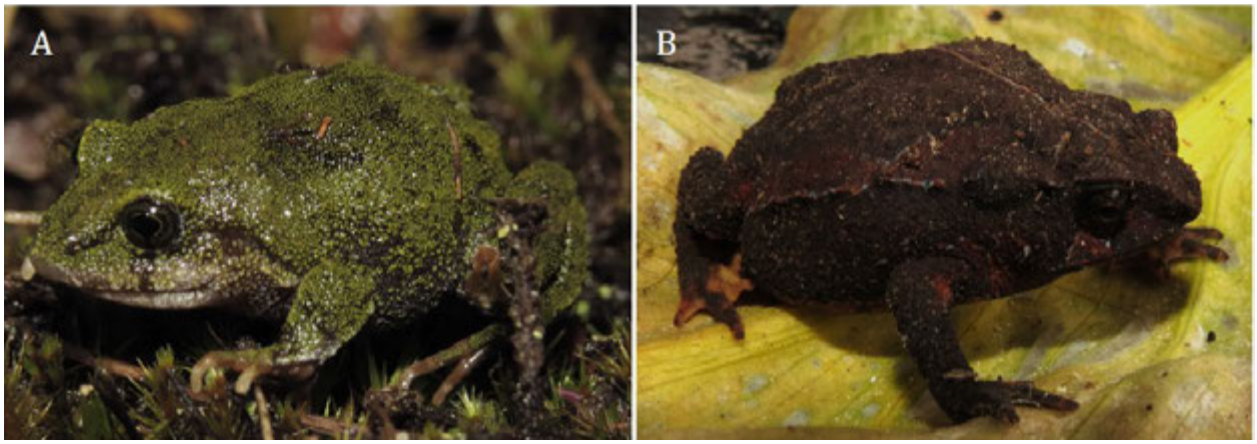


Image 4. Undescribed amphibian species registered for the upper Claro River basin, municipality of Villamaria, department of Caldas, Colombia. (A) *Niceforonia* sp. (Craugastoridae) SVL 22.9mm; (B) *Rhinella* sp. (Bufonidae) SVL 34.1mm. © Julián Andrés Rojas.

abundant species being found in all the sampling zones (Tabla 1, Fig. 2). When making comparisons between pairs of zones, it is observed that for zone A the results of ^1D and ^2D for beta diversity are lower than the ^0D expression (Fig. 3). This shows that zone A differs from the other two mainly because of its rare species ($^1D < {}^0D$), and some of the most abundant species are still shared ($^2D < {}^1D$). When comparing zone B with respect to C, it is observed that the values of ^1D (1.62 effective communities) are lower than for species richness ^0D (1.66 effective communities), while the values of ^2D are greater (1.68 effective communities). This indicates that the differences between these two sites are given to a greater extent by the abundant species ($^2D > {}^0D$), although some of these are shared ($^1D < {}^0D$). The most abundant species for zone B and C were *P. permixtus* and *P. paisa*, respectively (Fig. 2).

There was a significant association between the zones and the species (chi-square = 88.779, df = 28, P < 0.0001), indicating that the amphibians had a preference for a particular zone. Correspondence analysis (Fig. 4) showed that the amphibian fauna of the zones was distinct from each other. *Colomascirtus larinopygion*, *H. latens*, *P. boulengeri*, *Pristimantis* sp. 1 and *Rhinella* sp. were restricted to Zone A; *N. adenobrachia*, *Niceforonia* sp., *O. percrassa* and *Pristimantis* sp. 2 were restricted to Zone B, while *D. bogerti*, *P. thectopternus* and *Pristimantis* sp. 3 were restricted to Zone C. Although *P. paisa*, *P. permixtus* and *P. uranobates* were present in all three zones, *P. uranobates* was more ubiquitous in all three zones as compared to *P. permixtus* that was more abundant in Zone B and *P. paisa* that was more abundant in Zone C (Table 1).

Natural history observations and conservation status of the species

During fieldwork most of the individuals were observed at twilight and night hours, between 18:00–21:00 h, mainly stream-dwelling frogs such as *C. larinopygion*, which were observed by calling males. *Dendropsophus bogerti* was only observed in the flooded pastures during the first fieldtrip, formed by the constant rains during that period. Leaf-litter and understory frogs, like those of the genus *Pristimantis* (Image 3, Appendix I), were common both inside and on the edge of forests, and also in the pastures that surrounded them. Species such as *Rhinella* sp. and *H. latens* (Appendix I) were observed only during the day (10:30–12:00 h) on the litter or into the flooded soil. Typical nocturnal species, such as *P. uranobates* and *P. permixtus* were observed during the day, immobile on the ground, or hidden under leaf litter.

Of the 15 registered species, four are threatened with extinction according to the International Union for the Conservation of Nature (IUCN 2017). *Niceforonia adenobrachia* is Critically Endangered (CR) due to their very restricted distribution range (< 100km^2) (see Appendix II). *Hypodactylus latens* and *Osornophryne percrassa* (Appendix II) are Endangered (EN), both equally with restricted and fragmented distributions (< 5000km^2), and because the extension and quality of their habitat is decreasing in response to human intervention in cloud forests (Castro et al. 2004; IUCN SSC Amphibian Specialist Group 2015). Finally, the hylid frog *C. larinopygion* is Near Threatened (NT) due to their fragmented distribution, although it is a relatively common species where it has been registered (Bolívar et al. 2010) (Appendix II). On the other hand, *Pristimantis*

frogs present a state of Least Concern (LC) and their populations apparently remain stable; however, how species are responding to habitat intervention at local scale is unknown. The undescribed species *Rhinella* sp., *Niceforonia* sp. and *Pristimantis* sp. 2 are not yet categorized and therefore their conservation status is unknown.

DISCUSSION

Richness and species composition

Among current ectothermic vertebrates, amphibians are the most diversified group in the high mountain ecosystems of the tropical Andes (Lynch 1999a; Lynch & Suárez-Mayorga 2002; Navas 2006; Bernal & Lynch 2008; Hutter et al. 2013), however, amphibian distribution patterns show that there is a decrease in diversity as elevation increases, similar to latitudinal reduction patterns (Lynch 1986). In this study we recorded 15 amphibian species with a representativeness between 89–93 % for the three evaluated zones, indicating that the fauna observed is a representative sample, but possibly some additional species can be found with an increasing sampling effort. Among the latter, members of the family Centrolenidae (glass frogs), which are known to be important components of the Andean amphibian communities (Guayasamin et al. 2009; Hutter et al. 2013; Rojas-Morales et al. 2014b; and references therein included), were not found in this study. It is possible that species such as *Centrolene buckleyi* (Boulenger, 1882), *C. robledoi* Ruiz-Carranza & Lynch, 1995, *C. quindianum* Ruiz-Carranza & Lynch, 1995 and *Nymphargus grandisonae* (Cochran & Goin, 1970) are also present in the study area, but because of their arboreal habits and possible seasonal reproduction, they were not observed during this study.

On the other hand, the richness and representativeness of the *Pristimantis* genus registered in this study, is not surprising because these frogs represent about a third of the known amphibians in Colombia, being highly diversified in Andean ecosystems (Acosta & Cuentas 2018). In addition, its greatest peak of diversity is between 1,750–2,400 m (Lynch & Duellman 1980, 1997; Lynch & Rueda-Almonacid 1997). The high diversity of these frogs seems to be associated with their reproductive modes, which include terrestrial eggs and direct development, which does not limit their reproduction to aquatic environments. In this way, these frogs can inhabit all terrestrial environments that have sufficient moisture for the development of eggs and survival of juveniles and adults (Lynch & Duellman 1980, 1997; Lynch & Rueda-Almonacid 1997; Lynch et al. 1997; Lynch 1999a, b; Duellman & Lehr 2009).

Diversity and structure of the community

In amphibians, species diversity is affected by ecological traits, such as forest structure, microclimate and topography (Vonesh 2001; Dixo & Martins 2008; Santori & McManus 2014; Meza-Joya & Torres 2016).

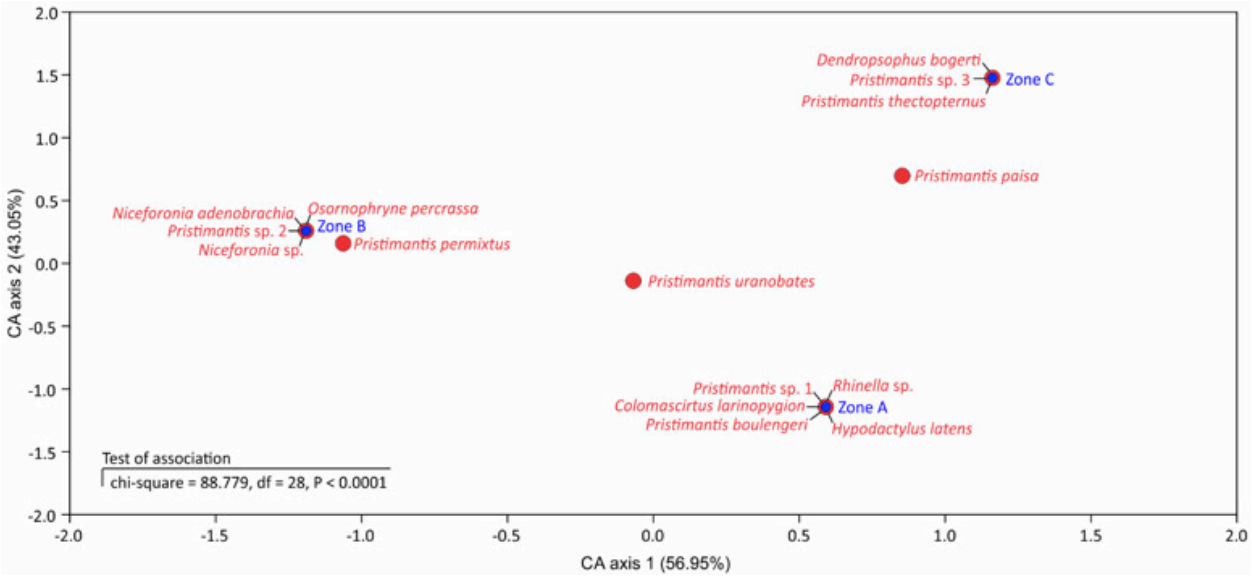


Figure 4. Correspondence analysis (CA) depicting the distribution of amphibians in the three zones evaluated. Test of association is shown in the inset. Percentage contribution by each CA axis is provided in parenthesis.

In this study, the zone A showed the highest diversity among all sites, with higher values in the three orders of diversity *q*, as well as the lowest values for the inequality factor (Table 2). This result may be due to the interaction of several factors, such as environmental conditions and elevation (2,400m); in addition, this is the area where the least intervened ecosystem persists. In spite of diversity values in zone A, it is important to emphasize that between this zone and zone B there was not a significant difference respect to the species richness, but they are not similar in species composition, mainly due to rare and threatened species. This is important, since the loss of these habitats due to deforestation could lead to the local extinction of some of these populations (Dodson & Gentry 1991). Unlike these two zones, zone C presented the lowest values of diversity, probably because this area has a greater degree of anthropogenic intervention, evidenced in large areas of open grasslands, with a minimum proportion of native forest.

On the other hand, although the elevation gradient between the zones is low (600m), 2.5 effective communities were found (beta diversity at the landscape level), and the differences between zones are given for its rare species in greater measure (Fig. 4). It is very likely that the 2.5 effective communities in this gradient correspond to the change in life zones across the landscape. In high mountain ecosystems it has been recognized that species composition can be relatively heterogeneous between localities at small spatial scales (Moen et al. 2009). We suggest that the 2.5 effective communities are composed, on the one hand, of species belonging to higher elevation ecosystems (Páramos, and high Andean forest), such as *O. percrassa* and *N. adenobrachia* (Ardila-Robayo et al. 1996; Bernal & Lynch 2008), and *Rhinella* sp., and *C. larinopygion* to medium elevation Andean forest. These species in turn were rare species within the sampling zones. On the other hand, it was found that *Pristimantis* frogs are important elements of the communities in all the zones evaluated. These frogs, as already mentioned, are the most specious genus in the Neotropics (Lynch & Rueda-Almonacid 1997; Santori & McManus 2014); in addition, most of their species are highly generalistic in the use of their resources, found in a wide range of habitats and microhabitats, and feeding on a great variety of prey (Arroyo et al. 2008; García et al. 2015; Santori & McManus 2014; Gutiérrez-Cárdenas et al. 2016). In the case of *P. uranobates*, which was the most abundant species and was also found in all zones, it has been reported that it may tolerate intervened environments and also have a wide altitudinal distribution (Lynch 1991; Lynch et al. 1996).

Conservation status of species

Of all species recorded in this study, three of them are threatened with extinction: two Endangered (EN) and one Critically Endangered (CR) (Table 1, Appendix II). The record of these species within the buffer zone of Los Nevados National Natural Park is highly significant, because the buffer zones have a management policy that permits the development of productive activities, such as cattle breeding and agriculture. Records of *Niceforonia* sp. (Fig. 5A) and *N. adenobrachia* (Appendix II) are of great value, because the former is an undescribed species and possibly has a restricted distribution like the other species of the genus (see Acosta-Galvis 2000); in the case of *N. adenobrachia*, this register represents one of the few known populations for the species (see Appendix II). It is very probable that the distribution of these threatened species (and also of *Hypodactylus latens*) encompasses the strict conservation area of the Los Nevados National Natural Park. For this reason, we suggest that it is important to delimit areas of protection within the farms, mainly the forest associated to creeks and streams, in order to establish a limit for the advance of human activities that threaten biodiversity outside of protected areas. In addition, it is important to restore the structural connectivity between forest fragments to mitigate the fragmentation of amphibian populations due to deforestation. Other recognized threats to amphibians such as climate change evidenced in extreme seasons (e.g., extended droughts), the introduction of exotic species, and emerging diseases such as chytridiomycosis, however, represent a latent risk for amphibian communities even within protected areas (see Lips et al. 2003, 2004; La Marca et al. 2005; Lampo et al. 2006; Acevedo et al. 2016).

REFERENCES

Acevedo, A.A., R. Franco & D.A. Carrero (2016). Diversity of Andean amphibians of the Tamá National Natural Park in Colombia: a survey for the presence of *Batrachochytrium dendrobatidis*. *Animal Biodiversity and Conservation* 39(1): 1–10; https://abc.museucienciesjournals.cat/files/ABC_39-1_pp_1-10.pdf

Acosta, A.R. (2000). Ranas, Salamandras y Caecilias (Tetrapoda: Amphibia) de Colombia. *Biota Colombiana* 1(3): 289–319; https://redalyc.org/pdf/491/49110303.pdf

Acosta-Galvis, A.R. (2009). Estado del conocimiento de los anfibios y reptiles del departamento de Caldas. Vacíos de información y las prioridades de conservación. Corporación Autónoma Regional de Caldas (Corpocaldas). Manizales, Caldas. 142 pp.

Acosta, A.R. & D. Cuentas (2018). Lista de los Anfibios de Colombia: Referencia en línea V.05.2015.0 (acceso 02-04-2016). Página web accesible en https://www.batrachia.com; Batrachia, Villa de Leyva,

Boyacá, Colombia.

Adams, W.M., R. Aveling, D. Brockington, B. Dickson, J. Elliot, J. Hutton, D. Roe, B. Vira & W. Womer (2004). Biodiversity conservation and the eradication of poverty. *Science* 306(5699): 1146–1149; https://www.researchgate.net/publication/51370569_Biodiversity_Conservation_and_the_Eradication_of_Poverty

Ardila-Robayo, M.C., P.M. Ruiz-Carranza & M. Barrera-Rodriguez (1996). Una nueva especie de *Phrynopus* (Amphibia, Anura, Leptodactylidae) de la Cordillera Central Colombiana. *Lozania* 67: 1–10.

Arroyo, S., A. Jerez & M.P. Ramírez-Pinilla (2003). Anuros de un bosque de niebla de la cordillera Oriental de Colombia. *Caldasia* 25(1): 153–167; https://www.unal.edu.co/icn/publicaciones/caldasia/25(1)/zoologia1.pdf

Arroyo, S.B., V.H. Serrano-Cardozo & M.P. Ramírez-Padilla (2008). Diet, microhabitat and time of activity in a *Pristimantis* (Anura, Strabomantidae) assemblage. *Phyllomedusa* 7(2): 109–119; https://doi.org/10.11606/issn.2316-9079.v7i2p109-119

Bernal, M.H. & J.D. Lynch (2008). Review and analysis of altitudinal distributions of the Andean anurans in Colombia. *Zootaxa* 1826: 1–25; https://www.researchgate.net/publication/276505871_Review_and_analysis_of_altitudinal_distribution_of_the_Andean_anurans_in_Colombia

Bolívar, W., L.A. Coloma, S. Ron & J.M. Rengifo (2010). *Hyloscirtus larinopygion*. The IUCN Red List of Threatened Species 2010: e.T55531A11328178. Downloaded on 17 March 2017; https://doi.org/10.2305/IUCN.UK.2010-2.RLTS.T55531A11328178.en

Cáceres-Andrade, S.P. & J.N. Urbina-Cardona (2009). Ensamblajes de anuros de sistemas productivos y bosques en el piedemonte llanero, departamento del Meta, Colombia. *Caldasia* 31(1): 175–194; https://revistas.unal.edu.co/index.php/cal/article/view/36085/37485

Cadavid, J.G., C. Román-Valencia & A.F. Gómez (2005). Composición y estructura de anfibios en un transecto altitudinal de los Andes centrales de Colombia. *Revista del Museo Argentino de Ciencias Naturales* 7(2): 103–118.

Casas-Pinilla, L.C., O. Mahecha-C, J.C. Dumar-R & C. Ríos-Maláver (2017). Diversidad de mariposas en un paisaje de bosque seco tropical, en la Mesa de los Santos, Santander, Colombia (Lepidoptera: Papilionoidea). *SHILAP Revista de Lepidopterología* 45(177): 83–108; https://www.redalyc.org/articulo.oa?id=45550375010

Castro, F., M.I. Herrera & J.D. Lynch (2004). *Hypodactylus latens*. The IUCN Red List of Threatened Species 2004: e.T56702A11517360. Downloaded on 07 January 2017; https://doi.org/10.2305/IUCN.UK.2004.RLTS.T56702A11517360

Chao, A. & L. Jost (2012). Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. *Ecology* 93(12): 2533–2547; https://doi.org/10.1890/11-1952.1

Cochran, D.M & J.C. Goin (1970). Frogs of Colombia. *Publications of the United States National Museum. Smithsonian Institution* 288: 1–641.

Cortés, C., A.M. Suárez-Mayorga& F.J. López-López (2006). Preparación y preservación de material científico, pp173–220. In: Angulo, A., J.V. Rueda-Almonacid, J.V. Rodríguez-Mahecha & E. La Marca (eds.). *Técnicas de inventario y monitoreo para los anfibios de la región tropical andina*. Conservación Internacional, Bogotá D.C., Colombia.

Dixo, M. & M. Martins (2008). Are leaf-litter frogs and lizards affected by edge effects due to forest fragmentation in Brazilian Atlantic forest? *Journal of Tropical Ecology* 24: 551–554; https://www.cambridge.org/core/journals/journal-of-tropical-ecology/article/are-leaflitter-frogs-and-lizards-affected-by-edge-effects-due-to-forest-fragmentation-in-brazilian-atlantic-forest/CD8F424D246CDDF9358D2BFE9C15D103

Dodson, C.H. & A.H. Gentry (1991). Biological extinction in western Ecuador. *Annals of the Missouri Botanical Garden* 78: 273–295.

Duellman, W.E. (1973). Descriptions of new Hylid frogs from Colombia and Ecuador. *Herpetologica* 29: 219–227; https://sci-hub.tw/https://www.jstor.org/stable/3892005

Duellman, W.E. & E. Lehr (2009). Terrestrial-Breeding Frogs (Strabomantidae) in Peru. Münster: Natur und Tier-Verlag GmbH. 382 p.

Duellman, W.E. & T.J. Berger (1982). A new species of Andean tree frog (Hylidae). *Herpetologica* 38: 456–460.

Duellman, W.E. & D.M. Hillis (1990). Systematic of frogs of the *Hyla larinopygion* group. *Occasional Papers of the Museum of Natural History, The University of Kansas, Lawrence, Kansas* 134: 1–23; https://archive.org/details/biostor-212

Ehrlich, P.R. & E.O. Wilson (1991). Biodiversity studies: Science and policy. *Science* 253(5021): 758–762.

Faivovich, J., C.F.B. Haddad, P.C.A. García, D.R. Frost & J.A. Campbell (2005). Systematic review of the frog family Hylidae, with special reference to Hylinae: Phylogenetic analysis and taxonomic revision. *Bulletin of the American Museum of Natural History* 294:1–240; https://digitallibrary.amnh.org/bitstream/handle/2246/462/B294.pdf?sequence=1

Frost, D.R. (2017). Amphibians Species of the World: an online reference. Version 6.0 (last Access on 25 September 2017). Electronic database accesible at https://research.amnh.org/herpetology/amphibia/index.html. American Museum of Natural History, New York, USA.

García J.C., H. Cárdenas & -F. Castro-H (2007). Relación entre la diversidad de anuros y los estados sucesionales de un bosque muy húmedo montano bajo del Valle del Cauca, suroccidente colombiano. *Caldasia* 29: 363–374; https://revistas.unal.edu.co/index.php/cal/article/view/39203/41056

Garcia, R.J.C., C.E. Posso-Gómez & H. Cárdenas-Henao (2015). Diet of Direct-Developing frogs (Anura: Craugastoridae: *Pristimantis*) from the Andes western Colombia. *Acta Biológica Colombiana* 20 (1): 79–87; https://www.scielo.org.co/pdf/abc/v20n1/v20n1a09.pdf

Greene, R.E., A. Balmford, P.R. Crane, G.M. Mace, J.D. Reynolds & R.K. Turner (2005). A framework for improved monitoring of biodiversity: Response to the world Summit on sustainable development. *Conservation Biology* 19(1): 56–65; https://johnreynolds.org/wp-content/uploads/2012/07/green-et-al-cons-bio-05.pdf

Gutiérrez-Cárdenas, P.D.A., K. Castillo, D. Martínez, C.F. Rocha & M.A. Rojas-Rivera (2016). Trophic ecology of *Pristimantis labiosus* (Anura: Craugastoridae) from Southwestern Colombia. *North-Western Journal of Zoology* 12(1): 102-109; https://www.researchgate.net/publication/304042766_Trophic_ecology_of_Pristimantis_labiosus_Anura_Craugastoridae_from_south-western_Colombia

Hammer, Ø., D.A.T. Harper & P.D. Ryan (2001). Past: Paleontological Statistics Software Package for education and data analysis. *Paleontología Electrónica* 4: 1–9.

Hill, M.O. (1973). Diversity and evenness: A unifying notation and its consequences. *Ecology* 54: 427–432; https://www.fcnym.unlp.edu.ar/catedras/ecocomunidades/Hill%20-%20Diversity%20and%20Evenness--%20A%20Unifying%20Notation%20and%20Its%20Consequences.pdf

Holdridge, L.R. (ed.) (1982). Ecología basada en zonas de vida. San José, Costa Rica. IICA. 215 pp.

Hutter, C.R., J.M. Guayasamin & J.J. Wiens (2013). Explaining Andean megadiversity: the evolutionary and ecological causes of glassfrog elevational richness patterns. *Ecology Letters* 16(9): 1135–1144; https://doi.org/10.1111/ele.12148

Hutter, C.R., S.M. Lambert & J.J. Wiens (2017). Rapid diversification and time explain Amphibian richness at different scales in the Tropical Andes, earth's most biodiverse Hotspot. *The American Naturalist* 190(6): 828–843; https://www.wienslab.com/Publications_files/Hutter_et_al_AmNat_2017.pdf

Hsieh, T.C., K.H. Ma & A. Chao (2016). iNEXT: An R package for rarefaction and extrapolation of species diversity (Hill numbers). *Methods in Ecology and Evolution* 7(12): 1451–1456; https://chao.stat.nthu.edu.tw/wordpress/paper/120_pdf_appendix.pdf

IUCN SSC Amphibian Specialist Group (2015). *Osornophryne percrassa*. The IUCN Red List of Threatened Species 2015: e.T54858A60783778. Downloaded on 02 March 2017. https://doi.org/10.2305/IUCN.UK.2015-2.RLTS.T54858A60783778.en

Jost, L. (2006). Entropy and diversity. *Oikos* 113(2): 363–375.

Jost, L. (2010). The relation between evenness and diversity. *Diversity* 2: 207–232; https://www.researchgate.net/publication/41667724_The_Relation_between_Evenness_and_Diversity

Kaplan, M. (1997). On the status of *Hyla bogerti* Cochran and Goin. *Journal of Herpetology* 31: 536–541.

Kattan, G.H., P. Franco, V. Rojas & G. Morales (2004). Biological diversification in a complex region: a spatial analysis of faunistic diversity and biogeography of the Andes of Colombia. *Journal of Biogeography* 31: 1829–1839; https://doi.org/10.1111/j.1365-2699.2004.01109.x/abstract

La Marca, E., K. Lips, S. Lötters, R. Puschendorf, R. Ibáñez, J.V. Rueda-Almonacid, , R. Schulte, C. Marty, F. Castro, J. Manzanilla-Puppo, J.E. García-Pérez, F. Bolaños, G. Chaves, J.A. Pounds, E. Toral & B.E. Young (2005). Catastrophic population decline and extinctions in Neotropical harlequin frogs (Bufonidae: *Atelopus*). *Biotropica* 37: 190–201; https://doi.org/10.1111/j.1744-7429.2005.00026.x

Lampo, M., A. Rodríguez-Contreras, E. La Marca & P. Daszak (2006). A chytridiomycosis epidemic and a severe dry season precede the disappearance of *Atelopus* species from the Venezuelan Andes. *Herpetological Journal* 16: 395–402; https://www.researchgate.net/publication/233616507_A_chytridiomycosis_epidemic_and_a_severe_dry_season_precede_the_disappearance_of_Atelopus_species_from_the_Venezuelan_Andes

Lips, K.R., D.E. Green & R. Papendick (2003). Chytridiomycosis in wild frogs from southern Costa Rica. *Journal of Herpetology* 37: 215–218; https://www.nwhc.usgs.gov/publications/documents/03KRL.JH01.pdf

Lips, K.R., Mendelson, J.R. III., A. Muñoz-Alonso, L. Canseco-Márquez & D.G. Mulcahy (2004). Amphibian population declines in montane southern Mexico: resurveys of historical localities. *Biological Conservation* 119: 555–564; https://www.sciencedirect.com/science/article/pii/S0006320704000217

Lynch, J.D. (1975). The identity of the frog *Eleutherodactylus conspicillatus* (Günther), with descriptions of two related species from northwestern South America (Amphibia, Leptodactylidae). Contributions in Science. *Natural History Museum of Los Angeles County* 272: 1–19.

Lynch, J.D. (1986). Origins of the high Andean herpetological fauna. Pp. 478–499. En: Vuilleumier, F. & Monasterio, M. (Eds.). High Altitude Tropical Biogeography. Oxford University Press. Oxford, UK.

Lynch, J.D. (1989). Intrageneric relationships of mainland *Eleutherodactylus* (Leptodactylidae). I. A review of the frogs assigned to the *Eleutherodactylus discoidalis* species group. *Contributions in Biology and Geology. Milwaukee Public Museum* 79: 1–25.

Lynch, J.D. (1991). A new diminutive *Eleutherodactylus* from the Cordillera Central of Colombia (Amphibia: Leptodactylidae). *Journal of Herpetology* 25(3): 344–352.

Lynch, J.D. (1999a). Ranas pequeñas, la geometría de la evolución, y la especiación en los Andes colombianos. *Revista de la Academia de Ciencias Exactas, Físicas y Naturales* 23(86): 143–159.

Lynch, J.D. (1999b). Lista anotada y clave para las ranas (Género *Eleutherodactylus*) chocoanas del Valle del Cauca y apuntes sobre las especies de la Cordillera Occidental adyacente. *Caldasia* 21(2): 184–202.

Lynch, J.D. & W.E. Duellman (1980). The Eleutherodactylus of the Amazonian slopes of the Ecuadorian Andes (Anura: Leptodactylidae). Miscellaneous Publication, University of Kansas Museum of Natural History 69: 1–86.

Lynch, J.D. & W.E. Duellman (1997). Frogs of the genus *Eleutherodactylus* in western Ecuador: systematic, ecology and biogeography. Museum of Natural History. University of Kansas. Special publication No 23. 236 pp.; https://www.biodiversitylibrary.org/bibliography/7951#/summary

Lynch, J.D. & J.V. Rueda-Almonacid (1997). Three new frogs Eleutherodactylus: Leptodactylidae) from cloud forest in eastern Departamento Caldas, Colombia. *Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales* 21: 131–142.

Lynch, J.D. & A.M. Suárez-Mayorga (2002). Análisis biogeográfico de los anfibios paramunos. *Caldasia* 24(2): 471–480; https://www.bdigital.unal.edu.co/37602/1/39427-175445-1-PB.pdf

Lynch, J.D., P.M. Ruiz-Carranza & M.C. Ardila-Robayo (1994). The identities of the Colombian frogs confused with *Eleutherodactylus latidiscus* (Boulenger) (Amphibia: Anura: Leptodactylidae). *Occasional Papers of the Museum of Natural History, University of Kansas* 170: 1–42; https://www.biodiversitylibrary.org/page/4466887#page/5/mode/1up

Lynch, J.D., P.M. Ruiz-Carranza & M.C. Ardila-Robayo (1996). Three new species of *Eleutherodactylus* (Amphibia: Leptodactylidae) from high elevations of the Cordillera Central of Colombia. *Caldasia* 18: 329–342.

Lynch, J.D., P.M. Ruiz-Carranza & M.C. Ardila-Robayo (1997). Biogeographic patterns of Colombians frogs and toads. *Revista de la Academia de Ciencias Exactas, Físicas y Naturales* 21: 237–248; https://zoologia.puce.edu.ec/vertebrados/Recursos/publicaciones/Cientifica/Lynch_and_Ruiz_Carranza1997.pdf

Mantilla-Castaño, J.C., S. Escobar-Lasso, J.A. Rojas-Morales & J.V. González-Arenas (in press). First record of the Colombian endemic toad *Osornophryne percrassa* Ruíz-Carranza and Hernández-Camacho 1976 (Anura: Bufonidae) from the department of Risaralda, Central Cordillera of Colombia. *Revista de Biodiversidad Neotropical*

Márquez, G. (2001). De la abundancia a la escasez: La transformación de ecosistemas en Colombia. Pp. 325–452. En: Palacio, G. (Ed.). Naturaleza en disputa. Ensayos de historia ambiental en Colombia 1850-1995. Universidad Nacional de Colombia, Bogotá, Colombia.

Méndez-Narváez, J. & W. Bolívar-G (2016). Complementary ecological approaches to understand decreases in frog diversity in altered Andean ecosystems. *South American Journal of Herpetology* 11(1): 1–11; https://www.researchgate.net/publication/301732403_Complementary_Ecological_Approaches_to_Understand_Decreases_in_Frog_Diversity_in_Altered_Andean_Ecosystems

Meza-Joya, F.L. & M. Torres (2016). Spatial diversity patterns of *Pristimantis* frogs in the Tropical Andes. *Ecology and Evolution* 6(7): 1901–1913; https://doi.org/10.1002/ece3.1968

Moen, D.S., S.A. Smith & J.J. Wiens. (2009). Community assembly through evolutionary diversification and dispersal in Middle American treefrogs. *Evolution* 63: 3228–3247; https://www.researchgate.net/publication/26725896_Community_Assembly_Through_Evolutionary_Diversification_and_Dispersal_in_Middle_American_Treefrogs

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. Da Fonseca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858; https://www.nature.com/articles/35002501

Navas, C.A. (2006). Patterns of distribution of anurans in high Andean tropical elevations: Insights from integrating biogeography and evolutionary physiology. *Integrative and Comparative Biology* 46(1): 82–91; https://www.researchgate.net/publication/51218756_Patterns_of_distribution_of_anurans_in_high_Andean_tropical_elevations_Insights_from_integrating_biogeography_and_evolutionary_physiology

Osorno, M., D.L. Gutiérrez-Lamus & J.C. Blanco (2011). Anfibios en un gradiente de intervención en el noroccidente de la Amazonia Colombiana. *Revista Colombia Amazónica* 4: 143–160; https://www.sinchi.org.co/revista-colombia-amazonica-iv

Ricotta, C. (2003). Parametric scaling from species relative abundances to absolute abundances in the computation of biological diversity: a first proposal using Shannon's entropy. *Acta Biotheoretica* 51: 181–188; https://link.springer.com/article/10.1023/A%3A1025142106292?no-access=true

Rivera-Correa, M. & J. Faivovich (2013). A new species of *Hyloscirtus* (Anura: Hylidae) from Colombia, with a rediagnosis of *Hyloscirtus larinopygion* (Duellman, 1973). *Herpetologica* 69(3): 298–313; https://www.researchgate.net/publication/256458524_A_New_Species_of_Hyloscirtus_Anura_Hylidae_from_Colombia_with_a_Rediagnosis_of_Hyloscirtus_larinopygion_Duellman_1973

Rojas-Morales, J.A., H.F. Arias-Monsalve & G.A. González-Durán (2014a). Anfibios y reptiles de la región centro-sur del departamento de Caldas, Colombia. *Biota Colombiana* 15(1): 73–93; https://www.

redalyc.org/pdf/491/49140738005.pdf

Rojas-Morales, J.A., A. Castro-Gómez & S. Escobar-Lasso (2014b). Joyas de los Andes Tropicales: Colombia, tierra de ranas de cristal. *Bioma* 19: 6–39; https://www.academia.edu/6948400/Joyas_de_los_Andes_tropicales_Colombia_tierra_de_ranas_de_cristal

Rös, M., F. Escobar & G. Halffter (2012). How dung beetles respond to a human-modified variegated landscape in Mexican cloud forest: a study of biodiversity integrating ecological and biogeographical perspectives. *Diversity and Distributions* 18(4): 377–389; https://www.researchgate.net/publication/230540150_How_dung_beetles_respond_to_a_human-modified_variegated_landscape_in_Mexican_cloud_forest_A_study_of_biodiversity_integrating_ecological_and_biogeographical_perspectives

Ruiz-Carranza, P.M. & J.I. Hernández-Camacho (1976). *Osornophryne*, género nuevo de anfibios bufónidos de Colombia y Ecuador. *Caldasia* 6: 93–148; https://revistas.unal.edu.co/index.php/cal/article/view/34333/34534

Santori, C. & N. McManus (2014). Herpetofaunal abundance and species diversity in coastal Ecuador: differences between forest types, the role of abiotic factors and edge effects. Tropical Conservation, Permaculture & Research Internship Jama-Coaque Ecological Reserve. 23 pp.

Stuart, S.N., M. Hoffmann, J.S. Chanson, N.A. Cox, R.J. Berridge, P. Ramani & B.E. Young (2008). *Threatened Amphibians of the World*. Lynx Edicions, Barcelona, Spain; IUCN, Gland, Switzerland; and Conservation International, Arlington, Virginia, USA.

Urbina, C.J.N. & M.C. Londoño (2003). Distribución de la comunidad de herpetofauna asociada a cuatro áreas con diferente grado de perturbación en la isla Gorgona, pacífico colombiano. *Revista de la Academia de Ciencias Exactas, Físicas y Naturales* 27(102): 105–113; https://www.researchgate.net/profile/Nicolas_Urbina-Cardona/publication/216019359_Distribucion_de_la_comunidad_de_herpetofauna_asociada_a_cuatro_areas_con_diferente_grado_de_perturbacion_en_la_Isla_Gorgona_Pacifico_colombiano/links/07ab43354ba7e91da7405dc5/Distribucion-de-la-comunidad-de-herpetofauna-asociada-a-cuatro-areas-con-diferente-grado-de-perturbacion-en-la-Isla-Gorgona-Pacifico-colombiano.pdf

Valencia, A. (1985). La colonización y el desarrollo económico-social del Gran Caldas (Siglo XIX). Revista Universidad de Caldas 5(2): 146.

Vanegas-Guerrero, J. & J.D. Fernández-Roldán (2014). *Osornophryne percrassa* Ruiz-Carranza y Hernández-Camacho 1976. *Catálogo de Anfibios y Reptiles de Colombia* 2: 21–24.

Vanegas-Guerrero, J., G.A. González-Duran & S. Escobar-Lasso (2016). Distribution, diet, and vocalizations of the endangered Colombian toad *Osornophryne percrassa* (Anura, Bufonidae). *Herpetological Conservation and Biology* 11(1): 90–100; https://www.herpconbio.org/Volume_11/Issue_1/Vanegas-Guerrero_etal_2016.pdf

Vargas-Salinas, F. & A. Aponte-Gutiérrez (2016). Diversidad y recambio de anfibios y reptiles entre coberturas vegetales en una localidad del valle del Magdalena medio, departamento de Antioquia, Colombia. *Biota Colombiana* 17(2): 117–137; www.redalyc.org/pdf/491/49151352010.pdf

Vonesh, J.R. (2001). Patterns of richness and abundance in a tropical African leaf-litter herpetofauna. *Biotropica* 33(3): 502–510; https://doi.org/10.1111/j.1744-7429.2001.tb00204.x

Appendix 1. Ecological traits for the anurans recorded in the upper Claro River basin, municipality of Villamaría, department of Caldas, Colombia. The values correspond to the data range. Activity: calling (C), motionless (I), movement (M), perched (P).

Family	Species	Substrate	Perch height (m)	Distance from water (m)	Activity
Bufonidae	*Osornophryne percrassa*	Moss, leaf-litter	0	4–70	C, I
	Rhinella sp.	Leaf-litter, fallen trunk	0	12–15	M
Craugastoridae	*Hypodactylus latens*	Muddy ground	0	3	M
	Niceforonia adenobrachia	Fallen trunk, moss	0.25–1	70–80	M, I
	Niceforonia sp.	Moss	0	30	M
	Pristimantis boulengeri	Leaf-litter, ferns	0.9–1.65	2–15	C, M
	Pristimantis paisa	Pastures, ground	0–1	0–>100	C, I, P, M
	Pristimantis permixtus	Pastures, moss, leafs, ferns	0–1.02	13–80	C, I, P, M
	Pristimantis uranobates	Leaf-litter, pasture, leafs, ferns	0–2.5	0–>100	C, I, P, M
	Pristimantis thectopternus	Leaf-litter	0	>100	M
	Pristimantis sp. 1	Ground	0	>100	M
	Pristimantis sp. 2	Bamboo leafs	0,3–1,3	50–100	C, P, M
	Pristimantis sp. 3	Pasture	0,3	>100	
Hylidae	*Dendropsophus bogerti*	Flooded pasture	0	0	C
	Colomascirtus larinopygion	Leafs, branches, ferns	0–>5	0–3	C

Appendix 2. Particular comments on threatened amphibians recorded in this study.

Amphibia: Anura
Family Bufonidae

Osornophryne percrassa
Ruiz-Carranza & Hernández-Camacho, 1976
Herveo Plump Toad (Image 5)

Conservation status: Endangered (EN) B1ab(iii)

Abundance in the study area: Rare. During fieldwork only two individuals were recorded, both on moss and litter at the edge of the secondary forest in zone B (3,000m).

Morphological characters: A small toad with short limbs that limit it to an exclusively slow locomotion (Ruiz-Carranza & Hernández-Camacho 1976). It does not present parotoid glands as well as tympanic rings; manual and pedial fingers very reduced and little differentiated, wrapped by a thick integument like a palm that reaches almost to the distal end of the fingers. The skin of the whole body is covered with tubercles of variable size and shape, and ventrally more uniform in number and arrangement. It presents a uniform dark dorsal coloration, variable between black, dark brown and olive, and ventrally present yellow spots of variable size, especially concentrated in the posterior region of the belly, forearms and thighs (Image 5) (Ruiz-Carranza & Hernández-Camacho 1976; Vanegas-Guerrero & Fernández-Roldán 2014).

Distribution: This species is endemic to Colombia, being known for the Páramo and cloud forest biomes on both sides of the Central Cordillera, from 2,700–3,840 m (Bernal & Lynch 2008, Vanegas-Guerrero et al. 2016). Politically it is registered in the departments of Antioquia, Caldas, Risaralda, Quindío, Tolima, and Valle del Cauca (Vanegas-Guerrero et al. 2016; Mantilla-Castaño et al. in press).

Family Craugastoridae

***Hypodactylus latens* (Lynch, 1989)**
Boqueron Robber Frog (Image 6)

Conservation status: Endangered (EN) B1ab(iii)

Abundance in the study area: Very rare, although this may be a result of its cryptic behavior. A single individual (Image 6) was registered during the field work, specifically in zone A (2,400m) buried in marshy ground inside secondary forest (10:55h; 16.6^{0}C, 91% HR). It is presumed that its presence is restricted to forests with adequate moisture conditions and vegetation cover.

Morphological characters: Small frog with a robust body and short extremities with thin, short, well-differentiated fingers without discs; the first manual finger longer than the second; absent manual and pedial membranes; tympanic ring absent. *Hypodactylus latens* has a finely granular skin, with relatively smooth flanks. Its coloration is variable, from light brown with a thin white line crossing the back, to dorsal uniform purple, with the exception of the groins, armpits and flanks that have yellow spots, which is characteristic of the species (Image 6). It also has a dark rostral band that is not very conspicuous and the edge of the eyelid is outlined in pale yellow. Iris reddish-brown to dark brown.

Distribution: Endemic to high mountain ecosystems (cloud forests, subpáramo and páramo, between 2,600–3,200 m) in the Central Cordillera of Colombia. Politically it is registered in the departments of Antioquia, Caldas, Quindío and Tolima. The record in the study area was to 2,400m, 200m below the lowest known limit for the species.

Niceforonia adenobrachia
(Ardila-Robayo, Ruiz-Carranza & Barrera-Rodríguez, 1996)
(Image 7)

Conservation status: Critically Endangered (CR) B1ab(iii)+2ab(iii)

Abundance in the study area: Very rare, although possibly due to its cryptic behavior. Two individuals (males) were registered during the field work, both in zone B (3,000m). Both individuals were active at night between 21:30–22:07 h (12-13.8 ^{0}C, 90–92 % RH). One of them was moving on a fallen trunk 80cm above the ground and more than 100m from the Nereidas Stream. The second individual was registered on moss that covered a rock on the edge of a secondary forest. This finding represents the fourth known population for the species, expanding its distribution in 23.7km to the southwest of its type locality on the western flank of the Central Cordillera.

Morphological characters: A small frog (range SVL 14.5–23.1 mm, Ardila-Robayo et al. 1996), with a robust body, oval in shape, with the head narrower than the body. Dorsal skin smooth with few small and scattered tubercles; presents one or two tubercles in the eyelids, and a conical tubercle prominent in the heels; the skin of the belly is slightly granular; forearms widened in the males; the fingers of the hands are short, the first and the second of equal size and do

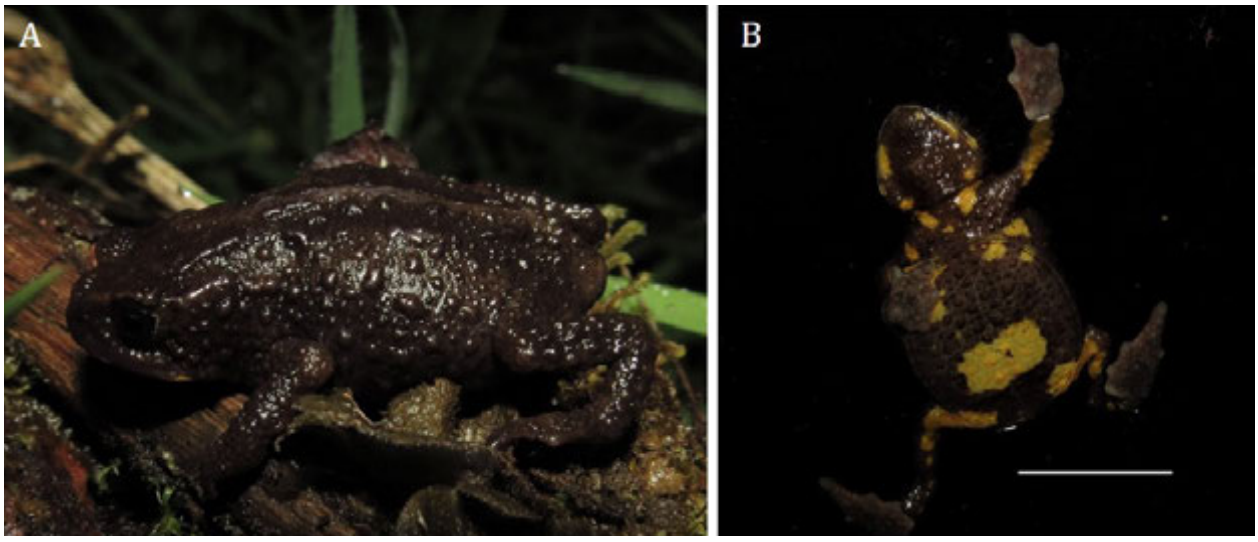


Image 5. Dorsolateral (a) and ventral view (b) of *Osornophryne percrassa* (SVL 21.3mm; weight 2.4g), from Nereidas Stream, Playa Larga Village, municipality of Villamaría, department of Caldas, Colombia. Scale bar 10mm. © Julián Andrés Rojas.

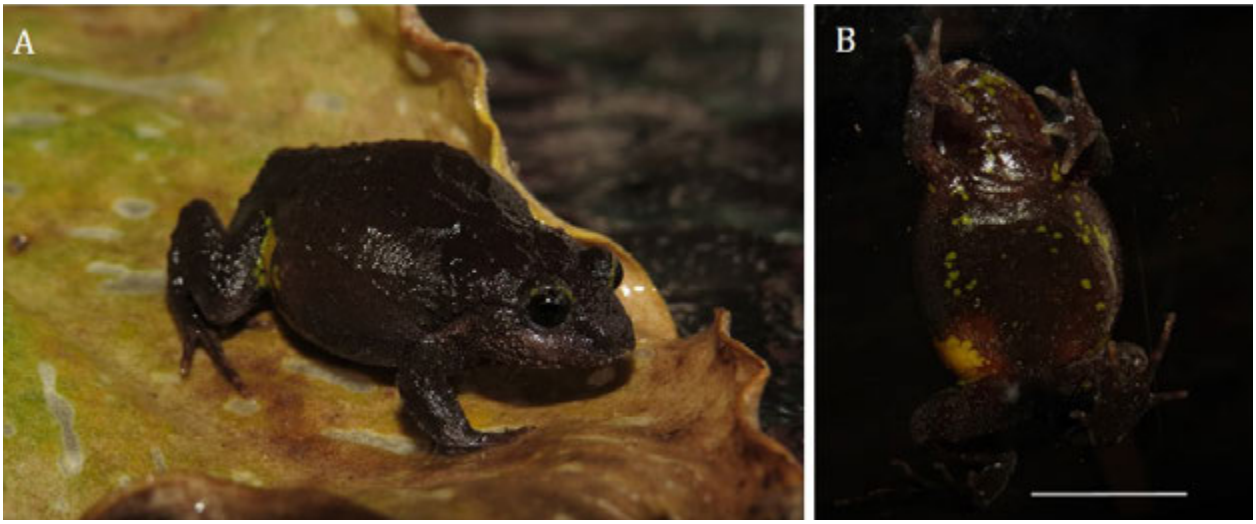


Image 6. Dorsolateral (a) and ventral views (b) of a *Hypodactylus latens* (female SVL 30.4mm; weight 2.7g) from La Cadena Stream, Playa Larga Village, municipality of Villamaría, department of Caldas, Colombia (MHN-UCa 0765). Scale bar 10mm. © Julián Andrés Rojas.

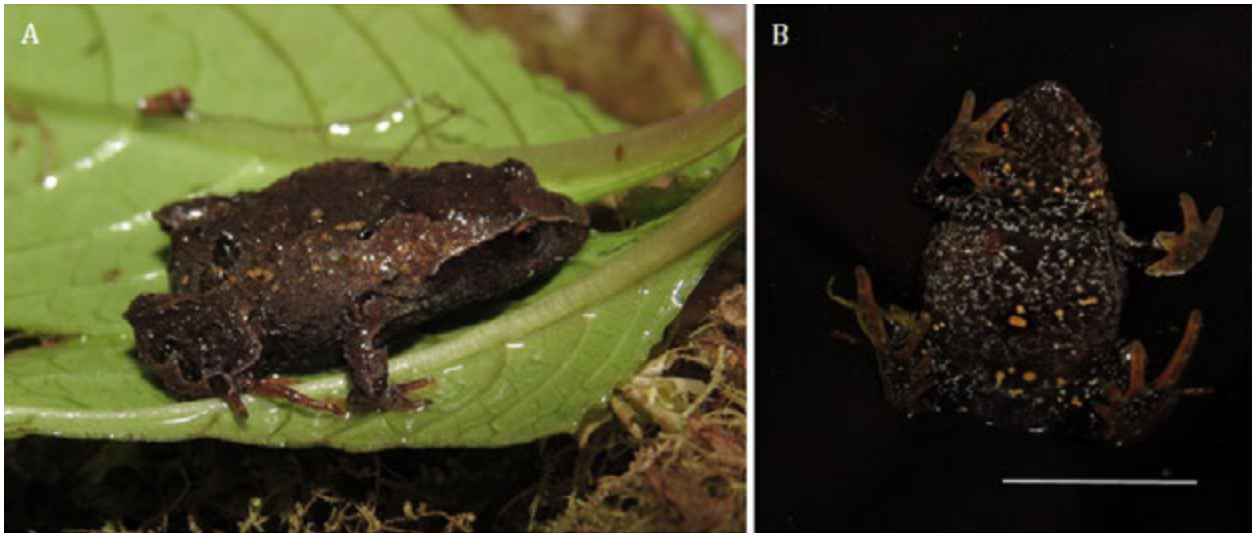


Image 7. Dorsolateral (a) and ventral view (b) of *Niceforonia adenobrachia* (male SVL 18.5mm; weight 0.8g) (MHN-UCa 0775), from the Nereidas Stream, Playa Larga Village, municipality of Villamaría, department of Caldas, Colombia. Scale bar 10mm. © Julián Andrés Rojas.

not have terminal discs; the toes are longer and thinner; absence of interdigital membranes in hands and feet. The face is short, sub-acuminate in dorsal view and inclined in lateral view. Tympanic ring absent. The coloration of the back varies from light to dark brown, with an axillary and inguinal cream spot; some individuals have a thin longitudinal white dorsal line. It presents a dark brown post-ocular band resembling a mask. Fingers and hands light orange. Copper iris with red crosslinks. The belly has a black and white crosslinking, accompanied by some dark brown spots on the reticulations, and some yellow spots of variable shape and arrangement in the interspaces (Image 7).

Distribution. Endemic to Colombia, *N. adenobrachia* is known from a small number of localities around Los Nevados National Natural Park, in the department of Caldas (this register), Tolima (Ardila-Robayo et al. 1996; Romero-García et al. 2015) and Quindío (Buitrago-González et al. 2016). Its type locality is the Cerro Bravo Volcano, Páramo of Letras, Albania village, municipality of Herveo, department of Tolima, between 3,000–3,400 m), in the Central Cordillera of Colombia.

Family Hylidae

***Colomascirtus larinopygion* (Duellman, 1973)**
(Image 8)

Conservation status: Near Threatened (NT)

Abundance in the study area: A common species, inhabitant of primary and secondary forests associated with rapid flow streams. In the study area and Los Nevados Natural National Park, this is a characteristic element of the tree frogs associated with creeks and streams.

Morphological field characters: A medium-sized tree frog with a robust body (see Duellman 1973, Duellman & Berger 1982, Duellman & Hillis 1990, Rivera-Correa & Faivovich 2013 for a detailed description).

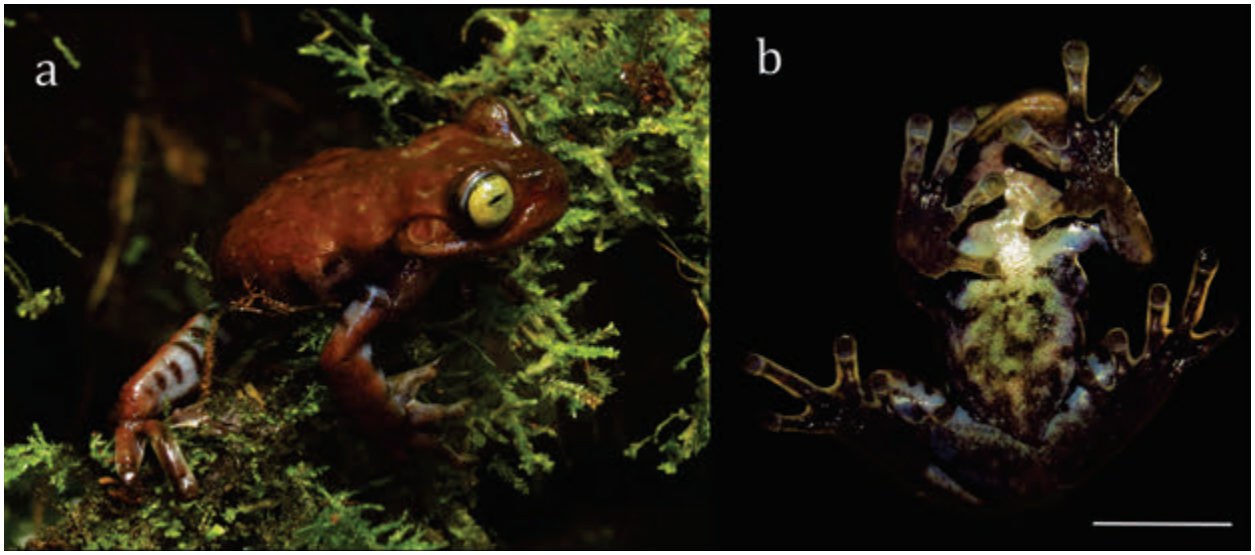


Image 8. Dorsolateral (a) and ventral view (b) of an *Colomascirtus larinopygion* (SVL 47.6mm, weight 3.7g), from La Cadena stream, Playa Larga village, municipality of Villamaría, department of Caldas, Colombia. © Julián Andrés Rojas.

Individuals in the study area have an average of SVL 56.6±3 mm (n = 8). This is an easily distinguishable species in the study area by the following set of characters: head as wide as the body, with the face truncated in dorsal and lateral view; protruding eyes, bordered by a black line on top and back; elliptical pupil and yellow iris; tympanic ring present; long and slender manual fingers, terminated in expanded discs; the discs of the pedial fingers are smaller than those of the hands. Thick forearms and thin, slender hind legs. Basal manual membranes and extended on the feet. Anal region markedly swollen and bordered by a white line. Skin smooth and slightly corrugated on the flanks. Dorsal coloration dark brown uniform, in some individuals purple; flanks, belly, and inner surface of the fingers, thighs and forearms pale blue color with black stripes that radiate from the belly. Ventrally the coloration is dark gray (Image 8).

Distribution. *Colomascirtus larinopygion* is the widest distributed species of the *larinopygion* group (Faivovich et al. 2005), inhabiting cloud forests of the northern Andes in Colombia and Ecuador. In Colombia it is distributed on both flanks of the Central and Western Cordilleras, between 1,950–3,100 m (Acosta 2000; Bernal & Lynch 2008; Rivera-Correa & Faivovich 2013). Politically it is registered in the departments of Antioquia, Caldas, Cauca, Huila, Quindío, Tolima and Valle del Cauca (Rivera-Correa & Faivovich 2013).

Spanish abstract: Resumen: Presentamos una evaluación sobre la composición, diversidad y estructura de los anfibios en tres zonas a lo largo de un gradiente de elevación (2,400–3,000 m) en la Cordillera Central de Colombia. Para esto, se llevaron a cabo dos jornadas de muestreo, una en noviembre 2014 y otra en febrero 2015, en períodos de lluvia y seco, respectivamente. Los muestreos fueron tanto diurnos (08:00–12:00 h) como nocturnos (18:00–22:00 h) usando la metodología de relevamiento por encuentros visuales, sin restricciones espaciales. La diversidad fue evaluada en términos del número efectivo de especies para cada zona (alfa) y para todo el paisaje en general (gamma), y la estructura de las comunidades fue analizada mediante curvas de rango-abundancia. Se calculó un factor de inequidad para cada zona de muestreo. Se registró un total de 15 especies pertenecientes a siete géneros y tres familias, todas del orden Anura. La familia Craugastoridae fue la más rica con 11 especies (73,3%), y el género más rico fue *Pristimantis* con ocho especies. La diversidad alfa promedio por zona fue de 6,6 especies efectivas, siendo la zona A la más diversa con ocho especies. En términos de la diversidad beta, existen 2,5 comunidades efectivas a nivel de todo el gradiente evaluado. Las diferencias de composición entre zonas están dadas por las especies raras, mientras que las especies más abundantes (p. ej. *Pristimantis uranobates*) son compartidas entre las mismas. Se presume que la mayor diversidad en la zona A es debido a su ubicación a menor elevación y por presentar un hábitat en mejor estado de conservación respecto a las otras dos zonas. Del total de especies registradas, dos están amenazadas de extinción: *Hypodactylus latens* (En Peligro), y *Niceforonia adenobrachia* (Peligro Crítico). Se resalta el hallazgo de tres especies indescritas.

Author Details: Julián A. Rojas-Morales has research interests on the natural history and biogeography of the tropical herpetofauna, particularly frogs and Neotropical snakes, aspects that he intends to integrate to develop programs and initiatives for biodiversity conservation. Currently, he teaches the courses for Managing of Biodiversity and Ecosystems conservation in the University of Santa Rosa de Cabal (UNISARC). Mateo Marín-Martínez he is a Colombian herpetogist focused on amphibian and reptile ecology. He is very interested in the study of trophic interactions and species diversity patterns. Currently, he is working in the project "Vertebrate fauna monitoring in the influence areas of ISAGEN at the east department of Caldas-Colombia", supported by University of Caldas.

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13278–13286

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM
OPEN ACCESS

Medium and large-sized mammals in an Atlantic Forest fragment of Brazil: recording of threatened species

Vinícius Nunes Alves [1], Caroline Marques Maia [2], Telma Regina Alves [3] & Renata Cristina Batista Fonseca [4]

[1,3,4] Departamento de Ciências Florestais, Faculdade de Ciências Agronômicas, UNESP, Avenida Universitária, 3780 Botucatu, SP - Brazil.
[2] Departamento de Fisiologia, Instituto de Biociências, UNESP, Rua Prof. Dr. Antonio Celso Wagner Zanin, s/nº Botucatu, SP - Brazil.
[1] viniciusnunesalves@ymail.com (corresponding author), [2] carolmm_luzi@hotmail.com, [3] tr_alves@yahoo.com.br, [4] rfonseca@fca.unesp.br

Abstract: Deforestation and habitat fragmentation affect to a great extent larger wild mammals, which require large areas to establish their populations. These mammals can have important functions in the structure and dynamics of tropical forests, acting as seed dispersers, herbivory regulators, and umbrella species. In the present paper, we characterize the community of medium and large wild mammals in a semi-deciduous seasonal forest fragment, a denominated IB Forest (Institute of Biosciences) in Edgardia Experimental Farm, UNESP, Botucatu, São Paulo State, Brazil. By adopting sand plots on three trails as the main method, we identified the occurrence of nine species, besides the occurrence of one species by direct visualization. Some of these are in national red lists — *Leopardus pardalis* and *Puma concolor* are listed as threatened and *Sapajus* cf. *nigritus* as Near Threatened in São Paulo State; *Puma concolor* is also listed as Vulnerable at the national level. Thus, we emphasize the importance of this forest remnant as a wildlife refuge, which makes it necessary to monitor the occurrence of these animals in the area and conserve similar remnants in the region.

Keywords: Conservation, deforestation, habitat fragmentation, IB forest, inventory, Mammalia, red lists, São Paulo State, tropical forests.

DOI: https://doi.org/10.11609/jott.4480.11.3.13278-13286 | **ZooBank:** urn:lsid:zoobank.org:pub:90B225A8-0B30-4A23-8E34-620B681556CB

Editor: Spartaco Gippoliti, Socio Onorario Società Italiana per la Storia della Fauna "Giuseppe Altobello", Rome, Italy. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4480 | Received 09 August 2018 | Final received 02 November 2018 | Finally accepted 07 February 2019

Citation: Alves, V.N., C.M. Maia, T.R. Alves & R.C.B. Fonseca (2019). Medium and large-sized mammals in an Atlantic Forest fragment of Brazil: recording of threatened species. *Journal of Threatened Taxa* 11(3): 13278–13286; https://doi.org/10.11609/jott.4480.11.3.13278-13286

Funding: None.

Competing interests: The authors declare no competing interests.

For **Portuguese abstract** see end of this article.

Author Details: Vinícius Nunes Alves, Biologist, MSc in Ecology and Natural Resources Conservation. He participates as a collaborator in the Laboratory of Botany and Ecology in the Cerrado Domain (LABEC, UFU) an in the Laboratory of Nature Conservation (FCA, UNESP). He is currently School Teacher of the Education Secretariat of São Paulo State. Caroline Marques Maia, Biologist, MSc and PhD in Zoology. She works with animal behavior and welfare, participating as a collaborator with the Department of Animal Production (FMVZ, UNESP) and GEC (Scientific Group of the Cão Cidadão Company). She is currently the Manager of the Science Club of IGVEC (GilsonVolpato Institute of Scientific Education). Telma Regina Alves, Biologist, MSc in Forest Science and PhD in Ecology and Natural Resources. She is currently an environmental consultant, working mainly on inventories and monitoring of wildlife, directed to wild mammals in the Lwarcel Cellulose Company. Renata Cristina Batista Fonseca, Forest Engineer, MSc in Forestry Sciences and PhD in Ecology. She is currently the coordinator of Laboratory of Nature Conservation (FCA, UNESP), manager of FEPAF (Foundation for Agricultural and Forest Research). Moreover, she is also currently an Assistant Professor at UNESP.

Author Contribution: Conception: VNA, RCBF and CMM. Theoretic foundations: VNA, RCBF, TRA and CMM. Field work: VNA and TRA. Statistical analyzes: VNA. Resources: RCBF. Writing - original draft: VNA. Writing - review & editing: VNA, CMM, RCBF and TRA.

Acknowledgements: We thank Aparecido A. Arruda and José L. Martinelli, retired staff from Department of Forest Sciences from UNESP of Botucatu campus by helping us with data collection in the field. We thank Juliana Griese for helping us to analyze our data and Daniela P. Traficante for maps elaboration. We also thank Claire P.R. Ferrando for English edition of the manuscript.

INTRODUCTION

The Atlantic Forest is the second largest rainforest in South America (Metzger 2009), and one of the biomes with the greatest rates of endemism (Myers et al. 2000; Ribeiro et al. 2009). This rainforest is also one of the most threatened tropical ecosystems on the planet suffering constant area loss (Myers et al. 2000). Most of the deforestation in the Atlantic Forest occurred about 70 years ago (Viana & Tabanez 2000), presenting nowadays only 11–16 % of the original cover (Ribeiro et al. 2009). The fragmentation process in the Atlantic Forest reduced the biome area into small, disturbed, and isolated remnants surrounded by agro-mosaic matrices, human settlements, and roads (Ribeiro et al. 2009; Lira et al. 2012). Such fragmentation impairs the maintenance of natural mammal assemblies by limiting their population sizes and results in changes in species composition (Galetti et al. 2017).

Less than 10% of the areas with original vegetation of the Atlantic Forest has 100 or more hectares (Ranta et al. 1998), and most of the other remnants have less than 10 hectares (Canale et al. 2012). In this forest, 298 mammal species are known, of which 90 are endemic (Paglia et al. 2012). Considering that large mammal species usually require larger areas (Chiarello 2000) and have lower population densities (Damuth 1981), it is clear that fragmentation and natural habitat loss is more pervasive for threatened large-sized species, which already have a greatly reduced population.

Thus, loss of natural vegetation areas through human occupation is one of the greatest threats to terrestrial mammals (Costa et al. 2005). The mammals have important functions in tropical ecosystems (Carvalho et al. 2014), with many of them being efficient seed dispersers (Andreazzi et al. 2009) and plant biomass regulators through restricting the population size of herbivores (Estes et al. 2011). Moreover, many large mammals, particularly carnivores, are considered umbrella species (Roberge & Angelstam 2004). Thus, by conserving such mammals, a large number of other species that may occur in the same natural area are also conserved. In this context, it is relevant to evaluate the occurrence of such mammals in the Atlantic Forest remnants, since these remnants are highly compromised because of their poor connectivity and small size (Ribeiro et al. 2009).

The largest remaining forest cover of the entire eastern Brazilian region is located in São Paulo State (Galindo-Leal & Câmara 2003; Ribeiro et al. 2009). In this state, the environmental protection area (EPA) called Corumbataí-Botucatu-Tejupá belongs to the basin of Capivara River (Jorge 2000). In this EPA, there is an experimental farm composed of fragments of natural vegetation with different disturbance influences. We characterize the community of medium and large-sized mammals in this Atlantic Forest fragment of São Paulo State.

MATERIALS AND METHODS

Study site

The Edgárdia Experimental Farm (EEF) is located in the basin of Capivara River, municipality of Botucatu in São Paulo State (-22.791 t o-22.833 ^{0}S & -48.437 to -48.375 ^{0}W) (Jorge 2000) (Fig. 1), altitude about 475m and with climate conditions characterized by two different seasons over the year — a rainy season (from September to March) and a dry season (from April to August) (Alves et al. 2012). This farm is part of the Corumbataí-Botucatu-Tejupá EPA and suffers different degrees of fragmentation and disturbance over time (Ortega & Engel 1992) since inside the EEF and its surroundings there are agro-pastoral activities, erosion areas, roads, and buildings (Jorge 2009). Despite this, fragments of natural vegetation represent a considerable area of the EEF and can be used as a refuge for wildlife species such as mammals.

EEF has five fragments of Atlantic Forest, which in total is about 740ha. These fragments are classified as semi-deciduous forest and consist of primary, secondary, and riparian forests. Primary forests were modified by wood-selective extractions, while secondary forests were modified by fires (Ortega & Engel 1992; Jorge & Sartori 2002). It is known that, since 1978, such fragments are intercalated or separated with agriculture crops, pasture, and natural regeneration areas (Jorge & Sartori 2002). More specifically, matrices that stand out inside and/or around the EEF are areas of rice cultivation, orchards, bamboo plantations, asphalted and rural roads, besides rural buildings, areas of bare soil under erosive processes, and pasturelands (Jorge 2009). We performed the study in one of the fragments of the EEF called IB Forest. This fragment is located at the border of the farm (Fig. 2), has about 90.86ha, and belongs to the Instituto de Biociências of the Unesp Campus de Botucatu Faculdade de Medicina (UNESP), Botucatu.

Data collection

The occurrence of medium and large mammals was recorded from footprint tracks on three tracks in the IB Forest. In each track (T), we placed 12 sand plots distributed in three sets. Each set presented four 50cm×50cm sand plots 50m apart (Fig. 3). Plots from

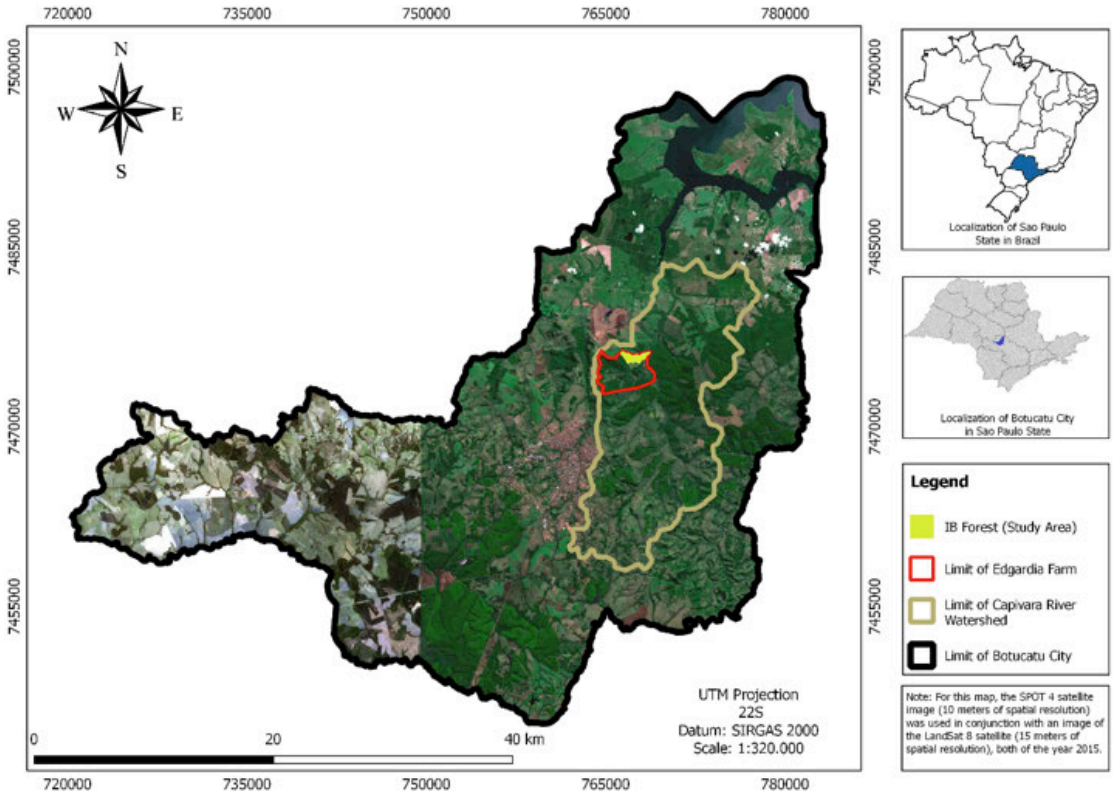


Figure 1. Limits of the municipality of Botucatu, state of São Paulo, highlighting the Capivara River basin and the Edgardia Experimental Farm.

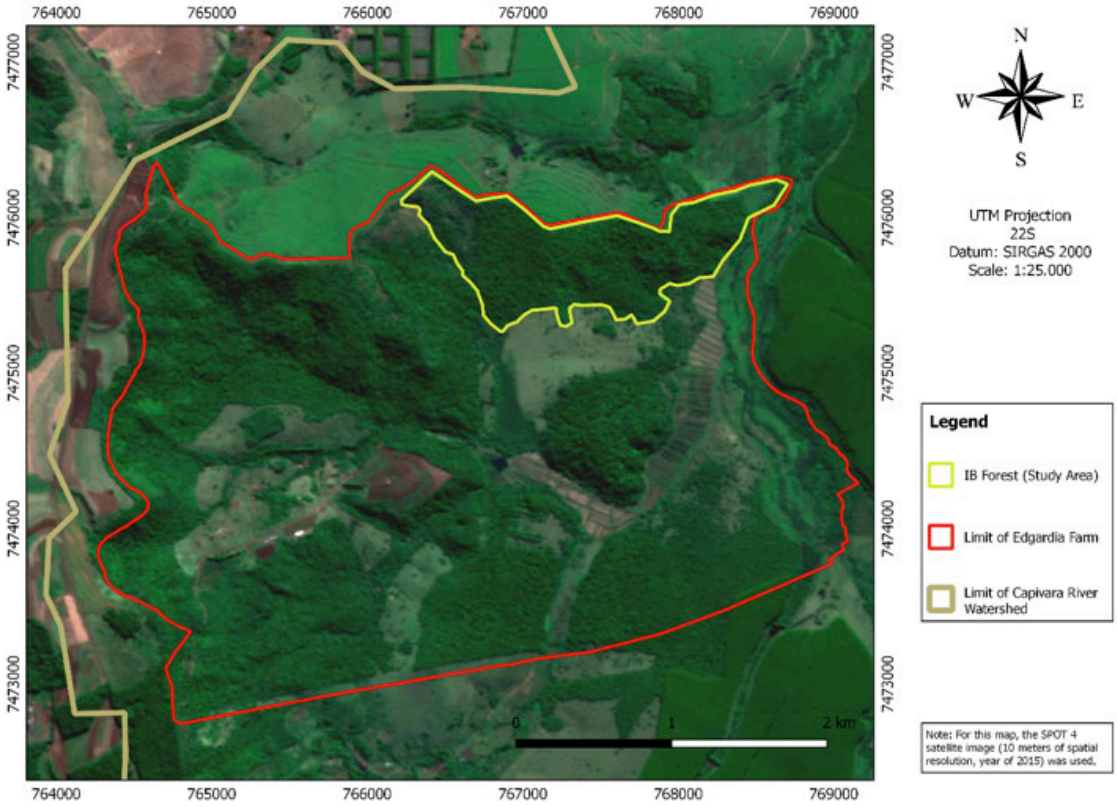


Figure 2. Limits of the Edgardia Experimental Farm and IB Forest (adapted from Google Earth 2018).

the same set were arranged so that they were at least 10m apart, resulting in a quadrangular shape (Fig. 3). Each plot was filled with fine, clear, and wet sand, with an average layer thickness of 3cm. They were delimited with PVC tubes and covered with an extended raffia bag, to assure that the sand mostly remained inside the plot area and that the sand humidity was maintained over time, respectively.

In order to optimize the recording of the mammals in our samples, we offered in each sand plot different kinds of baits to attract them, such as banana, bacon, avocado, sea salt, sardines, corn, pepperoni, and guava. These baits were chosen in relation to their attractiveness; additionally, the fruit selection was based on their lower risk of germination, greater resistance to decay, and portability (Pardini et al. 2003). The baits were separated in equal numbers and were also alternately distributed day after day (Image 1).

We checked sand plots during the dry and wet seasons as well as during transitional periods between them to access possible seasonal variations of mammals' footprints occurrence. We checked the plots every morning on seven consecutive days in April (wet-dry), July (dry), and October (dry-wet) of 2010, and in January (wet) of 2011. Our sample effort was of 252 plots per season.

For the mammals' footprints identification, we used Becker & Dalponte (1991) and Borges & Tomás (2004). To verify the accuracy of the scientific names of registered mammals, we used the nomenclature proposed by Vivo et al. (2011). We used the guide of Emmons & Feer (1997) to classify the recorded mammals as medium or large-sized. Moreover, we consulted two official lists of threatened fauna, the Red List of São Paulo State (MPSP 2014) and the Red List of Brazil (ICMBio 2016) to verify the species' state of extinction risk. We specified trophic categories of all registered taxa following the guides of Robinson & Redford (1986) and Fonseca et al. (1996).

Image 1. Plots of sand with various baits used. a - banana, b - sardine, c - corn with peanut butter, d - mixed (mixture of baits to attract any trophic category).

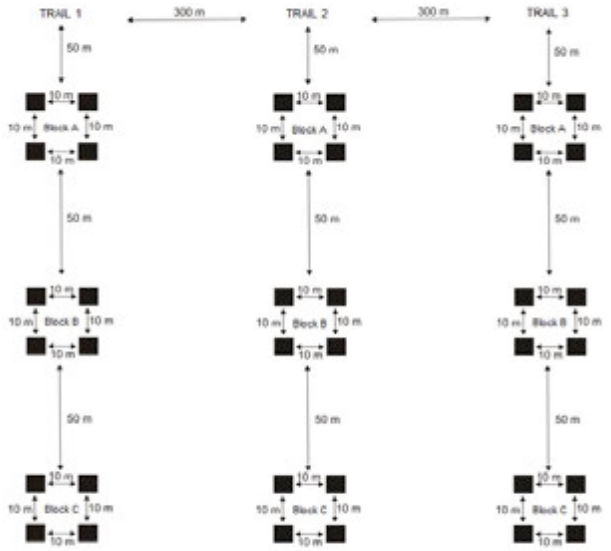


Figure 3. Organization of three tracks with three blocks of four plots (black squares) each and their respective distances in metres (arrows).

Data analysis

To verify if our sample effort was sufficient to record medium and large mammals, we performed the species accumulation curve. All registered mammal species were included to calculate this curve, which was adjusted by using the nonparametric estimator Mao Tau through Estimates Win 7.5 program (Colwell 2005). We used the rarefaction procedure performing 1,000 randomizations of samples (Colwell & Coddington 1994) to prevent the order in which the species were added along the accumulation curve in having any influence on the results. The cumulative curve tended to stabilize over time (Fig. 4).

RESULTS

We identified mammal species from different trophic categories in each set of sand plots (Table 1). We directly observed or detected any marks of the presence of other animals (lizards and birds) rarely. We identified 10 different mammal taxa — nine of them were detected considering our proposed method (footprinting in sand plots; Image 2), whereas just one was identified on occasion by direct visualization in the study area (Image 3). These 10 taxa were from five different orders: Artiodactyla, Carnivora, Didelphimorphia, Rodentia, and Xenarthra (Table 1).

Seven taxa were identified at the species level, including two different genera. The footprints most frequently recorded were of *Didelphis* sp., followed by *Dazyprocta azarae* (Lichtenstein, 1823) and *Leopardus pardalis* (Linnaeus, 1758), besides *Tamandua tetradactyla* (Linnaeus, 1758) and *Puma concolor* (Linnaeus, 1771), which were recorded only once (Table 2). From these identified taxa, *Leopardus pardalis* and *Puma concolor* are considered threatened species, while *Sapajus* cf. *nigritus* (Goldfuss, 1809) is considered a near threatened species in the São Palo State (MPSP 2014). Taking into account the national territory red list, *Puma concolor* is considered a vulnerable species (ICMBio 2016).

In relation to seasonal variations on the mammal footprints recordings, the dry season and the period of transition from dry to wet season have the highest frequency of occurrence of different taxa (eight taxa taking into account both seasons), followed by the wet season (five taxa) and the period of transition from wet to dry season (three taxa) (Table 2). Although *Dasypus novemcinctus* (Linnaeus, 1758) and *Eira barbara* (Linnaeus, 1758) were not the most frequently recorded species, as mentioned above, only these species were found in all the seasons (Table 2).

DISCUSSION

Here we demonstrate that at least 10 species of medium and large mammals occur in the IB Forest in Botucatu. Interestingly, among these recorded species, we found one threatened species, *Puma concolor*, and two others, *Leopardus pardalis* and *Sapajus* cf. *nigritus*, considered with some degree of threat at the state and

Table 1. Mammals identified in the study area with type of recording, food chain, and category of threat.

	Common name	Type of recording [1]	Trophic category [2]	Threatened species list [3]	
				SP	ICMBio
Artiodactyla Order					
Cervidae Family					
Mazama sp. (Rafinesque, 1817)	Small Brocket	P	FH	NT	NT
Carnivore Order					
Felidae Family					
Leopardus pardalis (Linnaeus, 1758)	Ocelot	P	CA	T	NT
Puma concolor (Linnaeus, 1771)	Puma	P	CA	T	VU
Mustelidae Family					
Eira barbara (Linnaeus, 1758)	Tayra	P	FO	NT	NT
Procyonidae Family					
Nasua nasua (Linnaeus, 1766)	South American Coati	P	FO	NT	NT
Didelphimorphia Order					
Didelphidae Family					
Didelphis sp. (Linnaeus, 1758)	Brazilian Common Opossum	P	FO	NT	NT
Primates Order					
Cebidae Family					
Sapajus cf. *nigritus* (Goldfuss, 1809)	Black-horned Capuchin	V	FO	AT	NT
Rodentia Order					
Dasyproctidae Family					
Dasyprocta azarae (Lichtenstein, 1823)	Azara's Agouti	P	FH	NT	NT
Xenarthra Order					
Dasypodidae Family					
Dasypus novemcinctus (Linnaeus, 1758)	Nine-banded Armadillo	P	IO	NT	NT
Myrmecophagidae Family					
Tamandua tetradactyla (Linnaeus, 1758)	Southern Tamandua	P	MY	NT	NT

[1] Registration Type: P (Footprints in the sand portion), V (direct view); [2] trophic categories according to Robinson and Redford (1986) and Fonseca et al. (1996): FO (frugivore-Omnivore), IO (Insectivorous-Omnivore), MY (Myrmecófago), CA (Carnivore) and FH (frugivore-herbivore); [3] Threat Category: NT (Not Threatened), VU (Vulnerable), AT (Almost Threatened) and T (Threatened), in the Reds Lists of the State of São Paulo (2014) and the Chico Mendes Institute for Biodiversity Conservation - Ministry of the Environment (2016).

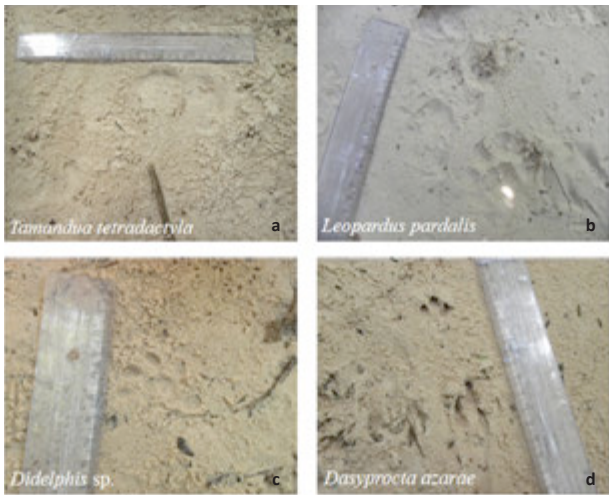


Image 2. Examples of footprints of mammals detected in the study area. a - *Tamandua tetradactyla*, b - *Leopardus pardalis*, c - *Didelphis* sp., d - *Dasyprocta azarae*.

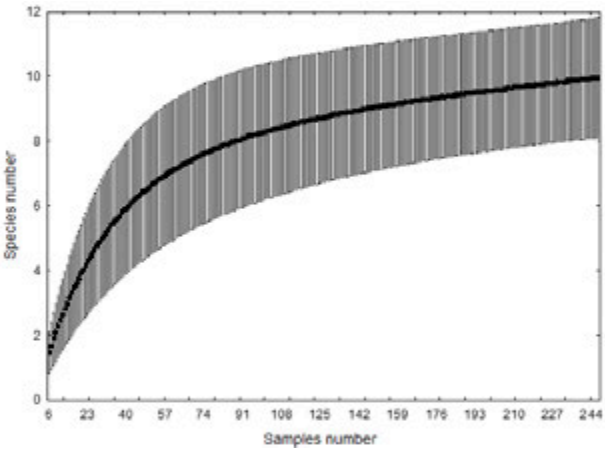


Figure 4. Average cumulative number of medium and large mammalian species with the increase of the sampling effort for sand plots in three tracks, using the Mao Tau estimator and confidence intervals (95%).

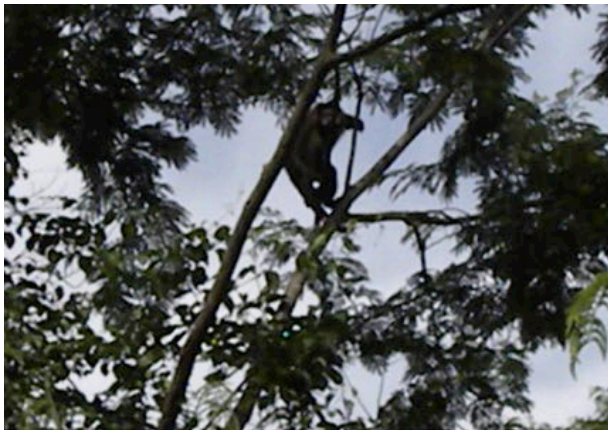


Image 3. Direct observation of Black-horned Capuchin *Sapajus* cf. *nigritus* in the study area.

national levels. Such degrees of threat, however, are not considered at the international level for *L. pardalis* and *P. concolor*, which are listed as Least Concern, but only for the endemic *S. nigritus*, which is internationally recognised as Near Threatened (IUCN 2018). Regardless of the international scenario, it is reasonable to emphasize the importance of the conservation of this area for such species that show a decreasing population trend. Moreover, some species were more frequently detected after a period of a year, mostly in the dry season than in the wet season. We discuss possible explanations for these findings below.

Considering that the cumulative curve of species tended to stabilize over time, we assume that our sampling effort by sand plots method was sufficient. The richness of species found in this study is similar with other studies conducted in the Atlantic Forest remnants of São Paulo State, being slightly higher (Dotta 2005) or equivalent (Gheler-Costa et al. 2002; Brocardo et al. 2012; Norris et al. 2012). Despite this, we found a lower richness of species than the majority of studies in the same state (Negrão & Valladares-Pádua 2006; Minami 2010; Siviero & Setz 2011; Alves et al. 2012; Magioli et al. 2014; Reale et al. 2014; Breviglieri et al. 2017). The higher richness in others' studies may have been favoured by increased sampling effort (more months or years of collection), a combination of sand plots with transects, much larger sample plots, or increased area of sampling (larger fragments).

Considering seasonal variations, more taxa were found in the dry season and dry-wet transition period, followed by the rainy season and wet-dry transition period. The fact that the wettest periods showed a low incidence of records may suggest less displacement of these mammals during rainy days, possibly because the search for water was reduced under this condition, though this needs further investigation. Another possibility here is that footprints may have been erased by the rains during the intervals of data recordings.

The taxon with the highest frequency of occurrence was *Didelphis* sp., small mammals that are among the most representative animals in fragmented and disturbed forests (Fonseca 1989). Moreover, this genus includes species that are generalists for habitat and diet resources, thus easily adjusting their populations to the environment (Fonseca & Robinson 1990). Although the most frequently detected footprints were from *Didelphis* sp,

Table 2. Occurrence of each taxon for seasons and total frequency of occurrence regardless of the season.

Taxon	Occurrence by season				Total frequency of occurence
	Wet-dry	Dry	Dry-wet	Wet	
Cebus cf. *nigritus* (Goldfuss, 1809)				X	1
Dasyprocta azarae (Lichtenstein, 1823)	X	X	X		11
Dasypus novemcinctus (Linnaeus, 1758)	X	X	X	X	8
Didelphis sp. (Linnaeus, 1758)		X	X	X	15
Eira barbara (Linnaeus, 1758)	X	X	X	X	7
Leopardus pardalis (Linnaeus, 1758)		X	X		11
Mazama sp. (Rafinesque, 1817)			X	X	3
Nasua nasua (Linnaeus, 1766)		X	X		7
Puma concolor (Linnaeus, 1771)				X	1
Tamandua tetradactyla (Linnaeus, 1758)		X			1
Total	3	7	7	6	65

X - presence of the species.

such footprints were not observed in all sampling periods. This may indicate that such animals could be transients in this fragment, in contrast with *Dasypus novemcinctus* and *Eira barbara* species that were recorded during all the seasons over the year (Table 2) and that use this fragment probably as a habitat. As we did not individualize our recorded footprints, however, we are not sure about how many individuals were sampled. Thus, these findings should be considered with caution.

On the other hand, the taxa less frequently recorded were *Tamandua tetradactyla* and *Puma concolor*. Taking into account that *T. tetradactyla* is an arboreal animal (Alves et al. 2012), this species is rarely recorded by its footprints; this may explain the reason why this species was recorded only once in our study. *Puma concolor* was also recorded just once, which is expected considering that these animals are top predators that require large areas for their maintenance, commonly using the fragments as a passage to expand their foraging area (Mazzolli 2010; Magioli et al. 2014). Even with only one recording, the presence of *P. concolor* in the evaluated area indicates the importance of the IB Forest in contributing for the species maintenance, since it is considered a threatened species in São Paulo State. Besides *P. concolor*, *Leopardus pardalis* and *Sapajus* cf. *nigritus* recorded in our study are also considered threatened or near threatened species, highlighting the IB Forest's importance and maintenance.

Furthermore, potential common preys of *Puma concolor* were also detected in our study as *Dasypus novemcinctus*, *Mazama* sp., and *Dasyprocta azarae.* This suggests that it is also important to conserve fragments as the one studied here not only focusing to protect possible threatened species such as in our case, but also considering the need to protect species that can be valuable to help maintain top predators such as *P. concolor*. In fact, prey animals are also one of the factors influencing carnivore population size and dynamics (a bottom-up process; Sandell 1989; Laundre & Hernández 2010). Moreover, the occurrence of potential natural common prey species of *P. concolor* in the studied area minimizes the risk of livestock predation, as already clearly demonstrated in the Atlantic Forest (Palmeira et al. 2015).

Even in larger forest fragments of the Brazilian Atlantic Forest, as in the corridor in southern Bahia with 50,000ha, the decline of mammal populations may be evident (Canale et al. 2012). This situation tends to be more aggravated for larger mammals, not only because they require larger areas to live, but as Galetti et al. (2017) reinforce, such species are more affected by hunting. Furthermore, the more recent economic crisis in Brazil may be contributing to defaunation in the largest Atlantic Forest remnants, since around 30% of all forest guards were dismissed from the protected parks in São Paulo State in the last few years (Galetti et al. 2017). In this scenario, considering threatened species that already have their population densities seriously compromised, protective actions should be more intense, including the reduction of fragmentation. Regarding this, Mansourian et al. (2017) recommend restoration across the landscape to connect habitat fragments for threatened species.

One may say that the richness of medium and large-sized mammals detected here can be a consequence of the baits used. We assume, however, that such kind of effect was minimized in our study because we changed the type of bait in each sampling unit daily, similar to other studies (Pires & Cademartori 2012; Reale et

al. 2014). Moreover, throughout the study, species of different trophic categories were recorded in each set of plots, thus reinforcing that such kind of bias was prevented. Furthermore, in our study, there were only isolated occurrences of animals that were not medium or large-sized mammals. Thus, such facts demonstrate that the baits used here were suitable for our focus.

CONCLUSION

Based on our findings, we suggest that the IB Forest incorporated in EEF is a refuge for wild mammals, including species with some extinction threat level in the state of São Paulo, such as *Leopardus pardalis*, *Puma concolor*, and *Sapajus* cf. *nigritus*, and also, in Brazil, *Puma concolor*. Since these mammals are subject to anthropogenic influences such as grazing, monocultures, and illegal hunting, we emphasize the importance of monitoring the occurrence of these mammals as well as of the maintenance of forest fragments in the region.

REFERENCES

Alves, T.R., R.C.B. Fonseca & V.L. Engel (2012). Mamíferos de médio e grande porte e sua relação com o mosaico de habitats na *cuesta* de Botucatu, Estado de São Paulo, Brasil. Medium and large sized mammalians and their relation to habitat patches at the Botucatu cuesta, state of São Paulo, Brazil. *Iheringia Série Zoologia* 102(2): 150–158; https://doi.org/10.1590/S0073-47212012000200006

Andreazzi, C., A.S. Pires & F.A.S. Fernandez (2009). Mamíferos e palmeiras neotropicais: interações em paisagens fragmentadas. Interactions of mammals and palms in fragmented neotropical landscapes. *Oecologia Brasiliensis* 13(4): 554–574; https://doi.org/10.4257/oeco.2009.1304.02

Becker, M. & J.C. Dalponte (1991). *Rastros de mamíferos silvestres brasileiros: um guia de campo*. Traces of Brazilian wild mammals: a field guide. Editora Universidade de Brasília, Brasília, 180pp.

Borges, P.A.L. & W.M. Tomás (2004). *Guia de rastros e outros vestígios de mamíferos do Pantanal*. Guide to footprints and others traces of Pantanal mammals. EMBRAPA Pantanal, Corumbá, 148pp.

Breviglieri, C.P.B., J.W. Laundré & G.Q. Romero (2017). Effects of puma on the diversity and composition of Neotropical mammals. *Journal of Tropical Ecology* 33(5): 317–326; https://doi.org/10.1017/S0266467417000293

Brocardo, C.R., R. Rodarte, R.S. Bueno, L. Culot & M. Galetti (2012). Mamíferos não voadores do Parque Estadual Carlos Botelho, continuum florestal do Paranapiacaba. Non-volant mammals of Carlos Botelho State Park, Paranapiacaba Forest Continuum. *Biota Neotropica* 12(4): 198–208; https://doi.org/10.1590/S1676-06032012000400021

Canale, G.R., C.A. Peres, C.E. Guidorizzi, C.A.F. Gatto & M.C.M. Kierulff (2012). Pervasive defaunation of forest remnants in a tropical biodiversity hotspot. *PLoS ONE* 7(8): e41671; https://doi.org/10.1371/journal.pone.0041671

Chiarello, A.G. (2000). Density and population size of mammals in remnants of Brazilian Atlantic Forest. *Conservation Biology* 14(6): 1649–1657; https://doi.org/10.1111/j.1523-1739.2000.99071.x

Colwell, R.K. (2005). EstimateS: Statistical Estimation of Species Richness and Shared Species from Samples. Available online at https://viceroy.eeb.uconn.edu/estimates/ Accessed on 16 April 2017.

Colwell, R.K. & J.A. Coddington (1994). Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions: Biological Sciences* 345(1311): 101–118; https://doi.org/10.1098/rstb.1994.0091

Costa, L.P., Y.L.R. Leite, S.L. Mendes & A.D. Ditchfield (2005). Conservação de mamíferos no Brasil. Conservation of mammals in Brazil. *Megadiversidade* 1(1): 103–112.

Carvalho, I.D., R. Oliveira & A.S. Pires (2014). Medium and large-sized mammals of the Reserva Ecológica de Guapiaçú, Cachoeiras de Macacu, RJ. *Biota Neotropica* 14(3): 1–9; https://doi.org/10.1590/1676-06032014007414

Damuth, J. (1981). Population density and body size in mammals. *Nature* 290: 699–700; https://doi.org/10.1038/290699a0

Dotta, G. (2005). Diversidade de mamíferos de médio e grande porte em relação à paisagem da Bacia do Rio Passa-Cinco, São Paulo. Diversity of medium and large mammals in relation to the landscape of the Passa-Cinco River Basin, São Paulo. M.Sc. Dissertation. Universidade de São Paulo, Piracicaba, 116pp.

Emmons, L.H. & F. Feer (1997). *Neotropical Rainforest Mammals — A Field Guide - 2nd Edition*. The University of Chicago Press, Chicago, 307pp.

Estes, J.A., J. Terborgh, J.S. Brashares, M.E. Power, J. Berger, W.J. Bond, S.R. Carpenter, T.E. Essington, R.D. Holt, J.B.C. Jackson, R.J. Marquis, L. Oksanen, T. Oksanen, R.T. Paine, E.K. Pikitch, W.J. Ripple, S.A. Sandin, M. Scheffer, T.W. Schoener, J.B. Shurin, A.R.E. Sinclair, M.E. Soulé, R. Virtanen & D.A. Wardle (2011). Trophic downgrading of planet Earth. *Science* 333(6040): 301–306; https://doi.org/10.1126/science.1205106

Fonseca, G.A.B. (1989). Small mammal species diversity in Brazilian tropical primary and secondary forests of different sizes. *Revista Brasileira de Zoologia* 6(3): 381–422; https://doi.org/10.1590/S0101-81751989000300001

Fonseca, G.A.B. & J.G. Robinson (1990). Forest size and structure: competitive and predatory effects on small mammal communities. *Biological Conservation* 53(4): 265–294; http://doi.org/10.1016/0006-3207(90)90097-9

Fonseca, G.A.B., G. Hermann, Y.L.R. Leite, R.A. Mittermeier, A.B. Rylands & J.L. Patton (1996). Lista anotada dos mamíferos do Brasil. Annotated list of Brazilian mammals. *Occasional Papers in Conservation Biology* 4(3): 1–38.

Galetti, M., C.R. Brocardo, R.A. Begotti, L. Hortenci, F. Rocha-Mendes, C.S.S. Bernardo, R.S. Bueno, R. Nobre, R.S. Bovendorp, R.M. Marques, F. Meirelles, S.K. Gobbo, G. Beca, G. Schmaedecke & T. Siqueira (2017). Defaunation and biomass collapse of mammals in the largest Atlantic forest remnant. *Animal Conservation* 20(3): 270–281; https://doi.org/10.1111/acv.12311

Galindo-Leal, C. & I.G. Câmara (2003). *The Atlantic Forest of South America: Biodiversity Status, Threats and Outlook*. Island Press, Washington DC, 488pp.

Gheler-Costa, C., L.M. Verdade & A.F. Almeida (2002). Mamíferos não-voadores do campus "Luiz de Queiroz", Universidade de São Paulo, Piracicaba, Brasil. Non-volant mammals of the "Luiz de Queiroz" campus, University of São Paulo, Piracicaba, Brazil. *Revista Brasileira de Zoologia* 19(2): 203–214.

ICMBio (2016). Red Book of the Brazilian Fauna Threatened Extinction. *Livro Vermelho da Fauna Brasileira Ameaçada de Extinção*. MMA/ICMBio, Brasília, 76pp.

IUCN (2018). The IUCN Red List of Threatened Species. Available online at https://www.iucnredlist.org/search?query=Sapajus%20nigritus&searchType=species. Accessed on 22 July 2018.

Jorge, L.A.B. (2000). Comportamento de fragmentos de vegetação natural na Bacia do Rio Capivara, em Botucatu/SP. Behavior of fragments of natural vegetation in the Capivara River Basin, Botucatu/SP. *Revista Árvore* 24(4): 389–396.

Jorge, L.A.B. (2009). Soil erosion fragility assessment using an impact model and geographic information system. *Scientia Agricola* 66(5): 658–666; https://doi.org/10.1590/S0103-90162009000500011

Jorge, L.A.B. & M.S. Sartori (2002). Uso do solo e análise temporal da

ocorrência de vegetação natural na Fazenda Experimental Edgárdia, em Botucatu-SP. Soil use and temporal analysis of natural vegetation in the Experimental Farm Edgárdia, in Botucatu-SP. *Revista Árvore* 26(5): 582–592.

Laundre, J. & L. Hernández (2010) What we know about Pumas in Latin America, pp76–90. In: Hornoker, M. & S. Negri (eds.). *Cougar, Ecology and Conservation*. University of Chicago Press, Chicago, 760pp.

Lira, P.K., L.R. Tambosi, R.M. Ewers & J.P. Metzger (2012). Land-use and land-cover change in Atlantic forest landscapes. *Forest Ecology and Management* 278: 80–90; https://doi.org/10.1016/j.foreco.2012.05.008

Magioli, M., K.M.P.M.B. Ferraz & M.G. Rodrigues (2014). Medium and large-sized mammals of an isolated Atlantic forest remnant, southeast São Paulo State, Brazil. *Check List* 10(4): 850–856; https://dx.doi.org/10.15560/10.4.850

Mansourian, S., J.A. Stanturf, M.A.A. Derkyi & V.L. Engel (2017). Forest landscape restoration: increasing the positive impacts of forest restoration or simply the area under tree cover? *Restoration Ecology* 25(2): 178–183; https://doi.org/10.1111/rec.12489

Mazzolli, M. (2010). Mosaics of exotic forest plantations and native forests as habitat of pumas. *Environmental Management* 46(2): 237–253; https://doi.org/10.1007/s00267-010-9528-9

Metzger, J.P. (2009). Conservation issues in the Brazilian Atlantic forest. *Biological Conservation* 142(6): 1138–1140; https://doi.org/10.1016/j.biocon.2008.10.012

Minami, D. (2010). Caracterização da comunidade de mamíferos silvestres de médio e grande porte em fragmentos de vegetação natural e talhões de eucalipto numa fazenda de reflorestamento em Borebi, SP. TCC monograph. Characterization of the community of medium and large wild mammals in fragments of natural vegetation and eucalyptus stands on a reforestation farm in Borebi, SP. Instituto de Biociências, Universidade Estadual Paulista, Botucatu, 15pp.

MPSP (2014). *Decreto nº 60.133 lista das espécies da fauna silvestre ameaçadas de extinção, as quase ameaçadas.* Assembleia Legislativa do Estado de São Paulo, São Paulo, 8pp.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. Fonseca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403(6772): 853–858; https://doi.org/10.1038/35002501

Negrão, M.F.F. & C. Valladares-Pádua (2006). Registros de mamíferos de maior porte na Reserva Florestal do Morro Grande, São Paulo. Records of mammals of larger size in the Morro Grande Forest Reserve, Sao Paulo. *Biota Neotropica* 6(2): 21–30; https://doi.org/10.1590/S1676-06032006000200006

Norris, D., J.M. Ramirez, C. Zacchi & M. Galetti (2012). A survey of mid and large bodied mammals in Núcleo Caraguatatuba, Serra do Mar State Park, Brazil. *Biota Neotropica* 12(2): 127–133; https://doi.org/10.1590/S1676-06032012000200013

Ortega, V.R. & V.L. Engel (1992). Conservação da biodiversidade de remanescentes de Mata Atlântica na região de Botucatu, SP. Biodiversity conservation of remnants of the Atlantic Forest in the region of Botucatu, SP. *Revista do Instituto Florestal* 4(3): 839–852.

Paglia, A.P., G.A.B. Fonseca, A.B. Rylands, G. Herrmann, L.M.S. Aguiar, A.G. Chiarello, Y.L.R. Leite, L.P. Costa, S. Siciliano, M.C.M. Kierulff, S.L. Mendes, V.C. Tavares, R.A. Mittermeier & J.L. Patton (2012). Lista Anotada dos Mamíferos do Brasil / Annotated Checklist of Brazilian Mammals. 2ª Edição / 2nd Edition. *Occasional Papers in Conservation Biology*, No. 6. Conservation International, Arlington, VA, 76pp.

Palmeira, F.B.L., C.T. Trinca & C.M. Haddad (2015). Livestock predation by Puma (*Puma concolor*) in the highlands of a southeastern Brazilian Atlantic forest. *Environmental Management* 56(4): 903–915; https://doi.org/10.1007/s00267-015-0562-5

Pardini, R., E.H. Ditt, L. Cullen Jr., C. Bassi & R. Rudran (2003). Levantamento rápido de mamíferos terrestres de médio e grande porte, pp437–479. In: Cullen, L. Jr., R. Rudran & C.V. Padua (eds.). *Métodos de Estudos em Biologia da Conservação e Manejo da Vida Silvestre*. Methods of Studies in Conservation Biology and Wildlife Management. Editora UFPR, Fundação O Boticário de Proteção à Natureza, Curitiba, 652pp.

Pires, D.P.S. & C.V. Cademartori (2012). Medium and large sized mammals of a semideciduous forest remnant in southern Brazil. *Biota Neotropica* 12(3): 239–245; https://doi.org/10.1590/S1676-06032012000300023

Ranta, P., T. Blom, J. Niemela, E. Joensuu & M. Siitonen (1998). The fragmented Atlantic rain forest of Brazil: size, shape and distribution of forest fragments. *Biodiversity and Conservation* 7(3): 385–403; https://doi.org/10.1023/A:1008885813543

Reale, R., R.C.B. Fonseca & W. Uieda (2014). Medium and large-sized mammals in a private reserve of natural heritage in the Municipality of Jaú, São Paulo, Brazil. *Check List* 10(5): 997–1004; https://doi.org/10.15560/10.5.997

Ribeiro, M.C., J.P. Metzger, A.C. Martensen, F.J. Ponzoni & M.M. Hirota (2009). The Brazilian Atlantic Forest: how much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation* 142(6): 1141–1153; https://doi.org/10.1016/j.biocon.2009.02.021

Roberge, J.M. & P. Angelstam (2004). Usefulness of the umbrella species concept as a conservation tool. *Conservation Biology* 18(1): 76–85; https://doi.org/10.1111/j.1523-1739.2004.00450.x

Robinson J.G. & K.H. Redford (1986). Body size, diet, and population density of neotropical forest mammals. *The American Naturalist* 128(5): 665–680.

Sandell, M. (1989). The mating tactics and spacing patterns of solitary carnivores, pp164–182. In: Gittleman, J.L. (ed.) *Carnivore Behavior, Ecology and Evolution*. Cornell University Press, New York, 624pp.

Siviero, M.C.B. & E.Z.F. Setz (2011). Pegadas de mamíferos em parcelas de areia em fragmentos de vegetação da bacia do ribeirão Anhumas, Campinas, São Paulo. Mammal tracks in sand plots in vegetation fragments of the Anhumas Creek Basin, Campinas, São Paulo. *Revista Instituto Florestal* 23(1): 39–55.

Tabanez, A.A.J. & V.M. Viana (2000). Patch structure within Brazilian Atlantic forest fragments and implications for conservation. *Biotropica* 32(4B): 925–933.

Vivo, M., A.P. Carmignotto, R. Gregorin, E. Hingst-Zaher, G.E. Iack-Ximenes, M. Miretzki, A.R. Percequillo, M.M. Rollo, R.V. Rossi & V.A. Taddei (2011). Checklist dos mamíferos do Estado de São Paulo, Brasil. Checklist of mammals from São Paulo State, Brazil. *Biota Neotropica* 11(1a): 1–22; https://doi.org/10.1590/S1676-06032011000500007

Portuguese Abstract: O desmatamento e a fragmentação do habitat afetam intensamente mamíferos silvestres de maior porte, que requerem grandes áreas para estabelecer suas populações. Esses mamíferos podem ter importantes funções na estrutura e dinâmica das florestas tropicais, atuando como dispersores de sementes, reguladores de herbivoria e espécies guarda-chuva. Aqui caracterizamos a comunidade de mamíferos silvestres de médio e grande porte em um fragmento de Floresta Estacional Semidecidual, denominado "Floresta do IB" (Instituto de Biociências), na Fazenda Experimental Edgardia, UNESP, Botucatu, SP. Para isso, por meio do estabelecimento de parcelas de areia em três trilhas como método principal, identificamos a ocorrência de nove espécies, além de uma espécie por visualização direta. Algumas delas estão em listas vermelhas: duas como ameaçadas (*Leopardus pardalis*, *Puma concolor*) e uma como quase ameaçada (*Sapajus* cf. *nigritus*) no Estado de São Paulo, sendo que a *Puma concolor* é também listada como vulnerável em nível nacional. Assim, enfatizamos a importância deste remanescente como refúgio da vida silvestre, o que torna necessário monitorar a ocorrência desses animais na área e conservar fragmentos similares na região.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13287–13294

Nuisance behaviors of macaques in Puerto Princesa Subterranean River National Park, Palawan, Philippines

Lief Erikson Gamalo [1], Joselito Baril [2], Judeline Dimalibot [3], Augusto Asis [4], Brian Anas [5], Nevong Puna [6] & Vachel Gay Paller [7]

[1] Department of Biological Sciences and Environmental Studies, University of the Philippines Mindanao, Mintal, Tugbok District, Davao City 8022, Philippines.
[1,2,3,7] Animal Biology Division, Institute of Biological Sciences, University of the Philippines Los Baños, Los Baños 4031, Laguna, Philippines.
[4,5,6] Puerto Princesa Subterranean River National Park Management Office Puerto Princesa City 5300, Palawan, Philippines.
[1] gamalolief@gmail.com (corresponding author), [2] joeybaril@yahoo.com.ph, [3] judimalibot@gmail.com, [4] asis.ffiphilippines@gmail.com, [5] nairballi@gmail.com, [6] nevong@gmail.com, [7] vvpaller@up.edu.ph

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

Abstract: Different nuisance behaviors of macaques have been reported in different parts of the world where humans and macaques have been living in the same habitats and sharing the same resources. In this study, nuisance behaviors of Long-tailed Macaques were documented in Puerto Princesa Subterranean River National Park using direct observation, survey questionnaire and by visiting the complaint section database. The attitudes and practices of the locals towards the macaques were also investigated. From the result of the study, it was observed that the most common nuisance behavior of macaques in Central Park Station was littering, while according to the locals, eating of crops was the most common nuisance behavior. There was no existing tourist complaint about the macaques in the area, however, park personnel reported that aggressive tourist-macaque encounters sometimes happened. These nuisance behaviors were observed to be linked to food security of the animals which results in negative interaction. Meanwhile, it was also observed that the practices of most people towards macaques in the area are still relatively positive despite the nuisance behaviors of the macaques. Only a small percentage of respondents hunted macaques, experienced keeping macaques as pets or experienced eating macaque meat. The direct observations revealed that the degree of human-macaque interaction in the park was relatively mild compared to the reports in other countries, partly because of the positive human attitudes towards the animals and the effective management practices in the area.

Keywords: Human-macaque interaction, nuisance behaviors.

DOI: https://doi.org/10.11609/jott.4702.11.3.13287-13294

Editor: Mewa Singh, University of Mysore, Mysuru, India. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4702 | Received 13 November 2018 | Final received 25 December 2018 | Finally accepted 05 February 2019

Citation: Gamalo, L.E., J. Baril, J. Dimalibot, A. Asis, B. Anas, N. Puna & V.G. Paller (2019). Nuisance behaviors of macaques in Puerto Princesa Subterranean River National Park, Palawan, Philippines. *Journal of Threatened Taxa* 11(3): 13287–13294; https://doi.org/10.11609/jott.4702.11.3.13287-13294

Funding: Department of Science and Technology- Science Education Institute- Accelerated Science and Technology Human Resource Development Program (DOST-SEI-ASTHRDP) scholarships and research grants.

Competing interests: The authors declare no competing interests.

Author Details: see end of this article.

Author Contribution: Lief Erikson Gamalo, Joselito Baril, Judeline Dimalibot and Vachel Gay Paller participated in the study design and wrote the paper. Lief Erikson Gamalo, Augusto Asis, Nevong Puna and Brian Anas conducted the fieldwork.

Acknowledgements: We would like to thank the Protected Area Management Board (PAMB) of PPSRNP for letting us conduct the study in a protected area (Resolution No.: 11-2017) and with the help of community organizers of the park. We would also like to acknowledge the Palawan Council for Sustainable Development (Permit No.: 2017-07) and the Biodiversity Management Bureau (Permit No.: 266) for giving the permission to conduct the study. We are grateful to the Research Ethics Board of the University of the Philippines Manila (Study protocol code: UPMREB 2017-513-01). We are also grateful to the participants who truthfully answered the questionnaire. We are also thankful to the Department of Science and Technology-Accelerated Science and Technology Human Resource Development Program (DOST-ASTHRDP) for the research grants and scholarship.

INTRODUCTION

Human-wildlife conflict (hereafter referred to as interaction) is one of the greatest challenges for the conservation of biodiversity (Madden & McQuinn 2014). In monkeys, the genus *Macaca* has been reported to have high interactions with humans which increases the encounters and often results in problems (Hsu et al. 2009). Such human-macaque interactions have been reported from many habitat countries where macaques are sympatric with humans.

Macaques near humans exhibit different nuisance behaviors. In agricultural areas, macaques are reported to raid crops in Sulawesi (Riley 2007) and in Kuala Selangor (Hambali et al. 2012). Although crop raiding could also have been done by different wildlife species, macaques could be more conspicuous because they are diurnal animals (Riley 2007). Additionally, the large number of macaques during crop raiding makes them more obvious compared to other animals as shown in the study by Hill (1997) on baboons.

Although macaques sometimes attract large numbers of visitors, different nuisance behaviors are also present in tourist areas. In Singapore, the degree of human and Long-tailed Macaque interaction in tourist sites is higher compared to the urban areas (Sha et al. 2009). This is because of the food provided by the tourists to macaques which could also result in direct aggression towards the tourists (Orams 2002). Biting tourists by Barbary Macaques was observed to be very frequent in Upper Rock Nature Reserve, Gibraltar (Fa 1992).

Long-tailed Macaque is the only monkey in the Philippines and is widely distributed in the country. There are two subspecies of Long-tailed Macaques in the country, *Macaca fascicularis fascicularis* inhabiting the southern Philippines and *Macaca fascicularis philippensis* which is present in most of the islands of the country (Smith et al. 2014). According to the IUCN Red List (Ong & Richardson 2008), *Macaca fascicularis philippensis*, which is the subspecies present in Palawan, is considered as Near Threatened.

In the Philippines, there are still very limited studies about human-wildlife interactions, in particular on macaques. There are no studies on human-macaque interactions in Puerto Princesa Subterranean River National Park (PPSRNP) and in the country as a whole. In this study, the current human macaque interaction was documented in terms of assessing the macaque's nuisance behaviors in PPSRNP through direct observation, survey questionnaire and by visiting the park's complaint database. This was done to determine the most common nuisance behaviors brought by Long-tailed Macaques to park personnel, local community and to tourists. The study also aimed to know the local peoples' practices and attitudes towards macaques in the area.

METHODS

Study site

Puerto Princesa Subterranean River National Park is a UNESCO World Heritage Park (10.192^{0}N & 118.926^{0}E), which spans 210km^2 of mosaic of dipterocarp, molave, karst, and montane forests (Mallari et al. 2011). In the park, Long-tailed Macaques are numerously present in the central park station, tourist area of the Underground River and in areas near human settlements.

Direct observation

Direct observation of the nuisance behaviors was done from August to September 2017 for 15 non-consecutive days in the Central Park Station (CPS) where macaques and some park personnel reside (Fig. 1). Continuous all-occurrences sampling on nuisance behaviors was done as there were only very few occurrences of these measured behaviors (Lehner 1992). The time of observation was 06:00h to 17:00h, totaling 165h of observation.

Survey questionnaire

The questionnaire was designed to know the peoples' encounters with the macaques and the nuisance behaviors shown by the animals toward the local people. Furthermore, the peoples' attitudes towards macaques were also determined through the questionnaire that included questions on hunting, eating, feeding and keeping macaques as pets.

The questionnaire was given to 303 households living inside the park (Fig. 1). The households were selected randomly and the answer was provided by one of the family members, preferably the head of the household (Mir et al. 2015). The respondents were not forced to answer all of the questions in the questionnaire. Privacy and confidentiality were maintained throughout the study.

Complaints from the tourists

The complaint section database of the park was visited to document the nuisance behaviors of macaques towards tourists in the area. Park personnel in the tourist areas of the park were also questioned about the

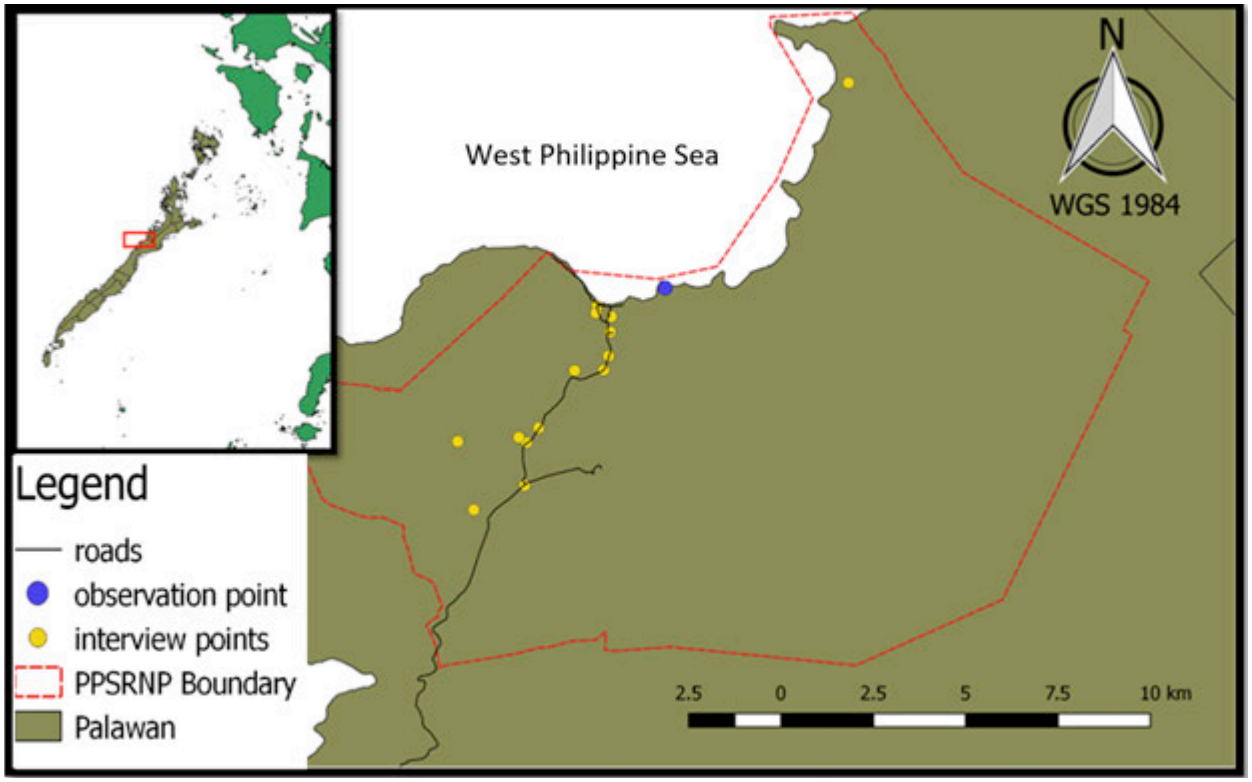


Figure 1. Central Park Station (Observation Site) and the interview sites in Puerto Princesa Subterranean River National Park (PPSRNP), Palawan, Philippines.

nuisance behaviors of macaques towards the tourists.

Data analysis

Chi-square test was used to test the differences in frequency among the different types of nuisance behaviors and/or between the answers of the respondents. This allows the researcher to know if a certain answer or a certain type of nuisance behavior is more common than the other/s (Sha et al. 2009). All statistics were carried out using Statistical Package for the Social Sciences (SPSS). Statistical significance for all tests was set at $P \leq 0.05$.

RESULTS

Nuisance behaviors towards park personnel

A total of 21 events of nuisance behavior of macaques were observed (Fig. 2). Littering, mostly in the form of messing up of garbage bins was the most common pest behavior (n = 9; 42%; X^2 = 5.524, p = 0.03). Aggressive behaviors such as provoking alarm calls and lunging were also observed (n = 8; 38.1%), especially when the macaques were provoked by humans whenever the animals were in proximity to the facilities. During the observations, a troop was observed once to damage the rooftop of a facility (n=1; 4.8%), though the indications were there of such behavior in the past. This action was related to the stealing nuisance behavior (n=3; 14.3%) as there was a macaque inside the house during the encounter. The other two stealing encounters happened when a door of the kitchen was left open. Lastly, there were no chasing and biting records throughout the observation.

Nuisance behaviors towards the local community

From 303 respondents, 50.8% reported that they observe macaques near their houses, mostly through direct observation (X^2 = 0.08, p = 0.774). Only one of the respondents reported the macaque's presence hearing a call. Macaques were also reported by some of the respondents (44%) to bring inconvenience to them (X^2 = 3.17, p = 0.075). From the survey, five types of nuisance behaviors from macaques were reported by the respondents (Fig. 3). The most common of these was macaques eating crops especially in rice fields (n=127), during harvest season (X^2 = 458.41, p = 0.0001). The reported crops/fruits which are raided by macaques were cassava, corn, sweet potato, banana, coconut, jackfruit, mango, papaya, santol, pineapple,

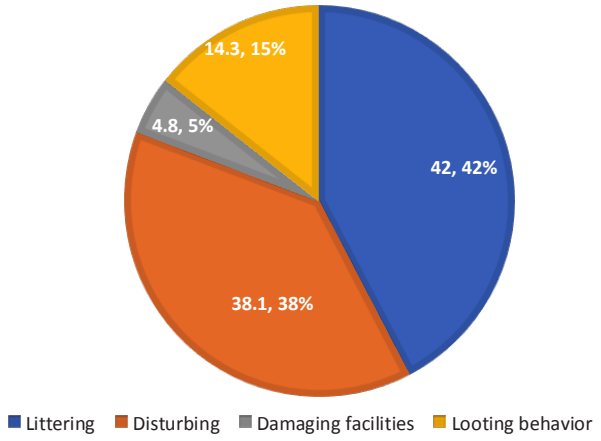


Figure 2. Proportion of the nuisance behaviors of Long-tailed Macaques directly observed in Puerto Princesa Subterranean River National Park (PPSRNP), Palawan, Philippines.

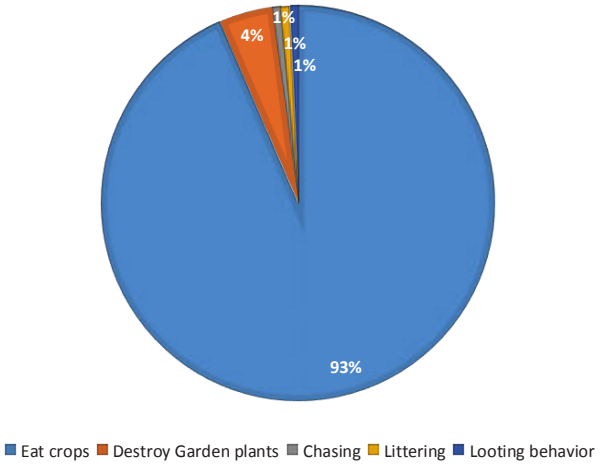


Figure 3. Proportion of the nuisance behaviors of Long-tailed Macaques reported by the respondents in Puerto Princesa Subterranean River National Park (PPSRNP), Palawan, Philippines.

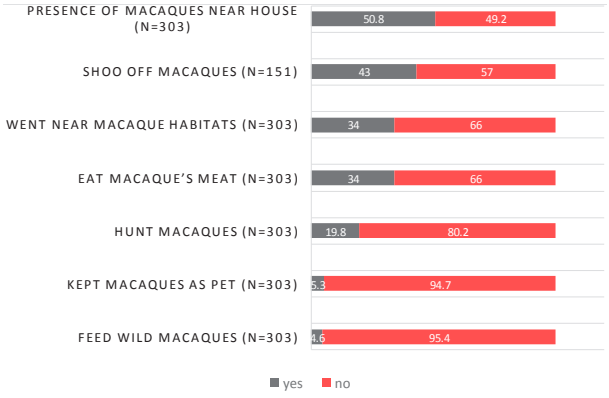


Figure 4. Responses of the respondents on their behavior towards Long-tailed Macaques and the presence of the animals in Puerto Princesa Subterranean River National Park (PPSRNP), Palawan, Philippines.

watermelon, and cucumber. Destroying of garden plants were also one of the problems reported by some people in the area (n=6).

Out of the 154 respondents who reported the presence of macaques near their houses, 32% reported to have observed one to three individuals a day (X^2 = 43.727, p = 0.0001); however, 37 reported that they could observe more than 15 macaques a day. Most of the sightings were also associated with the availability of food as most of the encounters were observed during crop raiding according to them. Due to this conflict, the farmers tried to protect their crops from raiding macaques. Sixty-five of the respondents (43%) scared off macaques by slingshots, making loud noises and using dogs to chase macaques away (X^2 = 43.727, p = 0.0001). Chasing (n=1), littering (n=1) and stealing (n=1) were also reported by a few respondents by their pet macaques.

Aside from inconvenience caused by macaques to the local people, the locals' attitudes and practices toward macaques in the area were also investigated (Fig. 4). Thirty-four percent (n=103) of the respondents had eaten macaque meat (X^2 = 31.053, p = 0.0001), while only 19.8% had experienced hunting macaques (X^2 = 110.525, p= 0.0001) in the past. Only 4.6 % (n=14) of the total respondents reported feeding wild macaques (X^2 = 249.587, p = 0.0001). Lastly, only 5.3% (n=16) of the respondents had experienced keeping macaques as pet (X^2 = 242.380, p = 0.0001).

Nuisance behaviors towards tourists

In the complaint section, there were no recorded complaints from tourists involving macaques; however, according to the present park personnel in the area, macaques were intentionally fed by the park rangers and tourists in the past, which resulted in their dependence on food provisioning.

DISCUSSION

Nuisance behaviors towards park personnel

In CPS, macaques were always present in the area during the entire duration of this study, ranging from 2–60 macaques present per day. Damaging facilities, littering by rummaging through garbage cans, stealing, and disturbing though aggressive actions were the observed nuisance behaviors of the macaques in the area.

Similar to the study of Hambali et al. (2012), littering was the most common nuisance behavior of macaques

observed in this study. This behavior was also observed in a study in Cagar Alam in Bahasa (a nature reserve) and in Taman Wisata Alam (Nature Recreational Reserve). Macaques are opportunistic omnivores which leads them to exhibit dietary plasticity. This plasticity, together with the changes in behavior, leads macaques to get food from human's houses, in addition to their natural food (Nila et al. 2014). The second most common nuisance behavior exhibited by the macaques was disturbing through aggressive behavior towards the park personnel in CPS. The aggressive behaviors were mostly executed by the alpha male in a troop residing approximately 50m from the station. Although macaques could be present any time of the day (05.00–18:00 h), it was observed that the whole troop usually got near the facility approximately around 11.00–15.00 h, suggesting that the animals were aware that food was available during lunch time. This could be the result of indirect feeding done by the macaques which includes foraging over leftover foods. In CPS, however, direct feeding was never observed as the park personnel were instructed by the management not to feed wildlife. This was also done in Universiti Kebangsaan Malaysia where interaction with macaques also occurs (Md-Zain et al. 2014) when food is available (Fuentes et al. 2008). The least observed nuisance behaviors of macaques were damaging a facility and stealing which are also associated with resource competition with humans. The results of the negative interaction in the Central Park Station suggest that the interaction between humans and Long-tailed Macaques is relatively less intense where there were more occurrences of nuisance behaviors. This could be the result of the effort of the current park management to avoid food provisioning of macaques, and shooing them away from the station.

Nuisance behaviors towards the local community

During the survey of the local communities in the park, the respondents were observed to be knowledgeable about Long-tailed Macaques' diet, group characteristics (e.g. presence of alpha), and the protection the animals get from the park.

As the natural habitat of macaques are increasingly degraded, the animals tend to become "agriculturalized" to survive. Due to encounters between macaques and people in agricultural areas, this would inevitably result in negative interaction (Priston & McLennan 2013). Similar to the results of this study, Long-tailed Macaques were also reported as crop raiders in Thailand (Aggimarangsee 1992), Indonesia (Loudon et al. 2006) and Malaysia (Hambali et al. 2012). On the other hand, crop raiding could also be done by different animals such as rats and squirrels, as reported by a few of the respondents in this study. But because macaques are much larger compared to squirrels and rats, they are more conspicuous when they exhibit crop raiding in farms (Riley 2007).

Due to the behavior of macaques as crop raiders, most farmers considered them as pests which sometimes results in hunting. Macaque hunting in the park was reportedly done for consumption, keeping as pets and even just to scare other macaques during crop raiding, mostly done using an invasive trap locally called 'ipit-ipit'. Macaque meat in the area was famous as a food accompaniment for alcoholic drinks as they believe that the meat is very clean, however, macaques, including Long-tailed Macaques were reported to carry a lethal zoonotic disease such as Macacine herpesvirus 1 (Lee et al. 2015). Transmission due to contact of simian bodily fluids could possibly happen during hunting, consumption or butchering of the macaque meat (Jones-Engel et al. 2005). Besides hunting, most of them also used dogs as deterrence. This kind of method to prevent macaques from crop raiding was described to be effective according to Priston & McLennan (2013) and was also reported by (Nahallage et al. 2008) in Sri Lanka, and in other countries such in Saudi Arabia to scare off baboons (Biquand et al. 1994).

A small number of houses have reported keeping macaques as pets, where only one house was currently keeping a juvenile macaque. Making pets of Long-tailed Macaques is widespread in Southeast Asia. Usually, these macaques become pets during their juvenile stage, either through buying or direct capturing. As pet macaques become adults, they tend to become aggressive (Fuentes 2013). In relation to this change in behavior, macaques also tend to steal food and litter inside the house, which was also reported in this study. These nuisance behaviors were also reported in the surveys done in nature parks (Hambali et al. 2012; Riley 2007; Sha et al. 2009), temples (Fuentes 2010), and even in a university (Md-Zain et al. 2014). Moreover, keeping them as pets could result in health problems of the animals. Pet macaques in the area were observed and reported by the respondents to be tethered to the waist connected to a rope. This could result in abrasions to the waist as the macaque ages.

Feeding of macaques could result in habituation of macaques near human's houses (Hambali et al. 2012). Since very few people in PPSRNP feed macaques intentionally, stealing inside houses and aggressive negative interaction was not observed from roaming

macaques in local-habituated areas.

PPSRNP is a national protected area which conserves the habitat and the wildlife species in Palawan. Strict implementation of wildlife law in the area results in the reduction of hunting, keeping macaque as pets, and eating macaque's meat. However, the presence of working ipit-ipit traps in the farms suggests that hunting of Long-tailed Macaques is still present in the park as the farmers considered them as pets.

Nuisance behaviors towards tourists

Due to the presence of macaques in the area, encounters including nuisance behaviors happen, as reported by the park personnel. In PPSRNP, macaques are one of the major tourist attractions. Macaque tourism is a practical way of engaging humans for macaque conservation and their habitats, however, this often results in negative behavioral changes in the animal and increases the possibility of zoonotic diseases in tourist places. Presently, tourists are instructed not to carry foods and plastic bags going to the Underground River area. This is to avoid aggressive encounters between the macaques and tourists in the area, however, although minimized, direct and indirect feeding is still reported in the tourist area according to the personnel, which could be the cause of some aggressive interactions between tourists and macaques (Loudon et al. 2006; Hsu et al. 2009). The macaques in the area were reported by park personnel to steal food from the bags and grabbing plastic bags. Although rare, chasing and scratching were also reported from the macaques in the area. According to the personnel, these usually happen when macaques were deprived of food by the tourists. Food provisioning of Long-tailed Macaques by tourists was reported by Fuentes & Gamerl (2005) in Indonesia, Fuentes et al. (2008) in Singapore, and Hambali et al. (2012) in Malaysia, which also was the cause of aggressive behavioral changes in the animals in those regions. Aside from the negative interaction between humans and macaques, it was also observed that the macaques in the area are relatively thin with several bruises, indicating that intra-troop fighting happens. This is possibly due to intra-troop competition during food provisioning by the tourists. In the study in Mudumalai Wildlife Sanctuary, Tamil Nadu, southern India, food provisioning by tourists to Bonnet Macaques resulted in increase of intra-troop tension between troop members (Ram et al. 2003).

Additionally, food provisioning for the macaques could increase the risk of anthropozoonotic diseases transmission between tourists and the animals (Goldberg et al. 2007; Muehlenbein et al. 2010). This could not only pose risk to the health of the macaque population in ecotourist spots, but also for those park personnel and tour guides working near the macaque population.

Conservation implications of the observed nuisance behaviors

Based on the results, varying nuisance behaviors of Long-tailed Macaques towards humans are present in the park. The park personnel observed that the most common problem was the "littering" behavior of the macaques in the Central Park Station due to scavenging of leftover foods. Littering of garbage bins through scavenging left over foods was also observed in the study of Md-Zain et al. (2014) in a university in Malaysia. In the present study, this nuisance behavior was only observed in the CPS, and there were no reported cases in the local community based on the results of the survey questionnaire. Thus, it could be argued that it would be helpful to use secured lids of garbage bins in the Central Park Station to stop the macaques from littering the area. The efficient garbage management should not only be done only in the CPS, but also outside the station to prevent "littering" to spread across the local communities. It was also observed that the CPS serves as an overlapping range of two Long-tailed Macaque troops, thus efficient management of leftovers should be done for the welfare of the animals as this could result in frequent troop encounters.

Interaction between humans and macaques over resources are the product of disturbance of macaque habitats and human agricultural expansion. In PPSRNP, it was reported by the locals that the most common nuisance behavior of Long-tailed Macaques is crop raiding, most specially to rice during harvest season. Although "scaring" by different means could be an effective deterrence of macaques as reported by the locals, a long-term solution of the problem should be found. This includes proper and effective management of agriculture-forest ecotones (Siex & Struhsaker 1999). Management strategies, such as encouraging fruit-bearing fruits trees beside agricultural plantations, should be supported by scientific research. Moreover, more research about behavioral adaptations and dietary requirements of macaques in human-modified habitats, where macaques are naturally occurring, should also be taken up. Although minimized by the current management of wildlife conservation in the area, negative attitudes of humans are still present in the park, such as the presence of hunting and feeding wild

macaques. Knowledge dissemination about the animals should be conducted by the park management for the local people. This will increase their awareness and appreciation in terms of the importance of Long-tailed Macaques in the area.

According to park personnel, stealing of plastic bags, scratching and aggressive chasing were the reported nuisance behaviors in tourists' areas due to the presence of foods brought by tourists. These could be the result of food provisioning by the tourists from the past as this was the practice before, according to the park personnel. Food provisioning is not allowed in the park at the present time, and should continue to be done to avoid aggressive macaque interactions with humans. Indirect food provisioning (in terms of scavenging leftover foods from tourists and park personnel), however, should also be controlled and avoided as this could still result in habituation of Long-tailed Macaques in tourist areas.

REFERENCES

Aggimarangsee, N. (1992). Survey for Semi-Tame Colonies of Macaques in Thailand.*Natural History Bulletin of the Siam Society* 40: 103–166.

Biquand, S., A. Boug, V. Biquand-Guyot & J.-P. Gauthier (1994). Management of commensal baboons in Saudi Arabia. *Revue D'ecologie e (Terre Vie)* 49: 213–222.

Esselstyn, J.A., P. Widmann & L.R. Heaney (2004). The mammals of Palawan Island, Philippines. *Proceedings of the Biological Society of Washington*117: 271–302; https://doi.org/10.1016/j.mambio.2008.05.006

Fa, J.E. (1992). Visitor-directed aggression among the Gibraltar macaques. *Zoo Biology* 11: 43–52; https://doi.org/10.1002/zoo.1430110106

Fuentes, A. (2010). Naturalcultural encounters in bali: Monkeys, temples, tourists, and ethnoprimatology. *Cultural Anthropolology* 25: 600–624; https://doi.org/10.1111/j.1548-1360.2010.01071.x

Fuentes, A. & S. Gamerl (2005). Disproportionate participation by age/sex classes in aggressive interactions between long-tailed macaques (Macaca fascicularis) and human tourists at Padangtegal monkey forest, Bali, Indonesia. *American Journal of Primatology* 66: 197–204; https://doi.org/10.1002/ajp.20138

Fuentes, A. (2013). Pets, property, and partners: Macaques as commodities in the human-other primate interface, pp107–123. In: Radhakrishna S., M. Huffman & A. Sinha (eds.). The Macaque Connection. Developments in Primatology: Progress and Prospects, Vol 43. Springer, New York.

Fuentes, A., S. Kalchik, L. Gettler, A. Kwiatt, M. Konecki & L. Jones-Engel (2008). Characterizing Human–Macaque Interactions in Singapore. *American Journal of Primatology* 70: 879–883; https://doi.org/10.1016/j.cell.2010.08.019.Gagnon

Goldberg, T.L., T.R. Gillespie, I.B. Rwego, E Wheeler, E.L. Estoff & C.A. Chapman (2007). Patterns of gastrointestinal bacterial exchange between chimpanzees and humans involved in research and tourism in western Uganda. *Biological Conservation* 135: 527–533; https://doi.org/10.1016/j.biocon.2006.10.050

Hambali, K., A. Ismail, S.Z. Zulkifli, B.M. Md-Zain & A. Amir (2012). Human-macaque conflict and pest behaviors of Long-Tailed Macaques (*Macaca fascicularis*) in Kuala Selangor Nature Park. *Tropical Natural History* 12: 189–205.

Hill, C.M. (1997). Crop-raiding by wild vertebrates: The farmer's perspective in an agricultural community in western uganda. *Internatiol Journal of Pest Management* 43: 77–84; https://doi.org/10.1080/096708797229022

Hsu, M.J., C.C. Kao & G. Agoramoorthy (2009). Interactions between visitors and formosan macaques (*Macaca cyclopis*) at Shou-Shan Nature Park, Taiwan. *American Journal of Primatology* 71: 214–222; https://doi.org/10.1002/ajp.20638

Jones-Engel, L., G.A. Engel, M.A. Schillaci, A. Rompis, A. Putra, K.G. Suaryana, A. Fuentes, B. Beer, S. Hicks, R. White, B. Wilson & J.S. Allan (2005). Primate-to-human retroviral transmission in Asia. *Emerging Infectious Diseases* 11: 1028–1035; https://doi.org/10.3201/eid1107.040957

Lee, M.H., M.K. Rostal, T. Hughes, F. Sitam, C.Y. Lee, J. Japning, M.E. Harden, A. Griffiths, M. Basir, N.D. Wolfe, J.H. Epstein & P. Daszak (2015). Macacine herpesvirus 1 in long-tailed macaques, Malaysia, 2009-2011. *Emerging Infectious Diseases* 21: 1107–1113; https://doi.org/10.3201/eid2107.140162

Lehner, P.N. (1992). Sampling methods in behavior research. *Poultry Science* 71: 643–649; https://doi.org/10.3382/ps.0710643

Loudon, J.E., M.E. Howells & A. Fuentes (2006). The importance of integrative anthropology: a preliminary investigation employing primatological and cultural anthropological data collection methods in assessing human-monkey co-existence in Bali, Indonesia. *Ecological and Environmental Anthropology* 2: 2–13.

Madden, F. & B. McQuinn (2014). Conservation's blind spot: The case for conflict transformation in wildlife conservation. *Biological Conservation* 178: 97–106; https://doi.org/10.1016/j.biocon.2014.07.015

Mallari, N.A.D., N.J. Collar, D.C. Lee, P.J.K. McGowan, R. Wilkinson & S.J. Marsden (2011). Population densities of understorey birds across a habitat gradient in Palawan, Philippines: implications for conservation. *Oryx* 45: 234–242; https://doi.org/10.1017/S0030605310001031

Md-Zain, B.M., F. Ruslin & W.M.R. Idris (2014). Human-macaque conflict at the main campus of Universiti Kebangsaan Malaysia. *Pertanika Journal of Tropical Agricultural Science* 37: 73–85.

Mir, Z.R., A. Noor, B. Habib & G.G. Veeraswami (2015). Attitudes of Local People Toward Wildlife Conservation: A Case Study From the Kashmir Valley. *Mountain Research and Development* 35: 392–400; https://doi.org/10.1659/MRD-JOURNAL-D-15-00030.1

Muehlenbein, M.P., L.A. Martinez, A.A. Lemke, L. Ambu, S. Nathan, S. Alsisto & R. Sakong (2010). Unhealthy travelers present challenges to sustainable primate ecotourism.*Travel Medicine and Infectious Disease* 8: 169–175; https://doi.org/10.1016/j.tmaid.2010.03.004

Nahallage, C.A.D., M.A. Huffman, N. Kuruppu & T. Weerasingha (2008). Diurnal primates in Sri Lanka and people's perception of them. *Primate Conservation* 23: 81–87; https://doi.org/10.1896/052.023.0109

Nila, S., B. Suryobroto & K.A. Widayati (2014). Dietary Variation of Long Tailed Macaques (*Macaca fascicularis*) in Telaga Warna, Bogor, West Java. *HAYATI Journal of Biosciences* 21: 8–14: https://doi.org/10.4308/hjb.21.1.8

Ong, P. & M. Richardson (2008). *Macaca fascicularis ssp. philippensis*. *The IUCN Red List of Threatened Species* 2008. Downloaded on 24 December 2018. e.T40788A10354490; http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T40788A10354490.en

Orams, M.B. (2002). Feeding wildlife as a tourism attraction: a review of issues and impacts. *Tourism Management* 23: 281–293; https://doi.org/10.1016/S0261-5177(01)00080-2

Priston, N., & M. McLennan (2013). Managing humans, managing macaques: human-macaque conflict in Asia and Africa, pp226–250. In: *The Macaque Connection: Cooperation and Conflict Between Humans and Macaques*; https://doi.org/10.1007/978-1-4614-3967-7

Ram, S., S. Venkatachalam & A. Sinha (2003). Changing social strategies of wild female bonnet macaques during natural foraging and on provisioning. *Current Science* 84: 780–790.

Riley, E.P. (2007). The human-macaque interface: conservation.

American Anthropology 109: 473–484; https://doi.org/10.1525/AA.2007.109.3.473.474

Sha, J.C.M., M.D. Gumert, B.P.Y.H Lee, L. Jones-Engel, S. Chan & A. Fuentes (2009). Macaque-Human interactions and the societal perceptions of macaques in Singapore. *American Journal of Primatology* 71: 825–839; https://doi.org/10.1002/ajp.20710

Siex, K.S. & T.T. Struhsaker (1999). Colobus monkeys and coconuts: a study of perceived human-wildlife conflicts**.** *Journal of Applied Ecology* 36: 1009–1020.

Smith, D.G., J. Ng, D. George, J.S. Trask, P. Houghton, B. Singh, J. Villano & S. Kanthaswamy (2014). A genetic comparison of two alleged subspecies of Philippine Cynomolgus Macaques. *American Journal of Physical Anthropology* 155(1): 36–148.

Author Details: Lief Erikson Gamalo, MSc, is currently a faculty of the Department of Biological Sciences and Environmental Studies, University of the Philippines Mindanao. He is also a staff of the newly formed Philippine Genome Center-Mindanao located in the University of the Philippines Mindanao. His research interest is on wildlife conservation, wildlife parasitology and primatology. Joselito Baril, MSc, is an Assistant Professor in Animal Biology Division Institute of Biological Sciences, University of the Philippines Los Baños. His special interests are on Animal Behavior and Conservation Genetics. He worked on molecular genetics of some bird species, feeding behavior of Long-tailed macaques and selected avian species. Judeline Dimalibot, MSc, is an Assistant Professor at the University of the Philippines Los Baños. She teaches zoology, animal physiology and wildlife biology and conservation courses. She mentors graduate students doing research on the biology and ecology of Philippine wildlife. Augusto Asis is currently an Environment Management officer of Puerto Princesa Subterranean River National Park. He was a former researcher of the Flora and Fauna International. His research interest is on flora and fauna in Palawan island. Brian Anas is currently the Records Officer and PAMB Secretariat of the Puerto Princesa Subterranean River National Park (PPSRNP). He graduated a Bachelor of Science in Environmental Studies at the Palawan State University. He has already worked on Peacock Pheasant in PPSRNP. Nevong Puna is a Senior Biologist of PPSRNP working as a terrestrial and marine biodiversity monitoring specialist in the park. His research interest is on wildlife in Palawan, Philippines. Vachel Gay Paller, PhD, is an Associate Professor at the Animal Biology Division, Institute of Biological Science at the University of the Philippines Los Baños. Her research interest is on Parasitology focusing on wildlife parasite ecology and public health.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13295–13303

COMMUNICATION

Current data on the reproduction of Four-horned Antelope *Tetracerus quadricornis* in zoological parks

Gérard Dubost [1], Stéphane Labes [2] & Armelle Lutz [3]

[1,2,3] UMR 7204, Ménagerie du Jardin des Plantes, MNHN, 57 rue Cuvier, 75005 Paris, France.
[1] gerard.dubost@mnhn.fr (corresponding author), [2] stephane.labes@mnhn.fr, [3] armelle.lutz@mnhn.fr

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

Abstract: The Four-horned Antelope *Tetracerus quadricornis* is currently facing numerous dangers throughout its natural range. The major threats include human overpopulation, deforestation, and degradation of its habitat. It is classified as Vulnerable on the IUCN Red List. Now, this species is rare or even absent in most zoos. Given the threats encountered by this species in the wild, its reproduction was analyzed from animal data obtained in European and Indian zoological parks during 39 consecutive years from 1977 to 2016. There was an average of 1.42 new-borns per litter. Twins were more numerous than singletons. Sexual maturity in females did not occur before 18–36 months of age. Most females, however, reproduced for the first time much later, on average at 6–7 years of age and more than half of females produced only one litter. In females that raised their young, new fertilization generally took place 101 days after the preceding birthing. In Indian zoos, where temperatures vary little between seasons, births were numerous in September–February, especially in September–November when rainfall decreases, contrary to deaths that occurred predominantly in June–August during peak rainfall. In European zoos, most litters occurred in December–February. Thus, Four-horned Antelopes maintain part of the birth season of their native countries, despite unfavourable local climate conditions. Deaths of individuals also occurred mainly in December–February in European parks, i.e., during the coldest season. Globally, more males than females died during the first month of life as in other species, but not so after that age. On the whole, there is a low reproductive success in populations of the Four-horned Antelope under managed care compared to other ruminant species. This could partly be due to husbandry and management procedures of individuals in these parks. This raises the question of the possibility of reintroducing individuals into the wild from ex situ livestock.

Keywords: Bovidae, captive population, Chousingha, ex situ conservation, reproductive success.

DOI: https://doi.org/10.11609/jott.4163.11.3.13295-13303

Editor: Karin R. Schwartz, Conservation Planning Specialist Group (CPSG), Apple Valley, USA. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4163 | Received 29 March 2018 | Final received 31 January 2019 | Finally accepted 06 February 2019

Citation: Dubost, G., S. Labes & A. Lutz (2019). Current data on the reproduction of Four-Horned Antelope *Tetracerus quadricornis* in zoological parks. *Journal of Threatened Taxa* 11(3): 13295–13303; https://doi.org/10.11609/jott.4163.11.3.13295-13303

Funding: None.

Competing interests: The authors declare no competing interests.

Author Details: Gérard Dubost is Professor Emeritus in the Muséum National d'Histoire Naturelle, Paris. Stéphane Labes and Armelle Lutz were student in Biological Sciences, and did their graduation internship.

Author Contribution: All authors participated in data collection in the French parks.

For **French abstract** see end of this article.

Acknowledgements: Many thanks to Dr. Tony King, conservation and reintroduction coordinator, The Aspinall Foundation, for his permission to use the data concerning the Howletts Wild Animal Park. Many thanks also to the Subject Editor for the helpful comments and corrections of the manuscript.

INTRODUCTION

The Four-horned Antelope *Tetracerus quadricornis* de Blainville, 1816, or Chousingha, is a small antelope in the family Bovidae (15–25 kg) of the tribe Boselaphini that inhabits wooded undulating or hilly areas never far from water in India and Nepal (Haltenorth 1963; Nowak 1999; Leslie & Sharma 2009). The species has a wide but scattered geographic distribution because its natural habitat is affected by deforestation and degradation (Rahmani 2001). Its status is difficult to assess with confidence (Mallon & Kingswood 2001). Numbers are estimated at about 10,000 wild individuals and the species is classified as Vulnerable on the IUCN Red List (IUCN SSC Antelope Specialist Group 2017). Apart from its presence in Indian national parks or protected areas (Mallon & Kingswood 2001), the species has been kept in some European and Indian zoos.

The Four-horned Antelope is exceptional because it is endemic to a restricted area of the Old World and is the only non-domestic mammal species where the male has two pairs of horns. It, however, is poorly known except for the general features of its biology — most authors characterize it as leading a solitary life in dry deciduous forests (Haltenorth 1963; Walther 1988; Nowak 1999; Krishna et al. 2009; Leslie & Sharma 2009). This lack of knowledge is also evident concerning its reproduction, although some specific data were reported by several authors (Shull 1958, 1962; Acharjyo & Misra 1975; Mauget et al. 2000; Leslie & Sharma 2009; Baskaran et al. 2011). Indeed, the species has been very little studied in the wild and is rarely kept under managed care in zoos. It was present in zoological parks in France between 1977 and 2004, in the United Kingdom between 1983 and 1999, and in India only from 2000. In 2018, it was reported as absent from all zoological parks in the world, except for 118 individuals in 12 institutions of India and three individuals in one institution of Nepal (ZIMS 2018). Consequently, in the absence of reliable information from natural populations, it is useful to consider the known characteristics of its reproduction and the fate of individuals that have been held in zoological parks. This will allow us to address the problem of the success of the species in zoological institutions, especially since the future of this species could depend in part on its ex situ conservation.

MATERIAL AND METHODS

Data used in the study exclusively came from two Parisian parks (Parc Zoologique de Paris and Ménagerie du Jardin des Plantes), one English park (Howletts Wild Animal Park), three Indian parks (Sakkarbaugh Zoo, Rajiv Gandhi Zoological Park, and Sri Chamarajendra Zoo), from a report of the Zoological Information Management System (ZIMS 2018). Some other data on the Parisian parks were added from personal observations. Together, this covered the period between 1977 and 2016 and concerned particularly captive-born individuals: 31 males and 34 females in the Parisian parks, 40 males and 61 females in the English park, and 18 males and 32 females in the Indian parks.

Dates of birth and death and age at death of all individuals were recorded for zoos within each country. Some new-borns were stillborn or died before one month of age (28 out of 30 new-borns died before 14 days), probably due to insufficient reproductive capacities of the mothers. They were grouped into the same category of young less than one month of age. Young older than one month were a priori considered as viable individuals.

All available information on the reproduction of females was taken into consideration: age at first litter, date, composition and sex ratio of each litter, and the interval between two successive litters. Finally, to determine whether the reproduction of this species was seasonal, these different parameters were compared to those of local temperature and rainfall according to four periods of three months each, i.e., December–February, March–May, June–August, and September–November.

Data were processed by categories of sex, age, rearing condition, and season, globally and in each country, using the χ^2-test. Means were compared with the t-test. Data concerning small samples were processed with the Mann-Whitney U-test, and the corresponding correlations calculated with the Spearman's rank-correlation coefficient r_s. In all statistical comparisons, $p>0.05$ was considered non-significant (ns).

RESULTS

Litter composition

As shown in Table 1, the Four-horned Antelope produces one or two young per litter (87 litters vs. 69 litters, respectively) with an average of 1.42 new-born per litter (1.38–1.45, according to the country). There is no difference in the litter composition between

Table 1. Composition of Four-horned Antelope litters, according to country. Parks in France: Parc Zoologique de Paris and Ménagerie du Jardin des Plantes. Park in the United Kingdom: Howletts Wild Animal Park. Parks in India : Sakkarbaugh Zoo, Rajiv Gandhi Zoological Park, and Sri Chamarajendra Zoo.

		France (two parks)	United Kingdom (one park)	India (three parks)	All parks (six parks)
Number of litters		46	71	39	156
Number of new-borns		65	103	54	222
Number of new-borns/litter		1.41	1.45	1.38	1.42
% of singleton new-borns	1 male	22.58	14.56	17.95	17.73
	1 female	22.58	23.30	15.38	21.16
	Subtotal	45.16	37.86	33.33	38.90
% of twin new-borns	2 males	6.45	11.65	10.26	9.79
	2 females	9.68	23.30	25.64	19.88
	1 male + 1 female	38.71	27.18	30.77	31.43
	Subtotal	54.84	62.14	66.67	61.10
Sex ratio male/female		1:1.07	1:1.51	1:1.29	1:1.31

Table 2. Males and females of Four-horned Antelopes born and surviving for less than one month in European zoological parks.

	France (two parks) % (number)	United Kingdom (one park) % (number)	All parks (three parks) % (number)
Males	45.16 (14)	56.10 (23)	51.39 (37)
Females	26.47 (9)	25.81 (16)	26.04 (25)
Both sexes	37.10 (23)	37.86 (39)	37.58 (62)

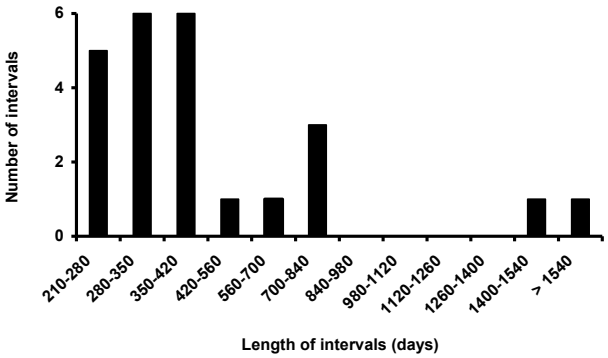


Figure 1. Distribution of intervals between successive litters in Four-horned Antelope females.

countries (X^2=1.291–8.085, df=4, p>0.05, ns). Twins are 1.55 times more numerous than singletons and as often of the same sex as of different sexes (64 vs. 60). The sex ratio at birth is in favour of females, although not significantly (X^2=0.114–1.367, df=4, p>0.8, ns).

Percentage of young living less than one month

New-borns dead before one month of age were taken into account in European parks, but not in Indian parks where age at death was reported for few young and only from the end of 2009. Males die more often than females during the first month of life, on average at 52.1% vs. 26.6%, respectively (X^2=11.228, df=1, p<0.001; Table 2). Consequently, the sex ratio at one month becomes unbalanced in favour of females: on average 0.56 male per female vs. 0.76 at birth (X^2=6.665, df=1, p<0.01). At one month, it remains only 0.90–0.91 living young per litter.

Interval between two successive litters

Twenty-four intervals between two successive litters were available concerning 14 out of 33 breeding females since the other females produced only one litter. The average inter-birth interval in all females was variable (Fig. 1). A new litter, however, was produced in the majority of cases (17/24) 318.8±13.3 days after the preceding one. Considering the gestation periods reported in this species (Table 3), new fertilization thus occurred on average 88.6±8.6 days after birthing.

The interval between two successive litters did not depend on the fate of new-borns. In females whose new-borns lived less than one month, the mean interval was not significantly shorter than that of females whose young lived 1–4 months or more (492.2±124.7 days vs. 496.7±94.3, respectively; $U_{9,15}$=68, p>0.05, ns). In nine females that reared their young until weaning, the interval indicated that they were again receptive an average of 100.6±51.3 days after birth (32–185 days), which is comparable to the above value.

Finally, the net production of 21 females followed

Table 3. Characteristics of reproduction of females and survival of individuals in Four-horned Antelopes.

	Shull 1958, 1962	Haltenorth 1963; Walther 1988; Nowak 1999	Acharjyo & Misra 1975	Mauget et al. 2000	Leslie & Sharma 2009	Baskaran et al. 2011	This study
Gestation period	233, 246 days	7.5–8 months				~8 months	
Number of new-borns/litter		1-3	1.83	1.59	1.6	1.6	1.38–1.45
Sex ratio M:F at birth				~1:1.04			1:1.07–1.51
% of young dead before one month							37.1%–37.9%
Interval between successive litters			285, 347 days				318 days (210–413)
Age at first fertilization			13 months				18–36 months
Age at first litter			21 months				26–44 months
Maximum longevity		10–12 years			17.4 years		12.7–17.5 years
Sex ratio M:F in individuals >1 month					1:1.41–2.70		1:1.08–2.70
Birth season (maximum)	Nov, Mar	(Jan–Feb)	Jan–Apr	Aug–May	Whole year (Oct–Nov)	(Feb–May)	Whole year (Sep–Feb)
Fertilization season (maximum)	Mar, Jul	(Jun–Sep)			(Jun–Jul)	(May–Jul)	Whole year (Jan–Jun)
Mortality season (maximum)							Sep–Feb or Jun–Aug

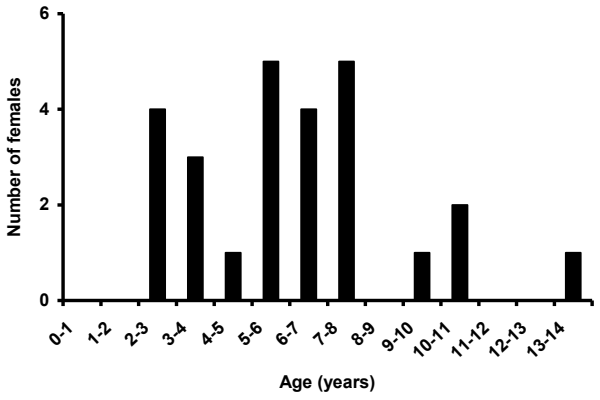


Figure 2. Age of Four-hourned Antelope females at first litter.

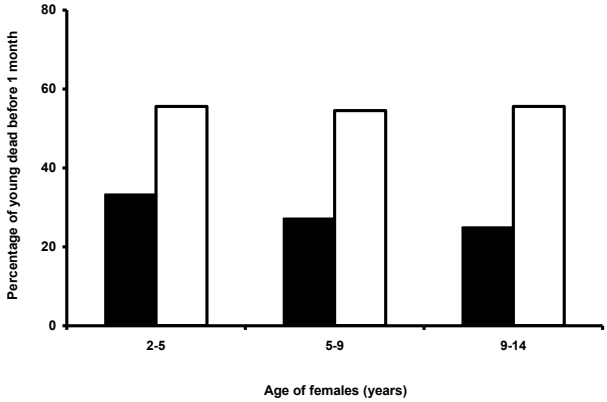


Figure 3. Overall percentage of young that died before one month of age, according to the age of Four-horned Antelope females. Black bars - first litters, white bars - following litters.

over eight consecutive years was an average of only 0.13 juvenile (older than one year) per female per year.

Variations according to age

(a) First litter in females

First litters do not occur in females before 26–44 months of age (Fig. 2). Considering again the gestation period, this corresponds to the first fertilization between 18 and 36 months of age. Many females (18/33), however, produce only one litter at an older age (after five years), and thus there is no significant difference in the mean age of all captive females between first litters and the following ones: 6.06±2.70 vs. 7.08±2.39 years (t=1.349, df=46, p>0.1, ns). There are as many new-borns per litter in first litters as in subsequent ones: 1.41±0.50 vs. 1.48±0.51 (t=0.519, df=55, p>0.5, ns).

(b) Percentage of young living less than one month (Europe only)

The percentage of young living less than one month is lower in females of 5–8 years of age than in younger and older females (30.0% vs. 55.8%; X^2=4.702, df=1, p<0.05). Curiously, this percentage in first litters is half of that of the subsequent litters, regardless of age

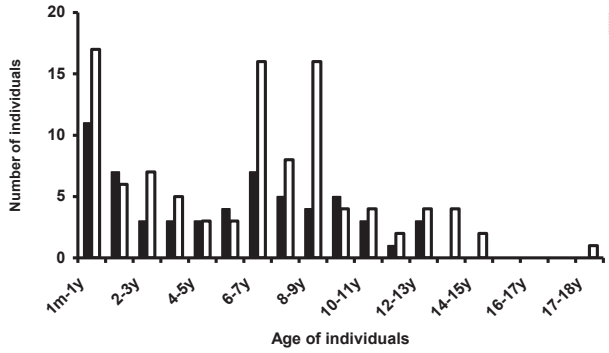


Figure 4. Age at death of viable individuals (>1 month of age) of Four-horned Antelopes. Black bars - males, white bars - females, m - month, y - year.

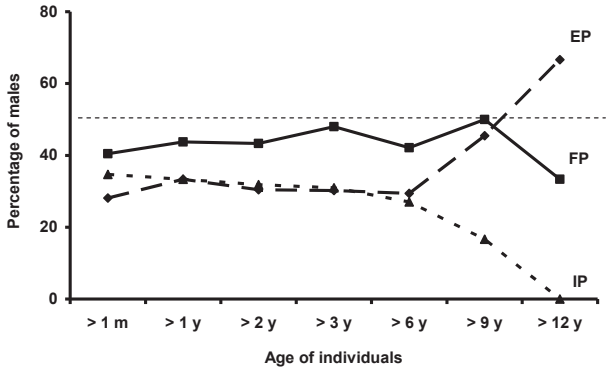


Figure 5. Percentage of males of Four-horned Antelopes, according to the age of individuals. The dashed horizontal line indicates 50% males. French parks - FP, continuous line; English park - EP, dashed line; Indian parks - IP, dotted line. m - month, y - year.

category (on average: 28.9% vs. 55.2%; X^2=4.702, df=1, p<0.05; Fig. 3).

(c) Death of viable individuals

The average percentage of individuals living in European parks decreases from 67.3% after one month of age to 52.4% after one year. Thereafter, individuals die especially between six and nine years in all parks (Fig. 4). The average lifespan varies from 4.8 years to 6.2 years, with no difference between sexes or countries (X^2=0.906–5.022, df=5, and X^2=0.656–3.363, df=6, respectively, p>0.2, ns). The maximum longevity for a female is 17.5 years in the Parc Zoologique de Paris and 12.8 years for a male in the Howletts Wild Animal Park.

From one month to nine years of age, the percentage of males in the population remains almost stable (between 27.0 and 48.0%; Fig. 5), with no difference between countries (X^2=0.719–1.866, df=5, p>0.8, ns).

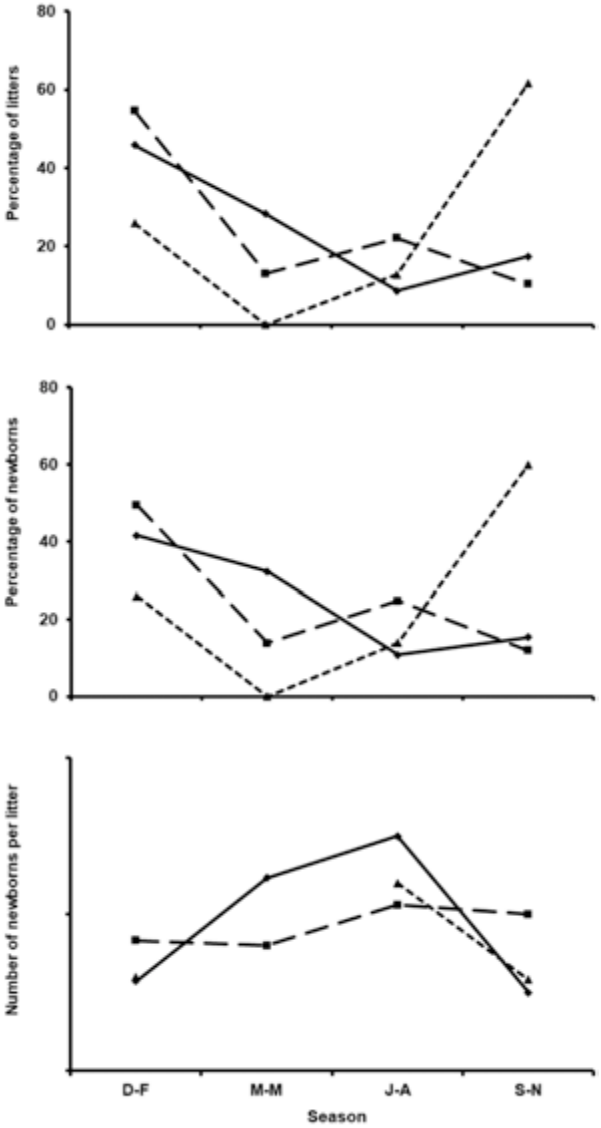


Figure 6. Seasonal distribution of Four-horned Antelope.
a - litters (%); b - new-borns (%); c - number of new-borns per litter. December–February (D-F), March–May (M-M), June–August (J-A), September–November (S-N). French parks - continuous line, English park - dashed line, Indian parks - dotted line.

Seasonal variations

(a) Litters

In all parks, births occur throughout the year, except between March and May in India (Fig. 6a). The percentage of litters born in each season, however, varies in each country (X^2=7.126–17.299, df=3, p~0.05–p<0.001). A high percentage occurs between December and February in the European parks (45.9% and 54.6% of all births in France and England, respectively), and between September and November in the Indian parks (61.5%). Differences between countries are significant (X^2=8.143–35.611, df=3, p<0.05–0.001).

(b) New-borns

Because the percentage of individuals born in each season is directly correlated to that of litters in the three countries (r_{s4}=1.00, p<0.05), the same seasonal distribution occurs concerning the new-borns (Fig. 6b), with comparable variations in each country (X^2=8.446–21.931, df=3, p<0.05–0.001) as differences between countries (X^2=11.301–41.024, df=3, p~0.01–p<0.001).

The number of new-borns per litter varies in the opposite direction to the percentage of litters, with a small increase between June and August (Fig. 6c). There, however, is no direct relationship between these two data (r_{s4} varying from -0.4 to 0.2, ns). Furthermore, the seasonal variations are not significant in each country (X^2=0.053–0.433, df=3, p>0.9, ns) as are the differences between countries (X^2=0.049–0.862, df=3, p>0.8, ns).

(c) Young dead before one month of age (Europe only)

Seasonal variations of young that died before one month of age are comparable to those of births, with a maximum between December and February (44.4% and 45.1% of all deaths in France and England, respectively), although deaths are also numerous in September–November in England, and with a minimum in June–August (Figs. 7A-2,B-2). These seasonal variations are obvious in England (X^2=9.313, df=3, p~0.02), but not in France (X^2=5.077, df=3, p>0.10).

(d) Death of viable individuals

As above, the maximum number of deaths of viable individuals occurs in December–February in European parks (47.4% and 31.5% of all deaths in France and England, respectively), with a minimum in June–August (Figs. 7A-2,B-2). On the contrary, there is a clear maximum of deaths in June–August in the Indian parks (Fig. 7C-2), principally in July where 83.3% of annual deaths are recorded in the Sakkarbaugh Zoo and 85.7% in the other parks. There is a great difference on this point between these two types of countries (X^2=55.877–77.187, df=3, p<0.001), since the seasonal variations are obvious in India (X^2=47.051, df=3, p<0.001), but not in Europe (X^2=5.334–5.671, df=3, p>0.1, ns).

(e) Correlations with local climate conditions

As reported above, the percentage of births in Europe is highest between December and February, when the temperature is the lowest (Figs. 7A-1,A-2 in France; Figs. 7B-1,B-2 in the United Kingdom). Consequently, an inverse relationship appears between these two events in France (r_{s4}=-1.00, p<0.05). The same could be true concerning the death of young before one month of age and that of viable individuals (r_{s4}=-0.80). On the contrary, there is no apparent link with rainfall (r_{s4}=-0.20–0.40, ns).

In India, where the average daily temperature varies little (24.7–28.7 ^{0}C, according to the season), births are numerous in September–February, especially in September–November when rainfall decreases, contrary to deaths of viable individuals that occur predominantly in June–August during peak rainfall (r_{s4}=0.80; Figs. 7C-1,C-2). Notable differences, however, exist between parks. At Sakkarbaugh Zoo (22°N), births are most numerous after heavy rainfall (74.3% of the total in September–November), contrary to deaths that are the

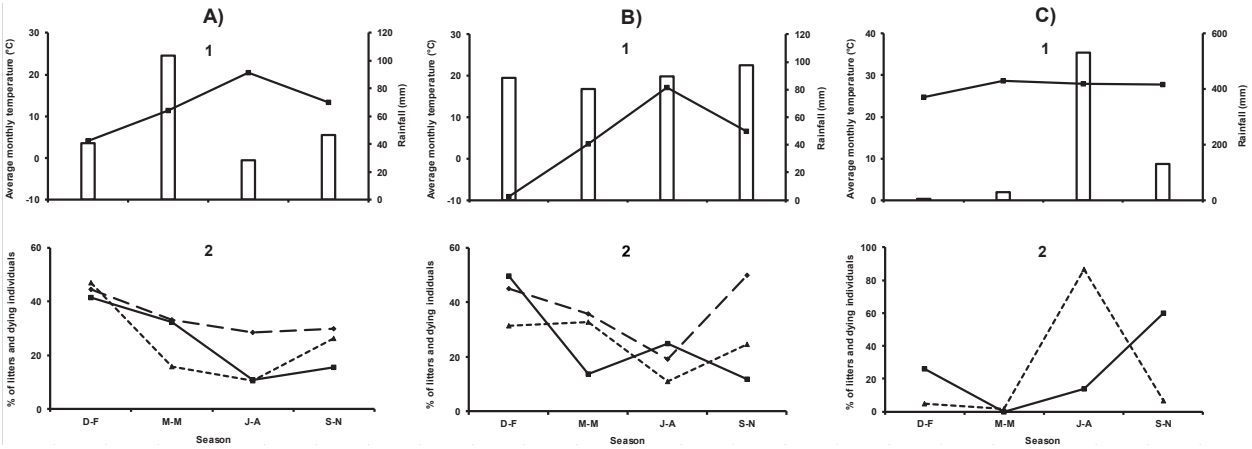


Figure 7. Climate conditions and percentage of litters and dead individuals of Four-horned Antelopes according to seasons in the parks. A - France; B - the United Kingdom; C - India. 1 - average monthly temperature (continuous line) and rainfall (white bars); 2 - percentage of litters (continuous line), young that died before one month of age (dashed line) and dead viable individuals (dotted line) in December–February (D-F), March–May (M-M), June–August (J-A), and September–November (S-N). Young dying before one month of age were not recorded in the Indian parks (see text).

most numerous (83.3%) precisely in July, the rainiest month of the year (840mm). In the other Indian parks (12–21 ^{0}N), heavy rains last longer, from June to October. At Rajiv Gandhi Zoological Park, the maximum number of births occurs later than above, in December–February. The maximum number of deaths (79.2%), however, still takes place in July, the month with the highest rainfall (235mm).

DISCUSSION

On the basis of values reported to date (Shull 1958, 1962; Haltenorth 1963; Walther 1988; Nowak 1999; cf. Table 3), the gestation period lasts between 228 and 246 days. It could even be shorter since an interval of only 210 days between two successive litters was reported in the Howletts Wild Animal Park. It, however, is greater than that of most ruminants of comparable body mass, such as *Sylvicapra grimmia* and *Capreolus capreolus*, where it often represents only 160–220 days (Dubost et al. 2011).

The average interval of 319 days between two successive litters in females is consistent with the data previously reported by Acharjyo & Misra (1975). Analysis of intervals occurring in females that raise their young indicates that they are receptive an average of 101 days after birth, which corresponds to a normal suckling period for a ruminant species of similar size (Dubost 1978; Dubost et al. 2011; Riesch et al. 2013). Nevertheless, two values deserve special attention. In the Howletts Wild Animal Park, one female gave birth 247 days after its preceding litter of which one of the two new-borns was suckled for 43 days. In the same park, another female gave birth 264 days after a preceding litter whose unique new-born had to be hand-reared. These two cases suggest that post-partum oestrus could occur 1–19 days or 18–36 days after birth, respectively, in this species. The average interval between two successive litters and the fact that the females that do not suckle their young do not become receptive again significantly before those that do rear their young, however, could signify that the Four-horned Antelope usually reproduce only once annually.

The number of new-borns per litter is one or two, an average of 1.42. Three young were never encountered, contrary to the indication of Walther (1988), and the high values reported in the literature are based on small samples (11 and 14 new-borns in Acharjyo & Misra 1975 and Baskaran et al. 2011, respectively) unlike in this study (216 new-borns). Twins are more numerous than singletons and as often of the same sex as of different sexes, as in other species (Williams & Rudge 1969; Riesch et al. 2013).

The sex ratio is not different from unity at birth, which is consistent with other ruminant species (Williams & Rudge 1969; Dubost 1978; Riesch et al. 2013). It becomes unbalanced in favour of females at one month of age, because males die more often than females during the first month of life for unknown reasons, as occurs also in numerous other ruminant species (Williams & Rudge 1969; Dubost 1978). It, however, does not significantly vary between one month and nine years of age.

The minimum age of females at first fertilization in these parks (1.5–3 years) is greater than that previously reported by Acharjyo & Misra (1975) and than those known in comparable-sized ruminant species (Williams & Rudge 1969; Dubost 1978; Dubost et al. 2011; Riesch et al. 2013). In addition, many females reproduce for the first time later in life and give birth to only one litter. Consequently, there is no difference in the mean age of all captive females between their first and following litters.

Contrary to what one might expect, first litters appear to be more successful than the following ones — they produce as many new-borns per litter as the latter, but their percentage of young that die before one month is half that of the subsequent litters, regardless of the age of the mother.

In Indian parks, most young are born during a period of six months (September–February), always after the heavy rains, as occurs in nature (Krishna et al. 2009). In Europe, births are at a maximum between December and February as in India, but this corresponds locally to the coldest season of the year. Thus, even after living for many years in Europe, this species has maintained part of the birth season of its native countries, despite unfavourable local climatic conditions. The length reduction of the maximum period of births from six to three months corresponds to the increase in latitude between the Indian and European parks (12–22 °N vs. 49–51 °N, respectively).

Maximum number of deaths also occurs in Europe in the same months as births, i.e., in December–February, the coldest season, although shelters were available in most parks. There is no apparent link with local rainfall, unlike in India where deaths almost exclusively occur in the rainiest month (July) while the temperature varies little. Thus, in each country, deaths seem correlated with the most locally unfavourable climatic factor.

In Europe, the number of young per litter decreases from 1.41–1.45 at birth to only 0.69–0.76 at one year

of age, when the young are supposed to disperse (Sharma et al. 2009; Baskaran et al. 2011) and breed for the first time. This corresponds to a survival rate of 48–54 %, which is comparable to that of other ruminant species where it is usually between 40% and 70%, as is comparable to the high mortality of adults between six and nine years of age (Williams & Rudge 1969; Dubost 1978; Garrat et al. 2015). The absence of sexual difference in the average longevity of individuals, however, is rather unusual and could be due to the living conditions in captivity, since males generally have a shorter lifespan than females under natural conditions (Dubost 1978; Garrat et al. 2015). The maximum lifespan of the Four-horned Antelope is consistent with data known from other ruminants of similar size under managed care (Dubost et al. 2011).

CONCLUSIONS

There is a relatively low success of sustainable populations of the Four-horned Antelope under managed care, since no more young survive to reproductive age in this species than in the others, despite a relatively larger litter size. For example, the Water Deer *Hydropotes inermis*, a small cervid of comparable body mass living semi-freely in a large park, multiplied its population by 1.4 in three years in France and showed a mean annual net increase in population of 26% during the first seven years in United Kingdom (Dubost et al. 2011). Considering that the average litter size of the Four-horned Antelope is 56% that of the Water Deer (2.53 new-borns per litter in *H. inermis*), the annual net increase of Four-horned Antelope populations must be between 7.5 and 14.6%. Thus, the Four-horned Antelope apparently shows a low success rate and this could explain why it is rarely kept in zoological parks.

It is not possible to know whether these results are characteristic of this species since there are no reliable data on its reproduction under natural conditions. The fact that the percentage of young that died before one month of age in first litters is half that of those in subsequent ones, however, could signify that the reproductive capacities of captive individuals decrease with time. Limited space, management requirements or difficulties, and delays in obtaining or exchanging individuals between parks could also be reasons why most females do not reproduce for the first time before 5–8 years of age and give birth to only one litter. Furthermore, the management process of captive individuals, such as the isolation of males, may cause a delay in the age of females at first reproduction and a lengthening of the interval between successive litters. Conversely, life in special conditions, as is the case in zoological parks, could explain why the percentage of males does not decrease significantly between one month and nine years of age, contrary to the wild. Finally, the fact that most births in Europe occur when the climatic factors are locally unfavourable could also be a cause of the low success of captive populations of this species. Unfortunately, we do not currently have the means to verify these points. If, as supposed, the survival of this species in the wild should depend partly in the future of populations kept in zoological parks, it is necessary that detailed scientific studies of this species be carried out as soon as possible.

REFERENCES

Acharjyo, L.N. & R. Misra (1975). A note on the breeding habits of Four-horned Antelope (*Tetracerus quadricornis*) in captivity. *Journal of the Bombay Natural History Society* 72(2): 529–530.

Baskaran, N., V. Kannan, K. Thiyagesan & A.A. Desai (2011). Behavioural ecology of Four-horned Antelope (*Tetracerus quadricornis* de Blainville, 1816) in the tropical forests of southern India. *Mammalian Biology* 76(6): 741–747; https://doi.org/10.1016/j.mambio.2011.06.010

Dubost, G. (1978). Un aperçu sur l'écologie du chevrotain africain *Hyemoschus aquaticus* Ogilby, Artiodactyle Tragulidé. *Mammalia* 42(1): 1–62.

Dubost, G., F. Charron, A. Courcoul & A. Rodier (2011). The Chinese Water Deer, *Hydropotes inermis* — a fast-growing and productive ruminant. *Mammalian Biology* 76(2): 190–195; https://doi.org/10.1016/j.mambio.2010.04.001

Garrat, M., J.F. Lemaitre, M. Douhard, C. Bonenfant, G. Capron, C. Warnant, F. Klein, R.C. Brooks & J.M. Gaillard (2015). High juvenile mortality is associated with sex-specific adult survival and lifespan in wild roe-deer. *Current Biology* 25(6): 759–763; https://doi.org/10.1016/j.cub.2014.11.071

Haltenorth, T. (1963). Klassifikation der Saügetiere: Artiodactyla. *Handbuch der Zoology* 8(32): 1–167.

IUCN SSC Antelope Specialist Group (2017). *Tetracerus quadricornis.* In: The IUCN Red List of Threatened Species: e.T21661A50195368. Downloaded on 15 December 2018; https://doi.org/10.2305/IUCN.UK.2017-2.RLTS.T21661A50195368.en

Krishna, Y.C., P.J. Clyne, J. Krishnaswamy & N.S. Kumar (2009). Distributional and ecological review of the Four-horned Antelope, *Tetracerus quadricornis*. *Mammalia* 73(1): 1–6; https://doi.org/10.1515/MAMM.2009.003

Leslie, D.M. Jr. & K. Sharma (2009). *Tetracerus quadricornis* (Artiodactyla: Bovidae). *Mammal Species* 843: 1–11.

Mallon, D.P. & S.C. Kingswood (eds.) (2001). Regional status of Antelopes in North Africa, the Middle East, and Asia, and identification of conservation priorities, pp213–243. In: Antelopes, Part 4: North Africa, the Middle East, and Asia. Global Survey and Regional Action Plans. SSC Antelope Specialist Group and IUCN, Gland, Switzerland and Cambridge, UK.

Mauget, C., R. Mauget & G. Dubost (2000). Ex situ conservation of the Four-horned Antelope: preliminary study of captive populations in the zoological parks of Paris. 3rd International Symposium on Physiology and Ethology of Wild and Zoo Animals, Advances in Ethology, Supplement to Ethology 35: 80.

Nowak, R.M. (1999). Four-horned Antelope, or Chousingha, pp1146–1147. In: *Walker's Mammals of the World, Vol. 2, 6th Edition*. Johns Hopkins University Press, Baltimore, MA, USA.

Rahmani, A.R. (2001). India, pp178–187. In: Mallon, D.P. & S.C. Kingswood (compilers). Antelopes, Part 4: North Africa, the Middle East, and Asia. Global Survey and Regional Action Plans. SSC Antelope Specialist Group and IUCN, Gland, Switzerland and Cambridge, UK.

Riesch, R., R.A. Martin, H. Lerp, M. Plath & T. Wronski (2013). Size and sex matter: reproductive biology and determinants of offspring survival in *Gazella marica*. *Biological Journal of the Linnean Society* 110(1): 116–127; https://doi.org/10.1111/bij.12121

Sharma, K., A.R. Rahmani & R.S. Chundawat (2009). Natural history observations of the Four-horned Antelope *Tetracerus quadricornis*. *Journal of the Bombay Natural History Society* 106(1): 72–82.

Shull, E.M. (1958). Notes on the Four-horned Antelope *Tetracerus quadricornis* (Blainville). *Journal of the Bombay Natural History Society* 55(2): 339–340.

Shull, E.M. (1962). Gestation period of the Four-horned Antelope *Tetracerus quadricornis* (Blainville). *Journal of the Bombay Natural History Society* 59(3): 945–947.

Walther, F.R. (1988). Waldböcke, pp344–359. In: Grzimeks Enzyklopädie. Saügetiere, 5.

Williams, G.R. & M.R. Rudge (1969). A population study of feral goats (*Capra hircus* L.), from Macauley Island, New Zealand. *Proceedings of the New Zealand Ecological Society* 16: 17–28.

ZIMS (2018). Species 360 Zoological Information Management System, Taxon Report of *Tetracerus quadricornis*. Accessed on 15 December 2018; Available online at https://zims.species360.org

French Abstract: Résumé: Le Tétracère *Tetracerus quadricornis* fait face actuellement à de nombreux dangers dans la nature, principalement à cause de la surpopulation humaine, de la déforestation et de la dégradation de son habitat. Il est classé comme Vulnérable dans la liste rouge de l'U.I.C.N. Actuellement, cette espèce est rare ou même absente dans la plupart des zoos. Compte-tenu des risques qu'il encourt à l'état sauvage, sa reproduction a été étudiée à partir de données obtenues dans des parcs zoologiques d'Europe et d'Inde pendant 39 années consécutives de 1977 à 2016. Il y a eu une moyenne de 1,42 nouveau-nés par portée. Les jumeaux étaient plus nombreux que les jeunes uniques. La maturité sexuelle des femelles n'avait pas lieu avant l'âge de 18-36 mois. Cependant, la plupart des femelles se sont reproduites pour la première fois beaucoup plus tard, en moyenne à 6–7 ans, et plus de la moitié n'ont eu qu'une seule portée. Chez les femelles ayant élevé leur jeune, une nouvelle fécondation avait lieu généralement 101 jours après la naissance précédente. Dans les zoos indiens, où la température varie peu selon les saisons, les mise-bas étaient nombreuses entre septembre et février, et surtout en septembre-novembre quand la pluviosité diminue, contrairement aux décès qui se produisaient surtout en juin-août, au maximum des pluies. Dans les zoos européens, la plupart des naissances avaient lieu en décembre-février. Le Tétracère avait donc gardé partiellement en Europe la saison de reproduction de son pays d'origine, en dépit de conditions climatiques localement défavorables. Les décès avaient également lieu surtout en décembre-février en Europe, donc pendant la saison la plus froide. Globalement, les mâles mouraient davantage que les femelles au cours de leur premier mois de vie, comme cela se rencontre chez d'autres espèces, mais il n'y avait plus de différence entre les sexes après cet âge. Dans l'ensemble, il y a un faible succès de reproduction du Tétracère maintenu en captivité, comparé aux autres ruminants. Cela pourrait être du en partie aux conditions de maintien et de gestion des individus dans ces parcs. Cela pose la question de la possibilité de réintroduire des individus dans la nature à partir d'élevages ex-situ.

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13304–13309

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM
OPEN ACCESS

Characterization of dorsal guard hair of the wild goats and sheep (Bovidae: Caprinae) occurring in the Himalaya and Western Ghats of India

Manokaran Kamalakannan

Mammal & Osteology Section, Zoological Survey of India, M-Block, New Alipore, Kolkata, West Bengal 700053, India.
kamalakannanm1@gmail.com

Abstract: The morphological and microscopic characteristics of dorsal guard hair of six species of the Indian goat-antelopes are described. Although the cuticular characteristics of hair of all the six species studied are similar, the morphological, medulla and transverse section characteristics of hair are varied between the species. The hair of Indian caprines can easily be identified on the basis of their unique medulla and transverse section. The high-resolution microphotographs and key characteristics of hair are presented here and can be used as an appropriate reference for species identification of the wild goats and sheep occurring in the Himalaya and Western Ghats of India.

Keywords: Argali, Bharal, caprines, Himalayan Goral, Himalayan Serow, Himalayan Tahr, Nilgiri Tahr, morphological characteristics, microscopic characteristics, tricho-taxonomy.

Tamil Abstract: இந்திய காடுகளில் வாழுகின்ற ஆறு இன காட்டாடுகளின் உடல் மேல்பகுதி ரோமத்தின் (dorsal guard hair) வெளிப்புற மற்றும் நுண்ணிய பண்புகள் ஆராய்ந்து விவரிக்கப்பட்டுள்ளது. இவ்விலங்குகளின் ரோமத்தின் கியூட்டிகிலனாது (cuticle) ஒத்த பண்புகளாக காணப்பட்டது. ஆனால் ரோமத்தின் மெடுலா (medulla) மற்றும் குறுக்குவாட்டு தோற்றம் (transverse-section) இந்த ஆறு இன காட்டாடுகளுக்கிடையே வேறுபட்டு காணப்பட்டது. இந்த தனிப்பட்ட மெடுலா மற்றும் குறுக்குவாட்டு தோற்ற பண்புகளை வைத்து இந்த ஆறு காட்டாடுகளை இன அடையாளம் கண்டறிய முடியும். இவ்விதழில் வழங்கப்பட்டுள்ள மிக தெளிவான நுண்ணிய பண்புகளை காட்டும் ரோமத்தின் புகைப்படங்கள் மற்றும் கண்டறியும் காரணிகள், இந்தியாவின் இமயமலை மற்றும் மேற்குத் தொடர்ச்சி மலைகளில் வாழுகின்ற காட்டாடுகளின் இனங்களை கண்டறியும் சரியான குறிப்புகளாக பயன்படுத்தலாம்.

DOI: https://doi.org/10.11609/jott.3344.11.3.13304-13309

Editor: Nishith Dharaiya, HNG University, Patan, India. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #3344 | Received 07 February 2017 | Final received 14 January 2019 | Finally accepted 13 February 2019

Citation: Kamalakannan, M. (2019). Characterization of dorsal guard hair of the wild goats and sheep (Bovidae: Caprinae) occurring in the Himalaya and Western Ghats of India. *Journal of Threatened Taxa* 11(3): 13304–13309; https://doi.org/10.11609/jott.3344.11.3.13304-13309

Funding: Ministry of Environment, Forest and Climate Change, Govt. of India.

Competing interests: The author declares no competing interests.

Author Details: Dr. M. Kamalakannan is specialized in mammal taxonomy, he is currently working as Senior Zoological Assistant at the Mammal & Osteology Section of Zoological Survey of India, Kolkata, India. His research interests on taxonomic studies of mammal components housed in the National Zoological Collections, ZSI. He also specialized in identification of confiscated materials of mammals. He holds a PhD in Zoology for working on the tricho-taxonomy of Indian mammals.

Acknowledgements: I am grateful to Dr. Kailash Chandra, director, Dr. C. Venkatraman, officer-in-charge of the Mammal & Osteology Section, and Dr. J.K. De, former scientist, of the Zoological Survey of India, for all facilities and encouragements to accomplish this work. Thanks are also due to the subject editor Dr. Nishith A. Dharaiya, for improving the manuscript. I also thank Mr. Subir Guha, Senior Zoological Assistant, ZSI for his motivation and kind help for this work.

INTRODUCTION

Both the morphological and microscopic characteristics of the hair are relatively significant in the study of mammalian species identification along with the diet-ecology and control of the illegal trade of wildlife or its derivatives (Stains 1958; Brunner & Coman 1974; Koppikar & Sabins 1976). The tricho-taxonomy (the study of mammalian hair) has been developed by many workers of the world (Hausman 1920; Mathiak 1938; Mayer 1952; Adorjan & Kolenosky 1969; Moore et al. 1974; Keogh 1983). In India, the tricho-taxonomic studies on different orders of class Mammalia: Carnivora (Chakraborty & De 2010), Primates (De 1993; Sarkar et al. 2011), and Rodentia (Bahuguna 2008) have been carried out; however, very meagre information is available on the species of wild goats and sheep (Indian caprines), except for a few studies by Bahuguna & Mukherjee (2000) (Tibetan Antelope), Sahajibal et al. (2010) (*Capra* sp.), and Kamalakannan (2018) (Takin).

As per Wilson & Reeder (2005), there are 11 species of the subfamily Caprinae under the family Bovidae distributed in the Himalaya (10 species) and Western Ghats (one species) of India, of which six species, namely Himalayan Serow *Capricornis thar* (Hodgson, 1831), Himalayan Tahr *Hemitragus jemlahicus* (C.H. Smith, 1826), Himalayan Goral *Naemorhedus goral* (Hardwicke, 1825), Nilgiri Tahr *Nilgiritragus hylocrius* (Ogilby, 1838), Argali *Ovis ammon* (Linnaeus, 1758), and Blue Sheep *Pseudois nayaur* (Hodgson, 1833) are available at the National Zoological Collections of the Zoological Survey of India (ZSI), Kolkata, India, as preserved skins.

Except for Bharal, the other species of Indian caprines are the threatened as per the IUCN Red List (2018), and are listed under Schedule I (except *N. goral* in Schedule III) of the Indian Wildlife (Protection) Act, 1972. As per CITES (2018), *C. thar* and *N. goral* are listed under the Appendix I. The aim of the study is to give a complete morphological and microscopic of characteristics of dorsal guard hair of Indian caprines for species identification.

MATERIAL AND METHODS

The dorsal guard hairs were collected from the 4–5 identified specimens of each species housed at the National Zoological Collections of Zoological Survey of India (ZSI), Kolkata, India. The hair samples were washed thoroughly with Acetone ($(CH_3)_2CO$ = 58.08) and Carbon tetrachloride (CCl_4 = 153.82) to remove the dirt of exogenous materials. The morphological characteristics of hair (n=20) such as colour, number of bands, shape and length were recorded using a hand lens and dial-caliper (Mitutoyo), and the diameter of hair was measured using the digital camera fitted on an optical microscope (Olympus BX41).

To study the characteristics of cuticula, the hair samples (n=20) were washed with various grades (40–90 %) of acetone; the processed hairs were chopped into small pieces, placed over the clear varnish coated-microscopic glass slide; after 2–3 hours, the dried hairs were dragged gently with a fine forceps for leaving the imprint or casts of scales over the microscopic glass slide. To study the characteristics of medulla, the processed hairs (n=20) were chopped into small pieces and whole mounted over the microscopic glass slide with the help of D.P.X. To study the shape of transverse section, a simple hand sectioning (slicing) method was done and the slicing samples (n=20) were whole mounted over the microscopic glass slide with the help of D.P.X. The cuticular scale characteristics of hair such as scale position, scale patterns, structure of scale margins and distance between scale margins; the medullary characteristics of hair such as width composition, structure and form of margins of the medulla and the shape of transverse section of hair was examined under 400x magnification with the help of the digital camera fitted an optical microscope (Olympus BX41) and the observed microscopic characteristics of hair were photographed. The measurement values include minimum, maximum, average and standard deviation records.

The methods and nomenclature of morphological, cuticular, medullary and transverse sectional characteristics of hair were followed according to the descriptions provided by Brunner & Coman (1974) and Teerink (1991) and the nomenclature of colour of hair was followed as per Ridgway (1886).

RESULTS AND DISCUSSION

Morphological characteristics of hair (Table 1)

The colour of the coat and individual hair of the six species had shown different shades of brown, black and grey. Among the six species, the hair of *C. thar*, *H. jemlahicus* and *N. goral* was observed as bicoloured with two bands, whereas *N. hylocrius*, *O. ammon*, and *P. nayaur* were observed as unicoloured and unbanded. The pelage of *H. jemlahicus* and *N. hylocrius* adults are sexually dimorphic thus, male and female have distinct

Table 1. Morphological characteristics of dorsal guard hairs of Indian caprines.

Species	Coat colour	Colour of hair	No. of bands	Profile	Length (mm)	Width (µm)
Capricornis thar	Black to red	Bicoloured, base: cream; tip: black	2	Slightly wavy	27.9–39.6 (33.5±4.7)	59.4–217.1 (152.7±64.8)
Hemitragus jemlahicus	Deep copper brown (male), light brown (female)	Bicoloured, base: taupe; tip: tan	2	Undulated	11.3–45.6 (30.3±12.5)	58.3–67.2 (62.3± 5.1)
Naemorhedus goral	Brownish-grey	Bicoloured, base: tan; tip: black	2	Slightly wavy	13.1–41.6 (29.1±11.1)	37.3–96.1 (78.2±20.4)
Nilgiritragus hylocrius	Blue-black grizzled with white hairs (male), greyish-brown (female)	Battleship grey	Unbanded	Undulated	13.6–38 (27.3±7.7)	36.9–130.1 (70.3±35.6)
Ovis ammon	Grey-brown	Wheat	Unbanded	Undulated	24.6–38.6 (30.8±4.5)	74.9–256 (182.7±79.1)
Pseudois nayaur	Slate blue	Beaver	Unbanded	Undulated	27.3–51.1 (42.2±7.9)	66.6–88.1 (74.2±4.4)

coat colour (Menon 2014). The shape of the hair of all the six species was observed also slightly different: *H. jemlahicus*, *N. hylocrius*, *O. ammon*, and *P. nayaur* were undulated whereas *C. thar* and *N. goral* were slightly wavy. The average length of hair of six species was ranged from 27.3mm to 42.2mm, the maximum length of hair was observed in *P. nayaur* (42.2±7.9 mm) and minimum in *N. hylocrius* (27.3±7.7 mm). The diameter of hair varied greatly from 182.7±79.1 µm as a maximum in *O. ammon* and 62.3±12.5 µm as a minimum in *H. jemlahicus*.

The specific morphological characteristics of hair (Table 1) preliminarily distinguish the six species studied. Teerink (1991) reported that the straight and undulated types of hair are one of the features of hair of bovids and according to Koppikar & Sabins (1976) and De & Chakraborty (2013), the species of the family Bovidae may be identified by their combination of physical and microscopic characteristics of hair.

Cuticular scale characteristics of hair (Table 2; Image 1–6a)

Among the six caprine species, the cuticular scale characteristics show no variations among the species and were observed as the scale position - 'transversal', scale patterns - 'regular wave', structure of scale margins - 'smooth' ('rippled' in *N. goral*) and the distance between scale margins - 'near'. The measurement values of cuticular scales of hair show great variations between the species, average scale count per millimetre length of hair were observed as maximum in *N. hylocrius* (276.5±20.1 µm) and minimum in *P. nayaur* (113.6± 23.2 µm). The average length of scale of hair vary greatly from 137.1±2.1 µm as a maximum in *O. ammon* and 55.2±3.2

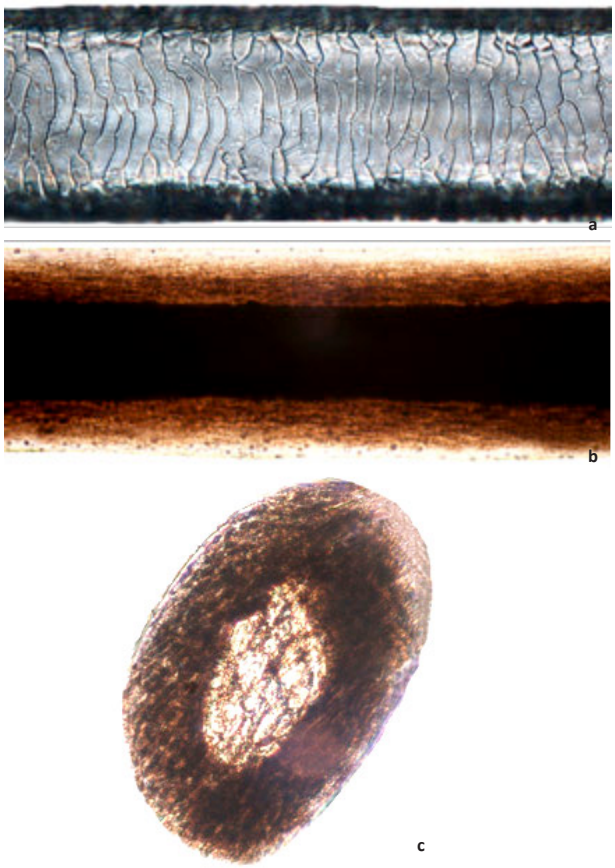


Image 1. Microscopic characteristics of dorsal guard hair of *Capricornis thar*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.

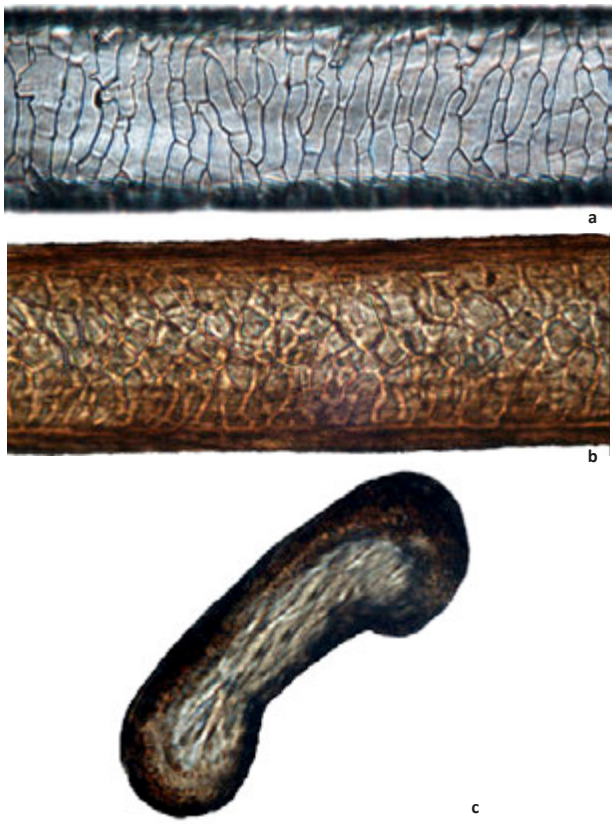


Image 2. Microscopic characteristics of dorsal guard hair of *Hemitragus jemlahicus*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.

Image 3. Microscopic characteristics of dorsal guard hair of *Naemorhedus goral*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.

µm as a minimum in *C. thar*. Similarly, the maximum and minimum scale width of hair range was recorded in *O. ammon* (17.1±3.2 µm) and *C. thar* (7.4±1.5 µm), respectively.

Although the cuticular scale characteristics are almost similar in all the six species studied, the measurement values can be considered for species identification. According to Chakraborty & De (2010) the cuticular scale values along with the other combination of characteristics of hair should be taken for species identification, if the cuticular scale characteristics of hair are same between the species.

Medullary characteristics of hair (Table 2; Image 1–6b)

The medullary characteristics of hair show substantial variations among all the six species studied. The composition of the medulla was observed as 'multicellular in rows' in all species except in *C. thar* ('unicellular regular'). The structure of the medulla is 'wide medulla lattice' in *H. jemlahicus*, *O. ammon* and *P. nayaur*; 'simple' in *C. thar*, 'wide aeriform lattice' in *N. goral,* and 'reversed cloisonné' in *N. hylocrius*. The form of the medulla margins observed as 'straight' in all species except in *N. hylocrius* ('scalloped'). The average width of the medulla also varies considerably from 120.8±2.1 µm as a maximum in *P. nayaur* and 42.5±1.6 µm as a minimum in *N. hylocrius*. The medulla of hair of the six species illustrate the different characteristics for identification of the species.

Transverse section of hair (Table 3; Image 1–6c)

The shape of the transverse section of hair shows variations among all the six species studied and was observed as an 'oval' shape in *C. thar* and *N. goral*, 'circular' in *P. nayaur*, 'biconvex' in *N. hylocrius* and *O. ammon*, and 'dumb-bell' in *H. jemlahicus*. The transverse section of hair of *O. ammon* ('biconvex') and *P. nayaur* ('circular') only determines the species identity among the six species in particular, as other characteristics are similar between the species. Dharaiya & Soni (2012) found in their study that the shape of the transverse section is one of the important characteristics for hair identification of the species.

Key characteristics of hair to identify the species

Apart from the morphological characteristics and

Table 2. Cuticular scale characteristics of dorsal guard hairs of the Indian caprines.

Species	Scale position	Scale patterns	Structure of scale margins	Distance between scale margins	Scale count/mm length of hair	Length of scale (µm)	Width of scale (µm)
Capricornis thar	Transversal	Regular wave	Smooth	Near	164–256 (187.5±24.2)	50.6–58.9 (55.2±3.2)	4.1–9.7 (7.4±1.5)
Hemitragus jemlahicus	Transversal	Regular wave	Smooth	Near	159–200 (177.2±10.4)	70.2–79.8 (75.4±3.2)	9.7–13.9 (10.7±2.2)
Naemorhedus goral	Transversal	Regular wave	Rippled	Near	108–146 (127.6±11.4)	85.1–98.5 (90.4±4.1)	10.6–20.5 (14.9±2.8)
Nilgiritragus hylocrius	Transversal	Regular wave	Smooth	Near	254–320 (276.5±20.1)	96.0–125.0 (112.1±11)	6.9–17.4 (12.3±3.1)
Ovis ammon	Transversal	Regular wave	Smooth	Near	96–152 (118.5±17.6)	134.1–140.1 (137.1±2.1)	13.9–23.7 (17.1±3.2)
Pseudois nayaur	Transversal	Regular wave	Smooth	Near	87–162 (113.6±23.2)	83.1–95.1 (87.5±3.7)	11.1–20.3 (14.2±2.6)

Table 3. Medullary characteristics and shape of cross-section of dorsal guard hairs of the Indian caprines.

Species	Composition of medulla	Structure of medulla	Margins of medulla	Width of medulla (µm)	Shape of transverse section
Capricornis thar	Unicellular regular	Simple	Straight	98.6–116 (107.7±5.3)	Oval
Hemitragus jemlahicus	Multicellular in rows	Wide medulla lattice	Straight	90.2–123 (103.4±9.9)	Dumb-bell
Naemorhedus goral	Multicellular in rows	Wide aeriform lattice	Straight	76.1–90.1 (85.1±4.9)	Oval
Nilgiritragus hylocrius	Multicellular in rows	Reversed cloisonné	Scalloped	40.4–46.3 (42.5±1.6)	Biconvex
Ovis ammon	Multicellular in rows	Wide medulla lattice	Straight	72.3–79.5 (76.4±2.5)	Biconvex
Pseudois nayaur	Multicellular in rows	Wide medulla lattice	Straight	117.5–124.3 (120.8±2.1)	Circular

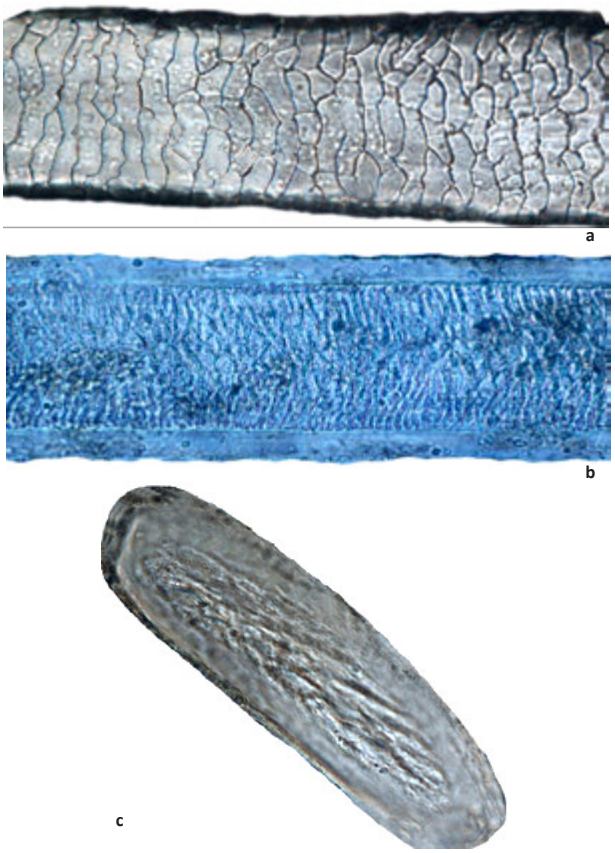


Image 4. Microscopic characteristics of dorsal guard hair of *Nilgiritragus hylocrius*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.

Table 4. Key characteristics of hair to identify the species.

Species	Key characteristics
Capricornis thar	Composition of medulla - unicellular regular; structure of medulla - simple; transverse section- oval
Hemitragus jemlahicus	Structure of medulla - wide medulla lattice; transverse section - dumb-bell
Naemorhedus goral	Structure of scale margins - rippled; structure of medulla - wide aeriform lattice; transverse section - oval
Nilgiritragus hylocrius	Structure of medulla- reversed cloisonné; margins of medulla - scalloped; transverse section - biconvex
Ovis ammon	Transverse section - biconvex
Pseudois nayaur	Transverse section- circular

measurement values of cuticular scale and medulla of the hair, the following important key characteristics may help to identify the species of Indian caprines correctly (Table 4).

Caprines are highly trafficked in the illegal trade after carnivores, used mainly for local bushmeat consumption, and for their skin and other derivatives (Menon & Kumar 1999). On the other hand, they are the chief prey to the large carnivores (Menon 2014). Therefore, the identification keys along with high-resolution microphotographs presented here may be used in animal forensic science as well as food-habit analysis of predator, as an appropriate reference for species identification of Indian caprines.

Image 5. Microscopic characteristics of dorsal guard hair of *Ovis ammon*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.

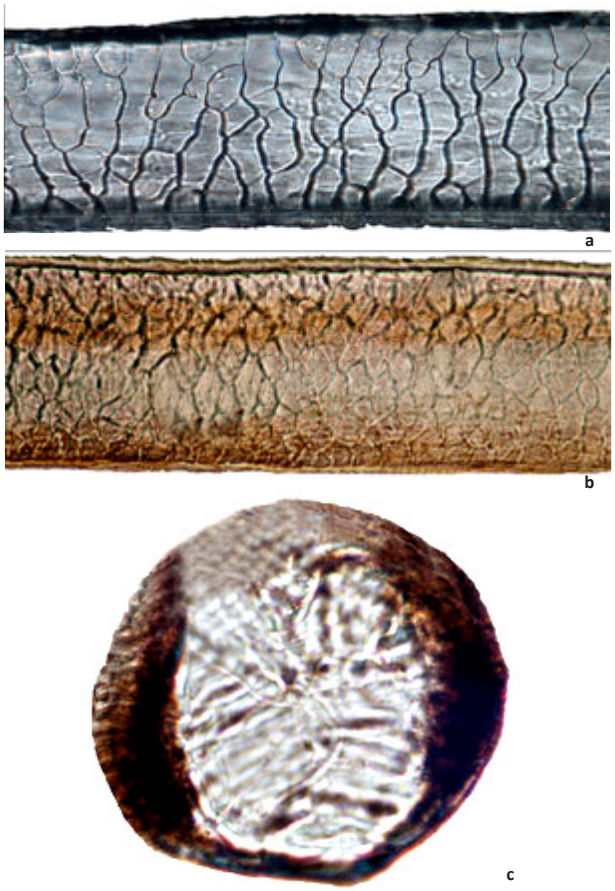


Image 6. Microscopic characteristics of dorsal guard hair of *Pseudois nayaur*. (a) cuticula (400x), (b) medulla (400x), (c) transverse section (400x). © M. Kamalakannan.

REFERENCES

Adorjan, A.S. & G.B. Kolenosky (1969). *A manual for the identification of hairs of selected Ontario mammals*. Toronto: Research Branch, Ontario Department of Lands and Forests 90, 64.

Bahuguna, A. (2008). Identification of Indian species of *Callosciurus* Gray through dorsal guard hair (Mammalia: Rodentia: Sciuridae). *Biosystematica* 1: 25–32.

Bahuguna, A. & S.K. Mukherjee (2000). Use of SEM to recognize Tibetan antelope (Chiru) hair and blending in wool products. *Science and Justice* 40: 177–182.

Brunner, H. & B. Coman (1974). *The identification of mammalian hair*. Inkata Press, Melbourne, Australia, 176pp.

Chakraborty, R. & J.K. De (2010). *Atlas on hairs Indian mammals*. Part-I: Carnivora. Zoological Survey of India, 141pp.

De, J.K. (1993). Study of surface structure of hair of some Primates of Indian sub- continent. *Records of the Zoological Survey of India* 110: 21–25.

De, J.K. & R. Chakraborty (2013). Identification of dorsal guard hairs of nine species of the family Bovidae (Artiodactyla: Mammalia). *Records of the Zoological Survey of India* 93: 31–34.

Dharaiya, N. & V.C. Soni (2012). Identification of hairs of some mammalian prey of large cats in Gir Protected Area, India. *Journal of Threatened Taxa* 4(9): 2928–2932; https://doi.org/10.11609/JoTT.o3032.2928-32

Hausman, L.A. (1920). Structural characteristics of the hair of mammals. *American Naturalist* 54: 496–523.

Kamalakannan, M. (2018). The identification of Takin *Budorcas taxicolor* (Mammalia: Bovidae) through dorsal guard hair. *Journal of Threatened Taxa* 10(15): 13014–13016; https://doi.org/10.11609/jott.3357.10.15.13014-13016

Keogh, H.J. (1983). A photographic reference system of the microstructure of the hair of southern African bovids. *South African Journal of Wildlife Research* 13: 89–132.

Koppikar, B.R. & J.H. Sabins (1976). Identification of hairs of some Indian mammals. *Journal of the Bombay Natural History and Society* 73: 5–20.

Mathiak, H.A. (1938). A key to hairs of the mammals of southern Michigan. *Journal of Wildlife Management* 2: 251–268.

Mayer, W.V. (1952). The hair of California mammals with keys to the dorsal guard hairs of California mammals. *American Midland Naturalist* 38: 480–512.

Menon, V. (2014). Indian *Mammals- A Field Guide*. Hachette Book Publishing India Pvt. Limited, Gurgaon, 528pp.

Menon, V. & A. Kumar (1999). *Wildlife Crime: An Enforcement Guide*. Wildlife Protection Society of India, New Delhi, 111pp.

Moore, T.D., L.E. Spence & C.E. Dugnolle (1974). *Identification of the dorsal guard hairs of some mammals of Wyoming*. Game and Fish Department, Wyoming, 177pp.

Ridgway, R. (1886). *Nomenclature of colours*. University Press, John Wilson and Son, Cambridge, 129pp.

Sahajibal, V., S.P. Goyal, K. Singh & V. Tahkur (2010). Dealing wildlife offences in India: role of the hair as physical evidence. *International Journal of Trichology* 1: 18–26.

Sarkar, P.S., J.K. De & C.K. Manna (2011). Identification of dorsal guard hair of five species of the family Cercopithecidae (Primates: Mammalia). *Current Science* 100: 1725–1728.

Stains, H.J. (1958). Field key to guard hair of middle western furbearers. *Journal of Wildlife Management* 22: 95–97.

Teerink, B.J. (1991). *Hair of West-European Mammals Atlas and Identification Key*. Cambridge University Press, Cambridge, 223pp.

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13310–13319

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM
OPEN ACCESS

Rediscovery of the 'extinct' bee *Hesperocolletes douglasi* Michener, 1965 (Colletidae: Colletinae: Paracolletini) in Western Australia and first description of the female

Juliana Pille Arnold [1], Mark V. Murphy [2], Raphael K. Didham [3] & Terry F. Houston [4]

[1,2,3] School of Biological Sciences, The University of Western Australia, 35 Stirling Highway, Crawley, Perth, Western Australia 6009, Australia.
[1,3] CSIRO Land & Water, Centre for Environment and Life Sciences, 147 Underwood Avenue, Floreat, Perth, Western Australia 6014, Australia.
[4] Western Australian Museum, 49 Kew Street, Welshpool, Perth, Western Australia 6106, Australia.
[1] juliana.pillearnold@research.uwa.edu.au (corresponding author), [2] murphymv@gmail.com,
[3] raphael.didham@uwa.edu.au, [4] terry.houston@museum.wa.gov.au

Abstract: The second known specimen of the bee *Hesperocolletes douglasi* Michener, 1965 is here reported as a serendipitous find among a collection of insect pollinators from an isolated woodland remnant in the Southwest Floristic Region of Western Australia. The unique male holotype of this monotypic genus of bees was collected 80 years ago and officially gazetted as presumed extinct in 1994. With our collection of a female specimen in 2015, however, it now appears that *H. douglasi* may persist as an extant localised population. Follow-up efforts to find more specimens at the collection locality so far proved unsuccessful, indicating that the species is likely either very rare or inhabits an ecological niche that is yet to be discovered. Analysis of the pollen load carried by the female indicates that the species may be polylectic. We discuss the context of the rediscovery of the bee, provide a detailed description and illustrations of the female, and make observations about the unusual morphological characteristics of the species. The rediscovery of *H. douglasi* emphasizes the importance of conservation efforts for remnant woodlands in the region, both as potential habitat for the bee and as remaining habitat essential for other rare and threatened species in this global biodiversity hotspot.

Keywords: Banksia woodlands, Douglas's Broad-headed Bee, global biodiversity hotspot, Hesperocolletes, pollinator, rediscovery, Southwest Australian Floristic Region, threatened species.

DOI: https://doi.org/10.11609/jott.4610.11.3.13310-13319 | **ZooBank:** urn:lsid:zoobank.org:pub:40D3C553-9807-4CF5-8CA8-4A882737DA42

Editor: Anonymity requested. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4610 | Received 19 October 2018 | Final received 08 February 2019 | Finally accepted 13 February 2019

Citation: Pille Arnold, J., M.V. Murphy, R.K. Didham & T.F. Houston (2019). Rediscovery of the 'extinct' bee *Hesperocolletes douglasi* Michener, 1965 (Colletidae: Colletinae: Paracolletini) in Western Australia and first description of the female. *Journal of Threatened Taxa* 11(3): 13310–13319; https://doi.org/10.11609/jott.4610.11.3.13310-13319

Funding: ARC Linkage Project LP110200304; Endeavour Postgraduate Scholarship; CSIRO Top-Up Scholarship; UWA School of Biological Sciences.

Competing interests: The authors declare no competing interests.

Author Details: Juliana Pille Arnold has a MSc degree in Applied Ecology and Conservation (University of East Anglia, UK) and is currently doing a PhD in Ecology at the University of Western Australia and CSIRO Land & Water, working on the effects of land-use change on insect pollinator diversity and plant-pollinator interaction networks. Mark V. Murphy recently completed a PhD (2012–16) and research position (2016–18) at the University of Western Australia, working on insect diversity and community ecology (Hymenoptera) in the Wheatbelt and Swan Coastal Plain regions of Southwest Australia. He is currently based in the UK writing up research from his PhD. Raphael K. Didham is Professor of Ecology in the School of Biological Science, University of Western Australia, and holds a joint research position with CSIRO Health & Biosecurity. His research focuses on the synergistic effects of multiple drivers of global change on biodiversity loss and ecological resilience within remnant natural ecosystems. Terry F. Houston is a research associate in the Department of Terrestrial Zoology, Western Australian Museum, Perth and has specialised in the systematics and natural history of Australian native bees for more than 50 years.

Author Contribution: JPA conceived and designed the project, conducted fieldwork, collected the bee, and analysed its pollen load; RKD contributed to project setup and design and data collection; RKD and JPA obtained funding for the project; MVM initially identified the specimen; TFH confirmed the bee identity and described the specimen; JPA wrote the first draft of the manuscript; all authors contributed substantially to revisions. Specimen illustrations are by TFH.

Acknowledgements: We thank the Department of Biodiversity, Conservation and Attractions (DBCA), Department of the Environment and Energy, and volunteers for all the assistance received. Permits to conduct research were obtained from the DBCA. JPA and RKD gratefully acknowledge the funding received from the Australian Government (ARC Linkage Project LP110200304 to RKD, Endeavour Postgraduate Scholarship to JPA), the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Top-Up Scholarship to JPA), and the School of Biological Sciences at the University of Western Australia.

INTRODUCTION

Wild bees are crucially important to crop production and the maintenance of native plant biodiversity globally (Ollerton et al. 2011; Winfree et al. 2011; Garibaldi et al. 2013; Mallinger & Gratton 2015; Ollerton 2017). In the Southwest Floristic Region (SWFR), a global hotspot of biodiversity in Western Australia (WA), the diverse fauna of native bees in the families Colletidae, Halictidae, Stenotritidae, Megachilidae, and Apidae are particularly important for the pollination of native plants (Brown et al. 1997; Houston 2000). While many bee species in the SWFR are generalist foragers (polylectic), many others are specialized to varying degrees on certain host plants, with some even showing morphology or behaviour adaptations related to oligolecty or monolecty (Houston 2000). The pollination biology of the exceptionally diverse insect-pollinated flora of the SWFR remains largely understudied, even though native insects and their plant hosts are highly vulnerable to environmental change (Phillips et al. 2010).

Native bees are under threat worldwide due to environmental degradation (Potts et al. 2010; Vanbergen 2013), with habitat loss and fragmentation being some of the main causes of species declines (Winfree et al. 2009, 2011). In the SWFR, vegetation clearing historically occurred at very high rates and, when associated with other impacts such as land use intensification, imposed serious threats to native fauna and flora (Threatened Species Scientific Committee 2016). Despite widespread land clearing and degradation, the last decade saw an increase of 10% on the number of recorded plant species in the SWFR (Gioia & Hopper 2017), indicating that the region still harbours very high levels of biodiversity that is yet to be described. Other anthropogenic disturbances such as sand extraction, inappropriate fire regimes, dieback, invasive species, hydrologic degradation, climate change, and loss of keystone species are currently threatening the region's ecosystems (Hobbs 1998; Coates & Atkins 2001; Threatened Species Scientific Committee 2016), potentially resulting in declines of pollinating and seed-dispersing fauna and their associated flora.

Banksia woodlands, one of the most threatened habitat types in the SWFR, is an extremely diverse ecosystem that declined significantly in extent throughout the Swan Coastal Plain (Fig. 1), where WA's state capital Perth is located. It is now highly fragmented, with only about 35% of its original cover (Government of Western Australia 2018), and was recently listed as a threatened ecological community under the Environment Protection and Biodiversity Conservation Act 1999 (Threatened Species Scientific Committee 2016). Despite increasing fragmentation, many Banksia woodlands fragments still have important conservation value since they represent critical remaining habitat for a large number of rare and threatened plant and animal species (Harvey et al. 1997; How & Dell 2000; Hopper & Gioia 2004).

Douglas's Broad-headed Bee *Hesperocolletes douglasi* Michener, 1965 (Colletidae: Paracolletini) is a short-tongued bee species from WA that was not recorded in the region for almost 80 years and was presumed extinct until now. This enigmatic species is known only from a single male specimen that was collected by A.M. Douglas in November 1938 on Rottnest Island, located approximately 18km off the coast of Perth (Fig. 1). From the single specimen, it was clear that Douglas's Broad-headed Bee represented a unique phylogenetic lineage of colletid bees, and Michener (1965) erected the genus *Hesperocolletes* for the new species.

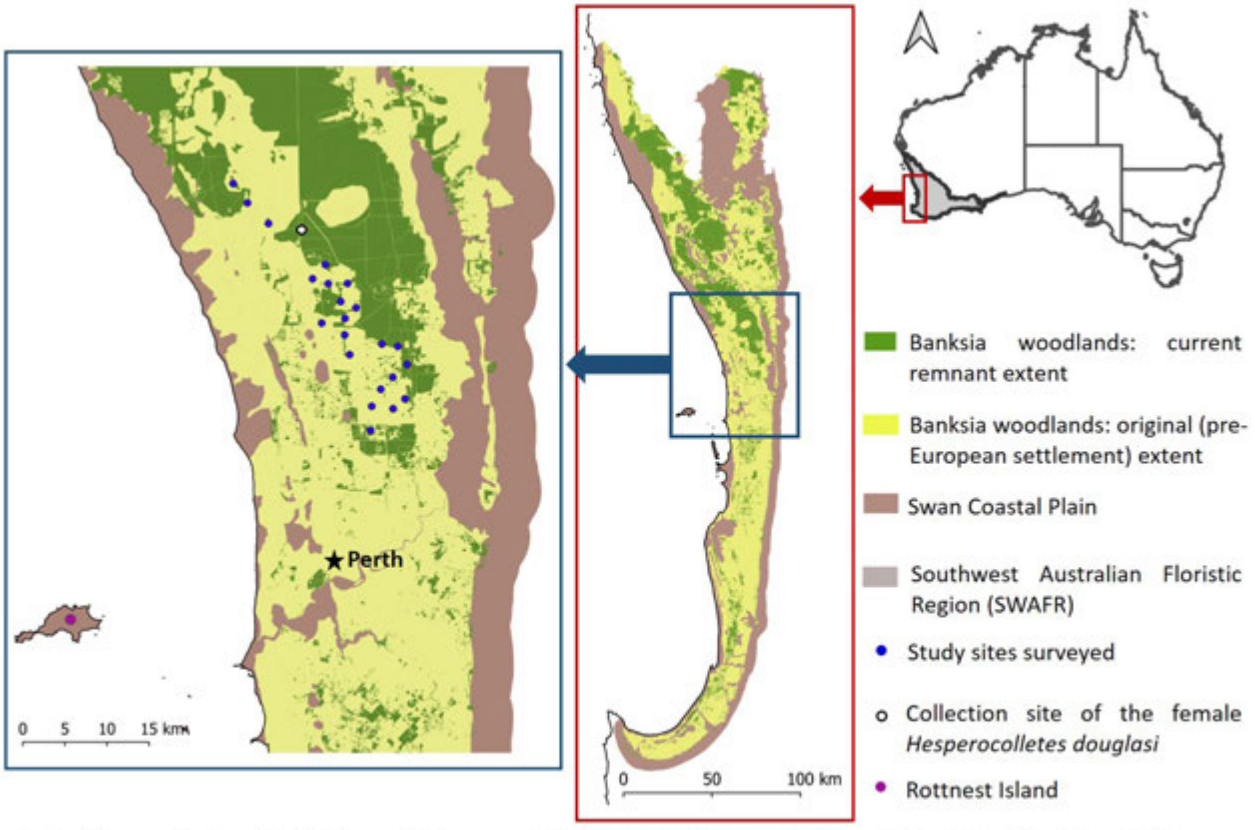
Following the publication of Michener's treatise on the bees of Australia (Michener 1965), and particularly during the period 1978–1992, extensive collecting of native bees in the Perth region and WA failed to produce any further specimens of *Hesperocolletes*. Targeted searches at the type locality (Rottnest Island) and nearby Garden Island likewise proved fruitless. As a consequence, in 1994, *H. douglasi* was gazetted by the WA Government as presumed extinct under the Wildlife Conservation Act 1950 (Department of Conservation and Land Management 1994). The fact that there was little information associated with the original specimen, such as detailed locality records or details of host plant species visited by the bee, made the search for additional specimens much more difficult.

Here we report the collection in 2015 of a second specimen and the first known female of the species, providing evidence that the species is extant. This female was identified among insect floral visitors collected during a survey of plant-pollinator interaction networks in Banksia woodlands remnants in the Perth region. We describe the rediscovery of *H. douglasi*, provide details of the location and circumstances of collection of the specimen, report on the pollen load the bee was carrying, and present the first formal description of the female. While generally morphologically consistent with the male specimen, the female exhibits some unusual characteristics. We compare the female of *H. douglasi* with females of other paracolletine genera and discuss whether it supports Michener's placement of the species in its own genus. The rediscovery of *H. douglasi* in remnant Banksia woodlands highlights the importance of preservation of remnant vegetation in the face of

ongoing anthropogenic threats. We briefly discuss key strategies for ensuring adequate conservation and protection of this threatened bee species.

MATERIALS AND METHODS

We collected the female of *H. douglasi* during surveys to study plant-pollinator interaction networks on the Swan Coastal Plain in the SWFR. For this study, we sampled 23 fragments of Banksia woodlands within a 152km^2 study area located in the Gnangara-Moore River State Forest, north of Perth, WA (Fig. 1). The woodland fragments show a small amount of within-patch degradation but are located in distinctive matrix contexts that vary greatly in habitat type, cover, structure, and microclimate, which are all likely to influence the survival and dispersal rates of insect pollinators. We randomized the order in which the study sites were visited for collection of insect-plant association data throughout the sampling season. In each woodland fragment, we established four belt transects (50m x 4m) spaced equally 20m apart. We subdivided each belt transect into 10m sections and in each section we spent 15min hand-collecting flower visiting insects alighting on flowers up to 2m from the ground with the use of a sweep net. We recorded each plant-pollinator association in the field, and insects collected were preserved in 70% ethanol until pinning for identification. We surveyed each of the four transects per study site once during each field season, which ran from September to November in 2015 and 2016. In 2015, however, we could only survey 16 of the 23 sites because the flowering season was shorter due to higher than average temperatures in the spring (Bureau of Meteorology 2016). To account for temporal variation in pollinator assemblages and flower visitation throughout the day, we surveyed transects on different days in a random order and at random times during the



Mapping data source: Department of the Environment, © Commonwealth of Australia, 2016. Banksia woodlands (remnant): Specified Beard Vegetation and System Associations mapping units that occur within the Swan Coastal Plain (SCP) boundary. SCP IBRA region plus a 5km buffer that occurs constrained to the Jarrah forest IBRA region. Caveat: Mapping is indicative only, data has been collated from a range of sources at various resolutions. GEODATA Coast 100K, 1:250,000, Geoscience Australia, 2004. Projection: Geographic Datum GDA94.

Figure 1. Twenty-three study sites surveyed and collection site of the female of *Hesperocolletes douglasi* in the Gnangara-Moore River State Forest, ca. 41km north of Perth, Western Australia, Australia; Rottnest Island, the type collection site; the original (pre-European settlement) and current extent of Banksia woodlands in the Swan Coastal Plain in the Southwest Australian Floristic Region.

peak activity period (09.00–16.00 h). We conducted sampling only in calm, sunny weather when bees were most likely to be active. Additionally, following recognition of the female of *H. douglasi* collected in 2015, TFH made separate visits to the collection site in the spring of 2016 (21 September, 05 & 27 October, and 14 November) and 2017 (06 & 19 October) in search of further specimens. These searches (each of 3–4 h in duration) were carried out between 09.30h and 15.00h.

We also searched for the bee amongst a second Hymenoptera collection we carried out previously in the same 23 study sites using UV-reflective pollinator vane traps (SpringStar Inc., Woodinville, USA). Vane traps, which consist of coloured plastic cross-vanes slotted into a funnel and screwed to a collecting jar containing preservative (100ml of 50% propylene glycol), is found to be extremely effective in attracting flower-visiting insects (Stephen & Rao 2005, 2007; Lentini et al. 2012). Blue vane traps are shown to be a particularly good method for capturing native bees (Kimoto et al. 2012; Joshi et al. 2015; Hall 2018). In each study site, we randomly deployed three blue vane traps in a 100m x 50m area near the northern and eastern boundaries of the remnant (i.e., 69 traps in total). Sampling was carried out for seven weeks in the spring of 2012 (5–7 day collections starting on 11 September, 23 October, 30 October, 6 November, 13 November, 20 November, 26 November), for five weeks in summer (a single collection from 20 December 2012 to 22 January 2013), and for one week in autumn (starting on 30 April 2013). Samples were stored in 70% ethanol and subsequently sorted and pinned for identification and analysis.

We identified specimens to species or morphospecies on the basis of morphology, with the aid of published keys and reference collections at the University of Western Australia's Entomology Laboratory and the Western Australian Museum. The confirmed female specimen of *H. douglasi* was deposited in the Entomology Collection of the Western Australian Museum (WAM # E 97779) after first recovering the pollen load of the specimen by washing using ultrasonic cleaning following a protocol based on Tur et al. (2014). Pollen grains on microscope slides were identified by comparison with a reference library of pollen slides including all of the dominant plant species found at the study sites (Jones 2012).

RESULTS

Across the 23 study sites, we collected a total of 3,168 specimens (bees, wasps, flies, butterflies, and beetles) using sweep nets over 156 surveys (115 net-hours sampling effort), and 13,150 bees and wasps using blue vane traps (5,838 trap-days sampling effort). Only a single female specimen of *Hesperocolletes douglasi* was collected with a sweep net on 08 October 2015 at 10.20h in a Banksia woodlands remnant located c. 15km west of Muchea Township and 41km north of Perth in Western Australia (Fig. 1). This location lies at the northern end of the rural suburb of Pinjar and on the western edge of the Australian Department of Defence Muchea Air Weapons Range (AWR), an extensive Banksia woodlands remnant with high-quality native vegetation and a relatively low degree of anthropogenic disturbance.

The collected female was captured while visiting flowers of a common native shrub called Pepper and Salt *Philotheca spicata* (A.Rich.) Paul G. Wilson (Rutaceae). Further searches for *H. douglasi* carried out at the collection site and several other locations in the surrounding region in 2016 and 2017, focusing chiefly on flowers of *P. spicata* but also surveying flowers of many other plant species, proved unsuccessful.

The pollen load analysis revealed that the bee was carrying pollen grains of eight different plant species representing five different families: Rutaceae (*Philotheca spicata* A. Rich. Paul G. Wilson, the species the bee was visiting when collected), Stylidiaceae (*Stylidium hesperium* Wege, *S. rigidulum* Sond., *Stylidium* sp., *Levenhookia stipitata* (Benth) F. Muell.), Iridaceae (*Patersonia occidentalis* R.Br.), Fabaceae (*Bossiaea eriocarpa* Benth.), and Myrtaceae (*Eremaea pauciflora* (Endl.) Druce var. *pauciflora*).

Description of female

Material examined: WAM # E 97779, 1 ex., female, 8.x.2015, site PER70, Pinjar, WA, Australia, -31.586^{0}S & 115.813^{0}E, elevation 60m, coll. J. Pille Arnold.

In size, general form, and colouration, the female makes a good match with the holotype male of *H. douglasi.* It shares with it, too, some of the diagnostic features noted for *Hesperocolletes* by Michener (1965, 2007), namely, the strong carina around the eyes (Image 1b) and the modified tarsal claws (Image 2e). In addition, both sexes share the strong carina around the upper part of the clypeus (although its presence in the male was not mentioned by Michener). Therefore, on morphologic grounds, there is no reason to doubt its conspecificity with the male type. Also, the collection

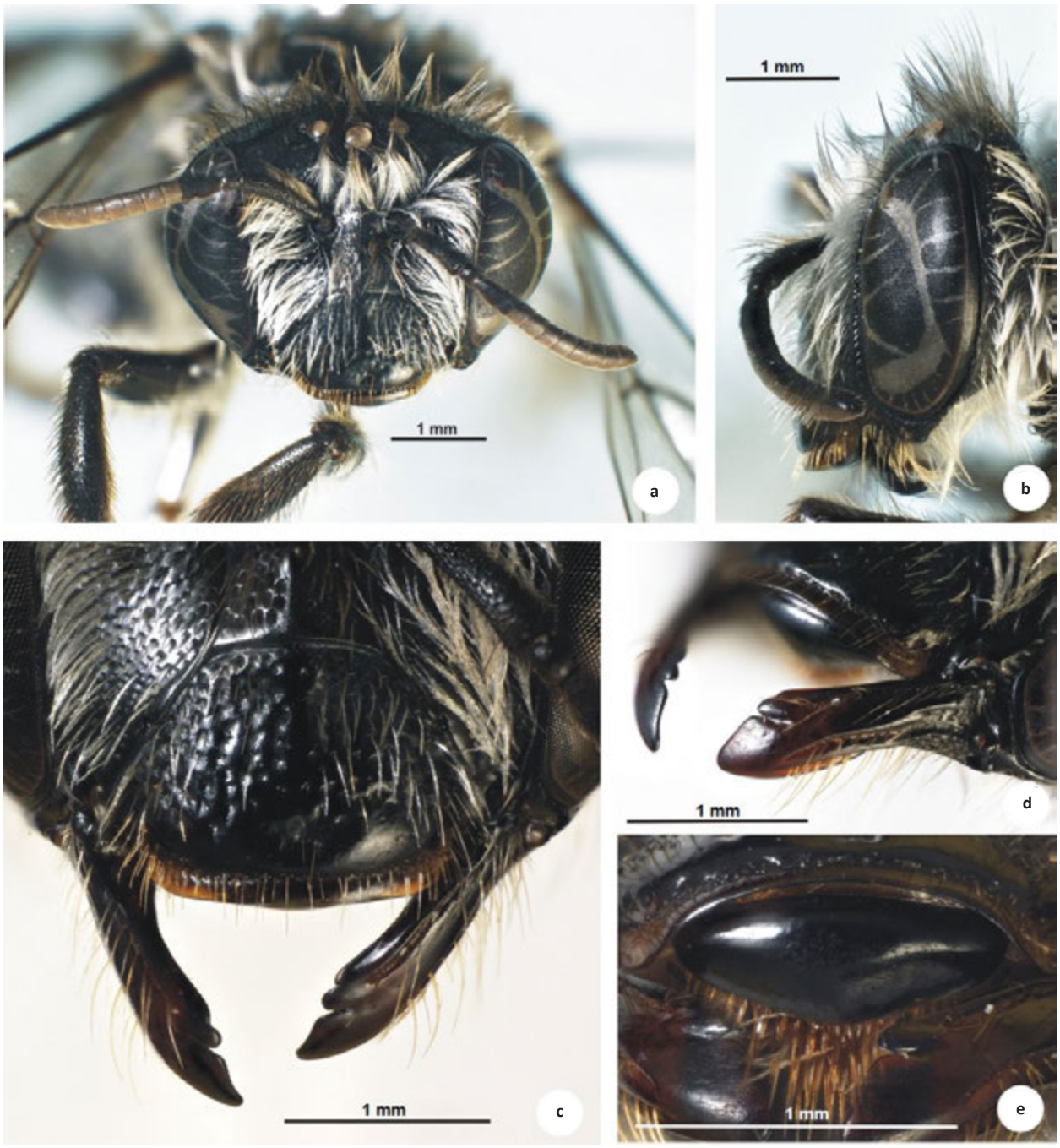


Image 1. *Hesperocolletes douglasi* female head features. a - head and antennae in anterior view; b - head and antennae in lateral view; c - lower part of face (note carina around upper part of clypeus, clearly demarcated ventral rim of clypeus, and somewhat tridentate apices of mandibles); d - outer view of left mandible; e - ventral view of labrum in situ. © T.F. Houston.

site of the female is only c. 51km from the type locality.

Dimensions: Body length c. 11.5mm; head width 4.1mm.

Relative dimensions (in mm): Head width 100; head length 78; upper width of face 63; lower width of face 55; clypeal length 28; clypeal width 46; upper width of clypeus 18; clypeoantennal distance 14; antennal socket diameter 8; width of mid ocellus 7; distance between lateral ocelli 14; ocellocular distance 20; width of ocellar cluster 26; ocelloccipital distance 10; scape length 25; scape width 6; length of flagellum c. 55; mandible length 38; basal width of mandible 15.

Habitus: Head (Image 1) markedly wider than long; vertex rising above level of ocelli; inner margins of eyes

Image 2. ***Hesperocolletes douglasi*** **female wing and leg features. a - outer part of fore wing; b - outer view of hind tibia and tarsus; c - basitibial plate; d - inner hind tibial spur; e - ventral view of distitarsus, showing expanded inner rami of tarsal claws. © T.F. Houston.**

converging slightly below; facial foveae faintly indicated by duller, almost impunctate integument, rounded triangular; interantennal area rising to weak median ridge; subantennal sutures vertical and about 2x as long as height of antennal socket; clypeus (Image 1a–c) gently convex in profile and transversely, its impunctate ventral margin clearly defined by transverse furrow and not coplanar with rest of clypeus; upper clypeus depressed slightly below level of supraclypeal and paraocular areas forming a distinct carina along epistomal suture (Image 1c); compound eye surrounded by a carina; median ocellus set in depression with carinate margin, especially posteriorly; malar areas present but much shorter than basal width of mandible; gena about half as wide as eye viewed laterally; occipital cavity reaching almost to summit of vertex; mandibles (Image 1c,d) 2.7x as long as basal width, narrowest at mid-section, obliquely truncate at apices, weakly tridentate (i.e., bidentate with smaller anterior tooth weakly notched); labrum (Image 1e) largely exposed when mandibles closed, 0.4x

Image 3. *Hesperocolletes douglasi* female metasomal features. a - dorsal view; b - left lateral view (arrow indicates long, white, plumose setae of base of hind leg that may form the scopa, but note also the long, dense, plumose setae of sterna 2–5 that might serve this purpose). © T.F. Houston.

as long as wide, rather elliptical but with ventral margin slightly angulate medially, surface smooth and gently convex, lacking tubercles or transverse ridge; upper margin of pronotum set very low relative to scutum which curves down strongly anteriorly; episternal groove present below scrobal groove but shallow; propodeum almost wholly vertical, enclosure broad, smooth and unsculptured with sinuate lateral margins; anterior surface of T1 weakly creased medially, rounding gently onto dorsal surface; metasomal terga (Image 3a) smooth, lacking premarginal lines, hind margins of T1–T4 slightly translucent; T2 without evident foveae; pygidial plate well-developed, clearly defined by marginal carina, rounded apically, flat dorsally; fore wing (Image 2a) with first submarginal cross vein ‹-shaped, bent mesad; jugal lobe of hind wing long, just exceeding cu-v; basitibial plate (Image 2b,c) distinct, rounded, and saucer-like because of raised carinate margin, about one-fourth the length of hind tibia; inner hind tibial spur (Image 2d) simple with ciliate margins; hind basitarsus viewed laterally (Image 2b) about 2/3 as wide and 0.6x as long as tibia, tapering slightly from base to apex; tarsal claws (Image 2e) deeply cleft with inner prongs broad (as in male); relatively long arolia present on all tarsi.

Colouration: Integument generally black, lacking iridescence; clypeus lacking the yellow-brown colouration of the male; only the underside of the flagellum, the distitarsi, and the mandibles somewhat brownish.

Sculpture: Integument generally moderately shining with fine, open pitting; clypeus (except impunctate lower quarter) with strong, coarse pitting; areas between ocelli and upper ends of eyes almost impunctate; metasomal terga lacking distinct pits; pygidial plate finely, longitudinally striate.

Pubescence: Head, mesosoma, T1, and bases of legs generally with long, moderately dense, plumose setae; setae of face, genae, lateral, ventral and posterior areas of mesosoma, T1 and bases of legs white; setae of vertex, scutum, and scutellum blackish; pubescence of clypeus and supraclypeal area sparser than that of paraocular areas and frons; lower one-third of clypeus virtually bare; metasomal T2–T4 with black, sparse, short, simple, erect setae except on hind margins where setae are whitish, somewhat adpressed and laterally directed, not forming bands; T5 and T6 with weak fimbriae of rust-coloured, plumose setae; posterior third of metasomal S2–S5 with dense, long, rust-coloured, plumose setae directed posteriorly, extending well beyond hind margins (Image 3b); fore tarsi clothed in moderately long, soft, brownish setae; basitibial plates with sparse, short, simple setae (Image 2c); hind tibia and basitarsus (Image 2b) covered on outer side with moderately dense, stiff, simple, black setae, only on dorsal and ventral margins of tibia and basitarsus are setae plumose; inner surface of hind tibia with dense, erect, simple, white setae (not keirotrichia), similar but denser setae on inner side of hind basitarsus.

Remarks

It is unfortunate that no details of the proboscis could be observed: the specimen's proboscis was tightly retracted into the proboscidial fossa and attempts

to relax and extend it proved unsuccessful (probably stemming from the specimen's protracted immersion in ethanol). Also, the pubescence suffered slightly from the specimen being put through a wash and ultrasound cleaner to remove its pollen load for analysis.

DISCUSSION

Michener noted that *Hesperocolletes douglasi* resembles species of *Paracolletes, Trichocolletes*, and *Leioproctus.* Indeed, there are many similarities between various members of these taxa. Table 1 shows the distribution of certain character states of *Hesperocolletes* among the three other genera. *Hesperocolletes* shares more character states with *Paracolletes* (sensu Michener 2007) than with the other taxa. Despite this, we do not question Michener's placement of *H. douglasi* in its own genus. Michener also noted that the peculiar tarsal claws of *H. douglasi* resemble those of various cleptoparasitic bees. Such claws, however, are not peculiar to cleptoparasitic species and are found in at least four Western Australian species of *Leioproctus* s. str. known to collect pollen loads.

Although the female carried a pollen load when it was collected, the position of the scopa was not noted, nor is it clear from the examination of the female where its scopa is situated. It is unlikely to be situated on the hind tibiae, given that they are covered externally with mostly simple setae. The hind coxa, trochanters, and femora bear numerous long, plumose setae (Image 3b) that might form the scopa. The unusual vestiture of long, dense, highly plumose setae on metasomal sterna 2–5 (Image 3b) has the appearance of a scopa, but we must await collection of a pollen-laden female to learn the truth.

Collection dates for the two known specimens of *H. douglasi* suggest that the species is active in mid-spring. The wing margins of the female (collected on 8 October) are entire indicating that the female was newly emerged. The holotype male (collected on 9 November) had ragged wings. It should be noted that Michener erred in his original description in giving the collection date as "February 9". We obtained the date of collection from the hand-written register book of the WA Museum for 1938 as the specimen's hand-written data label carried only a registration number and the locality name. Michener's error went undetected for many years and the first targeted searches for the species were doubtless too late in the season.

The some doubt was raised about the provenance of the holotype by Michener (2007) who remarked on the possibility that specimen labels may have been swapped. No doubt that was made in the knowledge that one of us (TFH) had searched for the species on Rottnest Island and nearby Garden Island without success and, despite extensive bee collecting in the Perth region over two decades, did not encounter any further specimens. The WAM register indicates that the holotype was among a batch of various insects collected by A.M. Douglas on Rottnest Island from 9 to 12 November 1938. Some specimens were identified individually, but the holotype (#2607) was included in a bracket of unidentified specimens numbered 2606–2613. Seven of these specimens, in addition to the holotype of *H. douglasi*, were located and are various kinds of native bees. Therefore, the register tends to corroborate the holotype data label.

From the collection record, we know that the female visits flowers of *P. spicata*, but other plant species might also be used as food resource. Since pollen grains may remain attached to bees' legs and body between flower visits (either incidentally or collected in a scopa), pollen load analysis increases the detectability of interaction links between pollinators and plants over simple flower visitation data (Bosch et al. 2009; Olesen et al. 2011).

Table 1. Character states shared between Hesperocolletes and three other genera of Paracolletini (N.B.: *Paracolletes* s. lato includes the subgenus *Anthoglossa*). Key: (+): present; (-): absent.

Hesperocolletes characters	*Paracolletes* s. lato	*Trichocolletes*	*Leioproctus*
Median ocellus set in depression	-	-	in some
Labrum smoothly convex	+	+	-
Mandibles somewhat tridentate	+	-	rarely
Basitibial plate not defined in male	+ some	+ most	rarely
Tarsal claws with expanded inner prongs	-	-	a few species
Clypeus of male yellow-brown	+ in some	+ in some	rarely (subgenus *Andrenopsis)*
Inner hind tibial spur of female simple	+ in most	-	in some

The results of this analysis indicate that *H. douglasi* may be a generalist forager since it was carrying pollen from a diverse set of plant species common to Banksia woodlands. However, it will be difficult to accurately assess the degree of resource specialization of this species without additional records. It should be noted that *P. spicata*, as well as the other plant species visited by the bee according to the pollen load analysis results, were not recorded on Rottnest Island (Rippey et al. 2003), which could be another indication that the bee is a generalist.

The collection of just one specimen despite a comprehensive survey of the 23 study sites using sweep nets and vane traps over multiple flowering seasons, in addition to a focused survey at the collection site and surrounding region, suggests that *H. douglasi* is extremely rare. It is also possible, however, that the sampled female was not in its typical habitat, and that we are yet to discover its particular ecological niche. The female specimen was collected in almost pristine Banksia woodlands, a habitat not represented at the type locality of Rottnest Island (Hesp et al. 1983; Rippey et al. 2003). The collection site lies within an area of multiple land uses, with extensive area of Banksia woodlands at the AWR military site, and intermixed areas of pine plantations, rural, and mixed-use land with encroaching suburban developments. The military area is protected and has restricted public access (Government of Western Australia 2000). More than 90% of the vegetation in the military area is considered in excellent to pristine condition (Government of Western Australia 2000). While we cannot yet claim Banksia woodlands as a definite habitat of *H. douglasi* without further successful collections, there is a high chance that the pristine woodlands within the AWR military site are important to the species. Moreover, the pollen load record is evidence that the bee was foraging on flowers of typical Banksia woodlands plant species. Several studies recognized military training areas as sites of conservation value for fauna and flora throughout the world, including for threatened and endangered species (Warren et al. 2007; Warren & Büttner 2008; Kim et al. 2015). Due to the restricted public access and heterogeneous habitat types they contain, often including patches of untouched vegetation, military training sites can even match the conservation value of formal conservation reserve areas (Cizek et al. 2013). Because there is no information on the ability of *H. douglasi* to disperse across the anthropogenic landscapes surrounding this area, we do not know if other populations could be using smaller, degraded, and more isolated woodland patches in the Perth region.

Ecological and life-history traits of bees are strongly associated with species responses to environmental disturbances (Williams et al. 2010; Cariveau & Winfree 2015). Since there is little to no knowledge of the distribution, dispersal ability, life cycle, nesting requirements, and foraging resources of *H. douglasi*, the preservation of the woodlands in this region is of paramount importance for the conservation of this rare bee species. Any human disturbances that are likely to have an impact on the bee (e.g., vegetation clearing, prescribed burning, public access, and recreational activities) should be mitigated or managed appropriately to minimize extinction risk. Enhancing connectivity between suitable habitat patches as well as habitat restoration are also essential to ensure long-term viability of the species. Further studies to determine the ecological requirements, geographic range, population size, and key threatening processes of the species must be conducted as a matter of urgency.

REFERENCES

Bosch, J., A.M. Martín González, A. Rodrigo & D. Navarro (2009). Plant-pollinator networks: adding the pollinator's perspective. *Ecology Letters* 12(5): 409–419; https://doi.org/10.1111/j.1461-0248.2009.01296.x

Brown, E.M., A.H. Burbidge, J. Dell, D. Edinger, S.D. Hopper & R.T. Wills (1997). Pollination in Western Australia: A Database of Animals Visiting Flowers, Handbook No. 15. Western Australian Naturalists' Club, Perth, Western Australia, 450pp.

Bureau of Meteorology (2016). Annual Climate Report 2015 - Commonwealth of Australia. Available online at http://www.bom.gov.au/climate/annual_sum/2015/index.shtml. Downloaded on 4 September 2017.

Cariveau, D.P. & R. Winfree (2015). Causes of variation in wild bee responses to anthropogenic drivers. *Current Opinion in Insect Science* 10: 104–109; https://doi.org/10.1016/j.cois.2015.05.004

Cizek, O., P. Vrba, J. Benes, Z. Hrazsky, J. Koptik, T. Kucera, P. Marhoul, J. Zamecnik & M. Konvicka (2013). Conservation potential of abandoned military areas matches that of established reserves: plants and butterflies in the Czech Republic. *PLoS ONE* 8(1): e51124; https://doi.org/10.1371/journal.pone.0053124

Coates, D.J. & K. Atkins (2001). Priority setting and the conservation of Western Australia's diverse and highly endemic flora. *Biological Conservation* 97(2): 251–263; https://doi.org/10.1016/S0006-3207(00)00123-3

Department of Conservation and Land Management (1994). Wildlife Conservation (Protected Invertebrate Fauna) Notice 1994. *Western Australian Gazette* 45: 1464–1467.

Garibaldi, L.A., I. Steffan-Dewenter, R. Winfree, M.A. Aizen, R. Bommarco, S.A. Cunningham, C. Kremen, L.G. Carvalheiro, L.D. Harder, O. Afik, I. Bartomeus, F. Benjamin, V. Boreux, D. Cariveau, N.P. Chacoff, J.H. Dudenhöffer, B.M. Freitas, J. Ghazoul, S. Greenleaf, J. Hipólito, A. Holzschuh, B. Howlett, R. Isaacs, S.K. Javorek, C.M. Kennedy, K.M. Krewenka, S. Krishnan, Y. Mandelik, M.M. Mayfield, I. Motzke, T. Munyuli, B.A. Nault, M. Otieno, J. Petersen, G. Pisanty, S.G. Potts, R. Rader, T.H. Ricketts, M. Rundlöf, C.L. Seymour, C. Schüepp, H. Szentgyörgyi, H. Taki, T. Tscharntke,

C.H. Vergara, B.F. Viana, T.C. Wanger, C. Westphal, N. Williams & A.M. Klein (2013). Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science* 339: 1608–1611; https://doi.org/10.1126/science.1230200

Gioia, P. & S.D. Hopper (2017). A new phytogeographic map for the Southwest Australian Floristic Region after an exceptional decade of collection and discovery. *Botanical Journal of the Linnean Society* 184(1): 1–15; https://doi.org/10.1093/botlinnean/box010

Government of Western Australia (2000). Bush Forever - Keeping the Bush in the City. Vol. 2: Directory of Bush Forever Sites. Department of Environmental Protection, Perth, Western Australia, 529pp.

Government of Western Australia (2018). Statewide Vegetation Statistics Incorporating the CAR Reserve Analysis (Simplified Report). Current as of December 2017. Department of Biodiversity, Conservation and Attractions, Perth, Western Australia; https://catalogue.data.wa.gov.au/dataset/dbca-statewide-vegetation-statistics

Hall, M. (2018). Blue and yellow vane traps differ in their sampling effectiveness for wild bees in both open and wooded habitats. *Agricultural and Forest Entomology* 20(4): 487–495; https://doi.org/10.1111/afe.12281

Harvey, M.S., J.M. Waldock, R.A. How, J. Dell & E. Kostas (1997). Biodiversity and biogeographic relationships of selected invertebrates from urban bushland remnants, Perth, Western Australia. *Memoirs of the Museum of Victoria* 56: 275–280.

Hesp, P.A., M.R. Wells, J.R.H. Ward & B.H.R Riches (1983). Land Resource Survey of Rottnest Island. Bulletin 4086. Department of Agriculture, Perth, Western Australia, 32pp.

Hobbs, R.J. (1998). Impacts of land use on biodiversity in southwestern Australia, pp81–106. In: Rundel, P.W., G. Montenegro & F. Jaksic (eds.) *Landscape Disturbance and Biodiversity in Mediterranean-Type Ecosystems*. *Ecological Studies (Analysis and Synthesis), Vol. 136*. Springer-Verlag, New York, 451pp; https://doi.org/10.1007/978-3-662-03543-6_5

Hopper, S.D. & P. Gioia (2004). The Southwest Australian Floristic Region: evolution and conservation of a global hot spot of biodiversity. *Annual Review of Ecology, Evolution, and Systematics* 35: 623–650; https://doi.org/10.1146/annurev.ecolsys.35.112202.130201

Houston, T.F. (2000). Native Bees on Wildflowers in western Australia - A Synopsis of Bee Visitation of Wildflowers based on the Bee Collection of the Western Australian Museum. Special Publication No. 2, Western Australian Insect Study Society Inc., Perth, 235pp.

How, R.A. & J. Dell (2000). Ground vertebrate fauna of Perth's vegetation remnants: impact of 170 years of urbanization. *Pacific Conservation Biology* 6(3): 198–217.

Jones, G.D. (2012). Pollen analyses for pollination research - unacetolyzed pollen. *Journal of Pollination Ecology* 9(13): 96–107.

Joshi, N.K., T. Leslie, E.G. Rajotte, M.A. Kammerer, M. Otieno & D.J. Biddinger (2015). Comparative trapping efficiency to characterize bee abundance, diversity, and community composition in apple orchards. *Annals of the Entomological Society of America* 108(5): 785–799; https://doi.org/10.1093/aesa/sav057

Kim, S.S., T.S. Kwon & C.M. Lee (2015). Effect of military activity on butterfly (Lepidoptera) communities in Korea: conservation and maintenance of red listed species. *European Journal of Entomology* 112(4): 770–777; https://doi.org/10.14411/eje.2015.099

Kimoto, C., S.J. Debano, R.W. Thorp, S. Rao & W.P. Stephen (2012). Investigating temporal patterns of a native bee community in a remnant North American bunchgrass prairie using blue vane traps. *Journal of Insect Science* 12(1): 108; https://doi.org/10.1673/031.012.10801

Lentini, P.E., T.G. Martin, P. Gibbons, J. Fischer & S.A. Cunningham (2012). Supporting wild pollinators in a temperate agricultural landscape: maintaining mosaics of natural features and production. *Biological Conservation* 149(1): 84–92; https://doi.org/10.1016/j.biocon.2012.02.004

Mallinger, R.E. & C. Gratton (2015). Species richness of wild bees, but not the use of managed honeybees, increases fruit set of a pollinator-dependent crop. *Journal of Applied Ecology* 52(2): 323–330; https://doi.org/10.1111/1365-2664.12377

Michener, C.D. (1965). A classification of the bees of the Australian and South Pacific regions. *Bulletin of the American Museum of Natural History* 130: 1–362.

Michener, C.D. (2007). *The Bees of the World*, *2nd Edition.* The Johns Hopkins University Press, Baltimore, Maryland, 953pp.

Olesen, J.M., J. Bascompte, Y.L. Dupont, H. Elberling, C. Rasmussen & P. Jordano (2011). Missing and forbidden links in mutualistic networks. *Proceedings of the Royal Society B: Biological Sciences* 278(1706): 725–732; https://doi.org/10.1098/rspb.2010.1371

Ollerton, J. (2017). Pollinator diversity: distribution, ecological function, and conservation. *Annual Review of Ecology, Evolution, and Systematics* 48: 353–376; https://doi.org/10.1146/annurev-ecolsys-110316-022919

Ollerton, J., R. Winfree & S. Tarrant (2011). How many flowering plants are pollinated by animals? *Oikos* 120(3): 321–326; https://doi.org/10.1111/j.1600-0706.2010.18644.x

Phillips, R.D., S.D. Hopper & K.W. Dixon (2010). Pollination ecology and the possible impacts of environmental change in the Southwest Australian Biodiversity Hotspot. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 365(1539): 517–528; https://doi.org/10.1098/rstb.2009.0238

Potts, S.G., J.C. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger & W.E. Kunin (2010). Global pollinator declines: trends, impacts and drivers. *Trends in Ecology and Evolution* 25(6): 345–353; https://doi.org/10.1016/j.tree.2010.01.007

Rippey, E., M.C. Hislop & J. Dodd (2003). Reassessment of the vascular flora of Rottnest Island. *Journal of the Royal Society of Western Australia* 86: 7–23.

Stephen, W.P. & S. Rao (2007). Sampling native bees in proximity to a highly competitive food resource (Hymenoptera: Apiformes). *Journal of the Kansas Entomological Society* 80(4): 369–376.

Stephen, W.P. & S. Rao (2005). Unscented color traps for non-Apis bees (Hymenoptera: Apiformes). *Journal of the Kansas Entomological Society* 78(4): 373–380; https://doi.org/10.2317/0410.03.1

Threatened Species Scientific Committee (2016). Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (s 266B) - Approved Conservation Advice (incorporating listing advice) for the Banksia Woodlands of the Swan Coastal Plain Ecological Community, 143pp; Available online at www.environment.gov.au/epbc. Downloaded on 31 May 2018.

Tur, C., B. Vigalondo, K. Trøjelsgaard, J.M. Olesen & A. Traveset (2014). Downscaling pollen-transport networks to the level of individuals. *Journal of Animal Ecology* 83(1): 306–317; https://doi.org/10.1111/1365-2656.12130

Vanbergen, A.J. (2013). Threats to an ecosystem service: pressures on pollinators. *Frontiers in Ecology and the Environment* 11(5): 251–259; https://doi.org/10.1890/120126

Warren, S.D. & R. Büttner (2008). Active military training areas as refugia for disturbance-dependent endangered insects. *Journal of Insect Conservation* 12(6): 671–676; https://doi.org/10.1007/s10841-007-9109-2

Warren, S.D., S.W. Holbrook, D.A. Dale, N.L. Whelan, M. Elyn, W. Grimm & A. Jentsch (2007). Biodiversity and the heterogeneous disturbance regime on military training lands. *Restoration Ecology* 15(4): 606–612; https://doi.org/10.1111/j.1526-100X.2007.00272.x

Williams, N.M., E.E. Crone, T.H. Roulston, R.L. Minckley, L. Packer & S.G. Potts (2010). Ecological and life-history traits predict bee species responses to environmental disturbances. *Biological Conservation* 143(10): 2280–2291; https://doi.org/10.1016/j.biocon.2010.03.024

Winfree, R., R. Aguilar, D.P. Vazquez, G. LeBuhn & M.A. Aizen (2009). A meta-analysis of bees' responses to anthropogenic disturbance. *Ecology* 90(8): 2068–2076.

Winfree, R., I. Bartomeus & D.P. Cariveau (2011). Native pollinators in anthropogenic habitats. *Annual Review of Ecology, Evolution, and Systematics* 42: 1–22; https://doi.org/10.1146/annurev-ecolsys-102710-145042

COMMUNICATION

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM
OPEN ACCESS

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13320–13333

Butterflies of the myristica swamp forests of Shendurney Wildlife Sanctuary in the southern Western Ghats, Kerala, India

Prabhakaran Chandrika Sujitha [1], Gopal Prasad [2] & Kalesh Sadasivan [3]

[1,2] Department of Zoology, University of Kerala, Kariavattom Campus, Thiruvananthapuram, Kerala 695581, India.
[3] Travancore Nature History Society, MBRRA 65, Jyothis, Mathrubhumi Road, Vanchiyoor, Thiruvananthapuram, Kerala 695035, India.
[1] sujeespc@gmail.com, [2] probios1@gmail.com, [3] kaleshs2002in@gmail.com (corresponding author)

Abstract: Myristica swamps are unique freshwater swamp forests characterised by predominance of tree species of the Myristicaceae family. There have been few published works on the flora and fauna of myristica swamps but studies on butterflies have been scanty. This work was done in the myristica swamps of Kattilapara in Shendurney Wildlife Sanctuary, Kollam district, Kerala, located in the northern aspect of the Agasthyamalai Hills of the southern Western Ghats. Data on the butterflies were collected over a period of two years supplemented with data from previous visits using Transect method. Butterflies were identified based on field photographs and relevant literature. We recorded 206 species of butterflies belonging to 6 families from the myristica swamps. This included 17 species of Papilionidae, 20 species of Pieridae, 65 species of Nymphalidae, 56 species of Lycaenidae, two species of Riodinidae and 46 species of Hesperiidae.Of the total, 19 species of butterflies were Western Ghat endemics. A checklist of butterflies of the myristica swamp, larval hostplants, status with respect to IUCN criteria, endemicity, and classification as per Indian Wildlife Protection Act (WPA) of 1972 are also provided. Eighty-two species of plants were listed as butterfly larval hosts in the myristica swamp ecosystem, with 27 species being new host records for Western Ghats. None of the butterflies recorded were using plants of Myristicaceae family as larval hosts. A simple index—the percentage occurrence—is proposed to delineate the habitat affinity of species.

Keywords: Agasthyamalai Hills, larval host plants, habitat affinity.

DOI: https://doi.org/10.11609/jott.4399.11.3.13320-13333 | **ZooBank:** urn:lsid:zoobank.org:pub:18BFDC77-21A0-4221-8BBF-8013589A89A4

Editor: George Mathew, Indira Gandhi Technological and Medical Sciences University, Ziro, India. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4399 | Received 16 June 2018 | Final received 04 December 2018 | Finally accepted 15 February 2019

Citation: Sujitha, P.C., G. Prasad & K. Sadasivan (2019). Butterflies of the myristica swamp forests of Shendurney Wildlife Sanctuary in the southern Western Ghats, Kerala, India. *Journal of Threatened Taxa* 11(3): 13320–13333; https://doi.org/10.11609/jott.4399.11.3.13320-13333

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Author Details: P.C. Sujitha is a PhD scholar basically interested in ecology of aquatic and terrestrial ecosystems. G. Prasad, Professor in Zoology, has his interests in aquatic biology, invertebrate studies and man-animal conflicts in Western Ghats. Kalesh, S. is a microvascular surgeon interested in ecology, taxonomy and biogeography of invertibrates of Western Ghats especially ants, odonates and butterflies. He is a founding member of Travancore Nature History Society (TNHS) Trivandrum.

Author Contribution: KS conceived the concept of the work and the POc index, PCS and KS did the field work and writing the manuscript. Revisions and editing of the work was done by GP and KS.

Acknowledgements: We are thankful to the Kerala Forest and Wildlife Department for the research permits, and the Wildlife Warden, Range officers and forest staff of Shendurney Wildlife Sanctuary for their support. We would like to thank members of the Travancore Natural History Society (TNHS) Trivandrum for field assistance and comments on the manuscript.

INTRODUCTION

Myristica swamps are tropical swamp forests first reported from Kulathupuzha Reserve Forests and adjoining regions of Anchal, Thenmalai and Shendurney Wildlife Sanctuary (WS) in Kollam and Thiruvananthapuram districts of Kerala (Krishnamoorthy 1960). Besides Kerala, they are also known to occur in Karnataka and Goa (Joyce et al. 2014). Myristica swamp forests are floristically lowland (180–200 m) edaphic variants of evergreen forests with canopy at 30–40 m, with pure patches of Myristicaceae trees in a freshwater swamp amidst tropical evergreen patches (Subramanian 1995). These are highly fragmented ecosystems with restricted distribution (Rodgers & Panwar 1988a,b). The dominance of the trees of Myristicaceae family in the swamps gives them their common name (Roby et al. 2014). The myristica swamps are classified as forest type 4c/FS1, under Champion & Seth (1968).

There have been a few studies on the flora and fauna of myristica swamps. Notable works on their basic ecological aspects are by Nair et al. (2007) from Kerala and Ramabhat & Kaveriappa (2009) from Uttara Kannada. Floristic works on this unique ecosystem can be seen in Varghese & Menon (1999), Roby et al. (2007, 2014), Subash et al. (2008), Sreejith et al. (2016) and Joyce et al. (2014). Floristic studies by Roby et al. (2014) had listed 79 species of trees, 93 species of herbs and shrubs, and 49 species of climbers in this ecosystem of which 49 are endemic and 18 are IUCN Red List species. There are only a few studies available on faunal diversity of myristica swamps. The insect diversity in these swamps were studied by Sinu & Sharma (2013); spiders by Joyce et al. (2007a); reptiles by Joyce (2007b,c). The general insect diversity of Shendurney WS was covered by Mathew et al. (2004) and the butterflies list can be seen in Anonymous (2012).

Butterfly fauna of myristica swamps were largely unknown and only a very few studies are available in this regard. Ali et al. (2008) worked on the myristica swamps of Uttara Kannada and recorded 57 species of butterflies in three families Papilionidae, Pieridae, and Nymphalidae. Joyce et al. (2015) identified 72 species in five families and 57 genera during the work in Anchal, Kulathupuzha, and Shendurney over three years. Thus, studies on lepidopteran fauna of myristica swamps have been very scanty. The present study documents of butterflies of myristica swamps of Shendurney WS (8.858^{0}N & 77.210^{0}E) in the northern aspect of the Agasthyamalai Hills of the southern Western Ghats in Kerala.

MATERIALS AND METHODS

Study Area

The myristica swamps at Mankuthu and Onnam-Mile in Kattilapara region of Shendurney WS were studied (Fig. 1). The Mankuthu myristica swamp lies about 1.5km behind the Kattilapara base camp and is at the edge of the sanctuary, while the Onnam-Mile myristica swamp lies about 2.5km inside the sanctuary on the right of the road leading to Kallar. Anthropogenic factors do not seem to play any significant influence on the swamp ecosystem as both are inside the protected area of the sanctuary.

Two myristica swamps were studied in the Kattilapara region of the Shendurney WS (Image 1). Data on butterflies for POc scores (see below) were collected over a period of two years for every two weeks from May 2016–May 2018 using transect method. Permanent line transects covering 500m over 30 minutes were taken in the morning (8–9 am) and evening (3–4 pm) to study the butterfly diversity of the myristica swamp and the adjoining evergreen forest patch. The transects were such that it covered 500m of swamp and 500m of the adjoining evergreen forests. This intensive two-year work was supplemented with additional data from previous visits to this area using the same 500m/30 min transect method, taken once a month, spanning over the last 10 years (2008–2018), for butterfly diversity and hostplant records. For delineating species that are myristica swamp dependent, we compared the butterfly occurrences in the myristica transect with another 500m control transect laid in the adjacent evergreen forest. Butterflies that were recorded in more than 50% of transects in myristica swamps in comparison to the adjacent control transect was taken as myristica swamp species (MSS). This included species with 50–75 % occurrence in the swamp, treated as myristica swamp associates (MSA), and those with occurrence of more than or equal to 75% of transects classified as myristica swamp dependents (MSD).

MSS = MSA+MSD

Those species which were seen <50% were classified as stragglers and were present more outside the swamp than in it. This treatment was supplemented with host plant and early stage data for these butterflies from our observations. Species with their known hostplant distribution restricted to myristica swamps were also considered as myristica swamp dependents (MSD).

To ascertain the habitat affinity and distribution among habitats, we propose here a very simple index — the percentage of occurrence (POc). The total number

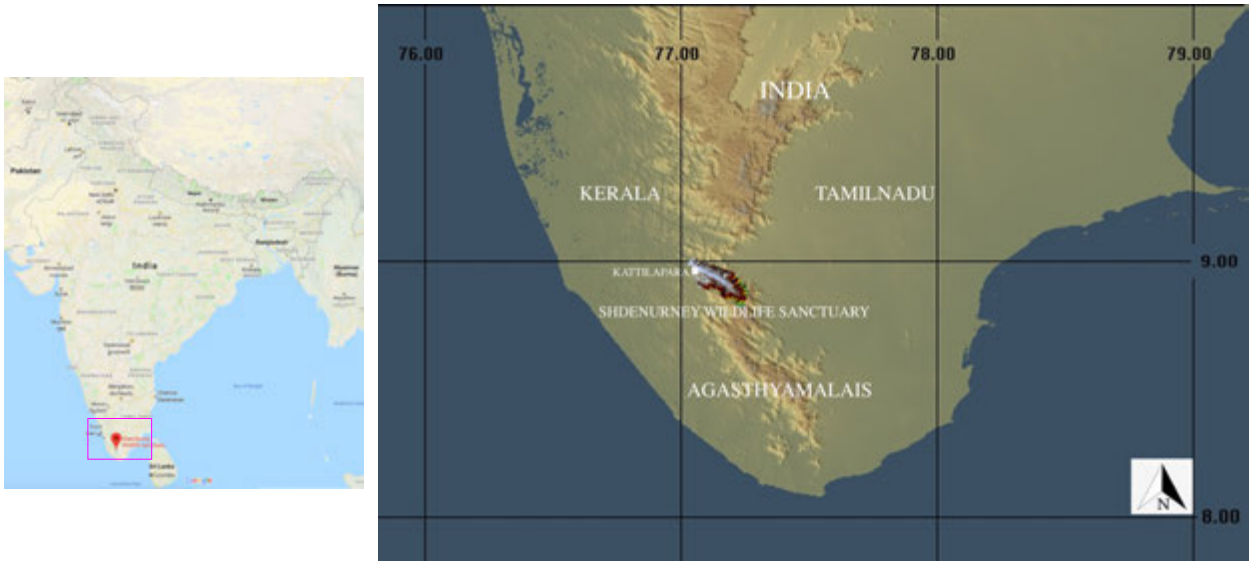


Figure 1. Study area in Shendurney Wildlife Sanctuary, Kerala.

Image 1. Myristica swamp forest.

of individuals of a species is taken and the proportion of them seen in the particular habitat is calculated. For example, in the case of the swamp, we calculated the POc score as per the following equation:

$$\text{Percentage of Occurrence (POc) in Swamp} = \frac{n\ (\text{Swamp}) \times 100}{n\ (\text{Swamp}) + n\ (\text{Evergreen})}$$

POc(Evergreen) = 100-POc(Swamp)

Here *n* was the absolute number of individuals of a particular species seen in a transect (myristica swamp or evergreen forest) added over the study period.

Butterflies were identified based on field photographs and relevant literature. Oviposition alone was not taken as primary criteria of hostplant confirmation because of the well-known oviposition mistakes. Oviposition on an already known plant species being utilized elsewhere, or presence of more than one instar of the larval stages of a butterfly on the plant on which an egg is laid or successful field observation of the larvae surviving to adulthood on the particular plant was taken into consideration to establish a plant as the larval hostplant. Larval identification follows Bell (1909–1927) and Kunte et al. (2018). Identification of adult butterflies are based on Evans (1932) and taxonomy follows Kunte et al. (2018). Larval host plants used by butterflies in the myristica swamps were photographed. Floras referred for identification of the larval hostplants are Ramarao (1914), Gamble (1967), Subramanian (1995), Blatter & Millard (1997), Sivarajan & Mathew (1997) , Seethalakshmi & Kumar (1998), Renuka (2000), Ravi & Mohanan (2004) and Nayar et al. (2006). Host plant utilization was checked against Sevastopulo (1973), Kunte (2000, 2006), Robinson et al. (2001), Kalesh & Prakash (2007, 2015), and Nitin et al. (2018).

RESULTS AND DISCUSSION

Vegetation

The vegetation of the swamps are evergreen species with a majority of the trees being from Myristicaceae. The swamps had a predominance of myristica trees *Gymnacranthera farquhariana* J.Hk. & Thoms., and *Myristica fatua* var. *magnifica* (Bedd.) Sinclair from Myristicaceae family. Other trees observed were *Syzygium travancoricum* Gamble, *Vateria indica* L., *Hopea parviflora* Bedd., *Lophopetalum wightianum*

Table 1. Percentage of occurrence (POc) of myristica swamp dependent butterflies.

	Family	Tribe	Genus	Species	Subspecies	POc
1	Nymphalidae	Danaini	*Idea*	*malabarica*	-	87.5
2	Papilionidae	Papilionini	*Papilio*	*dravidarum*	-	81.81
3	Lycaenidae	Polyommatini	*Neopithecops*	*zalmora*	*dharma*	80.95
4	Lycaenidae	Arhopalini	*Arhopala*	*alea*	-	76.92
5	Papilionidae	Troidini	*Pachliopta*	*pandiyana*	-	75.47
6	Lycaenidae	Arhopalini	*Arhopala*	*bazaloides*	*bazaloides*	75
7	Lycaenidae	Arhopalini	*Arhopala*	*abseus*	*indicus*	75

Arn., *Holigarna arnottiana* J.Hk., occurring as dominant species. *Pandanus thwaitesii* Martelli, *Phrynium pubinerve* Bume, *Indianthus virgatus* (Roxb.) Suksathan & Borchs., and *Carex* sp. constituted the undergrowth. The ground vegetation was mainly of *Lagenandra ovata* (L.). Climbers were also seen in the swamps especially *Parsonisia spiralis* Wall. ex G.Don and Lianas included *Kunstleria keralensis* Mohanan & Nair, *Chilocarpus denudatus* Blume, *Gnetum edule* (Willd.) Blume, and *Ventilago bombaiensis* Dals. There were also climbing ferns and *Calamus* represented by *Calamus thwaitesii* Becc., *Calamus hookerianus* Becc., and *C. travancorius* Bedd. ex Becc., especially in the ecotone with adjacent lowland evergreen forests. The swamp edges had a good undergrowth of plants from Rutaceae, Aristolocaceae, Fabaceae and Poaceae.

Table 2. Endemic species among myristica swamp associate butterflies

	Species	Endemic range
1	*Troides minos* (Cramer, [1779])	Southern India
2	*Graphium teredon* (Felder & Felder, 1865)	Southern India
3	*Mycalesis junonia* Butler, 1868	Southern India
4	*Discophora lepida lepida* (Moore, 1857)	Southern India, Sri Lanka
5	*Elymnias caudata* Butler, 1871	Southern India, Sri Lanka
6	*Cirrochroa thais thais* (Fabricius, 1787)	Southern India, Sri Lanka
7	*Papilio liomedon* Moore, [1875]	Western Ghats
8	*Papilio buddha* Westwood, 1872	Western Ghats
9	*Appias wardii* (Moore, 1884)	Western Ghats
10	*Parantirrhoea marshalli* Wood-Mason, 1881	Western Ghats
11	*Zipaetis saitis* Hewitson, 1863	Western Ghats
12	*Cethosia mahratta* Moore, 1872	Western Ghats
13	*Kallima horsfieldii* Kollar, [1844]	Western Ghats
14	*Curetis siva* Evans, 1954	Western Ghats
15	*Sovia hyrtacus* (de Nicéville, 1897)	Western Ghats
16	*Thoressa astigmata* (Swinhoe, 1890)	Western Ghats
17	*Thoressa honorei* (de Nicéville, 1887)	Western Ghats
18	*Pareronia ceylanica ceylanica* (Felder & Felder, 1865)	Western Ghats, Sri Lanka

Butterfly fauna

In the Myrstica swamp forests, 206 species of butterflies were recorded over a study period of two years (Appendix I). Of these, seven species were MSD with POc value more than or equal to 75, 151 species were MSS with POc >50 and the rest 48 were stragglers (POc <50).

Myristica swamp Dependents (MSD)

Idea malabarica (Moore, 1877) is a typical MSD species with a POc value of 87.5 (Table 1). The regionally preferred host plant is *Parsonisia spiralis* Wall. ex G.Don (Apocynaceae), and this plant is mostly restricted to the myristica swamps of the region, which explains its high POc value 87.5. For *Papilio dravidarum* Wood-Mason, 1880, *Clausena heptaphylla* (Roxb.) Wight & Arn. and *Glycosmis pentaphylla* (Retz.) DC. (Rutaceae) are the known larval hostplants seen in the swamp. The species was found to have a POc value of 81.81. For *Neopithecops zalmora dharma* (Moore, [1881]), *Glycosmis mauritiana* (Lam.) Tanaka, and *Glycosmis pentaphylla* (Retz.) DC. (Rutaceae) are the known larval hosts seen in the undergrowth of the swamp edges. This small lycaenid had a POc of 80.95. *Arhopala alea* (Hewitson, 1862) had three known host species *Terminalia paniculata* Roth, *Hopea* sp. (Dipterocarpaceae) and *Syzygium salicifolium* (Wight) J.Graham (Myrtaceae). This is a rare butterfly in the region with POc value of 76.92. Males were seen mudpuddling on the sandy edges of swamps in drier winter months. *Pachliopta pandiyana* (Moore, 1881) is a monophagus species endemic to Western Ghats that feeds on *Thottea siliquosa* (Lam.) Ding Hou (Aristolochiaceae). This host plant was an ecotone species seen at the edges of the swamps. The

Image 2. ***Parantirrhoea marshalli*** **Travancore Evening Brown**

POc value was 75.47. *Arhopala bazaloides bazaloides* (Hewitson, 1878) has *Hopea ponga* (Dennst.) Mabb. (Dipterocarpaceae) as the known larval hostplant. The butterfly was a rare one with POc 75. *Arhopala abseus indicus* Riley, 1923 was a rare butterfly of the region with high POc of 75 with *Shorea robusta* C.F. Gaertn. (Dipterocarpaceae) was the only recorded hostplant in literature. We report here a species of *Hopea* as its new host plant. This *Hopea* sp. was generally seen on the fringes of the myristica swamps of the region.

Among the MSD species *Idea malabarica* (Moore, 1877), *Papilio dravidarum* Wood-Mason, 1880, *Pachliopta pandiyana* (Moore, 1881) and *Arhopala alea* (Hewitson, 1862) are endemic to the Western Ghats (Larsen 1987). Two species of the MSD are on the IUCN Red Data List, viz., *Arhopala bazaloides bazaloides* (Hewitson, 1878) under Least Concern category and *Idea malabarica* (Moore, 1877) under the Near Threatened category (IUCN 2018). One species, *Arhopala bazaloides bazaloides* (Hewitson, 1878) comes under Schedule II of the Indian Wildlife (Protection) Act, 1972.

Myristica swamp associates (MSA)

There were 151 species that were MSA. They had a POc value between 50 and 75. This implies that they spend much of their time in and around the myristica swamps than outside it. These included 37 Hesperiid species, 40 Lycaenids, 45 Nymphalids, 13 Papilionids, 14 Pierids and two Riodinids (Appendix I). Eighteen taxa listed in the MSA category were found to be endemic species of which 11 species were strictly Western Ghat endemics (Table 2). Two species were Red-Listed by IUCN and 29 species were listed in the various Schedules of the Indian Wildlife (Protection) Act, 1972 (WPA 1972) (Appendix I).

Stragglers

Forty-eight species were found to be stragglers; of them, three were endemics, three were in IUCN Red List and six species were listed in the WPA 1972. Three species were endemics in the straggler category: *Prioneris* sita (Felder & Felder, 1865) is endemic to southern India and Sri Lanka, *Eurema nilgiriensis* (Yata, 1990) is endemic to the Western Ghats, and *Rapala lankana* (Moore, 1879)

Image 3. *Eurema nilgiriensis* Nilgiri Grass Yellow

is restricted to Western Ghats and Sri Lanka (Western Ghats complex). *Hypolimnas misippus* (Linnaeus, 1764) was listed under Schedule I & II, while *Catapaecilma major callone* (Fruhstorfer, 1915), *Dophla evelina laudabilis* Swinhoe, 1890 and *Halpe hindu* Evans, 1937 falls under Schedule II; *Appias libythea* (Fabricius, 1775) and *Prioneris sita* (Felder & Felder, 1865) were Schedule IV species under WPA, 1972. Three species were in IUCN Red List in the Least Concern category – *Junonia almana almana* (Linnaeus, 1758), *J. hierta hierta* (Fabricius, 1798), and *Eurema brigitta rubella* (Wallace, 1867).

Host plant utilization

The complete list of plants of myristica swamps of the study area was obtained from Nair et al. (2007). Eighty-one plant species recorded during the study were butterfly larval hosts in the myristica swamp. Of these, 54 species of plants that we observed as larval hosts were already known larval host plants being used elsewhere for butterflies in the Western Ghats (Table 3). We also found 27 species of new hostplant records being used by 43 species of butterflies (Table 4).

CONCLUSIONS

In our study, we found 206 species of butterflies from Papilionidae, Pieridae, Lycaenidae, Riodinidae, Nymphalidae, and Hesperiidae from myristica swamps of Shendurney. Of these only seven species were MSD, which are restricted to the swamps of the region, and 23 species of butterflies were endemic to peninsular India of the Western Ghats complex. With respect to WPA 1972, 32 species seen in the swamps are protected and seven species are in the Red List of IUCN. It was noted that most of the butterflies were shared species with the nearby evergreen patches and only seven species were specifically partial to it. We confirmed the presence of the rare *Eurema nilgiriensis* (Yata, 1990) Nilgiri Grass Yellow butterfly from Shendurney, extended its range into Agasthyamalais and have recorded *Ventilago bombaiensis* Dals., as its site-specific larval hostplant. Eighty-one species of plants were recorded as butterfly larval hosts in the myristica swamp ecosystem, with 27 species being new host plant records for Western Ghats. Interestingly, none of the butterflies recorded were

using plants of myristicaceae family as larval hosts as far as it is known. The POc is a simple index that can be easily applied to assess habitat association of any taxa.

REFERENCES

Ali, S.M., D. Chandran & T.V. Ramachandra (2008). Faunal assemblages in myristica swamps of central Western Ghats, Karnataka, India. *Sahyadri e-news* 2–13.

Anonymous (2012). Checklist of Butterflies of Shendurney, TNHS Thiruvananthapuram, in *Management plan for Shendurney Wildlife Sanctuary*, Kerala Forest Department. Government of Kerala.

Bell, T.R. (1909–1927). The Common Butterflies Of The Plains Of India (Including Those Met With In The Hill Stations of The Bombay Presidency). *Journal of the Bombay Natural History Society* 19(1)–31(4).

Blatter, E. & W.S. Millard (1997). *Some Beautiful Indian Trees*. Bombay Natural History Society. Oxford University Press, 2nd Edition. 165pp., xxi Colour Plates.

Champion, H.G., & S.K. Seth. (1968). *A Revised Survey of the Forest Types of India*. Delhi. https://dds.crl.edu/crldelivery/23005.

Evans, W.H. (1932). *Identifications of Indian Butterflies*. 2nd edition Bombay Natural History Society, Madras. X + 454 pp., 32pl.

Gamble, J.S. (1967). *The Flora of The Presidency Of Madras.* Botanical Survey Of India. 1389pp.

IUCN (2018). The IUCN Red List of Threatened Species. Version 2018-2. http://www.iucnredlist.org. Downloaded on 3 December 2018.

Joyce, J., K.K. Ramachandran & P.V. Nair (2007a). A Preliminary Overview and Checklist of the Spider Fauna of myristica Swamp Forests of Southern Kerala, India. *Bulletin of the British Arachnological Society* 109: 12–14.

Joyce, J., K.K. Ramachandran, & P.V. Nair (2007b). Animal diversity of the myristica swamp forests of Southern Kerala with special reference to herpetofauna. In: The Proceedings of the 19th Kerala Science Congress: 724–726.

Joyce, J., K.K. Ramachandran & P.V. Nair (2007c). A rare and little known lizard, *Otocryptis beddomi* from the myristica swamps of Southern Kerala, India. *The Herpetological Bulletin* 101: 27–31.

Joyce, J., T.J. Roby, K.K. Ramachandran & P.V. Nair (2014). Species abundance distributions of selected communities in the myristica swamp forests of southern Kerala. *Current Science* 107: 447–453.

Joyce, J., T.J. Roby, K.K. Ramachandran & P.V. Nair (2015). The state of myristica swamp forests in southern Western Ghats, India - butterfly species richness as an indicator. *Indian Forester* 141: 1056–1066.

Kalesh, S. & S.K. Prakash (2007). Additions to the larval host plants of butterflies of the Western Ghats, Kerala, South India (Rhopalocera, Lepidoptera): Part 1. *Journal of the Bombay Natural History Society*.104: 235–238.

Kalesh, S. & S.K. Prakash (2015). Additions to the larval host plants of butterflies of the Western Ghats, Kerala, South India (Rhopalocera, Lepidoptera): Part 2. *Journal of the Bombay Natural History Society* 112: 111–114.

Krishnamoorthy, K. (1960). Myristica swamps in the evergreen forests of Tranvancore. *Indian Forester* 86(5): 314–315.

Kunte, K. (2000). *Butterfles of Peninsular India*. Universities Press (Hyderabad) and Indian Academy of Sciences (Bangalore), 254pp.

Kunte, K. (2006). Additions to known larval host plants of Indian Butterflies. *Journal of the Bombay Natural History Society* 103(1): 119–122.

Kunte, K., S. Sondhi & P. Roy (Chief Editors) (2018). Butterflies of India, v. 2.37. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/. Accessed 14 March 2018.

Larsen, T.B. (1987). The butterflies of the Nilgiri mountains of southern India (Lepidoptera: Rhopalocera). *Journal of the Bombay Natural History Society.* 84(2):291–316.

Mathew, G., R. Chandran, C.M. Brijesh & R.S.M. Shamsudeen (2004). Insect fauna of Shendurney Wildlife Sanctuary, Kerala. *Zoos' Print Journal* 19(1):1321–1327; https://doi.org/10.11609/JoTT.ZPJ.19.1.1321-7

Nair, P.V., K.K. Ramachandran, K. Swarupanandan & P. Thomas. (2007). *Mapping biodiversity of the myristica swamps in southern Kerala*. Research Report, KFRI, Peechi, Kerala. 255pp.

Nayar, T.S., A.R. Beegam, N. Mohanan & G. Rajkumar (2006). *Flowering Plants Of Kerala – A Handbook.* Tropical Botanic Garden And Research Institute, Trivandrum, Kerala. 1069pp.

Nitin, R., V.C. Balakrishnan, P.V. Churi, S. Kalesh, S. Prakash & K. Kunte (2018). Larval host plants of the butterflies of the Western Ghats, India. *Journal of Threatened Taxa* 10(4): 11495–11550; https://doi.org/10.11609/jo .3104.10.4.11495-11550.

Ramabhat, P. & K.M. Kaveriappa (2009). Ecological studies on myristica swamp forests of Uttara Kannada, Karnataka, India. *Tropical Ecology* 50(2): 329–337.

Ramarao, M. (1914). *Flowering Plants of Travancore*. International Book Distributors, 495pp.

Ravi, N. & N. Mohanan (2004). *Common Tropical & Subtropical Sedges and Grasses – An Illustrated Account.* Oxford & IBH. 220pp.

Renuka, C. (2000). *Field Identification Key for Rattans Of Kerala*. Kerala Forest Research Institute & Kerala Forest Department. 33pp.

Robinson, G.S., P.R. Ackery, I.J. Kitching, G.W. Beccaloni & L.M. Hernández (2001). *Hostplants Of The Moth and Butterfly Caterpillars of The Oriental Region*. The Natural History Museum, London. 744pp.

Roby, T.J. & P.V. Nair (2007). Myristica swamps - a prime habitat of the critically endangered tree *Syzygium travancoricum*. In: The Proceedings of the XVIII Kerala Science Congress 764–765.

Roby, T J., J. Joyce & P.V. Nair (2014). Checklist of Flora of Myristica Swamps - A Critically Endangered Fresh Water Ecosystem of Southern Western Ghats of Kerala, India. *Indian Forester* 140: 608–616.

Rodgers, W.A. & H.S. Panwar (1988a). Planning wildlife protected area network in India. The Report. A report prepared for the Department of Environment, Forests and Wildlife, Government of India at Wildlife Institute of India, Vol I: 341pp.

Rodgers, W.A. & H.S. Panwar. (1988b). Planning wildlife protected area network in India. State Summaries. A report prepared for the Department of Environment, Forests and Wildlife, Government of India at Wildlife Institute of India, Vol II: 267pp.

Seethalakshmi, K.K. & M.S.M. Kumar (1998). *Bamboos of India: a Compendium.* Kerala Forest Research Institute, Peechi, Kerala and International Network For Bamboo And Rattan, Beijing, 342pp.

Sevastopulo, D.G. (1973). The foodplants of Indian Rhopalocera. *Journal of the Bombay Natural History Society.* 70(1): 156–83.

Sinu, P.A. & M.V. Sharma (2013). Insect functional guilds in the flowering canopy of myristica fatua in a lowland swamp, central Western Ghats, India.*Tropical Conservation Science - Special Issue* 6(5): 653–662.

Sivarajan, V.V. & P. Mathew (1997). *Flora of Nilambur (Western Ghats, Kerala).* Bishen Singh Mahendra Pal Singh, Dehradun, 900pp.

Sreejith, K.A., U.M. Chandrashekara, T.K. Nirmesh & V.B Sreekumar (2016). Tree species composition and distribution pattern in a myristica swamp of northern Kerala, India. Current World Environment 11(3): 743–750.

Subash C.M.D., D.K. Mesta, G.R. Rao, S. Ali, K.V. Gururaja & T.V. Ramachandran (2008). Discovery of two critically endangered tree species and issues related to relic forests of the Western Ghats. *The Open Conservation Biology Journal* 2: 1–8.

Subramanian, K.N. (1995). *Flora of Thenmala (and its environs.).* International Book Distributors, Dehra Dun, 516pp.

Varghese, A.O. & M.A.R.R. Menon. (1999). Floristic composition, dynamics and diversity of myristica swamp forests of southern Western Ghats of Kerala. *Indian Forester* 125(8): 775–783.

Table 3. List of larval host plants for butterflies of myristica swamp forests, Shendurney WS, recorded from our observations from 2008–2018.

	Species	Butterflies
1	*Abrus precatorius* L.	*Curetis thetis* (Drury, [1773]) *Jamides celeno celeno* (Cramer, [1775]) *Lampides boeticus* (Linnaeus, 1767) *Leptotes plinius plinius* (Fabricius, 1793)
2	*Acacia torta* (Roxb.) Craib	*Prosotas dubiosa indica* (Evans, [1925]) *Prosotas nora ardates,* Moore, [1875] *Rapala manea schistacea* (Moore, 1879) *Surendra quercetorum biplagiata* Butler, 1883 *Charaxes bharata* Felder & Felder, [1867]
3	*Areca catechu* L.	*Elymnias caudata* Butler, 1871
4	*Aristolochia tagala* Cham.	*Pachliopta aristolochiae aristolochiae* (Fabricius, 1775) *Troides minos* (Cramer, [1779])
5	*Atalantia racemosa* Wight ex Hook.	*Chilades lajus lajus* (Stoll, [1780]) *Papilio polymnestor polymnestor* Cramer, [1775] *Papilio polytes romulus* Cramer, [1775]
6	*Axonopus compressus* (Sw.) P. Beauv.	*Borbo cinnara* (Wallace, 1866) *Iambrix salsala luteipalpis* (Plötz, 1886) *Oriens goloides* (Moore, [1881]) *Pelopidas agna agna* (Moore, [1866]) *Pelopidas mathias mathias* (Fabricius, 1798) *Pelopidas subochracea subochracea* (Moore, 1878) *Potanthus pseudomaesa pseudomaesa* (Moore, [1881]) *Taractrocera ceramas* (Hewitson, 1868) *Ypthima ceylonica* Hewitson, 1865 *Ypthima huebneri* Kirby, 1871
7	*Bauhinia phoenicea* Wight & Arn.	*Charaxes schreiber wardii* (Moore, 1896) *Coladenia indrani indra* Evans, 1926
8	*Bombax ceiba* L.	*Neptis hylas varmona* Moore, 1872 *Neptis jumbah nalanda* Fruhstorfer, 1908
9	*Calamus hookerianus* Becc.	*Hyarotis adrastus praba* (Moore, [1866]) *Quedara basiflava* (de Nicéville, [1889]) *Salanoemia sala* (Hewitson, [1866])
10	*Calamus thwaitesii* Becc.	*Salanoemia sala,* (Hewitson, [1866]) *Gangara thyrsis thyrsis* (Fabricius, 1775) *Amathusia phidippus friderici* Fruhstorfer, 1904 *Elymnias caudata* Butler, 1871
11	*Calamus travancoricus* Bedd. ex Becc.	*Suastus minuta bipunctus* Swinhoe, 1894
12	*Cinnamomum malabatrum* (Burm.f.) J. Presl.	*Graphium doson eleius* (Felder & Felder, 1864) *Graphium teredon* (Felder & Felder, 1865) *Papilio clytia clytia* Linnaeus, 1758
13	*Combretum latifolium* Blume	*Badamia exclamationis* (Fabricius, 1775) *Bibasis sena sena* (Moore, [1866]) *Burara jaina fergusonii* (de Nicéville, [1893]) *Anthene emolus emolus* (Godart, [1824])
14	*Connarus* sp.	*Deudorix epijarbas epijarbas* (Moore, 1857) *Nacaduba beroe gythion* Fruhstorfer, 1916
15	*Cheilocostus speciosus* (J.Koenig) C. D. Specht	*Notocrypta curvifascia curvifascia* (Felder & Felder, 1862)
16	*Dalbergia horrida* (Dennst.) Mabb.	*Pantoporia sandaka davidsoni* Eliot, 1969
17	*Elaeocarpus* sp.	*Neptis jumbah nalanda* Fruhstorfer, 1908
18	*Entada rheedii* Spreng.	*Nacaduba hermus sidoma* Fruhstorfer, 1916 *Nacaduba pactolus continentalis* Fruhstorfer, 1916
19	*Ficus hispida* L.f.	*Euploea klugii kollari* Felder & Felder, [1865]
20	*Flacourtia montana* J. Graham	*Cupha erymanthis maja* Fruhstorfer, 1898 *Phalanta phalantha phalantha* (Drury, [1773])
21	*Glochidion ellipticum* Wight	*Athyma inara inara* Westwood, 1850 *Athyma perius perius* (Linnaeus, 1758)
22	*Glycosmis pentaphylla* (Retz.) DC.	*Chilades lajus lajus* (Stoll, [1780]) *Neopithecops zalmora dharma* (Moore, [1881]) *Papilio demoleus demoleus* Linnaeus, 1758 *Papilio dravidarum* Wood-Mason, 1880 *Papilio helenus daksha* Hampson, 1888 *Papilio polymnestor polymnestor* Cramer, [1775] *Papilio polytes romulus* Cramer, [1775]
23	*Grewia nervosa* (Lour.) Panigrahi	*Neptis hylas varmona* Moore, 1872 *Neptis jumbah nalanda* Fruhstorfer, 1908 *Coladenia indrani indra* Evans, 1926 *Odontoptilum angulata angulata* (Felder, 1862)
24	*Helicteres isora* L.	*Caprona ransonnetti potiphera* (Hewitson, 1873) *Neptis hylas varmona* Moore, 1872
25	*Ixora* sp.	*Cheritra freja butleri* Cowan, 1965 *Rathinda amor* (Fabricius, 1775) *Zeltus amasa amasa* (Hewitson, 1865)
26	*Lagerstroemia speciosa* (L.) Pers.	*Arhopala amantes amantes* (Hewitson, 1862) *Arhopala centaurus pirama* (Moore, [1881])
27	*Lepisanthes tetraphylla* Radlk.	*Acytolepis puspa felderi* Toxopeus, 1927 *Cheritra freja butleri* Cowan, 1965 *Megisba malaya* (Moore, [1881]) *Rapala manea schistacea* (Moore, 1879)
28	*Mallotus philippensis* (Lam.) Müll.Arg.	*Coladenia indrani indra* Evans, 1926 *Megisba malaya thwaitesi* (Moore, [1881]) *Prosotas dubiosa indica* (Evans, [1925]) *Prosotas nora ardates* (Moore, [1875]) *Neptis jumbah nalanda* Fruhstorfer, 1908
29	*Mangifera indica* L.	*Anthene emolus emolus* (Godart, [1824]) *Chilades lajus lajus* (Stoll, [1780]) *Horaga onyx cingalensis* Moore, [1884] *Rathinda amor* (Fabricius, 1775) *Spalgis epius epius* (Westwood, 1852) *Euthalia aconthea meridionalis* Fruhstorfer, 1913
30	*Melastoma malabathricum* L.	*Rapala iarbus sorya* (Kollar, [1844]) *Tanaecia lepidea miyana* (Fruhstorfer, 1913)
31	*Mimosa pudica* L.	*Prosotas dubiosa indica* (Evans, [1925]) *Junonia hierta hierta* (Fabricius, 1798) *Junonia orithya orithya* Butler, 1885 *Eurema hecabe hecabe* (Linnaeus, 1758)
32	*Mitragyna parvifolia* (Roxb.) Korth.	*Moduza procris procris* Fruhstorfer, 1906
33	*Mussaenda frondosa* L.	*Athyma inara inara* Westwood, 1850 *Moduza procris procris* Fruhstorfer, 1906
34	*Neolamarckia cadamba* (Roxb.) Bosser	*Moduza procris procris* Fruhstorfer, 1906
35	*Ochlandra travancorica* (Bedd.) Gamble	*Baoris farri* (Moore, 1878) *Caltoris kumara kumara* (Moore, 1878) *Caltoris philippina philippina* (Herrich-Schäffer, 1869) *Matapa aria* (Moore, [1866]) *Sovia hyrtacus* (de Nicéville, 1897) *Telicota bambusae bambusae* (Moore, 1878) *Telicota colon colon* (Fabricius, 1775) *Thoressa astigmata* (Swinhoe, 1890) *Thoressa honorei* (de Nicéville, 1887) *Potanthus pava pava* (Fruhstorfer, 1911) *Discophora lepida lepida* (Moore, 1857) *Parantirrhoea marshalli* Wood-Mason, 1881 *Zipaetis saitis* Hewitson, 1863
36	*Olea dioica* Roxb.	*Athyma ranga karwara* (Fruhstorfer, 1906)
37	*Oplismenus compositus* (L.) P. Beauv.	*Oriens goloides* (Moore, [1881]) *Melanitis leda leda* (Linnaeus, 1758) *Melanits phedima varaha* Moore, 1857 *Mycalesis perseus tabitha* (Fabricius, 1793)
38	*Parsonsia alboflavescens* (Dennst.) Mabb.	*Idea malabarica* (Moore, 1877)
39	*Persea macrantha* (Nees) Kosterm	*Graphium teredon* (Felder & Felder, 1865)
40	*Schleichera oleosa* (Lour.) Merr.	*Acytolepis puspa felderi* Toxopeus, 1927 *Arhopala centaurus pirama* (Moore, [1881]) *Catochrysops strabo strabo* (Fabricius, 1793) *Chilades pandava pandava* (Horsfield, [1829]) *Megisba malaya* (Moore, [1881]) *Rapala iarbus sorya* (Kollar, [1844])

	Species	Butterflies
41	*Indianthus virgatus* (Roxb.) Suksathan & Borchs	*Psolos fuligo subfasciatus* (Moore, 1878)
42	*Sida rhombifolia* L.	*Spialia galba* (Fabricius, 1793) *Hypolimnas bolina jacintha* (Drury, 1773) *Junonia lemonias lemonias* (Linnaeus, 1758)
43	*Smilax zeylanica* L.	*Spindasis lohita lazularia* Moore, 1881 *Zesius chrysomallus* Hübner, 1819 *Kaniska canace viridis* Evans, 1924 *Loxura atymnus atymnus* (Stoll, [1780])
44	*Strobilanthes ciliata* Nees	*Celaenorrhinus leucocera* (Kollar, [1844]) *Celaenorrhinus putra putra* (Moore, [1866]) *Junonia iphita iphita* (Cramer, [1779]) *Kallima horsfieldii* Kollar, [1844]
45	*Terminalia elliptica* Willd.	*Coladenia indrani indra* Evans, 1926 *Arhopala amantes amantes* (Hewitson, 1862)
46	*Terminalia paniculata* Roth	*Cupitha purreea* (Moore, 1877) *Anthene emolus emolus* (Godart, [1824]) *Arhopala alea* (Hewitson, 1862) *Arhopala amantes amantes* (Hewitson, 1862) *Arhopala centaurus pirama* (Moore, [1881]) *Catapaecilma major callone* (Fruhstorfer, 1915) *Spindasis lohita lazularia* Moore, 1881 *Zesius chrysomallus* Hübner, 1819
47	*Mallotus nudi orus* (L.) Kulju & Welzen	*Catapaecilma major callone* (Fruhstorfer, 1915) *Thaduka multcaudata kanara* Evans, 1925
48	*Thottea siliquosa* (Lam.) Ding Hou	*Pachliopta aristolochiae aristolochiae* (Fabricius, 1775) *Pachliopta pandiyana* (Moore, 1881) *Troides minos* (Cramer, [1779])
49	*Urena lobata* L.	*Caprona ransonnetti potiphera* (Hewitson, 1873) *Odontoptilum angulata angulata* (Felder, 1862) *Spialia galba* (Fabricius, 1793) *Rapala manea schistacea* (Moore, 1879) *Neptis hylas varmona* Moore, 1872
50	*Uvaria narum* Wall.	*Graphium agamemnon menides* (Fruhstorfer, 1904)
51	*Vateria indica* L.	*Nacaduba kurava canaraica* Toxopeus, 1927
52	*Zingiber zerumbet* (L.) Roscoe ex Sm.	*Notocrypta curvifascia curvifascia* (Felder & Felder, 1862) *Udaspes folus* (Cramer, [1775]) *Jamides alecto alocina* (Fruhstorfer, 1916)
53	*Zizyphus oenoplia* (L.) Miller	*Caleta decidia* (Hewitson, 1876) *Castalius rosimon rosimon* (Fabricius, 1775) *Discolampa ethion ethion* Westwood, 1851 *Tarucus ananda* (de Nicéville, [1883])
54	*Zizyphus rugosa* Lam.	*Caleta decidia decidia* (Hewitson, 1876) *Castalius rosimon rosimon* (Fabricius, 1775) *Catapaecilma major callone* (Fruhstorfer, 1915) *Rapala iarbus sorya* (Kollar, [1844]) *Rapala lankana* (Moore, 1879) *Rapala varuna lazulina* (Moore, 1879) *Spindasis vulcanus* (Fabricius, 1775)

Table 4. Newly discovered larval host-plants for butterflies of Western Ghats, recorded from myristica swamp forests, Shendurney WS, during our study from 2008–2018.

	Species	Butterflies
1	*Alpinia malaccensis* (N. L. Burman) Roscoe	*Notocrypta curvifascia curvifascia* (Felder & Felder, 1862) *Notocrypta paralysos mangla* Evans, 1949 *Udaspes folus* (Cramer, [1775]
2	*Areca catechu* L.	*Suastus gremius gremius* (Fabricius, 1798) *Gangara thyrsis thyrsis* (Fabricius, 1775) *Elymnias caudata* Butler, 1871
3	*Artabotrys zeylanicus* Hook.f. & Thomson	*Graphium agamemnon menides* (Fruhstorfer, 1904)
4	*Barleria courtallica* Nees	*Junonia atlites atlites* (Linnaeus, 1763) *Junonia hierta hierta* (Fabricius, 1798) *Junonia lemonias lemonias* (Linnaeus, 1758)
5	*Bauhinia phoenicea* Wight & Arn.	*Acytolepis puspa felderi* Toxopeus, 1927 *Cheritra freja butleri* Cowan, 1965
6	*Butea parviflora* DC.	*Chilades pandava pandava* (Horsfield, [1829]) *Curetis thetis* (Drury, [1773]) *Euchrysops cnejus cnejus* (Fabricius, 1798) *Jamides bochus bochus* (Stoll, [1782]) *Jamides celeno celeno* (Cramer, [1775]) *Coladenia indrani indra* Evans, 1926
7	*Calophyllum polyanthum* Wall. ex Choisy	*Rathinda amor* (Fabricius, 1775)
8	*Curcuma ecalcarata* Sivar. & Balach.	*Notocrypta curvifascia curvifascia* (Felder & Felder, 1862) *Notocrypta paralysos mangla* Evans, 1949 *Udaspes folus* (Cramer, [1775])
9	*Derris canarensis* (Dalzell) Baker	*Hasora badra badra* (Moore, [1858]) *Curetis thetis* (Drury, [1773])
10	*Desmodium heterocarpon* (L.)DC.	*Chilades pandava pandava* (Horsfield, [1829]) *Curetis siva* (Evans, 1954) *Euchrysops cnejus cnejus* (Fabricius, 1798)
11	*Dimocarpus longan* Lour.	*Nacaduba beroe gythion* Fruhstorfer, 1916
12	*Dioscorea bulbifera* L.	*Tagiades gana silvia*, Evans, 1934 *Tagiades litigiosa litigiosa* Möschler, 1878
13	*Diospyros species*	*Dophla evelina laudabilis* Swinhoe, 1890
14	*Hopea parviflora* Bedd.	*Arhopala bazaloides bazaloides* (Hewitson, 1878) *Arhopala centaurus pirama* (Moore, [1881]) *Arhopala amantes amantes* (Hewitson, 1862) *Arhopala abseus indicus* Riley, 1923 *Rathinda amor* (Fabricius, 1775)
15	*Hoya pauciflora* Wight	*Euploea sylvester coreta* (Godart, 1819) *Tirumala limniace exoticus* (Gmelin, 1790)
16	*Humboldtia decurrens* Bedd.	*Jamides celeno celeno* (Cramer, [1775])
17	*Hibiscus furcatus* Roxb.	*Neptis hylas varmona* Moore, 1872
18	*Hydnocarpus pentandra* (Buch.-Ham.) Oken	*Cirrochroa thais thais* (Fabricius, 1787)
19	*Lagerstroemia speciosa* (L.) Pers.	*Catapaecilma major callone* (Fruhstorfer, 1915)
20	*Litsea travancorica* Gamble	*Graphium teredon* (Felder & Felder, 1865) *Papilio clytia clytia* Linnaeus, 1758
21	*Pinanga dicksonii* (Roxb.) Bl.	*Gangara thyrsis thyrsis* (Fabricius, 1775) *Elymnias caudata* Butler, 1871 *Suastus gremius gremius* (Fabricius, 1798)
22	*Polyalthia fragrans* (Dalz.) Bedd.	*Graphium agamemnon menides* (Fruhstorfer, 1904) *Graphium doson eleius* (Felder & Felder, 1864) *Graphium nomius nomius* (Esper, 1799)
23	*Sterculia guttata* Roxb.	*Rapala maneaschistacea* (Moore, 1879)
24	*Syzygium species*	*Arhopala amantes amantes* (Hewitson, 1862) *Arhopala centaurus pirama* (Moore, [1881]) *Arhopala alea* (Hewitson, 1862)
25	*Tylophora mollissima* Wight	*Euploea core core* (Cramer, [1780]) *Parantica aglea aglea*, (Stoll, [1782]) *Tirumala limniace exoticus* (Gmelin, 1790)
26	*Vateria indica* L.	*Arhopala centaurus pirama* (Moore, [1881]) *Arhopala amantes amantes* (Hewitson, 1862) *Rathinda amor* (Fabricius, 1775)
27	*Ventilago bombaiensis* Dals.	*Eurema nilgiriensis* (Yata, 1990)

Appendix 1. A checklist of butterflies of myristica swamps of Shendurney WS, Kollam, Kerala.

	Genus	Species	Subspecies	Status	Endemic status	IUCN Redlist Status	WPA 1972
Papilionidae							
1	*Troides*	*minos*	-	MSA	Southern India		
2	*Pachliopta*	*aristolochiae*	*aristolochiae*	MSA			
3	*Pachliopta*	*hector*	-	MSA	Peninsular India, SL		Sh I
4	*Pachliopta*	*pandiyana*	-	MSD	Western Ghats		
5	*Graphium*	*agamemnon*	*menides*	MSA			
6	*Graphium*	*doson*	*eleius*	MSA			
7	*Graphium*	*teredon*	-	MSA	Southern India		
8	*Graphium*	*antiphates*	*naira*	STR			
9	*Papilio*	*buddha*	-	MSA	Western Ghats		Sh II
10	*Papilio*	*clytia*	*clytia*	MSA			Sh I
11	*Papilio*	*helenus*	*daksha*	MSA			
12	*Papilio*	*liomedon*	-	MSA	Western Ghats		Sh I
13	*Papilio*	*paris*	*tamilana*	MSA			
14	*Papilio*	*polymnestor*	*polymnestor*	MSA			
15	*Papilio*	*polytes*	*romulus*	MSA			
16	*Papilio*	*dravidarum*	-	MSD	Western Ghats		
17	*Papilio*	*demoleus*	*demoleus*	STR			
Pieridae							
18	*Catopsilia*	*pomona*	*pomona*	MSA			
19	*Catopsilia*	*pyranthe*	*pyranthe*	MSA			
20	*Eurema*	*blanda*	*silhetana*	MSA			
21	*Eurema*	*hecabe*	*hecabe*	MSA			
22	*Eurema*	*brigitta*	*rubella*	STR		Least Concern	
23	*Eurema*	*nilgiriensis*	-	STR	Western Ghats		
24	*Appias*	*albina*	*swinhoei*	MSA			
25	*Appias*	*indra*	*shiva*	MSA			Sh II
26	*Appias*	*lyncida*	*latifasciata*	MSA			Sh II
27	*Appias*	*wardii*	-	MSA	Western Ghats		Sh II
28	*Cepora*	*nadina*	*remba*	MSA			Sh II
29	*Delias*	*eucharis*	-	MSA			
30	*Hebomoia*	*glaucippe*	*australis*	MSA			
31	*Leptosia*	*nina*	*nina*	MSA			
32	*Pareronia*	*ceylanica*	*ceylanica*	MSA	Western Ghats, SL		
33	*Pareronia*	*hippia*	-	MSA			
34	*Appias*	*libythea*	-	STR			Sh IV
35	*Belenois*	*aurota*	*aurota*	STR			
36	*Cepora*	*nerissa*	*phryne*	STR			
37	*Prioneris*	*sita*	-	STR	Southern India, SL		Sh IV
Nymphalidae							
38	*Cethosia*	*mahratta*	-	MSA	Western Ghats		
39	*Acraea*	*violae*	-	STR			
40	*Euthalia*	*aconthea*	*meridionalis*	MSA			

	Genus	Species	Subspecies	Status	Endemic status	IUCN Redlist Status	WPA 1972
41	*Euthalia*	*lubentina*	*arasada*	MSA			Sh IV
42	*Tanaecia*	*lepidea*	*miyana*	MSA			Sh II
43	*Dophla*	*evelina*	*laudabilis*	STR			Sh II
44	*Amathusia*	*phidippus*	*friderici*	MSA			
45	*Discophora*	*lepida*	*lepida*	MSA	Southern India, SL		Sh II
46	*Ariadne*	*ariadne*	*indica*	MSA			
47	*Ariadne*	*merione*	*merione*	MSA			
48	*Charaxes*	*bharata*	-	MSA			
49	*Charaxes*	*psaphon*	*imna*	MSA			
50	*Charaxes*	*schreiber*	*wardii*	MSA			Sh I
51	*Charaxes*	*solon*	*solon*	MSA			
52	*Cyrestis*	*thyodamas*	*indica*	STR			
53	*Euploea*	*core*	*core*	MSA		Least Concern	
54	*Parantica*	*aglea*	*aglea*	MSA			
55	*Idea*	*malabarica*	-	MSD	Western Ghats	Near threatened	
56	*Danaus*	*chrysippus*	*chrysippus*	STR			
57	*Danaus*	*genutia*	*genutia*	STR			
58	*Euploea*	*klugii*	*kollari*	STR			
59	*Euploea*	*sylvester*	*coreta*	STR			
60	*Tirumala*	*limniace*	*exoticus*	STR			
61	*Tirumala*	*septentrionis*	*dravidarum*	STR			
62	*Elymnias*	*caudata*	-	MSA	Southern India, SL		
63	*Hypolimnas*	*bolina*	*jacintha*	MSA			
64	*Junonia*	*iphita*	*iphita*	MSA			
65	*Junonia*	*lemonias*	*lemonias*	MSA			
66	*Hypolimnas*	*misippus*	-	STR			Sh I & II
67	*Junonia*	*almana*	*almana*	STR		Least Concern	
68	*Junonia*	*atlites*	*atlites*	STR			
69	*Junonia*	*hierta*	*hierta*	STR		Least Concern	
70	*Junonia*	*orithya*	*swinhoei*	STR			
71	*Doleschallia*	*bisaltide*	*malabarica*	MSA			Sh II
72	*Kallima*	*horsfieldii*		MSA	Western Ghats		Sh II
73	*Kallima*	*horsfieldii*	-	STR	Western Ghats		Sh II
74	*Athyma*	*inara*	*inara*	MSA			
75	*Athyma*	*ranga*	*karwara*	MSA			Sh II
76	*Moduza*	*procris*	*procris*	MSA			
77	*Melanitis*	*leda*	*leda*	MSA			
78	*Melanitis*	*phedima*	*varaha*	MSA			
79	*Melanitis*	*zitenius*	*gokala*	MSA			Sh II
80	*Parantirrhoea*	*marshalli*	-	MSA	Western Ghats		Sh II
81	*Lasippa*	*viraja*	*kanara*	MSA			
82	*Neptis*	*hylas*	*varmona*	MSA			
83	*Neptis*	*jumbah*	*nalanda*	MSA			
84	*Pantoporia*	*hordonia*	*hordonia*	MSA			
85	*Pantoporia*	*sandaka*	*davidsoni*	MSA			

	Genus	Species	Subspecies	Status	Endemic status	IUCN Redlist Status	WPA 1972
86	*Kaniska*	*canace*	*viridis*	MSA			
87	*Parthenos*	*sylvia*	*virens*	MSA			Sh II
88	*Lethe*	*drypetis*	*todara*	MSA	Southern India, SL		
89	*Lethe*	*europa*	*europa*	MSA			
90	*Orsotriaena*	*medus*	*mandata*	MSA			
91	*Mycalesis*	*junonia*	-	MSA	Southern India		
92	*Mycalesis*	*mineus*	*polydecta*	MSA			
93	*Mycalesis*	*visala*	*visala*	STR			
94	*Ypthima*	*ceylonica*	-	STR	Peninsular India, SL		
95	*Ypthima*	*baldus*	-	MSA			
96	*Ypthima*	*huebneri*	-	MSA			
97	*Zipaetis*	*saitis*	-	MSA	Western Ghats		Sh II
98	*Cirrochroa*	*thais*	*thais*	MSA	Southern India, SL		
99	*Cupha*	*erymanthis*	*maja*	MSA			
100	*Vindula*	*erota*	*saloma*	MSA			
101	*Phalanta*	*alcippe*	*mercea*	STR			Sh II
102	*Phalanta*	*phalantha*	*phalantha*	STR			
Riodinidae							
103	*Abisara*	*bifasciata*	*suffusa*	MSA			
104	*Abisara*	*echerius*	*prunosa*	MSA			
Lycaenidae							
105	*Curetis*	*siva*		MSA	Western Ghats		
106	*Curetis*	*thetis*	-	MSA			
107	*Amblypodia*	*anita*	*dina*	MSA			
108	*Thaduka*	*multicaudata*	*kanara*	MSA			Sh II
109	*Iraota*	*timoleon*	*arsaces*	STR			
110	*Arhopala*	*abseus*	*indicus*	MSD			
111	*Arhopala*	*alea*	-	MSD	Western Ghats		
112	*Arhopala*	*bazaloides*	*bazaloides*	MSD		Least Concern	Sh II
113	*Arhopala*	*amantes*	*amantes*	STR			
114	*Arhopala*	*centaurus*	*pirama*	STR			
115	*Surendra*	*quercetorum*	*biplagiata*	STR			
116	*Catapaecilma*	*major*	*callone*	STR			Sh II
117	*Cheritra*	*freja*	*butleri*	MSA		Least Concern	
118	*Bindahara*	*moorei*	-	MSA			Sh II
119	*Deudorix*	*epijarbas*	*epijarbas*	STR			
120	*Rapala*	*lankana*	-	STR			
121	*Rapala*	*manea*	*schistacea*	STR			
122	*Rathinda*	*amor*	-	MSA			
123	*Hypolycaena*	*othona*	*othona*	MSA			Sh I
124	*Zeltus*	*amasa*	*amasa*	MSA			
125	*Tajuria*	*cippus*	*cippus*	MSA			
126	*Loxura*	*atymnus*	*atymnus*	MSA			
127	*Anthene*	*lycaenina*	*lycaenina*	MSA			
128	*Acytolepis*	*lilacea*	*lilacea*	MSA			

	Genus	Species	Subspecies	Status	Endemic status	IUCN Redlist Status	WPA 1972
129	*Acytolepis*	*puspa*	*felderi*	MSA			
130	*Caleta*	*decidia*	*decidia*	MSA			
131	*Castalius*	*rosimon*	*rosimon*	MSA			
132	*Celastrina*	*lavendularis*	*lavendularis*	MSA			
133	*Chilades*	*lajus*	*lajus*	MSA			
134	*Chilades*	*pandava*	*pandava*	MSA			
135	*Discolampa*	*ethion*	*ethion*	MSA			
136	*Ionolyce*	*helicon*	*viola*	MSA			
137	*Jamides*	*alecto*	*eurysaces*	MSA			
138	*Jamides*	*bochus*	*bochus*	MSA			
139	*Jamides*	*celeno*	*celeno*	MSA			
140	*Megisba*	*malaya*	-	MSA			
141	*Nacaduba*	*berenice*	*ormistoni*	MSA			
142	*Nacaduba*	*beroe*	*gythion*	MSA			
143	*Nacaduba*	*calauria*	-	MSA			
144	*Nacaduba*	*hermus*	*sidoma*	MSA			
145	*Nacaduba*	*kurava*	*canaraica*	MSA			
146	*Nacaduba*	*pactolus*	*continentalis*	MSA			Sh II
147	*Petrelaea*	*dana*	-	MSA			
148	*Prosotas*	*dubiosa*	*indica*	MSA			
149	*Prosotas*	*nora*	*ardates*	MSA			
150	*Prosotas*	*noreia*	*hampsonii*	MSA			Sh I
151	*Pseudozizeeria*	*maha*	*ossa*	MSA			
152	*Zizeeria*	*karsandra*	-	MSA			
153	*Zizina*	*otis*	*indica*	MSA			
154	*Zizula*	*hylax*	*hylax*	MSA			
155	*Neopithecops*	*zalmora*	*dharma*	MSD			
156	*Freyeria*	*putli*	-	STR			
157	*Leptotes*	*plinius*	*plinius*	STR			
158	*Talicada*	*nyseus*	*nyseus*	STR			
159	*Spalgis*	*epeus*	*epeus*	STR			
160	*Zesius*	*chrysomallus*	-	MSA			
Hesperiidae							
161	*Badamia*	*exclamationis*	-	MSA			
162	*Bibasis*	*sena*	*sena*	MSA			Sh II
163	*Burara*	*jaina*	*fergusonii*	MSA			
164	*Hasora*	*chromus*	*chromus*	MSA			
165	*Celaenorrhinus*	*leucocera*	-	MSA			
166	*Celaenorrhinus*	*putra*	-	MSA			
167	*Pseudocoladenia*	*dan*	*dan*	MSA			
168	*Sarangesa*	*dasahara*	*dasahara*	MSA			
169	*Tagiades*	*gana*	*silvia*	MSA			
170	*Tagiades*	*litigiosa*	*litigiosa*	MSA			
171	*Caprona*	*ransonnettii*	*potiphera*	STR			
172	*Coladenia*	*indrani*	*indra*	STR			Sh II

	Genus	Species	Subspecies	Status	Endemic status	IUCN Redlist Status	WPA 1972
173	*Gerosis*	*bhagava*	*bhagava*	STR			
174	*Odontoptilum*	*angulata*	*angulata*	STR			
175	*Tapena*	*thwaitesi*	-	STR			
176	*Aeromachus*	*pygmaeus*	-	MSA			
177	*Ampittia*	*dioscorides*	*dioscorides*	MSA			
178	*Cupitha*	*purreea*	-	MSA			
179	*Erionota*	*torus*	-	MSA			
180	*Hyarotis*	*adrastus*	*praba*	MSA			Sh IV
181	*Iambrix*	*salsala*	*luteipalpis*	MSA			
182	*Matapa*	*aria*	-	MSA			
183	*Notocrypta*	*curvifascia*	*curvifascia*	MSA			
184	*Notocrypta*	*paralysos*	*mangla*	MSA			
185	*Psolos*	*fuligo*	*subfasciatus*	MSA			
186	*Quedara*	*basiflava*	-	MSA	Western Ghats		
187	*Salanoemia*	*sala*	-	MSA			
188	*Sovia*	*hyrtacus*	-	MSA	Western Ghats		
189	*Suastus*	*minuta*	*bipunctus*	MSA			
190	*Thoressa*	*astigmata*	-	MSA	Western Ghats		
191	*Thoressa*	*honorei*	-	MSA	Western Ghats		Sh IV
192	*Udaspes*	*folus*	-	MSA			
193	*Gangara*	*thyrsis*	*thyrsis*	STR			Sh IV
194	*Halpe*	*hindu*	-	STR	Western Ghats		
195	*Halpe*	*porus*	-	STR			
196	*Zographetus*	*ogygia*	*ogygia*	STR			Sh IV
197	*Oriens*	*goloides*	-	MSA			
198	*Potanthus*	*pseudomaesa*	*pseudomaesa*	MSA			
199	*Telicota*	*bambusae*	*bambusae*	MSA			
200	*Telicota*	*colon*	*colon*	MSA			
201	*Baoris*	*farri*	-	MSA			
202	*Borbo*	*cinnara*	-	MSA			Sh IV
203	*Caltoris*	*kumara*	*kumara*	MSA			
204	*Caltoris*	*philippina*	*philippina*	MSA			
205	*Pelopidas*	*mathias*	*mathias*	MSA			
206	*Polytremis*	*lubricans*	*lubricans*	MSA			

Key: STR: Straggler, SL: Sri Lanka, Sh: Schedules of Indian Wildlife (Protection) Act, 1972.

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13334–13349

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM
OPEN ACCESS

Pollination ecology of three ecologically valuable carpetweed herbs, *Mollugo cerviana*, *M. nudicaulis* and *M. pentaphylla* (Molluginaceae)

Maddala Sulakshana [1] & **Aluri Jacob Solomon Raju** [2]

[1] Department of Botany, [2] Department of Environmental Sciences,
Andhra University, Visakhapatnam, Andhra Pradesh 530003, India.
[1] sulakshana.maddala3@gmail.com; [2] solomonraju@gmail.com (corresponding author)

Abstract: *Mollugo cerviana, M. nudicaulis* and *M. pentaphylla* are annual herbs which usually grow in open dry sandy and sandy/loamy soils, and also occur in moist habitats, especially cultivated lands. The flowers possess five tepals, functional stamens and 3-carpelled ovary with several ovules and three stigmas. *M. nudicaulis* and *M. pentaphylla* are pollinated by insects. *Haplothrips* uses the flowers for breeding and feeding, which affects pollination. These species have specialized floral structural and functional behaviours for self-induced and spontaneous autogamy while keeping the options open for insect pollination after anthesis. They are facultative autogamous, which is reflected in pollen-ovule ratios and natural fruit and seed set rates. Seed dispersal modes include anemochory, ombrohydrochory and hydrochory. The seeds germinate immediately after their dispersal, and soil moisture is important in rupturing the seed coat. These species are best adapted to survive in open dry habitats as they take advantage of any sign of temporary humidity to complete their life cycle quickly.

Keywords: Anemochory, facultative autogamy, hydrochory, insect-pollination, ombrohydrochory, soil binder.

DOI: https://doi.org/10.11609/jott.3999.11.3.13334-13349

Editor: Kannan C.S. Warrier, Institute of Forest Genetics and Tree Breeding, Coimbatore, India. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #3999 | Received 04 January 2018 | Final received 06 February 2019 | Finally accepted 12 February 2019

Citation: Sulakshana, M. & A.J.S. Raju (2019). Pollination ecology of three ecologically valuable carpetweed herbs, *Mollugo cerviana*, *M. nudicaulis* and *M. pentaphylla* (Molluginaceae). *Journal of Threatened Taxa* 11(3): 13334–13349; https://doi.org/10.11609/jott.3999.11.3.13334-13349

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Author Details: Mrs. M. Sulakshana PhD, has published four research papers on pollination ecology. Prof. A.J. Solomon Raju is working in the Department of Environmental Sciences, Andhra University, Visakhapatnam. He is the recipient of several national and international awards. He has more than 300 research papers in international and national Journals.

Author Contribution: Both the authors contributed equally overall.

Acknowledgements: We are thankful to Andhra University, Visakhapatnam, for providing the physical facilities.

INTRODUCTION

Hutchinson (1926) recognized Molluginaceae as distinct from Aizoaceae. Molluginaceae genera previously included in the larger family Aizoaceae have been separated and treated under the Molluginaceae in subsequent classifications of the Angiosperm Phylogeny Group (APG) 1998, APG II of 2003, APG III of 2009 and APG IV of 2016. APG IV classification is the modern molecular-based system of plant taxonomy for flowering plants (angiosperms). The genus *Mollugo* is distributed in tropical to warm temperate parts of North and South America, Europe, Africa and Asia. The generic name is derived from the Latin word "*mollis*" meaning soft (Short 2002). *M. cerviana* is native to India, Sri Lanka, Pakistan and Bangladesh (Parvathamma & Shanthamma 2000). *M. nudicaulis* is distributed throughout tropical Africa and Asia (Burrows & Willis 2005). *M. cerviana* is a C_4 species, *M. nudicaulis* C_3-C_4 species and *M. pentaphylla* C_3 species; the first species is distributed in hot arid regions from pantropics to temperate regions while the other two species are distributed from pantropical and subtropical regions (Christin et al. 2010). These three species are valuable in traditional medicine for treating different diseases and ailments (Parvathamma & Shanthamma 2000; Rajamanikandan et al. 2011; Sahu et al. 2012).

Little is known about the pollination ecology of Molluginaceae, where nectar secreting tissue is present in almost all species. In several genera showy sepals or petals have evolved, both of which strongly suggest entomophily (Watson & Dallwitz 1992; Kubitzki et al. 1993). *Mollugo verticillata* is pollinated by the syrphid fly *Mesogramma marginata* (Robertson 1928). The most widely spread, weedy species of *Mollugo verticillata, M. nudicaulis* and *M. cerviana* are self- and insect-pollinated (Pax & Hoffmann 1934; Bogle 1970). In Taiwan, *M. pentaphylla* is a minor pollen source for *Apis mellifera* (Lin et al. 1993). In southern India, honey bees use *Mollugo* species as pollen source and reciprocate the plants with pollination (Ponnuchamy et al. 2014). The present study examines how *M. cerviana, M. nudicaulis* and *M. pentaphylla* are able to reproduce in semi-dry and dry habitats where pollinators are usually scarce. The principal objective of this study is to understand how floral biology, sexual and breeding systems, pollination mechanisms, fruiting ecology and seed dispersal collectively contribute to the success of sexual reproduction in these three species growing in dry habitats.

MATERIALS AND METHODS

Wild patches of *Mollugo cerviana, M. nudicaulis* and *M. pentaphylla* growing in open dry and semi-dry areas of Visakhapatnam and its surroundings (17.686^{0}N & 83.218^{0}E) were selected for study during March 2015–May 2017. Field trips were conducted to record phenological aspects. Ten inflorescences which have not initiated flowering on five plants were tagged and followed to record anthesis schedule and the timing of anther dehiscence. Twenty-five fresh flowers were used to record the floral morphological details. Nectar could not be measured and analyzed due to its secretion in minute quantity which was further depleted by thrips during mature bud and flower life. Twenty mature, but un-dehisced anthers, two anthers each per flower/plant from ten plants were collected and examined for pollen output as per the protocol described in Dafni et al. (2005). The calculation of pollen output per flower and pollen-ovule ratio was done as per the formulas described in Cruden (1977). Ten flowers each from five individuals were used to test stigma receptivity. It was tested with hydrogen peroxide from mature bud stage to flower closure/drop as per Dafni et al. (2005). Seventy inflorescences were tagged prior to the initiation of their flowering and followed for three weeks to record fruit and seed set rate in open-pollinations. The fruit and seed morphological characteristics were observed in detail to evaluate their adaptations for dispersal by different means. Fields visits were made during rainy season to note the aspects of seed germination and production of new plants. Based on the timings of maturation of anthers and receptivity of stigmas, the sexual system was defined and also elaborately explained its functionality to achieve self-induced autogamy, spontaneous autogamy, geitonogamy and xenogamy. The positions of stamens and stigmas during and after anthesis were observed to evaluate as to how they facilitate spontaneous autogamy during anthesis and flower closure. Further, observations were also made to evaluate as to how these positions preclude self-pollination when flowers stay open.

Insects foraging at the flowers were observed from morning to evening on four different days for their mode of approach, landing, probing behavior and contact with the floral sexual organs. Bees were identified from representative specimens available with the Department of Environmental Sciences, Andhra University, Visakhapatnam. Butterflies were identified by consulting the books of Kunte (2007) and Gunathilagaraj et al. (1998). The foraging visits of

insects were recorded using 1mx1m area of flowering patch for 10min at each hour for the entire day on four different days and the data were tabulated to record the foraging pattern and the percentage of visits made by different insect categories. The pollen/nectar collection behaviour of insects was carefully observed to assess their role in effecting pollination. Ten specimens of each insect species were captured during 0800–1100 h and brought to the laboratory. Each specimen was washed in ethyl alcohol, stained with aniline-blue on a glass slide and observed under microscope to count the number of pollen grains present. From this, the average number of pollen grains carried by each insect species was calculated to know the pollen carryover efficiency.

RESULTS

Phenology

Mollugo cerviana is a small, glabrous, slender annual herb. It is common in open dry sandy and semi-dry soils along roadsides, waste places, bare ground and dry river beds (Image 1a). Its presence is usually overlooked due to its very low ground habit, wiry reddish orange stems and thin linear leaves. The stems are numerous, upright, thin and stiff. Leaves are sessile, grey green and linear with acute apex; they arise in whorls on the stem but some are in a rosette at the base. *M. nudicaulis* is a small acaulescent annual herb with a rosette of prostrate leaves while *M. pentaphylla* is small much-branched annual herb with a thin tap root. *M. nudicaulis* (Image 2a,b) and *M. pentaphylla* (Image 4a) are common in open dry sandy and moist soils along roadsides, waste places, bare ground and cultivated lands. In *M. nudicaulis*, the leaves are sessile, succulent, glabrous, obovate to spathulate, margin entire and apex rounded. In *M. pentaphylla,* the stem is thin, angular, glabrous and tinged with brownish red when old. Leaves are petiolate, unequal, succulent, glabrous, obovate to spathulate, margin entire and apex mucronate. The basal leaves are 5 or more in rosette formwhile those upwards vary from 4 to 1. All three species appear simultaneously in vegetative, flowering and fruiting phases in different populations growing in different habitats throughout the year (Image 1b, 4b). Individual plants, however, have a short life cycle of 3 months from seed germination to seed dispersal. Although they appear throughout the year, they show robust vegetative growth and profuse flowering and fruiting during July–October when soil is damp due to occurrence of rains. In *M. cerviana*, the flowers are borne on 7–8 mm long pedicels in dichotomous and trichotomous umbellate cymes produced terminally or in leaf axils. The inflorescence arises from the rosette of basal leaves in *M. nudicaulis* and from leaf axils and terminally in *M. pentaphylla*. In *M. nudicaulis*, the dichasial or trichasial cymes are common during dry season while polychasial cymes are common during wet season. In *M. pentaphylla*, polychasial cymes are common during wet season while di- or tri-chasial cymes are common during dry season. Further, the cymes are of spreading type, pedunculate and produce pedicellate flowers; the peduncle is 7–8 mm long pedicel is 4mm long in the former while the corresponding measures for the latter are 5–8 mm and 2–4 mm, respectively. In both, the peduncle and pedicel are wiry and stiff. A polychasial cyme produces 7.5 ± 1.5 flowers in *M. nudicaulis* and 13.83 ± 4.9 in *M. pentaphylla*.

Flower morphology

In all three species, the flowers are small, odourless, actinomorphic and bisexual. They are 2.52 ± 0.4 mm long, 1.51 **±** 0.5 mm wide, whitish green on adaxial side and green on abaxial side in *M. cerviana*; 3.51 ± 0.4 mm long, 4.03 **±** 0.3 mm wide, creamy white on adaxial side and light green on abaxial side in *M. nudicaulis*; and 2.75 ± 0.4 mm long, 1.8 **±** 0.4 mm wide, white on both adaxial and abaxial side in *M. pentaphylla*. In all, the sepals and petals are represented by a monochlamydeous perianth of 5 elliptic to oblong free tepals. They are 2.45 ± 0.4 mm long, 1.13 ± 0.2 mm wide with white margins in *M. cerviana*; 3.28 ± 0.41 mm long, 1.82 ± 0.33 mm wide, connate base and hooded apically in *M. nudicaulis*; and 2–3 mm long but connate at base in *M. pentaphylla*. The stamens are 5, anti-petalous and 1.22 ± 0.3 mm long in *M. cerviana*; 3–6 and 2.27 ± 0.17 mm long in *M. nudicaulis*; and 3-5 and 1.8 ± 0.17 mm long in *M. pentaphylla*. In all, the filaments are free, connate at base and tipped with dorsifixed dithecous anthers. In *M. pentaphylla*, the flowers with 3-stamens constituted 60%, those with 4-stamens 33% and those with 5-stamens 7%; these three types of flowers occur on the same plant. The flowers with 6-stamens are very rare. A single plant all with 5-stamened flowers was encountered during the study period and these flowers are prominently larger than other types of flowers. In 3-stamened flowers, one stamen is alterni-tepalous while the other two are anti-tepalous (Image 2e). In 4-stamened flowers, three stamens are alterni-tepalous while the other one is anti-tepalous. In 5-stamened flowers, two stamens are alterni-tepalous while the other three are anti-tepalous (Image 2f). In 6-stamened flowers, three stamens are alterni-tepalous while three

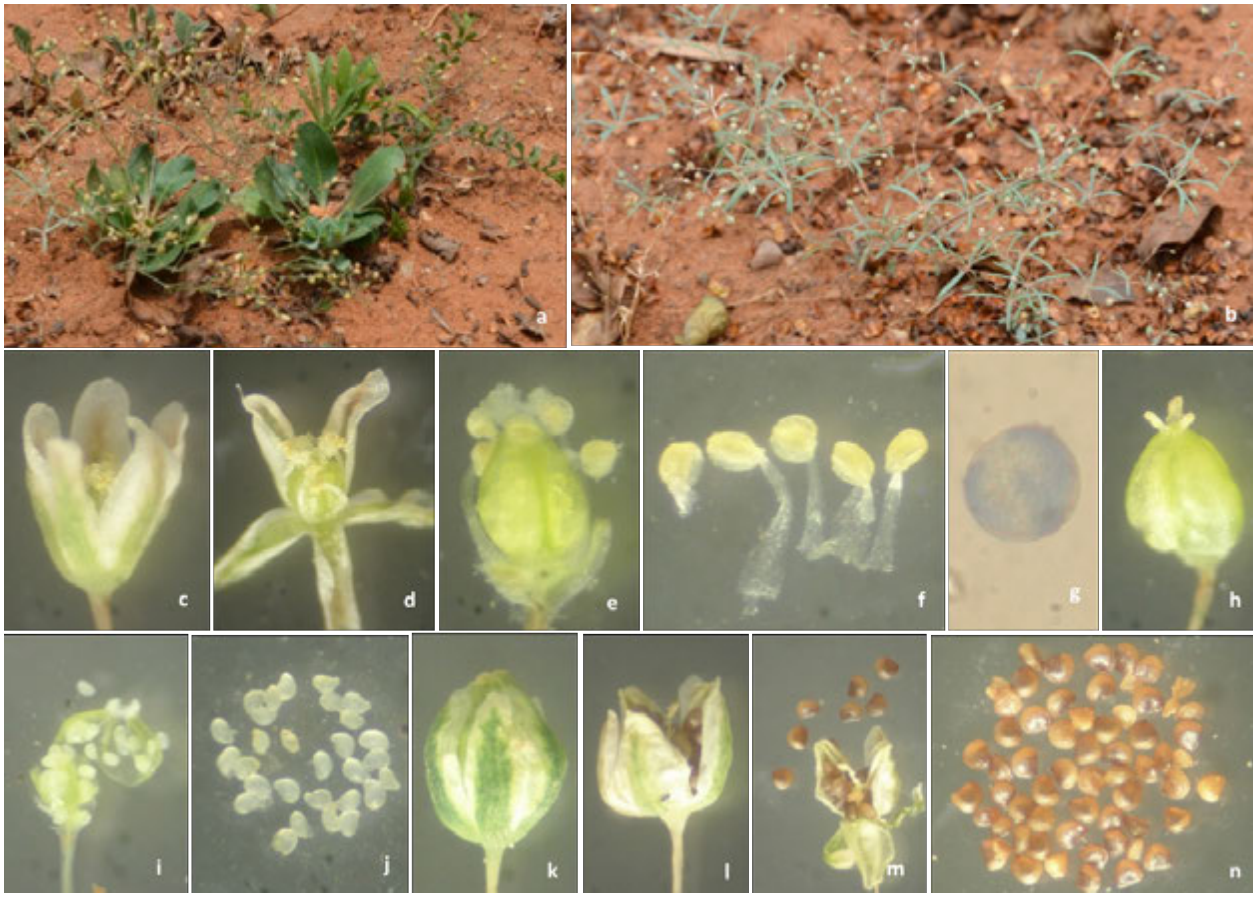


Image 1. *Mollugo cerviana*: a. Habitat with *M. nudicaulis*, b. flowering phase, c. & d. Flowering-opening phase, e. Position of stigmatic lobes and anthers at the same height contacting each other at anthesis, f. Dehisced anthers, g. Pollen grain, h. Ovary with three stigmas, i. & j. Multi-ovuled ovary, k. Maturing fruit, l. & m. Dehisced fruit capsule, n. Seeds. © A.J. Solomon Raju.

others are anti-tepalous (Image 2g). In *M. pentaphylla*, the flowers with 3-stamens constituted 91%, those with 4-stamens 7% and those with 5-stamens 2%; all theree types of flowers occur on the same plant. In 3-stamened flowers, one stamen is alterni-tepalous while the other two are anti-tepalous. In 4-stamened flowers, three stamens are alterni-tepalous while the other one is anti-tepalous. In 5-stamened flowers, two stamens are alterni-tepalous while the other three are anti-tepalous. In all three species, the ovary is light green, tri-carpellary, tri-locular syncarpous with ovules arranged on axile placentation (Image 1i,j, 2k, 4i). The ovules are 58.2 ± 8.16 in *M. cerviana* but the ovule number varied with change in stamen number in the other two species. In *M. nudicaulis*, they are 17.45 ± 3.51 in 3-stamened flowers, 19.9 ± 2.88 in 4-stamened flowers and 23.1 ± 3.70 in 5-stamened flowers. In *M. pentaphylla*, they are 16.02 ± 4.0 in 3-stamened flowers, 18.44 ± 2.0 in 4-stamened flowers and 20.11 ± 2.6 in 5-stamened flowers. The ovules are D-shaped in *M. cerviana* and *M. nudicaulis*, and reniform in *M. pentaphylla*. In all, the style is absent but the ovary is terminated with 3 free stigmas (Image 1h, 2j, 4h). The stigmas are minutely denticulate with membranous flaps in *M. cerviana* while they are densely papillose, shiny and spreading in the other two species.

Floral biology

In all three species, mature buds open during 0700-0800 h and extend until 0900h in *M. pentaphylla* (Image 2d). Individual buds take 5 to 10 minutes from partial to full opening (Image 1c,d; 4c–e). The flowers are homogamous as the anthers and stigmas attain maturity at the same time during anthesis; the former dehisce by longitudinal slits (Image 1f, 2h) while the latter continue receptivity until the noon of the second day. In *M. cerviana*, the pollen output is 159.7 ± 14.5 per anther and 798.5 ± 69.5 per flower. The pollen-ovule ratio is 14:1. In *M. nudicaulis*, the pollen output varied with change in stamen number. It varied from 209.6 ± 17.12 to 171.4 ± 13.44 per anther and from 628.8 ± 51.36 to

Image 2. ***Mollugo nudicaulis:*** **a. Habit - flowering phase, b. Individual plant in flowering, c. New plants, d. Bud, e. 3-stamened flower, f. 5-stamened flower, g. 6-stamened flower, h. Dehisced anthers, i. Pollen grain, j. Ovary with three styles, k. Ovules, l. Maturing fruit, m. Dehisced fruit capsule, n. Dehisced fruit capsule with seeds intact, o. Seeds. © A.J. Solomon Raju.**

Table 1. Pollen aspects in *Mollugo nudicaulis* and *Mollugo pentaphylla*

Flower type	Percentage of occurrence	Mean pollen output/ anther	Mean pollen output/ flower	Mean no. of ovules/ flower	Pollen: ovule ratio
Mollugo nudicaulis					
3-stamened	60	209.6 ± 17.12	628.8 ± 51.36	17.45 ± 3.51	36 : 1
4-stamened	33	184.4 ± 13.12	737.6 ± 52.48	19.90 ± 2.88	37 : 1
5-stamened	7	171.4 ± 13.44	857.0 ± 67.20	23.10 ± 3.70	37 : 1
Mollugo pentaphylla					
3-stamened	91	277.2 ± 13.4	831.6 ± 40.2	16.02 ± 4.0	52 : 1
4-stamened	7	242.6 ± 19.6	970.4 ± 78.4	18.44 ± 2.0	53 : 1
5-stamened	2	213.4 ± 12.9	1067 ± 64.5	20.11 ± 2.6	53 : 1

857 ± 67.2 per flower in 3- to 5-stamened flowers (Table 1). The pollen-ovule ratio is 36:1 in 3-stamened flowers while it is 37:1 in 4- and 5-stamened flowers. In *M. pentaphylla*, it varied from 277.2 ± 13.4 to 213.4 ± 12.9 per anther and from 831.6 ± 40.2 to 1067 ± 64.5 per flower in 3- to 5-stamened flowers (Table 1). The pollen-ovule ratio is 52:1 in 3-stamened flowers while it is 53:1 in 4- and 5-stamened flowers. In both *M. nudicaulis* and *M. pentaphylla*, the pollen production trend showed that pollen output rate gradually increased with a gradual decrease in the number of stamens produced per flower. The pollen grains are pale yellow, spheroidal, tri-colpate, tri-zonoaperturate, granulated, tectum scabrate, 21.9 ± 4.12 µm (Image 1g; 2i, 4g). In all three species, the nectar is secreted in traces during mature bud stage. The tepals together with the stamens and stigmas close

back by 1000–1100 h but this event extends until 1200h in *M. nudicaulis*.

Pollination mechanism and Pollinators

In all three species, dehisced anthers collected during anthesis showed some percentage of pollen formed tubes indicating *in situ* germination. It varied from 20% to 25% in *M. cerviana*, from 11% to 21% in *M. nudicaulis* and from 18% to 26% in *M. pentaphylla*. In all, the pollen tubes were also found on the stigma. The pollen germination and formation of tubes both within the dehisced anthers and on the stigma indicate that the presence of self-induced autogamy. In *M. cerviana*, during and after anthesis, the dehisced anthers and receptive stigmas contact with each other due to their close proximity and their position at the same height due to which autogamy occurs (Image 1e). In the other two species, during anthesis, one anther in 3-stamened flowers and 2–3 anthers in 4- and 5-stamened flowers contact the stigmas due to their close proximity and their position at the same height (Image 4f). With this situation, the anthers brush against the stigmas causing autogamy. After anthesis, all anthers move away from the stigmas but both the sex organs are situated at the same height facilitating vector-mediated self- or cross-pollination. In all the three species, during the closing of the flower, the stamens and stigmas contact each other very closely assuring autogamy if it did not occur during open state of the flower.

Thrips pollination

Haplothrips sp. (Thysanoptera: Thripidae) used the flower buds of all three species for breeding and flowers for feeding. The larvae emerged from the eggs in synchrony with anthesis and nectar production in flowers. The larvae and adults foraged for pollen and nectar. Individual thrips were dusted with pollen during their movements within the flowers. They carried pollen on their body setae, wings and legs. The pollen carried by them varied from 87 to 176 pollen grains in *M. cerviana*, from 69 to 158 in *M. nudicaulis* and 89 to 217 in *M. pentaphylla*. The thrips dispersed the pollen on free denticulate and membranous stigmas of *M. cerviana* and on free densely papillose spreading stigmas of *M. nudicaulis* and *M. pentaphylla* due to their active movement, rubbing of abdomen against the stigmatic surface, cleansing of their body parts with their hind legs and also by their wing combing mechanism. In all, the homogamous flowers were found to facilitate self-pollination in the same or different flowers of the same plant. As the plant occurs as small or large populations, thrips could fly to migrate to the flowers of other closely spaced plants and effect cross-pollination by feeding on the forage.

Insect pollination

The flowers of *M. cerviana* were never visited by any insects. The flowers of *M. nudicaulis* were foraged by bees, flies and butterflies while those of *M. pentaphylla* by bees and butterflies. Bees and flies foraged for pollen and nectar while butterflies for nectar only during 0800–1100 h with concentrated foraging activity during 0900–1000 h (Figs. 1–4). The bees, *Apis cerana* (Image 3a, 5a), *A. florea* (Image 3b, 5b), *Trigona iridipennis* (Image 3c, 5c), *Ceratina* sp. (Image 3d, 5d) visited the flowers of both *M. nudicaulis* and *M. pentaphylla*; the former was

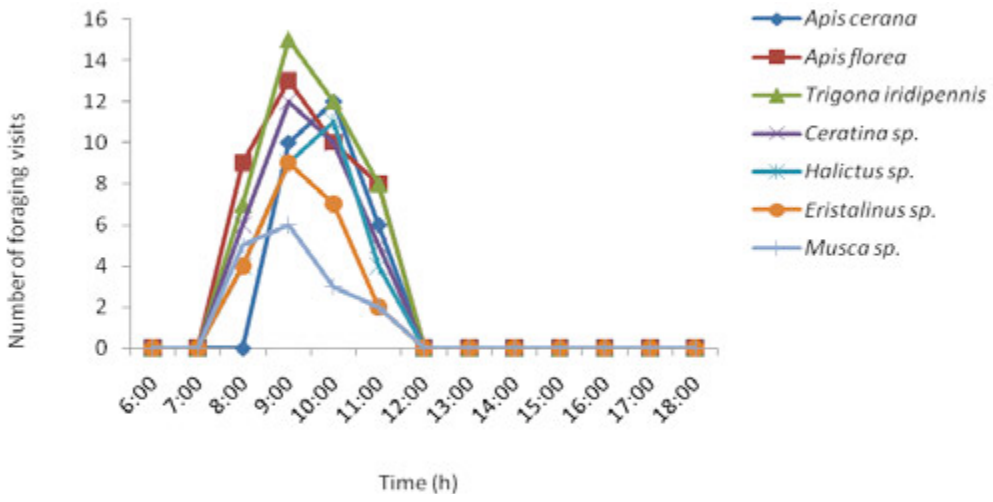


Figure 1. Hourly foraging visits of bees and flies on *Mollugo nudicaulis*

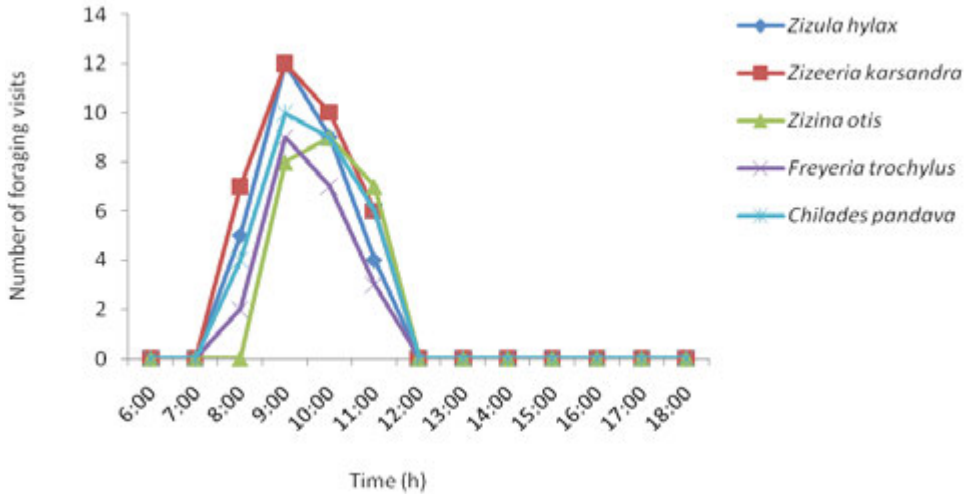


Figure 2. Hourly foraging activity of lycaenid butterflies on *Mollugo nudicaulis*

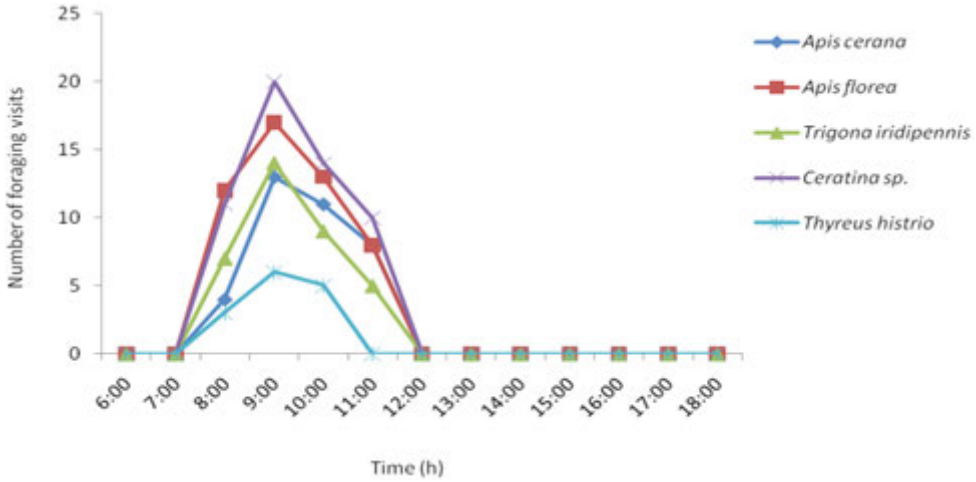


Figure 3. Hourly foraging activity of bees on *Mollugo pentaphylla*

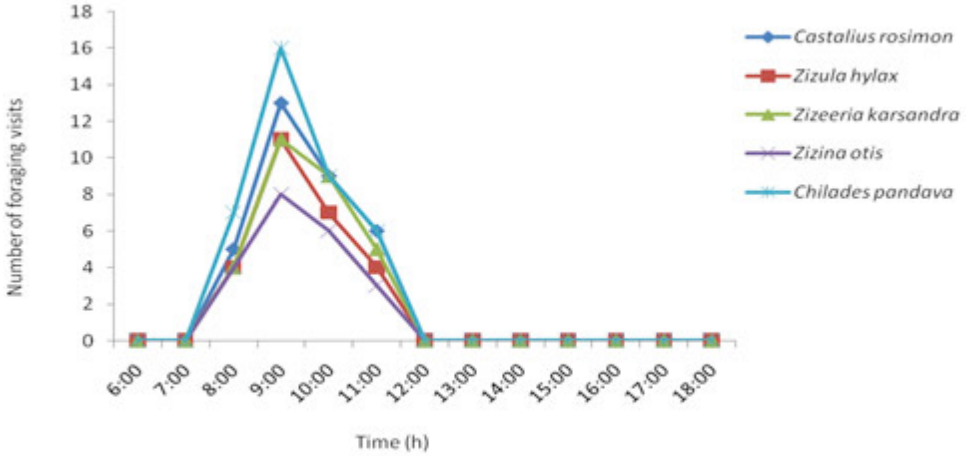


Figure 4. Hourly foraging activity of lycaenid butterflies on *Mollugo pentaphylla*

Image 3. *Mollugo nudicaulis:* a. *Apis cerana*, b. *Apis florea*, c. *Trigona iridipennis*, d. *Ceratina* sp., e. *Halictus* sp., f. *Eristalinus* sp., g. *Musca* sp., h–j. Lycaenids - h. *Zizeeria karsandra*, i. *Zizina otis*, j. *Chilades pandava*. © A.J. Solomon Raju.

also visited by *Halictus* sp. (Image 3e) and the latter also by *Thyreus histrio* (Image 5e). The flies recorded on *M. nudicaulis* were *Eristalinus* sp. (Image 3f) and *Musca* sp. (Image 3g). The butterflies represented only lycaenids - *Zizula hylax* (Image 5g), *Zizeeria karsandra* (Image 3h, 5h), *Zizina otis* (Image 3i) and *Chilades pandava* (Image 3j) (Table 2) foraged on the flowers of both plant species. *M. nudicaulis* was also visited by *Freyeria trochylus* and *M. pentaphylla* also by *Castalius rosimon* (Image 5f). All these insects approached the flowers in upright position, landed on the tepals and then probed for forage collection. Bees first accessed anthers to collect pollen and then moved to the flower base to collect nectar, if available in the same and/or different visits. Flies and butterflies stretched out their proboscis and inserted into the flower base to collect nectar. All insect species collected forage from several flowers of different cymes of the same or different plants to collect the forage. The bees during pollen collection brushed against the stigmas with their ventral surface effecting sternotribic pollination. Further, these insects during nectar collection brushed against anthers and stigmas with their dorsal surface effecting nototribic pollination. The flies and butterflies during nectar collection contacted the stamens and stigmas with their proboscis and occasionally front side of head and ventral surface of thorax and abdomen effecting sternotribic pollination. The butterfly wings never contacted the stamens and stigma during nectar collection as they kept them in vertical position. In *M. nudicaulis*, bees made 49%, flies

Table 2. List of insect foragers on *Mollugo nudicaulis* and *Mollugo pentaphylla*

Order/Family	Insect species	*Mollugo nudicaulis*	*Mollugo pentaphylla*
Hymenoptera			
Apidae	*Apis cerana* F.	+	+
	Apis florea F.	+	+
	Trigona iridipennis Smith	+	+
	Ceratina smaragdula F.	-	-
	Ceratina sp.	+	+
	Thyreus histrio	-	+
Halictidae	*Halictus* sp.	+	-
Megachilidae	*Megachile* sp.	-	-
Formicidae	*Camponotus* sp.	-	-
	Crematogaster sp.	-	-
Diptera			
Syrphidae	*Eristalinus* sp.	+	-
Muscidae	*Musca* sp.	+	-
Lepidoptera			
Lycaenidae	*Castalius rosimon* F.	-	+
	Zizula hylax F.	+	+
	Zizeeria karsandra Moore	+	+
	Zizina otis F.	+	+
	Freyeria trochylus Freyer	+	-
	Chilades laius Stoll	-	-
	Chilades pandava Horsfield	+	+

Table 3. Pollen recorded in the body washings of insects on *Mollugo nudicaulis* and *Mollugo pentaphylla*

Insect species	Sample size (N)	*Mollugo nudicaulis*			*Mollugo pentaphylla*		
		Number of pollen grains			Number of pollen grains		
		Range	Mean	S.D.	Range	Mean	S.D.
Apis cerana	10	73–204	133.5	37.5	82–246	159.2	51.8
Apis florea	10	61–183	126.1	33.31	68–217	145.1	43.56
Trigona iridipennis	10	37–95	63.4	14.4	31–86	62.1	13.5
Ceratina sp.	10	34–62	47.8	8.27	24–51	38.2	9.07
Halictus sp.	10	41–87	69.8	12.2	---	---	---
Thyreus histrio		---	---	---	19–43	30.6	7.60
Eristalinus sp.	10	26–50	38.2	7.26	---	---	---
Musca sp.	10	11–38	27.9	7.5	---	---	---
Castalius rosimon	10	---	---	---	15–41	29.5	6.38
Zizula hylax	10		21.3	5.47	9–30	20.6	5.27
Zizeeria karsandra	10	13–32	23.8	5.57	13–45	27.8	9.49
Zizina otis	10	16–40	28.1	6.48	10–36	23.7	6.63
Freyeria trochylus	10	8–31	24.4	7.19	---	---	---
Chilades pandava	10	15–36	28.5	6.27	8-43	30.7	8.8

11% and lycaenids 40% of total foraging visits. In *M. pentaphylla*, bees made 56% and lycaenids 44% of total foraging visits. The body washings of insects collected from the flowers during peak foraging period revealed that all insects carry pollen but bees carry the highest number of pollen grains. Further, the mean number of pollen grains varied with each insect species (Table 3). The nectar secretion in traces and its depletion by thrips during and after anthesis appeared to be driving the insects to visit as many flowering cymes as possible to quench their thirst for nectar. Such a foraging behavior was considered to be facilitating the promotion of cross-pollination.

Fruiting ecology and seed dispsersal

In all three species, fruits mature within 8–12 days (Image 6a). The stamens and stigmas are persistent and remain inside due to the closure of the flower. The tepals bulge gradually and protect the bulging ovary in which the seeds form and mature (Image 1k, 6b). The natural fruit set is 91.27% in M. cerviana, 86–89 % in *M. nudicaulis*, and 83–88 % in *M. pentaphylla*. Seed set rate is 61.94% in *M. cerviana*, 88–92 % in *M. nudicaulis*, and 83–86 % in *M. pentaphylla* (Table 4). Fruit is a loculicidal 3-valved broadly-ellipsoid capsule, stalked and membranous and densely pubescent in all three species but it is densely pubescent in *M. cerviana* and *M. nudicaulis* while it is glabrous in *M. pentaphylla*. It is 2.35 ± 0.36 mm and 1.85 ± 0.23 mm wide in *M. cerviana*, 3.4 ± 0.4 mm long and 2.33 ± 0.39 mm wide in *M. nudicaulis*, and 2.67 ± 0.4 mm long and 1.97 ± 1.4 mm wide in *M. pentaphylla*. In all three species, the seeds are arranged in two rows in each locule. In *M. cerviana*, the seeds are tiny, brown, shiny, D-shaped and faintly striate dorsally (Image 1n). The seed coat is studded with minute granular excrescences with reticulate ornamentation. In *M. nudicaulis* and *M. pentaphylla*, the seeds are tiny, black, slightly shiny, reniform and concentrically ridged (Image 2o, 6e). The seed coat is closely packed with uniformly distributed, pebble-like, lyrate and chipped areoles. Dry capsules break open when fruit pericarp and tepals are dry and expose the seeds (Image 1l,m; 2l,n; 6c). But the seeds remain so and gradually separate and fall to the ground on their own on clear sunny days. On rainy days, the water droplets falling on the dehisced capsules washout seeds to the ground. Water also acts as an efficient dispersal agent for seeds that fall during the rainy season. Seeds do not have adaptations for wind dispersal, but wind disperses dry cymes and dehisced capsules short distances and subsequently fall to the ground from capsules. Thus, seed dispersal modes include ombrohydrochory, hydrochory and anemochory. The seeds produced from plants growing in cultivated lands have the potential to be dispersed as a cereal grain contaminant and in effect agricultural produce movement contributes to seed dispersal and expansion of its distribution (Image 2c; 6f,g).

Image 4. *Mollugo pentaphylla:* a. Habit, b. Flowering phase, c–e. Different stages of anthesis, f. Position of anthers and stigmas at the same height, g. Pollen grain, h. Ovary with three stigmas, i. Ovules. © A.J. Solomon Raju.

Table 4. Natural fruit and seed set rate in *Mollugo nudicaulis* and *M. pentaphylla*

Flower type	Number of flowers sampled	Number of flowers set fruit	Fruit set (%)	Seed set (%)
Mollugo nudicaulis				
3-stamened	320	286	89	88
4-stamened	85	73	86	91
5-stamened	40	35	88	92
Mollugo pentaphylla				
3-stamened	250	220	88	83
4-stamened	150	130	87	84
5-stamened	75	62	83	86

DISCUSSION

Mollugo species are annual herbs which usually grow in open dry sandy and sandy and loamy soils but also occur in moist habitats, especially in cultivated lands. In this study, it is found that *M. cerviana*, *M. nudicaulis* and *M. pentaphylla* with their low ground habit populate the soil and for this reason, they are often called as carpet weeds. Of these, *M. cerviana* does not cover the soil extensively due to its wiry stems and thin, linear leaves. *M. nudicaulis* without any stem covers the soil with a rosette of prostrate leaves. *M. pentaphylla* with branched stems carpets the soil with its basal rosette form of leaves and upper spathulate leaves. All the three plant species grow throughout the year displaying vegetative, flowering and fruiting phases in different populations. Their robust growth, profuse flowering and fruiting, however, is confined to the wet season. Individual plants complete their life cycle within three months from seed germination to seed dispersal. Similarly, Owens & Lund (2009) reported that *M. cerviana* is a herbaceous ephemeral species and completes its life cycle in a very short time. In the present study, it is found that the inflorescence is a dichotomous or trichotomous umbellate cyme in *M. cerviana* while it is di- or tri- or poly-chasial cyme in *M. nudicaulis* and *M. pentaphylla*. In the last two species, di-/tri-chasial cymes are common during dry season while poly-chasial cymes are common during wet season, suggesting that the branching of inflorescences and the production rate of flowers is regulated by the soil moisture and nutrient environment. *M. cerviana* and *M. pentaphylla* produce inflorescences in leaf axils and terminally while *M. nudicaulis* produces inflorescences from the axils of rosette of leaves due to lack of stems. Since all the three plant species usually grow as green carpets, the simultaneous display of several flowers from individual plants and from the entire population(s) enhances their attraction to insect pollinators.

Image 5. *Mollugo pentaphylla:* Foragers: a. *Apis cerana*, b. *Apis florea*, c. *Trigona iridipennis*, d. *Ceratina* sp., e. *Thyreus histrio,* f–h. Lycaenid butterflies – f. *Castalius rosimon*, g. *Zizula hylax*, h. *Zizeeria karsandra*. © A.J. Solomon Raju.

Image 6. *Mollugo pentaphylla:* a. Fruiting phase, b. Maturing fruits, c. Dehisced fruit capsule, d. Dehisced fruit capsule with seeds intact, e. Seeds, f. & g. New plants. © A.J. Solomon Raju.

The floral descriptions of *Mollugo* species provided by different authors are not accurate. The present study provides details of the floral descriptions, especially of perianth, androecium and gynoecium in *M. cerviana, M. nudicaulis* and *M. pentaphylla* as these are important from the pollination of point view. In these species, perianth typically consists of five tepals which serve the function of calyx (sepals) and corolla (petals). In *M. cerviana* and *M. nudicaulis*, the abaxial surface of the perianth serves the role of calyx while the adaxial surface of the perianth serves the role of corolla due to display two different colours on each surface. But, in *M. pentaphylla*, the perianth is white on both abaxial and adaxial surface. The study shows that *M. cerviana* with perianth acting as both calyx and corolla is unable to attract any insect pollinators in pollinator-deprived

habitat or pollinator-available habitat. Such a situation explains that *M. cerviana* is not dependent on insect foragers for pollination. *M. nudicaulis* with perianth displaying light green on its abaxial surface and creamy white on its adaxial surface, and *M. pentaphylla* with perianth displaying white colour on both adaxial and abaxial surface attract insect foragers. Eckardt (1974) and Stannard (1988) reported that the sister genera of *Mollugo, Corbichonia* and *Lophiocarpus* have only four stamens of which three alternate with sepals and one is opposite a sepal. Batenburg & Moeliono (1982) reported that the presence of one stamen opposite a sepal is unusual in these genera and indicate that this stamen is derived from an original condition with five alternisepalous stamens by a fusion of two stamens under the influence of a reduced tetramerous ovary which is similar to a process occurring in *Mollugo*.

Ronse-De-Craene (2010) reported that in Molluginaceae including *Mollugo*, the androecium consists of generally of five stamens alternating with the sepals. In *Mollugo*, the number of stamens ranges from five in *M. cerviana* to three in *M. nudicaulis*. The present study shows that *M. cerviana* flowers produce a fixed number of 5 stamens and all are opposite to tepals suggesting that there is no process evolving to produce flowers with 3 or 4 stamens. *M. nudicaulis* produces flowers with 3-6 stamens while *M. pentaphylla* produces flowers with 3-5 stamens on the same plant. In these species, 3-stamened flowers have one stamen between two tepals and two stamens opposite to tepals, the 4-stamened flowers have three stamens alternate to tepals and one stamen opposite to a tepal, and the 5-stamened flowers have two stamens alternate to tepals and three stamens opposite to tepals. In *M. nudicaulis*, the 6-stamened flowers have three stamens alternate to tepals and three stamens opposite to tepals. The study indicates that all the three plant species produce trimerous ovary with three stigmas irrespective of the number of stamens produced in the flowers. In *M. nudicaulis* and *M. pentaphylla*, the production of 5-stamened flowers appears to be a residual trait still functional because these flowers are occasionally or rarely produced. In *M. nudicaulis*, the rarity of 6-stamened flowers may be a trait of polyploidy. In *M. nudicaulis* and *M. pentaphylla*, the two stamens opposite to tepals in 3-stamened flowers appear to be derived from the pair-wise fusion of four stamens (Ronse-De-Craene 2010) and the stamen opposite a tepal in 4-stamened flowers appear to be derived from the fusion of two stamens as in *Corbichonia* and *Lophiocarpus, sensu* Batenburg & Moeliono (1982). In *M. nudicaulis* and *M. pentaphylla*, the variation in pollen output levels due to variation in stamen number in 3-5(6) stamened flowers make bees and/or flies to fly from flower to flower in quick succession to collect pollen from the same or different conspecific plants and effect both self- and cross-pollination.

Hammer (1995) reported that different populations of Aizoaceae growing in the same habitat exhibit synchrony in flowering time. The period of flowering is usually short and the flowers show repeated opening but this phenomenon is restricted to a certain period of the day. Groen & van der Maesen (1999) observed that the mixed populations of Aizoaceae genera, *Bergeranthus, Faucaria* and *Orthopterum* flower simultaneously. These authors suggested that such a synchrony in flowering in these genera in the same habitat collectively enable them to enhance their floral attraction to pollinators. In the present study, it is found that *Mollugo* species form mixed and distinct populations in the same and different habitats depending on soil moisture and nutrient conditions. These species exhibit synchrony in flowering by opening flowers during morning time. Further, the flowers are too small, lack corolla, tepals not vividly coloured and stay open for a brief period of three hours for visitation by insects. Therefore, the synchrony in anthesis schedule and massive floral display appear to be imperative for them to attract pollinators during the brief period of open state of flowers.

Peter et al. (2004) reported that the temperature and relative humidity are probably important cues determining flower opening in the afternoon. In the present study, the anthesis during morning time in *Mollugo* species is attributable to their predominance in open, dry habitats where herbaceous flora usually do not grow. With synchrony in anthesis schedule, these species provide sufficient forage but insect foragers collect forage only from *M. nudicaulis* and *M. pentaphylla*. Bees and lycaenid butterflies visit and pollinate both the plant species while flies additionally visit and pollinate *M. nudicaulis*. Bees and butterflies are generalists which visit a wide range of flowers and hence are polylectic. Since *Mollugo* species keep the flowers open only for a brief period, the polylectic foragers soon switch over to other plant species which provide forage in the nearby habitats. The morning anthesis in *Mollugo* species ensures insect pollination and reciprocates the insect pollinators with pollen and/or nectar. The total absence of insect foraging activity on *M. cerviana* could be attributable to its common occurrence in pollinator-excluded or deprived habitats and production of tiny flowers which can be overlooked or unnoticed by

foragers.

Watson & Dallwitz (1992) stated that Molluginaceae members are entomophilous. These authors considered nectar secreting tissue and showy tepals in several species as adaptations for entomophily. Robertson (1928) reported that *Mollugo verticillata* is pollinated by syrphid fly, *Mesogramma marginata*. Pax & Hoffmann (1934) and Bogle (1970) stated that the showy sepals or petals evolved in several genera of Molluginaceae suggest entomophily. *Mollugo verticillata, M. cerviana* and *M. nudicaulis* are the most widely spread, weedy species and adapted for self- and insect-pollination. In the present study, it is found that in *Mollugo* species, the floral characters such as the erect position of flowers above foliage, adaxial surface of the tepals and nectar secreting tissue between the ovary base and connate part of staminal filaments appear to be adaptations for insect pollination. In *M. nudicaulis*, the bees while collecting pollen, and flies and butterflies while collecting nectar effect sternotribic pollination. Further, the bees while collecting nectar effect nototribic pollination. In *M. pentaphylla*, the bees while collecting pollen effect nototribic pollination. The bees and also butterflies while collecting nectar effect sternotribic pollination. In *M. nudicaulis* and *M. pentaphylla*, the pollen output per anther varies with the number of stamens present in the flowers; it increases with a decrease in the stamen number. The pollen output per flower in *M. pentaphylla* is more than in *M. nudicaulis*. The variation in pollen production in these plant species is partly attributable to the number of stamens produced. The varying amount of pollen output in the flowers of the same and different inflorescences on the same plant drives the pollen collecting bees to visit the flowers across population(s) in search of more pollen and such a foraging activity contributes to both self- and cross-pollination. The nectar secreted in traces in both the species and nectar removal by thrips species, *Haplothrips* also drives the nectar collecting bees, flies and lycaenid butterflies to visit flowers across population(s) due to which both self- and cross-pollinations occur. *M. nudicaulis* and *M. pentaphylla* appear to be important sources of pollen for bees, especially for honey bees. Further, these plant species in the study area are important nectar sources for lycaenid butterflies. Among butterflies, lycaenids are the smallest, low-flying and appropriate pollinators for prostrate herbs, *M. nudicaulis* and *M. pentaphylla*.

Bhargava (1934) and Kshirsagar (1960) reported *in situ* pollen germination in *M. nudicaulis* and *M. pentaphylla*. Johri et al. (1992) noted that self-pollination seems to occur in these species as pollen tubes reached the ovules of ovaries in un-opened flowers and pollen grains with pollen tubes occur both inside the anther and on the stigma of the same flowers. But, these authors did not mention the time of the occurrence of these events in unopened flowers. In the present study, all three *Mollugo* species show certain percentage of pollen germination only in the dehisced anthers and also the pollen tube formation on the stigma during anthesis process which occurs in individual flowers over a period of five to ten minutes. Such *in situ* pollen germination and the occurrence of pollen tubes on the stigma during the process of anthesis facilitates self-induced autogamy to some extent. In *M. cerviana*, the close proximity of dehisced anthers of all five anthers to the stigmas facilitate the occurrence of spontaneous autogamy. In *M. nudicaulis* and *M. pentaphylla*, the close proximity of one dehisced anther in 3-stamened flowers and 2-3 dehisced anthers in 4- and 5-stamened flowers facilitate the occurrence of spontaneous autogamy. The minutely denticulate stigmas with membranous flaps in *M. cerviana* and densely papillose spreading stigmas in *M. nudicaulis* and *M. pentaphylla* capture pollen easily from the dehisced anthers to result in pollination. Further, in all the three *Mollugo* species, the thrips emerging from the floral buds during anthesis and their movements in the flowers after anthesis for pollen and nectar collection result in autogamy. They also bring about geitonogamy due to their migration to different inflorescences on the same plant for forage collection and xenogamy due to their migration to other conspecific plants for forage collection. In these plant species, the movement of tepals together with stamens towards the pistil during the flower closure facilitates contact between the sex organs and effects spontaneous autogamy if pollen is still available in the dehisced stamens. Further, the tiny thrips have the possibility to carry pollen from other flowers, enter the closed flowers from the apical portion and laterally, and deposit the same on the stigmas effecting either geitonogamy or xenogamy. Therefore, all the three *Mollugo* species have specialized floral structural and functional behaviours for self-induced and spontaneous pollination while keeping the options open for insect pollination after anthesis.

In the present study, all three *Mollugo* species have three carpels with variation in ovule number per flower which is highest in *M. cerviana* and lowest in the other two *Mollugo* species. In *M. nudicaulis* and *M. pentaphylla*, the ovule number also varies depending on the number of stamens and pollen output per flower. This ovule production trend indicates that the pollen output increases with an increase in ovule number in

order to provide sufficient pollen to fertilize as many ovules as possible. This situation is reflected in the natural fruit and seed set rates in both the plant species. The highest fruit and seed set rates and also the lowest pollen-ovule ratios recorded in *Mollugo* species now studied indicate that they are facultatively autogamous.

Bittrich (1990) reported that in Molluginaceae, *Adenogramma* is the only genus which produces one-seeded nutlets. All other genera produce capsules with many seeds which become exposed by loculicidal dehiscence. Soerjani et al. (1987) reported that *Mollugo pentaphylla* is hydrochorous. In the present study, the *Mollugo* species produce fruits within a week or slightly more than a week. The fruit is a 3-valved broadly ellipsoid capsule which breaks open and exposes the seeds on clear sunny days; the seeds subsequently fall to the ground. On rainy days, water drops find their way into the fruits which are then filled with water. In effect, the fruits expel both water and seeds explosively. Further, wind disperses the dry cymes together with dry dehisced capsules to short distances and subsequently the seeds fall to the ground from the capsules. The seeds that reach the ground through these modes are further disseminated through surface water runoff during rain fall. Therefore, *Mollugo* species now studied exhibit anemochory, ombrohydrochory and hydrochory.

Narayana (1962) and Hofmann (1973) noted that *Mollugo* species produce seeds with a primordium-like swelling on the funiculus and this structure is considered to be a vestigial aril. In the present study, it is found that *M. cerviana* produces tiny, brown, shiny, D-shaped seeds with faintly striate dorsal surface. The seed coat is studded with minute granular excrescences with reticulate ornamentation. *M. nudicaulis* and *M. pentaphylla* produce tiny, black, slightly shiny, reniform and concentrically ridged seeds. The seed coat is closely packed with uniformly distributed, pebble-like, lyrate and chipped areoles. Since the seeds of these plant species lack any aril or strophiole-like structure that usually serves as food for ants, the possibility for myrmecochory is ruled out. Wagner et al. (1999) noted that *Mollugo* species produce fruit capsules and inside seeds that lack means of external attachment for dispersal by animals. The present study is also in agreement with this report as all the three *Mollugo* species now studied do not have external structures that aid in the dispersal of seeds by animals. Therefore, seed dispersal by animals is totally ruled out.

Bittrich & Ihlendfeldt (1984) reported that *Mollugo* seeds germinate by means of an operculum. *M. cerviana* and *M. pentaphylla* propagate by seeds and reseed themselves, often forming colonies. The present study showed that *Mollugo* species produce several batches of populations in a year and their seeds germinate as soon as they are dispersed but their germination is related to soil moisture which plays an important role in breaking the seed coat. As therophytes, these species are best adapted to survive in open dry habitats as they take advantage of any sign of temporary humidity that allows them to complete their life cycle quickly. Jurado et al. (1991) reported that *M. cerviana* does not form dense cover that inhibits other vegetation and compete well in crowded conditions. The present study also indicates that all the three *Mollugo* species do not grow in shaded habitats or form dense populations that inhibit other vegetation but *M. nudicaulis* and *M. pentaphylla* share insect pollinators along with other simultaneously flowering herbaceous taxa in certain habitats.

Brockington et al. (2009) reported that *Mollugo cerviana* is the only known C_4 species in Molluginaceae. Edwards & Walker (1983) noted that the genus *Mollugo* contains C_3, C_4 and C_3-C_4 species. Christin et al. (2010) reported that *M. cerviana* being a C_4 species is distributed in hot arid regions of tropical and temperate latitudes. *M. nudicaulis* is a C_3-C_4 species while *M. pentaphylla* is a C_3 species but both are distributed in tropical and subtropical regions of the world. Raghavendra et al. (1978) reported that *M. nudicaulis* produces some leaves with C_3 characteristics and some other leaves with C_4 characteristics according to their position on the stem. Sage et al. (1999) documented that C_3-C_4 photosynthesis is believed to be a relatively rare condition in plants and only a few dozen species have been identified so far, many of which belong to *Flaveria* (Asteraceae). The present study shows that *M. pentaphylla* with C_3 photosynthesis usually occurs in dry habitats displaying the sparse growth of a few other prostrate or erect herbs and the presence of insect pollinators although they grow in cultivated lands that enable herbaceous flora, especially weeds and insect pollinators thrive well. Their occurrence in habitats with scanty or robust vegetation indicates that C_3 photosynthesis does not facilitate them to grow in habitats without any vegetation or insect pollinators. On the contrary, *M. cerviana* with C_4 photosynthesis grows only in dry habitats which are almost devoid of other vegetation and also devoid of pollinator fauna. This finding is in line with the statement by Lundgren et al. (2015) that C_4 species are usually abundant in warm but not in cool environments and this photosynthetic pathway is physiologically advantageous for their niche broadening in warm environments. *M. nudicaulis* with C_3-C_4 photosynthesis is versatile

to flourish well both in dry habitats and cultivated areas with scanty and robust vegetation comprising of herbaceous flora that support insect pollinators. The C_3-C_4 photosynthetic pathway enables this species to grow in warm and cool habitats which in turn enables it to be widespread and abundant. Vogan et al. (2007) reported that of all C_3-C_4 intermediates, *M. nudicaulis* and *M. verticillata* are the most widespread and also abundant. These species are found in hot, ruderal habitats where competition is low and the potential for photorespiration is high. Their ability to survive in such habitats is likely due to their C_3-C_4 pathway. Their ecological success demonstrates that C_3-C_4 intermediacy is a successful photosynthetic pathway in its own right and not merely a transitional phase to C_4 photosynthesis. Lundgren & Christin (2017) also reported that C_3-C_4 taxa are remarkably widespread across geographical and environmental space, maintaining their ability to exist in both typical C_3 and C_4 niches. Because, the physiology of C_3-C_4 species does not strongly restrict the migration of species geographically or into new environments and it is a lineage that converges towards warm habitats to facilitate the transition to C_4 photosynthesis, effectively bridging the ecological gap between C_3 and C_4 plants. *M. pentaphylla* with C_3 photosynthesis, *M. nudicaulis* with C_3-C_4 photosynthesis and *M. cerviana* with C_4 photosynthesis have developed different pollination mechanisms to maximize fruit and seed set rate. Genetic variation achieved through insect pollination in all these species, except *M. cerviana,* is essential to broaden their ecological niches since they grow both in dry and moist habitats. In *M. cerviana*, genetic variation achieved through thrips pollination is important to expand and invade dry habitats.

REFERENCES

Batenburg, L.H. & B.M. Moeliono (1982). Oligomery and vasculature in the androecium of *Mollugo nudicaulis* Lam. (Molluginaceae). *Acta Botanica Neerlandica* 31: 215–220; https://doi.org/10.1111/j.1438-8677.1982.tb01615.x

Bhargava, H.R. (1934). Contribution to the morphology of *Mollugo nudicaulis* Lamk. *Proceedings of Indian Academy of Sciences (Section B)* 1: 271–278.

Bittrich, V. (1990). Systematic studies in Aizoaceae. Mitteilungen aus dem Institut fur Allgemeine *Botanik Hamburg* 23b: 491–507.

Bittrich, V. & H.D. Ihlenfeldt (1984). Morphologie fruher Keimungstadien bei Mesembryanthemaceae: eine Anpassung an aride Umweltbedingungen. *Mitteilungen aus dem Institut fur allgemeine Botanik in Hamburg* 19: 123–139.

Bogle, A.L. (1970). The genera of Molluginaceae and Aizoaceae in the southeastern United States. *Journal of Arnold Arboretum* 51: 431–462.

Brockington, S.F., F. Alexandre, J. Ramdial, M.J. Moore, S. Crawley, A. Dhingra, K. Hilu, D.E. Soltis & P.S. Soltis (2009). Phytogeny of the Caryophyllales *sensu lato*: revisiting hypotheses on pollination biology and perianth differentiation in the core Caryophyllales. *International Journal of Plant Sciences* 170: 627–643; https://doi.org/10.1086/597785

Burrows, J.E. & C.K. Willis (eds.) (2005). *Plants of Nyika Plateau Southern African Botanical Diversity Network Report* No. 31 SABONET, Pretoria, 212pp.

Christin, P.A., T.L. Sage, E.J. Edwards, R.M. Ogburn, R. Khoshravesh & R.F. Sage (2010). Complex evolutionary transitions and the significance of C_3-C_4 intermediate forms of photosynthesis in Molluginaceae. *Evolution* 65: 643–660; https://doi.org/10.1111/j.1558-5646.2010.01168.x

Cruden, R.W. (1977). Pollen-ovule ratios: a conservative indicator of breeding systems in flowering plants. *Evolution* 31: 32–46.

Dafni, A., P.G. Kevan & B.C. Husband (2005). *Practical Pollination Biology*. Enviroquest Ltd., Cambridge, 583pp.

Eckardt, T. (1974). Vom Blutenbau der Centrospermen-Gattung Lophiocarpus Turez. *Phyton* 16: 13–27.

Edwards, G. & D.A. Walker (1983). C_3, C_4*: Mechanisms, and cellular and environmental regulation of photosynthesis*. University of California Press, California, 543pp.

Groen, L.E. & L.J.G. van der Maesen (1999). Revision of the genus *Faucaria* (Ruschioideae: Aizoaceae) in South Africa. *Bothalia* 29: 35–58; https://doi.org/10.4102/abc.v29i1.570

Gunathilagaraj, K., T.N.A. Perumal, K. Jayaram & M.G. Kumar (1998). *Field Guide: Some South Indian Butterflies.* Niligiri Wildlife and Environmental Association, Niligiri, 274pp.

Hammer, S. (1995). Mastering the art of growing mesembs. *Cactus and Succulent Journal (U.S.)* 67: 195–247.

Hofmann, U. (1973). Morphologische Untersuchungen zur Umgrenzung und Gliederung der Aizoaceen. *Botanische Jahrbucher fur Systematik, Pflanzengeschichte und Pflanzengeographie* 93: 247–324.

Hutchinson, J. (1926). *The families of flowering plants. I. Dicotyledons (Molluginaceae).* Oxford Press, Oxford, 328pp.

Johri, B.K., K.B. Ambegoakar & P.S. Srivastava (1992). *Comparative Embryology of Angiosperms*. Vol. 1. Springer-Verlag, Berlin, 1220pp.

Jurado, E., M. Westoby & D. Nelson (1991). Diaspore weight, dispersal, growth form and perenniality of central Australian plants. *The Journal of Ecology* 79: 811–828; https://doi.org/10.2307/2260669

Kshirsagar, B.G. (1960). Contribution to embryology of *Polycarpea corymbosa* Lamk. and *Mollugo stricta* Linn. (Syn. *Mollugo pentaphylla* Linn.). *Proceedings of 47th Indian Science Congress (Bombay)* 3: 357.

Kubitzki, K., J.G. Rohwer & V. Bittrich (1993). *The families and genera of vascular plants. II. Flowering plants. Dicotyledons. Magnoliid, Hamamelid and Caryophillid families.* Springer-Verlag, Berlin. 652pp.

Kunte, K. (2007). *India – A Lifescape: Butterflies of Peninsular India.* Universities Press, Hyderabad, 254pp.

Lin, S-H., S-Y. Chang & S-H. Chen (1993). The study of bee-collected pollen loads in Nantou, Taiwan. *Taiwania* 38: 117–133.

Lundgren, M.R. & P.A. Christin (2017). Despite phylogenetic effects, C_3-C_4 lineages bridge the ecological gap to C_4 photosynthesis. *Journal of Experimental Botany* 68: 241–254; https://doi.org/10.1093/jxb/erw451

Lundgren, M.R., G. Besnard & B.S. Ripley (2015). Photosynthetic innovation broadens the niche in a single species. *Ecology Letters* 18: 1021–1029.

Narayana, H.S. (1962). Seed structure in the Aizoaceae. pp220–230. In: Maheshwari, P., B.M. Johri & L.K. Vasil (eds.). *Proceedings of Summer School of Botany*, Ministry of Scientific Research and Cultural Affairs, New Delhi.

Owens, J.N. & H.G. Lund (2009). *Forests and forest plants: Encyclopedia of life support systems.* Vol. II. Eolss Publ. Co. Pvt. Ltd., Oxford, UK. 311pp.

Parvathamma, S. & C. Shanthamma (2000). Antimicrobial activity of *Mollugo cerviana* ser. (Molluginaceae). *Ancient Science of Life* 20: 11–13.

Pax, F. & K. Hoffmann (1934). Caryophyllaceae. pp275–364. In: Engler, A. & K. Prantl. (eds.), *Die naturlichen Pflanzenfamilien.* 2. Aufl. Vol. 16c., W. Engelmann, Leipzig.

Peter, C.I., A.P. Dold, N.P. Barker & B.S. Ripley (2004). Pollination biology of *Bergeranthus multiceps* (Aizoaceae) with preliminary observations of repeated flower opening and closure. *South African Journal of Science* 100: 624–629.

Ponnuchamy, R., V. Bonhomme., S. Prasad., L. Das., P. Patel & C. Gaucherel (2014). Honey pollen: using melissopalynology to understand foraging preferences of bees in tropical South India. *PLoS ONE* 9: e101618; https://doi.org/10.1371/journal.pone.0101618

Raghavendra, A.S., G. Rajendrudu & V.S.R. Das (1978). Simultaneous occurrence of C_3 and C_4 photosyntheses in relation to leaf position in *Mollugo nudicaulis*. *Nature* 272: 143–144.

Rajamanikandan, S., T. Sindhu, D. Durgapriya, D. Sophia, P. Ragavendran & V.K. Gopalakrishnan (2011). Radical scavenging and antioxidant activity of ethanolic extract of *Mollugo nudicaulis* by *in vitro* assays. *Indian Journal of Pharmaceutical Education and Research* 45: 310–316.

Robertson, C. (1928). Flowers and Insects. XXV. *Ecology* 9: 505–526.

Ronse-De-Craene, L.P. (2010). *Floral diagrams: an aid to understanding flower morphology and evolution*. Cambridge Press, New York, 441pp.

Sage, R.F., M. Li & R.K. Monson (1999). The taxonomic distribution of C_4 photosynthesis. pp551–584. In: Sage, R.F. & R.K. Monson (eds.). *C_4 Plant biology*, Academic Press, San Diego, CA, 595pp.

Sahu, N.P., D. Das, N.K. Tripathy, S.C. Dinda & H.K.S. Kumar (2012). Evaluation of hypoglycemic activity of *Mollugo pentaphylla* and *Glinus oppositifolius* (L.) *Rasayan Journal of Chemistry* 5: 57–62.

Short, P.S. (2002). A new species of *Glinus* L. (Molluginaceae) from the Northern Territory, Australia. *Telopea* 9: 761–763; https://doi.org/10.7751/telopea20024014.19

Soerjani, M., A.J.G.H. Kostermans & G. Tjitrosoepomo (1987). *Weeds of rice in Indonesia*. Balai Pustaka, Jakarta, 716pp.

Stannard, B.L. (1988). Phytolaccaceae. pp163–173. In: *Flora Zambesiaca*. *Vol. 9.* Royal Botanical Gardens, Kew, UK.

Vogan, P.J., M.W. Frohlich & R.F. Sage (2007). The functional significance of C_3-C_4 intermediate traits in *Heliotropium* L. (Boraginaceae): gas exchange perspectives. *Plant Cell Environment* 30: 1337–1345; https://doi.org/10.1111/j.1365-3040.2007.01706.x

Wagner, W.L., D.R. Herbst & S.H. Sohmer (1999). *Manual of the flowering plants of Hawaii*. University of Hawaii Press and Bishop Museum Press, Honolulu, HI, 1919pp.

Watson, L. & M.J. Dallwitz (1992). The families of flowering plants: descriptions, illustrations, identification, and information retrieval. *Australian Systematic Botany* 4(4): 681–695; https://doi.org/10.1071/SB9910681

COMMUNICATION

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13350–13359

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM
OPEN ACCESS

Sacred groves: a traditional way of conserving plant diversity in West Midnapore District, West Bengal, India

Uday Kumar Sen

Department of Botany and Forestry, Vidyasagar University, Rangamati, Midnapore, West Bengal 721102, India.
uudaysen@gmail.com

Abstract: Sacred groves are forest patches conserved by the local people interwined with their socio-cultural and religious practices. An extricable link between the past and present society in terms of religion, socio-culture, heritage and biodiversity exists in the sacred groves. It is distributed globally where ethnic indigenous communities live. Several animals and plants that are threatened in forests are still abundant and well conserved in such sacred groves. The taboos, religious belief and sacredness play a significant role in promoting sustainable utilization and conservation. In this regard, the study of a sacred grove in the district of West Midnapore in West Bengal highlighting the tradition may provide a powerful tool for ensuring biodiversity conservation through community participation.

Keywords: Biodiversity, conservation, IUCN, socio-cultural.

DOI: https://doi.org/10.11609/jott.4310.11.3.13350-13359

Editor: P. Lakshminarasimhan, Botanical Survey of India, Pune, India. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4310 | Received 01 June 2018 | Final received 05 February 2019 | Finally accepted 11 February 2019

Citation: Sen, U.K. (2019). Sacred groves: a traditional way of conserving plant diversity in West Midnapore District, West Bengal, India. *Journal of Threatened Taxa* 11(3): 13350–13359; https://doi.org/10.11609/jott.4310.11.3.13350-13359

Funding: None.

Competing interests: The author declares no competing interests.

Author Details: Dr. Uday Kumar Sen, a post doctoral researcher, at the Department of Botany and Forestry, Vidyasagar University, has been conducting research mainly on ethnobotany, biodiversity and conservation of sacred groves. His research works are mainly on documenting diversity of traditional in situ conservation and their existence throughout southern West Bengal.

Acknowledgements: The author would like to express his gratitude to Ram Kumar Bhakat (supervisor) for providing help and facilities to work in the Department of Botany and Forestry. The author is also thankful to the local communities for sharing their knowledge of plants and help during the field survey.

INTRODUCTION

Sacred groves are patches of forest vegetation with rich diversity, which have been preserved by local communities for centuries based on taboos, religious beliefs and social sanctions with the implicit belief that the deities residing in them would protect the adjoining people from unfavourable calamities (Khan et al. 2008; Ormsby 2011). Sacred groves are generally considered as a part of a broader set of cultural values that may differ in various societies. But they are connected in meaningful ways to the environment of their origin (Wild et al. 2008). The interest in sacred groves from the perspective of nature conservation lies in the component of biological diversity that they harbour, such as plant species, the habitats and ecosystems, as well as the ecological dynamics and functions that support life within and outside the places. Linked to such biological diversity is the array of distinct human cultures that care for them and hold them sacred (Berkes et al. 2000).

The vast majority of sacred groves were arguably founded by indigenous or folk religions and spiritualities, but many were subsequently adopted or co-opted by mainstream religions (Verschuuren et al. 2012). There is a consequent mixing of religious and other spiritual or belief systems. Sacred groves are just one of the many domains where religions or belief systems interact with nature. Many sacred groves have been well protected over time and have seen little disturbance. Many are demonstrably high in biodiversity and represent a strong biodiversity conservation opportunity (Park 2002). Sacred groves also represent ancient and profound cultural values. The roles of sacred grove custodians from indigenous, local community and mainstream religions are expressions of dedicated cultural efforts that cared for nature in various ways (Wild et al. 2008). Sacred groves are linked to livelihoods in many ways and the concepts of cultural services and human well-being are associated with them (Gadgil & Vartak 1975; Butler & Oluoch-Kosura 2006).

The importance of sacred groves in conservation of biodiversity has recently gained wide acceptance; hence, several studies have been carried out in India to assess the biodiversity of the groves. Despite the vast and varied flora in southern West Bengal of eastern India, information on the biodiversity of the sacred groves is still limited and only a few studies have been done to understand the phytodiversity of the region (Sen 2016).

Based on this premise, this paper discusses how people ethos, local norms and belief systems surrounding plants, deities and forests in a tribal belt of West Midnapore District in West Bengal shape and conserve a large number of plant species.

MATERIALS AND METHODS

Study site

The study was conducted in an isolated sacred grove at the outer edge of two tribal dominated villages (Joypur and Sinhajora in Lalgeria Gram Panchayat) under Pirakata Police Station in Salboni Block (22.580^{0}N & 87.184^{0}E, average altitude 57m) in the West Midnapore District of West Bengal (Fig. 1). The grove is located about 32km northwest from district headquarters at Midnapore Town, located in the southern part of West Bengal, India.

The sacred grove

The present sacred grove popularly known as 'Joypur Joysini Matar Than' (named after its presiding goddess Joysini), is situated in the Midnapore Sadar subdivision of West Midnapore District. The grove is spread over an area of 1.174ha in public land along the outskirts of the villages on the southeastern bank of the perennial Parang Rivulet. It represents a 200–250-year-old relict forest patch consisting of evergreen, deciduous and semi-deciduous plants. After the day of annual 'Paus Sankranti' (a ritual celebrated on the last day of the Bengali Month Paus or middle of January) local people, both tribals and non-tribals of Joypur and adjoining Sinhajora villages, visit the grove and worship the deity. Since the grove is an abode of the deity, the entire area along with plants and other life forms is considered sacred. Owing to this socio-cultural tag on the grove, local people do not cut or disturb the grove flora, thus strictly adhering to the taboos and ethics.

Survey methods

The study area was thoroughly surveyed from the year 2011 to 2017 in different seasons to identify the floral wealth and ethnobotanical characteristics of angiosperm plants. Phytosociology data were collected by laying 10m x 10m quadrates for tree species, 5m x 5m for shrubs and lianas, 1m x 1m for herbs and grasses. A brief floristic survey was carried out through "spot identification" basis. Samples of plants with flowers or fruits were collected. After collection, the specimens were processed, preserved, poisoned and mounted on herbarium sheets following the standard and modern herbarium techniques (Jain & Rao 1977). Photographs were taken of some of the common, locally

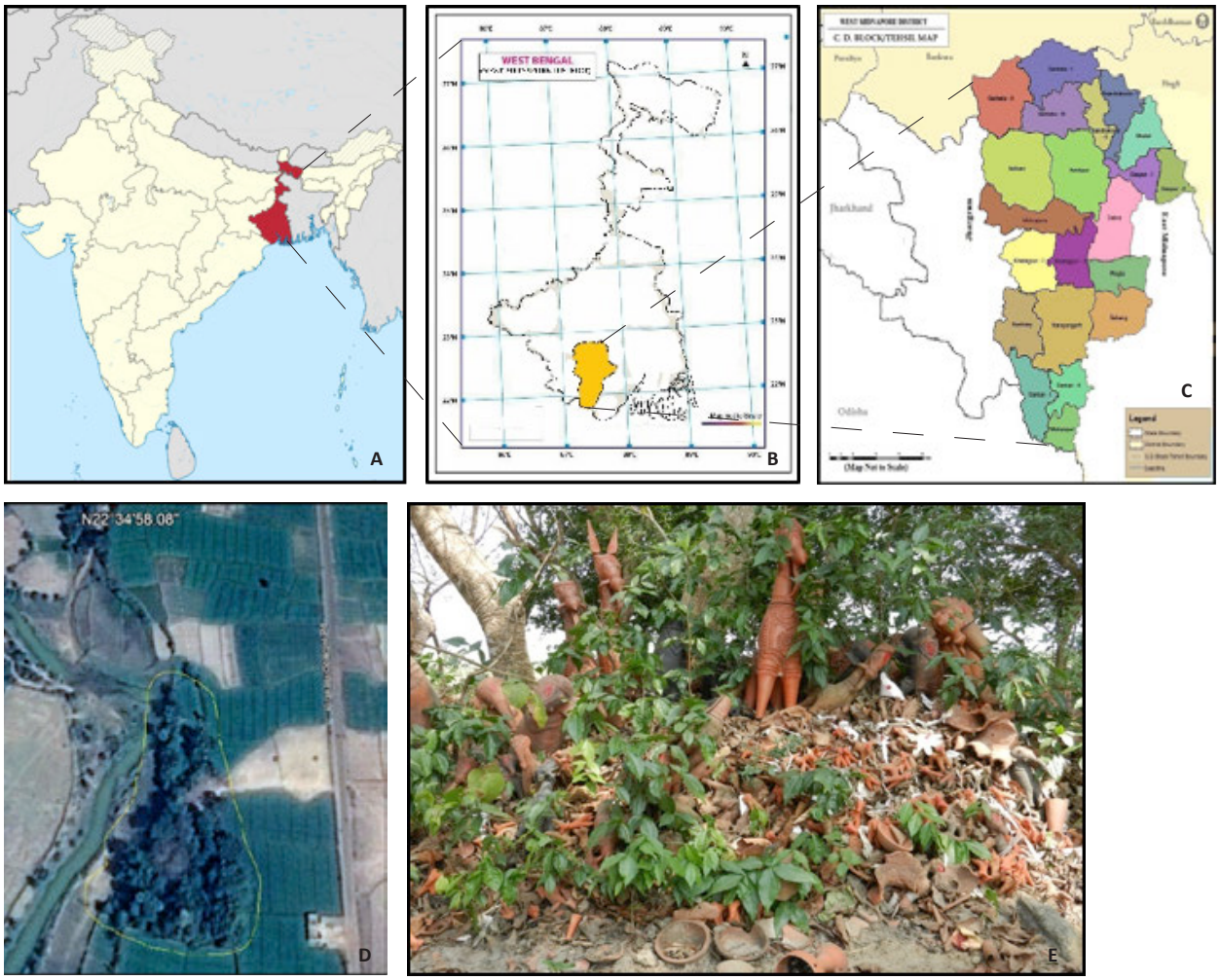


Figure 1. The study area: A -India, B - West Midnapore District in West Bengal, C - Salboni block in West Midnapore District, D - Joypur Joysini Matar Than sacred grove (Google image), E - Deity Joysini Mata inside the grove.

rare, endemic, economic and medicinally valuable plant species in the sacred grove. Abbreviations of authors' names of plant species strictly followed Brummitt & Powell (1992). The herbarium sheets were identified by matching with correctly annotated materials available at the Vidyasagar University Herbarium. For identification purposes, different relevant catalogue (Anderson 1862), regional floras (Hooker 1872–1897; Prain 1903a,b; Sanyal 1994), monographs (Mitra 1958), revision works (Datta & Majumdar 1966) and other literature (Maji & Sikdar 1983) were consulted.

In the systematic enumeration of the taxa; species with order and family, along with habit, life-span, IUCN status (IUCN 2018) and use(s) of the plant part(s) were arranged alphabetically (Table 1). Information about local inexpensive but useful plants was collected through literature (Kirtikar & Basu 1935; Ghosh 1997, 1998, 2001, 2005; Cunningham 2001; Pakrashi & Mukhopadhyay 2004; Paria 2005; Ghosh et al. 2008; Anon 2010) and by interviewing and cross-interviewing the local people.

RESULTS AND DISCUSSION

Diversity of different plant taxa

In the present study, a total of 177 species belonging to 165 genera distributed in 59 families from 31 orders were recorded from the sacred grove (Image 1). The major contributions of orders in terms of descending species number (≥10 species) were from Lamiales (12.99%), Gentianales (10.73%), Fabales (9.04%), Poales (9.04%), Malpighiales (7.91%), Asterales (6.21%), and Malvales (5.65%) (Table 1; Fig. 2). Gnanasekaran et al. (2012) and Karthik et al. (2016) showed a similar study on angiosperms of Cuddalore District, Tamil Nadu, India. Similar types of contribution of orders were highlighted

Table 1. Angiosperms in Joypur Joysini Matar Than sacred grove.

	Name of the plant species	Family	Habit	Lifespan	IUCN Red List Status	Part(s) used
1.	*Abroma augusta* (L.) L.f.	Malvaceae	S	P	NE	**M**:Le,Rb,Sb
2.	*Abrus precatorius* L.	Leguminosae	C	P	NE	**I:**Se;**M**:Se;**Or**:Se;**Sa**:Se
3.	*Abutilon indicum* (L.) Sweet	Malvaceae	S	A	NE	**M**:Le,Ro,Se
4.	*Acalypha indica* L.	Euphorbiaceae	H	A	NE	**M**:W
5.	*Achyranthes aspera* L.	Amaranthaceae	H	A	NE	**D**:W;**M**:W;**Sa**:W
6.	*Aegle marmelos* (L.) Corrêa	Rutaceae	T	P	NE	**D**:Fr;**E**:Fr,Le;**M**:Fr,Le;**Sa**:Fr,Le,W
7.	*Aerva lanata* (L.) Juss. ex Schult.	Amaranthaceae	H	A	NE	**M**:Fr,Ro;**Sa**:W
8.	*Agave vivipara* L.	Asparagaceae	S	P	NE	**Fi:**Le,St;**M**:Le,Ro
9.	*Ageratum conyzoides* (L.) L.	Asteraceae	H	A	NE	**M**:Le,Ro
10.	*Alangium salviifolium* (L.f.) Wangerin	Cornaceae	T	P	NE	**E**:Fr;**M**:Fr,Le,Rb,Sb,Se;**Ti**:St
11.	*Alocasia macrorrhizos* (L.) G.Don	Araceae	H	P	NE	**E**:Co;**M**:Le,Rh,Ro
12.	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	H	A	LC	**M**:W
13.	*Amaranthus spinosus* L.	Amaranthaceae	H	A	NE	**M**:W
14.	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Araceae	H	A	LC	**E**:Co;**M**:Rh
15.	*Ampelocissus latifolia* (Roxb.) Planch.	Vitaceae	C	P	NE	**M**:Le,Ro
16.	*Andrographis echioides* (L.f.) Nees	Acanthaceae	H	A	NE	**M**:Le,Ro,W
17.	*Anisochilus carnosus* (L. f.) Benth.	Lamiaceae	H	A	NE	**M**:Le
18.	*Anisomeles indica* (L.) Kuntze	Lamiaceae	H	A	NE	**M**:W
19.	*Annona reticulata* L.	Annonaceae	T	P	NE	**M**:Fr,Le,Sb;**Ti**:St
20.	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guillem. & Perr.	Combretaceae	T	P	NE	**Fo**:Le;**G**:Sb;**M**:Fr,Le,Sb;**Ti**:St
21.	*Apluda mutica* L.	Poaceae	H	P	NE	**Fo**:Le
22.	*Argemone mexicana* L.	Papaveraceae	H	A	NE	**M**:Fr,Ro
23.	*Aristolochia indica* L.	Aristolochiaceae	C	A	NE	**M**:Le,Ro,Se
24.	*Artabotrys hexapetalus* (L.f.) Bhandari	Annonaceae	C	P	NE	**M**:Le,Fl;**Oi**:Fl
25.	*Artocarpus lacucha* Buch.-Ham.	Moraceae	T	P	NE	**E**:Fr;**Fo**:Le;**Ti:**St
26.	*Asparagus racemosus* Willd.	Asparagaceae	C	P	NE	**M**:Le,Tu
27.	*Ayapana triplinervis* (Vahl) R.M.King & H.Rob.	Asteraceae	H	A	NE	**M**:Le,W
28.	*Azadirachta indica* A.Juss.	Meliaceae	T	P	NE	**E**:Le;**I**:Fr,Le,Sb,Se;**M**:Fr,Le,Sb,Se,St ;**Sa**:W;**Ta**:Sb;**Ti**:St
29.	*Azanza lampas* (Cav.) Alef.	Malvaceae	S	A	NE	**Fi**:St;**M**:W
30.	*Baccharoides anthelmintica* (L.) Moench	Asteraceae	H	A	NE	**M**:Fl,Ro,Se
31.	*Bacopa monnieri* (L.) Wettst.	Plantaginaceae	H	A	LC	**E**:W;**M**:Le,W
32.	*Bambusa bambos* (L.) Voss	Poaceae	T	P	NE	**Fo**:Le,St;Sa:St;**Ti**:St
33.	*Barleria cristata* L.	Acanthaceae	S	P	NE	**M**:Le,Ro,W
34.	*B. prionitis* L.	Acanthaceae	S	P	NE	**M**:Le,Ro,Sb
35.	*Blumea lacera* (Burm.f.) DC.	Asteraceae	H	A	NE	**M**:Le,Ro,W
36.	*Boerhavia diffusa* L.	Nyctaginaceae	H	A	NE	**M**:Le,Ro,W
37.	*Bombax ceiba* L.	Malvaceae	T	P	NE	**Fo**:Le;**Oi**:Se;**Ti**:St
38.	*Borassus flabellifer* L.	Arecaceae	T	P	NE	**E**:Fr;**M**:Fr;**Sa**:Le;**Ti**:St
39.	*Brachiaria reptans* (L.) C.A. Gardner & C.E. Hubb.	Poaceae	H	A	LC	**Fo**:Le
40.	*Breynia vitis-idaea* (Burm.f.) C.E.C.Fisch.	Phyllanthaceae	S	P	NE	**M**:Fr,Le
41.	*Bridelia retusa* (L.) A.Juss.	Euphorbiaceae	T	P	NE	**M**:Fr,Le;**Ta**:Sb;**Ti**:St
42.	*Caesalpinia bonduc* (L.) Roxb.	Leguminosae	C	P	NE	**M**:Le,Ro,Se
43.	*Cajanus scarabaeoides* (L.) Thouars	Leguminosae	C	A	LC	**E:**Fr;**M**:Fr,Se
44.	*Calotropis gigantea* (L.) Dryand.	Apocynaceae	S	P	NE	**Fi**:Sb,Se;**M**:Fl,La,Le,Rb,Ro;**Sa**:W

	Name of the plant species	Family	Habit	Lifespan	IUCN Red List Status	Part(s) used
45.	*Capparis zeylanica* L.	Capparaceae	C	P	NE	**M**:Le,Ro,Se,St;**Or**:W
46.	*Cardiospermum halicacabum* L.	Sapindaceae	C	A	NE	**M**:Le,Ro,Se;**Sa**:W
47.	*Carissa carandas* L.	Apocynaceae	C	P	NE	**E**:Fr;**M**:Fr,Ro
48.	*Cassia fistula* L.	Leguminosae	T	P	NE	**M**:Fr,Se;**Or**:Fl;Ta:Fr,Sb,Se;**Sa**:W
49.	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	T	P	NE	**M**:Fr,Sb
50.	*Cayaponia laciniosa* (L.) C.Jeffrey	Cucurbitaceae	C	A	NE	**M**:Fr
51.	*Cayratia trifolia* (L.) Domin	Vitaceae	C	P	NE	**M**:Le,Ro,St
52.	*Celastrus paniculatus* Willd.	Celastraceae	C	P	NE	**M**:Le,Ro,Sb,Se
53.	*Centella asiatica* (L.) Urb.	Apiaceae	H	A	LC	**M**:Le,Ro
54.	*Centranthera indica* (L.) Gamble	Orobanchaceae	H	A	NE	**M**:Ro
55.	*Cheilocostus speciosus* (J.Koenig) C.D.Specht	Costaceae	H	P	NE	**Fo**:Le;**M**:W
56.	*Chloris barbata* Sw.	Poaceae	H	P	NE	**Fo**:Le
57.	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Asteraceae	H	A	NE	**I:**Le,St;**M**:W
58.	*Chrysopogon zizanioides* (L.) Roberty	Poaceae	H	P	NE	**M**:Rh;**Sa**:Le
59.	*Cissus quinquangularis* Chiov.	Vitaceae	C	P	NE	**M:**Le,St
60.	*Cleistanthus collinus* (Roxb.) Benth. ex Hook.f.	Phyllanthaceae	T	P	VU	**I**:Fr,Le,Sb;**M**:Fr,Le,Ro,Sb;**Ti**:St
61.	*Cleome gynandra* L.	Cleomaceae	H	A	NE	**M**:Le,Ro,Se
62.	*Clerodendrum indicum* (L.) Kuntze	Lamiaceae	S	P	NE	**M**:La,Le,Ro
63.	*Coccinia grandis* (L.) Voigt	Cucurbitaceae	C	P	NE	**E**:Fr,Le;**M**:Fr,Le,Ro
64.	*Combretum decandrum* Jacq.	Combretaceae	C	P	NE	**Fo**:Le;**M**:Fr,Le,Sb;**Ta**:Fr,Sb
65.	*Commelina benghalensis* L.	Commelinaceae	H	A	LC	**Fo**:Le;**M**:W
66.	*Corchorus aestuans* L.	Malvaceae	H	A	NE	**E**:Le;**Fi**:Sb;**M**:Le,Se
67.	*Crotalaria prostrata* Rottler ex Willd.	Leguminosae	H	A	NE	**M**:Le,Se,St
68.	*C. pallida* Aiton	Leguminosae	S	A	NE	**M**:Le,Se,St
69.	*Croton bonplandianus* Baill.	Euphorbiaceae	H	P	NE	**M**:La,Le
70.	*Cryptolepis dubia* (Burm.f.) M.R.Almeida	Apocynaceae	C	P	NE	**M**:La,Le,Ro
71.	*Curculigo orchioides* Gaertn.	Hypoxidaceae	H	P	NE	**M**:Ro
72.	*Cynodon dactylon* (L.) Pers.	Poaceae	H	P	NE	**Fo**:Le;**M**:Rh,W;**Sa**:Le,W
73.	*Cyperus rotundus* L.	Cyperaceae	H	P	LC	**Fo**:Le;**M**:Ro,Tu
74.	*Datura metel* L.	Solanaceae	S	P	NE	**M**:Le,Ro,Se;**Sa:**Fl
75.	*Desmodium gangeticum* (L.) DC.	Leguminosae	H	P	NE	**M**:Ro
76.	*Digitaria sanguinalis* (L.) Scop.	Poaceae	H	P	NE	**Fo**:W;**M**:W
77.	*Dioscorea belophylla* (Prain) Voigt ex Haines	Dioscoreaceae	C	P	NE	**E**:Rh;**M**:Rh
78.	*D. pubera* Blume	Dioscoreaceae	C	P	NE	**E**:Rh;**M**:Rh
79.	*Ecbolium viride* (Forssk.) Alston	Acanthaceae	S	P	NE	**M**:Le,Ro
80.	*Eclipta prostrata* (L.) L.	Asteraceae	H	A	LC	**M**:Le,Ro,W
81.	*Eleocharis geniculata* (L.) Roem. & Schult.	Cyperaceae	H	P	LC	**M**:Le
82.	*Enydra fluctuans* DC.	Asteraceae	H	A	LC	**E**:Le,St;**M**:Le
83.	*Eragrostis amabilis* (L.) Wight & Arn.	Poaceae	H	P	NE	**Fo**:Le;**Or**:W
84.	*Eulophia graminea* Lindl.	Orchidaceae	H	P	NE	**M**:Tu;**Or**:Fl,W
85.	*Euphorbia antiquorum* L.	Euphorbiaceae	T	P	NE	**I**:La;**M**:La,W
86.	*E. hirta* L.	Euphorbiaceae	H	A	NE	**M**:W
87.	*Evolvulus alsinoides* (L.) L.	Convolvulaceae	H	A	NE	**M**:W;**Sa**:W
88.	*Ficus benghalensis* L.	Ulmaceae	T	P	NE	**E**:Fr;**Fi**:Ro;**Fo**:Le;**M**:Fr,La,Le,Ro,Sb, Se;**Or**:W;**Sa**:Le,W;**Ti**:St
89.	*F. racemosa* L.	Moraceae	T	P	NE	**M**:La,Le,Sb;**Sa**:Le
90.	*Fimbristylis eragrostis* (Nees) Hance	Cyperaceae	H	P	NE	**Fo**:W

	Name of the plant species	Family	Habit	Lifespan	IUCN Red List Status	Part(s) used
91.	*Flacourtia indica* (Burm. f.) Merr.	Salicaceae	S	P	NE	**E**:Fr;**M**:Sb,Fr,La,Le,Ro,Se
92.	*Flemingia strobilifera* (L.) W.T.Aiton	Leguminosae	H	A	NE	**M**:Le,Ro
93.	*Gardenia resinifera* Roth	Rubiaceae	S	P	NE	**Or**:Fl,W;**Sp**:Sb
94.	*Gymnema sylvestre* (Retz.) R.Br. ex Sm.	Apocynaceae	C	P	NE	**M**:Le,St
95.	*Haldina cordifolia* (Roxb.) Ridsdale	Rubiaceae	T	P	NE	**Fo**:Le;**Sa**:W;**Ti**:St
96.	*Helicteres isora* L.	Malvaceae	S	P	NE	**M**:Fr,Le,Ro,Sb
97.	*Hemidesmus indicus* (L.) R. Br. ex Schult.	Apocynaceae	C	P	NE	**M**:Ro
98.	*Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult.	Poaceae	H	P	NE	**Fo:**Le;**M**:Ro
99.	*Hibiscus vitifolius* L.	Malvaceae	S	P	NE	**M**:Ro
100.	*Holarrhena pubescens* Wall. ex G.Don	Apocynaceae	T	P	NE	**M**:Le,Ro,Sb,Se;**Oi**:Fl
101.	*Holoptelea integrifolia* Planch.	Ulmaceae	T	P	NE	**M**:Le,Sb;**Ti**:St
102.	*Hybanthus enneaspermus* (L.) F.Muell.	Violaceae	H	P	NE	**M**:Fr,Ro,W
103.	*Hygrophila difformis* (L.f.) Sreem. & Bennet	Acanthaceae	H	A	LC	**M**:Le,Ro,Se,St
104.	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	H	A	NE	**M**:Fl,Le,Ro
105.	*Ichnocarpus frutescens* (L.) W.T.Aiton	Apocynaceae	C	P	NE	**M:**Le,Ro
106.	*Imperata cylindrica* (L.) Raeusch.	Poaceae	H	P	NE	**Fo**:Le;**M**:Ro
107.	*Indigofera tinctoria* L.	Leguminosae	H	B	NE	**D**:Fr,Se;**M:**Le,Ro,W
108.	*Jatropha gossypiifolia* L.	Euphorbiaceae	S	P	NE	**M**:La,Le,Se;**Oi**:Se
109.	*Justicia adhatoda* L.	Acanthaceae	S	P	NE	**M**:Le,Ro
110.	*J. gendarussa* Burm. f.	Acanthaceae	S	P	NE	**M**:Le
111.	*Kaempferia galanga* L.	Zingiberaceae	H	P	NE	**M**:Le,Tu
112.	*Kyllinga brevifolia* Rottb.	Cyperaceae	H	P	LC	**Fo**:Le
113.	*Lantana camara* L.	Verbenaceae	S	P	NE	**I**:Fr,Le,Sb;**M**:W;**Or**:W
114.	*Leonotis nepetifolia* (L.) R.Br.	Lamiaceae	H	A	NE	**M**:Fl,Le,Ro
115.	*Leonurus sibiricus* L.	Lamiaceae	S	A	NE	**M:**Fl,Le,Ro
116.	*Lippia javanica* (Burm.f.) Spreng.	Verbenaceae	S	P	NE	**M**:Le,W
117.	*Ludwigia octovalvis* (Jacq.) P.H.Raven	Onagraceae	H	A	LC	**M**:W
118.	*Madhuca longifolia* var. *latifolia* (Roxb.) A.Chev.	Sapotaceae	T	P	NE	**D**:Sb;**E**:Fl,Fr;**Ta**:Sb;**Ti**:St
119.	*Mangifera indica* L.	Anacardiaceae	T	P	DD	**E**:Fr;**G**:Sb;Sa:Le;**Ti**:St
120.	*Martynia annua* L.	Martyniaceae	H	A	NE	**M:**Fr,Le
121.	*Meyna spinosa* Roxb. ex Link	Rubiaceae	S	P	NE	**M**:Fr,Le,Ro
122.	*Mimosa pudica* L.	Leguminosae	H	P	LC	**M**:Le,Ro
123.	*M. rubicaulis* Lam.	Leguminosae	S	P	NE	**M**:Le,Ro
124.	*Momordica dioica* Roxb. ex Willd.	Cucurbitaceae	C	A	NE	**E**:Fr;**M**:Fr
125.	*Mucuna pruriens* (L.) DC.	Leguminosae	C	A	NE	**M:**Fr,Le,Ro,Se
126.	*Ocimum americanum* L.	Lamiaceae	H	P	NE	**M**:Le,Ro,Se;**Sa**:Le,W
127.	*Oldenlandia corymbosa* L.	Rubiaceae	H	A	LC	**M**:W
128.	*Orobanche aegyptiaca* Pers.	Orobanchaceae	H	A	NE	**M:**W
129.	*Oxalis corniculata* DC.	Oxalidaceae	H	A	NE	**M**:Le,W
130.	*Pergularia daemia* (Forssk.) Chiov.	Apocynaceae	C	P	NE	**M**:La,Le,Se,W
131.	*Phoenix sylvestris* (L.) Roxb.	Arecaceae	T	P	NE	**E**:Fr;**M**:Fr;**Ti**:St
132.	*Phyllanthus fraternus* G.L.Webster	Phyllanthaceae	H	A	NE	**M**:W
133.	*P. virgatus* G.Forst.	Phyllanthaceae	H	A	NE	**M**:W
134.	*Plectranthus amboinicus* (Lour.) Spreng.	Lamiaceae	H	A	NE	**M**:Fl,Le,Se
135.	*Portulaca oleracea* L.	Portulacaceae	H	A	NE	**E**:St;**M**:W
136.	*Putranjiva roxburghii* Wall.	Putranjivaceae	T	P	NE	**M**:Fr,Le,Se;**Ti**:St

	Name of the plant species	Family	Habit	Lifespan	IUCN Red List Status	Part(s) used
137.	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Apocynaceae	S	P	NE	**M**:Le,Ro,W
138.	*R. tetraphylla* L.	Apocynaceae	S	P	NE	**M**:Le,Ro,W
139.	*Rhynchospora colorata* (L.) H.Pfeiff.	Cyperaceae	H	P	NE	**Fo:**Le;**M**:Le,Rb,Ro,Se
140.	*Rivea ornata* Choisy	Convolvulaceae	C	P	NE	**M**:Le,Ro
141.	*Rungia pectinata* (L.) Nees	Acanthaceae	H	A	NE	**M**:Le,Ro,W
142.	*Schleichera oleosa* (Lour.) Merr.	Sapindaceae	T	P	NE	**E**:Fr;**M**:Fr;**Oi**:Se;**Ti**:St
143.	*Schoenoplectiella roylei* (Nees) Lye	Cyperaceae	H	P	LC	**Fo**:W;**M**:Rh
144.	*Scindapsus officinalis* (Roxb.) Schott	Araceae	C	P	NE	**M**:Le,Rh;**Or**:W
145.	*Semecarpus anacardium* L.f.	Anacardiaceae	T	P	NE	**D**:Fr;**E**:Fr
146.	*Senna occidentalis* (L.) Link	Leguminosae	S	P	NE	**M**:Le,Ro
147.	*S. tora* (L.) Roxb.	Leguminosae	H	A	NE	**I**:Fr,Le;**M**:Le,P,Se
148.	*Shorea robusta* Gaertn.	Dipterocarpaceae	T	P	LR/LC	**G**:Sb;Oi:Se;**Sa**:W;**Ti**:St
149.	*Sida cordifolia* L.	Malvaceae	S	A	NE	**M**:Fr,Le,Ro,Se;**Fi**:Sb;**Fo**:Le
150.	*Solanum americanum* Mill.	Solanaceae	H	A	NE	**M:**Fr,Le,Ro,Se
151.	*S. virginianum* L.	Solanaceae	H	A	NE	**M**:Fr,Le,Ro
152.	*Spermacoce articularis* L.f.	Rubiaceae	H	A	NE	**M**:W
153.	*Sphaeranthus indicus* L.	Asteraceae	H	A	LC	**M**:W
154.	*Sphagneticola calendulacea* (L.) Pruski	Asteraceae	H	A	LC	**M**:Fl,Le,W
155.	*Stephania japonica* (Thunb.) Miers	Menispermaceae	C	P	NE	**M**:Le,Ro
156.	*Streblus asper* Lour.	Moraceae	T	P	NE	**E**:Fr;**Fo**:Le;**M**:Fr,La,Le,Ro,Sb,Se;**Or**:W;**Sa**:Le,W;**Ti**:St
157.	*Strychnos nux-vomica* L.	Loganiaceae	T	P	NE	**I**:Fr,Se;**M**:Fr,Le,Rb,Se;**Ti**:St
158.	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae	H	A	NE	**M**:Le
159.	*Syzygium cumini* (L.) Skeels	Myrtaceae	T	P	NE	**D**:Fr;**E**:Fr;**Ta**:Sb;**Ti**:St
160.	*Tacca leontopetaloides* (L.) Kuntze	Dioscoreaceae	H	P	LC	**E**:Rh;**M**:Rh
161.	*Tephrosia purpurea* (L.) Pers.	Leguminosae	H	P	NE	**D**:Fr,Se;**M**:Le,Ro
162.	*Terminalia alata* Roth	Combretaceae	T	P	NE	**Fo**:Le;**M**:Fr,Le,Sb;**Ta**:Fr,Sb;**Ti**:St
163.	*T. arjuna* (Roxb. ex DC.) Wight & Arn.	Combretaceae	T	P	NE	**Fo**:Le;**M**:Fr,Le,Sb;**Sa**:W;**Ta**:Fr,Sb;**Ti**:St
164.	*Tinospora sinensis* (Lour.) Merr.	Menispermaceae	C	P	NE	**M**:W;**Sa**:W
165.	*Tragia involucrata* L.	Euphorbiaceae	C	P	NE	**M**:Fr,Le,Ro
166.	*Tribulus terrestris* L.	Zygophyllaceae	C	A	NE	**M**:Fr,Le,Ro,Se
167.	*Trichosanthes tricuspidata* Lour.	Cucurbitaceae	C	A	NE	**M**:Fr,Ro
168.	*Tylophora indica* (Burm. f.) Merr.	Apocynaceae	C	A	NE	**M**:Le,Rb,Ro
169.	*Urena lobata* L.	Malvaceae	S	A	NE	**Fi**:Sb;**M**:Fl,Le,Ro,St
170.	*Vallaris solanacea* (Roth) Kuntze	Apocynaceae	C	P	NE	**M**:La,Le,Ro
171.	*Vanda tessellata* (Roxb.) Hook. ex G.Don	Orchidaceae	H	P	LC	**M**:Fl,Le;**Or**:Fl,W
172.	*Ventilago denticulata* Willd.	Rhamnaceae	C	P	NE	**D**:Rb,Sb;**M**:Fr,Rb,Sb;**Ti:**St
173.	*Viscum cruciatum* Sieber ex Boiss.	Santalaceae	S	A	NE	**M**:W
174.	*Vitex negundo* L.	Lamiaceae	T	P	NE	**I**:Le,St;**M**:Fl,Fr,Le,Rb,Ro,Sb,Se
175.	*Xanthium strumarium* L.	Asteraceae	H	A	NE	**M**:Fr,Le,Ro,Se
176.	*Ziziphus oenopolia* (L.) Mill.	Rhamnaceae	C	P	NE	**E**:Fr;**Fo**:Le;**M**:Fr,Ro,Sb,St;**Oi**:Se;**Ta**:Sb;**Ti**:St
177.	*Zornia gibbosa* Span.	Leguminosae	H	A	NE	**M**:W

Abbreviation: In Habit: C - Climber, **H** - Herb, **S** - Shrub, **T** - Tree. **In Lifespan: A** - Annual, **B** - Biennial, **P** - Perennial. **In IUCN Status: DD** - Data Deficient, **LC** - Least Concern, **LR/LC** - Lower Risk/ Least Concerned, **NE** - Not Evaluated, **VU** - Vulnerable. **Part(s) used: C -** Corm**, D -** Dye, **E -** Edible, **Fi -** Fiber, **Fl** - Flower, **Fo -** Fodder, **Fr** - Fruit, **G -** Gum, **I -** Insecticidal, **La** - Latex, **Le** - Leaf, **M -** Medicinal, **Oi -** Oil, **Or -** Ornamental, **P** - Pod, **Rb** - Root bark, **Rh** - Rhizome, **Ro** - Root, **Sa -** Sacred, **Sb** - Stem bark, **Se** - Seed, **Sp** - Spices, St - Stem, **Ta -** Tannin, **Ti -** Timber, **Tu** - Tuber, **W** - Whole plant

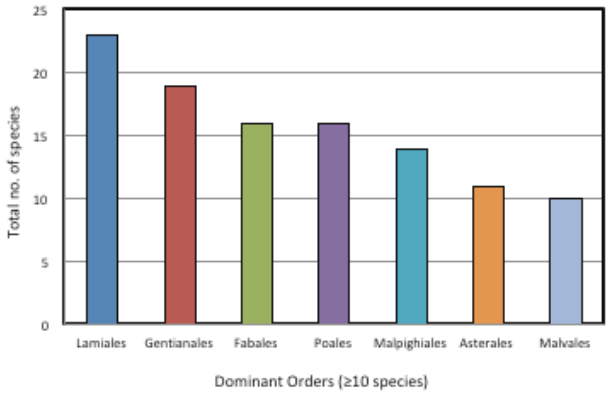


Figure 2. Major contribution of orders (≥ 10 species) in the study area.

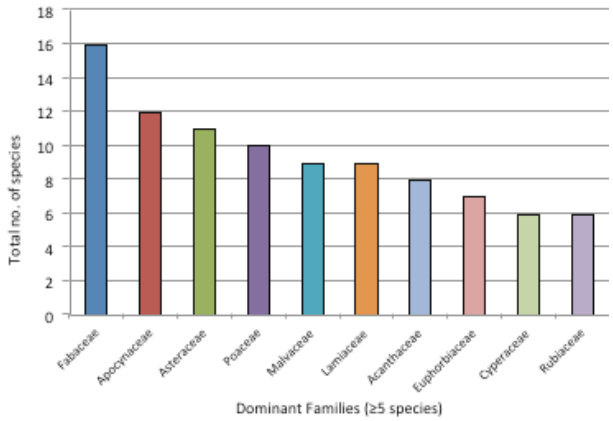


Figure 3. Major contribution of families (≥5 species) in the study area.

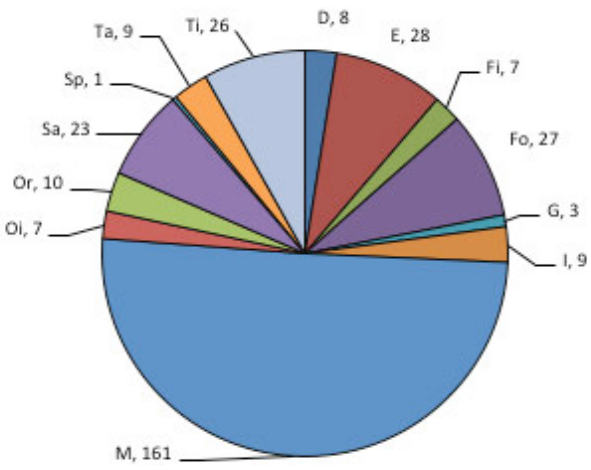


Figure 4. Local use (s) of plants for different purposes.

by Mygatt & Medeiros (2009); Perez-Luque et al. (2014) and Sen (2016).

The 10 well represented families in species (≥5 species), quantity-wise were: Leguminosae (9.04%), Apocynaceae (6.78%), Asteraceae (60.21%), Poaceae (5.65%), Malvaceae (5.08%), Lamiaceae (5.08%), Acanthaceae (4.52%), Euphorbiaceae (3.95%), Cyperaceae (3.39%), and Rubiaceae (3.39%) (Table 1; Fig. 3). Amaranthaceae, Combretaceae, Cucurbitaceae, Moraceae, and Phyllanthaceae comprised 4 (2.26%) species each. Araceae, Dioscoreaceae, Solanaceae, and Vitaceae covered only 3 (1.69 %) species. Only 11 families, namely Anacardiaceae, Annonaceae, Arecaceae, Asparagaceae, Convolvulaceae, Menispermaceae, Orchidaceae, Orobranchaceae, Rhamnaceae, Sapindaceae, and Verbenaceae contained 2 (1.13%) species each. Another 29 families each carried only a single species.

The 10 dominant plant families encompassing more than 53% genera with descending numbers (≥6 species) were Leguminosae (7.88%), Apocynaceae (6.67%), Asteraceae (6.67%), Poaceae (6.06%), Lamiaceae (5.45%), Malvaceae (5.45%), Acanthaceae (3.64%), Cyperaceae (3.64%), Euphorbiaceae (3.64%), and Rubiaceae (3.64%) (Table 1). Same type dominant families of sacred groves in India were observed by Rajendraprasad et al. (1998), Devi (2004), Sen & Bhakat (2009, 2012), and Sen (2016).

The 12 well represented genera containing two species were *Barleria*, *Crotalaria*, *Dioscorea*, *Euphorbia*, *Ficus*, *Justicia*, *Mimosa*, *Phyllanthus*, *Rauvolfia*, *Senna*, *Solanum*, and *Terminalia*. Another 141 species contained a single genus respectively (Table 1).

The present floristic study of the sacred grove showed that they harboured a total of 177 plant species [dicots 142 (80.22%) and monocots 35 (19.78%)] belonging to genera [dicots 134 (81.21%) and monocots 31 (18.79%)] of 59 families [dicots 46 (77.97%) and monocots 13 (22.03%)] under 31 orders [dicots 22 (70.97%) and monocots 9 (29.03%)]. Among these, 79 (44.63%) of the reported species were herbs. Other reported species were shrubs 30 (16.95%), trees 32 (18.08%) and climbers 36 (20.34%) respectively. Amongst the total dicots 142 (80.23%) and monocots 35 (19.77%), herbs, shrubs, trees and climbers represented 55, 29, 28, 30 and 24, 1, 4, 6 species respectively, representing 31.07%, 16.38%, 15.82%, 16.95% and 13.56%, 0.56%, 2.26%, 3.39% of the total species (Table 1).

The major five herbaceous families were Asteraceae (13.92%), Poaceae (11.39%), Leguminosae (10.13%), Cyperaceae (7.59%), and Lamiaceae (7.59%) held

Image 1. Plants in the study area. A - Stem patch of *Combretum decandrum* Jacq. (Combretaceae); B - *Curculigo orchioides*; C - *Abutilon indicum* (L.) Sweet (Malvaceae); D - Fruit dehiscence of *Pergularia daemia* (Forssk.) Chiov.; E - Fruit of *Terminalia alata* Roth (Combretaceae); F - Flower of *Madhuca longifolia* var. *latifolia* (Roxb.) A.Chev. © Uday Kumar Sen.

above 50% of the total herb population. The four major less-woody shrub families were Malvaceae (23.34%), Acanthaceae (16.67%), Apocynaceae (10%), and Leguminosae (10%) held above 60% of the total shrubs population. Moraceae (12.5%), Combretaceae (9.38%), Anacardiaceae (6.25%), Arecaceae (6.25%), Euphorbiaceae (6.25%), and Rubiaceae (6.25%) were the six highly diversified families which contained above 46% of the total tree population. Another 17 families contained single tree species. The four most speciose families in descending manner included Apocynaceae (22.23%), Cucurbitaceae (11.12%), Leguminosae (11.12%), and Vitaceae (8.34%) comprise above 52% of the total liana population (Table 1).

In the sacred grove, 67 (37.86%) annual plants went through their life cycle in one growing season. One (0.56%) biennial plant whose life cycle spans two years and 109 (61.58%) perennial plants that could survive most unfavourable conditions and stay alive for more than two years (Table 1).

IUCN categories

Among these 177 plants, 153 plants have not been evaluated until date. There are 21 Least Concerned (LC), one Vulnerable (VU), one Lower Risk/ Least Concerned (LR/LC), and one Data Deficient (DD) species. *Cleistanthus collinus* is assessed as a Vulnerable tree species according to IUCN (2018) (Table 1). In view of the above phytosociological analysis with ecological information about IUCN Red Listed plants reveals that the plants are still present and regenerate in the sacred groves but locally vanishing in nearby forests. This study would highlight the status of the species in the study area, the ecological characteristics necessary for their survival and the threats faced by some of the species by following the criteria devised by IUCN (2018).

Traditional use(s) of plants

The grove supports 26 timbers-yielding plant species and a good number of non-timber forest products, of which, eight species produce dye, 28 species bear edible parts, seven species produce fiber, 27 species have fodder value, three species yield gum, nine species have insecticidal properties, 161 species have medicinal properties, seven species yield oil, 10 species have ornamental value, 23 species have sacred value, one species yield spices, and nine species yield tannin (Table 1; Fig. 4).

CONCLUSION

This study reveals that the sacred groves in the West Midnapore District of West Bengal are rich repositories of plants with many locally rare and threatened species. Sacred groves are ecological units by themselves and perform a range of biological functions like nutrient cycling, prevention of soil erosion, water recharging and conservation of biodiversity. The present sacred grove, though fairly well-protected by the villagers, is under mild threats due to agricultural encroachment, exotic weed invasion and erosion of people's moral values towards plants and forests. It is, therefore, our collective responsibility to take all necessary measures to safeguard these islands of biological diversity.

REFERENCES

Anderson, T. (1862). *Catalogue of plants indigenous in the neighbourhood of Calcutta with directions for examination and preservation of plants*. Calcutta, India.

Anonymous (2010). *Medicinal plant resources of south West Bengal*, Vol.-2, Research Wing, Directorate of Forests, Government of West Bengal, Kolkata, 124pp.

Berkes, F., J. Colding & C. Folke (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological applications* 10(5): 1251–1262.

Brummit, R.K. & C.E. Powell (1992). *Authors of plant names.* Royal Botanic Gardens, Kew, 732pp.

Butler, C. & W. Oluoch-Kosura (2006). Linking future ecosystem services and future human well-being. *Ecology and Society* 11(1): 1–30.

Cunningham, A.B. (2001). *Applied Ethnobotany: People, Wild Plant use and Conservation*. Earthscan Publications Ltd., London, 320pp.

Datta, S.C. & N.C. Majumdar (1966). Flora of Calcutta and vicinity. *Bulletin of Botanical Society of Bengal* 20: 16–120.

Devi, K.A. (2004). *Studies on Plant Diversity and Regeneration of A Few Tree Species in the Sacred Groves of Manipur.* Unpublished PhD thesis, North Eastern Hill University, India.

Gadgil, M. & V.D. Vartak (1975). Sacred groves of India - a plea for continued conservation. *Journal of the Bombay Natural History Society* 72: 314–321.

Ghosh, A. (1997). *Paschimbanglar udvid (Vol. 1)*. Botanical Survey of India, Kolkata, 319pp.

Ghosh, A. (1998). *Paschimbanglar udvid (Vol. 2)*. Botanical Survey of India, Kolkata, 373pp.

Ghosh, A. (2001). *Paschimbanglar udvid (Vol. 3)*. Botanical Survey of India, Kolkata, 399pp.

Ghosh, A. (2005). *Paschimbanglar udvid (Vol. 4)*. Botanical Survey of India, Kolkata, 409pp.

Ghosh, A., C. Ghara & S. Murmu (2008). *Paschimbanglar udvid (Vol. 5)*. Botanical Survey of India, Kolkata, 472pp.

Gnanasekaran, G., P. Nehru & D. Narasimhan (2012). Angiosperms of Sendirakillai sacred grove (SSG), Cuddalore District, Tamil Nadu, India. *Check List* 8(1): 113–129.

Hooker, J.D. (1872–1897). *The Flora of British India. Vol. I-VII*. Reeve and Co., London.

IUCN (2018). The IUCN Red List of Threatened Species. Version 2018-2. <www.iucnredlist.org>. (Downloaded on 4 February 2019).

Jain, S.K. & R.R. Rao (1977). *A Handbook of Field and Herbarium Methods*. Today and Tomorrow's Printers and Publishers, New Delhi.

Karthik, S., M. Subramanian, S. Ravikumar & R. Dhamotharan (2016). Medicinal plants and their uses: a study of twelve sacred groves in cuddalore and villupuram districts, Tamil Nadu, India. *International Journal of Educational Research* 2(5): 95–102.

Khan, M.L., A.D. Khumbongmayum & R.S. Tripathi (2008). The sacred groves and their significance in conserving biodiversity: an overview. *International Journal of Ecology and Environmental Sciences* 34(3): 277–291.

Kirtikar, K.R. & B.D. Basu (1935). *Indian Medicinal Plants (Vols. 1–4)*. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Maji, S. & J.K. Sikdar (1983). Sedges and grasses of Midnapore District, West Bengal. *Journal of Economic and Taxonomic Botany* 4(1): 233–254.

Mitra, J.N. (1958). *Flowering Plants of Eastern India (Vol. I), Monocotyledons*. The World Press Private Ltd., Calcutta, India.

Ormsby, A.A. (2011). The impacts of global and national policy on the management and conservation of sacred groves of India. *Human Ecology* 39(6): 783–793.

Pakrashi, S.C. & Mukhopadhya, S. (Eds.) (2004). *Medicinal and aromatic plants of red laterite region of West Bengal (Bankura, Medinipore and Purulia)*, West Bengal Academy of Science and Technology, Kolkata, 508pp.

Paria, N. (ed.) (2005). *Medicinal plant resources of south West Bengal* (Vol. 1), Research Wing, Directorate of Forests in collaboration with Department of Environment, Government of West Bengal, Kolkata, 198pp.

Park, C. (2002). *Sacred Worlds: An Introduction to Geography and Religion*. Routledge, 352pp.

Perez-Luque, A.J., F.J. Bonet, R. Perez-Perez, R. Aspizua, J. Lorite & R. Zamora (2014). Sinfonevada: dataset of floristic diversity in Sierra Nevada forests (SE Spain). *PhytoKeys* 35: 1–15.

Prain, D. (1903a). *Bengal Plants* (Vol. 1). Botanical Survey of India, Calcutta, India, 487pp.

Prain, D. (1903b). *Bengal Plants* (Vol. 2). Botanical Survey of India, Calcutta, India, 488–1013pp.

Rajendraprasad, M., P.N. Krishnan & P. Pushpangadan (1998). The life form spectrum of sacred grove and a functional tool to analyse the vegetation. *Tropical Ecology* 39(2): 211–217.

Sanyal, M.N. (1994). *Flora of Bankura District*. Bishen Singh Mahendra Pal Singh, Dehra Dun, India, 493pp.

Sen, U.K. (2016). *Botanical and socio-cultural studies on some sacred groves of West Midnapore district, West Bengal*. Unpublished PhD Thesis, Vidyasagar University, India, 314pp.

Sen, U.K. & R.K. Bhakat (2009). Ecological role of sacred groves in plant conservation, pp211–219. In: Sinha, T.R.C (ed.). *Effects of environmental toxicology on human health*, National Environmental Science Academy, New Delhi, India.

Sen, U.K. & R.K. Bhakat (2012). Sacred grove and plant conservation: an insight from taxonomy and ecology, pp410–421. In: Maiti, G.G. & S.K. Mukherjee (eds.). *Mutidisciplinary Approaches in Angiosperm Systamatics*. Department of Botany, University of Kalyani, West Bengal, India

Verschuuren, B., J. McNeely, G. Oviedo & R. Wild (2012) (eds.). *Sacred Natural Sites: Conserving Nature and Culture*. Routledge, 336pp.

Wild, R., C. McLeod & P. Valentine (2008). Sacred natural sites: guidelines for protected area managers (No. 16), Gland, Switzerland: IUCN, IUCN Publications Services, 106pp.

Review

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13360–13376

Media reporting on the protected areas in Maharashtra, India: a thematic analysis

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

Trupthi Narayan [1] & Pankaj Sekhsaria [2]

[1] Bengaluru, India.
[2] Kalpavriksh, Apt 5, Sri Dutta Krupa Apartments, 908 Deccan Gymkhana, Pune, Maharashtra 411004, India.
[1] trupthinarayan@gmail.com, [2] psekhsaria@gmail.com (corresponding author)

Abstract: This research paper is an account and analysis of English media reporting on wildlife conservation and protected areas (PAs) in Maharashtra, India, between 1994 and 2015. It is based on 269 articles that first appeared in the media and were then edited for publication in the 'Protected Area Update'. The analysis attempts to draw out significant themes that the media deems important in matters of wildlife conservation. Themes that emerge prominently are related to issues of land, displacement of people, development projects, and tourism. We also discovered that some PAs like the Sanjay Gandhi National Park and the Tadoba-Andhari Tiger Reserve receive disproportionately large media space, while a third of the PAs were not reported on at all. This does not imply that these areas were not reported in the larger media that the newsletter draws upon, but points to the skewed coverage and (limited) importance these PAs get. We argue that media content analysis is a useful tool because the media is the first interface for the general public on issues of wildlife conservation and plays an important role in shaping public opinion. To our knowledge, this is the first such state-wide study of media reporting of wildlife conservation issues; it provides important insights into the wildlife conservation discourse in the country as well as the concerns, priorities, and challenges of the media.

Keywords: Conservation, media, media content analysis, protected areas, Protected Area Update, national parks, wildlife, wildlife sanctuaries.

DOI: https://doi.org/10.11609/jott.4461.11.3.13360-13376

Editor: Anonymity requested.

Date of publication: 26 February 2019 (online & print)

Manuscript details: #4461 | Received 01 August 2018 | Final received 09 January 2019 | Finally accepted 05 February 2019

Citation: Narayan, T. & P. Sekhsaria (2019). Media reporting on the protected areas in Maharashtra, India: a thematic analysis. *Journal of Threatened Taxa* 11(3): 13360–13376; https://doi.org/10.11609/jott.4461.11.3.13360-13376

Funding: Research for this paper was carried out with support from the Duleep Matthai Nature Conservation Trust, the Foundation for Ecological Security, and Kalpavriksh.

Competing interests: The authors declare no competing interests.

Author Details: Trupthi Narayan is an independent researcher interested in issues of wildlife conservation and indigenous peoples. She has worked on projects in Karnataka and Bhutan and also for UNESCO, Paris. Pankaj Sekhsaria is a member of Kalpavriksh, an environment action group, and editor of Protected Area Update. He is currently an Associate Professor in the Centre for Technology Alternatives for Rural Areas (C-TARA), IIT Bombay, India.

Author Contribution: All authors contributed equally.

Acknowledgements: We would like to thank Kalpavriksh, the Foundation for Ecological Security, and the Duleep Matthai Nature Conservation Trust for their continued support. Thanks are also due to the different individuals who over the years contributed to the editing and production of the Protected Area Update — Neena Singh, Saloni Suri, Ashish Kothari, Priya Das, K. Christopher, Suniti Jha, Farhad Vania, Vishal Thakre, Sangeeta Kaintura, Virender Anand, Anuprita Patel, Aanchal Kapur, Yashodara, Vidya, Roshni Kutty, Anuradha Arjunwadkar, and Reshma Jathar. We would also like to thank Ashni Dhawale, Kiran Singh, and the anonymous reviewer for their contribution and inputs.

INTRODUCTION

Reporting of wildlife conservation issues in India takes place at many scales — national, state, and regional — and in several languages. Many conservation news sites on the internet are also dedicated to reporting conservation issues and bringing them into the mainstream discourse. As one of the main sources of wildlife-related information for the public, conservation reporting in the media holds immense power in influencing not just the opinions of the public but also that of decision-makers and interest groups (Barua 2010). Reporting related to wildlife or conservation issues in mainstream papers and news-sites has to compete for space with several other topics such as politics, sports, and financial affairs; hence, news stories are filtered and only those that are considered relevant to the consuming population make it to print. This situation inevitably results in conscious and unconscious biases in the selection of conservation news for everyday consumption.

Studies show that issues involving conflict (negative interactions) and drama are considered more 'newsworthy' and are, therefore, more likely to be reported (Shoemaker & Reese 1991; Cook 1998). It was also shown that reporters often approach stories with unconscious biases to reinforce their views, such as interviewing sources who they know will confirm their opinions as opposed to more open-minded research (Shoemaker & Reese 1991). The media as an actor can also play a substantial role in the amplification or attenuation of perceptions of risk (Bhatia et al. 2013) and it becomes important, therefore, to understand and analyze themes in media coverage on issues relating to conservation.

Very few systematic analyses of conservation reporting in India have been carried out to understand the media portrayal of wildlife issues and their impact. The previous studies mainly focused on reporting of human-wildlife conflict/interactions in India — Barua (2010) looked at human-elephant conflict, while Bhatia et al. (2013) looked at human-leopard conflict and the disaster-framing approach. Others include an analysis of media reporting of the Kaziranga National Park in Assam based on reports in the 'Protected Area Update' (PAU) for the period 1996–2011 (Siddiqui & Reddi 2012) and a study that uses media reporting in the state of Karnataka to build a profile of leopard presence and range (Athreya et al. 2015).

This paper is an account and analysis of media reporting of issues related to wildlife conservation and protected areas (PA) in the state of Maharashtra, India, as reported in the English media between 1994 and 2015. It presents, perhaps, the only such longitudinal study of its kind for the state and one among the very few for any region or theme in India.

The analysis is based on a set of 269 articles that were first reported in the media and then edited for publication in the PAU, a newsletter on wildlife and conservation that has been published six times a year for the last two decades by the environment action group, Kalpavriksh, India. The newsletter is brought out with funding support from a range of non-governmental organizations[1] and donations from individual readers. The focus of the newsletter is the geographic unit of wildlife conservation and management generically called PA.

Protected areas in India and in Maharashtra: an introduction

The main PA categories in the Indian context are national parks (NP) and the wildlife sanctuaries (WS), which were notified under the provisions of the WildLife (Protection) Act, 1972 (WLPA). Categories of conservation reserve and community reserve were added to the list of PAs in 2002, while the tiger reserve (TR) that existed as an administrative unit since 1973 (Project Tiger 1973) became a legally constituted category via amendments made to the WLPA in 2006. A statutory body called the National Tiger Conservation Authority (NTCA) was also created via the same set of amendments in 2006 (Anonymous 1972; NTCA 2010).

A little less than 5% of the landmass of the country is included in the PA network today with the specific numbers being the following: national parks - 103, wildlife sanctuaries - 537, conservation reserves - 67, community reserves - 26 (Kutty & Kothari 2001; ENVIS Centre on Wildlife and Protected Areas 2017a). The number of tiger reserves, each one of which is constituted by multiple units that include NPs, WSs, and revenue and private lands, currently stands at 50 (Kutty & Kothari 2001; ENVIS Centre on Wildlife & Protected Areas 2016). The other important category relevant in the context of this paper is eco-sensitive zones (ESZ) or eco-sensitive areas (ESA) that is constituted under the provisions of the Environment Protection Act (EPA) 1986; the state of Maharashtra currently has four such ESZs (Environment Protection Act 1986; Kapoor et al. 2009).

[1] The organisations include, among others, the Foundation for Ecological Security, the Duleep Matthai Nature Conservation Trust, the Bombay Natural History Society, Indian Bird Conservation Network, and the World Wide Fund for Nature - India.

Also relevant here, particularly in the context of more recent developments, is the Scheduled Tribes and Other Forest Dwellers (Recognition of Rights) Act (FRA), 2006. There are other legal frameworks such as the Coastal Regulation Zone (CRZ) under the EPA 1986 and the Biodiversity Heritage Sites under the provisions of the Biological Diversity Act (BDA) 2002 that are relevant for a larger discussion on conservation but are outside the purview of this paper.

It is also important to mention here that there exists a large body of research, analysis, discussion, and debate on a range of issues related to the protection of forests and different ecosystems, the relevance and impact of conservation laws to the goal of conservation itself, and the impact these legal frames and the PA network have on local human communities (cf. Pathak-Broome & Desor n.d.; Pande et al. 1991; Dowie 2009; Lasgorceix & Kothari 2009; Sekhsaria 2007; Bijoy 2011; Desor 2015). Going into the details of all these discussions and debates is beyond the scope of the current paper. It is important to note, however, that this larger legal and policy context and its implications and related debates form a crucial backdrop to the reporting in the media, to the news and information that is carried in the PAU, and to the discussion and analysis of PA-related news from the state of Maharashtra that is the focus of this paper.

Maharashtra

Maharashtra, one of the three largest states of India in terms of area and population (Pande & Pathak 2005b), has a high concentration of English media houses and also a large number of PAs (n=42; Fig. 1), second only to the Andaman & Nicobar Islands where the number stands at 105 (ENVIS Centre on Wildlife & Protected Areas 2017a; MFD 2017)[2] These PAs cover an area of about 10,000km^2, which is about 3.26% of the total area of the state. The largest of these is the Tadoba-Andhari Tiger Reserve (TATR) at 1,727 km^2 (ENVIS Centre on Wildlife & Protected Areas 2016), followed by the Great Indian Bustard Sanctuary at 1,222km^2 (Pinjarkar 2011). The state also has six tiger reserves: Bor, Melghat[3], Nawegaon-Nagzira[4], Pench[5], Sahyadri[6], and TATR[7] (ENVIS Centre on Wildlife and Protected Areas 2016). There is also the Malvan Marine Sanctuary and the more recently created PAs like the Thane Creek Flamingo Sanctuary and the one in Mahul-Sewri (Anonymous 2015a; ENVIS Centre on Wildlife & Protected Areas 2017b). For a comprehensive account of the history, ecology, and management challenges related to the PAs in Maharashtra, see Pande & Pathak (2005a,b).

The Protected Area Update[8]

The PAU, published by the environment action group Kalpavriksh, was initiated as the 'Joint Protected Area Management Update' in 1994 (JPAM Update - 1 1994; Kothari 2012). The name was changed to the current Protected Area Update in 1999 (PA Update - 21 1999) in response to the kind of news that was being received and based on feedback from readers.

The newsletter is a collection of news stories related to PAs appearing in major English language dailies around the country that are collated and edited before being put together in a pre-determined format. Published once every two months, the PAU is a one-of-a-kind anthology of conservation reporting in India, including news reports and information from the pre-internet and pre-online newspaper era. It offers, on that count, an important resource to understand the nature of both conservation challenges and of the relationship between conservation issues and the media. That being said, there are a few caveats regarding the choice of news carried in the newsletter and, by implication, on the analysis and inferences drawn in this particular paper.

Firstly, the reporting in the PAU is almost entirely secondary — it publishes only a selection of news that has already appeared in English newspapers, magazines, and, increasingly, on online news sites. There is also a critical gate-keeping function performed by the editorial team, particularly by the editor, in the choice of news that goes into the newsletter. There is also a significant

[2] Other sources like the website of the Maharashtra Biodiversity Board suggest there are 46 PAs in the state.

[3] Melghat TR is one of the first tiger reserves in India and was constituted in 1974. It was enlarged in 2007 by combining Gugamal NP, Narnala WS, Ambabarawa WS, Wan WS, and Melghat WS (ENVIS Centre of Wildlife & Protected Areas 2016).

[4] The Nawegaon-Nagzira TR was constituted in 2013 and includes Tawegaon WS, Nawegaon NP, Nagzira WS, New Nagzira WS, and Toka WS. Stories from all these protected areas are clubbed together under the Nawegaon-Nagzira TR.

[5] Pench TR was constituted in 2007 and includes Indira Priyadarshini Pench NP and Pench Mowgli Sanctuary.

[6] The Sahyadri TR was created in 2012 and spreads over an area of 1,165m^2. The Chandoli WS, Chandoli NP, and Koyna WS are now included in the Sahyadri TR and all stories from these PAs are included in this section.

[7] Tadoba-Andhari TR was constituted in 1955 and is spread over an area of 1,727km^2. It was comprised of the Andhari WS and Tadoba NP (ENVIS Centre on Wildlife & Protected Areas 2016a).

[8] The print version of the newsletter is currently sent to about 2,000 individuals. It also goes out in a PDF format via a dedicated electronic mailing list: https://groups.google.com/forum/#!forum/paupdate. The newsletter is also hosted on a number of websites (e.g. www.wii.gov.in and www.kalpavriksh.org) and also has a dedicated Facebook page.

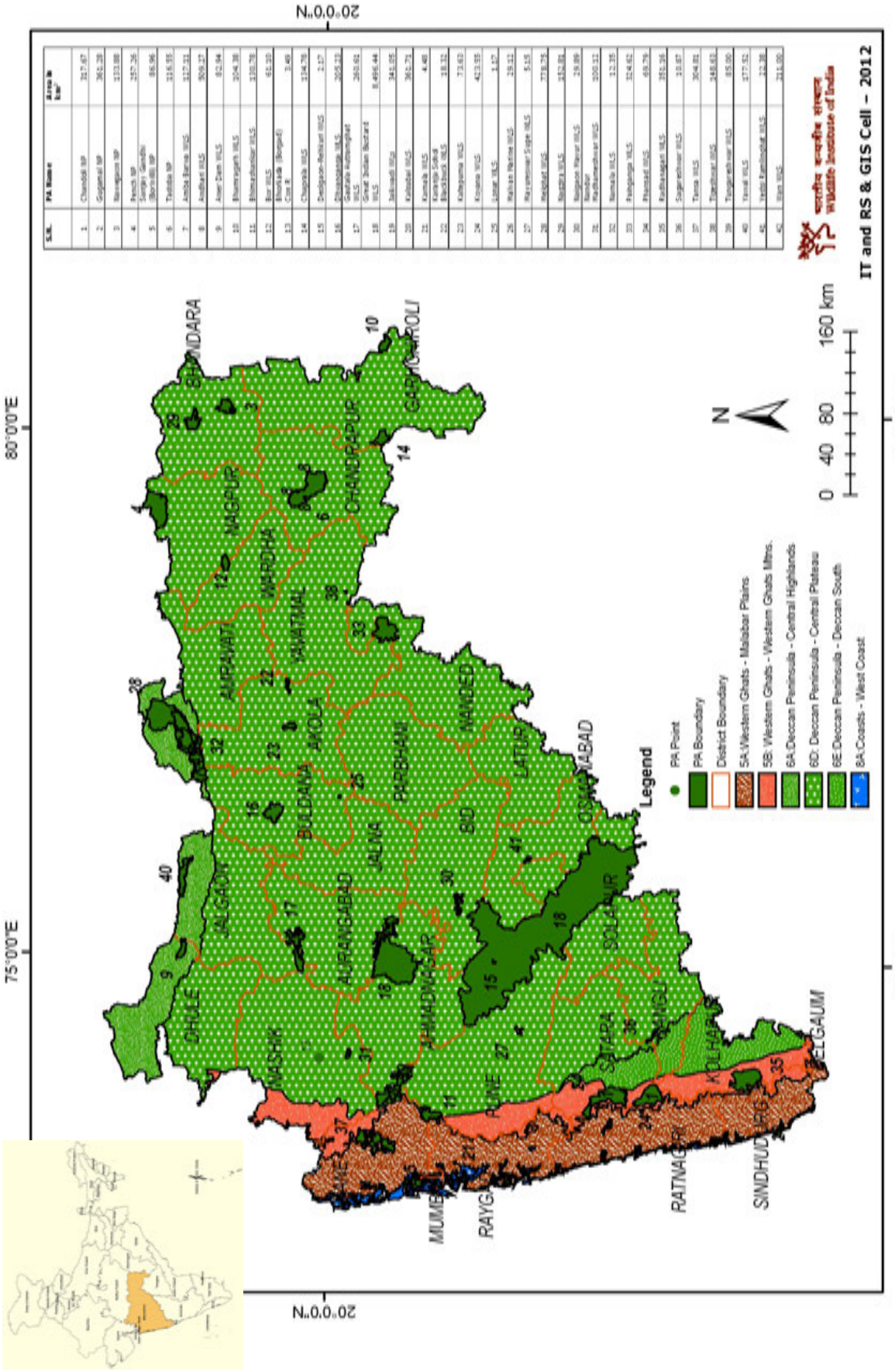


Figure 1. Protected areas in Maharashtra, India. Source: http://wiienvis.nic.in/WriteReadData/UserFiles/image/PAs_Map_Database/images/maharashtra.jpg (accessed on 21 February 2017). Source (Inset India map): Foundation for Ecological Security.

amount of editing the stories go through before they are re-published. There is a broad set of unwritten criteria-of-relevance that influences the decision on the news to be included and on the editing carried out. This choice is made by the editor leading to, most certainly, selection biases. An effort was made to draw attention to the existence of this selection bias and its influence at relevant places in the analysis that appears in this paper.

It is important, in the general context, to bear in mind that relevance and criteria for selection of news is a hugely subjective process and this is discussed extensively in the literature in media studies (cf. Wahl-Jorgensen & Hanitzsch 2009). This subjectivity is difficult to explicate beyond a point, but some of its clearly identifiable dimensions in the case of this paper are listed below to make it more explicit:

a) The two main sources for news on Maharashtra in the context of the PAU (and, therefore, for this paper) are 'The Times of India' and 'The Indian Express'. This is not surprising because these are the most prominent and widely read English newspapers published from Pune, where the editorial office of the PAU is located. This is visible in the stories in this collection from the very beginning. The other publication that is prominently accessed, particularly for the latter half of the period covered in this paper, is 'DNA', another newspaper. This may be explained by the fact that a Mumbai edition of the newspaper was started in 2005 and there was a Pune edition as well in the period 2008–2014. The other newspapers (and their websites) that news was accessed from include 'The Hitavada', 'Hindustan Times', 'Business Line', 'The Pioneer', and 'The Hindu'. The number of reports accessed from these, however, are significantly lower as compared to the three newspapers mentioned earlier.

b) For about the first eight years (1994–2002) covered in this paper, news carried in the PAU was mainly sourced from two different types of sources, the first being the Pune print editions of two prominent newspapers, The Times of India and The Indian Express mentioned above, and the second being the informal network of researchers, NGOs, and forest officials who sent news to the PAU directly from the field.

c) This begins to change from 2003 onwards. Increased access and spread of the internet is reflected in the fact that a small but noticeable number of stories in the newsletter are accessed from the web editions of newspapers like The Times of India. There is also a considerable decline in the news accessed directly from the field and from the informal network referred to above.

d) The year 2007 marks the first set of stories accessed from the Hindustan Times and from DNA. This may be explained, perhaps, by the fact that both the papers started their Mumbai editions in 2005. This meant a larger coverage of issues in Maharashtra in these newspapers and also easier access to this content in Pune where the editorial office of the PAU is located.

e) This period also marks a near complete shift in accessing of news from the print versions of the newspapers to their online editions. What is worth noting, however, is that the sources remain virtually the same, with The Times of India being the most prominent followed by The Indian Express and the DNA.

The editor also makes, on lines discussed earlier, a choice of news that is considered more relevant and more important for inclusion in the newsletter. Some non-exhaustive, illustrative examples of the same are listed below:

i. An individual news item on poaching is generally not considered for inclusion in the newsletter unless it marks a new development (poaching in a new area or using a new method) or is part of a prominent trend that has larger policy or intervention implications (one more animal killed in the same area over a long period of time).

ii. Based on the experience of regularly compiling and editing the newsletter, individual PAs that received relatively less coverage in preceding years are picked up on a priority as and when this information is available.

iii. Stories about certain issues like encroachments in the Sanjay Gandhi NP (SGNP), human-tiger conflict in the TATR, or denotification in the case of the Great Indian Bustard Sanctuary, virtually auto-selected themselves because of the developing-story nature of their relevance. This was deemed important by the editor to give the reader a full and continued sense of the issue and has, in all probability, also contributed to their prominence in a retrospective analysis that is sought to be done in this particular paper.

What is important to note here, indeed to reiterate, is that the PAU does not cover the entire universe of media reportage of PAs, but offers only an important subset. Our primary contention and, indeed, the foundational assumption of this paper and analysis is that the PAU is a good proxy for reporting on PAs that is seen in the media. The subset that makes up the PAU is on that account a good representation of the full universe of media coverage because of the specific nature of this newsletter:

a) its uninterrupted publication over a substantially long period of more than 20 years,

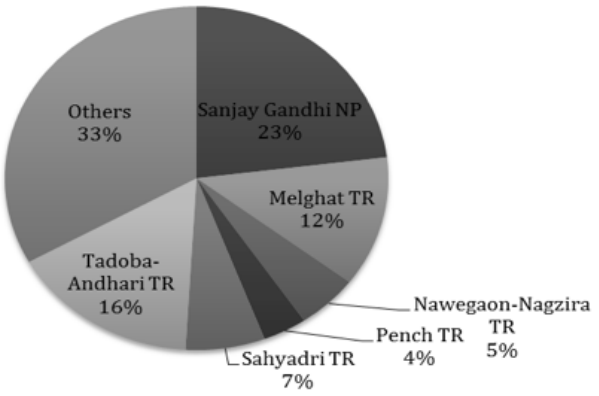


Figure 2. Share of news stories in Protected Area Update per protected area between 1994 and 2015 (total number of stories = 269).

b) its regular publication every two months, and

c) the focused nature of its news interest, the PAs.

The conclusions that we draw, therefore, are not (cannot) be definitive and conclusive. What we seek to present here is more in the nature of trends, patterns, and initial insights that can be the base for a larger engagement and understanding of both the nature of the media in general and of conservation-related reporting in particular.

METHODS

The database of press reports pertaining to Maharashtra that appeared in the PAU between 1994 and 2015 and upon which this paper is based number 269. This paper uses thematic analysis as its methodology for textual interpretation. This allows us to understand the underlying subjects within media content and is also exploratory while being realistic or fact-based (Vaismoradi et al. 2013). This method also lends itself to use across various kinds of data that may or may not have been collected explicitly for the purpose of analysis. Thematic analysis is a foundational, flexible, qualitative analytic method for identifying, analyzing, and reporting themes within data (Braun & Clarke 2006). It comprises the identification of patterns, themes, or 'categories' across an entire data set which, in this case, was the set of 269 media stories (Tuckett 2005; Fereday & Muir-Cochrane 2006).

'Themes' as they are described and identified in this study are the smallest units of data representation in the perspective of the researcher: "A theme captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set" (Braun & Clarke 2006). It is defined as "a pattern in the information that at minimum describes and organises the possible observations and at maximum interprets aspects of the phenomenon" (Boyatzis 1998).

The data does not inherently 'contain' themes — it is the researcher that identifies and teases out themes from the data iteratively; hence qualitative analyses such as this are subjective and dependent on the individual researcher(s) (Braun & Clarke 2006). Inductive thematic analysis, the method chosen for this paper, is similar to grounded theory in that themes are allowed to arise out of the data by themselves – they are "data-driven" — without trying to fit the themes into pre-conceived baskets. This was also better suited to this research paper since the data items were not collected primarily for this project as may have been the case with, say, focused group discussions or interviews, or a retrospective effort at gathering data along particular themes or with a particular research question in mind.

The identification of themes is of two kinds, semantic or latent, the latter also being referred to as narratology (Boyatzis 1998). Semantic analysis would be purely text-based while latent analysis goes one step further in interpreting the data to pick out themes. Interpretation of the data was more useful in the case of this paper. For example, a story about the discovery of snares in the forest would be classified as poaching, even if the term 'poaching' did not appear anywhere in the story. Thematic analysis at the latent level "starts to identify or examine the underlying ideas, assumptions, and conceptualisations" (Braun & Clarke 2006).

The theme may be 'big' or 'small' in terms of size and may recur often or just appear in one or two instances. Prevalence of a theme is counted as the number of appearances that it makes through the data corpus. In this case, a theme could appear in a particular data item, i.e., news report, only once, while each news report could contain multiple themes.

For this paper, we first collated all the news stories and classified them according to the PA they referenced. As the first step, we familiarized ourselves with the data by getting a sense of the way headlines were constructed and the meta-data such as the coverage per PA and sources. We then went over the data multiple times, going back and forth each time, noting down the themes that seemed to emerge from the stories.

At the end of the first 'pass', these themes were coded and clusters emerged. Here, we define 'pass' as one round of examination of the entire data corpus of 269 stories resulting in a list of themes per data item or

news story. Multiple passes were made through the data to arrive at the deductions presented. We then went over the data repeatedly until 'new' themes stopped emerging and there was consistency in the themes identified across passes. We then curated the coded themes. We then also summed up and tabulated these themes in an attempt to showcase them graphically. Within thematic analysis, the frequency of themes may be used as a 'proxy for significance' but with plenty of caution (Vaismoradi et al. 2013). In this study, while the most 'important' themes are the ones that occur most frequently, themes are also significant for their absence or rarity. We see a range of patterns emerging that are elaborated upon further.

Our analysis reveals three key points: a) unequal attention – certain PAs and issues get more news coverage while others get very little or no media attention at all, b) unique themes – certain themes occur frequently only in the case of certain PAs, indicating the local factors that may be most important to that PA, and c) emergence of broad key themes as well as actors across the full data set.

These are discussed in detail in the following sections followed by a case-study style detailed analysis of the two PAs in the state that were most frequently covered in PAU, the SGNP and the TATR.

Arguments

Unequal attention

News from 33 PAs[9] in Maharashtra was carried in the PAU between 1994 and 2015. That some PAs get greater media attention while most others are ignored by the press, tourists, and policy-makers alike would come as no surprise to those who follow conservation reporting. It is similar in Maharashtra with the SGNP in Mumbai accounting for about a quarter of all stories in the state (n=62). A reasonable conjecture is that the proximity of the park to a city of high population density, media outlets, and the urban English language news-reading public is primarily responsible for this. The other notable factor is the coverage that is accorded to the tiger reserves in the state.

Tiger reserves in focus

Apart from the SGNP, it is the state's six tiger reserves[10] that attract maximum media attention. TATR, located in Chandrapur District, is the largest and oldest tiger reserve in Maharashtra and accounts for 16% (n=43) of all news stories, second only to SGNP. Melghat (n=33), Pench (n=10), and Nawegaon-Nagzira (n=14), which lie along the state's northeastern boundaries and form an important contiguous tiger habitat in the central Indian landscape, are also reported on more than the others. Bor TR was a wildlife sanctuary until 2014 and was recently accorded the status of a tiger reserve. It provides important habitat connectivity between the northeastern tiger belt and the TATR. The Sahyadri TR (n=18) is Maharashtra's only tiger reserve in the Western Ghats. It was formed by combining the Koyna and Chandoli NPs, so the media stories pertaining to this reserve also combine the older stories related to these two parks.

These six tiger reserves in Maharashtra account for a significant 45% of all news stories over the last 20 years. It is also significant to note that although several tiger reserves are composed of wildlife sanctuaries and national parks, many of the individual PAs did not attract much media attention until they were accorded the status of tiger reserves. Tigers and tiger reserves attract the bulk of conservation funding and research attention. The charismatic large cat is also the main draw for a large number of local and international tourists, and this appears to allow (or perhaps even necessitates) more media coverage (Patra 2010; Anonymous 2015b; Menon 2016).

Unequal coverage

Around 15 PAs were not reported on at all or were covered very marginally in the PAU. Even 40-year-old parks such as the Gugamal NP[11] in Amaravati District did not find a single mention, nor did the Malvan Marine Sanctuary. Other PAs in this under-reported category were the Amba Barwa WS, Aner Dam WS, Bhamragarh WS, Chaprala WS, Karanjasohol WS, Katepurna WS, Mayureswar Supe WS, Naigaon Mayur WS, Narnala WS, Painganga WS, Phansad WS, Wan WS, and Yedsi Ramlinghat WS. These PAs are, in a sense, conspicuous by their absence. While understanding or analyzing the reasons for this is beyond the scope of this particular paper, the absence needs to be understood; an explanation of the dynamics involved would be as important as it would be instructive.

[9] The master list of protected areas used for this analysis was accessed from the website of the Wildlife Institute of India (ENVIS Centre on Wildlife & Protected Areas 2017).

[10] TRs often comprise one or more PAs. In the case of this paper, we clubbed news items of individual PAs under the TR that these PAs constitute; this partly explains why TRs show a larger number of news reports against their names (also see footnotes 3–7).

[11] Melghat TR, of which Gugamal NP is a part, does get considerable media coverage, as was noted already. The point here is that Gugamal as an independent entity has received little, if any, attention.

Table 1. Protected areas with four or more news reports in Protected Area Update along with the most recurrent themes in order of frequency.

Protected area	No. of stories	Top themes
Sanjay Gandhi NP	62	Encroachment, tourism, human-wildlife interacton
Tadoba-Andhari TR	43	Local communities, displacement, human-wildlife interaction, zoning, funding
Melghat TR	33	Local communities, poaching, research
Sahyadri TR	18	Displacement, local communities, development activities
Nawegaon-Nagzira TR	14	Local communities, administration
Bhimashankar WS	13	Religion, tourism, pollution, awareness
Great Indian Bustard Sanctuary	11	Denotification of land, conservation, awareness
Pench TR	10	Displacement, local communities, animal relocation
Matheran ESZ	7	Land (declaration as ESZ), zoning, tourism, pollution
Tungareshwar WS	6	Animal relocation, encroachment, institutional non-cooperation, religion
Karnala WS	5	Linear intrusion (widening of NH17), encroachment
Mahabaleshwar ESZ	5	Zoning, administration, tourism
Mansingdeo WS	5	Land (notification), institutional non-cooperation
Radhanagari WS	4	Mining, animal relocation
Sewri Wetlands	4	Development activity (sea link), land

PA-centric unique themes

The thematic analysis shows further that most PAs were associated with themes and issues that were unique to them. While PAs like the SGNP and the TATR that get wider coverage do have more multi-faceted reporting, each individual PA is characterized by a few themes that run through most of the stories related to them (see Table 1 for prominent themes associated with specific PAs).

Understanding the associations

Our analysis suggests that specific PA-related issues exist at two broad levels. While it is clear on the one hand that themes with a sociopolitical dimension such as conflict, displacement, and tourism get more traction in the media, individual PAs do have unique issues related to the human dimensions and cultural forces at play in that space.

In the case of the Bhimashankar WS, for example, the presence of the Shiva temple inside the sanctuary and the resulting pilgrimages and religious tourism appear to be one of the prime management issues (cf. Mavinkurve 1999; Shinde 2009), while in the Great Indian Bustard Sanctuary, issues of denotification attracted maximum reportage (Pinjarkar 2011). In the case of Matheran, the positioning of the hill station as an attractive tourist destination, the resulting development pressures, and its conservation status as an ESZ were the issues most relevant in the reporting (Balaram 2002; Vyas 2012). In the case of the Melghat TR, as with all other tiger reserves in the state, the displacement of local people and ensuing discord emerge repeatedly in the media as the tropes that are most significantly associated with them (cf. Anonymous 1999b; Negi 2011).

The Melghat and Nawegaon-Nagzira TRs also reported the highest incidences of poaching of tigers over the past 20 years (cf. Pinjarkar 2014; Deshpande 2015). It would be interesting to co-relate these features with actual incidences of poaching in these tiger reserves to see whether media reporting is reflective of the actual proportion of these incidents.

Themes were also seen to have an important temporal dimension, appearing as they did in several consecutive stories about respective PAs before fading away and being replaced by another thematic focus. Possibly, the media follows a case until its resolution before the next issue crops up. This was seen most prominently in the case of the SGNP with the reportage moving from issues of land, encroachment, and relocation in the first few years to issues of development threats, linear intrusions, and human-wildlife conflict for the period 2010–2015. Significantly, issues of encroachment and relocation were conspicuous by their absence in this period (see Table 2 for the changing focus and theme of reporting in the case of SGNP). As the vast majority of the stories are event- or conflict-based, these trends in media reporting may actually follow the current threats faced by particular PAs.

Themes in the reportage

Press coverage of PAs in Maharashtra touched on a number of themes over the years. Our analysis suggests 39 themes, the most common of which in order of frequency were local people, land, tourism, displacement, research and development activity, zoning, human-wildlife conflict, and encroachment. We reiterate, due to the latent nature of this analysis, that the identification of themes is subjective. A 'theme' was considered to be the smallest unit of a subject that was touched upon in the news report. Several of the 39 themes 'overlap' or are inter-related.

We see, for example, that although most of the stories about local people were related to their displacement, 'displacement' is still a unique theme

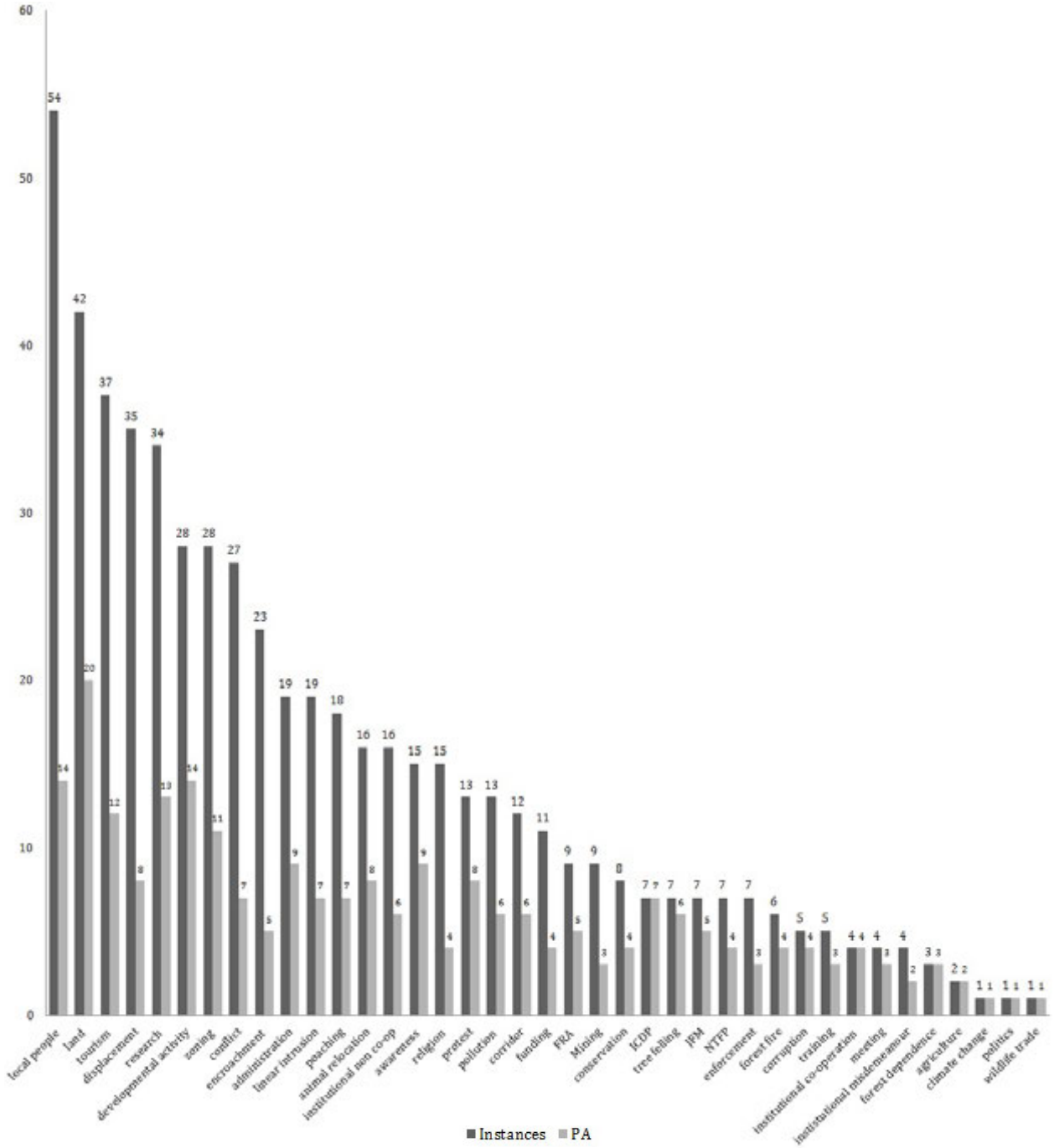


Figure 3. Themes in media reporting of protected areas and the number of stories in which they appear (instances) in Protected Area Update.

Table 2. Evolution of themes in time in the reporting on Sanjay Gandhi National Park in Maharashtra, India, in Protected Area Update. Themes are listed in order of frequency of appearance.

Period	1997–2000	2001–2005	2006–2010	2011–2015
No. of stories	14	13	19	16
Themes	- Encroachment - Tourism - Local people - Displacement	- Displacement - Human-wildlife interaction - Local people	- Encroachment - Tourism - Human-wildlife interaction	- Linear Intrusion - Research - Zoning - Human-wildlife interaction

in itself as it is distinct from the topic of 'local people', although associated with it in nearly all instances. Therefore, news reports discussing the displacement of local people would be tagged under both these themes. 'Zoning' is closely related to the theme of 'land', yet we tried to make a subtle distinction between, for example, stories about the declaration of buffer zones or disputes on mining in core or buffer areas of reserves and reports that were more distinctly land-related such as notification of new sanctuaries. The attempt was to remain consistent throughout our data analysis.

The number of stories in which a particular theme occurred as well as the number of PAs from which these themes were reported are shown in Fig. 3. For example, 'encroachment' was a highly concentrated theme, while 'land' was distributed across PAs. The details of all the themes emerging as important in the course of this analysis of media reporting of PAs in Maharashtra are shown in Fig. 4.

In the section that follows, we go into further details of key themes, 'local people', 'land', 'tourism', 'displacement', 'research', 'development projects', and 'conflict', that appeared in our analysis.

Local People

The most common theme that emerges in this analysis is that of 'local people', featuring as it does in 20% of the entire reportage. These stories were mainly concerned with the displacement of tribal people and villagers from within PAs. The reports speak of traditional forest-dwellers and inhabitants of villages inside or in the fringes of parks being relocated and recount the negotiations, protests, and legal consultations that were an inevitable part of this process. We see this most obviously in the case of the SGNP and in TRs such as Melghat and TATR. The tone of the reportage is heavily biased in favour of local people. Several of these stories also feature political parties, NGOs, and the courts, and present their roles in the displacement debate. It is also noteworthy that two-thirds of these stories about local people were related to the tiger reserves.

Other stories relating to 'local people' reported incidents of human-wildlife conflict, joint forest management practices, and poaching. Here we must mention that 'encroachment' as a theme is separate in our analysis. 'Encroachment' was used mostly to describe (as reported in the stories) "slum-dwellers" (cf.

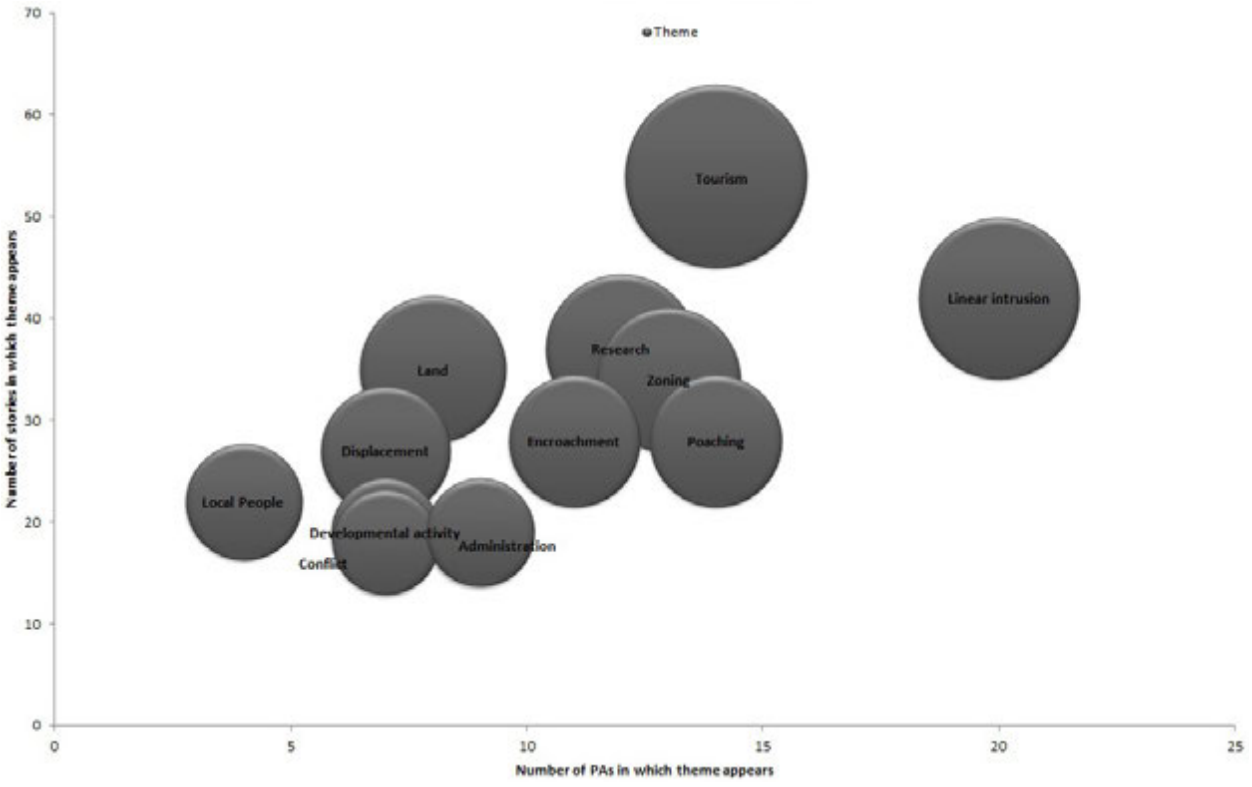


Figure 4. Most frequently occurring themes in Protected Area Update, with the X-axis indicating how 'widespread' the theme was across protected areas and the Y-axis indicating the frequency of appearance of the theme.

Anonymous 1999b; Singh 2000) "squatting" inside SGNP or other illegal structures that unlawfully utilized forest land.

Some other themes that emerge as closely related to the theme of 'local people' include the Forest Rights Act (FRA), dealing mainly with the interactions between the local people and authorities with regard to settlement of rights and land titles (Pinjarkar 2013; Upadhyay 2013) and joint forest management (JFM), and describe meetings and workshops for integrated forest management.

Land

With India's PA network being a dynamic, evolving scene of negotiations, protests, and legal interventions, 'land' emerged as the second most important theme in our analysis. The theme of 'land' cropped up in 42 of the 269 stories and was the single most common theme across PAs, featuring in stories related to 20 PAs in the state. Most of the reporting detailed the notification (n=26) and denotification (n=10) of PAs or parts of the PAs. This is mainly due to the denotification of large parts of the Great Indian Bustard Sanctuary from 8,496km^2 to 1,222km^2; (Pinjarkar 2011) and the notification of several new PAs, for example, in Vidarbha, in lieu of this denotification (Anonymous 2012)

Other 'land'-related stories discussed the encroachment of forest land, 'go' and 'no-go' areas for development activities, and the declaration of buffer areas. 'Zoning' as a theme overlapped considerably with 'land' in that the declaration of buffer or eco-sensitive zones or even the boundaries of PAs were crucial to the discourse on land usage. Several of the other themes can be seen as related to these contentions over space — 'displacement', 'encroachment', 'zoning', 'human-wildlife conflict', 'linear intrusions', and 'development activities' are all themes concerning the various approaches to land use in the country and this can even be seen influencing and being influenced by other themes.

Development projects

A major debate in India is one that pitches conservation against development and development projects. Such activities proposed or implemented inside PAs include, mostly, dams or power plants but also airports (Thane Creek Sanctuary, Karnala WS), the sea link (Sewri Wetlands), pipelines (SGNP), or irrigation projects. Their impacts and related concerns were reported widely and 'development projects' was one of the three most widespread themes reported from across PAs.

The narrative followed a similar trajectory in all the cases — proposal of the infrastructure/project, the opposition to it from environmentalists and local people, and the legal battles. The resulting institutional confrontation also garnered considerable notice with the courts and National Green Tribunal featuring often. Here, again, the tone was largely biased against the development activity.

A breakdown of this theme reveals that about half the reports on development activities were related to water-related infrastructure including dams and irrigation projects, numbering 13 out of the total 24 reports. The other topics included the sea link off the coast of Mumbai, windmills, airports, and pipelines.

We would like to note that the theme of 'linear intrusions' that includes roads, highways, and electric lines (n=19) was listed independently because of its particular impact on the landscape and the PA. If clubbed together with 'development projects' and also those related to 'mining' (n=9), this issue could be considered as one of the biggest challenges before the PAs in Maharashtra and, by extension, across the country.

Displacement

'Displacement' was the fourth most frequently reported theme with 35 reports discussing displacement-related issues. As noted earlier, the theme of 'displacement' is closely related to the themes of 'land' and 'local people' since it is the local people that are displaced from PAs. Perhaps the human-interest angle of this topic affords greater interest for the media. Another closely related theme is 'protest', with several media reports describing the clash between the local people and authorities over displacement from their settlements. Twenty-two of the 35 stories (63%) with the theme 'displacement' were from the tiger reserves. This raises some important questions that we would like to flag for further research and analysis: Do tiger reserves get wider news coverage, thus skewing the statistics just because of their status as tiger reserves? Is there greater engagement with local people within tiger reserves due to greater scrutiny and better funding? Is it possible that there is greater pressure on authorities to move local people out because of greater prestige and visibility associated with a tiger reserve?

Conflict

Twenty-seven news reports from Maharashtra were related to human-wildlife conflict and these came from

just seven PAs, making this one of the most concentrated themes[12]. More than 80% (n=22) of these reports came from just two PAs, SGNP and TATR. In SGNP, this was related to the presence and/or sighting of leopards in human habitations in and around the park, while in TATR this was related to attacks on humans by tigers.

While there is some analysis and understanding now on the genesis of these conflicts, full knowledge of the reasons and the patterns of these are not available. In the case of leopard-related conflicts in and around SGNP, it has been established, for example, that capture of leopards and their relocation to areas that they are not familiar with results in an increase of conflict incidents. Media advocacy and awareness work by researchers in association with authorities has had a significant impact in SGNP and could be a model to be followed in other parts of the country too (Athreya & Belsare 2007; Keddie 2014).

Research

Although 'research' features as one of the more commonly appearing themes in the analysis, it is important to note that most of the reports about research are from just three PAs, SGNP, TATR, and Melghat TR. These PAs account for nearly 75% of all news stories pertaining to this theme. This is in spite of a clear editorial bias in the PAU in favour of publishing reports about research that feature in the media, particularly those on less charismatic species such as insects and plants. Most of the research-related reports deal with the results of the census conducted in the PAs.

Other themes

Apart from the themes discussed above, we would also like to point to the topic of institutional relationships, particularly with and between government actors. The media appeared to be keen on highlighting the perceived inefficiency of the bureaucratic machinery, with several stories featuring squabbles amongst the forest, revenue, railways, tribal development, and even irrigation departments. Topics related to administration including themes such as corruption, training, institutional non-cooperation or cooperation, and institutional misdemeanours accounted for about a tenth of the news coverage.

Finally, the narrative focused largely on sociopolitical issues with the issue of scientific matters being conspicuous by its absence. While there was plenty of newsprint dedicated to the opposition to development activities, the impacts of these projects were described rather superficially. The importance of corridors, for instance, was stressed in numerous reports without explaining their ecologic significance.

The main types of 'animal-centric' stories that were reported, apart from poaching, were those concerned with the results of wildlife surveys, followed by those reporting wild animal relocations, whether due to over-crowding in zoos or due to human-conflict (see Fig. 3 for a full breakdown and details of the themes in reports in the PAU).

Most important actors

An analysis of the key actors involved in the issues reveals the FD and local communities as being the most significant. NGOs were also frequently mentioned. It will be interesting to study whether this is because of the proportionate involvement of the NGOs in conservation issues, an editorial bias of the PAU in the choice of stories (that the newsletter itself is an NGO publication), or because NGOs often partner with the media in order to amplify their concerns and actions, thereby getting more publicity in spite of limited resources. We need to emphasize here that we use the term 'actor' to indicate that an entity is 'involved'; it is not a use of the term to show a hierarchy as in the power to cause an action. A situation where a "villager kills a leopard" is treated

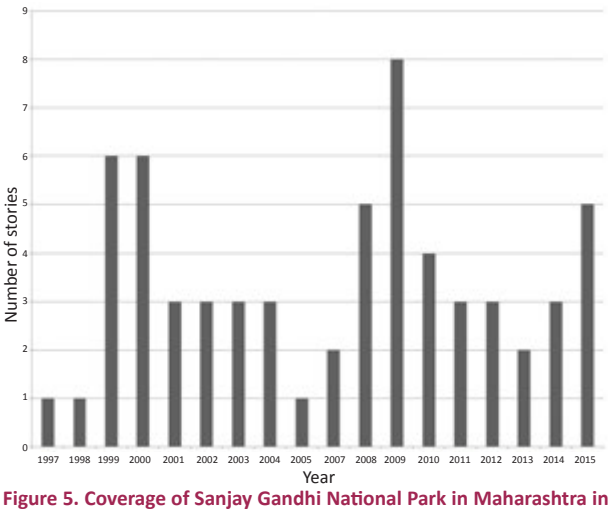


Figure 5. Coverage of Sanjay Gandhi National Park in Maharashtra in Protected Area Update by year.

[12] It is likely that a negative editorial bias in the matter of human-wildlife conflict reflects a lesser focus on this issue in the PA Update than would be seen in the media in general. The negative bias here is related to non-inclusion in the newsletter of stories of individual instances of conflict. The editorial focus was on reporting stories when they show existing or emerging trends or where incidents and events, even if solitary or isolated, are significant on account of new information, new kind of development, or a new trend.

symmetrically as one where a "leopard kills a villager".

The tiger was undoubtedly the most-featured 'wildlife actor', and was mentioned in about 15% (n=41) of all the news reports. It was followed by the leopard, with 23 instances. These two charismatic cats featured in half of all the stories that mentioned animal species, validating, one might argue, the discourse on charismatic mega fauna. Another prominent issue is that of tiger-poaching while the poaching of other wildlife goes largely ignored.

Having presented a broad overview of the reportage and the themes that (do not) appear, we now shift our focus to a detailed analysis of the two most reported PAs in Maharashtra, the SGNP and the TATR.

Case studies

Sanjay Gandhi National Park

The SGNP has been an important and, indeed, a contested landscape element for the city of Mumbai for a long time. Located in the suburbs of the sprawling metropolis, its forests have been an important water source for the city since the 19th Century. It was later expanded by the erstwhile Bombay Municipal Corporation when it came to be known first as the Krishnagiri National Park, then the Borivili National Park, before finally being christened the Sanjay Gandhi National Park in 1981, with a total area of about 103km^2. The 2000-year-old Kanheri Buddhist caves are also situated within the park (Pande & Pathak 2005a).

The park is at the centre of interactions amongst many actors — the local communities living in or around the park, NGOs, the courts, real estate dealers, leopards venturing outside its boundaries, and the many tourists who visit the park.

Changing focus of the coverage

Press coverage of the SGNP over the last couple of decades describes the various issues associated with the park and also how these evolved over the years. In the mid-1990s, the main narrative, as revealed through the news reports, was about the displacement of those living within the park boundaries. Other stories narrated cases of encroachment of the park for construction or diversion for other uses. Mumbai has one of the highest real estate prices in the country and land, therefore, is a highly contentious topic. The first phase of reporting from the SGNP discusses politicians and political parties getting involved along with the real estate mafia. The high court (HC) and the supreme court (SC) too played a major role in these cases, which also came to the notice of the human rights tribunal.

The next phase of reporting (2001–2005) focused on human-wildlife conflict and tourism, presumably once the issue of rehabilitation of slum-dwellers reached a steady state. There were several disagreements on the

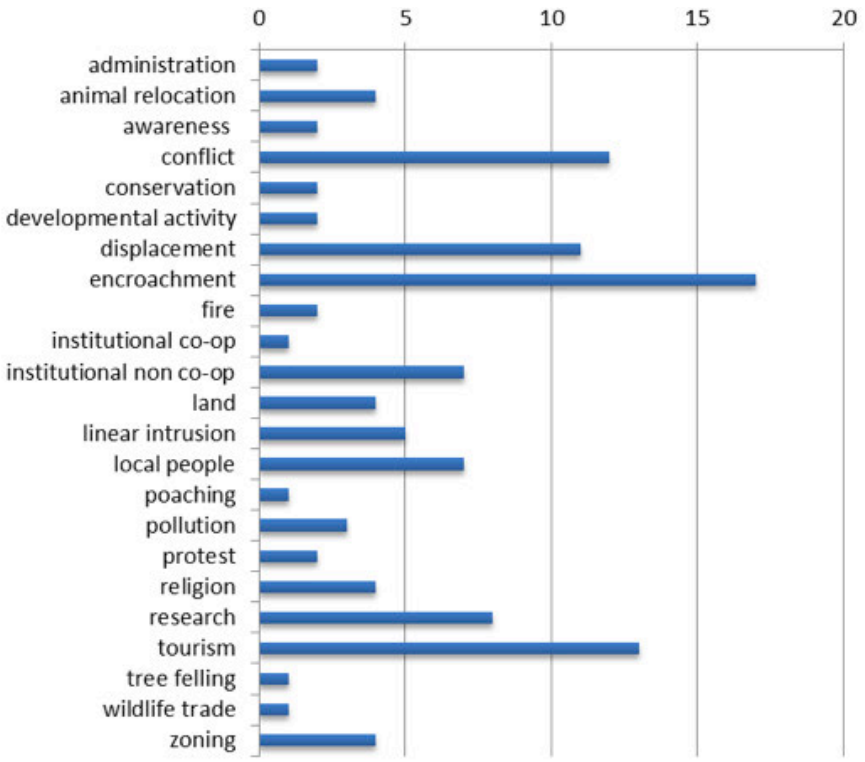


Figure 6. Prominent themes in reporting on Sanjay Gandhi National Park in Protected Area Update.

Table 3. Evolution of themes in time in the reporting on Tadoba-Andhari Tiger Reserve in Maharashtra, India[13], in Protected Area Update.

Period	1998–2006	2007–2009	2010–2012	2013–2015
No. of stories	2	15	11	14
Themes	- Enforcement - Poaching	- Displacement - Local people	- Local people - Corridor - Zoning	- Human-wildlife interaction - Administration - Funding - Zoning

[13] Breakdown in 2007–2009: administration, conflict (3), corruption, displacement (5), funding (3), institutional misdemeanour (3), local people (5), mining (3), NTFP, poaching, protest (2), research, tourism (3), training, tree felling, and zoning.
Breakdown in 2010–2012: administration (2), human-wildlife interaction, conservation (2), corridor (3), development activity (dam), displacement (2), funding, fire, FRA (2), land (diversion), linear intrusion (highway), local people (5), mining (2), NTFP, politics, poaching, protest, zoning (3).

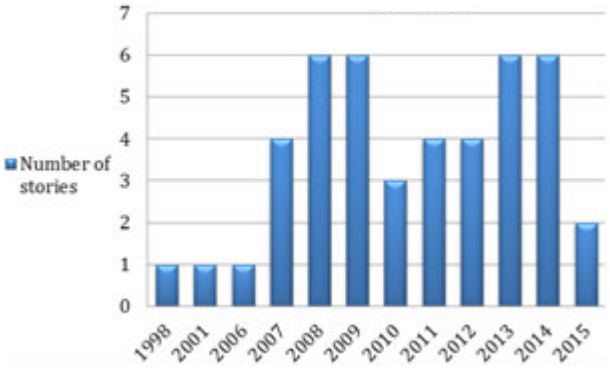


Figure 7. Coverage of Tadoba-Andhari Tiger Reserve in Protected Area Update by year.

kinds of tourism and tourist infrastructure that should be built in the park, ranging from information centres, zoo, safari, and a new entry gate. Reporting also highlighted the adverse impacts of high tourist numbers particularly with regard to littering. Conflict issues were mostly to do with leopards straying into human habitation or attacking dogs.

The more recent (2011–2015) years of reporting from SGNP were largely about other kinds of threats to the park in the form of development activities mainly as linear intrusions — railway lines, electric lines, highways, and even the metro — staking claim over the land that constitutes the national park.

Another interesting aspect is that of research. Going by the reporting in the PAU, research in the SGNP seemed to have taken off only in the last few years. Seven of the eight stories that discussed research were published after 2009. Topics of research varied widely from soil-testing to bird counts, but the leopard seemed to be the focus of most projects.

It is noteworthy that only one case of poaching was reported from the SGNP over the last 20 years, and this was in the early 90s. This may be on account of an editorial bias of the PAU against reporting individual cases of poaching, as was mentioned, but it is also possible that considerable focus on the park results in poaching rates being lower. In any case, the larger analysis seems to indicate that the media in general usually focus on poaching of large carnivores such as the tiger and that it is likely, therefore, that poaching of deer or other smaller animals goes unreported.

A variety of actors

The SGNP has the most varied set of actors mentioned in its reports. The most 'active' actor was the forest department, featuring in more than half the stories. The second most commonly mentioned actors were NGOs, featuring in 23 of the 62 stories. This was followed by the Mumbai HC, with many of the stories being related to the relocation of "slum-dwellers". The other participants were varied and included, among others, the state government and several individual ministers, the municipal corporation, the public works department, politicians, citizen groups, the urban development department, several central and state-level committees, and even the film industry — the last one more because the film city in Goregaon lies on land abutting the forests of the national park.

Tadoba Andhari Tiger Reserve

The TATR is one of the largest as well as oldest PAs in Maharashtra. Tadoba along with Kanha NP in adjoining Madhya Pradesh were established as the first sanctuaries of the Central Provinces and Berar in 1935. The tiger reserve was notified in 1995 by combining the Tadoba NP and the Andhari WS. It is located in the Chandrapur District in central India and is a popular tourist destination. This tiger reserve largely comprises dry deciduous forest and is home to several large mammals that include the Tiger, Leopard, Dhole, Muntjac, Sloth Bear, Nilgai, and Rusty-spotted Cat (Pande & Pathak 2005a).

The TATR features most often in the PAU after the SGNP with a total of 44 stories, and this is in spite of

the fact that there were very few stories before 2006.

Key themes

The overarching narrative about TATR that emerges from an analysis of the reports in the PAU is of the displacement of local communities and that of human-wildlife conflicts. The political nature of this issue clearly influenced its newsworthiness. The tone of the reporting appears to be largely neutral, but the political actors outside the government in each story appeared to play up the "tiger versus tribal" debate and were painted negatively by the media.

Unlike in the case of SGNP, the press reports pertaining to TATR are not as clearly thematic or 'phased', and cover a broader range of topics as seen in the thematic analysis of coverage of the reserve.

Stories of tiger-poaching found significant mention, but the media was largely silent on poaching of species other than the big cats. Enforcement measures taken by the forest department also caught the media's attention, by consequence.

From 2008 onwards, the issue of coal mining in and around the TATR started featuring regularly in the news stories. Significantly, the framing of the stories is strongly biased against the mining activities and mining companies. Zoning around the park also gets a significant mention and is pitched as an effective solution to prevent mining and other destructive activities in the area surrounding the park.

Key actors

We also looked at the human actors featuring in the news stories — the forest department has the highest number of mentions and is featured in 31 of the 44 stories. Local communities are next, followed by NGOs and the National Tiger Conservation Authority (NTCA). Academia features in only three stories. Unlike the overall trend, fewer cases pertaining to the TATR are referred to the courts, with the HC just finding one mention and an SC-appointed committee being the only other legal actor mentioned. From an overview perspective, it emerges that certain broad themes such as sociopolitical issues occupy centre-stage while others, science in particular, are conspicuous by its absence. This is in spite of greater research activity in the tiger reserve and the inordinate attention that large charismatic carnivores attract amongst the scientific community. All of the science-based stories mentioned pertain to radio-collaring of large cats or the reportage of survey results in the park. There is also a clear underdog bias in the reporting, with the hierarchy resembling something like tribal, tiger, development, and, finally, politics, with politicians getting the tough end of the stick.

The tiger

The tiger, quite expectedly, is one of the main 'actors' in the TATR, appearing in nearly half (n=20) of the 44 stories about the reserve. Leopards are next with six mentions. Apart from a cursory mention of the sloth bear, no other animal features in the news reports. On the whole, TATR has several more stories related to the general administration of the park including enforcement efforts to control poaching and details about funding. Tiger reserves also have a significantly larger number of stories related to funding.

CONCLUSION

Media content analysis is no doubt a powerful tool that can be utilized to understand the evolution of an issue over time or, conversely, to guide the discourse over an issue of public interest. There are inherent biases in reporting, whether positive or negative, and taking cognizance of this is essential to understanding the impact of the media.

Our study provides interesting insights and raises some important questions about conservation reporting in India. The main findings, as discussed, point to an unequal coverage given to PAs in the state, the emergence of broad key themes as well as actors across the full data set, and the also the association of certain themes more prominently with specific PAs.

There are, however, a number of key issues and questions this study highlights and which remain to be answered. These are presented here both as conclusions and as pointers and questions for further research and studies:

- Does the media represent issues on the ground accurately? What might be the metrics/methodologies of making such an assessment?
- What are the sources of media reporting of conservation issues in India? Are all voices in the debate given a platform?
- Why is there such a strong emphasis on sociopolitical dimensions of conservation while science-based reporting is largely missing?
- Is conservation reporting, as with reporting in general, a function of proximity (or distance) from 'power centres' such as Mumbai or Pune?
- An interesting question would be related to the coverage in the English media as represented in this

analysis as against reporting that is seen in the local, Marathi press. What might one find if this comparison was to be made?

- One notable development in the last decade or so is the proliferation of online news sources dedicated to wildlife and the environment as also the wider and easier access to regular news sites. This has its own compulsions and dynamics and one interesting comparison and analysis would be of a pre- and post-internet era.

We reiterate that as the primary and, often, only source of information about nature and wildlife conservation for the public, the media plays an extremely important role in awareness, understanding, and participation of people in conservation. We believe more analyses such as this one will help to understand the larger patterns and trends in what the media reports about wildlife and conservation, of what issues are considered important as also the larger political economy of the media itself, and how perceptions such as those of threat, importance, and rarity which are important tropes in the conservation issues actually mobilize the media as the media mobilizes them.

REFERENCES

Anonymous (1972). Wildlife (Protection) Act (1972). Professional Book Publishers, New Delhi, 217pp.

Anonymous (1999a) Court prods govt. on Borivli park settlers. *The Times of India* 10 July 1999.

Anonymous (1999b). Resettlement of Melghat evacuees discussed. *The Indian Express* 06 November 1999.

Anonymous (2012). Vidarbha gets three new sanctuaries. *The Hitavada* 05 March 2012.

Anonymous (2015a). Wildlife board approval for MTHL project. *The Times of India* 05 December 2015. Available online at https://timesofindia.indiatimes.com/city/mumbai/Wildlife-board-approval-for-MTHL-project/articleshow/50048783.cms. Accessed on 21 February 2017.

Anonymous (2015b). Where tiger is king! *Protected Area Update* 21(1): 3. Available online at http://oldkv.kalpavriksh.org/images/PAUpdate/ProtectedAreaUpdated113_Feb2015.pdf. Accessed on 02 February 2019.

Athreya, V. & A. Belsare (2007). *Human-Leopard Conflict: Management Guidelines*. Kaati Trust and Maharashtra Forest Department, Pune, 71pp. Available online at http://www.projectwaghoba.in/docs/human_leopard_conflict_management_guidelines_english.pdf. Accessed on 09 January 2019.

Athreya, V., A. Srivathsa, M. Puri, K.K. Karanth, N.S. Kumar & U. Karanth (2015). Spotted in the news: using media reports to examine leopard distribution, depredation and management practices outside protected areas in southern India. *PLoS One* 10(11): e0142647; https://doi.org/10.1371/journal.pone.0142647

Balaram, G. (2002). Matheran declared ecosensitive zone. *The Times of India* 22 February 2002.

Barua, M. (2010). Whose issue? Representations of human-elephant conflict in Indian and international media. *Science Communication* 32(1): 55–75; https://doi.org/10.1177/1075547009353177

Bhatia, S., V. Athreya, R. Grenyer & D.W. Macdonald (2013). Understanding the role of representations of human-leopard conflict in Mumbai through media-content analysis. *Conservation Biology* 27: 588–594; https://doi.org/10.1111/cobi.12037

Bijoy, C.R. (2011). The great Indian Tiger show. *Economic and Political Weekly* XLVI(4): 36–41.

Boyatzis, R.E. (1998). *Transforming Qualitative Information: Thematic Analysis and Code Development*. Sage, New Delhi, 200pp.

Braun, V. & V Clarke (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology* 3(2): 77–101; https://doi.org/10.1191/1478088706qp063oa

Cook, T.E. (1998). *Governing with the News*. University of Chicago Press, Chicago, 289pp.

Deshpande, V. (2015). Dhakna poaching case: 3 traders sentenced to seven years' imprisonment. *The Indian Express* 11 December 2015. Available online at https://indianexpress.com/article/cities/mumbai/dhakna-poaching-case-3-tiger-traders-sentenced-to-seven-years-imprisonment/. Accessed on 09 January 2019.

Desor, S. (2015). *Forest Goverance at the Interface of Laws Related to Forest, Wildlife & Biodiversity*. Natural Justice and Kalpavriksh, Pune, 64pp.

Dowie, M. (2009). *Conservation Refugees: The Hundred-year Conflict between Global Conservation and Native Peoples*. The MIT Press, Cambridge, MA, 376pp.

ENVIS Cente of Wildlife & Protected Areas (2012). Wildlife Protected Areas in Maharashtra. Wildlife Institute of India, Dehradun. Available online at http://wiienvis.nic.in/WriteReadData/UserFiles/image/PAs_Map_Database/images/maharashtra.jpg. Accessed on 02 February 2019.

ENVIS Centre of Wildlife & Protected Areas (2016). Wildlife Institute of India, Dehradun. Available online at http://wiienvis.nic.in/Database/trd_8222.aspx. Accessed on 21 February 2017.

ENVIS Centre of Wildlife & Protected Areas (2017a). Protected Areas of India. Wildlife Institute of India, Dehradun. Available online at http://www.wiienvis.nic.in/Database/Protected_Area_854.aspx. Accessed on 21 February 2017.

ENVIS Centre of Wildlife & Protected Areas (2017b). Protected area gazette notification database (Maharashtra). Wildlife Institute of India, Dehradun. Available online at http://wiienvis.nic.in/Database/Maharashtra_7829.aspx. Accessed on 02 February 2019.

Fereday, J. & E. Muir-Cochrane (2006). Demonstrating rigor using thematic analysis: a hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods* 5(1): 80–93; https://doi.org/10.1177/160940690600500107

JPAM Update - 1 (1994). Indian Institute of Public Administration, New Delhi, 2pp. Available online at http://oldkv.kalpavriksh.org/images/PAUpdate/PAUpdate1_17_Sept1994_Jul1998.pdf. Accessed on 02 February 2019.

Kapoor, M., K. Kohli & M. Menon (2009). *India's Notified Ecologically Sensitive Areas (ESAs) - The Story So Far.* Kalpavriksh, Pune & WWF-India, New Delhi, 112pp. Available online at http://assets.wwfindia.org/downloads/indias_notified_ecologicallysensitive_areas.pdf. Accessed on 01 January 2019.

Keddie, P. (2014). Living alongside leopards in Mumbai. *The Guardian* 19 May 2014. Available online at https://www.theguardian.com/environment/2014/may/19/living-alongside-leopards-in-mumbai. Accessed on 22 February 2017.

Kothari, A. (2012). Whither Protected Areas? *Protected Area Update* 18(6): 1. Available online at http://oldkv.kalpavriksh.org/images/PAUpdate/PROTECTED%20AREA%20UPDATE%20100_Dec2012.pdf. Accessed on 02 February 2019.

Kutty, R. & A. Kothari (2001). *Protected Areas in India: A Profile*. Kalpavriksh, Pune, 157pp.

Lasgorceix, A. & A. Kothari (2009). Displacement and relocation from protected areas: a synthesis and analysis of case studies. *Economic & Political Weekly* 44(49): 37–47.

Mavinkurve, A. (1999). Follow-up at Bhimashankar. *The Indian Express* 11 November 1999.

Melghat Tiger Reserve (2015). Melghat Tiger Reserve (1973–74 – 2014–15). Available online at http://www.melghattiger.gov.in/documents/MTR.pdf. Accecced on 02 February 2019.

Menon, A. (2016). Tiger is not the only animal that needs saving. Available online at http://www.dailyo.in/politics/project-tiger-incredible-india-wildlife-amitabh-bachchan-panama-papers-corbett-animals/story/1/10324.html. Accessed on 22 February 2017.

MFD (2017). Protected Areas. Maharashtra State Biodiversity Board. Available online at http://maharashtrabiodiversityboard.gov.in/habitat-diversity/protected-areas/. Accessed on 21 February 2017.

Negi, H. (2011). Letter No. 4-1(10)/2011-RT. Letter issued by the Deputy Inspector General, Forests. Government of India, Delhi.

NTCA (2010). *Compendium of Guidelines/Advisories/Gazette Notification - Updated upto 31st March 2010*. National Tiger Conservation Authority, New Delhi, 360pp.

PA Update - 21 (1999). Kalpavriksh, Pune, 22pp. Available online at http://oldkv.kalpavriksh.org/images/PAUpdate/Protected%20AreaUpdate21_july1999.pdf. Accessed on 02 February 2019.

Pande, P., A. Kothari & S. Singh (1991). *Directory of National Parks and Sanctuaries in Andaman and Nicobar Islands: Management Status and Profiles*. Indian Institute of Public Administration, New Delhi, 171pp.

Pande, P. & N. Pathak (2005a). *National Park and Sanctuaries in Maharashtra, Vol. II. Individual Profile and Management Status*. Bombay Natural History Society, Mumbai, xx+531pp.

Pande, P. & N. Pathak (2005b). *National Parks and Sanctuaries in Maharashtra, Vol. I. A State Profile*. Bombay Natural History Society, Mumbai, xxvi+212pp.

Pathak-Broome, N. & S. Desor (n.d.). *Applicability of the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (also called) The Forest Rights Act (FRA) to Protected Areas (PAs) Legislation Brief*. Kalpavriksh, Pune, 16pp.

Patra, S. (2010). Skewed conservation priorities in India. *IndiaWilds Newsletter* 2(10). Available online at http://www.indiawilds.com/diary/indiawilds-newsletter-vol-2-issue-x/. Accessed on 22 February 2017.

Pinjarkar, V. (2011). SC clears denotification of GIB Sanctuary. *The Times of India* - 25 July. Available online at https://timesofindia.indiatimes.com/city/nagpur/SC-clears-denotification-of-GIB-sanctuary/articleshow/9350669.cms. Accessed on 09 January 2019.

Pinjarkar, V. (2013). Encroachments overrunning Yawal Sanctuary. *The Times of India* 09 August 2013. Available online at https://timesofindia.indiatimes.com/city/nagpur/Encroachments-overrunning-Yawal-sanctuary/articleshow_b2/21718500.cms?mobile=no. Accessed on 09 January 2019.

Pinjarkar, V. (2014). Poachers killed four tigers together at Melghat. *The Times of India* 08 February 2014. Available online at https://timesofindia.indiatimes.com/home/environment/flora-fauna/Poachers-killed-four-tigers-together-at-Melghat/articleshow/30046764.cms. Accessed on 09 January 2019.

Project Tiger (1973). Guidelines for Execution of the Project by the States, Pub. L. No. J-11025/1/72-FRY(WLF)/Dt. 4.1.1974 (1973). Ministry of Agriculture, Govt. of India, India.

Sekhsaria, P. (2007). Conservation in India and the need to think beyond 'tiger vs. tribal.' *Biotropica* 39(5): 575–577; https://doi.org/10.1111/j.1744-7429.2007.00333.x

Shinde, S. (2009). Greens object to plans to hold religious function at Bhimashankar. *The Times of India* 23 October 2009. Available online at https://timesofindia.indiatimes.com/city/pune/Greens-object-to-plans-to-hold-religious-function-at-Bhimashankar/articleshow/5146714.cms. Accessed on 09 January 2019.

Shoemaker, P. & S. Reese (1991). *Mediating the Message: Theories of Influence on Mass Meda Content*. Longman, New York, 321pp.

Siddiqui, M. & C. R. Reddi (2012). The print media's Kaziranga obsession: an analysis, pp214–220. In: Sekhsaria, P. (Ed.), *The State of Wildlife in north-east India, 1996–2011: A Compilation of News from the Protected Area Update*. Foundation for Ecological Security, Anand, 300pp. Available online at https://www.academia.edu/3152382/_THE_STATE_OF_WILDLIFE_IN_NORTHEAST_INDIA_1996_2011_A_Compilation_of_News_from_the_Protected_Area_Update_. Accessed on 02 February 2019.

Singh, A. (2000). Villagers resent rehab of slum-dwellers on their turf. *The Times of India* 04 September 2000.

Tuckett, A.G. (2005). Applying thematic analysis theory to practice: a researcher's experience. *Contemporary Nurse* 19(1–2): 75–87; https://doi.org/10.5172/conu.19.1-2.75

Upadhyay, P. (2014). Community Forest Rights (CFRs) rejected in Melghat TR. *Protected Area Update* 20(1): 19. Available online at http://oldkv.kalpavriksh.org/images/PAUpdate/ProtectedAreaUpdate107_Feb2014.pdf. Accessed on 02 February 2019.

Vaismoradi, M., H. Turunen & T. Bondas (2013). Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. *Nursing Health Sciences* 15: 398–405; https://doi.org/10.1111/nhs.12048

Vyas, S. (2012). Maharashtra tourism plans casinos, discotheques in Matheran. *The Times of India* 29 November 2012. Available online at https://timesofindia.indiatimes.com/india/Maharashtra-tourism-plans-casinos-discotheques-in-Matheran/articleshow/17407879.cms. Accessed on 09 January 2019.

Wahl-Jorgensen, K. & T. Hanitzsch (eds.) (2009). *The Handbook of Journalism Studies*. Routledge, New York, 446pp.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13377–13384

Avian survey in tourist sites near Putao in northern Myanmar

Alexey E. Scopin [1], Vladimir N. Sotnikov [2], Dmitry V. Skumatov [3] & Alexey A. Sergeyev [4]

[1,3,4] Zhitkov Russian Research Institute of Game Management and Fur Farming, 79 Preobrazhenskaya St., 610000 Kirov, Russia.
[2] Kirov Zoological Museum, 179 Lenina St., 610000 Kirov, Russia.
[1] scopin@bk.ru (corresponding author), [2] sotnikovkgzm@gmail.com, [3] skumatovd@bk.ru, [4] metalbird@mail.ru

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

Abstract: We present the results of short ornithological observations conducted in November–December 2014 and December 2015 in the territory near Putao in northern Myanmar at elevations below 1,500m. We recorded 105 species, which were mostly resident birds, and evaluated the species abundance with a relative scale along tourist walking routes in the area. The bird species richness in the Mali Hka River Valley was observed to be less than in the adjacent virgin mountain forests. Our results could be used for future bird monitoring fieldworks.

Keywords: Birdwatching, eastern Himalaya, ecotourism, Himalayan avifauna, Mali Hka River Valley, ornithologic survey, subtropical ecosystems.

In recent decades, birdwatching is extremely popular and is now one of the most attractive forms of ecotourism. Many birdwatchers are especially interested in the regions where the bird lists are not complete and where there is a space for exciting discoveries. The magnificent landscapes and diverse wildlife of Myanmar with their numerous bird species provide such wonderful opportunities. Although extensive research on birds of Myanmar was done more than half a century ago (e.g., Oates 1883; Baker 1922, 1930; Smythies 1953), most recent review publications are rare (e.g., Lwin & Thwin 2003; Twin et al. 2011; Renner et al. 2015) compared to bird distribution data from other countries of southeastern Asia.

Northern Myanmar forms a part of the eastern Himalayan mountain range. It represents an important bird area populated by many representatives of the Palearctic and Oriental faunal regions, including several sub- and endemic species (e.g., *Jabouilleia naungmungensis*, *Alcippe cinereiceps hkakaboraziensis*, and *Malacocincla abbotti kachinensis*; Rappole et al. 2005; Renner et al. 2015). This region is also known for its important bird migration routes, though the migration patterns are poorly investigated (Rappole 2013). Several general works on the avifauna of northern Myanmar with long checklists (Smythies 1949; King et al. 2001; Rappole et al. 2005, 2011; Renner et al. 2015; Zhang et al. 2017) as well as the published field notes of naturalists (e.g., Cornet & Alibert 2005) attract many ecotourists to this region.

The high diversity and endemism of the avifauna of northern Myanmar with the possibility of Himalayan origin (Rappole et al. 2011) was mentioned in the 19th Century (Oates 1883a,b; Renner & Rappole 2011; Twin et al. 2011; Renner et al. 2015). Between 1998 and 1999, 314 bird species were recorded across the entire elevation range of the mountains around Putao and 87% of this number occurred at altitudes of up to 1,500m

DOI: https://doi.org/10.11609/jott.4176.11.3.13377-13384 | **ZooBank:** urn:lsid:zoobank.org:pub:EE48DE63-D32E-46B9-9F3E-DFF15DDED3CF

Editor: Hem Sagar Baral, Charles Sturt University, New South Wales, Australia. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4176 | Received 05 April 2018 | Final received 06 January 2019 | Finally accepted 13 January 2019

Citation: Scopin, A.E., V.N. Sotnikov, D.V. Skumatov & A.A. Sergeyev (2019). Avian survey in tourist sites near Putao in northern Myanmar. *Journal of Threatened Taxa* 11(3): 13377–13384; https://doi.org/10.11609/jott.4176.11.3.13377-13384

Funding: Self-funded.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are grateful to the reviewers for their important comments on our manuscript. The authors thank Mariya Kushkova and Lanita Gutieva for their help in the translation of the manuscript into English.

(King et al. 2001). The number of reported species reached around 413 ten years later (Rappole et al. 2011) and was estimated to be 441 species according to the results of field surveys from 1997 to 2006 (Renner et al. 2015). The 2015–2017 bird diversity inventory detected 319 species (Zhang et al. 2017), which is significantly less than in previous publications. It is possible that the avifauna composition in this region varies due to ecologic factors and it is extremely important to understand the reasons for these changes.

The real chances to observe and photograph the checklist species in the wild during a certain season is hard to establish with confidence. Indeed, although such knowledge is crucial before planning any ecotours or trips, the relevant information is sometimes difficult to find. Therefore, we believe that, in addition to recording the occurrence of certain species, the field naturalists should also aim to evaluate the fauna of the study area from the quantitative perspective and, more importantly, to publish their observations. Furthermore, the evaluation of the avifauna is beneficial for the environment as it is necessary for bird monitoring in sparsely populated areas with unique natural ecosystems. Consequently, the principal goal of our work was to assess the bird occurrences in the territories with walking tracks that become popular during the tourist season.

Materials and Methods

Study Area

The field observations were carried out in the Putao District of Kachin State from late November to mid-December of 2014 and again in December 2015. The Putao Plain is surrounded by mountains covered by evergreen subtropical forests. As compared to river valleys with numerous villages, paddy fields, and gardens, the steep mountain slopes in the region are less affected by human activities that at most include localized hunting, selective logging of trees, harvesting of plants, and using wildlife products (Rappole et al. 2011; Renner et al. 2015).

Birdwatching surveys were conducted along permanent hiking paths and in different habitats near villages (Fig. 1). Due to poor roads that are limited to a few rather difficult mountain routes, the access to the study area is relatively limited for tourists. For our survey, we chose two old pathways with similar ecologic characteristics, used by many people daily. The starting sections of these mountain routes between 800m and 1,400m are rather easily accessible from Putao. On average, it took us one day to cover the distance one way (i.e., the round trip required two days). The first path runs towards the Hkakaborazi National Park near the eastern border of China and passes through the villages of Nansabun (27.391^{0}N & 97.516^{0}E) and Namthi (27.410^{0}N & 97.66^{0}E). The route is about 17km-long with elevations ranging between 600m and 900m. The second track runs towards Hponkanrazi Wildlife Sanctuary near the western Indian border with the villages of Shangaung (27.423^{0}N & 97.297^{0}E) and Wasandum (27.489^{0}N & 97.190^{0}E) along its course. This 15km-long route is located between 450m and 1400m with the prevailing altitudes of 600–800 m. The two tracks are divided by the vast Putao Valley located at a lower elevation (below 500m). We devoted several days to perform separate observations along the floodplain of the Mali Hka River and its tributaries (altitude of 400m) near Manu Village (27.436^{0}N & 97.474^{0}E). Birdwatching in different habitats near villages was carried out to assess the frequency of bird occurrence under the forest canopy, which was otherwise difficult to accomplish on the walking tracks, as well as to investigate synanthropic bird species.

Methods

The bird registration was performed by simple visual identification during daylight hours. We stood and recorded all the individuals flying by for at least one hour each in the morning after sunrise and in the evening before sunset to quantify the birds near the villages. Overall, we spent 120h observing the birds on the Nansabun-Namthi route, 100h on the Shangaung-Wasandum route, and 40h near Manu Village.

We passed along hiking paths at an average speed of about 2–3 km/h and tried to identify the birds that were seen. We recorded only those bird species that could be identified with a high degree of certainty in the field conditions. We stopped for 10–15 min to carry out bird identification. Also, we moved up to 50m into the forest from the footpath whenever possible. We worked in groups of two (one group went into the forest just to the left of the path, the other just to the right — in this way different bird individuals were taken into account). The data were then summarized. Birds that could be simultaneously taken into account by different observers as well as the time spent on their registration were excluded from the checklist. The total accounting time included only the time taken to hike along the path. The time spent on bird identification was not taken into account. We used Bresser waterproof binoculars (x7) and photographic equipment (Nikkon D3200, Canon EOS 1D X et al).

We documented the frequency of occurrence of bird

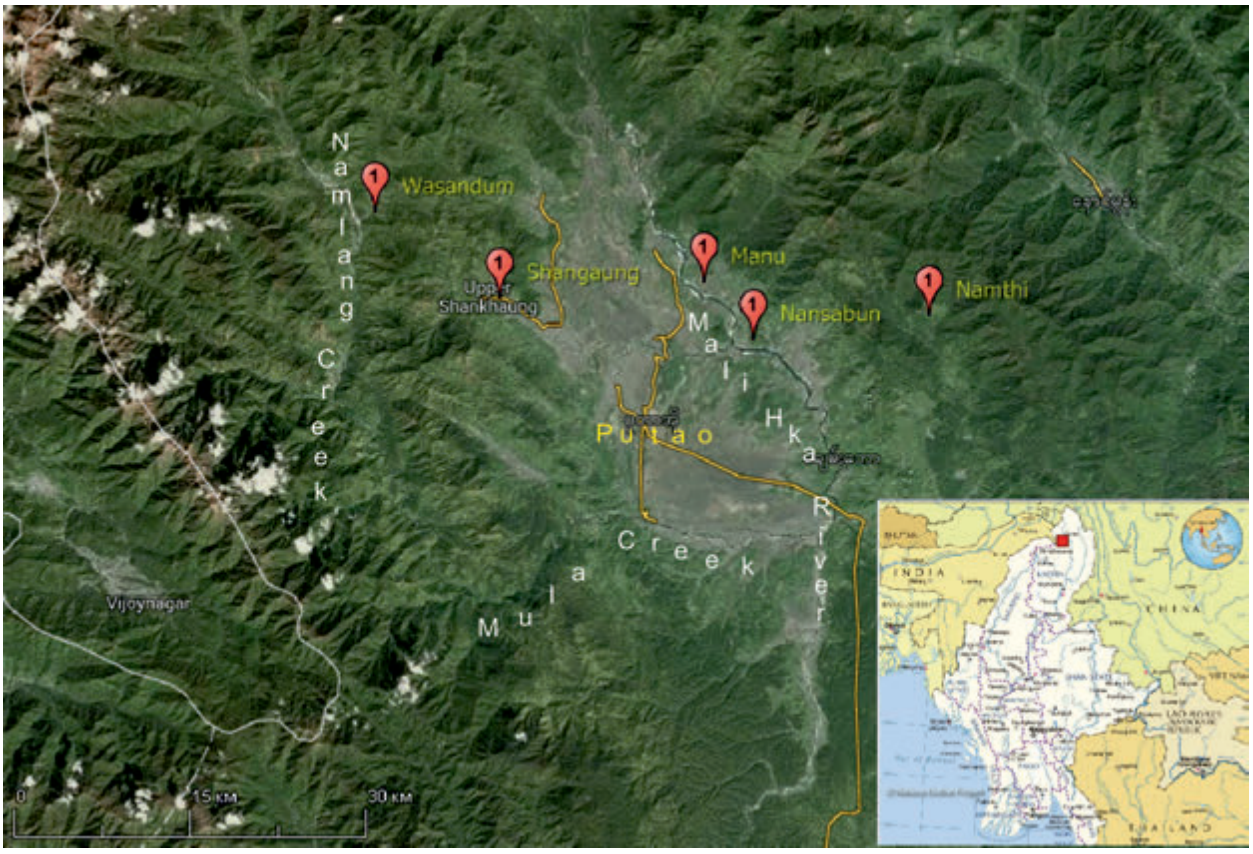


Figure 1. The birdwatching area in Putao District in Kachin State, Myanmar

species by adopting a four-point relative scale (King et al. 2001) and attributing each bird species to specific categories according to their total number: 'a' - abundant (more than 100 individuals of a certain species), 'c' - common (10–100 individuals), 'unc' - uncommon (2–10 individuals), and 's' - single (one individual). It should be noted that we did not aim to clarify the systematic position of birds, i.e., the systematic order shown in Table 1 is given in accordance with the accepted guidelines (del Hoyo & Collar 2014, 2016). Despite that, these publications have some limitations and the status of several species can be contested (Renner et al. 2018). These studies nevertheless forms a basis in the International Union for Conservation of Nature (IUCN) and are used by many birdwatchers.

We prepared the basemap in SAS Planet software using data from https://www.nationsonline.org/oneworld/map/myanmar_map2.htm (Fig. 1).

Results and Discussion

We recorded 105 species during the short hiking surveys across the low-mountain terrain of which only 12 were migratory and the rest were resident birds. In addition, we noted a large variability in the species encountered even over insignificant distances. For instance, only 19 bird species (18% of the total number of species encountered) were common for both the tracks (separated by the 27km-wide Putao Valley) and about 50 species were unique for one or the other route (Table 1). It should be noted that the percentage of species within particular categories was approximately the same for the routes in the mountain forest, i.e., about 70%–80% of identified species belong to the categories 'common' and 'uncommon', about 15%–20% species to 'single', and about 5% to 'abundant'.

In the Mali Hka River floodplain, which is surrounded by agriculture lands and is heavily affected by other human activities, the biodiversity is lower and the distribution of species between the four categories is different. Namely, the percentage of species in category 'abundant' is reduced to 2% and that in category 'common' to 20%, which is half as many as in the undisturbed forest. Likewise, there are half as many species with a single occurrence, largely due to the absence of indigenous avifauna of forest habitats in the region. Most species (about 70%) are assigned to the

category 'uncommon'. In the Mali Hka River Valley, many individuals encountered belong to the species typical of wetland habitats (e.g., White-throated Kingfisher *Halcyon smyrnensis*, Red-wattled Lapwing *Vanellus indicus* (Image 2), Great Cormorant *Phalacrocorax carbo*, Striated Heron *Butorides striata*, Ruddy Shelduck *Tadorna ferruginea* (Image 1), and Crested Kingfisher *Megaceryle lugubris*).

The synanthropic bird species begin to occur in agriculture landscapes and human settlements. This is observed on the background of the bird population decline in the vicinity of human-inhabited areas. The Common Myna *Acridotheres tristis* was found only in Putao Valley. We did not encounter this species in the virgin forest area despite the fact that the species can penetrate into the forest. The presence of Large-billed Crow *Corvus macrorhynchos* was noted only near human-related habitat territories (Manu, Shangaung, and Wasandum villages). The Oriental Turtle Dove *Streptopelia orientalis*, Spotted Dove *S. chinensis*, and White-rumped Munia *Lonchura striata* were also observed only in the cultivation area.

The interesting fact is that the presence of the Chinese Rubythroat *Calliope tschebaiewi*, a rare winter visitor in northern Myanmar, was not mentioned in the latest report by Rappole et al. (2011), although individual encounters with the species are known from the Chinese and Indian border regions (Cheng 1976; Ghosh et al. 2010). The presence of this species in Myanmar was only reported from rhododendron ecosystems (Kinnear 1934) above tree lines at altitudes above 3,500m.

Likewise, the record of Solitary Snipe *Gallinago solitaria*, previously indicated as winter visitor in northern Myanmar (Robson 2008; Ekstrom & Butchart 2016) and several individuals of which were registered at Mali Hka River tributaries during our fieldwork near Manu Village (Image 3), was absent from the checklist of Rappole et al. (2011).

Currently, there are not enough publications available to compare the relative abundance of bird species in northern Myanmar and in India (Singh 1991; King et al. 2001; Renner et al. 2015; Zhang et al. 2017). The 'abundant' category and observation time reported by these authors are often different, which makes it extremely difficult to make reliable comparisons. Nevertheless, we want to emphasize the abundance of certain species. In particular, the study shows that Common Sandpiper *Actitis hypoleucos*, Rufous-chinned Laughingthrush *Garrulax rufogularis*, Blue-winged Laughingthrush *Trochalopteron squamatum*, Spot-throated Babbler *Pellorneum albiventre*, Buff-breasted

Image 1. Ruddy Shelduck *Tadorna ferruginea* near Mali Hka River.

Image 2. Red-wattled Lapwing *Vanellus indicus* on the paddy fields of Putao Valley.

Babbler *Trichastoma tickelli*, White-gorgeted Flycatcher *Anthipes monileger*, and Black Drongo *Dicrurus macrocercus* are not be considered as rare species, despite being previously attributed to this category by King et al. (2001). Similarly, although Zhang et al. (2017) recorded quite a small number of Wreathed Hornbill *Rhyticeros undulates*, we observed several flocks of this species with 8–14 individuals in each suggesting that it is not rare in the Mali Hka River Valley and along the river's main tributaries. Moreover, according to local villagers, the flocks of this hornbill can reach several dozen individuals during the breeding season (April–May). Such anecdotal information is further supported by earlier official publications (Stanford & Ticehurst 1939; Renner et al. 2015) that reported several cases of large gatherings of the species. In contrast, Sultan Tit *Melanochlora sultanea* is indicated as a common species in these ecosystems by King et al. (2001) and Singh (1991) but appears as a rare species according to

Table 1. Bird species recorded along hiking paths near Putao in Kachin State, northern Myanmar

		Nansabun-Namthi route	Manu Village	Shangaung-Wasandum route
	Order: Galliformes			
	Family: Phasianidae			
1	*Arborophila rufogularis* Rufous-throated Partridge	unc		
	Order: Anseriformes			
	Family: Anatidae			
2	*Mergus merganser* Goosander		c	c
3	*Tadorna ferruginea* Ruddy Shelduck		unc	
	Order: Columbiformes			
	Family: Columbidae			
4	*Streptopelia orientalis* Oriental Turtle-dove		unc	
5	*Spilopelia chinensis* Eastern Spotted Dove		unc	
6	*Chalcophaps indica* Grey-capped Emerald Dove	unc		
	Order: Caprimulgiformes			
	Family: Apodidae			
7	*Aerodramus brevirostris* Himalayan Swiftlet	c		
	Order: Cuculiformes			
	Family: Cuculidae			
8	*Centropus sinensis* Greater Coucal		unc	
	Order: Ciconiiformes			
	Family: Ciconiidae			
9	*Ciconia nigra* Black Stork			unc
	Order: Pelecaniformes			
	Family: Ardeidae			
10	*Butorides striata* Green-backed Heron		unc	
	Order: Suliformes			
	Family: Phalacrocoracidae			
11	*Phalacrocorax carbo* Great Cormorant		unc	
	Order: Charadriiformes			
	Family: Ibidorhynchidae			
12	*Ibidorhyncha struthersii* Ibisbill			c
	Family: Charadriidae			
13	*Vanellus duvaucelii* River Lapwing		unc	unc
14	*V. indicus* Red-wattled Lapwing		unc	
	Family: Scolopacidae			
15	*Gallinago solitaria* Solitary Snipe		unc	
16	*Actitis hypoleucos* Common Sandpiper			c

		Nansabun-Namthi route	Manu Village	Shangaung-Wasandum route
	Order: Strigiformes			
	Family: Strigidae			
17	*Otus spilocephalus* Mountain Scops-owl			s
18	*O. lettia* Collared Scops-owl			s
19	*Glaucidium cuculoides* Asian Barred Owlet			unc
	Order: Accipitriformes			
	Family: Pandionidae			
20	*Pandion haliaetus* Osprey			unc
	Family: Accipitridae			
21	*Pernis ptilorhynchus* Oriental Honey-buzzard	s		
22	*Spilornis cheela* Crested Serpent-eagle		s	
23	*Circus cyaneus* Hen Harrier		s	
	Order: Trogoniformes			
	Family: Trogonidae			
24	*Harpactes erythrocephalus* Red-headed Trogon	unc		
	Order: Coraciiformes			
	Family: Meropidae			
25	*Nyctyornis athertoni* Blue-bearded Bee-eater	s	s	
	Family: Alcedinidae			
26	*Alcedo hercules* Blyth`s Kingfisher	unc		
27	*A. atthis* Common Kingfisher		unc	
28	*Megaceryle lugubris* Crested Kingfisher	c	unc	
29	*Halcyon smyrnensis* White-breasted Kingfisher		unc	
	Order: Bucerotiformes			
	Family: Bucerotidae			
30	*Rhyticeros undulatus* Wreathed Hornbill	unc	c	
31	*Aceros nipalensis* Rufous-necked Hornbill	unc	unc	
	Order: Piciformes			
	Family: Megalaimidae			
32	*Psilopogon asiaticus* Blue-throated Barbet	unc	unc	
	Family: Picidae			
33	*Sasia ochracea* White-browed Piculet	c		c
34	*Blythipicus pyrrhotis* Bay Woodpecker			s
35	*Gecinulus grantia* Pale-headed Woodpecker			s

		Nansabun-Namthi route	Manu Village	Shangaung-Wasandum route
	Order: Passeriformes			
	Family: Eurylaimidae			
36	*Psarisomus dalhousiae* Long-tailed Broadbill			c
	Family: Campephagidae			
37	*Pericrocotus sp.* Minivet	c	c	c
	Family: Rhipiduridae			
38	*Rhipidura albicollis* White-throated Fantail	unc	unc	
	Family: Dicruridae			
39	*Dicrurus macrocercus* Black Drongo	c		c
40	*D. aeneus* Bronzed Drongo	unc	unc	
41	*D. remifer* Lesser Racquet-tailed Drongo	unc	unc	
	Family: Laniidae			
42	*Lanius collurioides* Burmese Shrike	unc		
43	*L. schach* Long-tailed Shrike	c	c	c
44	*L. tephronotus* Grey-backed Shrike	unc	unc	
	Family: Corvidae			
45	*Dendrocitta frontalis* Collared Treepie	unc	unc	unc
46	*Urocissa flavirostris* Yellow-billed Blue Magpie	c		
47	*Cissa chinensis* Common Green Magpie	unc		
48	*Corvus macrorhynchos* Large-billed Crow		unc	c
	Family: Stenostiridae			
49	*Chelidorhynx hypoxanthus* Yellow-bellied Fairy-fantail			s
	Family: Stenostiridae			
50	*Culicicapa ceylonensis* Grey-headed Canary-flycatcher	c		
	Family: Paridae			
51	*Melanochlora sultanea* Sultan Tit	s		
52	*Parus monticolus* Green-backed Tit		s	
	Family: Hirundinidae			
53	*Riparia diluta* Pale Sand Martin			unc
	Family: Pycnonotidae			
54	*Alophoixus flaveolus* White-throated Bulbul	unc	unc	
55	*Hemixos flavala* Ashy Bulbul		unc	
56	*Hypsipetes leucocephalus* Black Bulbul	unc	c	
57	*Pycnonotus striatus* Striated Bulbul			unc
58	*P. flaviventris* Black-crested Bulbul	unc	unc	
59	*P. jocosus* Red-whiskered Bulbul	a	a	a
60	*Pycnonotus cafer* Red-vented Bulbul	c		c
	Family: Scotocercidae			
61	*Cettia castaneocoronata* Chestnut-headed Tesia			s
62	*Abroscopus superciliaris* Yellow-bellied Warbler			unc
63	*A. albogularis* Rufous-faced Warbler	c		
64	*Phyllergates cucullatus* Mountain Tailorbird			s
	Family: Sylviidae			
65	*Psittiparus bakeri* Rufous-headed Parrotbill			c
	Family: Zosteropidae			
66	*Yuhina flavicollis* Whiskered Yuhina	s		
	Family: Timaliidae			
67	*Stachyris nigriceps* Grey-throated Babbler	a		
	Family: Pellorneidae			
68	*Schoeniparus rufogularis* Rufous-throated Fulvetta	unc		
	Family: Pellorneidae			
69	*Pellorneum albiventre* Spot-throated Babbler			a
70	*Trichastoma tickelli* Buff-breasted Babbler	c		c
	Family: Leiotrichidae			
71	*Alcippe nipalensis* Nepal Fulvetta	a		
72	*Garrulax leucolophus* White-crested Laughingthrush	c		c
73	*G. rufogularis* Rufous-chinned Laughingthrush	unc		
74	*Trochalopteron squamatum* Blue-winged Laughingthrush			unc
75	*Leiothrix argentauris* Silver-eared Mesia	c		
76	*Leioptila annectens* Rufous-backed Sibia	unc		
77	*Minla ignotincta* Red-tailed Minla	unc		
78	*Liocichla phoenicea* Red-faced Liocichla	c		c
79	*Siva cyanouroptera* Blue-winged Minla	unc		
	Family: Cinclidae			
80	*Cinclus pallasii* Brown Dipper	c		c
	Family: Sturnidae			
81	*Acridotheres tristis* Common Myna		c	
82	*A. albocinctus* Collared Myna	c	c	c

		Nansabun-Namthi route	Manu Village	Shangaung-Wasandum route
	Family: Muscicapidae			
83	*Copsychus saularus* Oriental Magpie-robin		unc	unc
84	*Niltava sundara* Rufous-bellied Niltava	unc		unc
85	*N. macgrigoriae* Small Niltava	unc	unc	
86	*N. grandis* Large Niltava	unc	unc	
87	*Anthipes monileger* White-gorgeted Flycatcher			c
88	*Brachypteryx leucophrys* Lesser Shortwing	s		
89	*B. cruralis* Himalayan Shortwing	s		
90	*Calliope tschebaiewi* Chinese Rubythroat			s
91	*Myiomela leucura* White-tailed Blue Robin	s		
92	*Enicurus scouleri* Little Forktail	c		c
93	*E. schistaceus* Slaty-backed Forktail	c	unc	c
94	*Myophonus caeruleus* Blue Whistling-thrush	c	unc	c
95	*Ficedula tricolor* Slaty-blue Flycatcher			s
96	*F. hyperythra* Snowy-browed Flycatcher	c		
97	*F. strophiata* Rufous-gorgeted Flycatcher	s		
98	*Phoenicurus leucocephalus* White-capped Water-redstart	unc	unc	unc
99	*P. fuliginosus* Plumbeous Water-redstart	c	unc	c
100	*Saxicola ferreus* Grey Bushchat		unc	c
	Family: Irenidae			
101	*Irena puella* Asian Fairy-bluebird	s		
	Family: Chloropseidae			
102	*Chloropsis hardwickii* Orange-bellied Leafbird	unc		
	Family: Estrildidae			
103	*Lonchura striata* White-rumped Munia		c	
	Family: Motacillidae			
104	*Motacilla alba* White Wagtail		c	c
105	*M. cinerea* Grey Wagtail	c		c
	Total species	61	45	47
	Key			
	a - abundant	3	1	2
	c - common	22	9	24
	unc - uncommon	27	31	12
	s - single	9	4	9

Image 3. Solitary Snipe *Gallinago solitaria* on the bank of Mali Hka River.

Image 4. Sultan Tit *Melanochlora sultanea* in the rainforest upperstory.

our results and more recent surveys (Zhang et al. 2017; Image 4).

In summary, even brief birdwatching can give a general representation of the avifauna of a territory that was previously surveyed insufficiently. The results obtained allowed us to estimate the relative frequency of bird species occurrence on the permanent hiking routes in the region and to evaluate the potential of this territory for promoting birdwatching tourism.

References

Baker, E.C.S. (1922). *The Fauna of British India including Ceylon and Burma*: *Birds, Vol. 1*. Taylor & Francis, London, 479pp.

Baker, E.C.S. (1930). *The Fauna of British India including Ceylon and Burma*: *Birds, Vols. 7 & 8*. Taylor & Francis, London, 801pp.

Cheng, T.H. (1976). *Distributional List of Chinese Birds (in Chinese)*. Science Press, Beijing Institute of Zoology, Beijing, 1218pp.

Cornet, N. & E. Alibert (2005). Journey through the last untouched forests of Myanmar. *The Babbler* 13: 2–6; https://www.darwininitiative.org.uk/documents/12025/3485/12-025%20AR2%20Annex%208%20162.12.025.pdf

del Hoyo, J. & N.J. Collar (2014). *HBW and Birdlife International Illustrated Checklist of the Birds of the World*, *Vol. 1: Non-Passerines*. Lynx Edicions and BirdLife International, Barcelona, Spain and Cambridge, UK, 903pp.

del Hoyo, J. & N.J. Collar (2016). *HBW and Birdlife International Illustrated Checklist of the Birds of the World, Vol. 2: Passerines*. Lynx Edicions, Barcelona, 1013pp.

Ekstrom, J. & S. Butchart (2016). *Gallinago solitaria*. In: The IUCN Red List of Threatened Species 2016: e.T22693075A93382331; Downloaded on 01 April 2018. https://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T22693075A93382331.en

Ghosh, S., S.B. Roy & B.K. Dutta (2010). Occurrence of Himalayan Rubythroat, *Luscinia pectoralis tschebaiewi* (Prz.), Passeriformes: Turdinae in Chhattisgarh, India. *Records of the Zoological Survey of India* 110(3): 119–121.

King, B.F., H. Buck, R. Ferguson, T. Fisher, C. Goblet, H. Nickel & W. Suter (2001). Birds recorded during two expeditions to north Myanmar (Burma). *Forktail* 17: 29–40.

Kinnear, N.B. (1934). On the birds of the Adung Wang Valley, north-east Burma. *The Journal of the Bombay Natural History Society* 37: 347–368.

Lwin, K.N. & K.M.M. Thwin (2003). *Birds of Myanmar*. Silkworm Books, Bangkok, 166pp.

Oates, E.W. (1883a). *A Handbook of the Birds of British Burmah, including those from the adjoining state of Karennee, Vol. 1*. R.H. Porter & Co., London, 431pp

Oates, E.W. (1883b). *A Handbook of the Birds of British Burmah, including those from the adjoining state of Karennee, Vol. 2*. R.H. Porter & Co., London, 493pp.

Rappole, J.H. (2013). *The Avian Migrant: The Biology of Bird Migration*. Columbia University Press, New York, 464pp.

Rappole, J.H., S.C. Renner, N.M. Shwe & P.R. Sweet (2005). A new species of Scimitar-Babbler (Timaliidae: *Jabouilleia*) from the sub-Himalayan region of Myanmar. *The Auk* 122(4): 1064–1070; https://doi.org/10.1642/0004-8038(2005)122[1064:ANSOST]2.0.CO;2

Rappole, J.H., T. Aung, P.C. Rasmussen & S.C. Renner (2011). Ornithological exploration in the southeastern sub-Himalayan region of Myanmar. *Ornithological Monographs* 70: 10–29; https://doi.org/10.1525/om.2011.70.1.10

Renner, S.C. & J.H. Rappole (2011). Bird diversity, biogeographic patterns, and endemism of the eastern Himalayas and southeastern sub-Himalayan mountains. *Ornithological Monographs* 70: 153–166; https://doi.org/10.1525/om.2011.70.1.153

Renner, S.C., J.H. Rappole, C. Milensky, M. Aung, N.M. Shwe & T. Aung (2015). Avifauna of the southeastern Himalayan mountains and neighboring Myanmar hill country. *Bonn Zoological Bulletin - Supplementum* 62: 1–75.

Renner, S.C., J.H. Rappole, M. Kyaw, C.M. Milensky & M. Päckert (2018). Genetic confirmation of the species status of *Jabouilleia naungmungensis. Journal of Ornithology 159(1): 63–71;* https://doi.org/10.1007/s10336-017-1493-0

Robson, C. (2008). *A Field Guide to the Birds of south-east Asia*. Christofer Helm, London, 544pp.

Singh, P. (1994). Recent birds records from Arunachal Pradesh. *Forktail* 10: 65–104.

Smythies, B.E. (1949). A reconnaissance of the N'Mai Hka drainage, northern Burma. *The IBIS* 91(4): 627–648; https://doi.org/10.1111/j.1474-919X.1949.tb02314.x

Smythies, B.E. (1953). *The Birds of Burma*. Oliver & Boyd, Edinburgh, 668pp.

Stanford, J.K. & C.B. Ticehurst (1939). On the birds of northern Burma, part V. *The IBIS* 81(1): 1–45; https://doi.org/10.1111/j.1474-919X.1939.tb03959.x

Twin, H.K.M.M., K.S. Lwin, S.C. Renner & J.P. Dumbacher (2011). Ornithology of northern Myanmar. *Ornithological Monographs* 70(1): 109–141; https://doi.org/10.1525/om.2011.70.1.109

Zhang, M.-X., M. Kyaw, G.-G. Li, J.-B. Zhao, X.-L. Zeng, K. Swa & R.-C. Quan (2017). Bird diversity in northern Myanmar and conservation implications. *Zoological Research* 38(5): 264–280; https://doi.org/10.24272/j.issn.2095-8137.2017.059

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13385–13389

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM
OPEN ACCESS

SHORT COMMUNICATION

New record of Blue-eyed Eastern Spadefoot Toad *Leptobrachium bompu* (Amphibia: Megophryidae) from Sarpang District in Bhutan

Jigme Tenzin [1] & **Jigme Tshelthrim Wangyal** [2]

[1] Divisional Forest Office, Sarpang, Department of Forests and Park Services (DoFPS), Ministry of Agriculture & Forests, Sarpang 31002, Bhutan.
[2] Jigme Khesar Strict Nature Reserve, Haa 15001, Bhutan.
[1] jigmetenzin16@gmail.com (corresponding author), [2] jigmewangyal@gmail.com

Abstract: This study provides the first report of *Leptobrachium bompu* Sondhi & Ohler, 2011 from Bhutan. The species was recorded from Simkhar watershed in Jigmecholing under Sarpang District, at an elevation of 1,610m. Simkhar Stream is small and perennial, shaded and swampy, with a few moss-laden flat stones along the course, and is pollution-free and slow-flowing. The current report extends the distribution record of *L. bompu* towards the east and will help in understanding the range and conservation status of the species.

Keywords: Habitat, Jigmecholing, litter frogs, Megophryids, morphometric measurements, Simkhar watershed.

Megophryids are known as litter frogs and are native to warm southeastern Asian countries from the Himalayan foothills to Indonesia and Greater Sunda Islands in maritime southeastern Asia up to the Philippines (Zweifel 1998). There are currently 230 species in five genera assigned to Megophryidae Bonaparte, 1850 (Frost 2019) in the world, out of which seven species are reported from Bhutan (Wangyal 2014). The Eastern Spadefoot Toad genus *Leptobrachium* was described by Tschudi (1838) and is known to consist of 36 species (Frost 2019).

Leptobrachium bompu was described by Sondhi & Ohler (2011) from Eagle-nest Wildlife Sanctuary in Arunachal Pradesh, India. The distribution of the species was further extended to Talle Village Wildlife Sanctuary in Arunachal Pradesh (Saikia et al. 2017) and Upper Medog in Tibet, China (Liang et al. 2017). This paper presents the first report of the species in Bhutan along with information on its morphometry and habitat.

Materials and Methods

Study area

Simkhar watershed in Jigmecholing under Sarpang District is located within 27.031–27.054 ^{0}N & 90.495–90.497 ^{0}E at an elevation ranging from 1,160–2,646 m (Fig. 1). Geographically, Simkhar watershed falls within biological corridor no. 3, which covers the corridor of Jigme Singye Wangchuck National Park (JSWNP) in the north and Royal Manas National Park (RMNP) towards the east, and runs down to Pibsoo Wildlife Sanctuary in southern Bhutan (Tenzin & Dhendup 2017; Tenzin et al. 2018). Floristically, the study area comprises subtropical broad-leaved forests at the

DOI: https://doi.org/10.11609/jott.4134.11.3.13385-13389 | **ZooBank:** urn:lsid:zoobank.org:pub:FC11AF19-2649-4B9E-89D1-C62AA5F23DD4

Editor: Neelesh Dahanukar, Indian Institute of Science Education and Research (IISER), Pune, India **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4134 | Received 15 March 2018 | Final received 07 February 2019 | Finally accepted 12 February 2019

Citation: Tenzin, J. & J.T. Wangyal (2019). New record of Blue-eyed Eastern Spadefoot Toad *Leptobrachium bompu* (Amphibia: Megophryidae) from Sarpang District in Bhutan. *Journal of Threatened Taxa* 11(3): 13385–13389; https://doi.org/10.11609/jott.4134.11.3.13385-13389

Funding: Rufford Small Grant Foundation, UK [grant no. is 15631-1].

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are grateful to Rufford Small Grant Foundation based in UK for funding conservation initiative of *Nanorana leibigii* in Simkhar River, Jigmecholing, under Sarpang District, Bhutan. Dr. L. Scott Mills, Professor at Montana University, USA; Dr. D.B. Gurung, Professor at the College of Natural Resources (CNR), RUB, and Mr. Sangay Wangchuk, UWICER, Bumthang, Bhutan are immensely acknowledged for refereeing above studies. The author is also thankful to the community of Simkhar Village for their resourceful support during the field survey, and to the reviewers for their help in manuscript refinement.

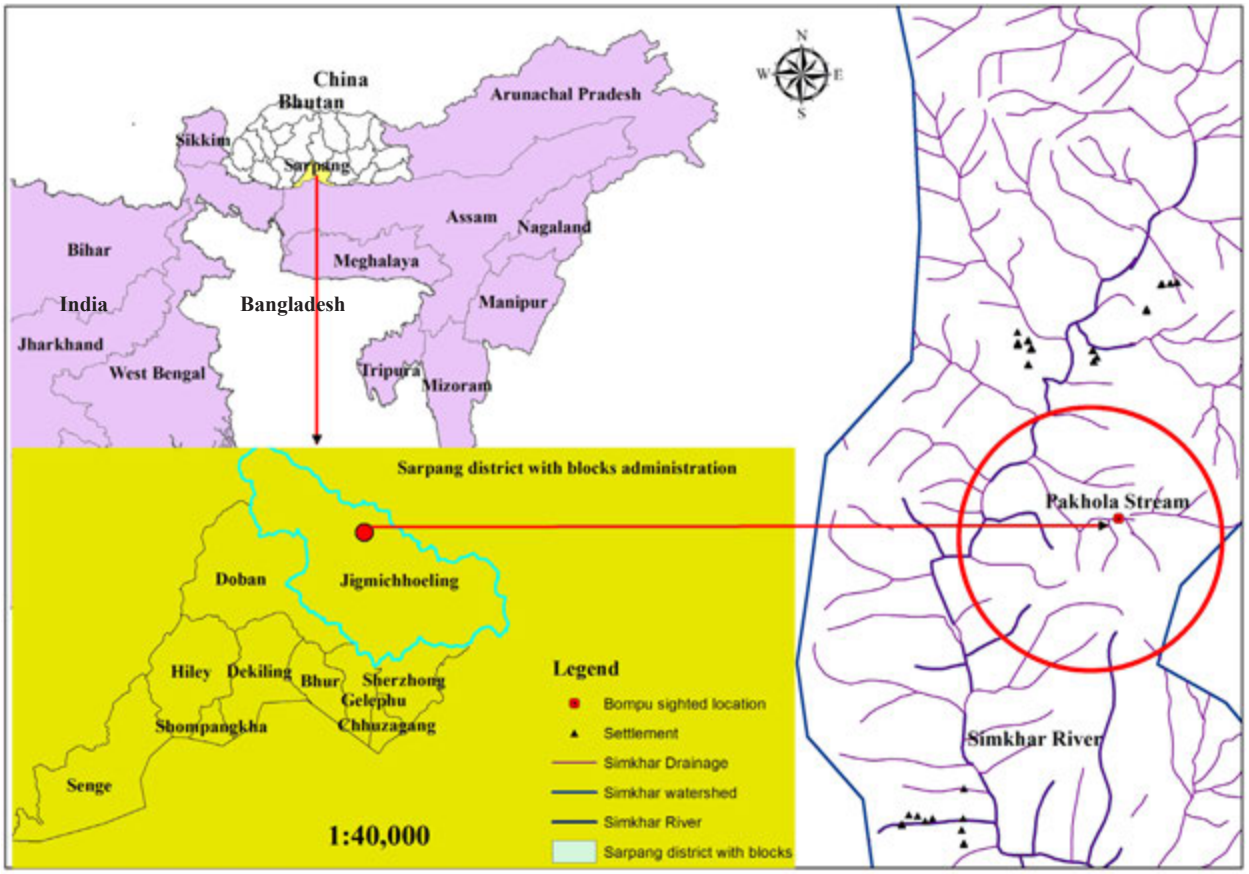


Figure 1. Spatial location of *Leptobrachium bompu* from Pakhola in Sarpang District, Bhutan.

lower altitudes (1,000–2,000 m) to warm temperate forests at the upper altitudes (2,000–2,500 m), which support diverse biologic fauna (Oshawa 1987). Besides its rich biodiversity, Simkhar River has seven major tributaries with more than 10 secondary tributaries that drain to the Mouchu River basin and finally reach the Brahmaputra in Assam.

Morphometric measurements of specimens

All morphometric measurements were taken with a digital calliper under a microscope. All the morphometric measurements used by Sondhi & Ohler (2011) based on one male specimen, Liang et al. (2017) collected from seven specimens, and one male specimen of Saikia et al. (2017) were taken for comparison. Habitat description was recorded. Abbreviations for morphometric measurements taken are provided in Table 1.

Specimen was collected following standard protocol where specimen was euthanized using 0.001% clove oil and treated in 10% formalin for short-time preservation after taking photographs when alive (Gurung et al. 2012; Tenzin & Dhendup 2017). The specimens were deposited in the museum collection of the Laboratory of the College of Natural Resources (CNR), Lobesa, in Punakha District, Bhutan.

Abbreviations: SVL - snout vent length; EL - eye length; EN - anterior eye corner to nostril distance; HL - head length; HW - head width; IBE - distance between posterior eye corners; IFE - distance between anterior eye corners; IN - internarial distance; IUE - maximum distance between upper eyelids; MBE - posterior mandible corner to posterior eye corner distance; MFE - distance from posterior mandible corner to anterior eye corner; MN - distance from posterior corner of mandible to nostril; NS - snout tip-nostril distance; SL - snout length; UEW - maximum width of the upper eyelid; FLL - forelimb length between elbow to base of outer palmer tubercle; HAL - hand length from base of outer palmer tubercle to the tip of the third finger; TFL - length of third finger (distal part of articulation between proximal phalanges and metacarpal bone of the third finger); Fw3 - width of third finger at mid length; FFTF - distance from maximum incurvation of web between fourth and fifth toe to tip of fourth toe; FL - femur length

from vent to knee; FOL - Foot length from base of inner metatarsal tubercle to the tip of the fourth toe; FTL - fourth toe length (between distal part to the articulation between proximal phalange and metatarsal bone of the fourth toe); IMT - length of inner metatarsal tubercle; ITL - length of the inner toe; MTFF - distance between distal edge of metatarsal tubercle to maximum incurvation of the web between fourth and fifth toe; TFOL - length of tarsus and foot from the base of tarsus to the tip of fourth toe; TFTF - distance between maximum incurvation of web between third and fourth toe to tip of fourth toe; TL - length of tibia; TW - maximum width of tibia; Tw4 - width of the fourth toe at mid length.

Results and Discussion

Leptobrachium bompu was known only from Bompu (27.116^{0}N & 92.684^{0}E; altitude 1,940m), the northernmost distribution limit of the genus *Leptobrachium* (Frost 2016) (Image 1). The new discovery of *L. bompu* in Upper Medog moved the northern limit to northern latitude 29.254^{0}N, 338km (crow-fly distance) from Bompu. A solitary *L. bompu* was spotted coincidentally during the field survey of *Nanorana leibigii* (Gunther, 1864) at Pakhola (27.034^{0}N & 90.494^{0}E) in Jigmecholing under Sarpang District on 26 April 2015, at an altitude of 1,610m. With this new record, Bhutan now has 57 amphibian species (Wangyal 2014). This record extends the record of the species eastward from it known range.

Pakhola is one of the primary tributaries of Simkhar River where herpetofauna are mostly prevalent due to the presence of natural lakes and swampy areas around the lake at the stream head. Many species congregate in this area, especially when there is water scarcity in winter. The area was unexplored and the richness of its biodiversity unknown until 2014 when the first presence

Image 1. *Leptobrachium bompu.* A - live view, B - ventral view, C - dorsal view. © Jigme Tenzin

Image 2. *Leptobrachium bompu* habitat. A - slow-flowing hill stream, B - moss laden rocks. © Jigme Tenzin

Table 1. Morphometric comparison among four specimens

Variables (in mm)	Specimen in current study	Specimen of Liang et al. 2017	Specimen of Saikia et al. 2017	Holotype of Sondhi & Ohler 2011
EL	6.5		6.4	6.5
EN	3.5	3.9	3.0	4.8
FFTF	9.7		8.7	9.6
FL	27.0	21.8	18.6	24.4
FLL	12.3		12.3	12.2
FOL	19.9		17.5	19.8
FTL	9.0		8.2	8.7
Fw3	1.3	2.3	0.9	1.2
HAL	12.9	15.6	10.8	12.8
HL	18.6	21.9	15.6	16.9
HW	20.0	23.6	18.2	18.8
IBE	15.4	17.0	15.4	14.0
IFE	7.9	8.9	8.1	6.3
IMT	3.2	3.4	2.3	3.0
IN	5.6	5.2	4.4	4.7
ITL	3.4	3.7	2.3	3.4
IUE	5.7	5.9	5.8	5.4
MBE	5.1	7.6	4.2	5.0
MFE	11.1	14.2	10.0	11.0
MN	13.9	17.9	13.1	13.5
MTFF	7.2		7.1	1.8
MTTF	7.1		6.8	4.3
NS	4.8	4.6	3.8	5.5
SL	7.7	8.7	7.5	7.6
SVL	44.8	51.8	42.6	47.0
TFL	7.8		7.6	6.4
TFOL	27.0	31.1	24.9	27.3
TFTF	10.5		9.1	10.4
TL	18.3	20.8	17.9	20.9
TW	5.8	6.7	4.4	5.7
Tw4	1.2	2.1	0.9	1.3
UEW	3.9	5.5	3.9	3.9

of *Nanorana leibigii* (Gunther, 1860) was recorded from Simkhar River (Tenzin & Dhendup 2017). Our current record of *L. bompu* from the same stream suggests that Simkhar watershed is likely to have rich amphibian diversity.

Habitat characteristics

Leptrobrachum bompu was found under a moss-laden flat stone near a shaded and swampy, pollution-free and slow-flowing perennial stream in Pakhola (Image 2).

The habitat is on the leeward side in a wet subtropical broad-leaved forest (1,000–2,000 m) (forest types as Oshawa 1987) dominated by *Castanopsis hystrix*, *Beilschmiedia gammieana, Quercus lamellosa, Q. glauca, Lithocarpus elegans*, and *Syzygium formusa.* Additionally, as undergrowth, *Elatostema platyphyllum*, *Chimonobambusa callosa, Cephalostachyum latifolium*, and *Plectocomia himalayana* were abundant along the banks of the perennial streams. Meanwhile, the riparian area was mostly covered by bamboo thickets *Chimonobambusa callosa* and *Cephalostachyum*

latifolium, *Ligustrum confusum, Elatoste-ma platyphyllum,* and *Acconogonon molle.* The streams have a total length of 1.42km, of which *L. bompu* was recorded from only one location (Image 2), which indicates the rarity of its population as per Saikai et al. (2017), WWF (2015), and Sondhi & Ohler (2011).

Sondhi & Ohler (2011) found *L. bompu* under leaf litter in small, slow-flowing perennial streams near campsites of Bompu in Eaglenest Wildlife Sanctuary, Arunachal Pradesh (27.116^{0}N & 92.684^{0}E at an altitude of 2,000m), while Saikia et al. (2017) recorded the species from damp and moist areas near hill streams at Pange Forest (27.546^{0}N & 93.895^{0}E, 1,926m) in Talle Valley Wildlife Sanctuary, Arunachal Pradesh, India. Liang et al. (2017) found seven male adults of the species from Gelin Village (29.224^{0}N & 95.185^{0}E, 1,600m) and Buqiong Lake (29.254^{0}N & 95.224^{0}E, 1,455m) in China within upper reaches of small streams (less than 1m) and tadpoles from lower reaches of two streams in broad-leaved forests. This suggests that *L. bompu* probably prefers moss-laden rocks for hiding, damp and swampy areas for sustenance, and slow-flowing hill streams for breeding and reproduction purposes, and that it can be located only during monsoons owing to its increased activity (Saikia et al. 2017).

In the current study, *L. bompu* was recorded at 1,610m, which is lower than the findings of Sondhi & Ohler (2011) and Saikia et al. (2017), but higher than Liang et al. (2017). This indicates that *L. bompu* may have an elevation range from 1,455–2,000 m, but it still requires extensive study within these geographic ranges in the future. In Bhutan, *L. bompu* was spotted from wet subtropical forests (forest type as per Oshawa 1987), while holotypes and the second specimen were spotted from the same transition forest between eastern Himalayan subtropical wet hill forest in lower altitudes and eastern Himalayan wet temperate forest at higher altitudes of Arunachal Pradesh, India (forest type as per Champion & Seth 1968). Likewise, Liang et al. (2017) also recorded the species from the broad-leaved hill streams of Medog in Tibet, China. This suggests that *L. bumpu* prefers hill streams of the wet sub-tropical broad-leaved forest as its niche habitat. The rarity of this population mandates a separate study on abundance, distribution patterns, and conservation threats for adopting long-term conservation of this species.

References

Champion, F.W. & S.K. Seth (1968). A Revised Survey of Forest Types of India. Government of India Press, Nasik, India, 404pp.

Frost D. R. (2016). Amphibian Species of the World: An Online Reference. Version 6.0 (accessed on 8th November 2016). American Museum of Natural History, New York, USA. Electronic Database accessible at http://research.amnh.org/herpetology/amphibia/index.html

Frost, D.R. (2019). Amphibian Species of the World: An Online Reference. Version 6.0. American Museum of Natural History, New York, USA. Accessed on 10 January 2019. Electronic database accessible at http://research.amnh.org/herpetology/amphibia/index.html

Gurung, D.B., Ugyen & D. Tshering (2012). Mon-paa Frog Survey Report from Mithun village (24–27 April 2012) under Dophuchen, Samtse District. Unpublished Technical Report. District Forestry Sector, Samtse, Bhutan, 30pp.

Liang, X., W. Liu, B. Wang, L. Ding., J. Wu, F. Xie & J. Jiang (2017). *Leptobrachium bompu* (Amphibia, Anura, Megophryidae) discovered in Upper Medog, Tibet, China with descriptions of its tadpoles, advertisement calls and systematic position. *Asian Herpetological Research* 8(2): 137–146; https://doi.org/10.16373/j.cnki.ahr.160023

Oshawa, M. (1987). Vegetation zones in the Bhutan Himalaya, pp1–71. In: Oshawa, M. (ed.). *Life Zone Ecology of the Bhutan Himalaya*. Yayoicho, Chiba University, Japan, 206pp.

Saikia, B., B. Sinha & I.J. Kharkongor (2017). A second record of the Eastern Spadefoot Toad (Amphibia: Anura: Megophryidae: *Leptobrachium bompu* Sondhi & Ohler, 2011) with a note on its morphological variations and natural history. *Journal of Threatened Taxa* 9(9): 10692–10696; https://doi.org/10.11609/jott.3300.9.9.10692-10696

Sondhi, S. & A. Ohler (2011). A blue-eyed *Leptobrachium* (Anura: Megophrydaie) from Arunachal Pradesh. *Zootaxa* 2912: 28–36.

Tenzin, J. & P. Dhendup (2017). Habitat characteristics, relative abundance and conservation threats of Himalayan Bull Frogs (*Nanorana leibigii* Gunther, 1860) in primary tributaries of Simkhar River, Bhutan. *Journal of Natural Resources and Development* 4(2): 29–38; https://doi.org/10.17102/cnr.2017.07

Tenzin, J., P. Dhendup, K. Choki & T. Dorji (2018). Sarpang: At a Glance. Divisional Forest Office, Sarpang, Department of Forests and Park Services, Ministry of Agriculture & Forests, Thimphu, Bhutan, 8pp.

Tschudi, J.J. (1838). *Classification der Batrachier, mit Beruckischtigung der fossilen thiere dieser Abtheilung der Reptilien.* Petitpierre, Neuchatel, ii+98pp+6pl.

Wangyal, J.T. (2014). The status of herpetofauna of Bhutan. *Journal of the Bhutan Ecological Society* 2(1): 20–39.

WWF (2015). Hidden Himalayas: Asia's Wonderland - New Species Discoveries in Eastern Himalayas, Vol. II, 2009–2014 WWF Report: Living Himalayas. WWF Bhutan, Thimphu, Bhutan, 43pp.

Zweifel, R.G. (1998). Frogs and toads, pp.76–105. In: Cogger, H.G. & R.G. Zweifel (eds.). *Encyclopedia of Reptiles and Amphibians*. Academic Press, San Diego, 88pp.

Short Communication

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13390–13394

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

New record of Low's Flatfaced Longhorn Beetle *Sarothrocera lowii* White, 1846 (Coleoptera: Cerambycidae: Lamiinae: Lamiini) in Nagaland, India, along with first-time descriptions of male and female genitalia

Kolla Sreedevi [1], Manisha Sharma [2] & Hemant Vasant Ghate [3]

[1,2] Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India.
[1] Division of Germplasm Collection and Characterization, ICAR-National Bureau of Agricultural Insect Resources, P.B. No. 2491, H.A. Farm Post, Hebbal, Bellary Road, Bengaluru 560024, Karnataka, India.
[3] Post-Graduate Research Centre, Department of Zoology, Modern College, Shivajinagar, Pune, Maharashtra 411005, India.
[1] kolla.sreedevi@gmail.com, [2] manisha.mannu10@gmail.com, [3] hemantghate@gmail.com (corresponding author)

Abstract: *Sarothrocera lowii* White, 1846 is the only species belonging to the genus *Sarothrocera* (Coleoptera: Cerambycidae: Lamiinae). Both the sexes of *S. lowii* were collected from Medziphema, Nagaland, northeastern India, during surveys in 2016. Earlier, Ghate et al. (2012) and Kumawat et al. (2015) reported this species from Manipur and Arunachal Pradesh, respectively, based on female specimens. This paper describes detailed characters of male *S. lowii* with comments on the female, along with the genitalia descriptions of both sexes for the first time. The species is a new report from Nagaland, India, adding to the known distribution.

Keywords: Additional characters, diagnostic characters, longhorn beetle, northeastern India.

Sarothrocera lowii White, 1846 (Coleoptera: Cerambycidae: Lamiinae) was named after Sir Hugh Low in honour of his great contribution to the natural history of the Malay Peninsula. This species was earlier reported from northeastern India in 2012 and 2015. Ghate et al. (2012) reported a single female of *S. lowii* from Manipur as the first record from India. Later, Kumawat et al. (2015) reported it from Arunachal Pradesh based on a single female. Ghate et al. (2012) provided the distinguishing characters of the female and male based on the descriptions of *S. lowii* given by White (1846) and von Breuning (1943) and also adequately illustrated various characters of the female. Since the first author collected both male and female specimens from Medziphema, Nagaland, during surveys in 2016, the paper aims at describing additional characters of adult male along with comments on the female. As the genitalia form an important diagnostic feature in species delineation, the descriptions of both male and female genitalia are provided here for the first time. This report presents the first record of the species from Nagaland and a new distribution locality for the species.

DOI: https://doi.org/10.11609/jott.4503.11.3.13390-13394 | **ZooBank:** urn:lsid:zoobank.org:pub:8A248C48-62C3-43B4-AD7C-6083709799B7

Editor: Eduard Vives, Museu de Ciències Naturals de Barcelona, Terrassa, Spain. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4503 | Received 23 August 2018 | Final received 16 February 2019 | Finally accepted 18 February 2019

Citation: Sreedevi, K., M. Sharma & H.V. Ghate (2019). New record of Low's Flatfaced Longhorn Beetle *Sarothrocera lowii* White, 1846 (Coleoptera: Cerambycidae: Lamiinae: Lamiini) in Nagaland, India, along with first-time descriptions of male and female genitalia. *Journal of Threatened Taxa* 11(3): 13390–13394; https://doi.org/10.11609/jott.4503.11.3.13390-13394

Funding: ICAR sponsored 'Consortium Research Platform on Borers' under grant number 12-128.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to Dr. Pankaj Neog, Assistant Professor, SASRD, Nagaland University, Medziphema, Nagaland, India, for facilitating the surveys. This work was supported by the ICAR sponsored project 'CRP on Borers' under grant number 12-128, which is gratefully acknowledged. Thanks are also due to the Director, ICAR-IARI and Head in division of entomology, ICAR-IARI, New Delhi, and the authorities of Modern College, Shivajinagar, Pune, for facilitating the work. The authors thank the Director, ICAR-NBAIR, Bengaluru, for the specimens deposition in the museum.

Materials and Methods

Specimens examined: NBAIR/COL-CER/1/2019, NBAIR/COL-CER/2/2019, 1 female, 1 male, 9.v.2016, Medziphema, Nagaland, India, 25^{0}45'N & 93^{0}53'E, 309m, coll. Kolla Sreedevi.

Specimens are deposited in ICAR-National Bureau of Agricultural Insect Resources, Bengaluru, India.

The adults of *S. lowii* were collected through light traps with mercury bulb as the light source in the second week of May 2016. The specimens were brought to the laboratory at the Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi. The morphologic and genitalia character studies along with genitalia dissection of the specimens were done using Leica KL300 LED stereo zoom microscope. For the isolation of genitalia, the abdomen was taken out and kept in warm distilled water to soften; dissection was carried out using 70% ethyl alcohol. Genitalia were then removed from the abdomen using microscissors and was kept in 10% KOH solution for 4–6 hours to dissolve the muscles. After examination under the microscope, the genitalia were preserved in glycerol in genitalia vial and pinned along with the specimen. The abdomen was glued back to the specimen. Images were taken using Sony 8x digital camera. The genitalia images and morphometry were done using Leica M205FA with 1.0x lens, using LAS V3.8 software. The terminology for genitalia descriptions is adopted from Lin et al. (2009) and Yamasako & Ohbayashi (2011).

Taxonomy

***Sarothrocera lowii* White, 1846**

Sarothrocera lowii White, 1846 *Ann. Mag. Nat. Hist.* 18: 47.

Sarothrocera lowei Thomson, 1861 Paris: 361.

Sarothrocera lowi Aurivillius, 1922 *Coleopt. Cat.* 73: 78.

Sarothrocera lowii Ghate et al., 2012 *J. Threat. Taxa* 4(7): 2709.

Sarothrocera lowii Kumawat et al., 2015 *J. Threat. Taxa* 7(12): 7879–7901.

Adult descriptions:

Male (Images 1A,B)

Colour: Body dorsally brownish or tawny, velvety in appearance. Head, pronotum, and ventral surface, along with legs, lighter than elytra, with yellowish or golden pubescence, basal 1/4 portion of elytra darker than whole body; head with eyes black, clypeus shinning brown, mandibles black, palpi dark brown, first five antennomeres brownish and rest dark brown to black; scutellum covered with pale yellow setae. Female, in general, is slightly lighter than male.

Structure

Head: Vertical, antennal tubercles close, elevated forming a V-shaped structure, eyes black with elongated inferior lobes, median sulcus on head between eyes; antenna 11-segmented, 1.5 times longer than body length, antennomeres progressively decreasing in length and becoming thinner gradually, tapering apically, tufts of black setae are present on inner side up to III antennomere or little beyond that to base of IV antennomere, which is the characteristic feature of male, as described by White (1846). First antennal segment thickened at apex, II antennomere very small. Mouth hypognathus, clypeus short, front trapezoidal, mandibles short, apically pointed maxillary, and labial palpi moderately long and fusiform.

Thorax: Pronotum transverse, bearing a pair of lateral spines; few long setae are present on lateral margin beneath spines and sparse on disc. All legs short, moderately robust and laterally compressed, tibia relatively slender but dilated apically, tibial spur short, claws divaricate. Acetabula of front and middle coxae rounded on the outer side. Prosternal process narrow between coxae and dilated distally. Scutellum longer than broad, more or less tongue-shaped. Elytra parallel sided, apex rounded, pubescent, elongate with prominent shoulder, moderately convex.

Abdomen: Abdomen gradually narrowed from base to apex, first sternite longer, rest almost of equal length (see ventral views in Images 1 & 2).

Description of male genitalia (Images 3–6)

Male terminalia 6.1mm long and 1.5mm wide, sclerotized, brown-coloured, slightly curved or convex. Tegmen (Images 4A,B) 5.2mm long and 1.27mm wide (at the middle) with two long, apically feebly pointed parameres, dorsally possessing brown long and thick setae on each lobe, near apex (Image 5A), ventrally entire sclerotized portion of parameres covered with setae, which gradually increase in length towards tip (Image 5B). Rings or lower lobes nearly parallel, widest at middle, forming a slight notch near base, then joins through a membrane, rounded at the tip.

Median lobe, along with median struts, curved (Image 3C), 4.6mm long and 1.5mm wide, without setae; median lobe approximately 1/3 longer than median struts, which are slightly broader and tapering apically; median orifice bluntly pointed at its ventral side, median foramen elongate (Image 3B); median struts broadest

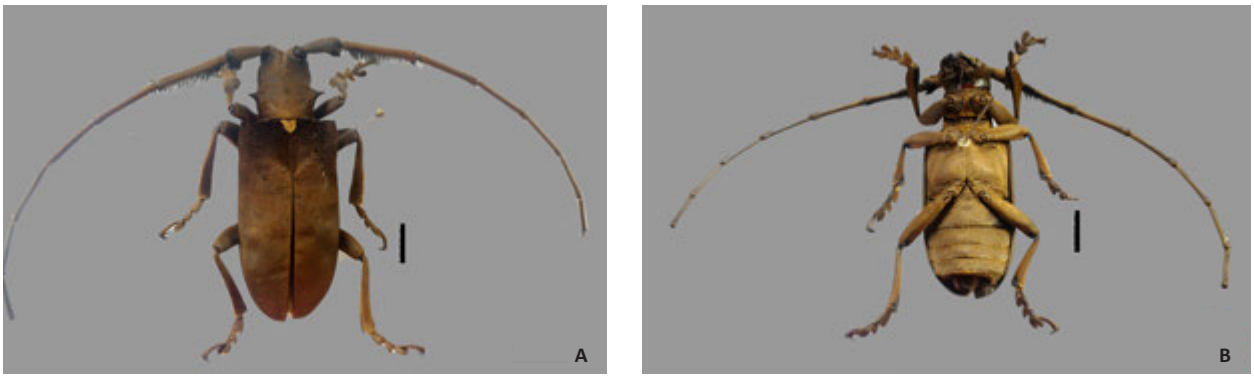


Image 1. *Sarothrocera lowii* male. A - dorsal view (scale: 1.0mm), B - ventral view. © Kolla Sreedevi.

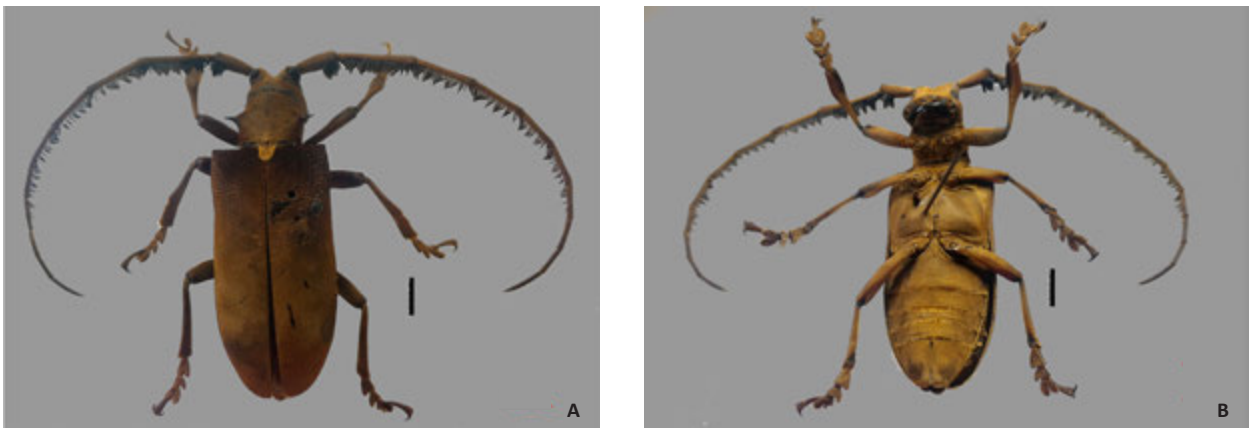


Image 2. *Sarothrocera lowii* female. A - dorsal view (scale: 1.0mm), B - ventral view. © Kolla Sreedevi.

and rounded at base, less sclerotized and lighter in remaining half (Image 3A).

Sternite VIII broader than long (length 1.6mm and width 2.32mm), apically sinuate, roughly trapezoidal, with long setae at apex, setae covering 1/4 portion close to apex and along margin (Image 6A), a protruding Y-shaped process in middle (Images 6A,B), 1.9mm long and 1.2–1.3 mm wide (from broader end) with setae on broader end. Tergite VIII as shown in Image 6B.

Female (Images 2A,B)

The female of this species was described adequately by Ghate et al. (2012). Therefore, here we are describing only the salient distinguishing features of the female.

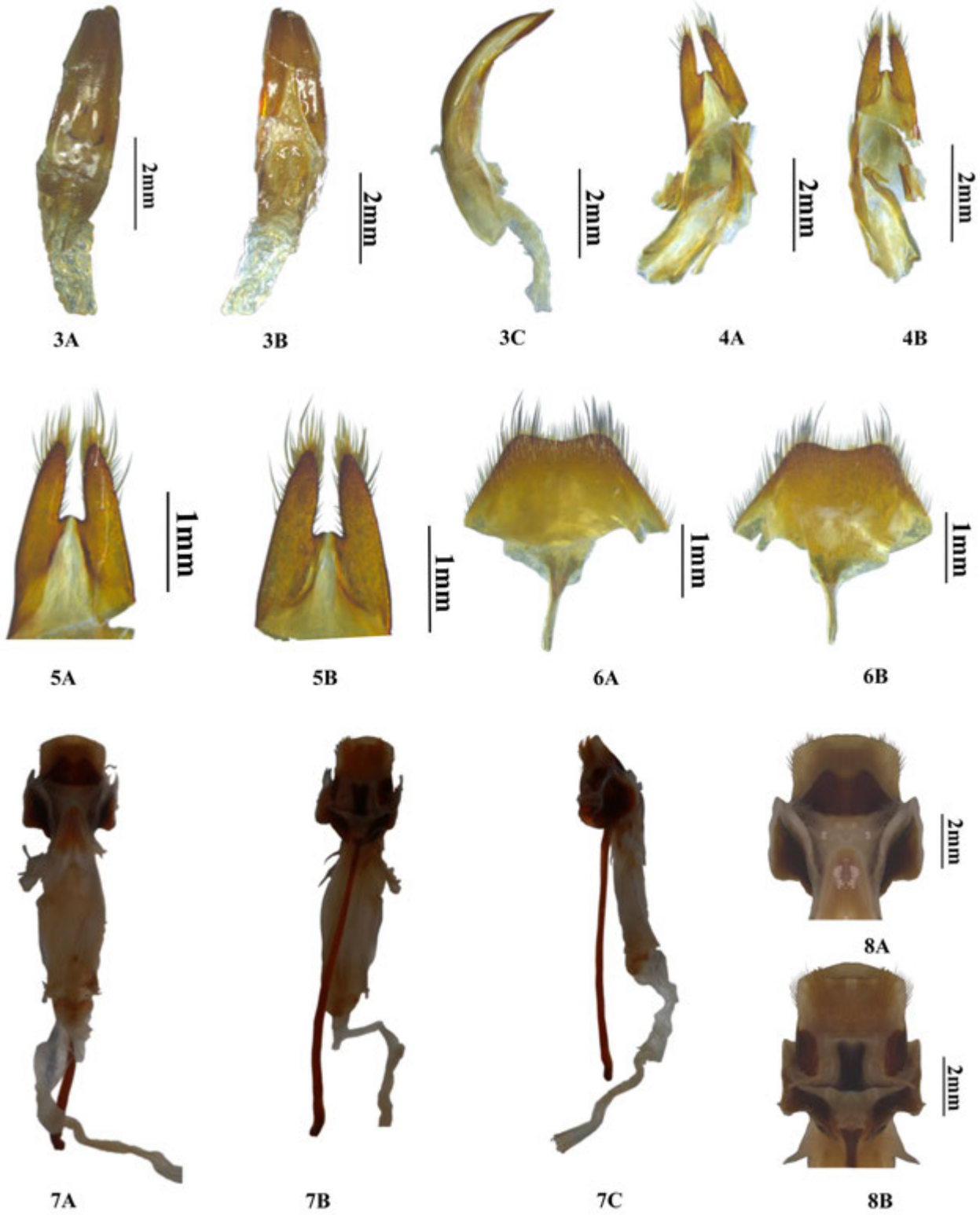
The species shows distinct sexual dimorphism. Female is almost 1.5 times larger and stouter than males. In female, antennae almost equal or little longer than body length, with characteristic presence of tufts of black hairs on inner side on antennomeres 1–8, which is the most prominent character, whereas in males, antennae are 1.5 times longer than body, covered with setae only up to base of IV antennomere. Another distinguishing feature is pronotal lateral spines are sharper and pointed in females than males (Images 2A,B). See Table 1 for various dimensions.

Description of female genitalia (Images 7 & 8)

Female terminalia light brown with dark brown to blackish shades (Image 7). Tignum (Image 7) 19mm long and 1mm wide, almost equal to abdominal length, with slight twist or bent at apex (Image 7). Tergite VIII (Image 8A) little curved apically or slightly convex, possessing setae along apical margins, having two petal-like sclerotized structures, that are 3mm long and 2.7mm wide (Image 7C). Sternite VIII (Image 8B) 4.01mm long and 3.78mm wide, apical edge straight, furnished with a bunch of long light-brown or yellowish setae on either side and some small setae scattered on discal surface.

Distribution: Borneo, India (Manipur, Arunachal Pradesh, and Nagaland (present report)), Indonesia, Laos, Myanmar, Sumatra, Thailand, Vietnam, and western Malaysia.

Comments: This is the only species described so far under the genus *Sarothrocera*. It is widely distributed in



Images 3–6. *Sarothrocera lowii* genitalia. 3 - median lobe and median struts A) dorsal, B) ventral, C) lateral; 4 - Tegmen A) dorsal, B) ventral; 5 - Upper lobes of tegmen A) dorsal, B) ventral; 6A - Tergite VIII, 6B - Sternite VIII. Images 7–8. *Sarothrocera lowii* female terminalia 7A) - dorsal, 7B) - ventral, 7C) - lateral; 8A - Tergite VIII, 8B - Sternite VIII. © Kolla Sreedevi.

Table 1. Morphometrics of adult *Sarothrocera lowii*.

	Characters	Male		Female	
		Length (in mm)	Width (in mm)	Length (in mm)	Width (in mm)
1.	Body	42	12	53	16
2.	Head	12	6	16	8
3.	Antennae	59.1		55.5	
4.	Mandibles	4	1.8	5	2
5.	Clypeus	0.6–0.7	2	0.8	2.5
6.	Thorax	10 (including spines)	7	13 (including spines)	8
7.	Scutellum	2	1	3	2
8.	Elytra	23	12	33	16
9.	Abdomen	15	11	20	14

southeastern Asia, but probably is a rare species. The species was found earlier in Manipur and, therefore, it is likely that it is present in other northeastern states of India. It is, therefore, necessary to conduct more surveys to assess the occurrence of this species in the various parts of this region.

References

Ghate, H.V., S. Riphung & N.S.A. Thakur (2012). First record of the long-horned beetle *Sarothrocera lowii* White, 1846 (Cerambycidae: Lamiinae: Lamiini) from India. *Journal of Threatened Taxa* 4(7): 2709–2712; https://doi.org/10.11609/JoTT.o2890.2709-12

Kumawat, M.M., K.M. Singh & V.V. Ramamurthy (2015). A checklist of the long-horned beetles (Coleoptera: Cerambycidae) of Arunachal Pradesh, northeastern India, with several new reports. *Journal of Threatened Taxa* 7(12): 7879–7901; https://doi.org/10.11609/JoTT.o4007.7879-901

Lin, M., O. Montreuil, G. Tavakilian & X. Yang (2009). Reinstatement of the genus *Heteroglenea* Gahan, with four new combinations, four new synonyms and three new species (Coleoptera: Cerambycidae: Lamiinae: Saperdini). *Zootaxa* 2137: 1–22.

von Breuning, S. (1943). Étudessur les Lamiaires, Douzièmetribu: Agniini Thomson. *Novitates Entomologicae, Supplement 3* 106: 273–280.

White, A. (1846). Description of four apparently new species of longicorn beetles in the collection of the British Museum. *Annals and Magazine of Natural History* 18: 47–49.

Yamasako, J. & N. Ohbayashi (2011). Review of the genus *Paragolsinda* Breuning, 1956 (Coleoptera, Cerambycidae, Lamiinae, Mesosini), with reconsideration of the endophallic terminology. *Zootaxa* 2882(1): 35–50; https://doi.org/10.11646/zootaxa.2882.1.4

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13395–13401

On the rediscovery of *Onychomesa susainathani*, an emesine bug endemic to India (Heteroptera: Reduviidae: Emesinae)

Hemant Vasant Ghate [1] & Balasaheb Sarode [2]

[1,2] Post-Graduate Research Centre, Department of Zoology, Modern College of Arts, Science & Commerce, Shivajinagar, Pune, Maharashtra 411005, India.
[1] hemantghate@gmail.com (corresponding author), [2] balasahebs78@gmail.com

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

Abstract: *Onychomesa susainathani* Wygodzinsky, 1966, an emesine bug known so far only from its type specimen, is illustrated with additional descriptive notes herein from Maharashtra State in India. It is a rediscovery after about 60 years.

Keywords: Emesinae, Hemiptera, Maharashtra, Metapterini, thread-legged bug.

A thread-legged bug belonging to the tribe Metapterini (Hemiptera: Heteroptera: Reduviidae: Emesinae), found dead trapped in a spider web, was collected near Pune in Maharashtra, India, in November 2017. It showed the main key characters of the genus *Onychomesa* Wygodzinsky, 1966, namely, the presence of a triangular projection on apical halves of claws of mid and hind legs ventrally, the pygophore of male subsemicircular in lateral view, and rod-shaped parameres. It was subsequently identified as *Onychomesa susainathani* Wygodzinsky, 1966 based on its original description (Wygodzinsky 1966).

Onychomesa susainathani was described based on two male specimens (one holotype and one paratype) from 'Jahalpur, central India' (actually Jabalpur in Madhya Pradesh, India; this must possibly be a typographic error in the original description). This is the type species of *Onychomesa*, a genus currently including only three species; these are, along with their respective recorded countries, *O. susainathani* (India), *O. sauteri* Wygodzinsky, 1966 (Taiwan), and *O. gokani* Ishikawa, 2000 (Japan).

O. susainathani was never reported from any part of India or elsewhere since its original description. Furthermore, because the specimen examined in the course of the present study exhibits some discrepancies with the original description and illustrations, additional description of the variation and several colour illustrations are provided in the present paper.

Material and Methods

Material examined: MCZH 140, 1 ex., male, 17.xi.2017, 25km north of Pune, coll. B. Sarode.

The material is deposited in Modern College, Pune. The methods of study follow that outlined in a recent paper by Sarode et al. (2018b).

DOI: https://doi.org/10.11609/jott.4546.11.3.13395-13401 | **ZooBank:** urn:lsid:zoobank.org:pub:DE224174-0327-438C-A1D3-D6B40E010B7F

Editor: Hélcio R. Gil-Santana, Instituto Oswaldo Cruz, Rio de Janeiro, Brasil. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4546 | Received 04 September 2018 | Final received 10 January 2019 | Finally accepted 30 January 2019

Citation: Ghate, H.V. & B. Sarode (2019). On the rediscovery of *Onychomesa susainathani*, an emesine bug endemic to India (Heteroptera: Reduviidae: Emesinae). *Journal of Threatened Taxa* 11(3): 13395–13401; https://doi.org/10.11609/jott.4546.11.3.13395-13401

Funding: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are indebted to Dr. Dávid Rédei (Nankai University, China) for support throughout our work, for reading the first draft of this note, and for making valuable suggestions to improve its contents. We thank Dr. James Carpenter and Dr. Ruth Salas (American Museum of Natural History, New York, USA) for helping us in getting images of the holotype and for permission to use the images. We also thank Dr. Salas for reexamining the type and providing us with comments on some characters. We thank Swapnil Boyane for excellent assistance in dissection, photography, and preparation of images used here. We are indebted to the authorities of Modern College, Pune, for the facilities and encouragement provided.

Taxonomy

Reduviidae: Emesinae: Metapterini

Genus *Onychomesa* Wygodzinsky, 1966

Onychomesa Wygodzinsky, 1966: 530. Type species by original designation: *Onychomesa susainathani* Wygodzinsky, 1966.

Onychomesa: Hsiao & Ren (1981: 393), Maldonado Capriles (1990: 135), Putshkov & Putshkov (1996: 163), Ishikawa (2000: 375), Rédei & Tsai (2010: 32).

***Onychomesa susainathani* Wygodzinsky, 1966**

Onychomesa susainathani Wygodzinsky, 1966: 533. Holotype: male, India, Jahalpur (= Jabalpur); one male paratype; deposited in the American Museum of Natural History, New York, USA.

Onychomesa susainathani: Maldonado Capriles (1990: 135), Ishikawa (2000: 378), Ambrose (2006: 2397).

Additional description: Macropterous male: total length 13.8mm.

Colour, integument, and vestiture: General colour brown. Head and thorax dorsally with numerous, pale, rounded scale-like setae that appear like small granules. Head with an elongate triangular pale patch of scale-like setae in front of transverse sulcus and a similar patch posteriad of sulcus, latter patch with pale line of scales on either side laterally. Antennal segments brown, apical part of segment I almost black but extreme tip pale. Prothorax dorsally with two longitudinal lines of scale-like setae throughout its length, these lines widely separated in anterior half but converge near middle and again diverge in posterior half. Mesonotum dark brown with two longitudinal lines of scale-like pale setae as well as a few scattered scale-like setae. Forewings pale brown with brown veins and brownish spots. Abdomen dorsally pale brown under wings, exposed portions behind forewing darker, almost blackish. Overall appearance in lateral view also brown to dark brown, with pale brownish spots or annuli on all legs; connexivum of each segment also with pale patches visible in lateral view. Head very pale brown ventrally, with scale-like setae; first and second visible segments of labium pale brown, especially laterally, third visible segment dark brown. Pro-, meso-, and metasternum dark brown; prosternum with scale-like setae, appearing finely rugulose; metasterna with two lateral pale lines of patches or blotches in anterior half; metasternum almost blackish, especially in posterior fourth; abdominal sternites brown with pale mottling up to fifth sternite but remaining part blackish with very few pale setae; spiracles blackish. Connexival pale patches also evident in ventral view; some pale mottling seen along prominent median keel as well. Posterior margin of third and fourth sternite appears as a thin pale line. Forelegs mostly brown; fore coxae pale brown with a small pale spot near apex, fore femur brown with oblique pale lines on inner and outer surfaces, fore tibia with one small basal and one large median pale annulation, fore tarsus with broad basal pale area. Mid coxae pale brown; hind coxae brown with incomplete longitudinal lines; mid and hind femora dark brown, with five pale spots or incomplete annulations; mid and hind tibia similar but with three pale spots in basal half; mid and hind tarsi pale (Image 1A–E).

Structure: Head more or less flat above and below, nearly rectangular in lateral view, anteocular portion slightly longer than postocular (Image 1F,G). In dorsal view, area posteriad of eye appears slightly globular, then gradually narrowed behind. Clypeus with a spine-like projection at its extreme apex immediately above base of labrum (Image 1H). Antennae long, inserted near apex of the head. Eyes of moderate size, remote from dorsal margin but reaching ventral margin of head, occupying more than half of height of head in lateral aspect; interocular transverse sulcus distinct, not surpassing the level of posterior border of eyes (Image 1I). Labium straight; first visible segment slightly longer than second and reaching anterior border of eye; apex of second visible segment just reaching level of posterior border of eye, third visible segment slightly slender, tapering, longest, reaching fore coxae (Image 1G).

Thorax moderately broad and elongate. Pronotum not covering mesonotum. Fore lobe more or less cylindrical, slightly broad near base and apex but narrow and parallel sided in between; hind lobe of pronotum very small, collar-like, well separated from fore lobe. In lateral view, mesothorax less high at apex than beyond middle where it is slightly less than twice in height. Mesonotum slightly convex in median part and depressed at sides forming shallow longitudinal grooves on either side (Image 2A–C,E); mesosternum flat over most part except near mesocoxae where it is hollowed to accommodate coxae. Metasternum shorter than mesosternum and slightly tumescent, with fine longitudinal median carina (Image 2F). Scutellum narrow, triangular with a few setae. Fore wings reaching fifth abdominal tergite, well-developed, showing usual venation (Image 3C). Hind wings colourless, translucent, only slightly shorter than fore wings.

Fore legs long and slender; femora parallel-sided, spined portion slightly longer than half of length of segment, with two series of spiniform processes:

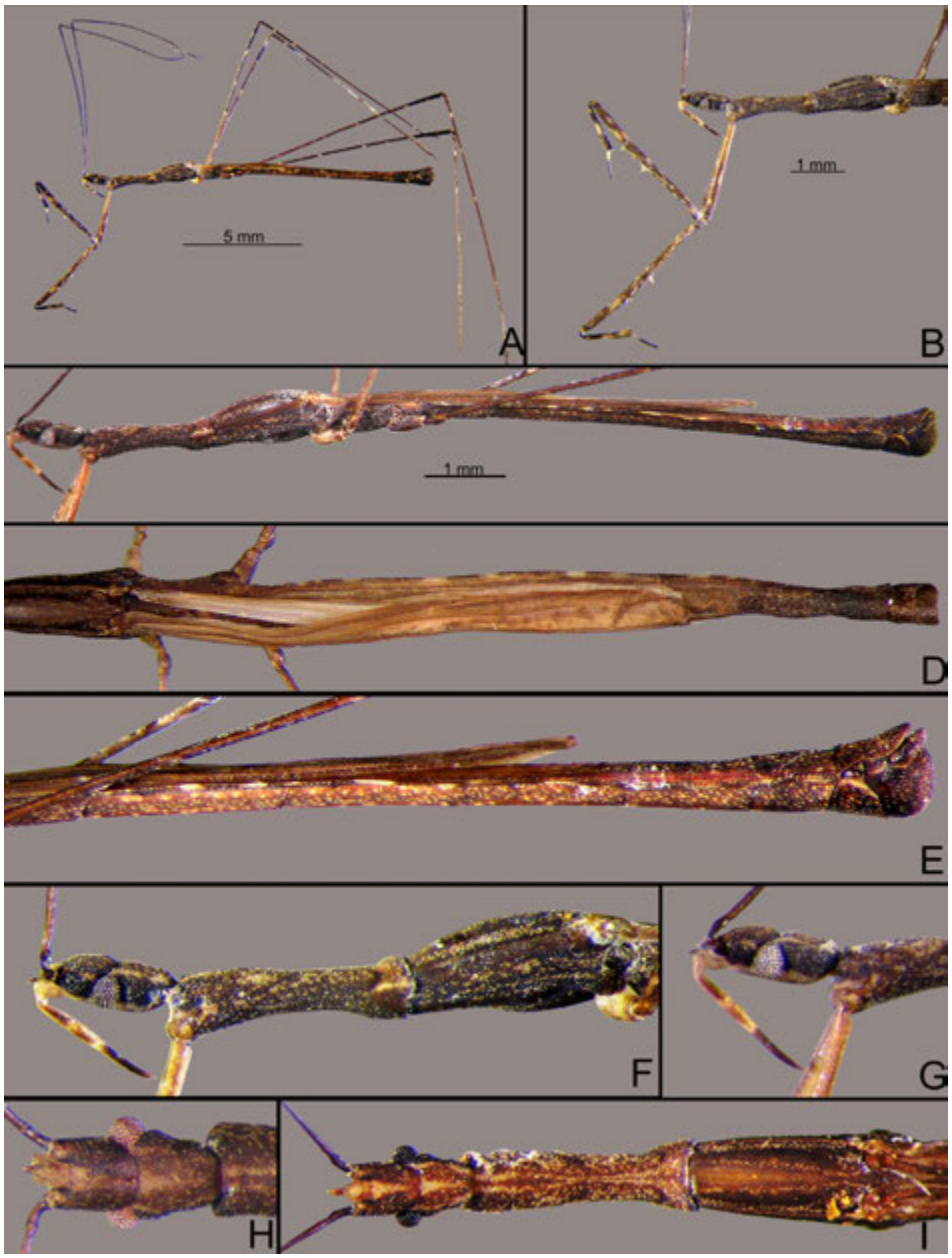


Image 1. *Onychomesa susainathani*. A - full lateral view; B - lateral view of anterior half; C - close-up of body in lateral view; D - dorsal view showing wings; E - lateral view of abdominal segments; F - head and prothorax in lateral view; G - lateral view of head; H - dorsal view of head; I - dorsal view of head and prothorax. © Hemant V. Ghate

posteroventral series with one long, three medium-sized, and about 35 short processes; apical portion of femur with very short teeth; anteroventral series with some medium-sized and more than 20 small spiniform processes (Image 2G,I). Fore tibia short, broad at apex, about one-third of length of femur, its ventral surface with one row of about 25 peg-like setae/denticles (Image 2I,J). Fore tarsus unsegmented (Image 2I), with one row of obliquely arranged spiniform setae (Image 3A). Claws of forelegs unequal in size. Mid and hind legs slender, hind femora slightly surpassing apex of abdomen (Image 2H), both femur and tibia of these legs with regularly spaced, modified setae with a round button-like base; tarsi of both these legs slender, with long setae on ventral surface. Claws of mid and hind legs moderately curved, ventrally with prominent triangular tooth near middle (Image 3A,B).

Abdomen slender, parallel-sided, with prominent keel on segments two to seven. Eighth tergite narrow, evenly rounded at posterior margin, tongue-like, covering

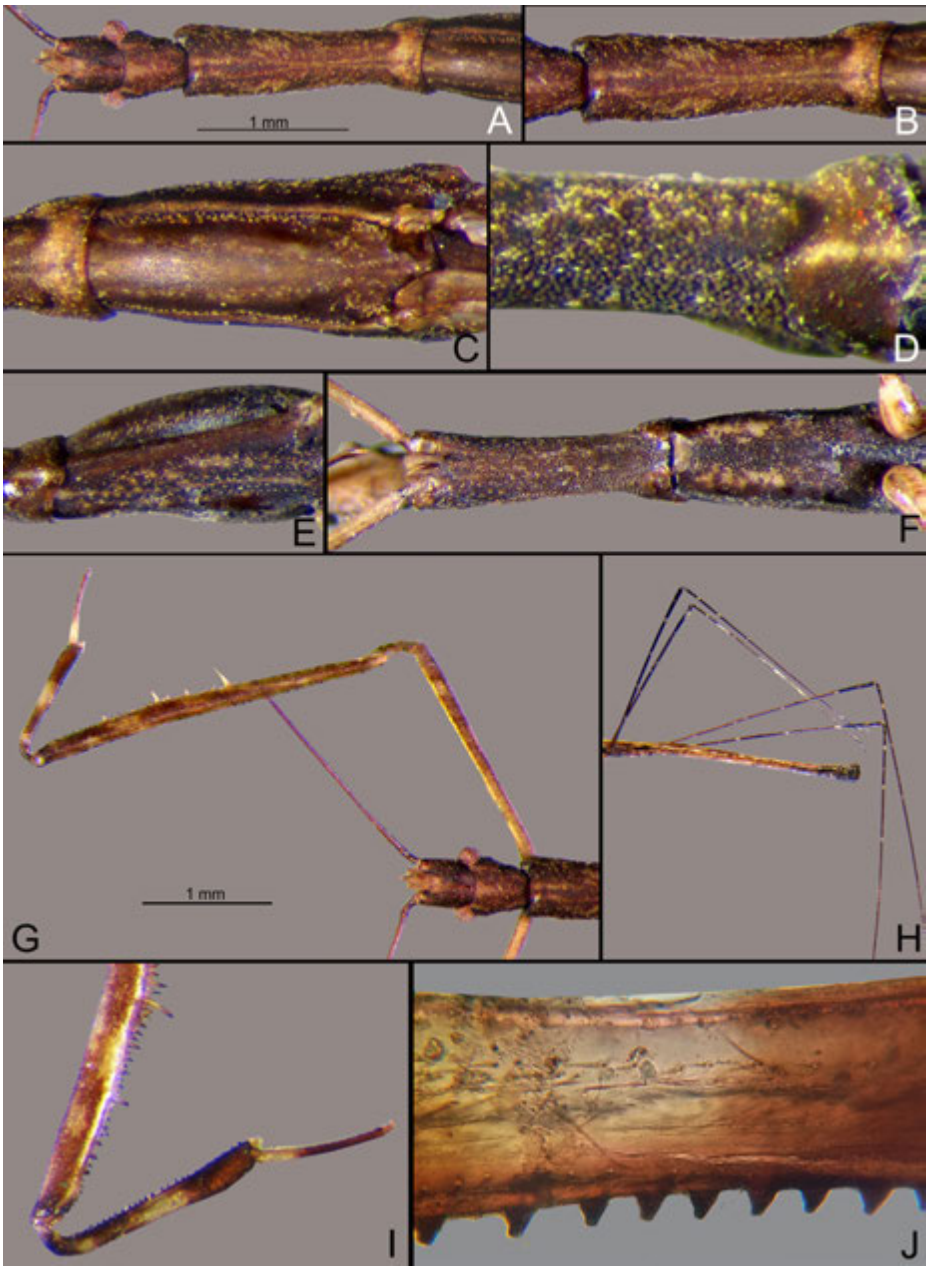


Image 2. *Onychomesa susainathani*. A - close-up of head and prothorax in dorsal view; B - close-up of prothorax in dorsal view; C - close-up of mesothorax in dorsal view; D - ventrolateral view of prothorax showing scale-like setae; E - close-up of mesothorax in lateral view; F - pro- and mesosternum; G - entire fore leg; H - hind legs and abdomen in lateral view; I - foreleg details; J - tibial peg-like setae. © Hemant V. Ghate.

pygophore; eighth sternite rounded on posterior margin (not incised in middle). Pygophore in straight line with rest of abdomen, not elevated, slightly compressed. Visible part of pygophore in situ subsemicircular in lateral view, with short posterosuperior projection; parameres visible in lateral view but obscured in dorsal view due to last tergite. Posterior outline of pygophore in situ broadly rounded (Image 3D), pygophore detached from body oval in ventral (Image 3E) and dorsal views (Image 3F). In dorsal view, anterior part appears slightly broad, anterior (basal) opening is oval; robust parameres with strong black setae on inner face are clearly visible; basal dorsal bridge is narrow. Pygophore much more sclerotized laterally and ventrally than in other surfaces. Phallus symmetrical. Basal plates short and robust, phallosoma short, subcylindrical, apically wider, partly sclerotized laterally and ventrally; endosoma short (not everted here), membranous (Image 3H). Parameres moderately robust, short and partially setose, with many strong conical spines on inner surface (Image 3I,J).

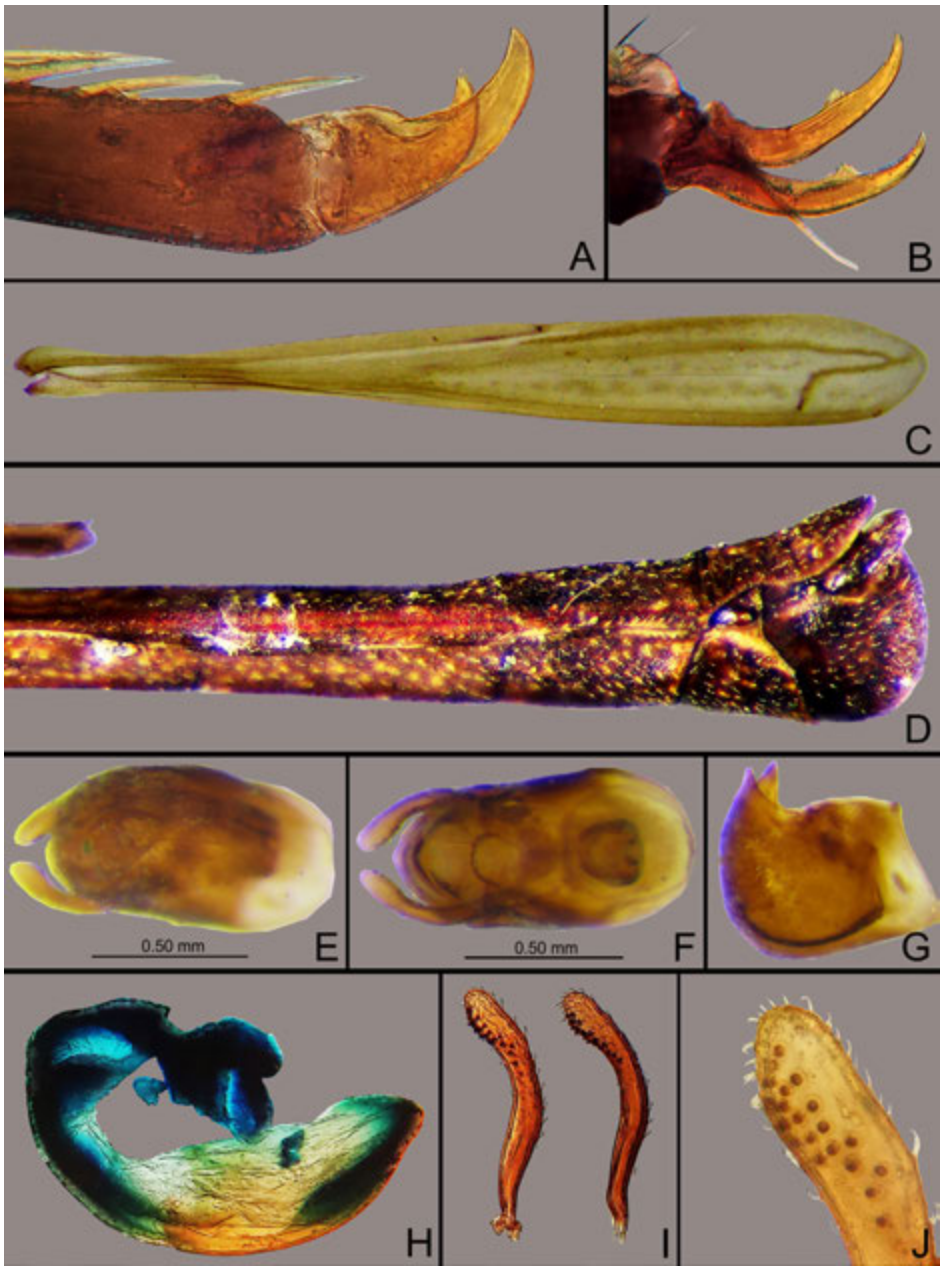


Image 3. *Onychomesa susainathani*. A - fore tarsus part and claw; B - fore leg claw; C - fore wing; D - abdominal segments in lateral view; E–G - pygophore in ventral, dorsal, and lateral views, respectively; H - phallus in lateral view; I - parameres in outer and inner view; J – close-up of paramere tip. © Hemant V. Ghate.

Measurements (in mm): Total length of head (including neck and spine of clypeus) 1.15; eye diameter 0.25; maximum width of head at eye 0.62; eye diameter seen laterally 0.22; anteocular 0.5; postocular 0.35; antenna: I segment 6.2, II segment 5.5, rest mutilated; visible segments of labium: I segment 0.31, II segment 0.25, III segment 0.5; thorax total length 4.65; maximum width of pronotum 0.55; pronotum median length 1.75 (hind lobe 0.17); mesonotum 1.45; prosternum 1.75; mesosternum 1.5; metasternum 0.87; fore wing 6.8; legs: fore leg (lengths): coxa 2.37, femur 3.37, tibia 1.12, tarsus with claw 0.67; mid leg (lengths): coxa 0.52, femur 6, tibia 8, tarsus with claw 0.5; hind leg (lengths): coxa 0.55, femur 8.9, tibia 12; abdomen 8.0; maximum width of abdomen 0.75; pygophore length 0.75; maximum width of pygophore 0.5; paramere length 0.45.

Remarks

The male examined in the present study exhibits all important diagnostic characters of *Onychomesa*

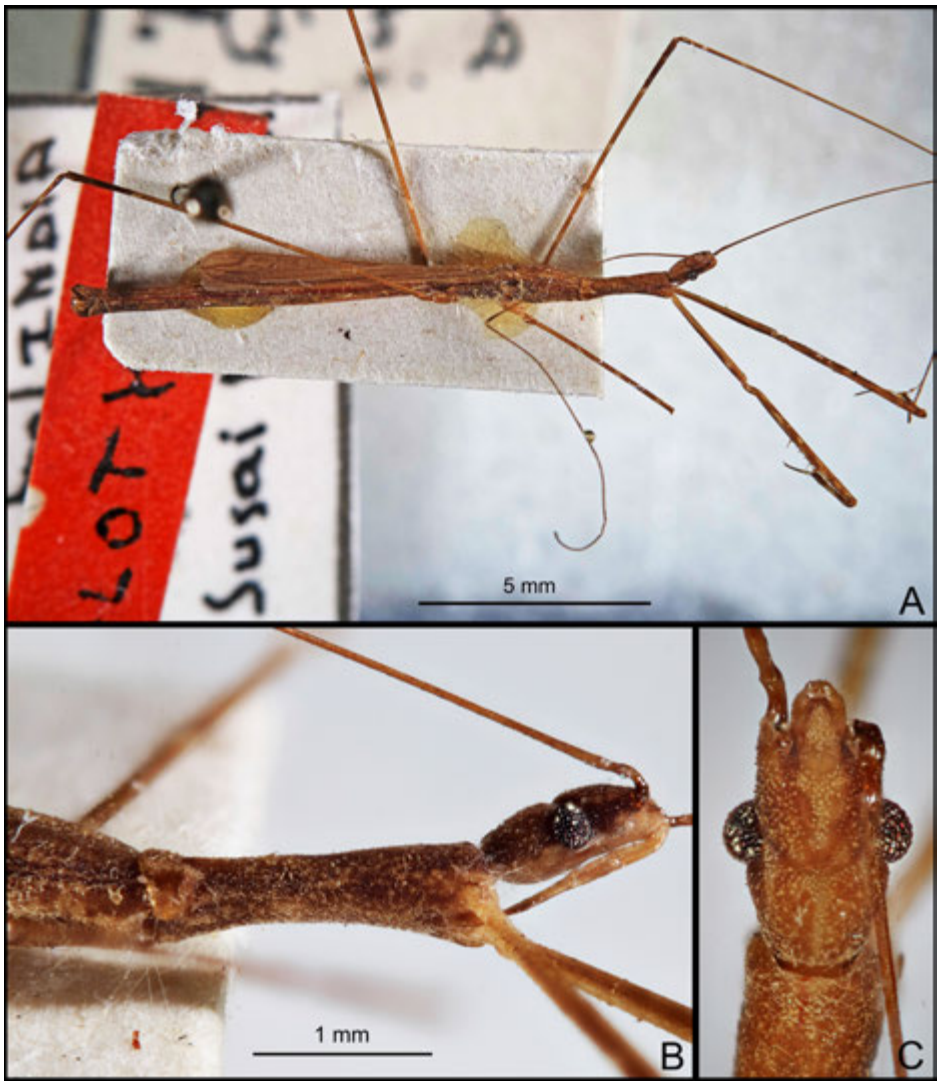


Image 4. Type images of *Onychomesa susainathani* Wygodzinsky. A - dorsolateral habitus; B - lateral aspect of head and prothorax; C - dorsal view of head. © American Museum of Natural History.

provided by Wygodzinsky (1966). The specimen matches well with the original description and illustrations as well as with a series of images of the holotype of *O. susainathani* (courtesy of American Museum of Natural History, USA). The male genitalia also does not seem to differ from that of *O. susainathani*. Therefore, the specimen is identified as such. Images of the type are also presented here (Image 4).

The specimen from Pune, however, differs from the holotype in the following three characters:

(1) In *Onychomesa*, the "mid and hind legs [are] slender, but [femora] not surpassing apex of abdomen" (Wygodzinsky 1966). In the specimen from Pune, the hind femora do pass the apex of the abdomen. As far as it can be judged from the available images, however, the hind femora slightly pass the apex of the abdomen also in the holotype of *O. susainathani*; therefore, the statement of Wygodzinsky (1966) appears to be erroneous. The hind femora of our specimen, nevertheless, seem to be somewhat longer than those of the holotype.

(2) The eyes of the specimen from Pune are considerably larger than those of the holotype of *O. susainathani* — in the latter, they do not reach dorsal and ventral outlines of the head in lateral aspect, whilst in the specimen from Pune, they reach the ventral outline. Such variability in the size of the eye is unusual among specimens of the same sex and same wing morph.

(3) The lack of projections on the clypeus (and labrum) was given as a diagnostic character for *Onychomesa* (Wygodzinsky 1966: 530). A conspicuous, anteriorly-directed projection, however, is found in the specimen from Pune. In many metapterine genera, the

clypeus can be provided with a distinct spine, or it might be salient but without a distinct spine; in other cases it is unarmed. Although this character was frequently used for distinguishing genera in the identification key to the genera of Metapterini by Wygodzinsky (1966: 432–436), the same author (Wygodzinsky 1966: 12) noted that "[t]hese characters generally are of not more than specific value". It may be that the development of the process on the clypeus is probably subject to intraspecific variability as well.

In conclusion, in spite of some differences from the holotype, we identify the specimen from Pune as *Onychomesa susainathani*. The occurrence of this species in Pune is not surprising as several species of Emesinae are widely distributed. Although the species was only described in 1966, the type material of *O. susainathani* was collected in 1957. Our record, therefore, represents a rediscovery of this species after over 60 years.

We are trying to locate and illustrate Emesinae. The total number of different species that we have studied during the period 2016–2018 exceeds 15. These species include many first reports for India, some new species, and some additional descriptions of known species. We published some of these findings earlier (Kulkarni & Ghate 2016a,b; Pansare et al. 2018; Ghate & Mathew 2018; Sarode et al. 2018a,b); a few more publications dealing with other poorly known emesine bugs are in preparation.

References

Ambrose, D.P. (2006). A checklist of Indian assassin bugs (Insecta: Hemiptera: Reduviidae) with taxonomic status, distribution and diagnostic morphological characteristics. *Zoos' Print Journal* 21(9): 2388–2406; https://doi.org/10.11609/JoTT.ZPJ.871.2388-406

Ghate, H.V. & M. Mathew (2018). First record of the genus *Gomesius* (Hemiptera: Heteroptera: Reduviidae: Emesinae) from India, with description of a new species. *Zootaxa* 4461(3): 421–428; https://doi.org/10.11646/zootaxa.4464.3.7

Hsiao, T.Y. & S.Z. Ren (1981). Reduviidae, pp390–538. In: Hsiao, T.Y., S.Z. Ren, L.Y. Zheng, H.L. Jing, H.G. Zou & S.L. Liu (eds.). *A Handbook for the Determination of the Chinese Hemiptera-Heteroptera, Vol. II*. Science Press, Beijing, 654pp+85pls [in Chinese].

Ishikawa, T. (2000). *Onychomesa gokani*, a new emesine assassin bug (Insecta: Heteroptera: Reduviidae) from Japan. *Species Diversity* 5: 375–379.

Kulkarni, S. & H.V. Ghate (2016a). First record of the thread-legged assassin bug *Myiophanes greeni* Distant, 1903 (Heteroptera: Reduviidae: Emesinae) from India. *Biodiversity Data Journal* 4: e7949; https://doi.org/10.3897/BDJ.4.e7949

Kulkarni, S. & H.V. Ghate (2016b). A new cavernicolous assassin bug of the genus *Bagauda* Bergroth (Heteroptera: Reduviidae: Emesinae) from the Western Ghats, India. *Zootaxa* 4127(2): 365–375; https://doi.org/10.11646/zootaxa.4127.2.8

Maldonado, C.J. (1990). Systematic Catalogue of the Reduviidae of the World (Insecta: Heteroptera), Special Edition of the Caribbean Journal of Science. University of Puerto Rico, Mayagüez, Puerto Rico, 694pp.

Pansare, P.P, H.V. Ghate & M. Webb (2018). Redescription of the thread-legged assassin bug *Ploiaria anak* (Hemiptera: Heteroptera: Reduviidae: Emesinae) from India, with notes on its biology. *Zootaxa* 4388(4): 557–566; https://doi.org/10.11646/zootaxa.4388.4.7

Putshkov, P.V. & V.G. Putshkov (1996). Family Reduviidae Latreille, 1807 — assassin-bugs, pp148–265. In: Aukema, B. & C. Rieger (eds.). *Catalogue of the Heteroptera of the Palaearctic Region, Vol. 2. Cimicomorpha I*. The Netherlands Entomological Society, Amsterdam, 359pp.

Rédei, D. & J.F. Tsai (2010). A survey of the emesine assassin bugs of the tribes Collartidini, Leistarchini, Emesini, and Metapterini of Taiwan (Hemiptera, Heteroptera, Reduviidae). *Deutsche Entomologische Zeitschrift* 57(1): 11–36.

Sarode, B.V., S.S. Boyane & H.V. Ghate (2018a). The first report of two thread-legged assassin bugs (Hemiptera: Reduviidae: Emesinae) from India. *Journal of Threatened Taxa* 10(5): 11659–11664; https://doi.org/10.11609/jott.3971.10.5.11659-11664

Sarode, B.V., N.U. Joshi, P.P. Pansare & H.V. Ghate (2018b). A report after 52 years, and additional description of the emesine assassin bug *Emesopsis nubila* (Hemiptera: Reduviidae: Emesinae) from western India. *Journal of Threatened Taxa* 10(9): 12282–12285; https://doi.org/10.11609/jott.3956.10.9.12282-12285

Wygodzinsky, P.W. (1966). A monograph of the Emesinae (Reduviidae, Hemiptera). *Bulletin of the American Museum of Natural History* 133: 1–614.

Short Communication

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13402–13405

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

First record of the callianassid ghost shrimp *Neocallichirus jousseaumei* (Nobili, 1904) (Decapoda: Axiidea) from India

Imtiyaz Beleem [1], Paresh Poriya [2] & Bharatsinh Gohil [3]

[1,3] Department of Life Sciences, [2] Department of Marine Science, Maharaja Krishnakumarsinhji Bhavnagar University, Gaurishanker Lake Road, Bhavnagar, Gujarat 364001, India
[1] imtiyazbelim7@gmail.com, [2]pareshporiya@gmail.com, [3] bharatsinhmgohil@gmail.com (corresponding author)

Abstract: From India, two species of the callianassid ghost shrimp genus *Neocallichirus* Sakai, 1988 are known. In this study, *Neocallichirus jousseaumei* (Nobili, 1904) is first recorded from India based on a single specimen collected from intertidal zone of Diu coast. A brief description for giving evidence of the identification and notes on habitat is presented.

Keywords: Callianassidae, description, Indian coast, new record.

Callianassid ghost shrimp (Decapoda: Axiidea) is among the most common burrowing organisms in littoral and sublittoral soft sediments (Sakai 1999). The global diversity of the Axiidea contains 465 species classified into 128 genera and 14 families in the world, although taxonomy of those taxa is still in a state of flux (Dworschak 2015). Sakai (2011) recognized 29 species in the genus *Neocallichirus* Sakai, 1988 whereas currently 62 valid species (38 living and 24 fossils) have been recorded from different regions of the world until now (WoRMS Editorial Board 2018). From India, several authors have reported upon callianassid fauna (e.g., Alcock & Anderson 1894, 1899; Sakai 1999, 2005). With regard to the genus *Neocallichirus* Sakai, 1988, two species, viz., *Neocallichirus audax* (de Man, 1911) and *N. rathbunae* (Glaessner, 1929) have been reported from the country (Rao & Kartha 1966; Sakai 1999). In this short communication, we record *N. jousseaumei* (Nobili 1904) from India for the first time on the basis of a single specimen from Diu coast. A brief description evidencing the identification and notes on the habitat are presented.

Materials and Methods

The intertidal zone of Diu (Union territory) coastal area is composed of different habitats, such as mangroves, sandy mud, mud, sand and rock with tidal pools. The specimen was collected from the Khukri on 16 October 2015 during rainy season in the upper intertidal of sandy-mud zone, under cobbles. It was collected and preserved in 10% buffered formalin solution. It was deposited in the museum of the Department of Life Sciences, Maharaja Krishnakumarsinhji Bhavnagar University, Bhavnagar (Voucher/Museum ID: LSAIAT21). The specimen was identified using keys of Sakai (1999, 2011) and the redescription of *N. jousseaumei* by Dworschak (2011). Size of the specimen is indicated

DOI: https://doi.org/10.11609/jott.3251.11.3.13402-13405 | **ZooBank:** urn:lsid:zoobank.org:pub:5A0CF19A-9D5D-4BCC-9296-7F131C5EA193

Editor: A. Biju Kumar, University of Kerala, Thiruvananthapuram, India. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #3251 | Received 17 February 2017 | Final received 09 January 2019 | Finally accepted 18 February 2019

Citation: Beleem, I., P. Poriya & B. Gohil (2019). First record of the callianassid ghost shrimp *Neocallichirus jousseaumei* (Nobili, 1904) (Decapoda: Axiidea) from India. *Journal of Threatened Taxa* 11(3): 13402–13405; https://doi.org/10.11609/jott.3251.11.3.13402-13405

Funding: Maulana Azad National Fellowship, University Grants Commission (MANF-SRF: Student ID: 201415-MANF-2014-15-MUS-GUJ-32805).

Competing interests: The authors declare no competing interests.

Acknowledgements: Authors are thankful to the head, of the Department of Life Sciences, Maharaja Krishnakumarsinhji Bhavnagar University, Bhavnagar. First author (IB) is thankful to the University Grants Commission for providing financial support as Maulana Azad National Fellowship (MANF scheme). Authors are thankful to Dr. Peter Dworschak (Dritte Zoologische Abteilung, Naturhistorisches Museum, Burgring, Austria) for suggestions and identification.

by carapace length (cl) measured from the tip of the rostrum to the midpoint of the posterodorsal margin of the carapace and the total length measured from the tip of the rostrum to the midpoint of the posterodorsal margin of the telson. Measurements were taken with vernier caliper. Other abbreviations used in the text are: Plp1 - first pleopod; Plp2 - second pleopod.

Result and Discussion

Systematics

Class Malacostraca Latreille, 1802
Order Decapoda Latreille, 1802
Suborder Pleocyemata Burkenroad, 1963
Infraorder Axiidea De Saint Laurent, 1979
Family Callianassidae Dana, 1852
Genus *Neocallichirus* Sakai, 1988

Neocallichirus jousseaumei (Nobili, 1904) (Image 1 A–C)

Material Examined: Reg. no. LSAIAT21, 16.x.2015, 1 male, tl 69.2mm, cl 20mm, Khukri coast, Diu (20.703^{0}N & 70.976^{0}E), upper intertidal zone of sandy/muddy beach, coll. Imtiyaz Beleem.

Description: Carapace as long as pleomeres 1 and 2 combined, with distinct linea thalassinica extending over entire length; rostrum broadly rounded in dorsal view, not reaching midlength of eyestalks, but reaching beyond lateral projections; anterolateral projections obtuse; dorsal oval distinctly defined with deep transverse cardiac furrow, extending anteriorly just above linea thalassinica as shallow grooves, acrossing postrostral region. Epistome bearing dense tuft of long setae on each subantennular region.

Eyestalks contiguous, narrowing distally to minutely denticulate terminal margin; no conspicuous terminal process. Cornea black, situated dorsolaterally in distal half of eyestalk, about 1/2 width of eyestalk; proximal area of cornea filled with black pigmentation. Antennular peduncle 2.5 times as long as carapace. Antennal peduncle longer and more slender than antennular peduncle.

Third maxilliped with ischium-merus subquadrate, about 1.1 times as long as wide; distal margin of merus obliquely truncate; propodus approximately as long as wide, with strongly convex lower margin.

Chelipeds distinctly unequal and dissimilar. Major cheliped massive; ischium with row of minute denticles proximally on inferior margin; merus widest proximally, with convex, denticulate blade on inferior margin; carpus slightly shorter than merus, distinctly higher than long, with straight superior and convex inferior margins; palm much longer than carpus and about as long as high, with low but sharp keel in proximal half of superior margin, inferior margin of palm weakly serrated; fixed finger slightly curved, cutting edge with low tubercles proximally; dactylus curved, slightly longer than fixed finger. Minor cheliped relatively stout; ischium with row of minute denticles proximally on inferior margin; merus unarmed; carpus as long as high; palm slightly longer than high; fixed finger shorter than palm; dactylus slightly curved; cutting edges of fixed finger and dactylus smooth, without conspicuous armature.

Second pereopod and fifth pereopods without distinctive features. Third pereopod with propodus subquadrate, heel subtruncate, not much produced. Fourth pereopod semicheleate; propodus with fixed finger reaching midlength of dactylus. Pleomere 6 with lateral constriction at about two-thirds length. Male first pleopod uniramous, consisting of two articles (Image 1D); second article longer than first, biramous with rounded lobe and acute hooked tip distally (Image 1E). Uropodal endopod slightly longer than telson, subrhomboidal, about as long as wide; exopod longer than endopod, with anterodorsal plate. Telson subtrapezoidal, narrowing posteriorly, about 1.2 times as wide as long; posterior margin gently convex, unarmed.

Color in life: Transparent with tinge of pink on the pleon and chelipeds.

Habitat: *Neocallichirus jousseaumei* (Nobili, 1904) occurs widely in boulder or lime stone rocks (carbonate rock) and sand to muddy-sand sediments (Sepahvand et al. 2012, 2014). In coastal area of Diu, we collected the specimen in upper intertidal zone of which the substrate consisting of muddy sand and boulders (Image 2A,B).

Distribution: Widely distributed in the Indo-West Pacific: Mauritius (Kensley 1976); Kangeang Reef, Bay of Kankamaran, Djibouti, Gulf of Aden, Red Sea (type locality; Nobili 1904, 1906), Socotra and Persian Gulf (Sakai & Apel 2002; Sepahvand & Sari 2010, Sepahvand 2014); Qeshm Island and Gulf of Oman (Sepahvand et al. 2012); Pakistan (Naderloo & Türkay 2012); Thailand, Philippines (Dworschak 2011); Cocos (Keeling) Islands (Dworschak 2014); Indonesia (de Man 1905; Sakai 2005); Tuamotu, French Polynesia, Ryukyu Islands, Japan (Sakai 1999; Sepahvand et al. 2018), India (new record).

Remarks

Diagnostic characters of the specimen examined agrees well with the description of *N. jousseaumei* given by Dworschak's (2011). The shape of male first and second pleopods of our specimen resembles that of the lectotype of *C. jousseaumei* Nobili, 1904

Image 1. ***Neocallichirus jousseaumei*** **(Nobili, 1904). (A) dorsal view, (B) ventral view, (C) lateral view, (D) first pleopod, (E) second pleopod. Scale bar = 1cm. © Imtiyaz Beleem & Paresh Poriya.**

(MNHN Th 83). The synonymization of *N. indicus* with *Neocallichirus jousseaumei* (Nobili, 1904) by Dworschak' (2011) "a serious error; for *jousseaumei* it should read 'senior' instead of 'junior' as evidenced by date of authors and text of the paper" (Naderloo & Türkay 2012).

References

Alcock, A. & A.R.S. Anderson (1894). Natural history notes from H.M. Royal Indian Marine Survey Steamer "Investigator", commander C.F. Oldham, R.N., commanding. - Series II, No. 14. An account of a recent collection of deep-sea Crustacea from the Bay of Bengal and Laccadive Sea. *Journal of the Asiatic Society of Bengal* (2) (Natural History) 63: 141–185, pl. 9.

Alcock, A. & A.R.S. Anderson (1899). Natural History Notes from H.M. Royal Indian Marine Survey Ship "Investigator", Commander T.H. Heming, R.N., commanding. Ser. III. No. 2. An Account of the deep-sea Crustacea dredged during the Surveying-Season of 1897–98. *Annals and Magazine of Natural History* (7)3: 1–27: 287–290.

Dworschak, P.C. (2011). Redescription of *Callianassa jousseaumei* Nobili, 1904, a junior subjective synonym of *Callianassa indica* de Man, 1905 with description of a new species of *Neocallichirus* (Decapoda: Axiidea: Callianassidae). *Zootaxa* 2746: 1–19; https://doi.org/10.11646/%25x

Dworschak, P.C. (2014). The Axiidea (Crustacea, Decapoda) of Cocos (Keeling) and Christmas Islands, with description of a new species of *Eucalliax* Manning & Felder, 1991. *Raffles Bulletin of Zoology* Supplement 30: 230–245.

Dworschak, P.C. (2015). Methods collecting Axiidea and Gebiidea (Decapoda): a review. *Annalen des Naturhistorischen Museums in Wien* 117 B: 415– 428.

Kensley, B. (1976). Records of mud-prawns (genus *Callianassa*) from South Africa and Mauritius (Crustacea, Decapoda, Thalassinidea). *Annals of the South African Museum* 69: 47–58.

Image 2. A - Khukri beach; B - *Neocallichirus jousseaumei* (Nobili, 1904) in sandy habitat. © Imtiyaz Beleem.

Man, J.G. de (1905). Diagnoses of new species of macrurous decapod Crustacea from the "Siboga-Expedition". Tijdschrift der Nederlansche Dierkundige Vereeniging 9: 587–614.

Naderloo, R. & M. Türkay (2012). Decapod crustaceans of the littoral and shallow sublittoral Iranian coast of the Persian Gulf: Faunistics, Biodiversity and Zoogeography. *Zootaxa* 3374: 1–67

Nobili, G. (1904). Diagnoses préliminaires de vingt-huit espèces nouvelles de Stomatopodes et Décapodes Macroures de la Mer Rouge. *Bulletin du Muséum d'Histoire Naturelle de Paris* 10: 230–238.

Rao, P.V. & K.N.R. Kartha (1966). Occurrence of *Callianassa (Callichirus) audax* de Man (Crustacea Decapoda - Callianassidae) on the southwest coast of India with a description of the male. In: Proceedings of the Symposium on Crustacea, Part 1; *Marine Biological Association of India* 12–15 January 1965, 1: 279–284, Ernakulam.

de st. Laurent, M. & P. LeLoeuff (1979). Crustacés décapodes Thalassinidea. I.Upogebiidae et Callianassidae. In: Résultats scientifiques des campagnes de la Calypso, Fasc.11, Campagnes de la Calypso au large des côtes Atlantiques Africaines (1956 et 1959) (suite), no. 22. *Annales de l'Institute Océanographique* 55: 29–101.

Sakai, K. (1987). Two new Thalassinidea (Crustacea: Decapoda) from Japan, with the biogeographical distribution of the Japanese Thalassinidea. *Bulletin of Marine Science* 41: 296–308.

Sakai, K. (1999). Synopsis of the family *Callianassidae*, with keys to subfamilies, genera and species, and the description of new taxa (Crustacea: Decapoda: Thalassinidea). *Zoologische Verhandelingen* 326: 1–152.

Sakai, K. (2005). Callianassoidea of the world (Decapoda, Thalassinidea). *Crustaceana Monographs* 4: 1–200.

Sakai, K. (2011). Axioidea of the world and a reconsideration of the Callianassoidea (Decapoda, Thalassinidea, Callianassida). *Crustaceana Monographs* 13: 1–616.

Sakai, K. & M. Apel (2002). *Thalassinidea* (Crustacea: Decapoda) from Socotra Archipelago, Yemen, with a new species of *Lepidophthalmus*. *Fauna of Arabia* 19: 273–288.

Sepahvand, V. & A. Sari (2010). Taxonomy and geographical distribution of intertidal thalassinidean shrimps (Crustacean: Decapoda) from the Qeshm Island, Persian Gulf. *Journal of Science, University of Tehran* 36: 43–52.

Sepahvand, V. (2014). Two new records of ghost shrimps (Crustacea: Decapoda: Axiidea) from Bushehr, Persian Gulf, Iran. *Iranian Journal of Animal Biosystematics* 10(1): 67–71.

Sepahvand, V., A. Sari, H. Salehi, S.M.B. Nabavi & S.G.H. Ghorbanzadeh (2012). Littoral mud shrimps (Decapoda: Gebiidea & Axiidea) of the Persian Gulf and Gulf of Oman, Iran. *Journal of the Marine Biological Association of the United Kingdom* 93: 999–1008; https//doi.org/10.1017/S0025315412001361

Sepahvand, V, A. Sari, C. Tudge & M. Bolouki (2014). A study of burrow morphology in representative axiidean and gebiidean mud shrimps, from the Persian Gulf and Gulf of Oman, Iran. *Nauplius* 22(2): 137–144.

Sepahvand, V, T. Komai, F. Momtazi & S. Shahabi (2018). A new species of the ghost shrimp genus *Neocallichirus* Sakai, 1988 from Iran, and new record of *N. manningi* Kazmi & Kazmi, 1992 (Decapoda: Axiidea: Callianassidae). *Zootaxa* 4527(2): 239–254; https://doi.org/10.11646/zootaxa.4527.2.5

WoRMS (2018). *Neocallichirus* Sakai, 1988. Available at: http://www.marinespecies.org/aphia.php?p=taxdetails&id=415685 accessed on 5 January 2019.

Short Communication

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 February 2019 | 11(3): 13406–13414

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

New distribution records of four species of crop wild relatives to India

K. Pradheep [1], K. Joseph John [2], G.D. Harish [3], S.M. Sultan [4], I. Jaisankar [5], K. Naveen [6], S.P. Ahlawat [7] & Manish Kanwat [8]

[1,7] Division of Plant Exploration and Germplasm Collection, ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR), Pusa Campus, New Delhi 110012, India.
[2] ICAR-NBPGR, Regional Station, Kerala Agricultural University P.O., Thrissur, Kerala 680656, India.
[3] ICAR-NBPGR, Regional Station, Umiam, Ri-Bhoi District, Meghalaya 793103, India.
[4] ICAR-NBPGR, Regional Station, Rangreth, Srinagar, Jammu & Kashmir 191007, India.
[5] ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman & Nicobar Islands 744101, India.
[6,8] Krishi Vigyan Kendra (ICAR), Hayuliang, Anjaw District, Arunachal Pradesh 792104, India
[1] k.pradheep@icar.gov.in (corresponding author), [2] joseph.k@icar.gov.in, [3] harish.gd@icar.gov.in, [4] sheikhmsultan@gmail.com, [5] ijaisankar@yahoo.com, [6] neveenkh@gmail.com, [7] sudhir.ahlawat@icar.gov.in, [8] kanwatmanish@gmail.com

Abstract: A field survey across various parts of India coupled with an analysis of the literature and an examination of herbarium specimens revealed the presence of four species of crop wild relatives that have not been reported from India, viz., *Dioscorea piscatorum* Prain & Burkill (from Little & Great Nicobar), *Fagopyrum gracilipes* (Hemsl.) Dammer ex Diels (from Arunachal Pradesh), *Rubus praecox* Bertol. (from Jammu & Kashmir), and *Ziziphus subquinquenervia* Miq. (from Great Nicobar). While *Rubus praecox* is naturalised in the Kashmir Valley, *Dioscorea piscatorum* and *Ziziphus subquinquenervia* were found truly wild, and *Fagopyrum gracilipes* occurs as a weed in buckwheat fields and orchards. *Ziziphus subquinquenervia* has been resurrected from the allied *Z. elegans* Wall. of peninsular Malaysia and Singapore owing to the distinct diagnostic characters. Their description, phenology, habitat, and other field observations have been highlighted here.

Keywords: Crop wild relatives, *Dioscorea piscatorum*, *Fagopyrum gracilipes*, India, new distribution, *Rubus praecox, Ziziphus subquinquenervia.*

During field surveys on plant genetic resources in various remote pockets of India in the past two years, the authors observed the natural distribution of a four species of crop wild relatives, viz., *Dioscorea piscatorum* Prain & Burkill, *Fagopyrum gracilipes* (Hemsl.) Dammer ex Diels, *Rubus praecox* Bertol. and *Ziziphus subquinquenervia* Miq., which have not been reported in Indian floras and allied literature (Kaul 1986; Naithani 1990; Bhandari & Bhansali 2000; Khuroo et al. 2007; Chowdhery et al. 2008; Pradheep et al. 2014; Murugan et al. 2016; Dash & Singh 2017). These plants were studied critically in their natural habitat as well as in the herbaria of London (BM), Edinburgh (E), Kew (K), Leiden (L), Paris (P), and Beijing (PE) including the type specimens and verified with all possible online sources. Germplasm collections of *Dioscorea piscatorum* and *Fagopyrum gracilipes* are being conserved at ICAR-National Bureau of Plant Genetic Resources (ICAR-NBPGR), Thrissur/New Delhi, while herbarium vouchers of all the species are deposited in the National Herbarium of Cultivated Plants (NHCP)

DOI: https://doi.org/10.11609/jott.4133.11.3.13406-13414

Editor: B. Ravi Prasad Rao, Sri Krishnadevaraya University, Ananthapuramu, India. **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4133 | Received 14 March 2018 | Final received 05 December 2018 | Finally accepted 02 January 2019

Citation: Pradheep, K., K.J. John, G.D. Harish, S.M. Sultan, I. Jaisankar, K. Naveen, S.P. Ahlawat & M. Kanwat (2019). New distribution records of four species of crop wild relatives to India. *Journal of Threatened Taxa* 11(3): 13406–13414; https://doi.org/10.11609/jott.4133.11.3.13406-13414

Funding: ICAR-National Bureau of Plant Genetic Resources, New Delhi.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors acknowledge the Director, ICAR-NBPGR, for his guidance and support. Also the authors acknowledge the authorities of the forest department at Port Blair for the permission granted for exploration and germplasm collection from Great Nicobar Biosphere Reserve, Andaman & Nicobar Islands.

at ICAR-NBPGR, New Delhi. Distribution-related studies in crop wild relatives not only help in understanding the ecogeography of the species in question, but also serve as a source of germplasm for crop improvement (Pradheep et al. 2011, 2017), which otherwise is to be introduced from adjoining countries under conditions involved in material transfer agreement.

1. *Dioscorea piscatorum* Prain & Burkill

Gard. Bull. Str. Settlem. 3: 123. 1924. H.N.Ridley, Fl. Mal. Penins. 4: 319. 1924. Van Steenis, Fl. Males. Ser. 1, 4: 310. 1951. *D. borneensis* R.Knuth in H.G.A.Engler (ed.), Pflanzen., IV, 43: 188. 1924. *D.* sp. Prain & Burkill, J. Roy. Asiat. Soc. Beng. 73: 186. 1904. H.N.Ridley, Mat. Fl. Mal. Penins., Monoc. 2: 84. 1907. [Dioscoreaceae]. (Fig. 1, Images 1 & 4).

Perennial climber. Tubers branched, robust, weigh 12–15 kg, conspicuously spiny throughout, arising from stem base just below soil surface and seated horizontally; juvenile tubers often emerge out of soil, skin brownish-yellow with short fleshy roots, which later become indurated spines; older tubers' spines 2.5–3.0 cm long, skin dark brown, flesh diluted red, fibrous, venenose. Arial parts glabrous; stem 10m or more tall, c. 1cm diameter at base with flat triangular brown prickles (0.6cm wide at base) arranged uninterruptedly in four or five longitudinal rows which get scattered upwards; young twigs twining to left, less prickly. Leaves alternate, glabrous, chartaceous, deeply broad-cordate, conspicuously large, 16–20 x 20–24 cm, basal sinus 1.5–-2 cm deep, nerves nine, abaxially elevated, transverse nervules prominent and numerous; young leaves cordate-acuminate, hairy beneath along nerves which disappear later; petioles 10–13 cm long with scattered small prickles on the back.

Distribution & Habitat: Indonesia (Sumatra,

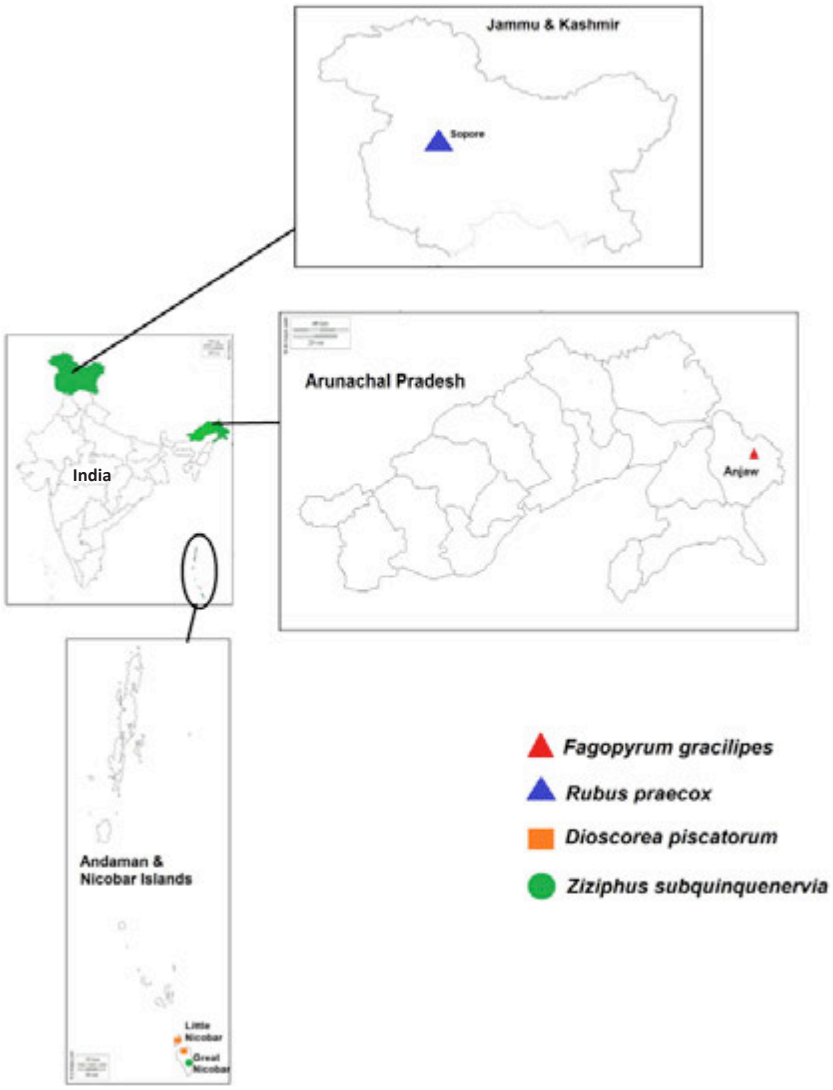


Figure 1. Distribution of *Dioscorea piscatorum*, *Fagopyrum gracilipes*, *Rubus praecox*, and *Ziziphus subquinquenervia* in India

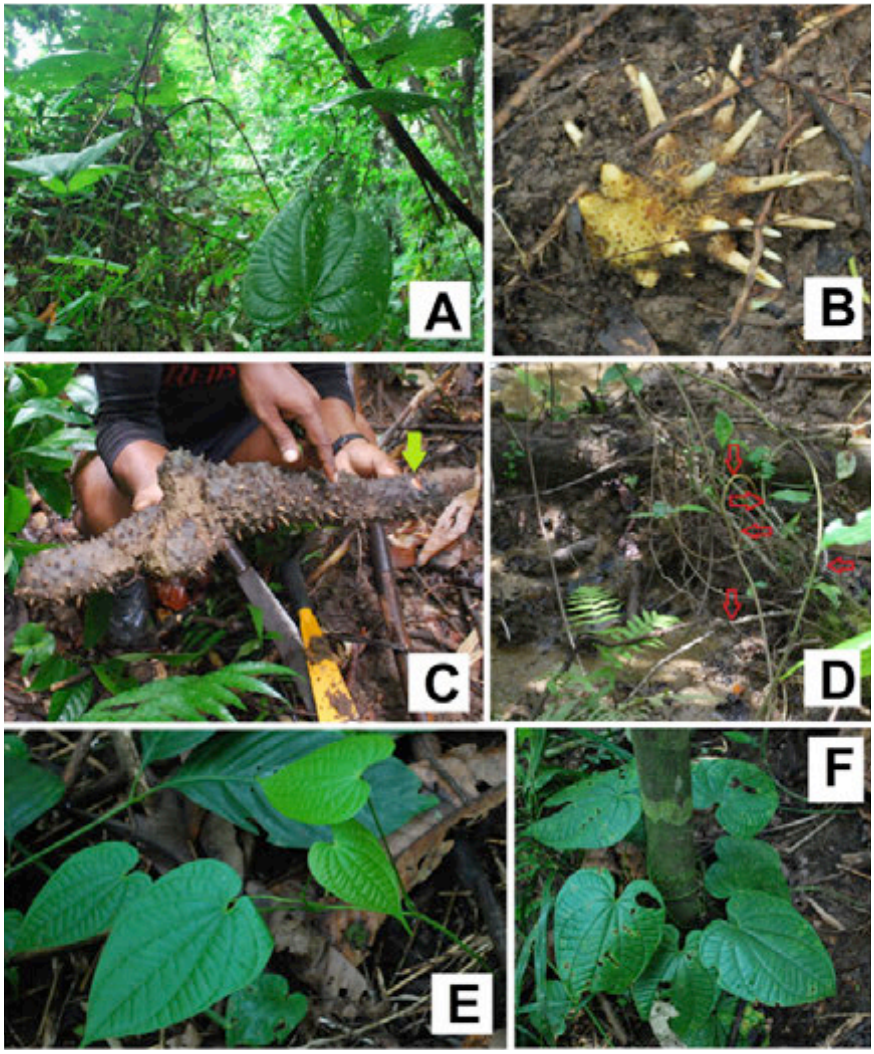


Image 1. ***Dioscorea piscatorum*****: A - Habit in forest; B - Young tuber; C - Aged tuber with spines (arrow mark showing diluted red flesh); D - Basal stems (marked) and their swampy habitat; E - Young plant; F - Grown-up plant. © K. Pradheep**

Kalimantan), Malaysia (Peninsular Malaysia, Sabah, Sarawak), India (Little & Great Nicobar in Andaman & Nicobar Islands). Lowland forest, near *Areca*/*Myristica* swamps, 10–50 m.

Specimen examined: 2751, 22.i.2018, Pulopanja, Little Nicobar, Andaman & Nicobar Islands, 7.35^{0}N & 93.74^{0}E, 48m, coll. K. Pradheep, K. Joseph John & I. Jaisankar [NHCP23104]; live collections JPJ/18-70 & JPJ/18-72 conserved at Field Genebank of ICAR-NBPGR, Regional Station, Thrissur.

Notes: Along with three other species (*D. flabellifolia* Prain & Burkill, *D. kjellbergii* R.Knuth, and *D. petelotii* Prain & Burkill), this typical spiny yam was grouped in sect. *Paramecocarpa* Prain & Burkill which accommodates species with left twining stem, pedicelled flowers with tepals borne on a broadened infundibular torus, longer capsules and winged seeds. Discovery of its occurrence in Little & Great Nicobar led to the finding of range extension for the section as well, which is otherwise restricted from Indochina to Palau Islands. Authors could only find about 20 plants of this curious species in two localities in Little Nicobar—Pulopanja (15 plants; 4 in wild, remaining under semi-cultivation) and Pulobhao (3 in wild); and one locality in Great Nicobar—Afra Bay (2 in wild). In wild, it co-occurs with *Dinochloa nicobariana* R.B.Majumdar, *Aglaonema simplex* Blume, *Horsfieldia glabra* (Blume) Warb., *Korthalsia* spp., *Cinnamomum bejolghota* (Buch.-Ham.) Sweet, *Chydenanthus excelsus* Miers, and *Alocasia macrorrhizos* (L.) G.Don. Recently, authors further observed its distribution from Katchal and Teressa islands in central Nicobar.

Roots arising on the surface of the tuber get modified as broad-based sharp spines; thus wears armour against predating wild boars. Known in English as ‘Fish-poison yam’, Nicobarees call it ‘okavu’, and excavate the young tubers from the wild for edible use. The flesh colour

of young tubers is creamy yellow when cut; thereafter turns pinkish-red. The de-skinned tubers are first cut into small pieces and boiled in water twice or three times and drained to remove bitter/poisonous substances, then consumed with fish or roasted. During monsoon, it forms an important article of food owing to disruptive transport and food supply system in Little Nicobar. Nicobarees protect this species in the wild and cultivate it in their cleared uplands. They dig up small pits in the cleared uplands, and put pieces of matured tuber as planting material and cover with soil. Burkill (1935) also mentioned its edible use after roasting by the Sahai in Malaya. Tubers are variously called and used across the regions of distribution – 'tuba ubi' in Sumatra (Indonesia) and peninsular Malaysia, and used as a piscicide; 'tuba gunjo' by Bataks of Tapanuli (Indonesia), and used as biopesticide against rice pests; 'tubah podeh gantung' in Borneo (PlantUse English contributors 2016).

2. *Fagopyrum gracilipes* (Hemsl.) Dammer ex Diels

Bot. Jahrb. Syst. 29: 315. 1900. Li Anjen & Suk-pyo Hong, Fl. China 5: 322. 2003. *Polygonum gracilipes* Hemsl., J. Linn. Soc., Bot. 26: 340. 1891. [Polygonaceae]. (Fig. 1, Images 2 & 5).

Herbs annual, with or without pigmentation. Stems sprawling or erect, 25–45 cm tall, branched profusely at base, striate, sparsely short-strigose. Leaves petiolate, petiole 0.7–1.1 cm, short-strigose; leaf blade ovate-triangular, 2.4–3.3 × 1.8–2.5 cm, sparsely short-strigose adaxially and abaxially, cordate to hastate at base, long-acuminate at apex; ochrea 4.5–5 mm, membranous, pubescent. Inflorescence axillary, racemose, long-interrupted, suberect, very lax, slender, peduncles 3–5 cm long; bracts green or pale pink, funnel-shaped, each 2- or 3-flowered; flowers white or pale pink, 3mm across. Pedicels longer than bracts, slender. Perianth pinkish, tepals elliptic, unequal, c. 2mm. Stamens included. Stigmas capitate. Achenes exceeding persistent perianth, greyish, shiny, sticky, broadly ovoid, ca. 3mm, sharply trigonous.

Flowering & Fruiting: June–October & July–Nov.

Distribution & Habitat: China (southern Gansu,

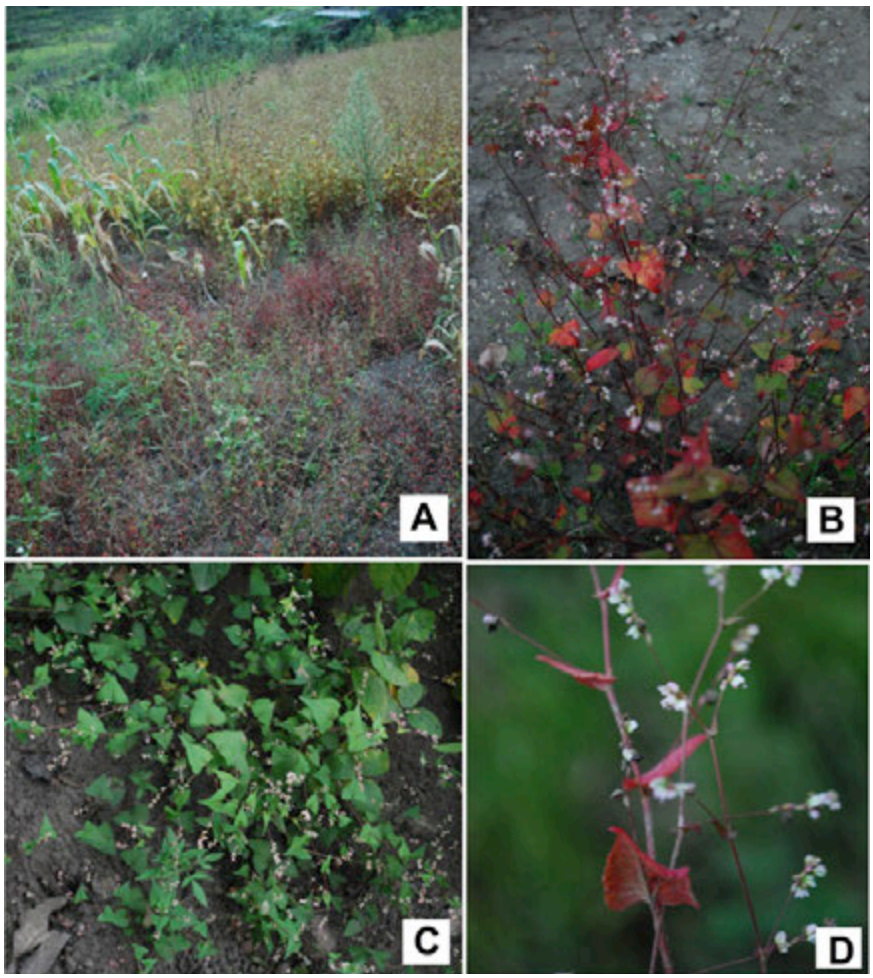


Image 2. *Fagopyrum gracilipes*: A - As weed in a buckwheat field at Sapkum village; B - Population with pigmented plants; C - Population with unpigmented plants; D - Close-up of flowering shoot. © K. Pradheep

Guizhou, Henan, Hubei, Shaanxi, Sichuan, Xizang (Tsuji et al. 1999), Yunnan); Bhutan (Ohnishi 1992; Parker 1992); India (Arunachal Pradesh (now)). Found as a locally abundant weed in upland fields of buckwheat crops and orchards from 1100–1500 m. Its weediness, aided through sticky nature of seeds, might have contributed to the fast dispersal adjacent to its native range.

Specimen examined: 2366, 22.x.2016, Sapkum, Anjaw District, Arunachal Pradesh, India, 28.16^{0}N & 97.04^{0}E, 1,187m, coll. K. Pradheep, G.D. Harish & K. Naveen [NHCP22855]; live collection PHN-2320 (IC622179) conserved at National Genebank of ICAR-NBPGR, New Delhi.

Notes: At Sapkum, it is known as 'therthek', and the local tribals informed that they use its leaves as vegetable. Further they informed that it is quite common in other villages of the Walong block, which lies adjacent to China (Tibet)/Myanmar border. We found both the pigmented and non pigmented plant forms co-occurring in the same field. This species is reported to be a homostylous, tetraploid, self-fertilizing with 2n=4x=32 (Yang et al. 2010). It is closely related to the diploid outcrossing species *F. capillatum* Ohnishi, and only distantly related to the cultivated species, *F. esculentum* Moench and *F. tataricum* (L.) Gaertn.

3. *Rubus praecox* Bertol.

Fl. ital. [Bertolini] 5: 220. 1842. Weihe ex H. G. L. Reichenbach, Fl. Germ. Excurs. 2: 600. 1832. *R. procerus* P.J.Müll. ex Boulay, Ronces vosg. 1: 7. 1864. *R. macrostemon* Focke, Syn. Rub. Germ. 193. 1877. *R. anglocandicans* A.Newton, Watsonia 11(3): 243. 1977. [Rosaceae]. (Fig. 1, Images 3 A,B & 6).

Robust semievergreen straggler, 3–4 m tall, with long arching stems up to 6m long. Stems biennial, twings c. 1cm in diameter, angled, channelled, glabrescent to glabrous, prickles curved, retrorse, moderately dense. Leaves alternate, 7–13 x 8–15 cm, leaflets five in primocanes, and 3(-5) in floricanes, ± elliptic, apex acute to short acuminate, terminal leaflet larger, 6–7 x 5–5.5 cm, adaxially green, smooth, abaxially grey-green, woolly beneath with hooked prickles on the largest vein, margin coarsely serrate-laciniate; petiole 5cm long, stipules linear, c. 7mm long. Infructescence terminal, sometimes also axillary, medium-sized, more compact, 5–10 fruited, densely hairy, prickles almost curved. Fruits black, smooth, globose to subcyclindric, 1–1.5 cm, drupelets 15–20, strongly coherent, separating with the torus attached.

Flowering & Fruiting: Flowering during April-May, fruiting during July–August.

Distribution & Habitat: Native to Europe (Ukraine, Austria, Belgium, Germany, Hungary, The Netherlands, Switzerland, Bulgaria, Italy, Romania, France, Portugal, and Spain) (USDA, Agricultural Research Service, National Plant Germplasm System 2018), naturalised and became serious weed in Australia (Evans & Weber 2003), Chile (Rejmánek 2015), Luxembourg (Helminger 2009), and Oregon (USA) (Bruckart et al. 2017); India (Jammu & Kashmir (Kashmir Valley)). Its actual distribution was marred by misidentification and lumping with the closely related species. It was found occasionally in roadside thickets from Bandipora to Kupwara with another *Rubus* species, *R. ulmifolius* Schott.

Specimen examined: 2598, 16.vii.2017, Sopore, Baramulla district, Jammu & Kashmir, India, 34.29^{0}N & 74.46^{0}E, 1,580m, coll. K. Pradheep & Sheikh M. Sultan [NHCP23028].

Notes: Although popularly known as 'Himalayan giant blackberry' or 'Himalayan blackberry', there is no evidence to show that this clonal species is native to the Himalayan region. *Rubus praecox* is very closely related to or often confused or lumped with *R. armeniacus* Focke; however notably different by the smaller terminal leaflet and petals, narrow-elliptic to elliptic leaflets (vs larger, broad-elliptic to rotund), mostly with curved prickles (vs. mostly with straight) in inflorescence axis, and moderate sized more compact inflorescence (vs large and loose) (Trávníček & Zázvorka 2005; Bruckart et al. 2017). The authors observed moderate laciniations in leaf margin in the Kashmir-naturalised species, while *R. armeniacus* has only serrulate to double serrate leaf margin. Ahmad et al. (2016) listed *R. armeniacus* in Kandi Forest Range in the Kamraj Forest Division of Kashmir, without any herbarium details.

Rubus discolor Weihe & Nees (kept under *R. fruticosus* L. by J.D. Hooker in Fl. Brit. India 2: 337. 1878), is currently recognised as the synonym of *R. ulmifolius*; the latter is a predominant weedy species occurring throughout the Kashmir Valley and flowers from June to September. *Rubus praecox* is easily distinguished from it by the absence of a pruinose stem, stems with large thorns, 5-leaflets in primocanes (vs. mostly 3) and whitish petal colour (vs. pink). Both the species are kept under sect. *Rubus*, which comprises closely allied blackberry (*R. fruticosus* L. agg.), hence useful in crop improvement programmes.

4. *Ziziphus subquinquenervia* Miq.

Fl. Ind. Bat., Suppl. 330. 1861. *Z. elegans* auct. non Wall.: King p.p. in J. Roy. Asiat. Soc. Beng. 65(3): 374. 1896. [Rhamnaceae]. (Fig. 1, Images 3 C,D,E & 7).

Scandent armed shrub, up to 5m tall. Main branches yellowish-brown; young twigs slender, softly brown tomentose, later becoming ashy nigrescent. Leaves bifarious, subcoriaceous, broad ovate, 6.8–7.3 x 4.1–-4.3 cm, apiculate, base oblique, sub-cordate, margin serrulate-crenulate, upper surface glabrous, lower surface brown-pubescent, especially along nerves; main longitudinal nerves three, running through central areas, leaving large width between lateral nerves and margin; lateral nerves 5(–7), prominent, arcuate, almost reaching the margin, the lower one originates at the point of origin of main nerves; petioles brown-tomentose, 0.5–0.6 cm long. Fruits pedicel brown-tomentose, 3.0–3.5 mm long, arising from subsessile peduncle (c.2 mm long); drupe obovoid, not compressed, 9.5–11 x 8.3–9.2 mm, base with conspicuous calyx ring scar, dark red upon ripening, endocarp leathery, pulp very thin, whitish; pyrene ovoid, c. 8.5 x 7.5 mm, reddish-brown.

Flowering & Fruiting: Flowering from October–December, fruiting from December–February.

Distribution: Indonesia (Sumatra), India (Great Nicobar).

Specimen examined: 2750, 19.i.2018, 13km from Campbell Bay in East-West Road, Great Nicobar, Andaman & Nicobar Islands, India, 6.99^{0}N & 93.86^{0}E, 133m, coll. K. Pradheep, K. Joseph John & I. Jaisankar [NHCP23103].

Notes: Dagar & Singh (1999) in their enumeration of the plant wealth of the Andaman & Nicobar Islands mentioned its occurrence in Central Nicobar Islands, without any herbarium details. We found only five plants (4-adult, 1-juvenile) of this extremely rare species within a four kilometer-stretch in the East-West Road connecting Campbell Bay to Koppenheat. Commonly associated species include *Piper miniatum* Blume, *Ziziphus horsfiedii* Miq., *Fagraea racemosa* Jack, *Alocasia macrorrhizos* (L.) G.Don, and *Amischotolype* sp.

Earlier, this Sumatran species was placed under the peninsular Malayan species *Z. elegans* Wall. by King (1896), since then it was left unnoticed in literature during the 20th Century (e.g., Laumonier 1997), probably because the treatment of the family Rhamnaceae in the Flora Malesiana is yet to be published. Our specimen exactly matches the type specimen (U0005768) of

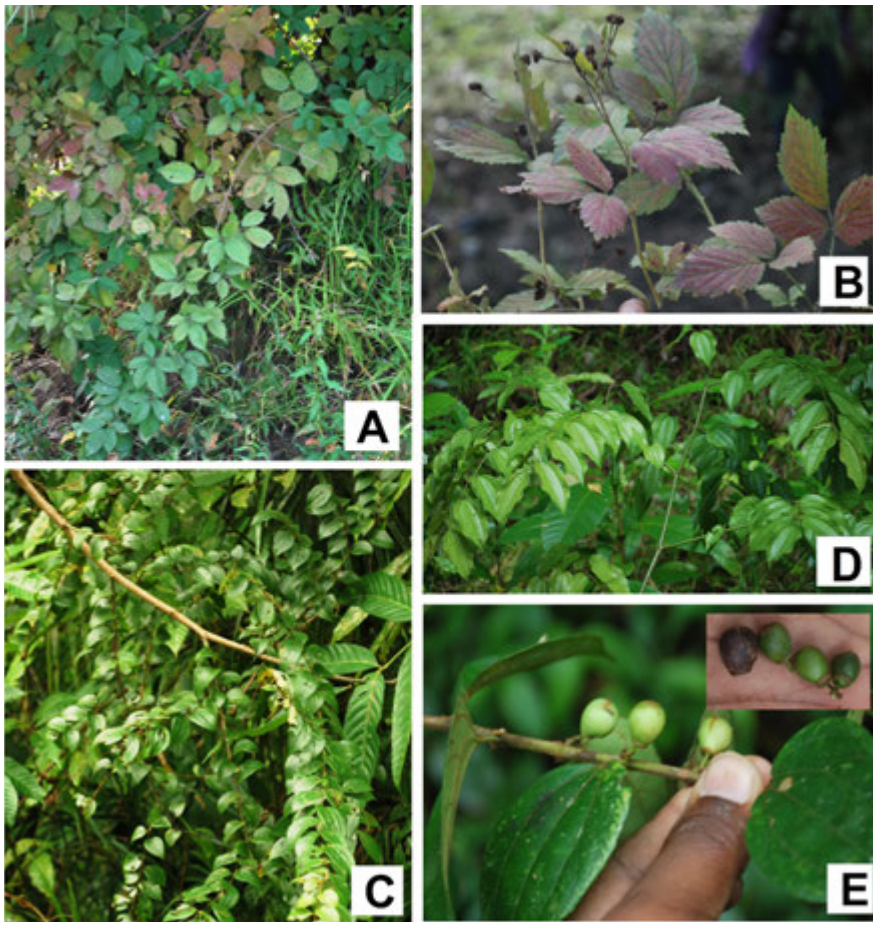


Image 3. *Rubus praecox*
A - Habit; B - Floricane shoot.
Ziziphus subquinquenervia
C - Habit; D - Young sapling; E - Twig with fruit (inset: unripe and ripe fruits).
© K. Pradheep

Table 1. Comparative morphological traits of two allied *Ziziphus* species from Southeast Asia

	Characters	*Z. subquinquenervia*	*Z. elegans*
1.	Twig nature	Armed with small recurved spines in almost every node	Nearly unarmed
2.	Leaf shape	(Broad-)ovate	Lanceolate
3.	Leaf apex	Apiculate	Long tail-like tip (retuse)
4.	Leaf longitudinal (main) nerves	Running through central areas	Distanced equally between and from margin
5.	Leaf transverse nerves (from lateral longitudinal nerves)	Prominent, 5–7 in number	Insignificant
6.	Drupe nature	Obovoid, not compressed	Sub-globular, compressed

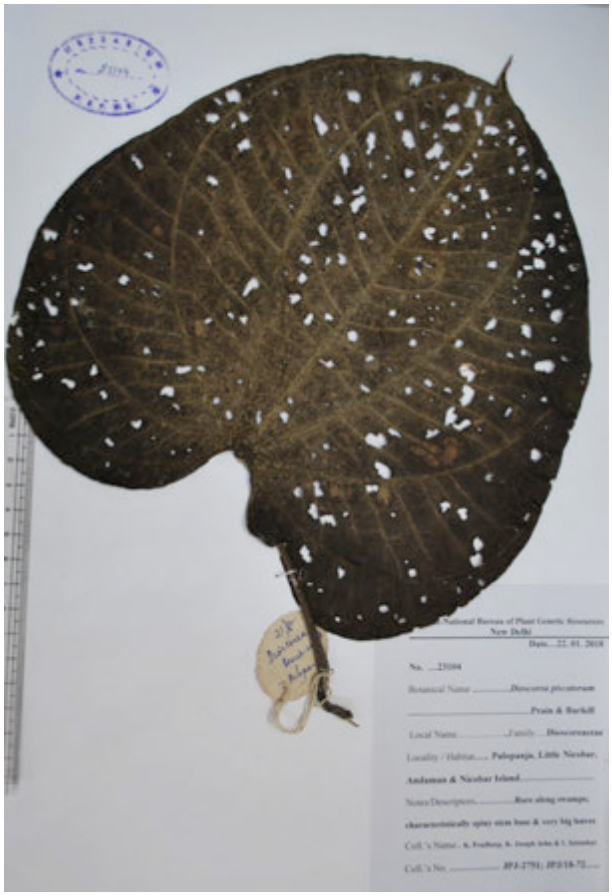


Image 4. Herbarium of *Dioscorea piscatorum* deposited in NHCP, New Delhi. © NHCP, ICAR-NBPGR

Image 5. Herbarium of *Fagopyrum gracilipes* deposited in NHCP, New Delhi. © NHCP, ICAR-NBPGR

Z. subquinquenervia housed at Leiden Herbarium (Naturalis Biodiversity Center 2018). This good species is resurrected here, based on the characters that distinguish it from *Z. elegans* (Table 1). King (1896) mentioned that the cyme of *Z. elegans* was dichotomous in nature, with 20–30 flowers. Although authors have not noticed inflorescence, examination of infructescence indicated simple axillary cyme with a possibility of not more than 4 or 5 flowers. Global Biodiversity Information Facility (GBIF Secretariat 2018) has many specimens kept under *Z. elegans*, of which only two (P06791814, P06791813; both from the Paris herbarium) are identical with the type [*Wallich* Cat. No. 4233 (K001038450) at Kew], while others represent different species.

Image 6. Herbarium of *Rubus praecox* deposited in NHCP, New Delhi. © NHCP, ICAR-NBPGR

Image 7. Herbarium of *Ziziphus subquinquenervia* deposited in NHCP, New Delhi. © NHCP, ICAR-NBPGR

References

Ahmad, H., T.H. Masoodi, S. Shahnaz & P.A. Sofi (2016). Altitudinal variation in community structure of Kandi forest range in north western Himalayas of Kashmir. *The Ecoscan* 10(1&2): 139–148.

Bhandari, M.M & R K. Bhansali (2000). Rhamnaceae, pp. 163–245. In: Singh, N.P., J.N. Vohra, P.K. Hajra & D.K. Singh (eds.). *Flora of India, Vol. 5*. Botanical Survey of India, Kolkata, India, 577pp.

Bruckart, W.L., J.L. Michael, M. Sochor, & B. Trávníček (2017). Invasive blackberry species in Oregon: Their identity and susceptibility to rust disease and the implications for biological control. *Invasive Plant Science and Management* 10(2): 143–154.

Burkill, I.H. (1935). *A Dictionary of Economic Products of Malay Peninsula, Vol. 1*. Crown Agents, London, 818–821pp.

Chowdhery, H.J., G.S. Giri, G.D. Pal, A. Pramanik & S.K. Das (2008). *Materials for the Flora of Arunachal Pradesh. Vol. 2 (Asteraceae-Ceratophyllaceae)*. Botanical Survey of India, Kolkata, 306–318pp.

Dagar, J.C. & N.T. Singh (1999). *Plant Resources of the Andaman and Nicobar Islands*, *Vol. 2*. Bishen Singh Mahendra Pal Singh, Dehradun, 755pp.

Dash, S.S & P. Singh (2017). *Flora of Kurung Kumey District, Arunachal Pradesh*. Botanical Survey of India, Kolkata, 782pp.

Evans, K.J. & H.E. Weber (2003). *Rubus anglocandicans* (Rosaceae) is the most widespread taxon of European blackberry in Australia. *Australian Systematic Botany* 16: 527–537.

GBIF Secretariat (2018). *Ziziphus elegans* Wall. In: GBIF Backbone Taxonomy. Electronic version accessed on 10 March 2018; https://www.gbif.org/occurrence/gallery?taxon_key=3876578

Helminger, T. (2009). Checklist of the brambles (*Rubus* L. subgenus *Rubus*, Rosaceae) of Luxembourg. *Bulletin de la Société des naturalistes luxembourgeois* 110: 53–68.

Kaul, M.K. (1986). *Weed Flora of Kashmir Valley*. Scientific Publishers, Jodhpur, 422pp.

Khuroo, A.A., I. Rashid, Z. Reshi, G.H. Dar, & B.A. Wafai (2007). The alien flora of Kashmir Himalaya. *Biological Invasions* 9(3): 269–292.

King, G. (1896). Materials for a flora of the Malayan Peninsula. *Journal of Royal Asiatic Society of Bengal* 65(3): 339–516.

Laumonier, Y. (1997). *The Vegetation and Physiography of Sumatra*. Kluver Academic Press, Dordrecht, The Netherlands, 225pp.

Murugan, C., S. Prabhu, R. Sathiyaseelan & R.P. Pandey (2016). *A Checklist of Plants of Andaman and Nicobar Islands*. (Edited by P. Singh & W. Arisdason). ENVIS Centre on Floral Diversity, Botanical Survey of India, Howrah. Published on the Internet. accessed on 13th March 2018; https://www.bsienvis.nic.in/database/Checklist-of-Nicobar-islands24427.aspx

Naithani, H.B. (1990). *Flowering Plants of India*, *Nepal and Bhutan*: *not Recorded in Sir JD Hooker's Flora of British India*. Surya Publications, Dehradun, 711pp.

Naturalis Biodiversity Center (2018). *Ziziphus subquinquenervia***.** In: BioPortal, Naturalis Biodiversity Center, Leiden, The Netherlands. Electronic version accessed 5 March 2018; https://data.biodiversitydata.nl/naturalis/specimen/U%20%200005786

Ohnishi, O. (1992). Buckwheat in Bhutan. *Fagopyrum* 12: 5–13.

Parker, C. (1992). *Weeds of Bhutan*. National Plant Protection Centre, Dept. of Agriculture, Bhutan, 236pp.

PlantUse English Contributors (2016). *Dioscorea piscatorum*. In:

PlantUse English, Plant Resources of South-East Asia (PROSEA), 7 April 2016, 15:27 UTC. Electronic version accessed 5 March 2018; https://uses.plantnet-project.org/e/index.php?title=Dioscorea_piscatorum_(PROSEA)&oldid=219012

Pradheep, K., A. Pandey & D.C. Bhandari (2011). Notes on naturalized taxa of plant genetic resource value in Himachal Pradesh. *Indian Journal of Plant Genetic Resources* 24(1): 74–80.

Pradheep, K., D.C. Bhandari & K.C. Bansal (2014). *Wild Relatives of Cultivated Plants in India*. Indian Council of Agricultural Research, New Delhi, 728pp.

Pradheep, K., R.S. Rathi, K.J. John, S.M. Sultan, B. Abraham, A. Pandey, E.R. Nayar, S.P. Ahlawat & R. Gupta (2017). New distributional records of some crop wild relatives to Indian states. *Journal of Threatened Taxa* 9(5): 10223–10228; https://doi.org/10.11609/jott.2930.9.5.10223-10228

Rejmánek, M. (2015). Invasion of *Rubus praecox* (Rosaceae) is promoted by the native tree *Aristotelia chilensis* (Elaeocarpaceae) due to seed dispersal facilitation. *Gayana Botanica* 72(1): 27–33.

Trávníček B. & J. Zázvorka (2005). Taxonomy of *Rubus* ser. *Discolores* in the Czech Republic and adjacent regions. *Preslia Praha* 77: 1–88.

Tsuji, K., Y. Yasui & O. Ohnishi (1999). Search for *Fagopyrum* species in eastern Tibet *Fagopyrum* 16: 1–6.

USDA, Agricultural Research Service, National Plant Germplasm System (2018). *Rubus praecox* Bertol. Germplasm Resources Information Network (GRIN-Taxonomy). National Germplasm Resources Laboratory, Beltsville, Maryland. Electronic version accessed 5 March 2018; https://npgsweb.ars-grin.gov/gringlobal/taxonomydetail.aspx?id=315364

Yang, X.-Y., Z.-F. Wu, H. Chen, J. Shao & Q. Wu (2010). Karyotype and genetic relationship based on RAPD markers of six wild buckwheat species (*Fagopyrum* spp.) from southwest of China. *Genetic Resources and Crop Evolution* 57: 649–656.

ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

PLATINUM OPEN ACCESS

Animal-fungal interactions 3: first report of mycophagy by the African Brush-tailed Porcupine *Atherurus africanus* Gray, 1842 (Mammalia: Rodentia: Hystricidae)

Todd F. Elliott [1], Camille Truong [2], Olivier Séné [3] & Terry W. Henkel [4]

[1] Ecosystem Management, University of New England, Armidale, NSW 2351, Australia.
[2] Instituto de Biología, Universidad Nacional Autónoma de México (UNAM), Tercer Circuito s/n, Ciudad Universitaria, Delegación Coyoacán, C.P. 04510, Mexico City, Mexico.
[3] USDA, US Forest Service International Program, Cameroon Program, S/C UICN-CP, BP 5506 Yaoundé, Cameroon.
[4] Department of Biological Sciences, Humboldt State University, 95521, Arcata, California, USA.
[1] toddfelliott@gmail.com (corresponding author), [2] camille.truong@ib.unam.mx, [3] olivier_sene@yahoo.fr, [4] terry.henkel@humboldt.edu

Mycophagy is a widespread phenomenon across many groups of mammals, birds, and reptiles around the world (Fogel & Trappe 1978; Claridge & May 1994; Cooper & Vernes 2011; Elliott & Vernes 2019). The behaviour is well-documented in some groups of animals while largely overlooked in others. The African continent has an incredible diversity of mammals; however, the majority have not been studied to determine if fungi are an important part of their diets. Most reports of mycophagy in Africa are of primates (Bermejo et al. 1994; Isbell 1998; Fossey 2000; Hanson et al. 2003; Isbell & Young 2007; Georgiev et al. 2011). There are scattered reports of mycophagy by non-primate vertebrates in Africa including six species of the African tortoise genus *Kinixys* (Hailey et al. 1997), the Suni *Neotragus moschatus* (Heinichen 1972), the Bushbuck *Tragelaphus scriptus* (Odendaal 1977, 1983), and Brown Hyaena *Hyaena brunnea* (Mills 1978). Since many of the fungi that are consumed by animals are mycorrhizal, the dispersal of spores assists with overall forest health and symbiotic colonization of plant roots (Cázares & Trappe 1994; Colgan & Claridge 2002; Caldwell et al. 2005; Trappe & Claridge 2005; Elliott et al. 2018). Fungi are typically very nutritious, making them important to many animals diets (Vogt et al. 1981; Cork & Kenagy 1989; Hussain & Al-Ruqaie 1999; Claridge & Trappe 2005; Kalač 2009; Wallis et al. 2012).

The African continent has more than 2,000 described macrofungi and is estimated to have twice that many undescribed species (Schmit & Mueller 2007). Given the prevalence of mycophagy in other regions of the world and the high diversity of African animals and fungi, it is very likely that similar relationships evolved, but were not studied. In this paper, we provide the first report of mycophagy by the African Brush-tailed Porcupine *Atherurus africanus*.

In September 2014, while conducting mycologic studies of ectomycorrhizal fungi near the village of Somalomo, Cameroon (3.358^{0}N & 12.729^{0}W, 650m), we

DOI: https://doi.org/10.11609/jott.4584.11.3.13415-13418

Editor: Jamie R. Wood, Landcare Research, Canterbury, New Zealand **Date of publication:** 26 February 2019 (online & print)

Manuscript details: #4584 | Received 24 September 2018 | Final received 30 October 2018 | Finally accepted 18 February 2019

Citation: Elliott, T.F., C. Truong, O. Sene & T.W. Henkel (2018). Animal-fungal interactions 3: first report of mycophagy by the African Brush-tailed Porcupine *Atherurus africanus* Gray, 1842 (Mammalia: Rodentia: Hystricidae). *Journal of Threatened Taxa* 11(3): 13415–13418; https://doi.org/10.11609/jott.4584.11.3.13415-13418

Funding: Funding was provided to TWH by the National Geographic Society's Committee for Research and Exploration grant #923513 and National Science Foundation grant DEB-1556338, and to CT by the Basler Stiftung für Biologische Forschung. The School of Environmental and Rural Science at the University of New England provided facilities and an International Postgraduate Research Scholarship to TFE.

Competing interests: The authors declare no competing interests.

Acknowledgements: In Cameroon, the Ministry of Research and Scientific Innovation issued research permits and the Conservator of the Dja Biosphere Reserve, Mengamenya Goue Achille, gave us access to the research sites. We are particularly grateful to Alamane Gabriel (a.k.a. Sikiro), Abate Jackson, and Essambe Jean-Pierre for negotiating with local hunters to get access to the stomach samples of the porcupine. We are grateful to the Bob and Babs Strickland of Walnut Creek Preserve for allowing the use of their photomicroscopy lab.

found that villagers were conducting some trapping in the area outside of the Dja Biosphere Reserve. We expressed interest to local hunters to have access to samples of stomach contents of any animals that they might have already killed. We were provided with the stomach contents of an African Brush-tailed Porcupine (Image 1A). The hunter asked to remain anonymous.

When the stomach contents were first examined macroscopically, we observed what appeared to be numerous pieces of the exterior of the hypogeous fungus genus *Elaphomyces* Nees (Eurotiales, Ascomycota). The stomach contents were stored in alcohol and were thoroughly mixed; four slide mounts were then made in water and examined with a Zeiss light microscope at 400x and 1000x magnification. Visual scanning of the stomach contents showed high densities of fungal spores (approximately 60–80 % of visible material). Spores were globose, dark brown between 35–40 µm in diameter (including ornamentation), with prominent, reticulate-alveolate ornamentation up to 4.5µm tall (Image 1C,D). These spores matched the species *Elaphomyces favosus* Castellano & T.W. Henkel that was first collected and described approximately 5km away from where the porcupine was trapped (Image 1B; Castellano et al. 2016a). Image 1B shows collection: Henkel 9874 (YA, HSC G1175, OSC 149786, K(M) 200224); GenBank accession numbers: ITS KT694135; 28S KT694147 (see the full technical description of this collection and species, in Castellano et al. 2016b). We were unable to find any other spore types present in the sample.

This is the first report of mycophagy by an African Brush-tailed Porcupine and the first report of mycophagy of the genus *Elaphomyces* in Africa. The genus *Elaphomyces* is widely eaten by animals, ranging from rodents and wild boar to marsupials, but it was never reported as a food source in Africa (Boudier 1876; Fogel & Trappe 1978; Vogt et al. 1981; Genov 1982; Cork & Kenagy 1989; Vernes et al. 2001, 2004; Vernes & Poirier

Image 1. A - The trapped African Brush-tailed Porcupine *Atherurus africanus* from which we sampled the stomach contents for our study; B - Fruiting bodies of *Elaphomyces favosus* (collection number Henkel 9874) collected from near the locations where the porcupine was trapped. The spores of this collection match those found in the stomach contents, indicating that the porcupine was digging and eating this species; C - A microscope mount at 40x magnification of stomach contents showing the density of spores typically observed; D - A spore of *E. favosus* at 1000x magnification from the stomach sample of the porcupine. © Todd F. Elliott

2007; Nuske et al. 2017b). We provide evidence from one sample, but based on studies of mycophagy in other parts of the world (Fogel & Trappe 1978), this likely represents a common but understudied behaviour among many African mammals. To our knowledge, only three other studies from Africa reported sequestrate (truffle-like) fungi being consumed by mammals; two involved unidentified "truffle" species being eaten by Bonobos *Pan paniscus* (Bermejo et al. 1994; Georgiev et al. 2011), and one involved *Kalaharituber pfeilii* (published as *Terfezia pfeilii*) being eaten by Brown Hyaena *Hyaena brunnea* (Mills 1978). In native and non-native forest habitats across sub-Saharan Africa, at least 15 species of sequestrate fungi from nine families have been reported (Dissing & Lange 1962; Dring & Pegler 1978; Castellano et al. 2000, 2016a,b; Ferdman et al. 2005; Beenken et al. 2016). These fungi likely evolved associations with vertebrates to enhance their spore dispersal and, in turn, may be an important component of these animals' diets (Cázares & Trappe 1994; Beenken et al. 2016). Ori et al. (2018) found that Crested Porcupines *Hystrix cristata* ate the sequestrate fungus *Tuber aestivum* in Italy and that some spores germinated in the scats, indicating that the mycorrhizal fungal spores are viable after passage through porcupine digestive tracts. We suspect spores would be similarly viable after passage through *Atherurus africanus* digestive systems.

The ectomycorrhizal fungal genus *Elaphomyces* forms a mutualistic symbiosis with the roots of a broad range of angiosperm and gymnosperm hosts in temperate and tropical regions (Trappe et al. 2009; Castellano et al. 2011, 2012, 2018; Paz et al. 2017). In tropical Africa, *Elaphomyces* was found in association with the tropical ectomycorrhizal tree *Gilbertiodendron dewevrei* (Castellano et al. 2016a). Ectomycorrhizal fungi play critical roles in host plant nutrition by mobilizing essential nutrients to their hosts in exchange for a carbon source (Smith & Read 2008). Their roles in tree establishment and survival directly influence species composition and the dynamics of plant communities (Peay et al. 2008; Tedersoo et al. 2010). Ectomycorrhizal fungi in tropical regions are thought to facilitate monodominance of ectomycorrhizal trees in forest regions otherwise composed of a wide diversity of tree species, which could also be the case for *G. dewevrei* (Henkel 2003; Peh et al. 2011; Corrales et al. 2016). *Elaphomyces* species and similar sequestrate fungi rely primarily on animal consumption for dispersal, and these mycophagists (eaters of fungi) are therefore essential to the maintenance of this fungal diversity, plant-fungal relationships, and related functions in the ecosystem (Nuske et al. 2017a). Maintaining both mammal and fungal diversity may, therefore, be essential in the management and conservation of these forest ecosystems, and we urge for further studies on the importance of mycophagy in Africa.

References

Beenken, L., M.N. Sainge & A. Kocyan (2016). *Lactarius megalopterus*, a new angiocarpous species from a tropical rainforest in central Africa, shows adaptations to endozoochorous spore dispersal. *Mycological Progress* 15: 58; https://doi.org/10.1007/s11557-016-1198-4

Bermejo, M., G. Illera & J.S. Pí (1994). Animals and mushrooms consumed by bonobos (*Pan paniscus*): new records from Lilungu (Ikela), Zaire. *International Journal of Primatology* 15(6): 879–898; https://doi.org/10.1007/BF02736074

Boudier, M. (1876). Du Parasitisme Probable De Quelques Espèces Du Genre *Elaphomyces* Et De La Recherche De Ces Tubéracés. *Bulletin de la Société Botanique de France* 23(3): 115–119.

Caldwell, I. R., K. Vernes & F. Barlocher (2005). The northern flying squirrel (*Glaucomys sabrinus*) as a vector for inoculation of red spruce (*Picea rubens*) seedlings with ectomycorrhizal fungi. *Sydowia* 57(2): 166–178.

Castellano, M.A., A. Verbeken, R. Walleyn & D. Thoen (2000). Some new and interesting sequestrate *Basidiomycota* from African woodlands. *Karstenia* 40(1): 11–21.

Castellano, M.A., B. Dentinger, O. Séné, T.F. Elliott, C. Truong & T.W. Henkel (2016a). New species of *Elaphomyces* (Elaphomycetaceae, Eurotiales, Ascomycota) from tropical rainforests of Cameroon and Guyana. *IMA Fungus* 7(1): 59–73.

Castellano, M.A., J.M. Trappe & K. Vernes (2011). Australian species of *Elaphomyces* (Elaphomycetaceae, Eurotiales, Ascomycota). *Australian Systematic Botany* 24(1): 32–57; https://doi.org/10.1071/SB10012

Castellano, M.A., T.F. Elliott & J.M. Trappe (2018). Three new black *Elaphomyces* species (Elaphomycetaceae, Eurotiales, Ascomycota) from eastern North America with notes on selected European species. *Fungal Systematics and Evolution* 1(1): 1–12; https://doi.org/10.3114/fuse.2018.01.01

Castellano, M.A., T.F. Elliott, C. Truong, O. Séné, B. Dentinger, & T.W. Henkel (2016b). *Kombocles bakaiana* gen. sp. nov. (Boletaceae), a new sequestrate fungus from Cameroon. *IMA Fungus* 7(2): 239–245.

Castellano, M.A., T.W. Henkel, S.L. Miller, M.E. Smith & M.C. Aime (2012). New *Elaphomyces* species (Elaphomycetaceae, Eurotiales, Ascomycota) from Guyana. *Mycologia* 104(5): 1244–1249.

Cázares, E. & J.M. Trappe (1994). Spore dispersal of ectomycorrhizal fungi on a glacier forefront by mammal mycophagy. *Mycologia* 86(4): 507–510; https://doi.org/10.2307/3760743

Claridge, A.W. & J.M. Trappe (2005). Sporocarp mycophagy: nutritional, behavioral, evolutionary and physiological aspects, pp599–611. In: Dighton, J., J.F. White & P. Oudemans (eds.). *The Fungal Community — Its Organization and Role in the Ecosystem*. Taylor & Francis, Boca Raton, FL, USA, 936pp.

Claridge, A.W. & T.W. May (1994). Mycophagy among Australian mammals. *Austral Ecology* 19(3): 251–275; https://doi.org/10.1111/j.1442-9993.1994.tb00489.x

Colgan, W. III & A.W. Claridge (2002). Mycorrhizal effectiveness of Rhizopogon spores recovered from fecal pellets of small forest-dwelling mammals. *Mycological Research* 106(3): 314–320.

Cooper, T. & K. Vernes (2011). Mycophagy in the larger bodied skinks of the genera *Tiliqua* and *Egernia*: are there implications for ecosystem health? *Australian Zoologist* 35(3): 681–684; https://doi.org/10.7882/AZ.2011.020

Cork, S.J. & G.J. Kenagy (1989). Nutritional value of hypogeous fungus for a forest-dwelling ground squirrel. *Ecology* 70(3): 577–586; https://doi.org/10.2307/1940209

Corrales, A., S.A. Mangan, B.L. Turner & J.W. Dalling (2016). An ectomycorrhizal nitrogen economy facilitates monodominance in a neotropical forest. *Ecology Letters* 19(4): 383–392; https://doi.org/10.1111/ele.12570

Dissing, H. & M. Lange (1962). Gasteromycetes of Congo. *Bulletin de le Jardin Botanique de l'Etat* 32(4): 325–416; https://doi.org/10.2307/3667249

Dring, D.M. & D.N. Pegler (1978). New and noteworthy gasteroid relatives of the Agaricales from tropical Africa. *Kew Bulletin* 32(3): 563–569; https://doi.org/10.2307/4109660

Elliott, T.F., J.M. Trappe & A. Türkoğlu (2018). Animal-fungal interactions 2: first report of mycophagy by the Eastern European Hedgehog *Erinaceus concolor* Martin, 1837 (Mammalia: Eulipotyphla: Erinaceidae). *Journal of Threatened Taxa* 10(9): 12277–12279; https://doi.org/10.11609/jott.4350.10.9.12277-12279

Elliott, T.F. & K. Vernes (2019). Superb Lyrebird Mycophagy, Truffles, and Soil Disturbance. *IBIS* 161(1): 198–204; https://doi.org/10.1111/ibi.12644

Ferdman, Y., S. Aviram, R.B. Nurit, J.M. Trappe & V. Kagan-Zur (2005). Phylogenetic studies of *Terfezia pfeilii* and *Choiromyces echinulatus* (Pezizales) support new genera for southern African truffles: *Kalaharituber* and *Eremiomyces*. *Mycological Research* 109(2): 237–245; https://doi.org/10.1017/S0953756204001789

Fogel, R. & J.M. Trappe (1978). Fungus consumption (mycophagy) by small mammals. *Northwest Science* 52(1): 1–31.

Fossey, D. (2000). *Gorillas in the Mist*. Houghton Mifflin Harcourt, Boston, New York, 400pp.

Ganzhorn, J. & P.M. Kappeler (eds.) (1993). *Lemur Social Systems and their Ecological Basis*. Springer Science & Business Media, Plenum Press, New York, viii+274pp; https://doi.org/10.1007/978-1-4899-2412-4

Genov, P. (1982). Fructification of *Elaphomyces granulatus* Fr. are food for boars. *Acta Mycologica* 18(1): 123–125; https://doi.org/10.5586/am.1982.008

Georgiev, A.V., M.E. Thompson, A.L. Lokasola & R.W. Wrangham (2011). Seed predation by Bonobos (*Pan paniscus*) at Kokolopori, Democratic Republic of the Congo. *Primates* 52: 309; https://doi.org/10.1007/s10329-011-0256-4

Hailey, A., I.M. Coulson & R.L. Chidavaenzi (1997). Fungus eating by the African tortoise *Kinixys spekii*. *Journal of Tropical Ecology* 13(3): 469–474; https://doi.org/10.1017/S0266467400010634

Hanson, A.M., K.T. Hodge & L.M. Porter (2003). Mycophagy among primates. *Mycologist* 17(1): 6–10; https://doi.org/10.1017/S0269915X0300106X

Heinichen, I.G. (1972). Preliminary notes on the Suni, *Nesotragus moschatus* and Red Duiker, *Cephalophus natalensis*. *Zoologica Africana* 7(1): 157–165; https://doi.org/10.1080/00445096.1972.11447436

Henkel, T.W. (2003). Monodominance in the ectomycorrhizal *Dicymbe corymbosa* (Caesalpiniaceae) from Guyana. *Journal of Tropical Ecology* 19(4): 417–437; https://doi.org/10.1017/S0266467403003468

Hussain, G. & I.M. Al-Ruqaie (1999). Occurrence, chemical composition, and nutritional value of truffles: an overview. *Pakastan Journal of Biological Sciences* 2(2): 510–514.

Isbell, L.A. (1998). Diet for a small primate: insectivory and gummivory in the (large) patas monkey (*Erythrocebus patas pyrrhonotus*). *American Journal of Primatology* 45(4): 381–398; https://doi.org/10.1002/(SICI)1098-2345(1998)45:4%3C381::AID-AJP5%3E3.0.CO;2-S

Isbell, L.A. & T.P. Young (2007). Interspecific and temporal variation of ant species within *Acacia drepanolobium* ant domatia, a staple food of patas monkeys (*Erythrocebus patas*) in Laikipia, Kenya. *American Journal of Primatology* 69(12): 1387–1398; https://doi.org/10.1002/ajp.20444

Kalač, P. (2009). Chemical composition and nutritional value of European species of wild growing mushrooms: a review. *Food Chemistry* 113(1): 9–16; https://doi.org/10.1016/j.foodchem.2008.07.077

Mills, M.G.L. (1978). Foraging behaviour of the Brown Hyaena (*Hyaena brunnea* Thunberg, 1820) in the southern Kalahari. *Ethology* 48(2): 113–141; https://doi.org/10.1111/j.1439-0310.1978.tb00252.x

Nuske, S.J., K. Vernes, T.W. May, A.W. Claridge, B.C. Congdon, A. Krockenberger & S.E. Abell (2017a). Redundancy among mammalian fungal dispersers and the importance of declining specialists. *Fungal Ecology* 27(A): 1–13; https://doi.org/10.1016/j.funeco.2017.02.005

Nuske, S.J., K. Vernes, T.W. May, A.W. Claridge, B.C. Congdon, A. Krockenberger & S.E. Abell (2017b). Data on the fungal species consumed by mammal species in Australia. *Data in Brief* 12: 251–260; https://doi.org/10.1016/j.dib.2017.03.053

Odendaal, P.B. (1983). Feeding habits and nutrition of bushbuck in the Knysna forests during winter. *South African Journal of Wildlife Research* 13(2): 27–31.

Odendaal, P.B. (1977). Some aspects of the ecology of bushbuck (*Tragelaphus scriptus* Pallas, 1776) in the Southern Cape. MS in Forestry Dissertation. Stellenbosch University, Stellenbosch, 200pp.

Ori, F., J.M. Trappe, M. Leonardi, M. Iotti & G. Pacioni (2018). Crested porcupines (*Hystrix cristata*): mycophagist spore dispersers of the ectomycorrhizal truffle *Tuber aestivum*. *Mycorrhiza* 28(5–6): 561–565; https://doi.org/10.1007/s00572-018-0840-1

Paz, A., J.M. Bellanger, C. Lavoise, A. Molia, M. Ławrynowicz, E. Larsson, I.O. Ibarguren, M. Jeppson, T. Læssøe, M. Sauve, F. Richard & P.A. Moreau (2017). The genus *Elaphomyces* (Ascomycota, Eurotiales): a ribosomal DNA-based phylogeny and revised systematics of European 'deer truffles'. *Persoonia - Molecular Phylogeny and Evolution of Fungi* 38(1): 197–239; https://doi.org/10.3767/003158517X697309

Peay, K.G., P.G. Kennedy & T.D. Bruns (2008). Fungal community ecology: a hybrid beast with a molecular master. *Bioscience* 58(9): 799–810; https://doi.org/10.1641/B580907

Peh, K.S.H., B. Sonke, J. Lloyd, C.A. Quesada & S.L. Lewis (2011). Soil does not explain monodominance in a central African tropical forest. *PLoS One* 6(2): e16996; https://doi.org/10.1371/journal.pone.0016996

Read, D.J. & J. Perez-Moreno (2003). Mycorrhizas and nutrient cycling in ecosystems – a journey towards relevance? *New Phytologist* 157(3): 475–492; https://doi.org/10.1046/j.1469-8137.2003.00704.x

Schmit, J.P. & G.M. Mueller (2007). An estimate of the lower limit of global fungal diversity. *Biodiversity and Conservation* 16(1): 99–111; https://doi.org/10.1007/s10531-006-9129-3

Smith, S.E. & D.J. Read (2008). *Mycorrhizal Symbiosis*. 3rd Edition, Academic Press, London, 800pp.

Tedersoo, L., T.W. May & M.E. Smith (2010). Ectomycorrhizal lifestyle in fungi: global diversity, distribution, and evolution of phylogenetic lineages. *Mycorrhiza* 20(4): 217–263; https://doi.org/10.1007/s00572-009-0274-x

Trappe, J.M. & A.W. Claridge (2005). Hypogeous fungi: evolution of reproductive and dispersal strategies through interations with animals and plants, pp613–622. In: Dighton, J., J.F. White & P. Oudemans (eds.). *The Fungal Community - Its Organization and Role in the Ecosystem*. Taylor & Francis, Boca Raton, FL, USA, 936pp.

Trappe, J.M., R. Molina, D.L. Luoma, E. Cázares, D. Pilz, J.E. Smith, M.A. Castellano, S.L. Miller & M.J. Trappe (2009). Diversity, Ecology and Conservation of Truffle Fungi in Forests of the Pacific Northwest. USDA Forest Service. General Technical Report PNW-GTR-772. Pacific Northwest Research Station, Portland OR, USA, 195pp.

Vernes, K. & N. Poirier (2007). Use of a robin's nest as a cache site for truffles by a red squirrel. *Northeastern Naturalist* 14(1): 145–149; https://doi.org/10.1656/1092-6194(2007)14%5B145:UOARNA%5D2.0.CO;2

Vernes, K., M. Castellano & C.N. Johnson (2001). Effects of season and fire on the diversity of hypogeous fungi consumed by a tropical mycophagous marsupial. *Journal of Animal Ecology* 70(6): 945–954; https://doi.org/10.1046/j.0021-8790.2001.00564.x

Vernes, K., S. Blois & F. Bärlocher (2004). Seasonal and yearly changes in consumption of hypogeous fungi by northern flying squirrels and red squirrels in old-growth forest, New Brunswick. *Canadian Journal of Zoology* 82(1): 110–117; https://doi.org/10.1139/z03-224

Vogt, K.A., R.L. Edmonds & C.C. Grier (1981). Biomass and nutrient concentrations of sporocarps produced by mycorrhizal and decomposer fungi in *Abies amabilis* stands. *Oecologia* 50(2): 170–175; https://doi.org/10.1007/BF00348033

Wallis, I., A.W. Claridge & J.M. Trappe (2012). Nitrogen content, amino acid composition and digestibility of fungi from a nutritional perspective in animal mycophagy. *Fungal Biology* 116(5): 590–602; https://doi.org/10.1016/j.funbio.2012.02.007

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.10

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
No. 12, Thiruvannamalai Nagar, Saravanampatti - Kalapatti Road,
Saravanampatti, Coimbatore, Tamil Nadu 641035, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa

www.threatenedtaxa.org

PLATINUM OPEN ACCESS

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

February 2019 | Vol. 11 | No. 3 | Pages: 13251–13418
Date of Publication: 26 February 2019 (Online & Print)
DOI: 10.11609/jott.2019.11.3.13251-13418

Publisher & Host

WILD ZOOREACH Threatened Taxa

Partner

صندوق محمد بن زايد للمحافظة على الكائنات الحية
The Mohamed bin Zayed SPECIES CONSERVATION FUND

Member

FJN