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Caption: Cameroon Scaly-tail *Zenkerella insignis* shot at Omo Biosphere Reserve, Nigeria. © Dolapo Adejumo



A history of primatology in India (In memory of Professor Sheo Dan Singh)

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Abstract: India harbors a wide diversity of primates with 24 species that include lorises, macaques, langurs and gibbons. Systematic research on the primates in India started about 60 years ago. In order to develop a historical perspective, we recognize three broad phases of primate research: largely natural history and base line research, primarily behavioral ecology research, and increasingly question and hypothesis-driven research. We describe the old and the recent primate research in the country and suggest research areas for the future.

Keywords: Gibbon, Indian primates, langur, loris, macaque.

Editor: Anonymity requested.

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Author details: MEWA SINGH is a renowned wildlife biologist at University of Mysore with over 45 years of research experience on Indian wildlife, especially primates. His interests are ecology, animal behavior and conservation management. He has trained a generation of students who are now excelling in many institutions all over the world. MRIDULA SINGH is a PhD in animal behavior and teaches psychology at Maharaja's College, University of Mysore. She carried out a long-term field study on maternal parental investment patterns in relation to dominance hierarchy in Lion-tailed Macaques in the Anamalai Hills. H.N. KUMARA is principal scientist at Salim Ali Centre for Ornithology and Natural History. His research interests encompass a large variety of taxa and topics in ecology, behavior and conservation. He initiated the first long-term studies on the Nicobar Long-tailed Macaques. DILIP CHERTY is a senior biologist with Aaranyak and carries out conservation research and action for wildlife, especially primates, in northeastern India. He also trains people in ecological research through various workshops and training programs. SANTANU MAHATO is a researcher at the University of Mysore and will be starting long-term studies on primates in the Anamalai Hills soon.

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INTRODUCTION

India is home to at least 24 species of nonhuman primates that include two species of lorises, 10 species of langurs, 10 species of macaques, and two species of small apes, with several of them being threatened or vulnerable (Table 1) (Molur et al. 2003). Several species including the Slender Loris, Bonnet Macaque, and Assamese Macaque also have distinct subspecies making India very rich in primate taxa. Due to this diversity, research in primatology in India has made prominent strides. Although in the past, many researchers came to India from other countries and carried out pioneering studies on different primate taxa, most of the published research on Indian primates today is by Indian scientists, unlike in many other habitat countries. At a conference organized by the Association of Indian Primatologists, a group recently established by young primatology researchers, at Bengaluru in 2019, one of us (Mewa Singh) delivered the inaugural address on the development of primatology in India, and was surprised to know that many young scholars had not even heard the names of many of the pioneers. This fact motivated us to prepare this article so that the historical information is made available at one source before such valuable information becomes inaccessible or is forgotten. This will also provide a historical perspective for the development of primate research in India. Primates have been used in a wide variety of research in India. Classical paleontological and evolutionary studies have been carried out by S.R.K. Chopra and Ashok Sahni at Panjab University, Chandigarh. Research on primate physiology has been carried out by N.K. Lohia at University of Rajasthan, Jaipur, by N.R. Moudgal, M.R.N. Prasad, N. Ravindranath and Polani B. Sheshagiri at the Indian Institute of Science, Bengaluru, and by scientists at the National Institute for Research in Reproductive Health, Mumbai. At the Indian Institute of Science, Aditya Murthy studies neurophysiology of primates and Praveen Karanth works on primate taxonomy. In addition, primates have also been employed for biomedical research at the Central Drug Research Institute, Lucknow, National Institute of Nutrition, Hyderabad, National Institute of Virology, Pune, Post Graduate Institute of Medical Education and Research, Chandigarh, National Institute of Immunology, and All India Institute of Medical Sciences, New Delhi. In this article, however, we will focus only on research on primates in their natural habitats concerning ecology and behavior.

As it could probably be true for primatology globally, we recognize three phases of primatology research in

India to develop a historical perspective. These include: a largely, natural history and baseline research; primarily behavioral ecology research; and increasingly question and hypothesis driven research. It must, however, be made clear that these are not strictly discrete phases as all types of research have been carried out at all times, but it is only a working time frame to trace the research perspectives and developments. Further, since there has not been any institution in the country with the primary focus on primate research and conservation, most research has been individual initiatives scattered across different institutions. In this review, therefore, we will primarily refer to Ph.D. theses and only few references, and website(s) wherever available, of each researcher since the total number of references on Indian primates number in thousands. This will help readers to find other publications of the same researchers. To our knowledge, we have included all Ph.D. theses written on primates in India, either by an Indian or by foreign researchers. We clarify that this article is not a critical review of the contributions of Indian primatology, which remains another topic to work on, but a repository of information on the subject. It is, however, more than an annotated bibliography as the contributions of all the scientists are discussed briefly. A brief timeline of crucial developments in Indian primatology is illustrated in Figure 1.

A LARGEY NATURAL HISTORY AND BASELINE RESEARCH

Although a few short articles on Indian primates in their natural habitats were published earlier (McCann 1933; Nolte 1955), it was only in the late 1950s and early 1960s that systematic and relatively long-term studies were taken up. The main emphasis in those studies was on the natural history of the study species, and these descriptive studies provided a baseline for further research. The researchers, therefore, focused on the species rather than on specific research questions. The pioneers of that era are Charles H. Southwick, Phyllis Jay Dolhinow, Paul E. Simonds, Yukimaru Sugiyama, and Sheo Dan Singh.

Charles H. Southwick

Although short descriptions of the behavior of Rhesus Macaques and Hanuman Langurs were published before 1959 (McCann 1933; Nolte 1955), the first long-term field study on the distribution, population status, ecology and behavior was undertaken by Charles H. Southwick (<https://neurotree.org/neurotree/publications.php?p>

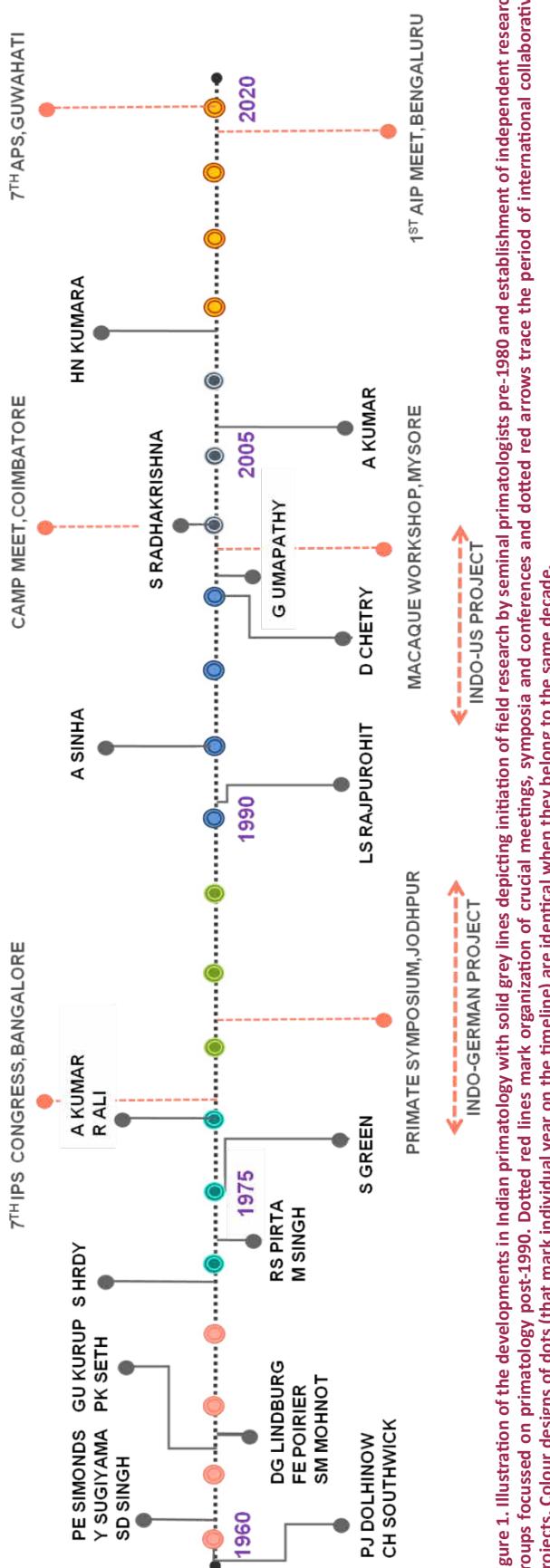


Figure 1. Illustration of the developments in Indian primatology with solid grey lines depicting initiation of field research by seminal primatologists pre-1980 and establishment of independent research groups focused on primatology post-1990. Dotted red lines mark organization of crucial meetings, symposia and conferences and dotted red arrows trace the period of international collaborative projects. Colour designs of dots (that mark individual year on the timeline) are identical when they belong to the same decade.

id=56382&searchstring=&showfilter=all). Southwick conducted his studies from 1959 to 60 in Uttar Pradesh and in 1962 in West Bengal. The results of the surveys conducted on the Rhesus Macaque populations in 280 villages, 30 towns, and 200 Hindu temples revealed that 16% villages, 69% towns and 6% Hindu temples had Rhesus Macaques (Southwick et al. 1961a), and 406, 37, 84 and seven groups of macaques were located along roadsides, canal banks, railroads, and forest areas, respectively (Southwick et al. 1961b). The first detailed study on the ecology and behavior of the Rhesus Macaque was published in 1965 (Southwick et al. 1965). The group size was 15.1 individuals with an average of 3.5, 6.9, 3.8, and 0.9 adult males, adult females, infants, and juveniles, respectively. The study found a clear inter-group and within-group hierarchy and peaceful to violent inter-individual relationships. This study also laid foundations for further research in ecology and behavior of Rhesus Macaques. Southwick maintained his research collaborations with Indian primatologists and continued to publish on population trends in Rhesus Macaques until 2001 (Malik et al. 1984; Southwick & Siddiqi 1966, 1977, 1988, 2001).

Phyllis Jay Dolhinow

Though there were reports about the taxonomy of Hanuman Langurs, the first comprehensive field study on the demography, ecology and behavior of this species was published in 1965 by Phyllis Jay (Jay 1965, later known as Dolhinow, P.J.). Jay conducted an 18-month field study between October 1958 and April 1960 at Orcha, a small village close to a forest in Madhya Pradesh, and Kaukori, a village among agricultural lands in Uttar Pradesh. The two habitats of langurs varied with respect to availability of forest, food items of langurs, human density and human interactions, interactions with other primates and forest dwelling mammals including predators. The groups were largely bisexual with 1.5 to 2 adult females per male, but there were also all-male groups. The groups remained relatively stable. Activity peaked during dawn and dusk. The home ranges of the groups averaged from 1 to 3 square miles. The social interactions were usually peaceful and relaxed. There were no overt dominance interactions and activities such as grooming could occur for over five hours per day. The infants and juveniles were found to undergo a fairly long process of socialization. Jay also provided a detailed ethogram of langurs describing a multitude of gestures and vocalizations used by various age-sex classes. Dolhinow also carried out a survey on Rhesus Macaques from 1964 to 1965 covering 9,510

Table 1. Primate species in India with their IUCN and Indian Wildlife (Protection) Act status.

	Common name	Species	Conservation status	
			IUCN	IW(P)A
Loris				
1	Slender Loris	<i>Loris lydekkerianus</i>	EN	I*
2	Slow Loris	<i>Nycticebus bengalensis</i>	EN	I
Langurs				
3	Himalayan Grey Langur	<i>Semnopithecus ajax</i>	EN	II
4	Bengal Hanuman Langur	<i>Semnopithecus entellus</i>	LC	II
5	Lesser Hill Langur	<i>Semnopithecus hector</i>	NT	II
6	Dark-legged Malabar Langur	<i>Semnopithecus hypoleucus</i>	LC	II
7	Coromandal Grey Langur	<i>Semnopithecus priam</i>	NT	II
8	Central Himalayan Langur	<i>Semnopithecus schistaceus</i>	LC	II
9	Nilgiri Langur	<i>Semnopithecus johnii</i>	VU	I
10	Capped Langur	<i>Trachypithecus pileatus</i>	VU	I
11	Golden Langur	<i>Trachypithecus geei</i>	EN	I
12	Phayre's Leaf Monkey	<i>Trachypithecus phayrei</i>	EN	I
Macques				
13	Rhesus Macaque	<i>Macaca mulatta</i>	LC	II
14	Assamese Macaque	<i>Macaca assamensis</i>	NT	II
15	Stump-tailed Macaque	<i>Macaca arctoides</i>	VU	II
16	Pig-tailed Macaque	<i>Macaca leonina</i>	VU	II
17	Arunachal Macaque	<i>Macaca munzala</i>	EN	Not listed
18	White-cheeked Macaque	<i>Macaca lueconensis</i>	Unknown	Not listed
19	Tibetan Macaque	<i>Macaca thibetana</i>	NT	Not listed
20	Lion-tailed Macaque	<i>Macaca silenus</i>	EN	I
21	Bonnet Macaque	<i>Macaca radiata</i>	VU	II
22	Nicobar Long-tailed Macaque	<i>Macaca fascicularis umbrosus</i>	VU	I
Gibbons				
23	Eastern Hoolock Gibbon	<i>Hoolock leuconedys</i>	VU	I
24	Western Hoolock Gibbon	<i>Hoolock hoolock</i>	EN	I

*Schedule types under IW(P)A. Lower schedule types have higher protection than higher schedule types.

kilometers in rural and forest areas, and found one group per 11.6km in forests and 32.8km in rural areas (Dolhinow & Lindburg 1978).

Paul E. Simonds

After a short-term study by Nolte (1955), the first detailed study on the behavior of Bonnet Macaques was published by Simonds (1965). Paul Simonds (<https://anthropology.uoregon.edu/profile/simonds/>) conducted his study on Bonnet Macaque between October 1961 and June 1962 on the Mysore-Ooty road near Bandipur forests. The group size of Bonnet Macaques varied from >10 to 40–60 individuals. Simonds described the macaques as gregarious and

spending much time in grooming and play. Hierarchies within the group were found to be subtle. Females indulged in promiscuous mating with extreme male tolerance. Groups had overlapping home ranges. Simonds later visited India in 1963, 1970, and 1975 for subsequent research. Simonds (1965) became a base line for subsequent studies on Bonnet Macaques.

Yukimaru Sugiyama

A contemporary of Phyllis Jay Dolhinow was Yukimaru Sugiyama (https://www.researchgate.net/profile/Yukimaru_Sugiyama) from Kyoto University, Kyoto who conducted studies on Hanuman Langurs and Bonnet Macaques in Dharwad from April 1961 to

April 1963. Dr. D. Miyadi, Kyoto University, Kyoto was the project director and the Indian collaborator was Dr. M.D. Parthasarathy from Central College, Bangalore. Sugiyama reported the social structure of one-male groups and instances of infanticide in Hanuman Langurs for the first time and proposed that such a pathological behavior could be due to high population densities, and could occur to induce estrus in females (Sugiyama 1964, 1965, 1966). The process involved ousting the dominant male and other males of a langur group by an outside male who took over the group, and the ousted males formed an all-male group. He also carried out short-term studies on Lion-tailed Macaques (Sugiyama 1968) and Bonnet Macaques (Sugiyama 1971) during the afore-mentioned period. Later, Sugiyama made several visits to India in 1972–73 to study Himalayan langurs (Sugiyama 1976) and Rhesus Macaques, and in 1976, 1978, and 1997 to study Hanuman Langurs (Sugiyama 1984).

Sheo Dan Singh

When these field studies were going on in the 1960s, there was also experimental work carried out on Rhesus Macaques at the Department of Psychology, Punjab University, Chandigarh by Sheo Dan Singh that resulted in some exceptional findings which unfortunately have not found much mention in later literature on Indian primates. Singh captured monkeys from urban and forest environments and studied behavioral differences between them under laboratory conditions. When presented with novel stimuli, the urban monkeys were far more active and manipulated presented objects more than the forest monkeys (Singh & Manocha 1966) and were more responsive to stimuli of higher complexity (Singh 1968). Urban monkeys were more aggressive than forest monkeys whereas forest monkeys groomed more often than urban monkeys (Singh 1969). The urban and forest monkeys, however, did not differ in their problem-solving capabilities (Singh 1969) indicating that whereas the selection pressures of an urban environment have shaped many new adaptive patterns in urban monkeys, the basic intelligence does not seem to be affected. S.D. Singh was invited to head the Psychology Department at the newly established university at Meerut in 1971. At Meerut, he continued laboratory experiments on Rhesus Macaques primarily on selective lobectomy and learning, and also started experimental studies on these macaques in their natural habitats in Siwalik Hills in the Asarori Range forests near Dehradun. The Rhesus Macaque infants were separated from their mothers shortly after birth and were reared in social isolation

and in peer-groups of six monkeys each. There were also mother-infant pairs in these experiments. The idea behind these experiments was to study the contribution of mothers, peers, and the group on the behavioral development of infant monkeys. Infants raised in peer groups when separated from others showed disturbed behaviors including 'protest' and 'despair' (Singh 1977). When these infants were exposed to strangers, they reacted aggressively just like the Rhesus Macaques in their natural groups (Singh 1980). S.D. Singh passed away on 26 June 1979 when he was less than 50 years old. The students trained by him continued their work and three of them, Waheeda Khan, Kiran Lata, and Suraj Bhan, submitted their theses under B.S. Gupta at Meerut. Waheeda Khan (Khan 1980) studied the effect of urban environment on social, emotional, and curiosity behaviors in Rhesus Macaques at different age levels. The urban monkeys were more aggressive whereas the forest monkeys were shy and timid. Urban monkeys also needed high levels of stimulation to satiate their curiosity. The same urban and forest monkeys were studied by Kiran Lata (Lata 1980) for development of cognitive behaviour. Environmental enrichment showed no effect on delayed response learning, object discrimination learning set, and oddity discrimination learning; however, the forest monkeys were slower to adapt to experimental situations than the urban monkeys. The above two studies were carried out in the Primate Laboratory at Meerut University. A field study carried out by Suraj Bhan (Bhan 1983) on the development of behaviour in Rhesus Macaque infants found developmental trends in play and social interactions at different age blocks, with male infants and juveniles being more playful than females. N.K. Chandel (Chandel 1981), though trained at Meerut, submitted his thesis at the University of Rajasthan, reported that patterns of affiliative behaviors in adult and adolescent Rhesus Macaques changed with age and mating season. Rajbir Singh (Singh 1981), who also went to Rajasthan from Meerut, reported that in free-ranging Rhesus Macaques, the social interactions among group members are not random but patterned by age, sex, and relative dominance in the social hierarchy.

Two other students of S.D. Singh, Raghbir Singh Pirta and Mewa Singh, made their careers in primatology and established many milestones in Indian primate research later. Pirta did his Ph.D. at Kashi Vidyapith University, his post-doctoral research at Utkal University, and later worked in Himachal Pradesh University till his retirement. Mewa Singh did his Ph.D. at the University of Mysore and continues to work there as Professor (for

Life) (The works of Pirta and Singh are discussed in later sections).

PRIMARILY BEHAVIORAL ECOLOGY RESEARCH

This was the phase when baseline data were available on some Indian primates and researchers could now look at the ecology and behavior of their study species in greater detail. The approach still was primarily species-oriented.

Donald G. Lindburg

D.G. Lindburg came to India to study Rhesus Macaques in 1964. Of the 21 months that the study lasted, the first nine months were devoted to a field survey on Rhesus Macaques under the leadership of Phyllis Jay Dolhinow and during the remaining 12 months, Lindburg carried out an ecological and behavioral study of Rhesus Macaque at Asarori Forest, Siwalik Hills, at the Forest Research Institute, near Dehradun (Lindburg 1971). Prior to this study, only a few experimental studies were carried out on the behavior of Rhesus Macaques by S.D. Singh (cited earlier) and Lindburg's was the first account of Rhesus Macaque behavior from its natural habitats. The Rhesus Macaque is the most widespread non-human primate from 20°E in Afghanistan to 120°E in China, and from 18°N in India to 40°N in China. The habitat occupied by the species included Sal *Shorea robusta* dominated deciduous forest and the area was heavily grazed by domestic buffaloes. The mean group size was about 32 though it varied significantly from one habitat type to another. The groups were bisexual with adult male to female ratio being about 1:3 and the reproductive rate was about 90%. The home range of a large group was approximated to 15km². The Rhesus Macaque is largely frugivorous but occasionally feeds on insects and grasshoppers. Lindburg also provided detailed information on intergroup interactions, social behavior, and social organization and his article became the general reference for later research on the ecology and behavior of Rhesus Macaques. Lindburg continued his association with Indian primatologists (Singh et al. 1999) and also carried out conservation breeding of Lion-tailed Macaques at San Diego Zoo, San Diego, USA.

Frank E. Poirier

Frank E. Poirier (<https://anthropology.osu.edu/people/poirier.1>) studied Nilgiri Langurs in the Nilgiri Hills between September 1965 and August 1966. This was the time when base line studies were already published

on many Indian primates, and Poirier advanced the research to finer details of ecology and behavior. He published several articles in various journals from 1966 to 1970 but a detailed single report on the Nilgiri Langur was published in 1970 (Poirier 1970). The Nilgiri Langurs are distributed in the southern Indian states of Kerala, Tamil Nadu, and Karnataka. The home ranges of Nilgiri Langur groups overlapped with Bonnet and Lion-tailed macaques and occasionally with Hanuman Langurs, and varied from ¼ to 1 square mile. The average group size was 8–9 individuals in bisexual groups, and solitary and uni-sex male groups were also observed. The main food of Nilgiri Langurs were leaves, flowers, buds, seeds, and bark or stem. Poirier also reported other behaviors including social communication, dominance hierarchies, grooming, and play in detail. This report, therefore, provided an excellent background for analytical studies later.

Suraj Mal Mohnot

Though there were a few Indian primatologists including M.A. Beg, M.R. Siddiqi, M.D. Parthsarathy, and H. Rahman who carried out field work with the previously-mentioned foreign scientists, the first independent field study in India was undertaken by S.M. Mohnot at Jodhpur University. Mohnot started studying Hanuman Langurs near Jodhpur in 1965, obtained his Ph.D. in 1974 and became a faculty member at the Department of Zoology at Jodhpur University. In the years since then, Mohnot has carried out many long-term studies on primates, guided several Ph.D. students, hosted many foreign scholars, and made Indian primatology known to the world over. The duo of Roonwal and Mohnot also published the first comprehensive book on primates of South Asia (Roonwal & Mohnot 1977). The langur population near Jodhpur is unique in many ways, it is an isolated population since hundreds of years with no distribution of any other primates up to at least a hundred kilometers. The rocky and open nature of the region allows close day-long observations throughout the year (Mohnot 1984). The basic social system, social changes, and infant-killing were reported in the Jodhpur langurs (Mohnot 1971; Makwana 1979a). (More details on Mohnot's work will come later along with his students and collaborators).

Steven Green, Karen Minkowski, John F. Oates, Rauf Ali, and Jayashree Ratnam

Steven Green and Karen Minkowski (http://www.momentum2.miami.edu/donors_steven_green.html) from Rockefeller University collaborated with the

Bombay Natural History Society to carry out a long field study lasting 19 months from September 1973 to April 1975 on the Lion-tailed Macaque at Ashambu Hills in Tamil Nadu. Except for a short term study by Sugiyama (1968) and Karr (1973), nothing was published about the ecology and behavior of Lion-tailed Macaques till 1977 (Green & Minkowski 1977). Surveys by Green & Minkowski revealed that there were about 405 Lion-tailed Macaques in the wild in the states of Karnataka, Tamil Nadu, and Kerala. The Lion-tailed Macaque is an obligate rainforest dweller and primarily arboreal. The average group size is about 15 individuals. Sexual maturity in females is attained at about five years of age and very few infants are produced by a female in her lifetime. The primarily fruit diet of the species is supplemented with insects. Green & Minkowski also initiated long-term conservation plans for the endangered Lion-tailed Macaque. Green offered a post-doctoral fellowship to John F. Oates (<https://anthropology.commons.gc.cuny.edu/john-f-oates/>) to continue research on the Lion-tailed Macaques. The conservation initiatives taken up by Green & Oates finally resulted in a large area in Kalakad-Mundanthurai being maintained as a reserve primarily for the Lion-tailed Macaques (Sekhsaria 2015). Oates, however, shifted his focus to the Nilgiri Langur and commented on its geographical distribution and status (Oates 1979), and reported that most food items of the Nilgiri Langur had low fibre and condensed tannin content but the staple food items were highly digestible (Oates et al. 1980). As John Oates took over from Steven Green, Rauf Ali (<https://www.feralindia.org/user/78>) came to Kalakad-Mundanthurai to take over from John Oates. Ali was registered for Ph.D. at the University of Bristol With John Crook (Ali 1981) and reported for the first time that in the subspecies of Bonnet Macaques that he was studying at Agastyamalai, it was the females that emigrated and dispersed between the groups, a behavior not known in the other subspecies of the Bonnet Macaque or most other macaque species. Ali also observed that at the time of intergroup encounters, there was also heightened within-group aggression that he explained as the group males trying to prevent the females from crossing over to the opposite group. Years later, following Rauf Ali, Jayashree Ratnam (<https://www.ncbs.res.in/mscprogram/program-management>) arrived at the Mundanthurai forests to study Bonnet Macaques with a more pointed question about the foraging decisions in a social forager (Ratnam 2002). Ratnam analyzed foraging decisions in response to experimentally-induced variations in ecological and social variables. Social dominance determined which

individual fed at a given time, and social rank affected spatial distribution and the feeding rate of an individual.

Ajith Kumar

Ajith Kumar (<https://www.ncbs.res.in/mscprogram/program-management>) carried out a six-year-long study on the ecology and population dynamics of Lion-tailed Macaques in the Anamalai Hills and received his Ph.D. degree from University of Cambridge in 1987 (Kumar 1987). He examined variations in the demographic parameters and correlates of ecology and behavior. He reported delayed sexual maturity in females, long inter-birth intervals, low population turnovers but high infant survival rates. These macaques fed on fruits and insects. Larger groups had larger ranges than smaller groups. The low birth rate was explained to be due to high mating interference resulting in suppression of conception in many females. This study site in the Anamalai Hills became one of the most important centers for wildlife research in subsequent years.

INCREASINGLY QUESTION-ORIENTED AND HYPOTHESIS-DRIVEN RESEARCH

Although several researchers continued to focus on particular species, primate research, from the mid 1970s, became increasingly question-oriented and hypothesis-driven. Therefore, while discussing this phase of development of primatology research in India, we will not focus on the research by any individual but by several institutions where primate research was conducted or is still underway.

Jai Narayan Vyas University, Jodhpur

S.M. Mohnot (Mohnot 1974) established a major primate research program at Jodhpur where he trained a large number of Indian students and hosted several researchers from abroad. The unique Jodhpur population of Hanuman Langurs became a major focus of ecological research. Sarah Blaffer Hrdy (Hrdy 1975) (<http://www.citrona.com/hrdy>), a graduate student of Irvin DeVore and tutored by E.O. Wilson and Robert Trivers arrived in Jodhpur in 1971 and S.M. Mohnot advised her to study Hanuman Langurs at Mount Abu in Rajasthan. Infanticide in langurs, reported by Sugiyama and Mohnot, was just becoming a hot topic in primatology and it was generally being characterized as a 'social pathology' occurring primarily due to overcrowding. Hrdy observed many cases of usurping control of different groups of langurs and instances of infanticide. The females who lost infants

gave birth within 6–8 months after the death of their infants whereas the normal inter-birth interval was up to about 27 months. Infanticide could also occur in places where there was no overcrowding. Hrdy, therefore, proposed that infant killing was not a social pathology but a male reproductive strategy to garner reproductive access to females. In the years to come, sexual selection as an explanation for infanticide became the main focus of research on Hanuman Langurs. In 1977, the Indo-German project, conceptualized by Christian Vogel, was launched at Jodhpur to study interrelations between individual life-histories and troop histories (Vogel 1988). This project continued for many years and sponsored several German researchers who worked on Jodhpur langurs. These langurs feed on 35 species of plants, and a unique foraging ‘invention’ is feeding on the ‘waternut’ *Trapa natans* recently introduced to the region. The main food items of a large number of troops were *Prosopis juliflora* and the food provided by humans (Winkler 1981). The females reached menarche at the age of 29 months, cycled for 24 days, had gestation of about 200 days, and an inter-birth interval of 15.3 months. About 80% infants survived for six months but only 35.9% completed two years of life (Winkler et al. 1984). Volker Sommer (Sommer 1985) (<https://www.ucl.ac.uk/anthropology/people/academic-and-teaching-staff/volker-sommer>), a student of Christian Vogel at Gottingen, and hosted by S.M. Mohnot studied the Jodhpur langurs for his Ph.D. between October 1981 and December 1982, and again as a post-doctoral research fellow in 1986–1987. He witnessed and also inferred many cases of infanticide and discussed the male reproductive strategy with respect to three conditions, postulating that the infanticidal male is not the father of the killed infants, but actually sires the subsequent offspring, and infanticide shortens inter-birth interval, and found that these conditions were largely met (Sommer & Mohnot 1985).

Makwana (1979b) studied rhesus monkeys in Asarori, Siwaliks, and reported group size to vary from 6 to 90 with a male to female ratio of 1:2.7. Home range size varied with group size, and the daily range was about 1803 m. P.R. Ojha (Ojha 1979) observed that the tail carriage of the Rhesus Macaque alpha male with the basal half carried upright, distal part leaning forward and the tip forming a loop is unique and is not shown by any other member in the group. The upright posture is usually assumed in tense situations such as intergroup interactions or alarms. L.S. Rajpurohit (Rajpurohit 1987) (https://www.researchgate.net/profile/Lal_Rajpurohit2) reported that the ousted males did not achieve residency in

their natal groups and weaned sons follow their fathers after ousting. Emigrating males have a higher mortality than females resulting in female-biased sex ratios. G. Agoramoorthy (Agoramoorthy 1987) observed several cases of abortions in Hanuman Langurs happening probably due to stress after male take-over of a group and conjectured that an abortion may be a female reproductive strategy to avoid infanticide after the birth of the infant. Since the inter-birth interval in females whose infants were killed by the new males was shorter than other females, it appears that the male achieves higher reproductive success by infanticide. Hanuman Langurs are primarily folivorous but were also observed to spend considerable time feeding on insects, especially during the monsoon season, which supported the ‘energy/nutrient maximization’ hypothesis (Srivastava 1989). Carola Borries (Borries 1989) (<https://www.stonybrook.edu/commcms/anthropology/faculty-and-staff/borries.php>), a student of Christian Vogel, and hosted by S.M. Mohnot, studied competition in female langurs of Jodhpur from October 1984 to January 1986. She found that the young females occupied high ranks, and the hierarchical position of a female declined with age. Reproductive success was rank related that declined significantly from high, over middle, to low ranking females (Borries et al. 1991). In Kumbalgarh Wildlife Sanctuary, there were about 69% bisexual and about 31% all-male band groups of Hanuman Langurs, and their social organization was the same as in the Jodhpur langurs (Chhangani 2000) (https://mgsubikaner.ac.in/wp-content/uploads/2015/10/1396502908-2014Faculty_MemberDrAnilKumarChhangani.pdf). D.S. Rajpurohit (Rajpurohit 2005) determined dominance hierarchy and its role in social organization in Hanuman langurs, and G. Sharma (Sharma 2007) reported details of paternal care in these langurs. In 1994, S.M. Mohnot launched a mega research project (Indo-US Primate Project) for a period of five years, which was further extended by three years. Most of the research under this project was in northeastern India where Mohnot collaborated with P.C. Bhattachrjee at Gauhati University, Guwahati. Since most researchers were from the northeast, we will have a separate section for the research on northeastern Indian primates.

Hanuman Langurs being widespread have also been studied in different habitats in India. The Himalayas are a different ecological niche and the Himalayan Hanuman Langurs, though studied at different altitudes in Indian and Nepalese Himalayas, exhibit traits such as multi-male groups which are different from the langurs in the Indian plains that are largely uni-male (Bishop 1975).

Hanuman Langurs in Kanha Tiger Reserve are organized in mostly uni-male groups with an adult sex ratio of 1:7.9. In Kanha, an attack by a male band on the uni-male study group, resulting in killing of three infants, and the timing of takeover with respect to the birth season, supported the 'sexual selection' and not the 'social pathology' hypothesis (Newton 1984). At Morni Hill ranges of Siwalik Hills, 75% groups of Hanuman Langurs were uni-male with a sex ratio of 1:3.2, and these langurs shifted home ranges seasonally (Bala 2013). In Bidar District of Karnataka, there were 142, 55, and 28 uni-male, multi-male and all-male groups, respectively, with a total population of 6,384 individuals (Patil 2019). In the six study groups, the population size of 199 in 2012 increased to 270 in 2014.

University of Delhi and Vatavaran

Several studies were carried out on primates at the Department of Anthropology, University of Delhi by Praveen K. Seth. Though most of his work was on primate anatomy (which is beyond the scope of this article), Iqbal Malik (<http://www.vatavaran.org/>) and he carried out studies on population trends and behavior of Rhesus Macaques. The surveys conducted between 1975 and 1980 revealed that in several localities, the population of Rhesus Macaques increased by 66–79%, mainly due to human-provisioning (Seth & Seth 1983a; Malik et al. 1984). The populations, however, showed a declining trend in the later years (Malik 1989). Malik was also involved in translocations of urban Rhesus Macaques and found that most translocated monkeys appeared to exhibit normal behavior (Imam et al. 2000).

University of Mysore, Mysuru

Mewa Singh (<http://uni-mysore.ac.in/psychology/faculty/dr-mewa-singh>) started research on primates at the University of Mysore in 1975 and has studied Bonnet, Rhesus, Lion-tailed, and Long-tailed macaques, Hanuman and Nilgiri langurs, and Slender Loris. The group has carried out extensive studies on the ecology, behavior, and conservation management, both in situ and ex situ, on primates with over 150 publications (see <https://uni-mysore.ac.in/psychology/faculty/dr-mewa-singh>). Long-term field studies were initiated on Slender Loris (Singh et al. 1999, 2000; Kumara et al. 2006) and other primates (Kumara & Singh 2004) in various habitats. Population trends in Bonnet Macaques have been monitored in and around Mysuru for over 30 years showing a nearly 70% decline in the population (Erinjery et al. 2017a). Bonnet Macaques showed laterality in various activities as a division of labor

between the two hands (Mangalam et al. 2014, 2016). Sindhu Radhakrishna (Radhakrishna 2001) (<https://www.nias.res.in/professor/sindhu-radhakrishna>) carried out a 21-month-long study on the Slender Loris in the forests of Dindigul, Tamil Nadu. Most of the aggressive interactions among individuals were observed in the contexts of territorial defense and mating; individuals communicated through chemical and vocal signals, and immigrations were frequently seen in the study area (Radhakrishna & Singh 2002). Females were seen to be in estrus largely in October–December and births occurred in April–June; gestation lasted for 5.5 months and there was an inter-birth interval of seven months (Radhakrishna & Singh 2004). Anantha Krishna Sharma (Sharma 2002) (https://www.researchgate.net/profile/Ananthakrishna_Sharma) studied reproductive biology of the Lion-tailed Macaques in the Western Ghats and reported that there were two birth peaks in January to April and in September to December, which remained constant over the years and across forest fragments of different sizes (Sharma et al. 2006). In contrast, births in captive Lion-tailed Macaques occurred throughout the year. H.S. Sushma (Sushma 2004) (<https://www.sacon.in/adjunct-scientist/>) studied sympatric Lion-tailed Macaques, Nilgiri Langurs, Bonnet Macaques, and Indian Giant Squirrels and found that both macaque species had relatively narrow food niche breadth and high niche overlap resulting in co-occurrence of these species only in a few months of the year. On the other hand, Nilgiri Langurs had a low niche overlap with Lion-tailed Macaques and both langurs and squirrels had broad niches resulting in tolerance and co-occurrence of all three species (Sushma & Singh 2006). B.A. Krishna (Krishna 2007) studied maternal and parental investment patterns in Lion-tailed Macaques and observed that weaning occurs from five and a half months to about nine months of age of the infant (Krishna et al. 2008) and the weaning patterns indicated that the dominant females are positively biased towards their male offspring (Singh et al. 2007). Kuladeep Roy (Roy 2011) (https://www.researchgate.net/profile/Kuladeep_Roy) also studied sympatric primates in a different forest and found that though there was a high niche overlap between Lion-tailed and Bonnet macaques for about two months, it occurred at the time of resource abundance of the shared resources, and as a result, both of these macaques species and the Hanuman Langur which is a folivore, unlike frugivore macaques, could co-exist throughout the year (Singh & Roy 2011). Kavana T.S. (Kavana 2015) and Joseph J. Erinjery (Erinjery 2016) (https://www.researchgate.net/profile/Joseph_J_Erinjery)

Erinjery) studied individual differences indicating behavioral variability in macaques (Bonnet and Lion-tailed) and langurs (Nilgiri and Hanuman), respectively. Behavioral variability was higher in macaques than in langurs (Erinjery et al. 2017b). The ideal gas model approach showed that primates in the Western Ghats do not form active associations with each other (Erinjery et al. 2015). In context to langurs, Hanuman Langurs are more social than Nilgiri Langurs as the latter are more folivorous and require to spend much time in resting to digest leaves (Kavana et al. 2015). Prerna Singh (Singh 2017) observed abandonment of infants by Bonnet Macaque females after a group split, and reported that weaning may also occur without aggressive responses from mothers. Matthew Cooper from University of Georgia studied Assamese Macaques under the supervision of Irvin Bernstein in 1997–98 for his Ph.D. (Cooper 1998) and worked as a post doc in 1999–2001 at the University of Mysore on dominance style and relationship quality in Bonnet Macaques (Cooper et al. 2004a,b). Under the supervision of Clifford Jolly, Lisa Schlotterhausen (Schlotterhausen 2000) (<https://as.nyu.edu/departments/anthropology/graduate/alumni/doctoral-alumni/schlotterhausen-lisa.html>) from New York University, New York in affiliation with the University of Mysore reported that wild Bonnet Macaques moved and fed on more food items but engaged less in social activities than the commensal bonnets. Anna Nekaris (Nekaris 2000) (<https://www.brookes.ac.uk/templates/pages/staff.aspx?wid=&op=full&uid=p0029554>) from Washington University, Missouri under the supervision of David Tab Rasmussen, affiliated with the University of Mysore and observed that the Slender Loris was exclusively faunivorous feeding on insects and small vertebrates, and distributed their activity budget evenly between foraging and travelling. Cornelia Bertsch from Austria collaborated with the research group and studied Lion-tailed Macaques from 1998 to 2003 in the Anamalai Tiger Reserve.

National Institute of Advanced Studies, Bengaluru

At NIAS, primate research was initiated by Anindya Sinha (<https://www.nias.res.in/professor/anindya-sinha>) and joined later by Sindhu Radhakrishna. The group has been focusing on primate ecology, behavior, conservation, and cognition. After Simonds (1965), Sinha (2001) provided the first detailed description of distribution, ecology, and behavior of the Bonnet Macaque. Inarguably the best long-term field study on behavior of any primate species in India is Sinha's research on Bonnet Macaques in Bandipur National

Park, Karnataka, the study now covering a period of two decades. The Bonnet Macaques usually live in bisexual groups with each group having several adult males and adult females. Sinha, however, found that in Bandipur, 11 of the 21 groups of Bonnet Macaques were uni-male-multi-female groups (Sinha et al. 2005). The origin and evolution of this unique social organization in the Bonnet Macaque has been explained through a research-based model illustrating the following process (Sinha & Mukhopadhyay 2013). In deciduous forests, food becomes scarce and patchy in the dry season, and at the same time, tourists passing through the forest offer food which is rich and clumped. These two factors induce intense competition among females in a multi-female-multi-male group, leading to group fission, resulting in small groups of females. In such a situation, it becomes easier for a single male to monopolize reproduction, and consequently, the evolution of uni-male social organization takes place.

Sinha (Sinha et al. 2005) and his group also described a new macaque species, the Arunachal Macaque *Macaca munzala* from the forests of Arunachal Pradesh. Four students have carried out their Ph.D. research with Sinha. Rishi Kumar (Kumar 2012) (https://www.researchgate.net/profile/Rishi_Kumar24) reported the distribution, demography, and behavioral ecology of mixed groups of Bonnet and Rhesus macaques in peninsular India and observed that Rhesus Macaques were extending their range into the range of Bonnet Macaques, due perhaps to human intervention (Kumar et al. 2011, 2013). Mayukh Chatterjee (Chatterjee 2013) (<https://www.wti.org.in/members/mayukh-chatterjee/>) studied behavioral flexibility and social diversity in Bonnet Macaques with special reference to uni-male groups. Ecological differences can cause intra-specific and even intra-population differences in social systems which, in turn, produce flexibility and variability in behavioral strategies such as grooming and proximity. Narayan Sharma (Sharma 2013) (https://www.researchgate.net/profile/Narayan_Sharma3) studied effects of habitat fragmentation on primate populations in Upper Brahmaputra Valley where at least one species was lost in the last 30 years. Many, largely habitat specialist species, have shown decline in their populations whereas a more commensal and generalist Rhesus Macaque has become more abundant. Geographical distance, dissimilarity in spatial features and anthropogenic factors affected turnover in primate species composition. Shreejata Gupta (Gupta 2016) (https://www.researchgate.net/profile/Shreejata_Gupta2) found that Bonnet Macaques produce flexible and intentional gestures with context

variability. Gestures such as those used in play decrease with age and others such as those related to aggression and affiliation appear at the adult stage. Females had a higher repertoire of signals than males. Anindya Sinha also hosted Avanti Mallapur (<https://www.linkedin.com/in/avanti-mallapur-b9b2a615>), a Ph.D. student from the University of Edinburgh, Edinburgh (Mallapur 2005). Mallapur studied the effect of visitor presence on behavior of captive Lion-tailed Macaques and found that the visitor presence might adversely affect welfare of animals causing an increase in abnormal and other social behaviors (Mallapur et al. 2005).

Sindhu Radhakrishna joined NIAS in 2002 and continued surveys on lorises in northeastern India and Kerala. In Meghalaya, the Bengal Slow Loris was found in only two of the 16 sites surveyed and the habitat was found to be severely affected by anthropogenic activities (Radhakrishna et al. 2010). In Tripura, the encounter rate of the Slow Loris was 0.22 individuals (Swapna et al. 2008). The Slender Loris was found in 22 of the 36 forest ranges surveyed in Kerala with an abundance ranging from 0.02 to 1.44 individuals/km (Radhakrishna et al. 2011). She is also tracing human-monkey relationships in literature and folklore (Radhakrishna 2018). Asmita Sengupta (Sengupta 2015) (<https://www.atree.org/users/dr-asmita-sengupta>) studied seed dispersal as an ecosystem function by Rhesus Macaques in Buxa Tiger Reserve in 2012–2014. Macaques dispersed 84% of the 49 species they fed on. The macaque-handled seeds were largely deposited outside the tree canopy, were undamaged and had enhanced germination. Provisioning reduced the daily range of macaques and resulted in lesser seed dispersal than in unprovisioned macaque group. Shaurabh Anand (Anand 2019) (https://www.researchgate.net/profile/Shaurabh_Anand3) studied perceptions about human-Rhesus Macaque conflict in Himachal Pradesh. Whereas higher level forest officers proposed strict rules for management of negative interactions, the lower level officers agreed more with the farmers who actually suffered losses. Forest officers believed that sterilization and culling of monkeys were the effective interaction resolution measures, the farmers found these ineffective and against cultural and religious beliefs. Therefore, there appears to be higher human-human conflict than human-animal negative interactions (Anand & Radhakrishna 2020).

Northeastern India and Gauhati University

Northeastern India is an extremely rich region for primate diversity with 13 of the 27 Indian primate species including lorises, macaques, langurs, and small apes found

there. Until the early 1980s, virtually nothing was known about these primates in northeastern India. Anwaruddin Choudhury (Choudhury 1989) (https://en.wikipedia.org/wiki/Anwaruddin_Choudhury) was the first person to begin primate research in northeastern India in 1986 when he reported that the Pig-tailed and the Stump-tailed macaques were restricted by the Brahmaputra River towards west of their range. He also discovered a new population of macaques which he described as a subspecies of *Macaca thibetana* but the same has now been described as a new species with the name *Macaca munzala*.

In one of the earlier studies conducted in 1987–1991 on the Golden Langurs (Dutta 1992), it was found that they were confined to the northwestern belt of Assam. The group had 7–13 individuals and shifted the home range seasonally. They fed on flowers, blossoms, leaves and fruits of 34 plant species. Atul Kumar Gupta (Gupta 1997) (<http://tdu.edu.in/governance/akgupta/>) observed that due to continuing loss of forests, primate populations in northeastern Indian region were being adversely affected.

Although a few field studies were carried out in the 1980s and 90s, it was in 1994 that long-term studies on several primate species in northeastern India were initiated under the Indo-US Primate Project with S.M. Mohnot of J.N.V. University, Jodhpur and P.C. Bhattacharjee of Guwahati University as the principal investigators. Prabal Sarkar (Sarkar 2000) (<https://www.ustm.ac.in/zoology-list-of-faculties/dr-prabal-sarkar/>) reported that in Assamese Macaques, a provisioned group spent more time on clumped resources than forest groups. As a result, the provisioned monkeys were more aggressive towards each other, and to reduce tension, also indulged more in grooming than the forest monkeys. Jayanta Das (Das 2002) found Gibbons in three and five reserved forests in Silchar and Karimganj divisions respectively with a median group size of three. In Borajan where the forest damage was extensive, Gibbons were forced to move on ground to cross between food patches and they showed many vigilance behaviors while walking on open grounds. Dilip Chetry (Chetry 2002) (https://www.researchgate.net/profile/Dilip_Chetry2) recorded altitudinal distribution range of Stump-tailed Macaques from 50–1,300 m in northeastern India with group size ranging from 2–63 individuals. Home range size was 336–587 ha. These monkeys fed on 200 food plants. Stump-tailed Macaques are terrestrial and non-seasonal breeders. Habitat loss, fragmentation, jhum cultivation, and traditional hunting were determined as the major threats. Rekha

Medhi (Medhi 2004) (https://www.researchgate.net/profile/Rekha_Chetry) studied the behaviour of a semi-provisioned introduced troop of Golden Langur outside its distribution range. Grooming played an important role in maintaining inter-individual relationship. She also reported development of neonate, neonate behaviour, intra-troop social dynamics and development of inert individual relationships. Jihosuo Biswas (Biswas 2004) (https://www.researchgate.net/profile/Jihosuo_Biswas) found that in Golden Langurs, the home ranges of the two study groups were 25 and 58 ha. Home range size correlated with group size and there was an overlap between ranges of different groups. There was a bimodal feeding peak in the mornings and evenings. These langurs spent about 44.75% of their time resting, probably to digest leaves which are their primary food items ingested. Joydeep Bose (Bose 2005) reported that Phayre's Leaf Monkey is found only in southern Assam, Tripura, and Mizoram. The home range size correlated with group size and varied from 2.7 to 17.6 ha with a day range of 304 to 592 m. Time-activity budgets differed between groups in plantations and forests. Leaves (54%), followed by shoots (23.2%) and fruits, flowers, and seeds were ingested. Dhiraj Kumar Borah (Borah 2010) studied ecology and behavior of Capped Langurs and found that though the time-activity budgets did not differ, the home range was larger and the day time length of movement was smaller in the undisturbed habitat than in the disturbed habitat. Langurs spent most time resting, followed by feeding, and grooming was the predominant social activity. Nabajit Das (Das 2013) (https://www.researchgate.net/profile/Nabajit_Das) found Bengal Slow Loris in seven protected areas and two reserved forests in Assam with a density ranging from 2.78 to 9.21 animals/km². Loris spent 42.59% of their time resting, followed by 27.46% in locomotion, and 21.28% in feeding. They used 44 trees and 12 lianas and the food consisted of 80.93% plant exudates and only 2.32% animal matter. The average home range size was 15.60ha.

PRIMATE STUDIES FROM THE NORTH-EAST IN OTHER UNIVERSITIES

University of Cambridge

Kashmira Kakati (Kakati 2005) (https://www.researchgate.net/profile/Kashmira_Kakati/research) found that in Hoolock Gibbons, the encounter rates were 0.09 animal/km, 0.23 animal/km, and 0.58 animal/km in small (<5km²), medium (20–30 km²), and large

(>100km²) forest patches, respectively. Likewise, the group size was 2.5, 3.29, and 3.9 in small, medium, and large fragments. There were fewer young in small fragments than in medium and large fragments.

North Eastern Hill University, Shillong

G.S. Solanki (Solanki 1987) and Awadhesh Kumar (Kumar 2006) (<https://nerist.ac.in/forestry/faculties/awadhesh>) studied the behavior of Capped Langurs in Pakhui Wildlife Sanctuary in Arunachal Pradesh and found that the langurs spent 54% time resting and 36% in feeding. Age-sex classes did not differ in their time-activity budgets. Most activities occurred between the heights of 10 and 15m. Langurs fed on 52 plant species, mostly of the family Moraceae, and 68% of their diet comprised leaves. Hunting for meat was the major threat for these langurs.

Mizoram University, Aizawl

Zothansiama (Zothansiama 2013) (<https://mzu.edu.in/department-of-zoology/>) found that Stump-tailed Macaques were scarcely distributed to the south bank of Brahmaputra River. In a captive group of Stump-tailed Macaques, copulations in females correlated with sexual attractiveness indicated by the bright red genital skin color. Males often indulged in homosexual behavior perhaps to regulate aggression. The forest study group fed on fruits, leaves, shoots, and flowers of 36 plant species. Pallab Deb (Deb 2015) studied the Western Hoolock Gibbon in southern Assam and Mizoram and found 51 individuals in 16 family groups with a mean group size of 3.1. Tree density varied among different habitats. Gibbons used tree from 5 to 30 m, though most of their activities were between the heights of 6 and 25 m. They fed on fruits, flowers, leaves and petioles of 32 plant species. Most of the habitats of Gibbons were under anthropogenic pressures.

North Orissa University, Baripada

Raju Das (Das 2012) (https://www.researchgate.net/profile/Raju_Das2) found that in the Chirang Reserved Forest, Golden Langurs fed on 91 plant species of trees and climbers. The spectrum of food plant species in the diet of langurs appeared to be determined by the floristic composition of the habitat.

Assam University, Silchar

Mofidul Islam (Islam 2015) (https://www.researchgate.net/profile/Mofidul_Islam) studied Hoolock Gibbons in the Inner-Line Reserved Forest in Assam and observed that gibbons mainly fed on *Ficus*,

Artocarpus, *Dysoxylum*, *Gmelina*, and *Syzygium*. Gibbon population positively correlated with canopy cover and tree density. The dramatically changing land cover due to reasons such as shifting cultivation is a major threat to the gibbons in the region.

North Eastern Regional Institute of Science and Technology, Nirjuli, India

Kuldip Sarma (Sarma 2015) studied the Eastern Hoolock Gibbon in Lower Dibang Valley and Lohit districts of Arunachal Pradesh and found 77 groups and three solitary individuals with a mean group size of 3.04. He estimated the presence of 6,953 groups of gibbons with 21,710 individuals in the state. Groups in protected forests had larger home ranges than in unprotected forests.

Tezpur University, Tezpur

Mrigankhi Borah (Borah 2016) found that Hoolock Gibbons in Hoolongapar fed on 54 plant species in which *Ailanthus*, *Ichnocarpus*, *Trichosanthes*, and *Ficus* were the most preferred species. Fruits comprised 51.14% of the diet. *Vatica lanceaefolia* and *Artocarpus chaplasha* grew and survived better in the gaps than in understory whereas *Artocarpus chaplasha* grew better in the understory.

SOME OTHER CENTERS OF PRIMATE RESEARCH

Salim Ali Center for Ornithology and Natural History, Coimbatore

Ajith Kumar initiated a study to explore the impact of habitat fragmentation on various taxa including primates. G. Umapathy (Umapathy 1998) (<https://www.ccmb.res.in/People/Research-Group/G-Umapathy>) found that in forest fragments, tree density and canopy height best predicted occurrence of primates, and it is suggested that arresting further degradation, and improving quality, of habitats along with retention of jackfruit orchards may help primate conservation in the fragmented landscape (Umapathy & Kumar 2000). An Indo-German Project funded by the Volkswagen Foundation with Werner Kaumanns from German Primate Centre, Gottingen and Ajith Kumar from SACON as Principal Investigators was launched to further study the effect of forest fragmentation. Though not based at SACON, the effect of forest fragmentation on the behavior of Lion-tailed Macaques was also studied by Shaily Menon (Menon 1993), a student of Frank Poirier from The Ohio State University. Menon

studied groups of Lion-tailed Macaques in 1989–91 in a degraded forest fragment near Valparai and in an undisturbed forest at Varagaliyar and reported that the monkeys in fragments spent more time in ranging than resting or feeding, and were more terrestrial than the macaques in undisturbed forest. R. Krishnamani (Krishnamani 2002) (https://www.researchgate.net/profile/Krishnamani_Ramanathan) reported that of the 190 woody plant species in the study area, Lion-tailed Macaques used 74 as food trees. The relative density of these species being 57.1% indicated that the habitats in Karnataka could support a good population of Lion-tailed Macaques. H.N. Kumara (<https://www.sacon.in/division/conservation-biology/#ffs-tabbed-12>) joined the institute in 2010 and continued studies on primates. Surveys were carried out on Lion-tailed Macaques, Nilgiri Langurs, and Slender Loris in the unexplored forests, and several conservation actions were initiated, resulting in the formation of Sharavathi Lion-tailed Macaque Wildlife Sanctuary. K. Santhosh (Santhosh 2017) (https://www.researchgate.net/profile/K_Santhosh2) reported that in the Lion-tailed Macaque in its northernmost population in the Western Ghats, the mean monthly day path length correlated positively with the number of fruiting trees, and tree density and fruit tree density also correlated positively with habitat use (Santhosh et al. 2015). Kumara initiated long-term studies on the Nicobar Long-tailed Macaque (NLTM). This island population surveyed earlier (Umapathy et al. 2003) suffered a heavy loss to the 2004 Indian Ocean tsunami, however, in the following decade or so, the population of these macaques has not only recovered but increased (Velankar et al. 2016). Arijit Pal (Pal 2018) (https://www.researchgate.net/profile/Arijit_Pal4) found that in NLTM, the number of births correlated with the monthly rainfall, and about 71% of the births occurred in the rainy season (Pal et al. 2018a). These macaques showed six extractive foraging behaviors, including some being tool-aided, and teeth flossing (Pal et al. 2018b). Partha Sarathi Mishra (Mishra 2020) (https://www.researchgate.net/profile/Partha_Mishra3) found reciprocity, though not equitable, in grooming among NLTM males, but no rank-related differentiation of affiliation, indicating lack of social bonds in this subspecies (Mishra et al. 2020a). Females directed grooming towards high ranking males, though dominance hierarchy was less steep than expected in *Macaca fascicularis* (Mishra et al. 2020b).

University of Rajasthan, Jaipur

It was found that multi-male Hanuman Langur groups split only after a takeover by a male from an all-

male band, and the split resulted in formation of two uni-male groups (Mathur & Manohar 1990). In another study, Mathur & Manohar (1992) demonstrated that population density and not habitat disturbance was correlated with takeover in Hanuman Langurs. Reena Mathur (https://www.researchgate.net/profile/Reena_Mathur2) at the University of Rajasthan also hosted Linda D. Wolfe who arrived from the USA in 1984 on an NSF grant and studied feeding ecology of Rhesus Macaques. The monkeys in a town group foraged more, moved less, engaged in fewer aggressive acts, and slept less during the day than the monkeys in a forest/temple complex (Wolfe 1992).

Himachal Pradesh University, Shimla

R.S. Pirta (https://www.researchgate.net/profile/Raghbir_Pirta) carried out his Ph.D. research at Kashi Vidyapith University, Varanasi where he studied cooperative behavior in Rhesus Macaques and reported that adult females were the main groomers, and grooming duration increased during the mating season; play was largely restricted to infants and juveniles (Pirta 1983). In cooperative attacks, adult females were help-givers in both forest and urban groups, though cooperative attacks were more among the latter (Pirta 1984). Human disturbance caused more detrimental effects on Hanuman Langurs who were largely restricted to broad-leaf forests than Rhesus Macaques who often visited towns too (Ross et al. 1993). Anita Chauhan (Chauhan 2009) (https://www.researchgate.net/profile/Anita_Chauhan5) reported that the Rhesus Macaques subsisting in temple areas interacted more aggressively with humans than the macaques in a marketplace and the Hanuman Langurs, due possibly to the heavy dependence of the temple macaques on human resources. Santosh Kumar Sahoo (Sahoo 1993) carried out a study from 1988 to 1991 in Shimla and found that the Rhesus Macaques engaged in agonistic interactions more than the Hanuman Langurs, and most of these agonistic interactions occurred during human feeding. Pramod Kumar (Kumar 1992) studied Rhesus Macaques and Hanuman Langurs in Shimla between 1987 and 1991 and found that populations of both species increased 26.61% and 25.86%, respectively, during the study period. Rhesus Macaques were more urban than langurs and the adult sex ratio in the two species was 1:2.3 and 1:5.6, respectively. As Shimla gets very cold in winter, there were significant seasonal variations in the behavior of both species.

Kerala Forest Research Institute, Peechi

K.K. Ramachandran (<http://www.kfri.res.in/whois.asp?ID=10&sub=1>) initiated primate research at KFRI, primarily on Lion-tailed Macaques and Nilgiri Langurs and supervised Ph.D. research of two students. Gigi K. Joseph (Joseph 1999a) (<https://nirmalacollege.ac.in/department-faculty/dr-gigi-k-joseph/>) reported the presence of 14 groups of Lion-tailed macaques and 85 groups of Nilgiri Langurs in Silent Valley. The food of Lion-tailed Macaques comprised 91% plant and 9% animal matter. The average group size of Nilgiri Langurs was 5.89. R. Suganthasakthivel (Suganthasakthivel 2011) (https://www.researchgate.net/profile/R_Suganthasakthivel) found a total of 13 groups with an average group size of 15.4 of Lion-tailed Macaques and 23 groups of Nilgiri Langurs with an average group size of 6.5 in the Nelliampathy forests. The relative abundances of diurnal arboreal mammals ranged between 1.2 and 12.6 individuals per 10km.

Centre for Cellular and Molecular Biology, Hyderabad

After his Ph.D. from SACON and post-doc from University of Mysore, G. Umapathy joined Laboratory for the Conservation of Endangered Species (LaCONES) at CCMB, Hyderabad and continued his studies on effects of habitat fragmentation on demography, genetic status, hormones, and endoparasites in primates in the Anamalai Hills. Sustained habitat fragmentation and exposure to human and livestock increased the prevalence of endoparasite in Lion-tailed Macaques (Hussain et al. 2013) and Nilgiri Langurs (Tiwari et al. 2017). M.S. Ram (Ram 2018) (https://www.researchgate.net/profile/Ram_M_S2) constructed phylogeography of the Lion-tailed Macaque across its range and found that these macaques in forest fragments had depleted mitochondrial diversity and that the Palghat gap in the Western Ghats separated their populations into two almost 2.11 million year ago (Ram et al. 2015). In the Endangered Golden Langur in Assam, though the genetic diversity was high, populations in smaller forest fragments showed lower nucleotide diversity than in larger fragments (Ram et al. 2015).

Aligarh Muslim University, Aligarh

Ekwal Imam (Imam 2000) (https://www.researchgate.net/profile/Ekwal_Imam) monitored populations of Rhesus Macaque near Aligarh. In the study region, 963 monkeys in 1993 increased to 1337 in 1995 with a birth rate of 0.81 infant/female/year and high infant survivorship. These observations agree with general trends in population increase in Rhesus Macaques in

several places in 1980s and 1990s.

University of California, Davis

Uma Ramakrishnan (Ramakrishnan 1999) found that in the wild bonnet macaques, discrimination of predators, and anti-predatory responses, develop ontogenetically as juveniles, subadults and adults respond to the stimuli differently.

University of Burdwan, Bardhaman

Sangita Mitra (Mitra 2000) studied behavior of Assamese Macaques near Darjeeling during 1996 and 1999 in broadleaf forests up to 2,500m, though the macaques were found mostly between 200 and 500 m. The adult sex ratio was 1:2.88 and the ranges varied from 0.6 to 3.5 km².

University of Calicut, Kozhikode

Arboreal mammals with special reference to the Nilgiri Langur were studied in the high ranges in Kerala (Joseph 1999b). A surprising finding was that Nilgiri Langurs were observed to feed on fruits (50%) more than on leaves (30% and flowers (20%). More carbohydrates containing food were used by langurs in summer and more protein and lipid were consumed during rainy season and winter.

Maharaja Ganga Singh University, Bikaner

Rhesus Macaques in the Aravali Hills were active during mornings and evenings in summer, but more active during the day in winter (Sharma 2009).

Indian Institute of Science, Bengaluru

Though taxonomy research on primates has been going on in the Indian Institute of Science for long, it is only recently that an ecological study by Mehreen Khaleel (Khaleel 2020) (https://www.researchgate.net/profile/Mehreen_Khaleel) has shown that Hanuman Langurs in Kashmir Himalaya are distributed wider than previously thought. These langurs show seasonal variations in home ranges and diet in accordance with the energy maximizing strategy.

University of Madras, Chennai

R. Sasi (Sasi 2018) provided the status and distribution pattern of lion-tailed macaque and slender lorises for the less explored regions including Parambikulam landscape and Megamalai-Srivilliputhur-Tirunelveli hills in the southern Western Ghats.

Bharathiyar University, Coimbatore

Shanthala Kumar (Kumar 2019) (https://www.researchgate.net/profile/Shanthala_Kumar) reported that the relocation of Bonnet Macaques from urban areas to a wild habitat facilitated the spread of alien endoparasites to Lion-tailed Macaques where these parasites were otherwise absent. Even on an isolated island system, the increased use of human-dominated spaces by Nicobar long-tailed Macaques has resulted in an increased endoparasite richness and prevalence.

FUTURE

National survey of primates

There have been some attempts in the past to census primates in different regions of the country. The earliest surveys were on the Rhesus Macaques in certain parts of northern India initiated by Charles Southwick (described earlier in this article). Zoological Survey of India undertook surveys in northern India under the leadership of R.P. Mukherjee (Mukherjee & Mukherjee 1972), in southern India by G.U. Kurup (Kurup 1984), and in the northeastern India by J.R.B. Alfred (Alfred & Sati 1990; Alfred et al. 2004) and some others at localized places the details of which are available with ZSI at <http://faunaofindia.nic.in/>. Primates in northeastern India were also surveyed under the Indo-US Primate Project (Srivastava 1999). Ullas Karanth (Karanth 1985) surveyed Lion-tailed Macaques in the state of Karnataka. Most of these surveys are now outdated and were largely localized. It is only recently that a systematic survey on Rhesus Macaques has been carried out in Himachal Pradesh (Kumara & Singh 2020). There have been several status assessments of primates by Zoo Outreach Organization including PHVAs for the Lion-tailed Macaque (Kumar et al. 1995), primates of South Asia (Molur et al. 2003) and Hoolock Gibbon (Molur et al. 2005). There is, therefore, an urgent need to take up a nationwide survey of primates in India.

Population monitoring

Population dynamics can be studied if a population is monitored for decades. Most research studies are of two to three year durations, and hence cannot bring out the stochasticity of primate populations. A lesson is learnt from the monitoring of Bonnet Macaque populations around the city of Mysore for over 30 years now by Mewa Singh and his team which has shown a ~70% decline in these macaques (Erinjery et al. 2017a). We need to identify populations that are representatives

of each species in different habitats and monitor them at least once in three years for several decades to comprehensively know the trends.

Taxonomic studies

Several species of primates in India are classified into subspecies. In order to prioritize conservation, it is necessary that genetic studies are carried out on all subspecies to determine whether there are more distinct species. For example, the Hanuman Langur was considered as only one species but it is now shown that there are many distinct species of this langur (Ashalakshmi et al. 2015). Morphologically similar populations of the Lion-tailed Macaque north and south of the Palghat gap have been genetically differentiated for the past 2.1 million years (Ram et al. 2015).

Ecological and behavioral research with long term field studies

There are many subspecies of few primate species in India for which even baseline ecological and behavioral information are not yet available. There is therefore a need to not only study these subspecies, but also all species across varied habitats. There are hardly any long-term field studies carried out in India. The one carried out by Anindya Sinha and his group on Bonnet Macaques at Bandipur brought out excellent results about evolution of sociality (Sinha & Mukhopadhyay 2013). A study on the Himalayan Grey Langur near Chamba by the Wildlife Information Liaison Development / Zoo Outreach Organization has been going on since 2012 (<https://www.speciesconservation.org/case-studies-projects/himalayan-grey-langur/9744>) though the results are yet to be published.

Conservation and management

Many species of primates, because of their threatened or vulnerable status, require active intervention for in situ management. Wildlife Trust of India has been carrying out rehabilitation of Eastern Hoolock Gibbon from small and isolated forest fragments to large forest complexes (Roy et al. 2015). Since different species inhabit different ecological settings and experience anthropogenic pressures, Singh (2019), for example, has provided approaches to management of urban- and forest-dwelling species. Likewise, appropriate management strategies need to be synthesised through dialogues between primate biologists and wildlife managers.

Conservation breeding

Several species of primates in India are threatened. An expert group of primatologists and wildlife managers should decide which of these species require conservation breeding in order to develop sustainable captive populations for restocking or rehabilitation, if required in the future. An initiative has already been taken for conservation breeding of Lion-tailed Macaques but it has not yielded desired results. Perspectives for systematic management on the basis of analysis of conservation breeding programs in various countries have been provided to aide planning (Kaumanns et al. 2005, 2013, 2020).

National Primate Research Centre

There is a long pending demand of primatologists to have a National Primate Research Centre that should be managed both by primate biologists and wildlife managers, and funded by the Ministry of Environment, Forest and Climate Change and Ministry of Science and Technology, Government of India. This Centre would not only initiate new research but will also coordinate among various institutions and governmental agencies in the country that are engaged in primate research and management. The Primate Centre could also host a National Primate Museum to showcase primate taxa, educate people and build awareness for their protection and conservation.

A Platform for Interactions

A Primatological Society of India was established in the late 1970s but it became inactive in the 1980s. Since then, there has not been a single platform for Indian primatologists to meet and exchange information except a CAMP meeting conducted by Zoo Outreach Organization (Molur et al. 2003). An enthusiastic group of Indian primatologists have established a new platform named, Association of Indian Primatologists (<https://www.indianprimates.org/>) in 2019 and conducted its first national workshop at Indian Institute of Science, Bengaluru in November 2019. This platform needs to be strengthened.

International Cooperation

Only three important international meetings have been held in India: the 7th Congress of the International Primatological Society at Bengaluru in January 1979, International Symposium on Primates at Jodhpur University in February 1982, and the 7th Asian Primate Symposium at Gauhati University in February 2020. The proceedings of the Bengaluru and Jodhpur meetings led

to seminal publications (Seth & Seth, 1983b, 1989a,b; Roonwal et al. 1984, respectively). We encourage the research groups in India to become more active in developing international cooperation so that expertise from different countries could be integrated in research and conservation. A successful example of such a cooperation has been the conduct of an international workshop on macaques at the University of Mysore that resulted in the publication of an outstanding volume with contributions from prominent primatologists from several countries (Thierry et al. 2004). This cooperation also helped develop strategies for conservation management, both in situ and ex situ, of the endangered Lion-tailed Macaque (Singh et al. 2009; Kaumanns et al. 2013).

REFERENCES

Agoramoorthy, G. (1987). Reproductive behaviour in Hanuman Langur, *Presbytis entellus*. PhD Thesis. University of Jodhpur, Jodhpur.

Alfred, J.R.B., A. Murmu, P.C. Majumder & S. Chaudhuri (2004). A note on the primates of Tawang District, Arunachal Pradesh. *Records of the Zoological Survey of India* 102: 1–5.

Alfred, J.R.B. & J.P. Sati (1990). Survey and census of the Hoolock gibbon in West Garo Hills, Northeast India. *Primates* 31: 299–306. <https://doi.org/10.1007/BF02380951>

Ali, R. (1981). The ecology and social behaviour of the Agastyamalai Bonnet Macaques (*Macaca radiata diluta*). PhD Thesis. University of Bristol, Bristol.

Anand, S. (2019). Patterns and determinants of Human–Rhesus macaque conflict. PhD Thesis. Manipal Academy of Higher Education, Manipal.

Anand, S. & S. Radhakrishna (2020). Is Human–Rhesus macaque (*Macaca mulatta*) conflict in India a case of human–human conflict? *Ambio* 1–12. <https://doi.org/10.1007/s13280-020-01324-w>

Ashalakshmi, N.C., K.S.C. Nag & K.P. Karanth (2015). Molecules support morphology: species status of south Indian populations of the widely distributed Hanuman langur. *Conservation Genetic* 16: 43–58. <https://doi.org/10.1007/s10592-014-0638-4>

Bala, M. (2013). Study on the ecology and behaviour of Hanuman Langur in Morni range Panchkula, Haryana. PhD Thesis. Kurukshetra University, Kurukshetra.

Bhan, S. (1983). Development of social behavior in Rhesus monkey (*Macaca mulatta*) infants in free ranging habitats. PhD Thesis. Meerut University, Meerut.

Bishop, N.H. (1975). Social behaviour of langur monkeys (*Presbytis entellus*) in high altitude environment. PhD Thesis. University of California, Berkeley.

Biswas, J. (2004). Ecology and social behaviour of Golden Langur, *Trachypithecus geei* (Khajuria, 1956), in Assam, India. PhD Thesis. Gauhati University, Guwahati.

Borah, D.K. (2010). Ecology and social behaviour of Capped Langur *Trachypithecus pileatus* (Blyth, 1843) and its conservation perspectives in Assam. PhD Thesis. Gauhati University, Guwahati.

Borah, M. (2016). Feeding behaviour and analysis of food plant diversity of *Hoolock hoolock* in a tropical forest of Assam, India. PhD Thesis. Tezpur University, Tezpur.

Borries, C. (1989). Konkurrenz unter freilebenden Langurenweibchen (*Presbytis entellus*) – [Competition in wild female langurs (*Presbytis entellus*)]. PhD Thesis. Georg-August University, Gottingen.

Borries, C., V. Sommer & A. Srivastava (1991). Dominance, age, and reproductive success in free-ranging female Hanuman Langurs (*Presbytis entellus*). *International Journal of Primatology* 12: 231–257. <https://doi.org/10.1007/BF02547586>

Bose, J. (2005). An ecobehavioural study of Phayre's Leaf Monkey *Trachypithecus phayrei* (Blyth, 1847). PhD Thesis. Gauhati University, Guwahati.

Chandek, N.K. (1981). Affiliation, attention and spacing mechanisms among free-ranging Rhesus monkeys (*Macaca mulatta*). PhD Thesis. University of Rajasthan, Jaipur.

Chatterjee, M. (2013). An uncommon performing monkey: behavioural flexibility and social diversity in the Northern Bonnet Macaque *Macaca radiata radiata*. PhD Thesis. Manipal Academy of Higher Education, Manipal.

Chauhan, A. (2009). A cognitive and behavioural study of human and monkey agonistic interactions. PhD Thesis. Himachal Pradesh University, Shimla.

Chhangani, A.K. (2000). Eco-behavioural diversity of langurs (*Presbytis entellus*) living in different eco systems. PhD Thesis. Jai Narayan Vyas University, Jodhpur.

Chetry, D. (2002). Socioecology of Stump-tailed Macaque, *Macaca arctoides* (L. Geoffroy, 1831). PhD Thesis. Gauhati University, Guwahati.

Choudhury, A. (1989). Primates of Assam: their distribution, habitat and status. PhD Thesis. Gauhati University, Guwahati.

Cooper, M. (1998). Social tolerance in Assamese macaques. PhD Thesis. University of Georgia, Athens.

Cooper, M.A., F. Aureli & M. Singh (2004a). Between-group encounters among Bonnet Macaques (*Macaca radiata*). *Behavioral Ecology and Sociobiology* 56: 217–227. <https://doi.org/10.1007/s00265-004-0779-4>

Cooper, M.A., M.S. Chaitra & M. Singh (2004b). Effect of dominance, reproductive state, and group size on body mass in *Macaca radiata*. *International Journal of Primatology* 25: 165–178. <https://doi.org/10.1023/B:IJOP.0000014648.12402.b6>

Das, J. (2002). Socioecology of Hoolock Gibbon: *Hylobates hoolock hoolock* (Harlan, 1836) in response to habitat change. PhD Thesis. Gauhati University, Guwahati.

Das, N. (2013). Ecology and behaviour of Bengal Slow Loris *Nycticebus bengalensis* (Lepech, 1800) in Assam, India. PhD Thesis. Gauhati University, Guwahati.

Das, R. (2012). Nutritional ecology of Golden Langur *Trachypithecus geei* (Khajuria, 1956) in Chirang reserve forest, Assam, India. PhD Thesis. North Orissa University, Baripada.

Deb, P. (2015). Habitat evaluation and status of Western Hoolock Gibbon (*Hoolock hoolock* Harlan, 1834) in some distributional ranges in Assam and Mizoram. PhD Thesis. Mizoram University, Aizawl.

Dolhinow, P.J. & D.G. Lindburg (1978). A population survey of forest-dwelling Rhesus monkeys (Primates: Cercopithecidae) in North India. *Records of Zoological Survey of India* 76: 207–219.

Dutta, A.N. (1992). Some aspects of ecolobiology of Golden Langur *Presbytis geei* Khajuria of Assam. PhD Thesis. Gauhati University, Guwahati.

Erinjery, J.J. (2016). A comparative study of life history traits, social systems and individual behavior of Lion-tailed macaques and Bonnet Macaques. PhD Thesis. University of Mysore, Mysuru.

Erinjery, J.J., S. Kumar, H.N. Kumara, K. Mohan, T. Dhananjaya, P. Sundararaj & M. Singh (2017a). Losing its ground: A case study of fast declining populations of a 'least-concern' species, the Bonnet Macaque (*Macaca radiata*). *PLoS One* 12: e0182140. <https://doi.org/10.1371/journal.pone.0182140>

Erinjery, J.J., T.S. Kavana & M. Singh (2017b). Behavioural Variability in macaques and langurs of the Western Ghats, India. *Folia Primatologica* 88: 293–306. <https://doi.org/10.1159/000480010>

Erinjery, J.J., H.N. Kumara, T.S. Kavana & M. Singh (2015). Are interspecific associations of primates in the Western Ghats a matter of chance? A case study of the Lion-tailed Macaque. *Journal of Tropical Ecology* 32: 41–49. <https://doi.org/10.1017/S0266467415000528>

Green, S. & K. Minkowski (1977). The Lion-tailed monkey and its south Indian rain forest habitat, pp.289-337. In: Prince Rainier III, H. S. H. and G. H. Bourne (Eds.). *Primate Conservation*. Academic Press, New York, 658pp.

Gupta, A.K. (1997). Conservation ecology of primates and human impact in North East India. PhD Thesis. University of Cambridge, Cambridge.

Gupta, S. (2016). Other voices: gestural communication of wild Bonnet Macaques *Macaca radiata* in the Bandipur National Park, Southern India. PhD Thesis. Manipal Academy of Higher Education, Manipal.

Hrdy, S.B. (1975). Male and female strategies of reproduction among the langurs of Abu. PhD Thesis. Harvard University, Cambridge.

Hussain, S., M.S. Ram, A. Kumar, S. Shivaji & G. Umapathy (2013). Human presence increases parasitic load in endangered Lion-tailed Macaques (*Macaca silenus*) in its fragmented rainforest habitats in southern India. *PLoS One* 8: e63685. <https://doi.org/10.1371/journal.pone.0063685>

Imam, E. (2000). A study on some behavioural aspects of Rhesus monkey *Macaca mulatta* in Aligarh and adjoining districts. PhD Thesis. Aligarh Muslim University, Aligarh.

Imam, E., H.S.A. Yahya & I. Malik (2000). A successful mass translocation of commensal Rhesus monkeys *Macaca mulatta* in Vrindaban, India. *Oryx* 36: 87-93. <https://doi.org/10.1017/S0030605302000013>

Islam, M. (2015). Status survey of Hoolock Gibbon (*Hoolock hoolock*) with special reference to habitat analysis, food analysis and anthropogenic pressure in the Inner Line Reserve Forest and its adjoining areas of Cachar District, Assam. PhD Thesis. Assam University, Silchar.

Jay, P. (1965). The common langur of North India, pp.197-249. In: I. DeVore (Eds.), Holt, Rinehart and Winston (eds.), *Primate Behavior: Field Studies of Monkeys and Apes*. New York, 654pp.

Joseph, G. (1999a). Ecology of Lion-tailed Macaque (*Macaca silenus*) in tropical forests of southern Western Ghats. PhD Thesis. Forest Research Institute, Dehradun.

Joseph, P. (1999b). Resource utilization by arboreal mammals with special reference to the Nilgiri Langur *Presbytis johnii* in the high ranges of Kerala. PhD Thesis. University of Calicut, Malappuram.

Kakati, K. (2005). Impact of forest fragmentation on the Hoolock Gibbon in Assam, India. PhD Thesis. University of Cambridge, Cambridge.

Karanth, K.U. (1985). Ecological status of the Lion-tailed Macaque and its rainforest habitats in Karnataka. *Primate Conservation* 6: 73-84.

Karr, J.A. (1973). Ecological and behavioural notes on the Lion-tailed Macaque (*Macaca silenus*) in South India. *Journal of the Bombay Natural History Society* 70: 191-193.

Kaumanns, W., N. Begum & H. Hofer (2020). "Animals are designed for breeding": captive population management needs a new perspective. *Journal of Zoo and Aquarium Research* 8: 76-85. <https://doi.org/10.19227/jzar.v8i2.477>

Kaumanns, W., E. Krebs & M. Singh (2005). An endangered species in captivity: Husbandry and management of the Lion-tailed Macaque (*Macaca silenus*). *My Science* 1: 43-71.

Kaumanns, W., M. Singh & A. Sliwa (2013). Captive propagation of threatened primates-the example of the Lion-tailed Macaque *Macaca silenus*. *Journal of Threatened Taxa* 5: 4825-4839. <https://doi.org/10.11609/JoTT.o3625.4825-39>

Kavana, T.S. (2015). A comparative study of life history traits, social systems and individual behaviour of Hanuman Langurs and Nilgiri Langurs. PhD Thesis. University of Mysore, Mysuru.

Kavana, T.S., J.J. Erinjery & M. Singh (2015). Folivory as a constraint on social behaviour of langurs in south India. *Folia Primatologica* 86: 420-431. <https://doi.org/10.1159/000438990>

Khaleel, M. (2020). Distribution, activity budget and feeding ecology of Himalayan Gray Langur in Kashmir Himalayas. PhD Thesis. Indian Institute of Science, Bengaluru.

Khan, W. (1980). Effect of urban environment on social, emotional and curiosity behaviors in Rhesus Monkeys (*Macaca mulatta*) at different age levels. PhD Thesis. Meerut University, Meerut.

Krishna, B.A. (2007). Social hierarchy and parental investment pattern in female Lion-tailed Macaques. PhD Thesis. University of Mysore, Mysuru.

Krishna, B.A., M. Singh, M. Singh & W. Kaumanns (2008). Infant development and weaning in *Macaca silenus* in the natural habitats of the Western Ghats, India. *Current Science* 94: 347-355.

Krishnamani, R. (2002). Phyto-ecology of the Lion-tailed Macaque (*Macaca silenus*) habitats in Southern India. PhD Thesis. Bharathiar University, Coimbatore.

Kumar, A. (1987). The ecology and population dynamics of the Lion-tailed Macaque (*Macaca silenus*) in South India. PhD Thesis. University of Cambridge, Cambridge.

Kumar, A. (2006). Studies on ecological and behavioural aspects of Capped Langur, *Trachypithecus pileatus* (Blyth, 1843) in Pakhui Wildlife Sanctuary, Arunachal Pradesh, India. PhD Thesis. North Eastern Hill University, Shillong.

Kumar, A., S. Molur & S. Walker (1995). Population and Habitat Viability Assessment (P.H.V.A.) Workshop for Lion-tailed Macaque (*Macaca silenus*), Madras, 1993. Zoo Outreach Organisation/CBSG, India, Coimbatore, India, 110pp.

Kumar, P. (1992). Ecology and behaviour of Rhesus macaques *Macaca mulatta* and Hanuman langurs *Presbytis entellus* in Shimla. PhD Thesis. Himachal Pradesh University, Shimla.

Kumar, P. (2012). Distribution, demography and behavioural ecology of mixed-species troops of Bonnet Macaques (*Macaca radiata*) and Rhesus macaques (*Macaca mulatta*) in peninsular India. PhD Thesis. Manipal Academy of Higher Education, Manipal.

Kumar, S. (2019). Population status and prevalence of gastrointestinal parasites in selected primates of India: A special emphasis on Bonnet macaque *Macaca radiata*. PhD Thesis. Bharathiar University, Coimbatore.

Kumar, R., S. Radhakrishna & A. Sinha (2011). Of least concern? Range extension by Rhesus Macaques (*Macaca mulatta*) threatens long-term survival of Bonnet Macaques (*M. radiata*) in peninsular India. *International Journal of Primatology* 32: 945-959. <https://doi.org/10.1007/s10764-011-9514-y>

Kumar, R., A. Sinha & S. Radhakrishna (2013). Comparative demography of two commensal macaques in India: implications for population status and conservation. *Folia Primatologica* 84: 384-393. <https://doi.org/10.1159/000351935>

Kumara, H.N. & A. Singh (2020). Population status of Rhesus macaque (*Macaca mulatta*) in Himachal Pradesh. Technical Report, Salim Ali Centre for Ornithology and Natural History, Coimbatore.

Kumara, H.N. & M. Singh (2004). Distribution and abundance of primates in rain forests of the Western Ghats, Karnataka, India and the conservation of *Macaca silenus*. *International Journal of Primatology* 25: 1001-1018. <https://doi.org/10.1023/B:IJOP.0000043348.06255.7f>

Kumara, H.N., M. Singh & S. Kumar (2006). Distribution, habitat correlates, and conservation of *Loris lydekkerianus* in Karnataka, India. *International Journal of Primatology* 27: 941-969. <https://doi.org/10.1007/s10764-006-9054-z>

Kurup, G.U. (1984). Nonhuman primate census surveys in southern India, pp.57-65. In: Roonwal, M.L., S.M. Mohnot, S.M. & N.S. Rathore (eds.). *Current Primate Researches*. Department of Zoology, University of Jodhpur, 627pp.

Lata, K. (1981). Impact of urban environment on the development of cognitive behavior in Rhesus monkeys. PhD Thesis. Meerut University, Meerut.

Lindburg, D.G. (1971). The Rhesus Monkey in North India: An ecological and behavioral study, pp. 1-106. In: Rosenblum, L.A. (eds.), *Primate Behavior: Developments in Field and Laboratory Research*. Volume 2. Academic Press, New York, 267pp.

Makwana, S.C. (1979a). Infanticide and social change in two groups of the Hanuman Langur, *Presbytis entellus*, at Jodhpur. *Primates* 20: 293-300. <https://doi.org/10.1007/BF02373381>

Makwana, S.C. (1979b). (Field) ecology and behaviour of the rhesus monkey, *Macaca mulatta* (Zimmerman, 1780). PhD Thesis. University of Jodhpur, Jodhpur.

Malik, I. (1989). Population growth and stabilizing age structure of the Tughlaqabad rhesus. *Primates* 30: 117–120. <https://doi.org/10.1007/BF02381218>

Malik, I., P.K. Seth & C.H. Southwick (1984). Population growth of free-ranging Rhesus monkeys at Tughlaqabad. *American Journal of Primatology* 7: 311–321. <https://doi.org/10.1002/ajp.1350070402>

Mallapur, A. (2005). The welfare of captive Lion-tailed Macaques housed in Indian zoos. PhD Thesis. University of Edinburgh, Edinburgh.

Mallapur, A., N. Waran & A. Sinha (2005). Use of enclosure space by captive Lion-tailed macaques (*Macaca silenus*) housed in Indian zoos. *Journal of Applied Animal Welfare Science* 8: 175–186. https://doi.org/10.1207/s15327604jaws0803_2

Mangalam, M., N. Desai & M. Singh (2014). Division of labor in hand usage in free-ranging Bonnet macaques, *Macaca radiata*. *American Journal of Primatology* 76: 576–585. <https://doi.org/10.1002/ajp.22250>

Mangalam, M., N. Desai & M. Singh (2016). Division of labour: a democratic approach towards understanding manual asymmetries in non-human primates. *Current Science* 110: 1630–1638.

Mathur, R. & B.R. Manohar (1990). Splitting in *Presbytis entellus* groups. *Behavioural Processes* 22: 1–11. [https://doi.org/10.1016/0376-6357\(90\)90002-W](https://doi.org/10.1016/0376-6357(90)90002-W)

Mathur, R. & M.B. Ram (1992). Rate of takeovers in groups of Hanuman Langurs (*Presbytis entellus*) at Jaipur. *Folia Primatologica* 58: 61–71. <https://doi.org/10.1159/000156610>

McCann, C. (1933). Observations on some of the Indian langurs. *Journal of the Bombay Natural History Society* 36: 618–628.

Medhi, R. (2004). Behaviour of Golden langur, *Trachypithecus geei* (Khajuria, 1956) in a riverine island. PhD Thesis. Gauhati University, Guwahati.

Menon, S. (1993). Ecology and conservation of the endangered Lion-tailed macaque in the landscape mosaic of the Western Ghats. PhD Thesis. The Ohio State University, Ohio.

Mishra, P.S. (2020). A study on the aggression and post-conflict affiliation in Nicobar Long-tailed Macaque (*Macaca fascicularis umbrosa*). PhD Thesis. Bharathiar University, Coimbatore.

Mishra, P.S., A. Pal, A.D. Velankar, H.N. Kumara & M. Singh (2020a). Do males bond? A study of male-male relationships in Nicobar long-tailed macaques *Macaca fascicularis umbrosa*. *Journal of Biosciences* 45: 22. <https://doi.org/10.1007/s12038-020-9995-y>

Mishra, P.S., A. Pal, A.D. Velankar, H.N. Kumara, M. Singh & M. Cooper (2020b). Does rank rule? Rank-related grooming patterns in Nicobar long-tailed macaques *Macaca fascicularis umbrosa*. *Primates* 61: 443–453. <https://doi.org/10.1007/s10329-020-00807-4>

Mitra, S. (2000). Eco behavioural study of the Assamese macaque. PhD Thesis. The University of Burdwan, Bardhaman.

Mohnot, S.M. (1971). Some aspects of social changes and infant-killing in the Hanuman langur, *Presbytis entellus* (Primates: Cercopithecidae), in western India. *Mammalia* 35: 175–198. <https://doi.org/10.1515/mamm.1971.35.2.175>

Mohnot, S.M. (1974). Ecology and behaviour of the common Indian langur *Presbytis entellus*. PhD Thesis. University of Jodhpur, Jodhpur.

Mohnot, S.M. (1984). Research potential of Jodhpur langurs (*Presbytis entellus*), pp.47–55. In: Roonwal, M.L., S.M. Mohnot & N.S. Rathore (eds.), *Current Primate Researches*. Department of Zoology, University of Jodhpur, 627pp.

Molur, S., D. Brandon-Jones, W. Dittus, A. Eudey, A. Kumar, M. Singh, M.M. Feeroz, M. Chalise, P. Priya & S. Walker (2003). Status of South Asian Primates: Conservation Assessment and Management (C.A.M.P.) Workshop Report. Zoo Outreach Organisation / CBSG-South Asia, Coimbatore, India, viii+432pp.

Molur, S., S. Walker, A. Islam, P. Miller, C. Srinivasulu, P.O. Nameer, B.A. Daniel & L. Ravikumar (Eds.) (2005). Conservation of Western Hoolock Gibbon (*Hoolock hoolock hoolock*) in India and Bangladesh. Zoo Outreach Organisation/CBSG-South Asia, Coimbatore, India, 132pp.

Mukherjee, R.P. & C.D. Mukherjee (1972). Group composition and population density of Rhesus monkey (*Macaca mulatta* (Zimmermann)) in northern India. *Primates* 13: 65–70. <https://doi.org/10.1007/BF01757937>

Nekaris K.A.I. (2000). The socioecology of the Mysore slender loris in Dindigul, Tamil Nadu, South India. PhD Thesis. Washington University, St. Louis, Missouri (MO).

Newton, P.N. (1984). The ecology and social organization of Hanuman langurs (*Presbytis entellus* Dufresne, 1797) in Kanha Tiger Reserve, central Indian highlands. PhD Thesis. University of Oxford, Oxford.

Nolte, A. (1955). Field observations on the daily routine and social behavior of common Indian monkeys with special reference to the Bonnet Monkey (*Macaca radiata* Geoffroy). *Journal of the Bombay Natural History Society* 53: 177–184.

Oates, J.F. (1979). Comments on the geographical distribution and status of the South Indian Black Leaf-monkey (*Presbytis johnii*). *Mammalia* 43: 485–494. <https://doi.org/10.1515/mamm.1979.43.4.485>

Oates, J.F., P.G. Waterman & G.M. Choo (1980). Food selection by the south Indian Leaf-monkey, *Presbytis johnii*, in relation to leaf chemistry. *Oecologia* 45: 45–56. <https://doi.org/10.1007/BF00346706>

Ojha, P.R. (1979). Ethology and ecology of the Rhesus Monkey, *Macaca mulatta*. PhD Thesis. University of Jodhpur, Jodhpur.

Pal, A. (2018). A study on the reproductive behavior of Nicobar long-tailed macaque (*Macaca fascicularis umbrosa*) in Great Nicobar Island, India. PhD Thesis. Manipal Academy of Higher Education, Manipal.

Pal, A., H.N. Kumara, A.D. Velankar, P.S. Mishra & M. Singh (2018a). Demography and birth seasonality in the Nicobar long-tailed macaque (*Macaca fascicularis umbrosa*). *Current Science* 114: 1732–1737.

Pal, A., H.N. Kumara, P.S. Mishra, A.D. Velankar & M. Singh (2018b). Extractive foraging and tool-aided behaviors in the wild Nicobar long-tailed macaque (*Macaca fascicularis umbrosa*). *Primates* 59: 173–183. <https://doi.org/10.1007/s10329-017-0635-6>

Patil, S.N. (2019). Studies on present status and invasion of Hanuman langur *Seminopithecus entellus* into human habitation in Bidar district of Karnataka. PhD Thesis. Gulbarga University, Kalaburagi.

Pirta, R.S. (1983). Cooperative behaviour in Rhesus monkeys living in urban and forest areas. *Proceedings of the Indian Academy of Sciences (Animal Sciences)* 92: 199–205. <https://doi.org/10.1007/BF03186187>

Pirta, R.S. (1984). Maintenance of cooperative life in forest and urban Rhesus monkeys (*Macaca mulatta*). *Proceedings of the Indian Academy of Sciences (Animal Sciences)* 93: 83–89. <https://doi.org/10.1007/BF03186064>

Poirier, F.E. (1970). The Nilgiri langur (*Presbytis johnii*) of South India, pp251–383. In: L.A. Rosenblum (eds.), *Primate Behavior: Developments in Field and Laboratory Research*. Volume 1. Academic Press, New York, 400pp.

Radhakrishna, S. (2001). Reproductive and social behaviour of the Slender Loris (*Loris tardigradus*) in its natural habitat. PhD Thesis. University of Mysore, Mysuru.

Radhakrishna, S. (2018). Primate tales: using literature to understand changes in human–primate relations. *International Journal of Primatology* 39: 878–894. <https://doi.org/10.1007/s10764-018-0035-9>

Radhakrishna, S., A. Datta-Roy, N. Swapna & A. Sinha (2010). Population survey of the Bengal slow loris, *Nycticebus bengalensis*, in Meghalaya, Northeast India. *Primate Conservation* 105–110.

Radhakrishna, S. & M. Singh (2002). Social behaviour of the Slender loris (*Loris tardigradus lydekkerianus*). *Folia Primatologica* 73: 181–196. <https://doi.org/10.1159/000065426>

Radhakrishna, S. & M. Singh (2004). Reproductive biology of the Slender loris (*Loris lydekkerianus lydekkerianus*). *Folia Primatologica* 75: 1–13. <https://doi.org/10.1159/000073424>

Radhakrishna, S., H.N. Kumara & R. Sasi (2011). Distribution patterns of Slender loris subspecies (*Loris lydekkerianus*) in Kerala, southern India. *International Journal of Primatology* 32: 1007–1019. <https://doi.org/10.1007/s10764-011-9518-7>

Rajpurohit, D.S. (2005). Study the dominance hierarchy and its role in social organisation in Hanuman langur, *Semnopithecus entellus entellus* (Dufresne, 1797) Rajasthan, India. PhD Thesis. Jai Narain Vyas University, Jodhpur.

Rajpurohit, L.S. (1987). Male social organisation in Hanuman langur (*Presbytis entellus*). PhD Thesis. University of Jodhpur, Jodhpur.

Ram, M.S. (2018). Studies on reproductive and genetic consequences of habitat fragmentation on endangered Lion-tailed Macaque populations in the fragmented rainforests of Western Ghats. PhD Thesis. Jawaharlal Nehru University, New Delhi.

Ram, M.S., M. Marne, A. Gaur, H.N. Kumara, M. Singh, A. Kumar & G. Umapathy (2015). Pre-historic and recent vicariance events shape genetic structure and diversity in endangered Lion-tailed Macaque in the Western Ghats: Implications for Conservation. *PLoS One* 10: e0142597. <https://doi.org/10.1371/journal.pone.0142597>

Ramakrishnan, U. (1999). The ontogeny of anti-predator behavior in Bonnet Macaques (*Macaca radiata*). PhD Thesis. University of California, Davis.

Ratnam, J. (2002). Ecological and social correlates of foraging decisions in a social forager, the Bonnet macaque, *Macaca radiata diluta*. PhD Thesis. Syracuse University, New York.

Roonwal, M.L. & S.M. Mohnot (1977). *Primates of South Asia: Ecology, Sociobiology, and Behavior*. Harvard University Press, Cambridge, United Kingdom, 448pp.

Roonwal, M.L., S.M. Mohnot & N.S. Rathore (1984). *Current Primate Researches*. Department of Zoology, University of Jodhpur, Jodhpur, India, 627pp.

Ross, C., A. Srivastava & R.S. Pirta (1993). Human influences on the population density of Hanuman langurs *Presbytis entellus* and Rhesus macaques *Macaca mulatta* in Shimla, India. *Biological Conservation* 65: 159–163. [https://doi.org/10.1016/0006-3207\(93\)90445-7](https://doi.org/10.1016/0006-3207(93)90445-7)

Roy, K. (2011). Resource partitioning in three sympatric primates in the rainforests of the Northern Western Ghats. PhD Thesis. University of Mysore, Mysuru.

Roy, K., H. Nautiyal & S. Dasgupta (2015). A preliminary study of activity budget of post released Eastern Hoolock gibbon *Hoolock leuconedys* (Mammalia: Primates: Hylobatidae) in Mehalo Wildlife Sanctuary, Arunachal Pradesh, India. *Journal of Threatened Taxa* 7: 7862–7869. <https://doi.org/10.11609/JoTT.o3869.7862-9>

Sahoo, S.K. (1993). Agonistic behavior of Rhesus monkeys (*Macaca mulatta*) and Hanuman langurs (*Presbytis entellus*) in Shimla. PhD Thesis. Himachal Pradesh University, Shimla.

Santhosh, K. (2017). Study of the population, ecology and conservation of Lion-tailed macaque *Macaca silenus* in Sirsi-Honnava, Western Ghats, Karnataka. PhD Thesis. Bharathiar University, Coimbatore.

Santhosh, K., H.N. Kumara, A.D. Velankar & A. Sinha (2015). Ranging behavior and resource use by Lion-tailed macaques (*Macaca silenus*) in selectively logged forests. *International Journal of Primatology* 36: 288–310. <https://doi.org/10.1007/s10764-015-9824-6>

Sarkar, P. (2000). Ecology and dynamics of social relationships of Assamese macaque: *Macaca assamensis* (McClelland, 1839). PhD Thesis. Gauhati University, Guwahati.

Sarma, K. (2015). Studies on population status, behavioural and habitat ecology of Eastern Hoolock gibbon (*Hoolock leuconedys*) in Arunachal Pradesh, India. PhD Thesis. North Eastern Regional Institute of Science and Technology (Deemed University), Nirjuli.

Sasi, R. (2018). Geographical mapping and ecological impact of lion-tailed macaque and slender lorises in Southern India. PhD Thesis. University of Madras, Chennai.

Schlotterhausen, L. (2000). Town monkeys, country monkeys: A socioecological comparison of a human commensal and wild group of Bonnet macaques (*Macaca radiata*). PhD Thesis. New York University, New York.

Sekhsaria, P. (2015). KMTR's one-mile corridor. *Sanctuary Asia* 45–49.

Sengupta, A. (2015). Seed dispersal by Rhesus macaques (*Macaca mulatta*). PhD Thesis. Manipal Academy of Higher Education, Manipal.

Seth, P.K. & S. Seth. (1983a). Brief report: Population dynamics of free-ranging rhesus monkeys in different ecological conditions in India. *American Journal of Primatology* 5: 61–67. <https://doi.org/10.1002/ajp.1350050107>

Seth, P.K. & S. Seth. (1983b). Perspectives in Primate Biology Volume I. Today & Tomorrow's Printers and Publishers, New Delhi, 242pp.

Seth, P.K. & S. Seth. (1989a). Perspectives in Primate Biology Volume II. Today & Tomorrow's Printers and Publishers, New Delhi, 208pp.

Seth, P.K. & S. Seth. (1989b). Perspectives in Primate Biology Volume III. Today & Tomorrow's Printers and Publishers, New Delhi, 260pp.

Sharma, A.B.A. (2002). A study of reproductive behaviour of Lion-tailed Macaque (*Macaca silenus*) in the rain forests of Western Ghats. PhD Thesis. University of Mysore, Mysuru.

Sharma, A.K., M. Singh, W. Kaumanns, E. Krebs, M. Singh, M.A. Kumar & H.N. Kumara (2006). Birth patterns in wild and captive Lion-tailed macaques (*Macaca silenus*). *International Journal of Primatology* 27: 1429–1439. <https://doi.org/10.1007/s10764-006-9077-5>

Sharma, G. (2007). Paternal care in Hanuman Langur *Semnopithecus entellus* in and around Jodhpur. PhD Thesis. Jai Narain Vyas University, Jodhpur.

Sharma, N. (2013). Primates on the edge: Ecology and conservation of primate assemblages in the fragmented lowland rainforests of the Upper Brahmaputra Valley, Northeastern India. PhD Thesis. Manipal Academy of Higher Education, Manipal.

Sharma, R.K. (2009). Ecology and behaviour of the Rhesus monkey *Macaca mulatta* in the Aravali ranges. PhD Thesis. Maharaja Ganga Singh University, Bikaner.

Simonds, P.E. (1965). The Bonnet macaque in South India, pp175–196. In: I. DeVore (Eds.), *Primate Behavior: Field Studies of Monkeys and Apes*, Holt, Rinehart and Winston, New York, 654pp.

Singh, M. (2019). Management of forest-dwelling and urban species: Case studies of the Lion-tailed macaque (*Macaca silenus*) and the Bonnet macaque (*M. radiata*). *International Journal of Primatology* 40: 613–629. <https://doi.org/10.1007/s10764-019-00122-w>

Singh, M., W. Kaumanns, M. Singh, H.S. Sushma & S. Molur (2009). The Lion-tailed macaque *Macaca silenus* (Primates: Cercopithecidae): conservation history and status of a flagship species of the tropical rainforests of the Western Ghats, India. *Journal of Threatened Taxa*. 1: 151–157. <https://doi.org/10.11609/JoTT.o2000.151-7>

Singh, M., B.A. Krishna & M. Singh (2007). Maternal parental investment in the Lion-tailed macaque (*Macaca silenus*): Dominant females are biased towards sons. *Psychological Studies* 52: 348–356.

Singh, M., M.A. Kumar, H.N. Kumara & S.M. Mohnot (2000). Distribution and conservation of Slender lorises (*Loris tardigradus lydekkerianus*) in southern Andhra Pradesh, South India. *International Journal of Primatology* 21: 721–730. <https://doi.org/10.1023/A:1005573506489>

Singh, M., K. Roy & M. Singh (2011). Resource partitioning in sympatric langurs and macaques in tropical rainforests of the central Western Ghats, South India. *American Journal of Primatology* 73: 335–346. <https://doi.org/10.1002/ajp.20900>

Singh, M., A. Udhayan, M.A. Kumar, H.N. Kumara & D.G. Lindburg (1999). Status survey of Slender loris *Loris tardigradus lydekkerianus* in Dindigul, Tamil Nadu, India. *Oryx* 33: 30–36. <https://doi.org/10.1046/j.1365-3008.1999.00033.x>

Singh, P. (2017). Parental investment patterns in relation to dominance status in Bonnet macaque *Macaca Radiata*. PhD Thesis. University of Mysore, Mysuru.

Singh, R. (1981). Study of behavioral patterns of age sex classes during transitional periods in free ranging Rhesus Monkeys (*Macaca mulatta*). PhD Thesis. University of Rajasthan, Jaipur.

Singh, S.D. (1968). Effect of urban environment on visual curiosity behavior in Rhesus monkeys. *Psychonomic Science* 11: 83–84.

Singh, S.D. (1969). Urban monkeys. *Scientific American* 221: 108–115.

Singh, S.D. (1977). Effects of infant-infant separation of young monkeys in a free-ranging natural environment. *Primates* 18: 205–214. <https://doi.org/10.1007/BF02382959>

Singh, S.D. (1980). Xenophobic reactions of free-ranging Rhesus infant groups raised in natural habitat. *Primates* 21: 492–497. <https://doi.org/10.1007/BF02382959>

[org/10.1007/BF02373837](https://doi.org/10.1007/BF02373837)

Singh, S.D. & S.N. Manocha (1966). Reactions of the Rhesus Monkey and the langur in novel situations. *Primates* 7: 259–262. <https://doi.org/10.1007/BF01730791>

Sinha, A. (2001). Report on the Monkey in the Town's Commons: A Natural History of the Indian Bonnet Macaque. Report to National Institute of Advanced Studies, Bengaluru.

Sinha, A., A. Datta, M.D. Madhusudan & A. Mishra (2005). *Macaca munzala*: A new species from Western Arunachal Pradesh, Northeastern India. *International Journal of Primatology* 26: 977–989. <https://doi.org/10.1007/s10764-005-5333-3>

Sinha, A. & K. Mukhopadhyay (2013). The monkey in the town's commons, Revisited: An anthropogenic history of the Indian Bonnet Macaque, pp187–208. In: Radhakrishna, S., M.A. Huffman & A. Sinha (Eds.), *The Macaque Connection: Cooperation and Conflict Between Humans and Macaques*. Springer, xii+256pp.

Sinha, A., K. Mukhopadhyay, A. Datta-Roy & S. Ram (2005). Ecology proposes, behaviour disposes: ecological variability in social organization and male behavioural strategies among wild Bonnet macaques. *Current Science* 89: 1166–1179.

Solanki, G.S. (1987). Ecology and behaviour of Capped Langur in Pakhui Wildlife Sanctuary, India. PhD Thesis. Saurashtra University, Rajkot.

Sommer, V. (1985). Weibliche und männliche reproduktionsstrategien der Hanuman-Languren (*Presbytis entellus*) von Jodhpur, Rajasthan, India. PhD Thesis. University of Göttingen, Gottingen.

Sommer, V. & S.M. Mohnot (1985). New observations on infanticides among Hanuman langurs (*Presbytis entellus*) near Jodhpur (Rajasthan/India). *Behavioral Ecology and Sociobiology* 16: 245–248. <https://doi.org/10.1007/BF00310987>

Southwick, C.H., M.A. Beg & M.R. Siddiqi (1961a). A population survey of Rhesus monkeys in villages, towns and temples of northern India. *Ecology* 42: 538–547.

Southwick, C.H., M.A. Beg & M.R. Siddiqi (1961b). A population survey of Rhesus monkeys in northern India: II. Transportation routes and forest areas. *Ecology* 42: 698–710.

Southwick, C.H., M.A. Beg & M.R. Siddiqi (1965). Rhesus monkeys in North India, pp111–159. In: I. DeVore (Eds.), Holt, Rinehart & Winston (eds.). *Primate Behavior: Field Studies of Monkeys and Apes*, New York, 654pp.

Southwick, C.H. & M.R. Siddiqi (1966). Population changes of Rhesus monkeys (*Macaca mulatta*) in India, 1959 to 1965. *Primates* 7: 303–314. <https://doi.org/10.1007/BF01730644>

Southwick, C.H. & M.F. Siddiqi (1977). Population dynamics of Rhesus monkeys in northern India, pp. 339–362. In: Bourne Rainier III (eds.). *Primate Conservation*. Academic Press, New York, 658pp.

Southwick, C.H. & M.F. Siddiqi (1988). Partial recovery and a new population estimate of Rhesus monkey populations in India. *American Journal of Primatology* 16: 187–197. <https://doi.org/10.1002/ajp.1350160302>

Southwick, C.H. & M.F. Siddiqi (2001). Status, conservation and management of primates in India. *ENVIS Bulletin* 81–91.

Srivastava, A. (1989). Feeding ecology and behaviour of Hanuman langur, *Presbytis entellus*. PhD Thesis. University of Jodhpur, Jodhpur.

Srivastava, A. (1999). *Primates of Northeast India*. Megadiversity Press, New Delhi, 208pp.

Suganthasakthivel, R. (2011). Ecology and behavior of selected arboreal mammals in the southern Western Ghats, India. PhD Thesis. Forest Research Institute, Dehradun.

Sugiyama, Y. (1964). Group composition, population density and some sociological observations of Hanuman langurs. *Primates* 5: 7–37. <https://doi.org/10.1007/BF01791642>

Sugiyama, Y. (1965). On the social change of Hanuman langurs (*Presbytis entellus*) in their natural condition. *Primates* 6: 381–418. <https://doi.org/10.1007/BF01730356>

Sugiyama, Y. (1966). An artificial social change in a Hanuman langur troop (*Presbytis entellus*). *Primates* 7: 41–72. <https://doi.org/10.1007/BF01730557>

Sugiyama, Y. (1968). The ecology of the Lion-tailed macaque (*Macaca silenus* (Linnaeus)): A pilot study. *Journal of Bombay Natural History Society* 65: 283–292.

Sugiyama, Y. (1971). Characteristics of the social life of Bonnet macaques (*Macaca radiata*). *Primates* 12: 247–266. <https://doi.org/10.1007/BF01730414>

Sugiyama, Y. (1976). Characteristics of the ecology of the Himalayan langurs. *Journal of Human Evolution* 5: 249–277. [https://doi.org/10.1016/0047-2484\(76\)90029-4](https://doi.org/10.1016/0047-2484(76)90029-4)

Sugiyama, Y. (1984). Some aspects of infanticide and intermale competition among langurs, *Presbytis entellus*, at Dharwar, India. *Primates* 25: 423–432. <https://doi.org/10.1007/BF02381665>

Sushma, M.S. (2004). Resource utilization and niche separation in sympatric rainforest arboreal mammals. PhD Thesis. University of Mysore, Mysuru.

Sushma, H.S. & M. Singh (2006). Resource partitioning and interspecific interactions among sympatric rain forest arboreal mammals of the Western Ghats, India. *Behavioral Ecology* 17: 479–490. <https://doi.org/10.1093/beheco/arj058>

Swapna, N., A. Gupta & S. Radhakrishna (2008). Distribution survey of Bengal Slow loris *Nycticebus bengalensis* in Tripura, northeastern India. *Asian Primates Journal* 1: 37–40.

Thierry, B., M. Singh & W. Kaumanns (Eds.). (2004). *Macaque Societies: A Model for the Study of Social Organization*. Cambridge University Press, 418pp.

Tiwari, S., M. Reddy, M. Pradheeps, G.S. Sreenivasamurthy & G. Umapathy (2017). Prevalence and co-occurrence of gastrointestinal parasites in Nilgiri Langurs (*Trachypithecus johnii*) of fragmented landscape in Anamalai Hills., Western Ghats, India. *Current Science* 113: 2194–2200.

Umapathy, G. (1998). Impacts of habitat fragmentation on the arboreal mammals in the wet evergreen forests of the Anamalai Hills in the Western Ghats, South India. PhD Thesis. Bharathiar University, Coimbatore.

Umapathy, G. & A. Kumar (2000). The occurrence of arboreal mammals in the rain forest fragments in the Anamalai Hills, south India. *Biological Conservation* 92: 311–319. [https://doi.org/10.1016/S0006-3207\(99\)00097-X](https://doi.org/10.1016/S0006-3207(99)00097-X)

Umapathy, G., M. Singh & S.M. Mohnot (2003). Status and distribution of *Macaca fascicularis umbrosa* in the Nicobar Islands, India. *International Journal of Primatology* 24: 281–293. <https://doi.org/10.1023/A:1023045132009>

Velankar, A.D., H.N. Kumara, A. Pal, P.S. Mishra & M. Singh (2016). Population recovery of Nicobar Long-tailed Macaque *Macaca fascicularis umbrosa* following a Tsunami in the Nicobar Islands, India. *PLoS One* 11: e0148205. <https://doi.org/10.1371/journal.pone.0148205>

Vogel, C. (1988). Sociobiology of Hanuman langurs (*Presbytis entellus*): Introduction into the Jodhpur field project. *Human Evolution* 3: 217. <https://doi.org/10.1007/BF02435854>

Winkler, P. (1981). Zur öko-ethologie freilebender Hanuman Languren (*Presbytis entellus entellus* Dufresne, 1797) in Jodhpur (Rajasthan), India. PhD Thesis. University of Gottingen, Gottingen.

Winkler, P., H. Loch & C. Vogel (1984). Life history of Hanuman langurs (*Presbytis entellus*). *Folia Primatologica* 43: 1–23. <https://doi.org/10.1159/000156167>

Wolfe, L.D. (1992). Feeding habits of the Rhesus monkeys (*Macaca mulatta*) of Jaipur and Galta, India. *Human evolution* 7: 43–54. <https://doi.org/10.1007/BF02437477>

Zothansima (2013). Socio-ecology and breeding behaviours of Stump-tailed macaque (*Macaca arctoides*) in Mizoram. PhD Thesis. Mizoram University, Aizawl.



University campuses can contribute to wildlife conservation in urbanizing regions: a case study from Nigeria

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Abstract: Globally, colleges and universities are increasingly mandating sustainability and environmental protection into their practices. To date, such institutions have focused their efforts on recycling and energy-use reduction and less on the management and conservation of wildlife and wildlife habitats. However, in an increasingly urbanizing world, well-managed campuses can provide habitat and even refuge for wildlife species. On the campus of a sustainability-minded university in Nigeria, we used camera traps to determine the presence of wildlife and used occupancy modeling to evaluate factors that influenced the detectability and habitat use of two mammals for which we had sufficient detections: White-tailed Mongoose *Ichneumia albicauda* and Gambian Rat *Cricetomys gambianus*. Our intent was to gather baseline data on campus wildlife to inform future research and make recommendations for maintaining wildlife populations. We detected wildlife primarily within less-disturbed areas that contained a designated nature area, and the presence of a nature area was the key predictor variable influencing habitat use. No measured variables influenced detectability. This study supports other research that highlights the importance of undisturbed or minimally disturbed natural habitats on university campuses for wildlife, especially in increasingly built-up and developed regions. We recommend that institutions of higher education devote greater resources to making campuses wildlife-friendly and increase opportunities for students to engage in campus-based wildlife research and conservation and other sustainability-related programs.

Keywords: Camera trap, *Cricetomys gambianus*, detectability, habitat use, *Ichneumia albicauda*, occupancy modeling, sustainability, wildlife management.

Hausa abstract: A duk fadin duniya, kwalejoji da jami'o'i suna kara ba da umarnin dorewa da kiyaye muhalli cikin ayyukansu. Har ya zuwa yau, irin wadannan cibiyoyin sun mayar da hankalinsu kan sake sarrafawa da rage amfani da makamashi sun kuma rage kulawa da kiyaye namun daji da muhalli. Sai dai kuma, duk da yawan karuwar birane, harabar jami'a mai kyakkyawan tsari na iya samar da mazauni har ma da mafaka ga nau'ukan namun daji. A wata harabar jami'a mai dorewa a Nijeriya, mun yi amfani da tarko na kyamara don kaddara kasancewar halittu da amfani da tallan zama don kimanta abubuwana da suka shafi tasirin ganowa da amfani da mazaunin dabbobi masu shayarwa guda biyu wadanda muke da cikakkun bincike game da su: White-tailed Mongoose *Ichneumia albicauda* da Gambian Rat *Cricetomys gambianus*. Manufarmu ita ce tattara bayanan asali kan namun daji na harabar don sanar da bincike na gaba da ba da shawarwari don kiyaye yawan namun daji. Mun gano dabbobin daji da farko a cikin yankunan da ba hayanya wanda ya kunshi yanki na musamman, kuma kasancewar wani yanki shine maballin canjin tasiri mai amfani da wurin zama. Babu wani canji da aka auna wanda yayi tasiri akan ganowa. Wannan binciken yana karfa wasu binciken da ke nuna mahimmancin rashin hayanya a wuraren zama na rayuwa a makarantun jami'a don rayuwar namun daji, musamman a wuraren da ke da ingattattun gine-gine da yankuna masu tasowa. Muna ba da shawarar cewa cibiyoyin ilimi mafi girma su ba da kasu mai tsoka don samar da cibiyoyin karatun abokantaka na namun daji tare da habaka dama ga dalibai don shiga cikin bincike da kiyaye namun daji na cikin harabar makarantar da sauran shirye-shiryen da suka dace.

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INTRODUCTION

Institutions of higher education are increasingly integrating sustainability and environmental protection into their missions and practices (van Weenen 2000; Calder & Clugston 2003). This movement has led to several partnership platforms, such as the U.S.-based Association for the Advancement of Sustainability in Higher Education and United Nations Environment Program's Mainstreaming Environment and Sustainability in African Universities Partnership. Although some universities have given biodiversity conservation elevated importance (e.g., Kyushu University in Japan, Normile 2004), to date campus sustainability efforts have largely emphasized recycling programs and energy use (Bocsi et al. 2018). Management and conservation of wildlife and wildlife habitats have received comparatively limited attention. For institutions that do engage in wildlife habitat management, they generally favor certain practices, notably planting native species and using sustainable practices for lawn maintenance and landscaping, over providing food, water, and cover for wildlife (Bocsi et al. 2018).

Where campuses occur in crowded, urban landscapes or landscapes affected by habitat degradation and deforestation, natural campus sites may provide refuge for wildlife, including rare and endangered species (Ramlı 2004; Aneesh et al. 2013). For institutions that devote resources to wildlife management, they may, at times by necessity, focus resources on the most visible, common species or shift resources to managing "problem" domestic animals. Such situations might include managing abundant wildlife species that threaten people on campus (Hubbard & Nielsen 2009) or managing increasing populations of feral cats (Tennent et al. 2009; Dombrosky & Wolverton 2014). As a result, campus authorities may overlook rare or cryptic species.

We investigated the status of wildlife on the campus of a sustainability-minded university in Nigeria. We determined the presence of mammals using cameras and assessed how anthropogenic and natural factors influenced detectability and habitat use of these species using occupancy modeling. At the time of our study, the university's sustainability programs focused on waste management, recycling, and water and energy conservation. Although the university informally set aside two plots of land as nature areas in 2013 and 2015, there have been no dedicated efforts to manage these sites for wildlife; for example, authorities regularly clear grasses in these areas to make the campus more attractive to visitors and reduce the risk of fire. The

surrounding region has no official protected areas designated for biodiversity conservation. Because the university prohibits hunting and trapping, the campus may provide wildlife with respite from anthropogenic pressures in the region. The objectives of this work were to gather baseline data on campus wildlife to inform future research and recommend to university authorities best practices for maintaining wildlife populations.

METHODS

We conducted this study in the dry season (January–March 2018) on the American University of Nigeria (AUN) campus in Yola, Adamawa State, in northeastern Nigeria (Image 1). AUN was constructed in 2003 on ~110ha of land previously disturbed by livestock grazing, farming, and construction (Dariye 2016). Over time, grazing and farming were restricted. Regional habitat comprises woodland-savanna-grassland mosaic. Campus grounds are relatively open with sparse tree cover and abundant grasses, particularly Gamba Grass *Andropogon gayanus*. A 3m-high wall demarcates the campus perimeter. This wall does not restrict wildlife movement, however. Three open areas along the wall serve as an entrance for vehicles and a few parts of the wall are degraded, creating gaps through which wildlife could pass. Outside the university are mainly residential areas, farmland, and farm-savanna mosaic; however, local development is increasing.

We divided the campus into four study zones representing undeveloped sites: North Nature Zone (20ha, about half of which encompassed one of the two nature areas), South Nature Zone (16.5ha, nearly all of which encompassed the other nature area), Southwest Zone (4ha), and Northwest Zone (14ha). Although the university designated two nature areas on campus, they were informally delimited and not strictly protected. Each study zone varied by amount of vegetative cover and distance from built structures, with the nature-area zones having greater tree and shrub densities, commonly of *Azadirachta indica* and *Guiera senegalensis*. South Nature Zone had the highest species richness and diversity of woody plants (Dariye 2016).

Using a 150m-x-150m-grid overlay of the campus, we systematically placed two cameras (Bushnell Trophy HD Aggressor) at 150m intervals along the grid within each zone; we selected these intervals to ensure widespread coverage of each study zone and the campus. We used portable camera mounts set at a height of 30cm. Our sampling effort was proportional, based on size of the study zone: North Nature Zone: 37% (10 sampling points),

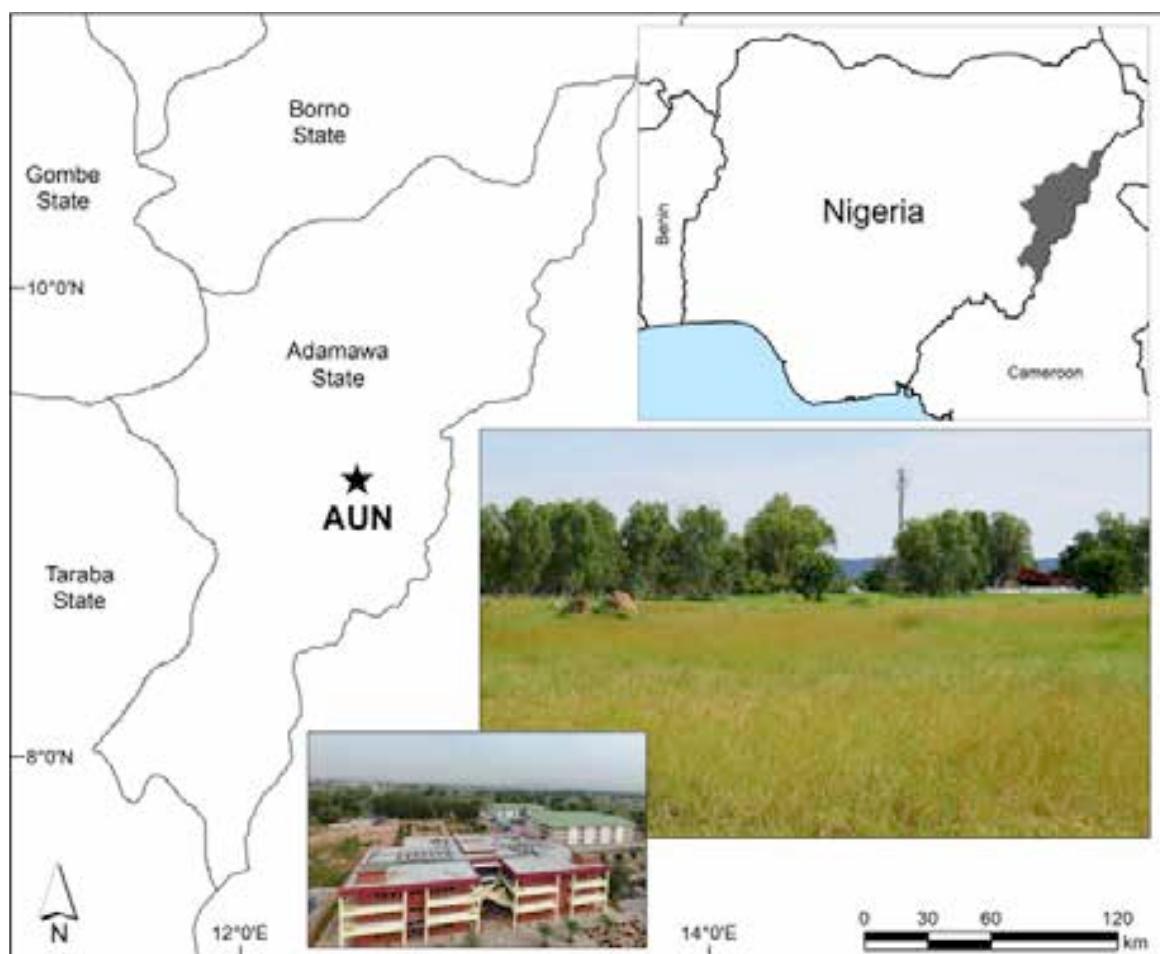


Image 1. Location of the American University of Nigeria (AUN) campus in Adamawa State, northeastern Nigeria, and photos of a nature area and aerial view of campus.

South Nature Zone: 30% (8 points), Southwest Zone: 7% (3 points), and Northwest Zone: 26% (8 points). Total number of sampling points was 29. During the study, we placed the two cameras at different sampling points and surveyed each sampling point for three nights.

Using Program PRESENCE (Hines 2006), we fitted a series of single-season occupancy models to the data. Number of cameras deployed per site represented spatially replicated surveys. We modeled the presence of each species to evaluate the influence of two site (habitat) covariates: presence of livestock and presence of a nature area. We included three sampling (survey-specific) covariates: detection of domestic cats (potential predators), whether the camera was physically under tree cover, and distance (in meters) to the nearest food/waste bin (standardized using a z-transformation).

Occupancy estimates rely on study designs that do not violate the basic assumptions of occupancy modeling, of which one is closure. We could not ensure that closure

was met in this study, so we interpreted occupancy (ψ) as the proportion of sites used, instead of occupied, by a species (MacKenzie et al. 2006). The models, thus, estimated habitat use (ψ) and detection probabilities (p).

We initially held habitat use constant and modeled detection probabilities considering sampling covariates; we then held detection probabilities constant and modeled habitat use considering site-specific covariates. We used Akaike's information criterion (AIC) adjusted for small sample size (AIC_c) to calculate model weights. Starting with a null model [$\psi(.), p(.)$], we used a forward-selection approach (Baker et al. 2011). If a covariate did not reduce AIC_c compared to the null model, we removed that variable from the analysis. For each species, we initially conducted a goodness-of-fit test on the global model. Using 10,000 parametric bootstraps, we obtained a Pearson's chi-square statistic and estimated a variance inflation factor, \hat{c} . We then adjusted model ranks for overdispersion ($\hat{c} > 1$) using $QAIC_c$.

RESULTS

Cameras captured four wild mammals: White-tailed Mongoose *Ichneumia albicauda* (Image 2), Gambian Rat *Cricetomys gambianus* (Image 3), Banded Mongoose *Mungos mungo*, and Striped Ground Squirrel *Xerus erythropus*. None is a threatened species, and all are widely distributed in Africa. Cameras also captured feral cats and West African Dwarf goats. Of the mammals detected, we focused our analyses on the species for which we had sufficient data: White-tailed Mongoose and Gambian Rat. We detected White-tailed Mongoose only on the north side of campus and never in the same zone as Banded Mongoose; we detected Gambian Rat only in zones with nature areas. Cats occurred across all study zones and goats in just one zone (Table 1).

For both White-tailed Mongoose and Gambian Rat, no sampling covariates influenced detectability; all models with sampling covariates had a $\Delta\text{QAIC}_c > 5$, indicating little support for these models (Table 2). For White-tailed Mongoose, the best-supported models of habitat use included both site covariates: nature area and livestock (in this case, goats) (Table 2a). Each covariate had a slightly positive effect (nature area: $\beta = 0.215$, SE = 1.607; goats: $\beta = 25.952$, SE = not estimated). For Gambian Rat, the best-supported models also included nature area and livestock (Table 2b). Nature area had a positive effect on habitat use ($\beta = 29.199$, SE = not estimated), whereas presence of goats had a negative effect ($\beta = -27.327$, SE = not estimated).

DISCUSSION

Given regional anthropogenic pressures, such as population growth, deforestation, and land degradation, we expected wildlife to use the AUN campus as university grounds provide some protection from exploitation. Most detections of wildlife in this study were within less-



Image 2. White-tailed Mongoose *Ichneumia albicauda*



Image 3. Gambian Rat *Cricetomys gambianus*

disturbed zones containing nature areas. That we did not detect wildlife in the Southwest Zone may be an artefact of sampling effort (i.e., smaller area) or because human disturbance around this area was common during our study. This research supports other studies that show that undisturbed or minimally disturbed natural habitats on campuses can support wildlife, providing refuge in urban or urbanizing regions (e.g., rare birds in Malaysia,

Table 1. Species detected in this study, zones where detected, and number of detections. A '+' denotes one detection, while '—' denotes no detection. Multiple '+' signs reflect the total number of detections for that zone.

Species	Northwest Zone	North Nature Zone	Southwest Zone	South Nature Zone
White-tailed Mongoose	+++	++	—	—
Gambian Rat	—	++	—	+++
Banded Mongoose	—	—	—	+
Striped Ground Squirrel	—	+	—	—
Domestic cat	+	+	+	+++
Dwarf goat	+	—	—	—

Table 2. Results of model selection for habitat use and detection probability using AIC corrected for sample size and overdispersion (QAIC_c). Best-supported models were those with lower QAIC_c scores relative to the null model [$\psi(\cdot, p(\cdot))$] and model weights > 0.10.

a) White-tailed Mongoose

Model	QAIC _c	ΔQAIC _c	Model weight	Likelihood	K ^b	-2* Loglikelihood
$\psi(\text{nature area}), p(\cdot)$	25.13	0.00	0.4997	1.0000	2	23.22
$\psi(\text{goats}), p(\cdot)$	26.49	1.36	0.2531	0.5066	2	24.78
$\psi(\cdot, p(\cdot))$	27.35	2.22	0.1647	0.3296	2	25.76
$\psi(\cdot, p(\text{distance-bins}))$	30.64	5.51	0.0318	0.0636	2	29.52
$\psi(\cdot, p(\text{cats}))$	31.04	5.91	0.0260	0.0521	2	29.98
$\psi(\cdot, p(\text{tree cover}))$	31.26	6.13	0.0233	0.0467	2	30.23
Global model ^a	36.83	11.70	0.0014	0.0029	5	24.92

b) Gambian Rat

Model	QAIC _c	ΔQAIC _c	Model weight	Likelihood	K ^b	-2* Loglikelihood
$\psi(\text{nature area}), p(\cdot)$	24.88	0.00	0.4964	1.0000	2	23.22
$\psi(\text{goats}), p(\cdot)$	26.23	1.35	0.2528	0.5092	2	24.78
$\psi(\cdot, p(\cdot))$	27.07	2.19	0.1661	0.3345	2	25.76
$\psi(\cdot, p(\text{distance-bins}))$	30.33	5.45	0.0325	0.0655	2	29.52
$\psi(\cdot, p(\text{cats}))$	30.72	5.84	0.0268	0.0539	2	29.98
$\psi(\cdot, p(\text{tree cover}))$	30.94	6.06	0.0240	0.0483	2	30.23
Global model ^c	36.57	11.69	0.0014	0.0029	5	24.94

(.) Indicates that the parameter was held constant

^a Used to estimate \hat{c} using 10,000 parametric bootstraps ($\hat{c} = 1.1424$)

^b Number of model parameters

^c Used to estimate \hat{c} using 10,000 parametric bootstraps ($\hat{c} = 1.1565$)

Ramli 2004; endemic and rare butterflies in India, Aneesh et al. 2013).

We were unsurprised that White-tailed Mongoose occurred in areas of the AUN campus disturbed by road traffic, lighting, and regular mowing activity. The species is known to tolerate anthropogenic pressures (Schuette et al. 2013). We most often captured White-tailed Mongoose in relatively open areas with abundant short and medium grasses, habitat preferred by this species (Waser 1980). Although the species also prefers open woodland and bush, within these habitats it forages in grassy areas where invertebrate prey may be abundant (Admasu et al. 2004). Although modeling revealed that the presence of goats positively influenced habitat use of White-tailed Mongoose, this relationship may not be meaningful; instead, it may relate to the habitat characteristics in the zone where we detected goats. Sheep and goats infrequently occur on campus, and we detected goats once, in the Northwest Zone. This zone is primarily open, grassy habitat, which is likely important foraging habitat for White-tailed Mongoose. Additionally, studies have shown that livestock activity negatively influences the detectability of White-tailed Mongoose (e.g., Ramesh & Downs 2015). That this species did not use the South

Nature Zone may relate to the area's greater tree cover or the presence of Banded Mongoose, even though the two species have different activity regimens and sociality.

Cameras captured Gambian Rat only in nature-area zones. This was expected given the species prefers well-shaded areas and burrows inside deserted termite mounds and underneath tree roots (Ajayi 1977). Having a low tolerance to heat, Gambian Rat is physiologically adapted to burrowing habitats in cooler environments, such as under tree cover (Knight 1988). In this study, the presence of feral cats, potential predators of rats, did not affect the species' detectability.

Our findings should be considered in context of the limitations of this research. Only two cameras were available for this study, which restricted the number of trap nights and our ability to survey areas simultaneously across campus. In addition, we were unable to model habitat use for other captured species due to an insufficient number of detections.

Although limited in scope, this study provided insight into wildlife habitat use on the AUN campus. The importance of maintaining minimally disturbed nature areas is evident. We recommend that campus authorities clearly delineate the two nature areas, train facility workers

on acceptable activities in these areas, and post clearly marked signboards along boundaries and walking trails. Presently, controlling feral cats does not seem important; however, the university should monitor the campus cat population to track potential changes over time. For White-tailed Mongoose, we recommend that authorities avoid completely cutting down grasses. For Gambian Rat, we recommend tree planting to provide additional cover and food sources, as well as the preservation of old termite mounds as potential burrows for this species. Given the use of pesticides across campus, we also recommend research to investigate potential impacts of pesticide spraying on insect abundance and water sources.

Finally, campus authorities should involve students more in campus-based wildlife research and other sustainability projects. This could include promoting and engaging conservation, wildlife, sustainability, or similar student associations in institutional-level sustainability research and planning. In addition, institutions that maintain natural habitats on their campuses provide convenient research sites for students. Campus projects allow for experiential learning in which students can contribute to practical wildlife research and management (McCleery et al. 2005). Furthermore, university sustainability programs that place greater emphasis on student involvement in environmental activities lead to physical campus improvements, such as tree planting, as well as affect students' sense of place and mental well-being (Krasny & Delia 2015).

REFERENCES

Admasu, E., S.J. Thirgood, A. Bekele & M.K. Laurenson (2004). Spatial ecology of white-tailed mongoose in farmland in the Ethiopian Highlands. *African Journal of Ecology* 42: 153–159. <https://doi.org/10.1111/j.1365-2028.2004.00498.x>

Ajai, S.S. (1977). Field observations on the African giant rat *Cricetomys gambianus* Waterhouse in southern Nigeria. *East African Wildlife Journal* 15: 191–198. <https://doi.org/10.1111/j.1365-2028.1977.tb00397.x>

Aneesh, K.S., C.K. Adarsh & P.O. Nameer (2013). Butterflies of Kerala Agricultural University (KAU) campus, Thrissur, Kerala, India. *Journal of Threatened Taxa* 5: 4422–4440. <https://doi.org/10.11609/JoTT.02870.4422-40>

Baker, L.R., T.W. Arnold, O.S. Olubode & D.L. Garshelis (2011). Considerations for using occupancy surveys to monitor forest primates: a case study with Sclater's monkey (*Cercopithecus sclateri*). *Population Ecology* 53: 549–561. <https://doi.org/10.1007/s10144-011-0274-5>

Bocsi, T., P.S. Warren, R.W. Harper & S. DeStefano (2018). Wildlife habitat management on college and university campuses. *Cities and the Environment* 11(1): Article 1.

Calder, W. & R.M. Clugston (2003). International efforts to promote higher education for sustainable development. *Planning for Higher Education* 31: 30–44.

Dariye, E.P. (2016). Woody plant diversity and composition in two nature areas on the American University of Nigeria campus, Yola, Adamawa State. Unpublished undergraduate thesis. American University of Nigeria, Yola, Adamawa State, Nigeria.

Dombrosky, J. & S. Wolverton (2014). TNR and conservation on a university campus: a political ecological perspective. *PeerJ* 2: e312. <https://doi.org/10.7717/peerj.312>

Hines, J.E. (2006). PRESENCE—Software to estimate patch occupancy and related parameters. USGS-PWRC. <https://www.mbr-pwrc.usgs.gov/software/presence.html>

Hubbard, R.D. & C.K. Nielsen (2009). White-tailed deer attacking humans during the fawning season: a unique human–wildlife conflict on a university campus. *Human-Wildlife Conflicts* 3: 129–135. <https://doi.org/10.26077/409s-td37>

Knight, M.H. (1988). Thermoregulation in the largest African cricetid, the giant rat *Cricetomys gambianus*. *Comparative Biochemistry and Physiology* 89: 705–708. [https://doi.org/10.1016/0300-9629\(88\)90856-0](https://doi.org/10.1016/0300-9629(88)90856-0)

Krasny, M.E. & J. Delia (2015). Natural area stewardship as part of campus sustainability. *Journal of Cleaner Production* 106: 87–96. <https://doi.org/10.1016/j.jclepro.2014.04.019>

MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L.L. Bailey & J.E. Hines (eds.) (2006). *Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence*. Elsevier, San Diego, CA.

McCleery, R.A., R.R. Lopez, L.A. Harveson, N.J. Silvy & R.D. Slack (2005). Integrating on-campus wildlife research projects into the wildlife curriculum. *Wildlife Society Bulletin* 33: 802–809. [https://doi.org/10.2193/0091-7648\(2005\)33\[802:IOWRPI\]2.0.CO;2](https://doi.org/10.2193/0091-7648(2005)33[802:IOWRPI]2.0.CO;2)

Normile, D. (2004). Conservation takes a front seat as university builds new campus. *Science* 305(5682): 329–331. <https://doi.org/10.1126/science.305.5682.329>

Ramesh, T. & C.T. Downs (2015). Impact of land use on occupancy and abundance of terrestrial mammals in the Drakensberg Midlands, South Africa. *Journal for Nature Conservation* 23: 9–18. <https://doi.org/10.1016/j.jnc.2014.12.001>

Ramli, R. (2004). Green areas and avian species richness in University of Malaya campus, peninsular Malaysia. *Malaysian Journal of Science* 23: 7–13. <https://mjs.um.edu.my/article/view/8498>

Schuette, P., A.P. Wagner, M.E. Wagner & S. Creel (2013). Occupancy patterns and niche partitioning within a diverse carnivore community exposed to anthropogenic pressures. *Biological Conservation* 158: 301–312. <https://doi.org/10.1016/j.biocon.2012.08.008>

Tennent, J., C.T. Downs & M. Bodasing (2009). Management recommendations for feral cat (*Felis catus*) populations within an urban conservancy in KwaZulu-Natal, South Africa. *South African Journal of Wildlife Research* 39: 137–142. <https://doi.org/10.3957/056.039.0211>

Waser, P.M. (1980). Small nocturnal carnivores: ecological studies in the Serengeti. *African Journal of Ecology* 18: 167–185. <https://doi.org/10.1111/j.1365-2028.1980.tb00640.x>

van Weenen, H. (2000). Towards a vision of a sustainable university. *International Journal of Sustainability in Higher Education* 1: 20–34. <https://doi.org/10.1108/1467630010307075>

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Author contribution: All authors designed the study; IS collected the data; IS and JC organized the data; LRB performed data analyses; IS and LRB drafted the manuscript; JC provided editorial inputs to the manuscript.





Killer Whale *Orcinus orca* (Linnaeus, 1758) (Mammalia: Cetartiodactyla: Delphinidae) predation on Sperm Whales *Physeter macrocephalus* Linnaeus, 1758 (Mammalia: Cetartiodactyla: Physeteridae) in the Gulf of Mannar, Sri Lanka

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Abstract: To date in Sri Lankan waters, there has been limited research on Killer Whales. These animals have been recorded almost all around the island, except in the northernmost waters and in Palk Bay. The highest observed concentrations are from the northeastern, south/southwestern and northwestern coastal waters of Sri Lanka. These have come from both opportunistic observations and dedicated scientific surveys. Seasonal trends in sightings in some locations suggest fairly consistent occupancy. Transient Killer Whales have been documented attacking/killing Sperm Whales from many geographic locations around the world. To date, there is only one published account of Killer Whales feeding in Sri Lankan waters. Our paper presents, for the first time, field observations of Killer Whales preying upon superpods of Sperm Whales in the waters off the Kalpitiya Peninsula (eastern half of the Gulf of Mannar), northwestern Sri Lanka. The incidents took place on two separate occasions during the months of March and April, 2017.

Keywords: Dolphin, feeding, Kalpitiya Peninsula, marine mammal, observations.

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INTRODUCTION

The Killer Whale *Orcinus orca* is an Odontocete belonging to the family Delphinidae (Oceanic dolphins) and is the largest member of the family. Killer Whales are found in all oceans (Forney & Wade 2006). They range from polar ice edges to the tropics and from the shoreline to the open oceans. Their abundance is highest in temperate and polar waters (Forney & Wade 2006). Killer Whales are the dominant oceanic predator, with a varied diet, including cephalopods, bony fish, sharks, seabirds, marine turtles, and a variety of marine mammals (Jefferson et al. 1991; Dahlheim & Heyning 1999; Ford & Ellis 1999; Ford 2017).

Prey specialization of Killer Whale communities depends on the 'type' they belong to; currently there are three recognized types in the North Pacific: (i) resident, (ii) transient, and (iii) offshore Killer Whales (Ford 2017). Out of the three types, the transients are specialised marine mammal hunters with the occasional bird or cephalopod taken, whereas the other two types appear to feed almost exclusively on fish and invertebrates (Ford 2017), to date only the transient type has been recorded in Sri Lankan waters. Killer Whale predation on marine mammals has been documented from localities around the world (Jefferson et al. 1991). Long-term research in the northeastern Pacific has given us most of our understanding of mammal hunting by Killer Whales. Pinniped and dolphin predation by Killer Whales is reasonably well documented (see Dahlheim & White 2010, for example), but scientific reports of them hunting the great whales are less common (Jefferson et al. 1991; Reeves et al. 2006; Gemmell et al. 2015).

In Sri Lankan waters, there has been limited research on Killer Whales. These animals have been recorded almost all around the island, except in the northernmost waters and in Palk Bay (Illangakoon 2011; Martenstyn 2013). The highest observed concentrations are from the northeastern, south/southwestern, and northwestern coastal waters of Sri Lanka. These have come from both opportunistic observations and dedicated scientific surveys. Seasonal trends in sightings in some locations suggest fairly consistent occupancy (Ranil P. Nanayakkara 2010, 2011, 2015, 2016, 2017, 2018). Most sighting data so far, however, have been collected during whale-watching trips, Sri Lanka Coast Guard records and from fisher folk; none of these can be considered scientifically rigorous.

Transient Killer Whales have been documented attacking/killing Sperm Whales from many geographic locations around the world (Pitman et al. 2001). To date,

there is only one published account of Killer Whales feeding in Sri Lankan waters. Gemmell et al. (2015) observed Killer Whales off southwestern Sri Lanka (Mirissa) preying on a mesoplodont beaked whale and Sperm Whales. The latter incident coincided with the egress of the migration (leaving) of Sperm Whales from the Gulf of Mannar. In the same paper, there is a report of a Blue Whale *Balaenoptera musculus* that bore scars from an attack by Killer Whales. Our paper presents, for the first time, field observations of Killer Whales preying upon superpods of Sperm Whales in the waters off the Kalpitiya Peninsula (eastern half of the Gulf of Mannar), northwestern Sri Lanka. The incidents took place on two separate occasions during the months of March and April 2017.

METHODS

Study Site

The Gulf of Mannar is an inlet of the Indian Ocean that lies between southeastern India and western/northwestern Sri Lanka (Image 1). Observations were made from a 19ft fibreglass boat fitted with a 40BHP outboard motor, dedicated to cetacean research during the months of March and April 2017; this period coincides with large mating aggregations of Sperm Whales in the eastern half of the Gulf of Mannar. The vessel departed Kandakuliya fishing harbour (6:45h), northwest, Sri Lanka, and headed offshore, approximately 15nm in a westerly direction in a zig-zag manner. The survey was dedicated to the study of large aggregations of Sperm Whales in the eastern Gulf of Mannar.

For each encounter, we attempted to photograph all the Killer Whales present using DSLR cameras with telephoto zoom lenses following established protocols for photo-identification studies of cetaceans (Ford 2017; Barrett-Lennard 2011). Individual animals were identified by a combination of features including notches of the dorsal fin and fin shape, as well as differences in the eye patch and saddle patch pigmentation and shape. Furthermore, for each encounter we used a GoPro Hero 6 underwater camera to record the underwater activities <<https://vimeo.com/227727434>>. Additionally, we used a SQ26-08 (Cetacean Research Technology) hydrophone to record the codas, clicks of the Sperm Whales and Killer Whales.

Observation 1: 18 March 2017

The research team followed and observed a pod of 100–200 Sperm Whales distributed in a radius of about

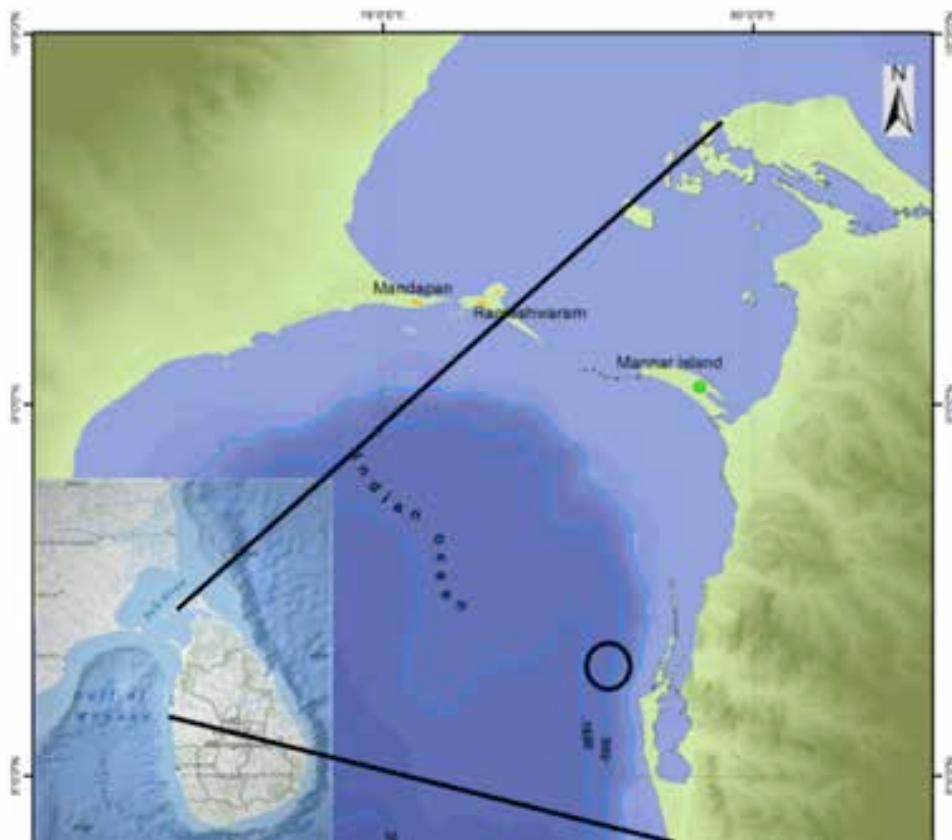


Image 1. The study area in the eastern half of the Gulf of Mannar.

1–3 km. The sea was calm (Beaufort 1) and the team could see to the horizon with blows of Sperm Whales scattered around the research vessel. At around 09.45h, a group of Sperm Whales broke away from the larger aggregation and started travelling in a north-easterly direction at great speed (almost porpoising); the breakaway group consisted of the largest members of the superpod (males), numbering approximately 15–20 individuals. We followed the breakaway group for approximately 1 nautical mile. The other whales were far behind and widely spread out. Meanwhile, the breakaway group slowed down and joined up with a smaller group of Sperm Whales, consisting of approximately 10 individuals, which was a maternal pod that consisted of females, sub-adults, and calves. They reoriented in one great mass, packed as close together as possible (the depth of the water was 1,068m). We then noticed a commotion on the water surface just ahead of us; when the vessel approached, we saw the Sperm Whales huddled in a tight group on the surface, with the largest individuals occupying the outer margins of the group; they were arranged laterally, aligned together. They all appeared agitated. Body orientation changed haphazardly, respiration became frequent, there was rolling and tail slapping and the large males

kept opening and shutting their jaws below the surface of the water.

Suddenly, a falcate dorsal fin surfaced approximately 5m from the research vessel. Several more falcate dorsal fins soon appeared followed by the unmistakable large triangular dorsal fin of an adult male Killer Whale. It was clear now that the breakaway group had responded to Sperm Whales who were in danger and had sent out sonar signals. They may have been delegated to deal with the situation perhaps even to act as a decoy to allow the Sperm Whales they'd left behind to get away.

The Killer Whales then surfaced again and charged directly into the Sperm Whale pod, with a female Killer Whale leading the attack, while the large male remained 10m away from the focus of attack. The Sperm Whales reacted by thrashing their tails and clustering close together on the surface, with the large mature males guarding the maternal pod by forming a defensive flotilla facing the attacking predators. The Killer Whales attack pod, which comprised approximately 12 individuals including one large male and two calves, was led by a female (Female 1) with a notch on its dorsal fin (Image 2). Female 1 repeatedly charged at the Sperm Whales along with five other Killer Whales (Image 3), whilst the remaining Killer Whales started circling the prey,

not letting them get away (Image 4). The Killer Whales circled around the Sperm Whales, diving in among them, apparently trying to separate the smaller juveniles and the calves. The water at the centre of the Sperm Whales turned white as they started tail slapping. Two Killer Whales then suddenly cut into the midst of the Sperm Whales and moved aggressively between individual Sperm Whales in an apparent attempt to break the pod apart (Image 5 & 6). At times, the attacking Killer Whales seemed to withdraw from the attack and busily jostle along the outer edges before resuming the assault. All the while the large male Killer Whale kept its distance, patrolling the perimeter. The Killer Whales displayed a lot of surface behaviour while attacking the Sperm Whales, e.g., tail slapping, breaching, whilst the members that were not involved in the attack, were seen rolling as well.

The attack lasted from 10.03h to 11.37h. In the turmoil, two Sperm Whales got separated from the pod and were immediately pursued by about six Killer Whales, which swam about 2m from their quarry. The two separated Sperm Whales managed to re-join the maternal pod when three large male Sperm Whales rushed to their rescue and came between them and the attackers. It was evident that the Sperm Whales were agitated; their faeces stained the water orange (Image 7). As the Killer Whales continued their attack, the Sperm Whales changed orientation, bringing their heads into the middle, tails outwards, creating a 'marguerite' formation (Nishiwaki 1962). This did not seem to slow the intensity of the attack, however, so the Sperm Whales reoriented their heads outward, while maintaining the circle formation, now apparently using our nearby boat as another line of defence. The large male Sperm Whales appeared to be trying to shield the females and young from the attacking Killer Whales, opening and closing their mouths to show their teeth. By now, blood was visible in the water. We observed the predators led by the same adult female (Female 1) take bites out of the male defenders, mostly from their bellies and tail stock, beneath the surface. Several Sperm Whales bore scars, from bite marks of the Killer Whales.

After approximately 90 minutes of sustained attack, the Killer Whales gradually started to peel off and we observed them at a distance; they were very active, tail slapping, breaching and, at times, spy hopping. We followed the Killer Whales. Abruptly, the Killer Whales came directly at our research vessel and started to circle it. Closer and closer they came, surrounding us the same way they had surrounded the Sperm Whales. Then one butted our boat; we clearly felt the impact.



Image 2. Female 1: the leader of the attacking pod of Killer Whales.



Image 3. Female 1 leading the attack on the Sperm Whales.



Image 4. Part of the Killer Whale pod circling the Sperm Whale pod.



Image 5. Killer Whales attacking the Sperm Whales.

As we recorded the incident on our GoPro camera, five Killer Whales charged directly at our vessel and dove suddenly just a couple of metres below our boat, passing <1m away from the hull. This behaviour was similar to the technique used by Killer Whales in the Antarctic to dislodge seals from ice floes (Pitman et al. 2001). After this, the Killer Whales broke off and moved away from us all the while displaying a lot of surface activity.

Observation 2: 3 April 2017

At 10.00h, a group of about 20 Killer Whales was observed, comprising all the members of the pod observed on 18 March 2017, as well as eight new members. This pod was made up of adult females, two large adult males, sub-adult males/females and two calves and they were sighted approximately 10nm from shore. The pod was travelling in a northerly direction with consistent surfacing intervals. At around 10.20h, the pod suddenly changed direction and started heading north-east with increasing speed. Our first sighting of Sperm Whales occurred at 10.45h, about 2nm from the 18 March location. It is customary for the superpods of Sperm Whales in the Gulf of Mannar to break up into smaller pods of 20–30 individuals around the end of March (RN unpublished). The Sperm Whales we encountered on 3 April comprised such a smaller



Image 6. Remaining Killer Whales joining the attack.

grouping and consisted of females, young, and five large males.

The Killer Whales started to attack the Sperm Whales as soon as they encountered them at 10.52h (the depth of the water was 1,021m). Led by the same lead female (Female 1) (Image 3) we observed during the March 18 encounter, the Killer Whales commenced by nudging and ramming the adult females, in an attempt to get at the calves, while swimming abreast of them. The Sperm Whales responded by swimming rapidly away, with their bodies almost leaving the water, with the predators in close pursuit. Except for the two male Killer Whales



Image 7. Sperm Whales defecating, possibly to distract the Killer Whales.

that stayed about 20m away, all the other Killer Whales repeatedly charged the Sperm Whale pod from left and right. The Sperm Whales were swimming abreast with the calves in the middle. At 11.09h we observed at least five additional Killer Whales appearing to join the attack. The Sperm Whales stopped swimming, and seemed agitated, with considerable surface activity and splashing. They were defecating as was evident from the orange-stained water. The large Sperm Whale males, turned on the Killer Whales, and began to chase them away, the Killer Whale pod started to swim away at great speed. The whole incident lasted two hours.

Curiously, the attack seemed to be confined to harassment because we never observed the Killer Whales lunging to bite chunks from their quarry as we had on 18 March. No signs of physical injury were noted in the Sperm Whales after the attack, nor was blood evident. Perhaps the Killer Whales may have been trying to determine whether there were any particularly vulnerable individual Sperm Whales to take advantage of or perhaps the encounter may have constituted practice or play for the juvenile Killer Whales, which were present in the pod.

DISCUSSION

Sperm Whales are found in Sri Lankan waters year-round in small pods that mostly number 2–15 individuals (Illangakoon 2002). Between January and April, however, they start to occur in larger pods to ultimately form superpods numbering 100–450 individuals (<https://uk.whales.org/2015/04/01/an-armada-of-whales-wdc-in-sri-lanka/> & <https://www.theguardian.com/environment/gallery/2017/mar/29/sex-death-sperm-whales-orcas-indian-ocean-in-pictures>). At that time of the year large males are seen in Sri Lankan waters; these males, denizens of temperate and polar waters, migrate to tropical waters to mate. Superpods congregate in the eastern half of Gulf of Mannar, northwestern Sri Lanka. Our observations confirm Gemmell et al. (2015)'s finding that Killer Whales are predators of Sperm Whales in Sri Lankan waters. For the first time, we show that Killer Whales enter Sri Lankan waters and prey on large aggregations of Sperm Whales.

It was clear that the adult Killer Whales we saw during both incidents were experienced hunters of Sperm Whales. The attacks were well-coordinated and efficient. The copious defecation by the Sperm Whales may well have been occasioned by hyperarousal (Jansen et al. 1995) because we observed that particular

response during both incidents. It was interesting to see the different roles played by adult female and male Killer Whales (see Pitman et al. 2001). Like in a pride of lions (Rudnai 1974) the adult females led the hunt. Was the hunting technique a series of lunges at the much-bigger and potentially dangerous prey, designed to minimize risk for the attacker? No Sperm Whale was observed killed during the two incidents, as far as we could tell. Yet we did see chunks being bitten off the quarry during the 18 March attack and the immediate waters were stained with blood.

The role of the large male in hunting parties of Killer Whales is unclear. The Heinrichs video (2013) of a hunt by Killer Whales on Sperm Whales off southwestern Sri Lanka shows an adult male Killer Whale in the thick of a melee, as attackers appear to try to drown a juvenile Sperm Whale. The male is seen actively participating in the attack, even though a female is leading the pack and inflicting most of the injuries. Interestingly, none of the individuals recorded from the attacks in north-west of the country match to the ones in the video nor from the northern Indian Ocean Killer Whale catalogue (Northern Indian Ocean Killer Whale Alliance (NIOKWA)). None of the adult Killer Whale males we saw actually attacked Sperm Whales; their role appeared to be to intimidate, frighten and corral breakaway quarry. Other accounts of Killer Whale attacks show adult males adopting aggressive, peripheral or passive roles (Whitehead & Glass 1985; Arnbom et al. 1987; Silber et al. 1990). Vidal & Pechter (1989) asserted that predation on large whales by Killer Whales is successful when adult males are involved in the attack, and that attacks on large whales involving only females and subadults are largely unsuccessful. Estes et al. (2006), mentioned that some specialization of roles have been noted in Killer Whales. Adult females appear to be the most active and effective individuals during an actual killing phase of an attack on large whales. An adult male participates in the successful attack on large whales only to finish off a whale that has been critically wounded by the females and immature Killer Whales; however, we did not see a pod of Killer Whales that lacked an adult male, so we are unable to test these hypotheses. Budylenko (1981) observed large male Killer Whales leading attacks; prey weakened by the males were then 'handed over' to females and subadults for final despatch. Our observations do not support this technique being used in Sri Lankan waters. The females and subadults did a very effective job by themselves with no adult male intervention. Cultural differences among different communities of transient Killer Whales may account for the utility of various

hunting strategies in different geographical locations (see Whitehead & Glass 1985).

The defensive marguerite formation appeared initially to be dangerous for the Sperm Whales and a hopeless gambit, but is perhaps an attempt by Sperm Whales to present to the predator bodies that they could withstand being injured, yet survive, while shielding the vulnerable young at the centre, with a lot of tail slapping. Perhaps sufficient meat is bitten off during an attack to satiate the Killer Whales, which then leave the young Sperm Whales alone. If this is true, it would be a clear and striking demonstration of altruism among these sentient creatures. The marguerite formation also spreads risk more or less evenly amongst the defenders. During the 18 March attack, evidently the presentation of bodies failed to satisfy the hunger of the large party of Killer Whales, hence the abandonment of the passive technique and the reversion to the full-on threatening forward-facing posture in a line, facing the same direction (flotilla formation). It must be noted that, despite the vulnerability of Sperm Whales as they keep their bodies oriented inward while in marguerite formation, they are not entirely defenceless; the tail stock can deliver a heavy blow. Pitman et al. (2001) asserted that the marguerite formation is used when the Sperm Whale pod is small (10–15 individuals) whereas larger aggregations generally adopt the flotilla strategy to thwart predator attack. We saw both formations being used and the use of one or the other appeared to be determined by the effectiveness of resisting the attackers.

Diving is also used as a defensive strategy by Sperm Whales, and because they can dive at least 2km below the surface, it can be hypothesised that it can be an effective defence against predators that are unable to reach such depths (Rice 1989). Berzin (1972) identified three separate fright reactions of Sperm Whales — diving, aggregating at the surface and flight — but did not identify the circumstances that gave rise to each. Our observations are similar to those of Pitman et al. (2001), and show that a specific reaction is context-dependent. For example, small Sperm Whale pods will dive if a vessel approaches, but large pods will remain at the surface until the perceived threat is imminent. An attack by predators, such as Killer Whales, will on the other hand, elicit a reaction such as a marguerite formation or frontal confrontation (flotilla formation) with jaws being open and shut threateningly (Ranil P. Nanayakkara 2008, 2012, 2013, 2014, 2015). Flight is also possible, but we did not observe diving as a defensive manoeuvre when under predator attack. We

did, however, observe several individual Sperm Whales, approximately 5–10 m below the surface. The inability of the vulnerable young to dive deeper and faster than attacking Killer Whales may discourage defending Sperm Whales from taking that approach.

We observed a pod of about 10–15 adult male Sperm Whales rushing to the aid of a maternal pod during the March 18 incident. The question arises as to how the male group was gathered and how the individuals were coordinated in responding to the danger. Did the maternal pod signal danger or did the males sense peril and respond accordingly? Caldwell et al. (1966) and Arnbom et al. (1987) state that Sperm Whales can sound long-distance alarm/summons calls when threatened. Of course, the gathering of superpods will shorten alarm response times considerably.

Mammal-hunting Killer Whales elsewhere occur mostly in small-sized pods, whereas piscivorous and generalist feeders occur in larger-sized pods of up to 30 individuals (Ford 2017; Dahlheim & White 2010). Baird & Dill (1996) suggested that the optimal group size for northern Pacific transient mammal-hunting Killer Whales is three individuals and suggest that larger groups would suffer the cost of increased probability of detection by prey and therefore reduced hunting success, as the northern Pacific transients feed mainly on seals. Other marine mammal-eating Killer Whales have also been observed around the world in small pods. Hoelzel (1991) reported an average of two individuals for the Patagonian population, while Beck et al. (2012) provided the figure of five for Killer Whales in Scottish waters. Antarctic populations of Killer Whales take the opposite tack. The mammal-feeding Type A and Type B populations gather in large pods —up to 38 individuals for the former and 24 for the latter (Pitman & Ensor 2003). These authors report a pod of 21 individuals of Type A Killer Whales attacking an Antarctic Minke Whale *Balaenoptera bonaerensis*. Visser et al. (2010) reported eight Killer Whales in New Zealand attacking a pod of false Killer Whales *Pseudorca crassidens*. Transient Killer Whales that attack and kill great whales generally operate in large pods, as the large group size would probably be much more effective. As such, the Sperm Whale hunters found in Sri Lankan waters operate in a similar manner, in large pods of 10–20 individuals.

From our limited observations it appears that the hunting packs of Killer Whales off Sri Lanka's coast follow the pattern of their Antarctic counterparts. But again, the high numbers we observed may simply reflect a gathering that comes from the temporary bounty and opportunity offered by the Sperm Whale superpods.

Hunting packs of Killer Whales at other times of year may be far smaller. Indeed, Gemmell et al. (2015) did not report a massed attack when they observed the mesoplodont whale being killed. Another interesting observation is that while mammal-hunting Killer Whales are generally silent in other localities, while pursuing Sperm Whale superpods off northwestern Sri Lanka they were very vocal; our hydrophone and recorder picked up loquacious chatter from the predators, even as they attacked their huge prey. This sort of vocalization has been recorded from Monterey Bay, California, where a pod of Killer Whales has been recorded vocalizing frequently while hunting down a female Grey Whale *Eschrichtius robustus* (Goley & Straley 1994). Deecke et al. 2005 stated that being silent may help in being stealthy and in locating prey, and that active sound processing presumably becomes allowable, and might be functionally important, once the Killer Whales have made contact with the prey. As with the encounter of 18 March 2017, Deecke et al. (2005) also mentioned that the sound produced by the hunting pack of Killer Whales might attract other distant foraging Killer Whales to the site, to take advantage of the kill, if a kill should happen. They went on to say that the possibility is unlikely. Conversely, from our April encounter, we did see a smaller pod suddenly appearing on the scene and taking part in the attack. We photographed the dorsal fins of the Killer Whales we observed and are in the process of building up a catalogue, although it is likely that not all the individuals were photographed (Appendix A).

While encounters with Killer Whales typically have been considered rare and unpredictable off Sri Lanka, the area offshore from the northwest to the northeast appears to support abundant Killer Whales throughout the year (Ranil P. Nanayakkara 2009, 2010, 2011–2017.) and provides an opportunity to study the dynamics of this little-known population. Interestingly, before 2008, there was only one record of a Killer Whale and that was an individual that landed ashore as bycatch (Ilangakoon et al. 1992). Since then there have been many sightings of Killer Whales off the south and southeastern waters of the country (RN pers. comm. with whale watching operators). After the end of the 30-year war in Sri Lanka, researchers have had access to the northwestern and northeastern waters off Sri Lanka, resulting in an increase in research activity. Undoubtedly, Killer Whales have always been present, but researchers have been absent, hence the contemporary rise in observations. Along with the considerable increase in Killer Whale sightings there has been a related increase in observations of their predation on large whales, such as the present paper

and Gemmell et al. (2015). Furthermore, anecdotal evidence from the fisher community suggests that Killer Whales have been following Sperm Whales superpods for many years in the waters off northwestern Sri Lanka. Research in Sri Lanka into predator/prey relationships of Killer Whales in the littoral waters off Sri Lanka is still in its infancy and warrants additional study.

REFERENCES

Arnborn, T., V. Papastavrou, L.S. Weilgart, & H. Whitehead (1987). Sperm Whales react to an attack by Killer Whales. *Journal of Mammalogy* 68(2): 450–453.

Baird, R.W. & L.M. Dill (1996). Ecological and social determinants of group size in transient Killer Whales. *Behavioral Ecology* 7: 408–416.

Barrett-Lennard, L., C. Matkin, J. Durban, E. Saulitis & D. Ellifrit (2011). Predation on gray whales and prolonged feeding on submerged carcasses by transient Killer Whales at Unimak Island, Alaska. *Marine Ecology Progress Series* 421: 229–241.

Beck, S., S. Kunigas, R. Esteban & A.D. Foote (2012). The influence of ecology on sociality in the Killer Whale (*Orcinus orca*). *Behavioral Ecology* 23: 246–253.

Berzin, A. (1972). The Sperm Whale. Israeli Program for Scientific Translations, Jerusalem. (translated from Russian), 394pp.

Budylengko, A. (1981). Distribution and some aspects of the biology of Killer Whales in the South Atlantic. Report of the International Whaling Commission 31: 523–525.

Caldwell, D.K., M.C. Caldwell & D.W. Rice (1966). Behaviour of the Sperm Whale, *Physeter catodon* L. Pages 677–717. In: Norris, K.S. (ed.). *Whales, Dolphins and Porpoises*. University of California Press, Berkeley, CA, USA.

Dahlheim, M.E. & J.E. Heyning (1999). Killer Whale *Orcinus orca* (Linneaus, 1758), pp.281–322 In: Ridgway, S.H. & R. Harrison (eds.). *Handbook of Marine Mammals, Vol. 6: The second book of dolphins and the porpoises*. Academic Press, 486pp.

Dahlheim, M.E & P.A. White (2010). Ecological aspects of transient Killer Whales (*Orcinus orca*) as predators in southeastern Alaska. *Wildlife Biology* 16: 308–322.

Ford, J.K.B. & G.M. Ellis (1999). *Transients: Mammal-hunting Killer Whales of British Columbia, Washington, and southeastern Alaska*. University of British Columbia Press, 96pp.

Ford, J.K.B. (2017). Killer Whale *Orcinus orca*. pp. 531–537 In: Würsig, B., J.G.M. Thewissen & K. Kovacs (eds.). *Encyclopedia of Marine Mammals, 3rd Edition*. Academic Press, Burlington, MA, 1190pp.

Forney, K.A. & P.R. Wade (2006). Worldwide distribution and abundance of Killer Whales, pp.145–162. In: Estes, J. (ed.). *Whales, Whaling and Ecosystems*. University of California Press, Berkeley, California, USA, 418pp.

Gemmell, G.L., J.D. McInnes, S.J. Heinrichs & G. Wijeyeratne (2015). Killer Whale (*Orcinus orca*) Predation on Whales in Sri Lankan Waters. *Aquatic Mammals* 41: 265–271. <https://uk.whales.org/2015/04/01/an-armada-of-whales-wdc-in-sri-lanka/>.

<https://www.theguardian.com/environment/gallery/2017/mar/29/sex-death-sperm-whales-orcas-indian-ocean-in-pictures>.

Heinrichs, S.J. (2013). <https://www.youtube.com/watch?v=sRFp3kEBV-A>.

Hoelzel, A.R. (1991). Killer Whale predation on marine mammals at Punta Norte, Argentina: food sharing, provisioning and foraging strategy. *Behavioral Ecology and Sociobiology* 29: 197–204.

Ilangakoon, A.D., H.A.K. Subasinghe & W.P. Mahendra (1992). On rare cetacean species off Sri Lanka including the Killer Whale *Orcinus orca* (Linn.) (Delphinidae: Cetacea). Miscellaneous Note 3. *Journal of the Bombay Natural History Society* 89: 363–365.

Ilangakoon, A.D., R. Jayewardene & L. Perera (2011). First confirmed sightings of the Killer Whale (*Orcinus orca*) in Sri Lanka's waters. *Marine Biodiversity Records* 3: 1–4. <https://doi.org/10.1017/S1755267210000047>

Jansen, A., X. Nguyen, V. Karpitsky & M. Mettenleiter (1995). Central Command Neurons of the Sympathetic Nervous System: Basis of the Fight-or-Flight Response. *Science Magazine* 5236 (270).

Jefferson, T.A., P.J. Stacey & R.W. Baird (1991). A review of Killer Whale interactions with other marine mammals: Predation to co-existence. *Mammal Review* 21(4): 151–180. .

Martenstyn, H. (2013). *Out of the Blue, Guide to the Marine Mammals of Sri Lanka, Southern India and the Maldives*. Gunaratne Offset (Pvt) Ltd., Sri Lanka, 256pp.

Northern Indian Ocean Killer Whale Alliance (<http://niokillerwhales.wixsite.com/niokwa/copy-of-id-catalogue-of-nio-killer>). downloaded on 3 April 2017.

Pitman, R.L., L.T. Ballance, S.I. Mesnick & S.J. Chivers (2001). Killer whale predation on sperm whales: observations and implications. *Marine Mammal Science* 17(3): 494–507. <https://doi.org/10.1111/j.1748-7692.2001.tb01000.x>

Pitman, R.L. & P. Ensor (2003). Three forms of Killer Whales (*Orcinus orca*) in Antarctic waters. *Journal of Cetacean Research and Management* 5: 131–139.

Reeves, R.R., J. Berger & P.J. Clapham (2006). Killer Whales as predators of large baleen whales and Sperm Whales pp. 174–187. In: Estes, J.A., D.P. DeMaster, D.F. Doak, T.M. Williams, & R.L. Brownell, Jr. (Eds.), *Whales, Whaling, and Ocean Ecosystems*. University of California Press, Berkeley, California, USA.

Rice, D.W. (1989). Sperm Whale *Physeter macrocephalus* Linnaeus, 1758, pp. 177–233. In: Ridgway, S.H. & R. Harrison, (eds.). *Handbook of Marine Mammals. Volume 4*. Academic Press, London, UK, 442pp.

Rudnai, J.A. (1974). The pattern of lion predation in Nairobi Park. *East African Wildlife Journal* 12: 213–225.

Silber, G.K., M.W. Newcomer & M.H. Perez-Cortes (1990). Killer Whales (*Orcinus orca*) attack and kill a Bryde's whale (*Balaenoptera edeni*). *Canadian Journal of Zoology* 68(7): 1603–1606. <https://doi.org/10.1139/z90-238>

Vidal, O. & G. Pechter (1989). Behavioral observations on fin whale, *Balaenoptera physalus*, in the presence of Killer Whale, *Orcinus orca*. *Fishery Bulletin*, U.S. 87: 370–373.

Visser, I.N., J. Zaeschmar, J. Halliday, A. Abraham, P. Ball, R. Bradley, S. Daly, T. Hatwell, T. Johnson, W. Johnson, L. Kay, T. Maessen, V. McKay, T. Peters, N. Turner, B. Umuroa & D.S. Pace (2010). First record of predation on false Killer Whales (*Pseudorca crassidens*) by Killer Whales (*Orcinus orca*). *Aquatic Mammals* 36(2): 195–204. <https://doi.org/10.1578/AM.36.2.2010.195>

Whitehead, H. & C. Glass (1985). Orcas (Killer Whales) attack humpback whales. *Journal of Mammalogy* 66: 183–185.

Appendix 1. ID catalogue of Killer Whales encountered in both attacks



NIO-054



NIO-055



NIO-056



NIO-057



NIO-058



NIO-059



NIO-060



NIO-061



The Critically Endangered White-rumped Vulture *Gyps bengalensis* in Sigur Plateau, Western Ghats, India: Population, breeding ecology, and threats

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Abstract: The present study aimed to assess the population status, breeding ecology, and conservation threats of Critically Endangered White-rumped Vulture in Sigur Plateau, Tamil Nadu, India from June 2011 to May 2012. The population of White-rumped vulture was estimated in the roosting and nesting sites twice in a month. Nesting colonies were systematically visited four times in a month during the breeding season to study nesting and breeding ecology. Carcasses and vulture counting was done by opportunistic count method. Two sets of questionnaires namely 'precise and closed' and 'broad and open-ended' were developed to assess the people's perception on vulture conservation. The overall population of White-rumped Vultures was estimated about 70 to 115 individuals. In total, 68 nests were observed in two nesting colonies. Most of the nests (97%) were recorded on *Terminalia arjuna* and only 3% on *Spondias mangifera*. Among the 68 constructed nests, 34 were incubated and 30 chicks were fledged out from the nests with 88% breeding success. Feeding behavior was observed from 28 carcasses, Vultures were attended only 15 carcasses an average of 56.04±3.29 individuals of vultures were recorded. Interestingly, Elephant (61.8±5.1) and Indian Gaur (58.5±0.3) carcasses were attracted in greater numbers of vultures in subsequent days (3.5±0.2) than other carcasses. People's attitude to vulture conservation was positive and useful in 90.82% of the cases (n=99). Cattle carcass disposal method favored to vultures in these regions. The Sigur Plateau to be declared as "Vulture Sanctuary" in order to legally protect and conserve the country's southern-most wild and viable Critically Endangered White-rumped Vulture population in the landscape.

Keywords: Carcass, conservation, feeding behavior, Mudumalai Tiger Reserve, nest, Nilgiri Hills, population estimation, vulture sanctuary.

Tamil abstract: இந்த ஆய்வு கட்டுரை ஆனது மிக அருகிய (Critically Endangered) வெள்ளமுத்துக் கழுகுகளின் எண்ணிக்கை இனப்பெருக்க தழுவியல் மற்றும் பாதுகாப்பு அச்சுறுத்தல்கள் மதிப்பிடுவதை நோக்கமாகக் கொண்டது ஜூன் மாதம் 2011 முதல் மொதம் 2012 வரை இந்தியாவின் தமிழ்நாட்டின் உள்ள சிகர் பிடுமிகி வன பகுதியில் இந்த ஆய்வு மேட்காள்ப்பட்டது வெள்ளமுத்துக் கழுகுகளின் எண்ணிக்கையை கண்ணகிட ஒரு மாதத்தில் இரண்டு முறையும் மற்றும் இனப்பெருக்க தழுவியல் மற்றும் இனப்பெருக்க காலம் பற்றிய ஆய்வுக்கு ஒரு மாதத்தில் நன்கு முறையும் கூடு கட்டுப் பட்டது தாங்களில் ஆய்வு மேட்காள்ப்பட்டது மேலும் இரந்த விவங்களில் கழுகு எண்ணிக்கை நிறுத்தல் சந்திரப்பவாத எண்ணிக்கை முறையால் செய்யப்பட்டது மக்களின் கருத்தை மதிப்பிடுவதற்காக துல்லியமான மற்றும் முடிய மற்றும் பாந்த மற்றும் திரந்த-முடிவான இரண்டு கேள்வித்தாங்கள் உருவாக்கப்பட்டன வெள்ளமுத்துக் கழுகுகளின் ஒட்டுமொத்த எண்ணிக்கை கூமர் 70 முதல் 115 கழுகுகள் என மதிப்பிடப்பட்டுள்ளது மொத்தத்தில் ஒ கூடும் காலனிகளின் காணப்பட்டன பெரும்பாலான கூடுகள் 97% டெர்மினியா அரசூஜனாவிலும் 3% மட்டுமே ஸ்போன்டியாஸ் மங்கி-பெரா மரங்களிலில் பதிவு செய்யப்பட்டன கட்டப்பட்ட 8 கூடுகளில் 34 அடைகாத்தன 30 குக்கள் பொறுத்து கூடுகளிலிருந்து 88% இனப்பெருக்க வெற்றியைப் பெற்றன உணவு உட்கார்னாம் மற்று 28 இரந்த விலங்குகளில் கண்ணகிடக்கப்பட்டது குக்கள் 15 இருந்த விலங்குகளில் உண்ணிவைத் 56.04±3.29 மட்டும் பதிவு செய்யப்பட்டன தவராஸ்ஸமாக மாகன (61.8±5.1) மற்றும் கட்டுமாடு (68.5±0.3) சடலங்களில் அதிக எண்ணிக்கையைக் கழுகுகள் கண்ணப்பட்டன மக்களின் மனின்வை கழுகு பாதுகாப்பு குறித்த மக்களின் அனுகுமுறை நேர்மறையாகவும் பயனுள்ளதாகவும் இருந்தது இந்த சிகர் பிடுமிகியில் கழுகுகளுக்கு சாக்கமாக கால்நடத் தலைங்களை அகற்றும் முறை காணப்படுகிறது இந்த ஆய்வு சிகர் பிடுமிகியை 'கழுகு சரணாலயம்' ஆக அறிவிக்குமாறு அரசுக்கு பரிந்தரை செய்கின்றது இதன் மூலம் மிக அருகிய வெள்ளமுத்துக் கழுகுகளின் பாதுகாப்பு சிகர் பிடுமிகியில் கட்டப்படுவமான பாதுகாப்பாக அமையும்.

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INTRODUCTION

White-rumped Vulture *Gyps bengalensis* was once abundant in southern and southeastern Asia. Populations of the White-rumped Vulture and other resident *Gyps* vulture species have declined very rapidly since the mid-1990s across the Indian subcontinent (Prakash 1999; Gilbert et al. 2006; Prakash et al. 2007; Chaudhary et al. 2012). Declines in numbers of the White-rumped Vulture have exceeded 99.9% in India (Prakash et al. 2007) and the species is now classified as Critically Endangered (BirdLife International 2001, 2018). The cause of these declines has been due to the veterinary drug diclofenac (Green et al. 2004; Oaks et al. 2004), which was widely used to treat livestock in Asia. Vultures are exposed to diclofenac by feeding on livestock carcasses which contain residues of this drug. Efforts to achieve the voluntary withdrawal of diclofenac for veterinary use began in 2004. The license to manufacture veterinary formulations of diclofenac was withdrawn by the Drug Controller General of India via a letter dated 11 May 2006 addressed to all the state drug controllers. A similar ban on the veterinary use of diclofenac was also introduced in Nepal and Pakistan in 2006 and Bangladesh in 2010. Despite the ban of this drug in the veterinary sector since 2006, the spillover of human diclofenac multi-dose formulations into the veterinary sector has continued to be the major threat along with other vulture-toxic veterinary drugs (Cuthbert et al. 2016). Vultures play an important role in the ecosystem by scavenging dead animals (Moleón et al. 2014) and the sharp decline of vultures in India has impacted disposal of livestock carcass, sky burial of Zoroastrians and is implicated in increases in human-related diseases such as rabies (Pain et al. 2003).

In southern India there are six species of vultures, viz.: Egyptian Vulture *Neophron percnopterus*, Red-headed Vulture *Sarcogyps calvus*, White-rumped Vulture *Gyps bengalensis*, Long-billed Vulture *Gyps indicus* and two migrants namely, Cinereous vulture *Aegypius monachus*, and Himalayan Griffon Vulture *Gyps himalayensis* are found. Some short term and sporadic studies have been carried out in Tamil Nadu (Davidar & Davidar 2002; Davidar 2007; Ramakrishnan et al. 2010, 2012, 2014; Praveen et al. 2014; Samson et al. 2014a, 2015, 2016a,b,c, 2017, 2018, 2019; Samson & Ramakrishnan 2017a,b, 2018a,b,c; Ramakrishnan et al. 2018; Kalanithi et al. 2018; Sebastián-González et al. 2019), Karnataka (Subramanya & Naveen 2006; Thejaswi 2004; Samson et al. 2014b; Samson & Ramakrishnan 2016; Padma 2018; Rajkumar 2018)

and Kerala (Sashikumar 2001; Sashikumar & Vishnudas 2018). In Sigur Plateau, populations of the four resident species excluding Cinereous and Himalayan Griffon vultures mainly depend on wild carcasses (90%) (Ramakrishnan et al. 2010). Previous studies in the study area reported that the retaliatory killing of carnivores through poisoning the carcasses was one of the threats to the vulture population (Davidar & Davidar 2002). The present study was aimed to assess the population status, breeding ecology, and conservation threats of Critically Endangered White-rumped Vulture in Sigur Plateau, Tamil Nadu, India from June 2011 to May 2012.

STUDY AREA

The Sigur Plateau is located in Mudumalai Tiger Reserve and its strategically situated between the Nilgiri Hills and the Eastern Ghats landscape (Figure 1). It covers an area of 778.80km² at an average elevation of 280m above mean sea level. The boundaries of the Sigur Plateau are Bandipur National Park (Karnataka) in the north, Wayanad Wildlife Scantuary to the west, and Sathyamangalam Tiger Reserve to the south and east. It harbors a diverse range of wild animals including Asian Elephant *Elephas maximus*, Tiger *Panthera tigris*, Leopard *Panthera pardus*, Indian Gaur *Bos gaurus*, Chital *Axis axis*, Sambar *Rusa unicolor*, and numerous other important mammal and bird species. The Critically Endangered *Gyps* vultures such as Long-billed, White-rumped, & Red-headed vultures and Endangered Egyptian vultures are also known to occur in this plateau (Ramakrishnan et al. 2012; Samson et al. 2016). The five major streams in the Sigur Plateau are the Moyar River, the Sigur River, the Avarahalla River, the Kedarhalla River, and the Gundatti-halla River crisscrosses the Moyar Valley and finally end up into the Bhavanisagar reservoir.

MATERIALS AND METHODS

Nest site count

A preliminary survey was conducted in June 2011 to identify the nesting and roosting sites of White-rumped Vulture in the Sigur Plateau (Image 1). Information was also gathered from past literature and questionnaire survey was conducted to the local and tribal people (n=60) in six villages viz. cattle grazers (n=25), NTFP collectors (n=40) and forest field staff (n=35) to locate roosting and nesting colonies of White-rumped Vultures

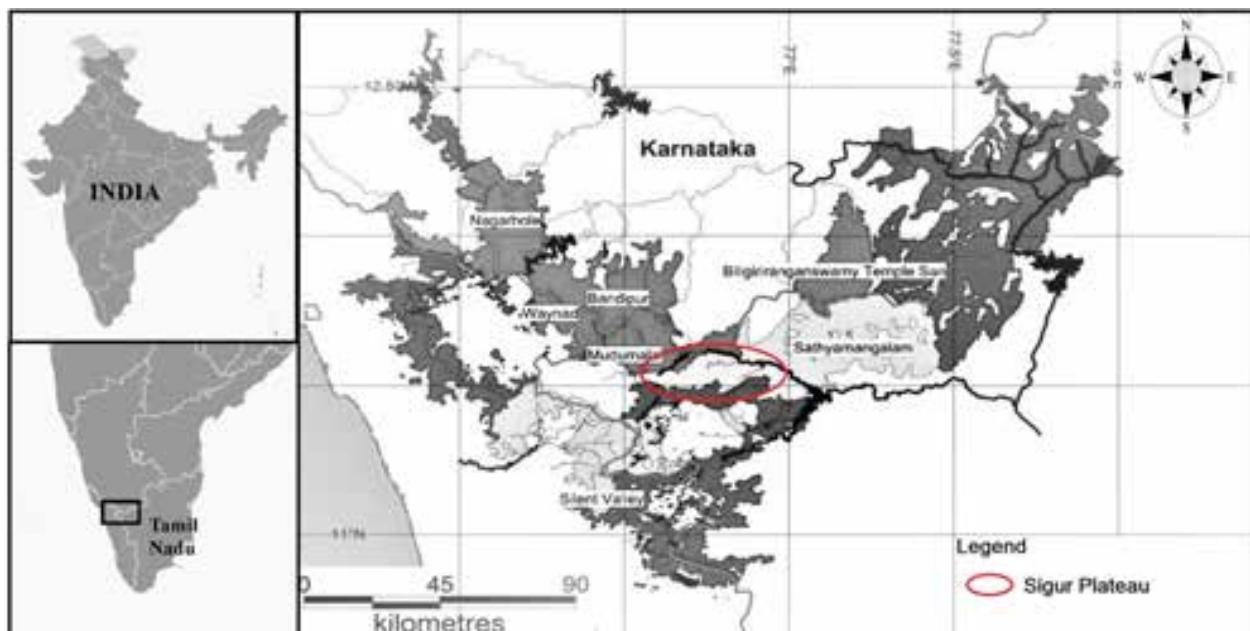


Figure 1. Map showing the study area Sigur Plateau located on the Nilgiris Eastern Ghats Landscape.



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Image 1. White-rumped Vulture *Gyps bengalensis* roosting on the tree in Sigur Plateau.

in Sigur Plateau. Once the roosting and nesting locations were confirmed. Population estimation was done twice (15 days interval) in a month. The rivers and nullas (streams) were thoroughly searched for nesting sites' shreds of evidence of White-rumped Vulture to monitor the population. We divided the age-class of White-rumped Vultures into two categories namely Adult (Fully matures after five years) and Immature (1–4 years). The population size of White-rumped vultures was estimated by counting the individuals in the roosting and nesting sites during the early morning (06.30–09.30 h) and late evening (17.30–19.30 h) hours. We assumed fidelity of nesting sites, fixed time of roosting and geographic closure, no movement into (immigration), or out of (emigration) sites to estimate population size as described by Baral et al. (2005).

Breeding ecology

To study the nesting and breeding ecology of White-rumped Vulture, each nesting colony was systematically visited four times (Seven days interval) in a month during the breeding season (September-2011 to May-2012) to check the status and number of vultures present in each nest. All nesting colonies' observations were done using binoculars (Nikon 52×10) from an appropriate distance (100–300m). The focal animal sampling method (Altmann 1972) was used to monitor the status and behavior of the White-rumped Vulture in nesting colonies (Postupalsky 1974; Acharya et al. 2009). Every visit, five to 10 minutes were spent to check the breeding status of each nest. All observations were made between 07.00h and 12.00h. Nests were identified by the presence of fresh nesting materials and whitewash (excreta) below the nesting tree or by the presence of the incubating vulture in the nest. All the nests were identified and nesting trees were tagged for future monitoring (Postupalsky 1974). The nesting variables such as tree height, Diameter at Breast Height (DBH), trunk size, primary branch, branch start, branch end, nest height, number of nests in a tree, nest dimension, nest position, and nest location were recorded. Tree height was measured using a rangefinder (Bushnell) and diameter at breast height (DBH) was measured using a measuring tape. All nesting trees were tagged (using a metal plate by numbering the nesting trees). The direction of nests on the nesting trees was determined by compass. Nest locations on trees were determined by visual estimation, viz., top of the crown, and limb (offshoot growing directly out of a tree trunk). Confirmation of active (occupied) and abandoned (unoccupied) nests was done based on the criteria laid down by Postupalsky (1974). An active breeding pair

was defined as that laid an egg, and non-breeding pair was confirmed that occupied the nest at least for three weeks but did not lay an egg. Breeding success was calculated based on the number of fledglings divided by the number of breeding pairs (that laid eggs). On each visit, an active nest was considered occupied by a pair by only when a single or two adult vultures were observed at the nest, one standing and one incubating or one incubating adult was present or one adult with a chick or a young chick alone was presented in the nest. A colony was considered as active, only if it contained at least one active nest with egg (Xirouchakis & Mylonas 2005).

Counts at carcasses

In this, we counted the number of carcasses found by the opportunistic count method (Information gathered by forest officials and local people) as well as the number vultures intake the carcasses. Similarly, other scavenger animals were also noted. Besides the type of carcass, the cause of death, type of habitat, domestic or wild, and locations were recorded.

People's on vulture conservation

Questionnaire survey was carried out between the months of April and May 2012 in the villages and settlements located in the vicinity of vulture colonies to understand inhabitant's perceptions about vulture population, carcass disposal methods, livestock holdings, livestock depredation by wild animals, veterinary practice, forest resource use, and conservation attitudes. A total of 109 persons were interviewed (87 cattle holders, six veterinary doctors, and 12 quacks, and four medical shops keepers). Two sets of questionnaires were developed for this study. One was 'precise and closed' and the other one was 'broad and open-ended'. Most of the people in this plateau are illiterate, so the questions were asked in local language for easy communication. Questions were asked concerning diclofenac usage and knowledge about diclofenac and their perceived effect on vulture populations and sale of diclofenac in drug stores. Mode of veterinary practice and treatment to injured livestock was interviewed to the veterinary doctors and veterinary assistants (quacks).

Statistics and mapping

Statistical analyses were done using past3 statistical software and mapping on nest locations was done using Quantum GIS 1.7.1walcrow version computer software with the help of GPS field data.

RESULT

Population status

Although three colonies namely Anaikatty, Jagalikadu, and Siriyur were found during our study, the Anaikatty nesting colony was abandoned by the White-rumped vultures. Monthly two visits (once in a fortnight) were carried out in two colonies namely, Jagalikadu and Siriyur from June 2011 to May 2012. The numbers recorded are presented in Table 1. There is a significant variation was found in the numbers of White-rumped Vultures observed between breeding 108.75 ± 2.91 (October–May) and non-breeding 79.25 ± 2.06 (June–September) seasons in both the vulture nesting colonies ($t=4.74$; $P<0.0000$).

Nesting behavior

The breeding season of White-rumped Vulture was observed from September 2011 to May 2012. The nesting colonies were located in the riparian ecosystem of Sigur and Gundattihalla rivers (Figure 2). Two tree species namely *Terminalia arjuna* and *Spondias mangifera* were utilized for nesting by White-rumped Vultures in the study area. A total of 31 trees with 51 nests were recorded in the Jagalikadu nesting colony

(49 nests in *Terminalia arjuna* and 2 nests in *Spondias mangifera*). On the other hand, 17 nests were seen in 10 *Terminalia arjuna* trees at the Siriyur nesting colony. The mean height of the nesting tree was 26.73 ± 0.76 and the DBH was 478.43 ± 36.27 irrespective of the tree species in both the nesting colonies. The maximum height of the nesting tree was 36m and a minimum height was 17m in the Jagalikadu nesting colony. The average trunk size of the nesting trees was 10.15 ± 0.54 m irrespective of the tree species in both the nesting colonies. Similarly, the branch start and branch end of the nesting trees showed that 9.92 ± 0.54 m and 23.80 ± 0.75 m respectively. The primary branch was 4.39 ± 0.21 m and the canopy size shows much higher values on length 16.82 ± 0.68 and width 28.63 ± 0.75 the nest height from the ground level shows 24.72 ± 0.62 . The height of the nest location was ranged from 14m to 36m. White-rumped Vultures construct cup type nests and the nest dimension was approximately 1m length and 40cm width and 15cm depth. Most of the nests (34%) were positioned towards north-east direction (NE) ($n=23$) followed by south-west (SW) (29%; $n=20$), south-east (SE) (25%; $n=17$) and north-west (NW) (12%; $n=8$) (Figure 3). Most of the nests were located on the tree crown ($n=51$) and a considerable number of nests were located on the limb

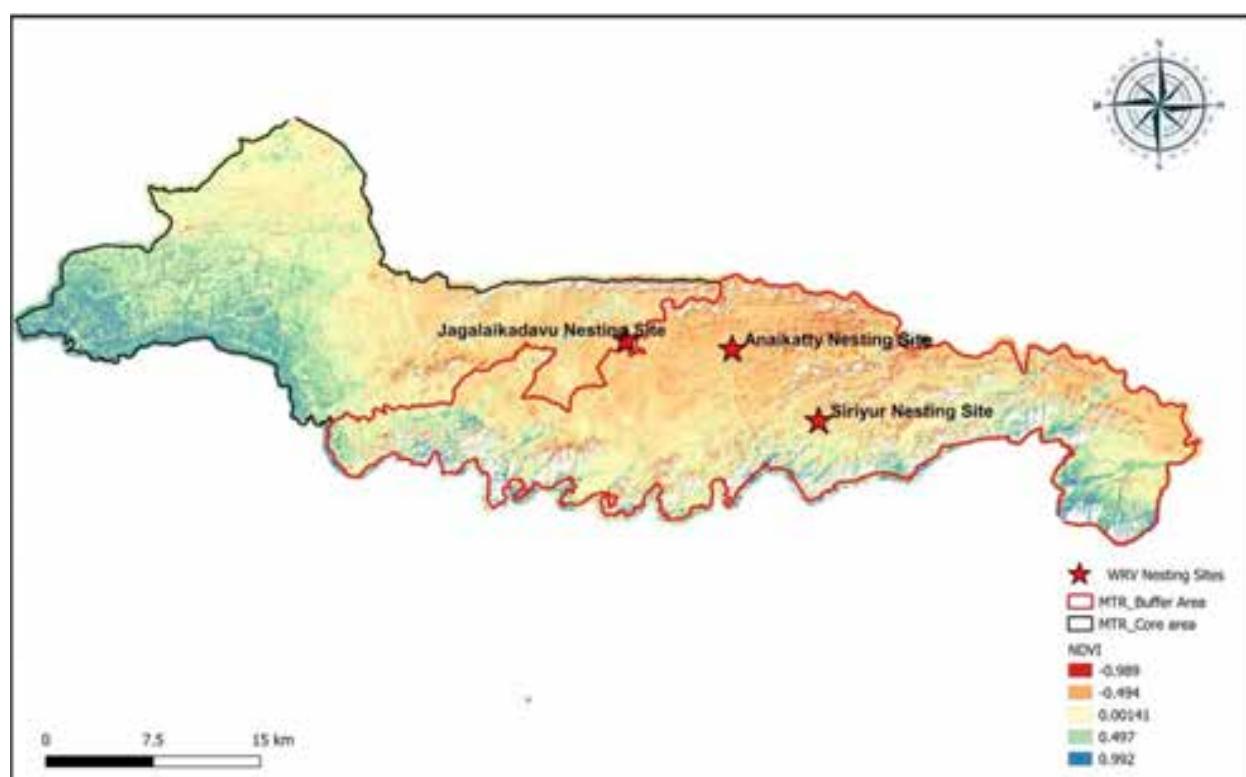


Figure 2. The nesting colonies of White-rumped Vulture in Sigur Plateau, Mudumalai Tiger Reserve, Tamil Nadu, India.

Table 1. Population estimation of White-rumped Vulture in Sigur Plateau, Western Ghats, India.

Colonies	Seasons	Adult		Immature		Total	
		Maximum Minimum	M \pm SE	Maximum Minimum	M \pm SE	Maximum Minimum	M \pm SE
Jagalikadavu + Siriur Overall	Non-breeding (June– September)	62–50	58 \pm 1.5	28–12	21.25 \pm 2.04	86–70	79.25 \pm 2.06
	Breeding (October–May)	84–69	77.37 \pm 1.15	56–20	31.37 \pm 2.47	138–97	108.75 \pm 2.91
Jagalikadavu (June 2011–May 2012)		61–34	48.75 \pm 1.69	40–06	18.56 \pm 1.56	98–44	67.04 \pm 2.78
Siriur (June 2011–May 2012)		28–10	22.16 \pm 0.75	17–06	9.70 \pm 0.55	41–22	31.87 \pm 0.91
Overall			70.91 \pm 2.10		28 \pm 2.02		98.91 \pm 3.54

Table 2. Nesting trees and nest variables details of White-rumped Vulture in the Sigur Plateau, Western Ghats, India.

Variables	Nesting trees		Overall
	<i>Terminalia arjuna</i> (N=39)	<i>Spondias mangifera</i> (N=2)	
Height	27.07 \pm 0.75	20 \pm 1	26.73 \pm 0.76
DBH	478.43 \pm 36.27	478 \pm 41.5	478.43 \pm 34.51
Trunk Size	10.15 \pm 0.54	5.5 \pm 0.5	9.92 \pm 0.54
Branch Start	10.15 \pm 0.54	5.5 \pm 0.5	9.92 \pm 0.54
Branch End	24.12 \pm 0.76	17.5 \pm 0.5	23.80 \pm 0.75
Main Branches	4.41 \pm 0.21	4 \pm 1	4.39 \pm 0.21
Canopy size	16.92 \pm 0.71	15 \pm 1	16.82 \pm 0.68
Nest Height	24.92 \pm 0.63 (n=66)	18 \pm 1 (n=2)	24.72 \pm 0.62

Table 3. Nesting success details of White-rumped Vulture nesting colonies from the Sigur Plateau, Western Ghats, India.

Nesting colonies	No of trees	No of nest constructed	Nests with eggs	Nests with hatched chicks	Confirmed fledged	Breeding success	Abandoned or failed nests
Jagalikadavu	31	51	26	22	22	85%	29
Siriur	10	17	8	8	8	100%	9
Total	39	68	34	30	30	88%	38

(n=15) portion of the tree. The percentage of canopy cover was classified into four categories (0% to 25%, 25% to 50%, 50% to 75% and 75% to 100%). The result showed that the most nesting trees (n=15) were in the 25%–50% canopy cover, followed by 50%–75% (n=12), 75%–100% (n=9) and 0%–25% (n=5) (Table 2).

Breeding success

Although nest-building activity of White-rumped Vultures started from September–October, the intensive nest construction was observed in October (n=48) and nest attendance by parent birds was until the end of chicks fledged out from the nests (May). The nests (n=68) were classified as occupied and abandoned. It was unfortunate to note that the proportion of

abandoned nests were gradually increased during the breeding i.e. in the month of October 52% (n=20), in November 38% (n=14), and in even in December it was 10% (n=4) during nest construction and egg-laying stages. Among the 68 constructed nests, 50% (n=34) completed incubation. Of which, 88% (n=30) of nests had successfully hatched, and all hatched young ones were successfully fledged out. The incubation took place from November to January (55 to 60 days). Hatchlings were seen from the first week to the second week of January 2012 (30 chicks). The breeding success has differed between the nesting colonies. Siriur nesting colony (100%) had higher breeding success than the Jagalikadavu colony (85%) (Table 3). The nesting success in the nesting trees was also measured in which 56.41%

Table 4. Preference of carcasses by vultures in Sigur Plateau, Tamil Nadu, India.

	Name of the carcasses	Number of Individuals	Avg. No of days Observed	WRV	LBV	RHV	Total	WB	SD
1	Buffalo	1	2	62±4	3±1	2.5±0.5	67.5 2.5	6±2	8
2	Cow	3	2.5	36.6±5.7	1.6±0.2	0.8±0.1	39.9±5.6	8.1±1.3	6.2±2.4
3	Elephant	2	4	56.5±5.4	2.1±0.4	3.1±0.6	61.8±5.1	16.6±2.5	3±1.4
4	Indian Gaur	3	3.3	53±7.7	2.5±0.6	3±0.3	58.5±0.3	5.4±6.95	0
5	Sambar Deer	3	1	35.3±3.1	1±0.5	1±0.5	37.3±4.1	4.2±1.8	0
6	Spotted Deer	3	1	29.3±5.6	1.3±0.3	1.3±0.3	32.3±6.1	2.1±0.6	0
7	Buffalo	1	6	0	0	0	0	18.7±3.4	6.21±2.1
8	Buffalo calf	11	2.5	0	0	0	0	12.3±3.8	4.2±1.9
9	Indian Gaur calf	1	1	0	0	0	0	8	0

WRV—White-rumped Vulture | LBV—Long-billed Vulture | RHV—Red-headed Vulture | WB—Wild Boar | SD—stray dogs

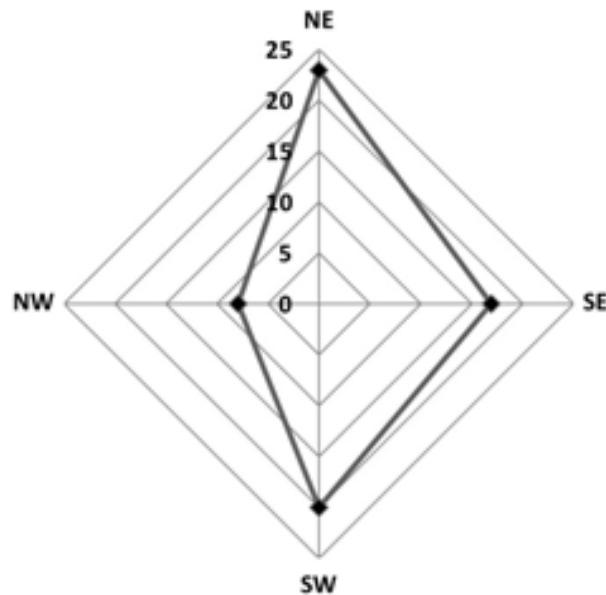


Figure 3. Nest orientation of White-rumped Vultures within nesting tree.

(n=22) was observed from *T.arjuna* trees. On the other hand, 100% of the failure of nesting was recorded in *S.mangifera* trees (n=2). The overall breeding success of both the nesting trees was 41.07% in *T.arjuna* followed by 0% in *S.mangifera*.

A total of 24 visits, we had observed 30.12 ± 5.36 individuals of both Tufted Grey Langur *Semnopithecus priama* and Bonnet Macaque *Macaca radiata* were disturbed on the nesting trees. Four broken eggs and eight destroyed nests were recorded during our fieldwork envisaged that there was a severe disturbance by these primates.

Observation of carcasses

A total of 28 ungulate carcasses were observed during the study period, which included 16 domestic and 12 wild animals (Table 4). Among the carcasses, most of them were found near human settlements (n=15) and considerable numbers were in forest areas (n=13). Out of 28 carcasses, 11 of them were Tiger kills, just one was Wild Dog kill and others (n=16) were natural deaths. Vultures were attended only 15 carcasses an average of 56.04 ± 3.29 individuals of vultures were recorded viz White-rumped Vultures (51.62 ± 3.1), Long-billed Vultures (2.2 ± 0.2), and Red-headed Vultures (2.5 ± 0.2). Interestingly, Elephant (61.8 ± 5.1) and Indian Gaur (58.5 ± 0.3) carcasses were attracted in greater numbers of vultures in subsequent days (3.5 ± 0.2) than other carcasses. It is very important to note that out of 15 domestic animal carcasses, just 3 carcasses (2 cow and 1 buffalo) were attended by vultures and the rest of them (1 buffalo and 11 buffalo calves) were not attended by vultures. But these 12 carcasses were fed by wild boars (16.2 ± 4.7) and stray dogs (5.4 ± 2.1) as these carcasses were found very close to human habitations.

People's perceptions on vulture conservation

A total of 109 local people were interviewed on vulture conservation which includes cattle owners and local veterinarian and drug store owners. Of which, 90.82% (n=99) of them were opined that the vulture conservation is good for ecosystem services. Interestingly most of them were opined that the vultures are nature scavengers (73.39%; n=80) and some of them were also presumed that the vulture is a bird (20.18%; n=22), and few of them were also opined that the vultures are hunter bird (6.42%; n=7). The

questionnaire survey revealed that most of the cattle holders were illiterate (93.10%; n=81) and unaware of the drug diclofenac and the threat it poses to vultures. The respondents opined that the tiger has killed their livestock more (n=252) followed by leopard and wild dogs each consumed 14 individuals during the last five years. The mode of livestock carcass disposal by the livestock holders revealed that most of them were (83.90%; n=73) just throw their carcasses into forests in the distance between 300-500m from the villages and rests (16.09%; n=14) were buried their cattle carcasses. All the veterinarians and quacks who were interviewed responded that they used meloxicam to treat livestock and none of them used diclofenac through 4 medical shops were selling diclofenac for the human purpose near vulture habitats in the study area.

DISCUSSION

The population of vultures has declined dramatically across South Asia due to the drug diclofenac, a Non-Steroidal Anti-Inflammatory Drug (NSAID), and other veterinary drugs (Prakash et al. 2003; Oaks et al. 2004; Margalida et al. 2015). In Sigur Plateau, the vulture population is possibly protected from some of these drug effects, as they depend on 90% of their food from wild carcasses (Ramakrishnan et al. 2010), even though the remaining 10% could still pose risks. The present study recorded the minimum and the maximum number of White-rumped Vulture populations viz. 44-98 and 22-38 in Jagalikadavu and Siriyur colonies respectively from June 2011 to May 2012. It was quite interesting to note that the vulture population was very low in June, and gradually increased subsequent months and reached its maximum numbers at the end of May. A similar pattern was also noted by Baral et al. (2005) in the White-rumped Vulture population in Nepal. This could be mainly because, during non-breeding seasons, the adult's birds fly far away for food, and may not return to nesting colonies on the same day (Rabenold 1987). Therefore, the maximum number of vultures were seen in and around nesting colonies only during breeding months, unlike non-breeding seasons.

The nests were located on the fork of the trees which are well-foliaged along the watercourses. Similar observations were documented in India by (Das et al. 2011; Pande et al. 2013; Khan 2013; Ramakrishnan et al. 2014; Majgaonkar et al. 2018; Jha et al. 2020). The present study has recorded two tree species were preferred by White-rumped vultures for nest

construction in the study area. Of which, more number (94.12%) of nests on *Terminalia arjuna* trees and just 4.88% of nests on *Spondias mangifera* trees in the riparian ecosystem. Because these two tree species were only seen as tallest trees in the study area. Similarly, many tree species were preferred by White-rumped vultures for nest construction across India and Bangladesh was documented by several authors. *Tectona grandis*, *Bombax ceiba*, *Terminalia tomentosa*, *Dalbergia sissoo* in Uttarakhand (Das et al. 2011); *Terminalia arjuna*, *Terminalia bellerica*, *Alstonia scholaris*, *Mangifera indica* in Maharashtra (Pande et al. 2013); *Ficus benghalensis*, *Ficus religiosa*, in erstwhile East Bengal now Bangladesh (Khan 2013) and *Terminalia arjuna* in Tamil Nadu (Ramakrishnan et al. 2014). Road (2010) reported that in Associated Private Nature Reserves located in the Limpopo Province, South Africa the African elephants (*Loxodonta africana*) interfere the nesting habitat and break the branches as well as debarking the nesting trees and destroyed the nesting trees of White-backed vultures (*Gyps africanus*). Similar kind of observation is observed in Sigur plateau Tusk punch mark on the nesting trees, debarking as well as feeding on bamboos under the nesting trees and interestingly note that 20 Honey Hives are recorded in the nesting trees in four nesting trees Sloth bear hunt the Honey hives we confirmed based on the nail marks on the bark on the nesting trees. Jha et al (2020) recorded that out of 44 tree species used by vultures for roosting, 14 (mostly shorter) trees were not used for nesting, indicating a preference for taller trees in Madhya Pradesh. Large trees (Chhangani 2007; Dhakal et al. 2014) provide predator avoidance, suitable microclimates (Campbell 2015), and increased mobility (Wright et al. 1986) for vultures. The present study has recorded 14-36m above the ground level of White-rumped vulture nests in the study area irrespective of the nesting tree species. 16.6m height was recorded by Chomba & M'Simuko (2013) in Lochinvar National Park on the Kafue flats, Zambia, 8-28m in central west Nepal (Subedi & DeCandido 2014), 14.8m in Himachal Pradesh, India (Thakur & Narang 2012), 18-36m (Naoroji 2006), above 21m in southern Pennsylvania, northern Maryland, and northeastern Virginia (Thompson et al. 1990) and 25-30m in Sigur Plateau of the Nilgiris (Ramkrishnan et al. 2014). Other species were recorded in smaller trees (*Mangifera indica*, *Acacia nilotica*, *Azadirachta indica*, *Prosopis cineraria*) in other regions such as arid Rajasthan and Maharashtra (Chhangani 2007; Kambale 2011; Khatri 2013). Among the 68 nests recorded by this study, 34% were facing towards north-east, 25% south-east, and 29% south-west directions.

This was mainly due to a possible influence of sunlight effect. The maximum nests' width and length were 1m and 40cm respectively. Canopy size plays a huge role for the selection of nesting trees by White-rumped vultures in the study area. The average length was 16.82 ± 0.68 m and the width was 28.63 ± 0.75 m recorded in the study area.

The present study found that out of 68 constructed nests, 34 were incubated and 30 chicks were successfully fledged out from the nests with 88% of breeding success during the year 2011–2012. Sashikumar & Vishnudas (2018) reported an overall 65% breeding success of White-rumped Vultures in Wayanad Wildlife Sanctuary, Kerala from 2003 to 2017. Majgaonkar et al. (2018) reported that overall 21.2% of occupied nests in a coconut plantation colony affected by storm damage, 52.9% was successful in a nearby forest colony in western Maharashtra, India. Thakur (2015) reported that 56.1% breeding success in 2009–2010, and slowly increased to 72.7% in 2010–2011 and finally 79.4% success in 2011–2012 from 24 breeding colonies of White-rumped Vultures in Shahpur, Nurpur, and Kangra regions in Kangra District of Himachal Pradesh. Baral et al. (2005) reported that 72–102 individuals of White-rumped Vultures in six colonies during their breeding season had 50% breeding success at 70 occupied nests in Rampur Valley, Nepal. In Pakistan, a total of 2,281 occupied nests of White-rumped vultures were recorded between 2000 and 2004 the nest success was observed in 1,231 nests taking the breeding success to 51% (Gilbert et al. 2006). The mean nesting success of African White-backed Vultures (*Gyps africanus*) in the Masai Mara over the five years was 59%, which compares favorably with previous studies conducted in southern Africa (Monadjem 2003; Herholdt & Anderson 2006). The nesting success rates after the year 2000 for White-rumped Vulture colonies in India, Nepal, and Pakistan ranged between 30% and 73% (Gilbert et al. 2006; Baral & Gautam 2007; Thakur & Narang 2012); however, the breeding success of White-rumped vultures in Bangladesh between 2009 and 2011 was only 15.6% and 25.8% due to the effect of multiple dosages of diclofenac (Khan 2013). The 88.23% breeding success of White-rumped vultures recorded by this study is a positive sign envisaged that this population is gradually growing when compared to other studies across the country and the world as a whole.

We observed a total of 38 (56%) nests were abandoned by the White-rumped vultures during the breeding season (October to December 2011) of the study period. Of which, 90% of the nests were abandoned before eggs were laid (October to November) and 10%

of the nests were abandoned after the eggs were laid (December). Similar observation was noticed in Nepal by Baral et al. (2005). Samson et al (2018) reported that anthropogenic threats were resulted in nest site abandonment by White-rumped Vultures in Sigur Plateau. Newton (2002) stated that certain pairs may occupy a territory for only a few days or a few weeks, or may even build a nest, but the process stops there. He added the major factor influencing on the egg-laying process in vultures was the food supply, and in poor food years, territorial pairs in some populations fail to lay eggs. Baral et al (2005) seen that the nest abundance by vultures due to mortality of chicks in the previous year and Moran-lopez et al (2006) explained that anthropological threats in the nesting areas would also cause the nest abandoned behaviour in vultures. This study recorded the Gray langur and Bonnet macaques were caused severe threats to the breeding population of White-rumped Vultures (n=8 nests) by jumping or shaking the branches, destroying the nests and depredation of eggs especially by the Bonnet macaques. A similar observation was observed in Himachal Pradesh where monkeys were recorded continuously in nesting site (Pehad nesting site) although, no direct evidence of interference of the monkey troops with vultures were observed, the number of vulture nests at Pehad nesting site decreased from six occupied (breeding season 2009–2010) to one occupied nest (breeding season 2010–2011), he stated that it may be due to interference by monkeys. Finally, the vultures at Pehad shifted to a new nesting site at Chattri (around 1km away) with three occupied nests (breeding season 2010 to 2011) (Thakur and Narang 2012). The present study observed the direct impact of Grey langurs and Bonnet macaques play behavior in both the White-rumped vulture nesting sites in Sigur plateau. Many studies in Africa confirmed that the monkeys and baboons interfered in the normal breeding of African vultures (Mundy et al. 1992; Emmett 2003; Roche 2000 & 2006).

In Sigur Plateau, both the nesting colonies were located near to human settlements (average of 1.92km). Green et al. (2004) stated that based on demographic modeling, less than 0.8% of ungulate carcasses available to foraging vultures would need to contain a lethal dose of diclofenac for this to have caused the observed population declines. Therefore, educating livestock holders, farmers, and veterinary personnel on the usage of diclofenac awareness may help to secure the vulture population although 93.10% of livestock holders did not aware of diclofenac and its effects as per this study.

Management Recommendations

- The present study suggests that the creation of awareness is important among the school children for the schools that are surrounded by the vulture habitat to bring out future conservationists.

- Declaration of "Vulture Sanctuary" would support legally for the population. The Karnataka Government has declared a "Vulture Sanctuary" to conserve another Critically Endangered Long-billed Vulture species in Ramnagaram Hills, Karnataka as a first of its kind. The sanctuary was declared for a total of 346.14ha area was to secure 15–18 individuals and their nesting sites in the hill.

- Sigur Plateau is strategically located at the tri-junction of three Tiger Reserves namely Mudumalai Tiger Reserve, Biligiri Rangaswamy Tiger Reserve, and Sathyamangalam Tiger Reserve. This would ensure long-term food supply to vultures as they are dependent to tiger kills majoritively than other co-predators

REFERENCES

Acharya, R., R. Cuthbert, H.S. Baral & K.B. Shah (2009). Rapid population declines of Himalayan Griffon *Gyps himalayensis* in Upper Mustang, Nepal. *Bird Conservation International* 19(1): 99–107. <https://doi.org/10.1017/S0959270908007417>

Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behaviour* 49: 227–267. <https://doi.org/10.1163/156853974X00534>

Baral, N. & R. Gautam (2007). Socio-economic perspectives on the conservation of critically endangered vultures in south-east Asia: an empirical study from Nepal. *Bird Conservation International* 17: 1–10. <https://doi.org/10.1017/S0959270907000688>

Baral, N., R. Gautam & B. Tamang (2005). Population status and breeding ecology of White-rumped Vulture *Gyps bengalensis* in Rampur Valley, Nepal. *Forktail* 21: 87–91.

BirdLife International (2001). Threatened birds of Asia – the BirdLife International Red Data Book, BirdLife International, Cambridge, UK, 3038pp.

BirdLife International (2018). Species factsheet: *Gyps bengalensis*. Downloaded from <http://www.birdlife.org> on 29 August 2018.

Campbell, M. (2015). Vultures: their evolution, ecology and conservation. London and New York, CRC Press, Taylor and Francis Group, 374pp. <https://doi.org/10.1201/b18638>

Chomba, C.E. & M'Simuko (2013). Nesting patterns of raptors: White-backed Vulture (*Gyps africanus*) and African fisheagle (*Haliaeetus vocifer*), in Lochinvar National Park on the Kafue flats, Zambia. *Open Journal of Ecology* 3(5): 325–330. <https://doi.org/10.4236/oje.2013.35037>

Cuthbert, R., J. Parry-Jones, R.E. Green & D.J. Pain (2016). NSAIDs and scavenging birds: potential impacts beyond Asia's critically endangered vultures. *Biological Letters* 3: 90–93. <https://doi.org/10.1098/rsbl.2006.0554>

Chaudhary, A., T.S. Subedi, J.B. Giri, H.S. Baral, I. Chaudhary, K. Paudel & R.J. Cuthbert (2012). Population trends of Critically Endangered Gyps vultures in the lowlands of Nepal. *Bird Conservation International* 22: 270–278. <https://doi.org/10.1017/S0959270911000426>

Chhangani, A.K. (2007). Sightings and nesting sites of red-headed vulture *Sarcogyps calvus* in Rajasthan, India. *Indian Birds* 3(6): 218–221.

Das, S.K., A. Dashahare, S. Marathe, N. Kundu & R. Kesharwani (2011). Status of raptors with special reference to vultures in and around Rajaji National Park, India. *World Journal of Zoology* 6(4): 350–356.

Davidar, P. (2007). Indian White-backed Vultures *Gyps bengalensis* in the Sigur region of Tamil Nadu. *Indian Birds* 3(4): 149.

Davidar, E.R.C. & P. Davidar (2002). Possible causes for the decline of Oriental White-rumped vultures (*Gyps bengalensis*) in the Sigur region (Nilgiris, Tamil Nadu), India. *Vulture News* 47: 3–6.

Dhakal, H., K.M. Baral, K.P. Bhusal & H.P. Sharma (2014). First record of nests and breeding success of red-headed vulture *Sarcogyps calvus* and implementation of vulture conservation programs in Nepal. *Ela Journal* 3(3): 9–15.

Emmett, M. (2003). A preliminary survey of the density of Chacma baboon at Ngala. *Ecology Journal* 5: 84–89.

Gilbert, M., R.E. Green, S. Ranade, S. Saravanan, D.J. Pain, V. Prakash & A.A. Cunningham (2006). Rapid population declines and mortality clusters in three Oriental White-backed Vulture *Gyps bengalensis* colonies in Pakistan due to diclofenac poisoning. *Oryx* 40: 388–399. <https://doi.org/10.1017/S0030605306001347>

Green, R.E., I. Newton, S. Shultz, A.A. Cunningham, M. Gilbert, D.J. Pain & V. Prakash (2004). Diclofenac poisoning as a cause of vulture population declines across the Indian subcontinent. *Journal of Applied Ecology* 41(5): 793–800. <https://doi.org/10.1111/j.0021-8901.2004.00954.x>

Herholdt, J.J. & M.D. Anderson (2006). Observations on the population and breeding status of the African White-backed Vulture, the Black-chested Snake Eagle, and the Secretarybird in the Kgalagadi Transfrontier Park. *Ostrich* 77: 127–135. <https://doi.org/10.2989/00306520609485523>

Jha, K.K., M.O. Campbell & J. Radhika (2020). Vultures, their population status and some ecological aspects in an Indian stronghold. *Notulae Scientia Biologicae* 12(1): 124–142. <https://doi.org/10.15835/nsb12110547>

Kalanithi, S., A. Samson & B. Ramakrishnan (2018). Research and survey operation by engaging vulture watchers, The Nilgiris North Forest Division, Udhagamandalam, The Nilgiris. pp. 114–118. In: Ramakrishnan, B. (ed.) Proceedings of the workshop on "Securing Vulture Population in Southern India (SVPSI 2018). Udhagamandalam, The Nilgiris, Tamil Nadu, India, 138pp.

Kambale, A.A. (2011). A study on breeding behaviour of oriental white-backed vulture (*Gyps bengalensis*) in Anjarle and Deobag, Maharashtra. Wildlife Institute of India, Dehradun, India.

Khan, M.M.H. (2013). Population, breeding and threats to the White-rumped Vulture *Gyps bengalensis* in Bangladesh. *Forktail* 29: 52–56.

Khatri, P.C. (2013). Home range use of winter migratory vultures in and around Jorbeer, Bikaner (Rajasthan) India. *Bioscience Discovery* 4(1): 96–99.

Majgaonkar, I., C.G.R. Bowden, & S. Quader (2018). Nesting success and nest-site selection of White-rumped Vultures (*Gyps bengalensis*) in western Maharashtra, India. *Journal of Raptor Research* 52(4): 431–442. <https://doi.org/10.3356/JRR-17-26.1>

Margalida, A., G. Bogliani, C. Bowden, J.A. Donázar, F. Genero, M. Gilbert, W. Karesh, R. Kock, J. Lubroth, X. Manteca, V. Naidoo, A. Neimanis, J.A. Sánchez-zapata, M. Taggart, J. Vaarten, L. Yon, T. Kuiken, & R.E. Green (2015). One health approach to use of pharmaceuticals. *Science* 346: 1296–1298. <https://doi.org/10.1126/science.1260260>

Moleón, M., J.A. Sánchez-Zapata, A. Margalida, M. Carrete, N. Owen-Smith & J.A. Donázar (2014). Humans and Scavengers: The Evolution of Interactions and Ecosystem Services. *BioScience*, 64(5): 394–403. <https://doi.org/10.1093/biosci/biu034>

Monadjem A. (2003). Nesting distribution and status of vultures in Swaziland. *Vulture News* 48: 12–19.

Moran-Lopez, R., J.M. Sanchez, E. Costillo, C. Corbacho & A. Villegas (2006). Spatial variation in anthropic and natural factors regulating the breeding successes of the Cinereous Vulture (*Aegypius monachus*) in the SW Iberian Peninsula. *Biological Conservation* 130(2): 169–182. <https://doi.org/10.1016/j.biocon.2005.12.011>

Mundy, P., D. Butchart, J. Ledger & S. Piper (1992). *The vultures of Africa*. Academic Press Limited, London, UK460pp.

Naoroji, R. (2006). *Birds of Prey of the Indian Subcontinent*. Om book international, India, 692pp.

Newton, I. (2002). Population limitation in Holarctic owls, pp. 3–29. In: Newton, I., R. Kavanagh, J. Olsen & I. Taylor (eds.). *Ecology and conservation of owls* CSIRO Publishing, Collingwood, Victoria, Australia, 400pp.

Oaks, J.L., M. Gilbert, M.Z. Virani, R.T. Watson, C.U. Meteyer, B.A. Rideout, H.L. Shivaprasad, S. Ahmed, M.J.I. Chaudhry, M. Arshad, S. Mahmood, A. Ali & A.A. Khan (2004). Diclofenac residues as the cause of vulture population decline in Pakistan. *Nature* 427: 630–633. <https://doi.org/10.1038/nature02317>

Padma, A. (2018). Population, breeding ecology and conservation threats of Long-billed vultures (*Gyps indicus*) in the Ramadevarabettu Vulture Sanctuary (RVS) in Ramanagara Hills, Karnataka, pp. 63–68. In: Ramakrishnan, B. (ed.) Proceedings of the workshop on "Securing Vulture Population in Southern India (SVPSI 2018). Udhagamandalam, The Nilgiris, Tamil Nadu, India, 138pp.

Pain, D.J., A.A. Cunningham, P.F. Donald, J.W. Duckworth, D.C. Houston, T. Katzner, J. Parry-Jones, C. Poole, V. Prakash, P. Round & R. Timmins (2003). Causes and effects of temporospatial declines of *Gyps* vultures in Asia. *Conservation Biology* 17(3): 661–671. <https://doi.org/10.1046/j.1523-1739.2003.01740.x>

Postupalsky, S. (1974). Raptor reproductive success: some problems with methods, criteria, and terminology, pp. 21–31. In: Hamestrom Jr., F.N., B.E. Harrell & R.R. Olendorff (eds.). *Proceedings of the conference on raptor conservation techniques*. Fort Collins, Colorado, U.S.A.

Prakash V. (1999). Status of vultures in Keoladeo National Park Bharatpur Rajasthan with special reference to population crash in *Gyps* species. *Journal of Bombay Natural History Society* 3: 365–378.

Prakash, V., D.J. Pain, A.A. Cunningham, P.F. Donald, N. Prakash Verma, R. Gargi, S. Sivakumar & A.R. Ramani (2003). Catastrophic collapse of Indian White-backed (*Gyps bengalensis*) and Long-billed (*Gyps indicus*) vultures population. *Biological Conservation* 109(3): 381–390. [https://doi.org/10.1016/S0006-3207\(02\)00164-7](https://doi.org/10.1016/S0006-3207(02)00164-7)

Prakash, V., R.E. Green, D.J. Pain, P. Ranades, S. Saravanan, N. Prakash, A. Venki & A.A. Cunningham (2007). Recent changes in population of resident *Gyps* vultures in India. *Journal of Bombay Natural History Society* 104: 129–135.

Praveen, J., P.O. Nameer, D. Karuthedathu, C. Ramaiah, B. Balakrishnan, K.M. Rao, S. Shurpali, R. Puttaswamaiah & I. Tavcar (2014). On the vagrancy of the Himalayan Vulture *Gyps himalayensis* to southern India. *Indian Birds* 9(1): 19–22.

Rajkumar, D. (2018). Status of Vultures in Bandipur Tiger Reserve, pp. 63–68. In: Ramakrishnan, B. (ed.) Proceedings of the workshop on "Securing Vulture Population in Southern India (SVPSI 2018). Udhagamandalam, The Nilgiris, Tamil Nadu, India, 138pp.

Ramakrishnan, B., G. Kannan, A. Samson, K. Ramkumar & S. Ramasubramanian (2014). Nesting of White-rumped vulture (*Gyps bengalensis*) in the Sigur Plateau of the Nilgiri North Forest Division. *Indian Forester* 140(10): 1014–1018.

Ramakrishnan, B., S. Ramasubramanian & A. Samson (2012). Occurrence of Red-headed vulture in Sigur Plateau, Tamil Nadu. *Current Science* 102(6): 832.

Ramakrishnan, B., S. Ramasubramanian, M. Saravanan & C. Arivazhagan (2010). Is diclofenac the only culprit for declining population of *Gyps* vultures in the Moyar Valley. *Current Science* 99(12): 1645–1646.

Ramakrishnan, B., A. Samson & A. Veeramani (2018) Conservation strategies for securing Critically Endangered White-rumped (*Gyps bengalensis*) and Long-billed (*Gyps indicus*) vulture species in the Tamil Nadu part of the Nilgiri Biosphere Reserve, pp. 55–62, In: Ramakrishnan, B. (ed.) Proceedings of the workshop on "Securing Vulture Population in Southern India (SVPSI 2018). Udhagamandalam, The Nilgiris, Tamil Nadu, India, 138pp.

Rabenold, P.P. (1987). Recruitment to food in Black Vultures: evidence for following from communal roosts. *Animal Behavior* 35: 1775–1785.

Rode, R.C. (2010). Elephant impact on the large tree component and its potential effect on selected fauna. M.Sc dissertation. University of South Africa, South Africa, 104pp.

Roche, C. (2000). Birds of prey nest survey at Nagala. *Journal of Ecology* 2: 142–146.

Roche, C. (2006). Breeding records and nest site preference of Hooded Vulture in the greater Kruger National Park. *Ostrich* 77(1): 99–101. <https://doi.org/10.2989/00306520609485515>

Samson, A., B. Ramakrishnan, S. Renuka, P. Ravi, & S. Ramasubramanian (2014a). Bathing behavior and waterhole importance of white-rumped vulture conservation in the Sigur Plateau, Tamil Nadu, Southern India. *Journal of Applied Science and Research* 2(5): 92–99.

Samson, A., B. Ramakrishnan, G. Kannan, S. Renuka & S. Ramasubramanian (2014b). Emerging threats for Egyptian Vulture (*Neophron percnopterus ginginianus*) in the Chamundi Hills Reserved Forest, Mysore, Karnataka. *Newsletter for Birdwatchers* 50(2): 16–17.

Samson, A., B. Ramakrishnan, A. Veeramani & P. Ravi (2015). Occupation of Indian Giant Squirrel nests by White-rumped Vultures *Gyps bengalensis* in India. *Podoces*, 10(2): 35–36.

Samson, A., B. Ramakrishnan & P. Ravi (2016a). Wild boar predation on White-rumped vulture fledgling. *Zoos Print XXXI* (8): 8.

Samson, A., B. Ramakrishnan, A. Veeramani & P. Ravi (2016b). Population status and habitat preference of vultures in Mudumalai Tiger Reserve, Tamil Nadu southern India. *Podoces* 11(1): 7–12.

Samson, A., B. Ramakrishnan, B.A. Veeramani & P. Ravi (2016c). Taphonomy perspectives on Tiger (*Panthera tigris*) kills and Natural deaths of domestic buffalo *Bubalus bubalis* (Linnaeus, 1785) with special reference to vultures and others scavenger vertebrates. *Journal of Scientific Transactions in Environment and Technovation* 10(1): 222–224.

Samson, A. & B. Ramakrishnan (2016). Observation of a population of Egyptian Vultures *Neophron percnopterus* in Ramanagaram Hills, Karnataka, southern India. *Vulture News* 71: 36–49. <https://doi.org/10.4314/vulnew.v71i1.3>

Samson, A. & B. Ramakrishnan (2017a). Letters to the Editor: Accidental death of a feeding vulture. *Indian Birds* 13(2): 56.

Samson, A. & B. Ramakrishnan (2017b). Scavenging Mode of Vertebrate Scavengers on Domestic Buffalos *Bubalus bubalis* (Linnaeus, 1785) Killed by Tiger *Panthera tigris* and Natural Deaths in Southern India. *Podoces*, 12(1): 22–26.

Samson, A., B. Ramakrishnan P. Arun & P. Ravi (2017). International Vulture Awareness Day celebration at the Nilgiris. *Zoo's Print XXXII* (9): 38–39.

Samson, A. & B. Ramakrishnan (2018a). Long-billed vultures: Additional new breeding site of Long-billed vultures (*Gyps indicus*) in Moyar Valley, Tamil Nadu, Southern India. *Bird-o-soar #09*. In: *Zoo's Print* 33(1): 23–25.

Samson, A. & B. Ramakrishnan (2018b). People's Perception on Vulture Conservation in Tamil Nadu part of The Nilgiri Biosphere Reserve, Southern India, pp. 106–111. In: Ramakrishnan, B. (ed.) Proceedings of the workshop on "Securing Vulture Population in Southern India (SVPSI 2018). Udhagamandalam, The Nilgiris, Tamil Nadu, India, 138pp.

Samson, A. & B. Ramakrishnan (2018c). Impact of Awareness on Vulture Conservation Among the Schools Students in The Sigur Plateau, The Nilgiris, pp. 122–126. In: Ramakrishnan, B. (ed.) Proceedings of the workshop on "Securing Vulture Population in Southern India (SVPSI 2018). Udhagamandalam, The Nilgiris, Tamil Nadu, India, 138pp.

Samson, A., B. Ramakrishnan & R. Ganavel (2018). Is peoples movement affect White-rumped vulture nesting colony. a cause studies for siriyur nesting colony, Nilgiri North Forest Division, The Nilgiris, Tamil Nadu, pp. 120–121. In: Ramakrishnan, B. (ed.) Proceedings of the workshop on "Securing Vulture Population in Southern India (SVPSI 2018). Udhagamandalam, The Nilgiris, Tamil Nadu, India, 138pp.

Samson, A., B. Ramakrishnan, V. Selvan & S. Manigandan (2019).

Cinereous Vulture *Aegypius monachus* in Mudumalai Tiger Reserve, Western Ghats, and its status in southern India. *Indian BIRDS* 15(3): 93–94.

Sebastián-González, E., J.M. Barbosa, J.M. Pérez-García, Z. Morales-Reyes, F. Botella, P.P. Olea, P. Mateo-Tomás, M. Moleón, F. Hiraldo, E. Arondo, J.A. Donázar, A. Cortés-Avizanda, N. Selva, S.A. Lambertucci, A. Bhattacharjee, A. Brewer, J.D. Anadón, E. Abernethy, O.E. Jr Rhodes, K. Turner, J.C. Beasley, T.L. DeVault, A. Ordiz, C. Wikenros, B. Zimmermann, P. Wabakken, C.C. Wilmers, J.A. Smith, C.J. Kendall, D. Ogada, E.R. Buechley, E. Frehner, M.L. Allen, H.U. Wittmer, J.R.A. Butler, J.T. du Toit, J. Read, D. Wilson, K. Jerina, M. Krofel, R. Kostecke, R. Inger, A. Samson, L. Naves-Alegre & J.A. Sánchez-Zapata. (2019). Scavenging in the Anthropocene: Human impact drives vertebrate scavenger species richness at a global scale. *Global Change Biology* 25(9): 3005–3017. <https://doi.org/10.1111/gcb.14708>

Sashikumar, C. (2001). Vultures in Kerala. *Newsletter for Birdwatchers*. 41: 10–15.

Sashikumar, C. & C.K. Vishnudas (2018) Status of Vultures in Kerala. Securing Vulture Population in Southern India, pp. 114–118. In: Ramakrishnan, B. (ed.). Proceedings of the workshop conducted from 8th to 10th, January, 2018 at Udhagamandalam, The Nilgiris, Tamil Nadu, India, 138pp.

Subramanya, S. & O.C. Naveen (2006). Breeding of Long-billed vulture *Gyps indicus* at Ramnagaram hills, Karnataka, India. *Indian Birds* 2(2): 32–34.

Subedi, T.R. & R. de Candido (2013). Population and breeding success of red-headed vulture *Sarcogyps calvus* and Egyptian vulture *Neophron percnopterus* in central west Nepal. *Vulture News* 67(10): 21–32. <https://doi.org/10.4314/vulnew.v67i2.2>

Thakur, M.L. (2015). Breeding Ecology and Distribution of White-rumped Vultures (*Gyps bengalensis*) in Himachal Pradesh, India. *Journal of Raptor Research* 49(2): 183–191. <https://doi.org/10.3356/rapt-49-02-183-191.1>

Thakur, M.L. & S.K. Narang (2012). Population status and habitat-use pattern of Indian White-backed Vulture (*Gyps bengalensis*) in Himachal Pradesh, India. *Journal of Ecology and the Natural Environment* 4(7): 173–180. <https://doi.org/10.5897/JENE11.103>

Thejaswi, S. (2004). A sight record of the Cinereous Vulture *Aegypius monachus* near Mysore, Karnataka, India. *Newsletter for Ornithologists* Vol. 1 No. 5: 74.

Thompson, W.L., R.H. Yahner & G.L. Storm (1990). Winter use and habitat characteristics of vulture communal roosts. *Journal of Wildlife Management* 54(1): 77–83.

Wright, A., R. Yahner & G.L. Storm (1986). Roost-tree characteristics and abundance of wintering vultures at a communal roost in south central Pennsylvania. *Journal of Raptor Research* 20(3/4): 102–107.

Xirochakis S.M. & M. Mylonas M (2005). Selection of breeding cliffs by Griffon Vultures *Gyps fulvus* in Crete (Greece). *Acta Ornithologica* 40(2): 155–161. <https://doi.org/10.3161/068.040.0211>



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Author contribution: AS conceived and designed the experiments, performed the experiments, and analyzed the data. AS and BR wrote the paper.



Avifauna of Saurashtra University Campus, Rajkot, Gujarat, India

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Abstract: We examined the avifauna of Saurashtra University Campus (SUC), Rajkot, Gujarat from July to December 2017. The study area was divided into four sections: North (N), East (E), South (S) and West (W) and surveyed over 18 visits (four line transects/visit). We recorded a total of 82 bird species from 67 genera, 40 families and 16 orders. Of these 57 species were terrestrial and 25 aquatic. By population size the most abundant birds were members of Columbidae (28%), Sturnidae (13%), and Charadriidae (8%). Seventy per cent of birds observed (n=7665) were classed as very common and 2% (n=261) as very rare. Species density (S/N = 3.39) and population density (n/N = 196) were at their maximum in December. Ecological indices on temporal base reveal high species richness and Simpson diversity (1/D = 17.0 and 1-D = 0.942) in August and November and Shannon diversity was high (H'=3.275) in November during study period.

Keywords: Birds, checklist, population density, status, temporal.

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Author contribution: The final manuscript was prepared, analyzed, read, approved and communicated by the VT and SV undertook field data collection, organized and assimilated the data, table and graphic preparation and drafted the manuscript.

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INTRODUCTION

Birds play key roles as agents of flower pollination and seed dispersal (Nason 1992). Likewise, structurally complex habitats provide more niche and diverse ways of exploiting environmental resources, increase species diversity (Bazzaz 1975), and the inter-relationship between vegetation and bird population (Mac Arthur & Mac Arthur 1961) including the positive and negative changes in the bird population result in the transformation of the natural environment (Emlen 1974). Skead (1966), Maxwell & Kale (1977), and McCrimmon (1978) have discussed that the habitat is significant for the successful completion of the life cycle of the organism. The highly dynamic nature of urban ecosystems means that a small effort in management can have a great effect on bird abundance and diversity (Savard et al. 2000). It is stated by Tews et al. (2004) that animal species diversity is driven by habitat heterogeneity.

The present work deals with urban ecosystems using birds as a target group. Birds are quite sensitive to changes in habitat structure and composition, and are, therefore, excellent indicators of changes and stresses in the urban ecosystem (Savard & Falls 1982; Clergeau et al. 1998). Joshi (2009) reported 79 species of birds from some reservoirs of Rajkot City and 30 species of water birds from Nyari Dam1 (Vadhel 2010) of Rajkot. Past record of year 2016 on avifauna from Saurashtra University Campus (SUC), Rajkot reports a total of 80 species of birds belonging to 66 genera of 39 families (Gohil 2017). The current study of avian fauna was carried out to understand the impact of the current developmental work being undertaken in the SUC on habitat suitability for wildlife in the coming years. Moreover, every year habitat characteristics are changing due to the construction of new buildings, decrease in open landscapes and fragmentation of the various macro and micro-habitats in SUC. So, the specific attention on avian diversity of SUC is the intention of the present study. In addition, the study also aims to develop a wildlife database on wildlife of this university campus.

This study presents a checklist of birds with updated systematic, familial distribution, abundance status, species composition, conservation status and their population on temporal base including ecological indices. Hypothetically, it is assumed that the overall bird population and their species community assemblage is expected to diversify on temporal scale as well as with changes in macro and microhabitat types at SUC, Rajkot.

STUDY AREA

Saurashtra University Campus (SUC) Rajkot (Latitude: 22.291610°, Longitude: 70.793220°, 140m) is located at the centre of peninsular Saurashtra region in Gujarat State (Fig. 1A). The climate of Rajkot is tropical arid to semi-arid with three distinct seasons each year, monsoon, winter, and summer. The annual rainfall is erratic in its occurrence, duration and intensity. Annual rainfall was high 1,311.2mm during 2017; average temperature varies between 21.5°C and 34.5°C and average humidity ranges between 57.9 and 88.4% (morning) and 17.4 to 80.3% (evening). The area is spread over 1,456km² (360 acres) with hilly terrain (Fig. 1B).

The ecological overview of all four sections of SUC include predominant vegetation layer such as trees: *Azadirachta indica*, *Lawsonia inermis*, *Aegle marmelos*, *Delonix regia*, *Ficus benghalensis*, *F. religiosa*, *Kesiya auriculata*, *Prosopis juliflora*, *P. spicigera*, *Emblica officinalis*, *Tamarindus indica*, *Jetropha kalkas*, *Cassia roxburghii*, *C. fistula*, *Albizia lebbeck*, *Pongamia pinnata*, etc.; shrubs: *Ocimum tenuiflorum*, *Caesalpinia pulcherrima*, *Calotropis procera* and *Zyziphus numularia*; ornamental plants: *Tecoma stans*, *Cascabela thevetia*, *Duranta repens*, *Bougainvillea spectabilis*, *Catharanthus roseus*, and *Lantana camara*.

METHODS

The work was carried out during July to December 2017 at Saurashtra University Campus (SUC), Rajkot Gujarat. To record the birds of all four sections (i.e., North, East, South, and West) surveyed using line transects (by road 1km long and 5m broad right and left using binocular) and some places at water reservoirs by point count methods. Inside each zone approaching peripheral boundaries by road with motor bike, by walk-ways and walk at random. Data records on bird sightings, the birds present in and around the selected four sections at SUC; including overflying individuals or flock, resting on trees, feeding on the ground and some individual as well as large flock by photos also.

In total 18 surveys (3 visits/month and 4 transects/visit in each sections) were done during study periods from 06:00hrs to 12:00hrs and 90 minutes were spent at each section. The data were collected using a pair of binoculars (Olympus, 12 X 50) and photographs (Sony cyber shot 18.2 mega pixel 20x zoom) by digital still camera for close examinations.

Systematic updates, identification of birds were

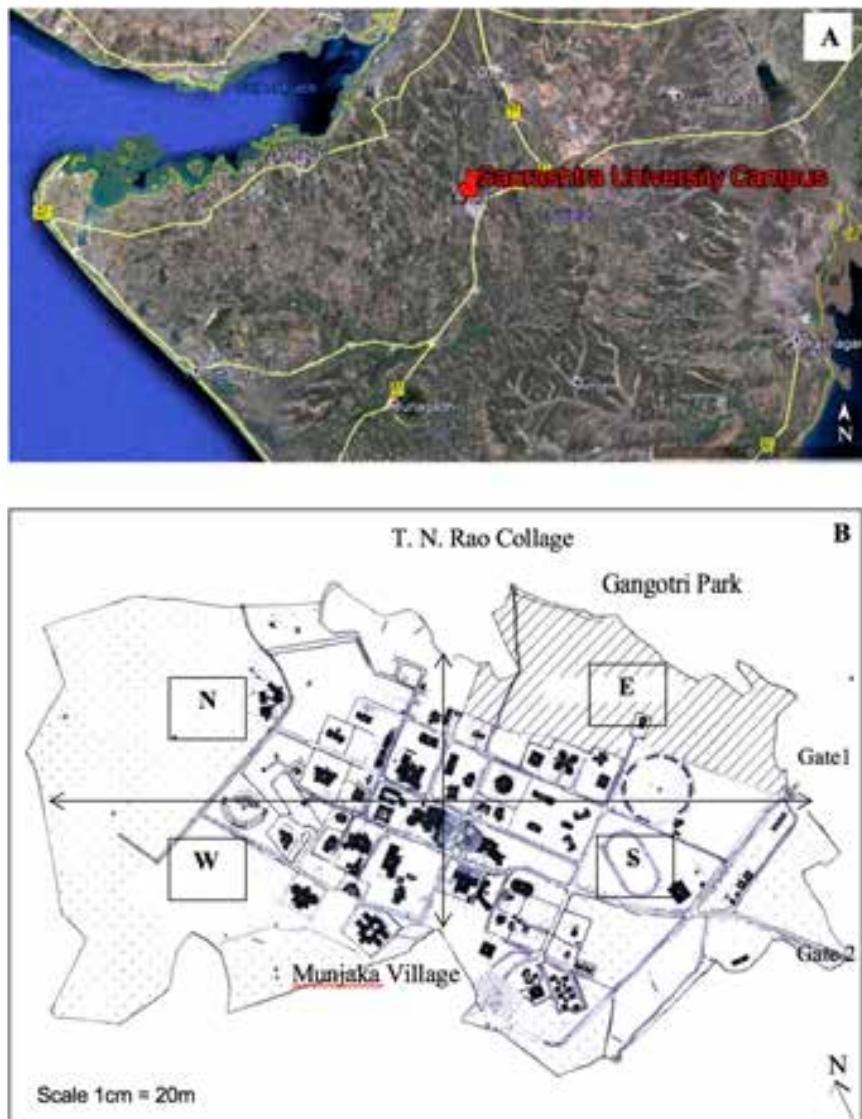


Figure 1. Location of Saurashtra University Campus, Rajkot, Gujarat.

A—Digital map of Study Site | B—Samplings sub areas of Saurashtra University Campus. [E – East, S – South, W – West, N- North]

■ - Buildings, □ - Non residential

followed by using references such as Ali & Ripley (1983), Sugathan & Varghese (1996), Ali (2012), Parasharya et al. (2004), Sangha & Naoroji (2005), Grimmett et al. (2013), Ansari & Nawab (2015), Ganpule (2016), Manohar et al. (2017); common name and scientific name updated as Praveen et al. (2018) and Satose et al. (2020).

Data analysis

The abundance status of the recorded bird species was categorized into five groups (i.e., VR—Very Rare (1–20 %), R—Rare (21–40%), O—Occasional (41–60 %), C—Common (61–80 %), and VC—Very Common (81–100 %), established on the basis of frequency (%) (Table 1, Fig. 2) and frequency calculated (i.e., total no of occurrence/total no of visit x 100).

A checklist of birds with systematics including

conservation status is followed as per IUCN (2020-version 1), WPA (1972) and CITES (2020) (Table 1). Classification was followed and updated (Praveen et al. 2018; Satose et al. 2020); familial number and percentages of individual birds, genera and species were calculated (Table 2; Fig. 3). Species community and their assemblages by month, cumulative count of individuals and species number (Fig. 4) on temporal scale were scrutinized.

The quantitative and qualitative analysis as population and species density, species diversity indices like Simpson diversity $1/D$; $1-D$; Shannon diversity $-H'$, evenness - e^H/S , Margalef's species richness (d), and Fisher alpha diversity (α) were computed using software PAST (version: 3.15 March 2017) by Hammer et al. (2001).

RESULTS AND DISCUSSION

A total 82 species of birds, belonging to 67 genera, 40 families and 16 orders were recorded. Of these, terrestrial population (86.82%) of birds and species (n=57, 69.51%) were higher than aquatic population (13.18%) and numbers of species (n=25, 30.49%) of birds (Table 1, 2) during study period at studied areas.

Out of 40 families, Scolopacidae dominated with seven species (8.54%) followed by Muscicapidae with six species (7.32%), Accipitridae and Motacillidae with five species (6%), Ardeidae, Columbidae, Hirundinidae, Sturnidae with four species (4.88%) each, Charadriidae, Cisticolidae with three species (3.66%) each, Threskiornithidae, Anatidae, Phasianidae, Laridae, Cuculidae, Sylviidae, Leiothrichidae with two species (2.44%) each, whereas 23 families Rallidae, Pelecanidae, Burhinidae, Recurvirostridae, Strigidae, Upupidae, Megalaimidae, Meropidae, Alcedinidae, Psittaculidae, Oriolidae, Dicruridae, Laniidae, Corvidae, Nectariniidae, Ploceidae, Estrildidae, Passeridae, Alaudidae, Acrocephalidae, Psyncronotidae, Ciconiidae, Phalacrocoracidae with only one species each respectively (Table 2). The population of a member of family Columbidae (27.94%, n=3085) stands first; followed by Sturnidae (13.39%, n=1478) and Charadriidae (7.77%, n=858) has shown higher population and the lowest population Laniidae (0.04%, n = 4) i.e. Long-tailed Shrike *Lanius schach*. Maximum genus was found in family Muscicapidae (8.96%) and Accipitridae (7.465%) (Fig. 3).

Species community and status

Seventy per cent (n=7665) population of birds were very common, 2% (n=261) very rare, 27% (n=22) species were common, and only 10% were rare (n=8) (Table 1, Fig. 2). Of the 82 species recorded, the five species observed with highest population were the Rock Pigeon *Columba livia* (106 mean), Rosy Starling *Pastor roseus* (43 mean), Large Grey Babbler *Turdoides malcolmi* (35 mean), Red-wattled Lapwing *Vanellus indicus* (34 mean), and Common Myna *Acridotheres tristis* (33 mean) (Table 1).

Out of 17 very common bird species, nine species were sighted in every visit (100%) namely Rock Pigeon, Eurasian Collared Dove *Streptopelia decaocto*, Laughing Dove *Streptopelia senegalensis*, Asian Koel *Eudynamys scolopaceus*, Red-wattled Lapwing, House Sparrow *Passer domesticus*, Red-vented Bulbul *Pycnonotus cafer*, Common Myna and Indian Robin *Saxicoloides fulicatus*. There were eight common species sighted between 11 and 14 visits out of the 18 visits; among these, the most dominant were Rosy Starling (13 times out of 18,

n=796); as Indian Silverbill *Euodice malabarica* (n=362) and Purple Sunbird *Cinnyris asiaticus* (14 times out of 18, n=139). Fifteen species were occasionally seen, 22 species rare and 20 species were very rare; among the very rare category, the rarest one was Marsh Sandpiper *Tringa stagnatilis*. Long-legged Buzzard *Buteo rufinus* and Lesser White throat (*Sylvia curruca*) were sighted only once during the survey (Table 1).

Conservation status of avian fauna

The SUC supports six species of birds included in Schedule I, 70 species included in Schedule IV of the Wildlife Protection Act (WPA, 1972) and six species that are listed in Appendix II of the Convention on International Trade in Endangered Species of Flora and Fauna (CITES 2020). As per IUCN red list, SUC supports three Near-threatened (NT) species such as Painted Stork *Mycteria leucocephala*, Curlew Sandpiper *Calidris ferruginea* and River Tern *Sterna aurantia* (IUCN 2020-ver. 1), remaining 79 species are under Least Concern (LC) (Table 1).

Species composition and assemblages on temporal scale

Throughout the six-month study period, it reflects that population of Rock Pigeon was maximum from August to December; second most was Rosy Starling and third most populous species (Large Grey Babbler) dominated from post monsoon to winter (October–December). Accumulation curve of number of species and individual shows a steep increase from July to October, thereafter, species and population of birds reveal gradual increase up to December (Fig. 4).

STATISTICAL ANALYSIS

Avian species density and diversity

Out of 11,041 individuals of birds reveal 82 species of all total survey (N=18). The species Density (S/N) was high 4.56 species per survey during entire study period. Evenness index (e): Evenness index is low ($e < 0$, 0.357). As evenness index increase with decrease in stress (Pielou 1966), this clears study areas has no stress elements. Species richness Margalof's index (d): Margalof's index of species richness was high 8.701; and this minimizes the effect of sample size bias (cited by Odum 1971). Species richness as a measure on its own takes no account of the number of individuals of each species present. It gives as much weight to those species which have very few individuals as compared to those which have many individuals. Simpson's Index Dominance (D): The value of D ranges between 0 and 1.

Table 1. Checklist of birds of Saurashtra University Campus, Rajkot. (July to December 2017; Total Survey=18).

	Common name	Scientific name	M	Fr %	AS	IUCN	WPA	CITES
	Order: Anseriformes (i) Family: Anatidae							
1	Lesser Whistling-duck	<i>Dendrocygna javanica</i>	0.78	28	R	LC	Sch-IV	-
2	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	1.67	28	R	LC	Sch-IV	-
	Order: Galliformes (i) Family: Phasianidae							
3	Indian Peafowl	<i>Pavo cristatus</i>	1.78	39	R	LC	Sch-I	-
4	Grey Francolin	<i>Francolinus pondicerianus</i>	9.39	56	O	LC	Sch-IV	-
	Order: Columbiformes (i) Family: Columbidae							
5	Rock Pigeon	<i>Columba livia</i>	105.72	100	VC	LC	Sch-IV	-
6	Eurasian Collared Dove	<i>Streptopelia decaocto</i>	29.28	100	VC	LC	Sch-IV	-
7	Red Collared Dove	<i>Streptopelia tranquebarica</i>	10.06	50	O	LC	Sch-IV	-
8	Laughing Dove	<i>Streptopelia senegalensis</i>	26.33	100	VC	LC	Sch-IV	-
	Order: Cuculiformes (i) Family: Cuculidae							
9	Greater Coucal	<i>Centropus sinensis</i>	2.00	72	C	LC	Sch-IV	-
10	Asian Koel	<i>Eudynamys scolopaceus</i>	2.94	100	VC	LC	Sch-IV	-
	Order: Gruiformes(i) Family: Rallidae							
11	Common Coot	<i>Fulica atra</i>	0.78	11	VR	LC	Sch-IV	-
	Order: Pelecaniformes (i) Family: Pelecanidae							
12	Great White Pelican	<i>Pelecanus onocrotalus</i>	0.89	11	VR	LC	Sch-IV	-
	(ii) Family: Ardeidae							
13	Indian Pond Heron	<i>Ardeola grayii</i>	1.00	39	R	LC	Sch-IV	-
14	Cattle Egret	<i>Bubulcus ibis</i>	8.56	94	VC	LC	Sch-IV	-
15	Intermediate Egret	<i>Ardea intermedia</i>	0.28	17	VR	LC	Sch-IV	-
16	Little Egret	<i>Egretta garzetta</i>	2.83	56	O	LC	Sch-IV	-
	(iii) Family: Threskiornithidae							
17	Indian Black Ibis	<i>Pseudibis papillosa</i>	2.44	61	C	LC	Sch-IV	-
18	Glossy Ibis	<i>Plegadis falcinellus</i>	0.28	22	R	LC	Sch-IV	-
	Order: Charadriiformes (i) Family: Burhinidae							
19	Indian Thick-Knee	<i>Burhinus indicus</i>	3.17	44	O	LC	Sch-IV	-
	(ii) Family: Recurvirostridae							
20	Black-winged Stilt	<i>Himantopus himantopus</i>	2.94	28	R	LC	Sch-IV	-
	(iii) Family: Charadriidae							
21	Little Ringed Plover	<i>Charadrius dubius</i>	1.00	28	R	LC	Sch-IV	-
22	Yellow-wattled Lapwing	<i>Vanellus malabaricus</i>	13.00	83	VC	LC	Sch-IV	-
23	Red-wattled Lapwing	<i>Vanellus indicus</i>	33.67	100	VC	LC	Sch-IV	-
	(iv) Family: Scolopacidae							
24	Curlew Sandpiper	<i>Calidris ferruginea</i>	1.11	17	VR	NT	Sch-IV	-
25	Little Stint	<i>Calidris minuta</i>	1.06	17	VR	LC	Sch-IV	-
26	Common Sandpiper	<i>Actitis hypoleucos</i>	1.22	44	O	LC	Sch-IV	-
27	Green Sandpiper	<i>Tringa ochropus</i>	0.56	22	R	LC	Sch-IV	-
28	Common Greenshank	<i>Tringa nebularia</i>	0.22	11	VR	LC	Sch-IV	-
29	Wood Sandpiper	<i>Tringa glareola</i>	0.72	17	VR	LC	Sch-IV	-
30	Marsh Sandpiper	<i>Tringa stagnatilis</i>	0.17	6	VR	LC	Sch-IV	-

	Common name	Scientific name	M	Fr %	AS	IUCN	WPA	CITES
	(v) Family : Laridae							
31	River Tern	<i>Sterna aurantia</i>	0.17	11	VR	NT	Sch-IV	-
32	Common Tern	<i>Sterna hirundo</i>	0.22	11	VR	LC	Sch-IV	-
	Order: Accipitriformes (i) Family: Accipitridae							
33	Black-winged Kite	<i>Elanus caeruleus</i>	0.17	11	VR	LC	Sch-I	App II
34	Shikra	<i>Accipiter badius</i>	1.72	67	C	LC	Sch-I	App II
35	Brahminy Kite	<i>Halias turindus</i>	0.56	33	R	LC	Sch-I	App II
36	Black Kite	<i>Milvus migrans</i>	0.50	28	R	LC	Sch-I	App II
37	Long-legged Buzzard	<i>Buteo rufinus</i>	0.11	6	VR	LC	Sch-I	App II
	Order: Strigiformes (i) Family: Strigidae							
38	Spotted Owllet	<i>Athene brama</i>	0.89	50	O	LC	Sch-IV	App II
	Order: Bucerotiformes (i) Family: Upupidae							
39	Common Hoopoe	<i>Upupa epops</i>	2.78	50	O	LC	-	-
	Order: Piciformes (i) Family: Megalaimidae							
40	Coppersmith Barbet	<i>Psilopogon haemacephalus</i>	2.28	50	O	LC	Sch-IV	-
	Order: Coraciiformes (i) Family: Meropidae							
41	Green Bee-eater	<i>Merops orientalis</i>	25.89	94	VC	LC	-	-
	(ii) Family: Alcedinidae							
42	White-throated Kingfisher	<i>Halcyon smyrnensis</i>	1.17	67	C	LC	Sch-IV	-
	Order: Psittaciformes (i) Family: Psittaculidae							
43	Rose-ringed Parakeet	<i>Psittacula krameri</i>	19.44	94	VC	LC	Sch-IV	-
	Order: Passeriformes (i) Family : Oriolidae							
44	Indian Golden Oriole	<i>Oriolus kundoo</i>	2.94	50	O	LC	Sch-IV	-
	(ii) Family:Dicruridae							
45	Black Drongo	<i>Dicrurus macrocercus</i>	19.44	94	VC	LC	Sch-IV	-
	(iii) Family: Laniidae							
46	Long-tailed Shrike	<i>Lanius schach</i>	0.22	11	VR	LC	Sch-IV	-
	(iv) Family:Corvidae							
47	Rufous Treepie	<i>Dendrocitta vagabunda</i>	3.11	78	C	LC	Sch-IV	-
	(v) Family:Nectariniidae							
48	Purple Sunbird	<i>Cinnyris asiaticus</i>	7.72	78	C	LC	Sch-IV	-
	(vi) Family: Ploceidae							
49	Baya Weaver	<i>Ploceus philippinus</i>	3.44	22	R	LC	Sch-IV	-
	(vii) Family: Estrildidae							
50	Indian Silverbill	<i>Euodice malabarica</i>	20.11	78	C	LC	Sch-IV	-
	(viii) Family: Passeridae							
51	House Sparrow	<i>Passer domesticus</i>	29.33	100	VC	LC	Sch-IV	-
	(ix) Family: Motacillidae							
52	Paddyfield Pipit	<i>Anthus rufulus</i>	2.06	39	R	LC	Sch-IV	-
53	Western Yellow Wagtail	<i>Motacilla flava</i>	0.89	50	O	LC	Sch-IV	-
54	Citrine Wagtail	<i>Motacilla citreola</i>	0.83	28	R	LC	Sch-IV	-
55	White-browed Wagtail	<i>Motacilla maderaspatensis</i>	0.39	28	R	LC	Sch-IV	-
56	White Wagtail	<i>Motacilla alba</i>	0.83	44	O	LC	Sch-IV	-

	Common name	Scientific name	M	Fr %	AS	IUCN	WPA	CITES
(x) Family : Alaudidae								
57	Ashy-crowned Sparrow Lark	<i>Eremopterix griseus</i>	10.72	83	VC	LC	Sch-IV	-
(xi) Family: Cisticolidae								
58	Ashy Prinia	<i>Prinia socialis</i>	1.11	28	R	LC	Sch-IV	-
59	Plain Prinia	<i>Prinia inornata</i>	2.89	56	O	LC	Sch-IV	-
60	Common Tailorbird	<i>Orthotomus sutorius</i>	2.06	44	O	LC	Sch-IV	-
(xii) Family:Acrocephalidae								
61	Paddy field Warbler	<i>Acrocephalus agricola</i>	3.83	22	R	LC	Sch-IV	-
(xiii) Family: Hirundinidae								
62	Red-rumped Swallow	<i>Cecropis daurica</i>	9.94	33	R	LC	-	-
63	Wire-tailed Swallow	<i>Hirundo smithii</i>	2.11	22	R	LC	-	-
64	Barn Swallow	<i>Hirundo rustica</i>	4.56	22	R	LC	-	-
65	Dusky Crag Martin	<i>Ptyonoprogne concolor</i>	3.61	50	O	LC	-	-
(xiv) Family : Sylviidae								
66	Red-vented Bulbul	<i>Pycnonotus cafer</i>	17.50	100	VC	LC	Sch-IV	-
(xv) Family:Leiothrichidae								
69	Large Grey Babbler	<i>Argya malcolmi</i>	35.00	94	VC	LC	Sch-IV	-
70	Common Babbler	<i>Argya caudata</i>	3.33	17	VR	LC	Sch-IV	-
(xvi) Family:Sturnidae								
71	Rosy Starling	<i>Pastor roseus</i>	42.72	72	C	LC	Sch-IV	-
72	Brahminy Starling	<i>Sturnia pagodarum</i>	5.56	89	VC	LC	Sch-IV	-
73	Common Myna	<i>Acridotheres tristis</i>	33.28	100	VC	LC	Sch-IV	-
74	Bank Myna	<i>Acridotheres ginginianus</i>	0.56	11	VR	LC	Sch-IV	-
(xvii) Family:Muscicapidae								
75	Indian Robin	<i>Saxicoloides fulicatus</i>	10.00	100	VC	LC	Sch-IV	-
76	Oriental Magpie Robin	<i>Copsychus saularis</i>	0.89	33	R	LC	Sch-IV	-
77	Spotted Flycatcher	<i>Muscicapa striata</i>	0.67	17	VR	LC	Sch-IV	-
78	Red-breasted Flycatcher	<i>Ficedula parva</i>	0.83	22	R	LC	Sch-IV	-
79	Black Redstart	<i>Phoenicurus ochruros</i>	0.50	17	VR	LC	Sch-IV	-
80	Pied Bushchat	<i>Saxicola caprata</i>	0.67	33	R	LC	Sch-IV	-
Order: Ciconiiformes (i) Family: Ciconiidae								
81	Painted Stork	<i>Mycteria leucocephala</i>	0.78	11	VR	NT	Sch-IV	-
Order: Suliformes (i) Family: Phalacrocoracidae								
82	Little Cormorant	<i>Phalacrocorax niger</i>	4.50	50	O	LC	Sch-IV	-

M—Mean per visit | Fr—Frequency | AS—Abundance Status (frequency based) | LC—Least Concern | NT—Near Threatened | IUCN (2020-version 1) | Sch-I & IV (WPA, 1972) | App. II (CITES, 2020).

Identification of birds followed as per Grimmett et al. (2013), Satose et al. (2020),and Common name & Scientific Name updated (Praveen et al. 2018).

VR—Very Rare (1–20 %), R—Rare (21–40 %) | O—Occasional (41–60 %) | C—Common (61–80 %) | VC—Very Common (81–100 %) established on the basis of frequency (%)

Table 2. Familial numbers of genus and species of birds.

	Family	Genus	Species
1	Anatidae	2	2
2	Phasianidae	2	2
3	Columbidae	2	4
4	Cuculidae	2	2
5	Rallidae	1	1
6	Pelecanidae	1	1
7	Ardeidae	4	4
8	Threskiornithidae	2	2
9	Burhinidae	1	1
10	Recurvirostridae	1	1
11	Charadriidae	2	3
12	Scolopacidae	3	7
13	Laridae	1	2
14	Accipitridae	5	5
15	Strigidae	1	1
16	Upupidae	1	1
17	Megalaimidae	1	1
18	Meropidae	1	1
19	Alcedinidae	1	1
20	Psittaculidae	1	1
21	Oriolidae	1	1
22	Dicruridae	1	1
23	Laniidae	1	1
24	Corvidae	1	1
25	Nectariniidae	1	1
26	Ploceidae	1	1
27	Estrildidae	1	1
28	Passeridae	1	1
29	Motacillidae	2	5
30	Alaudidae	1	1
31	Cisticolidae	2	3
32	Acrocephalidae	1	1
33	Hirundinidae	3	4
34	Psyncronotidae	1	1
35	Sylviidae	2	2
36	Leiothrichidae	1	2
37	Sturnidae	3	4
38	Muscicapidae	6	6
39	Ciconiidae	1	1
40	Phalacrocoracidae	1	1
	Total	67	82

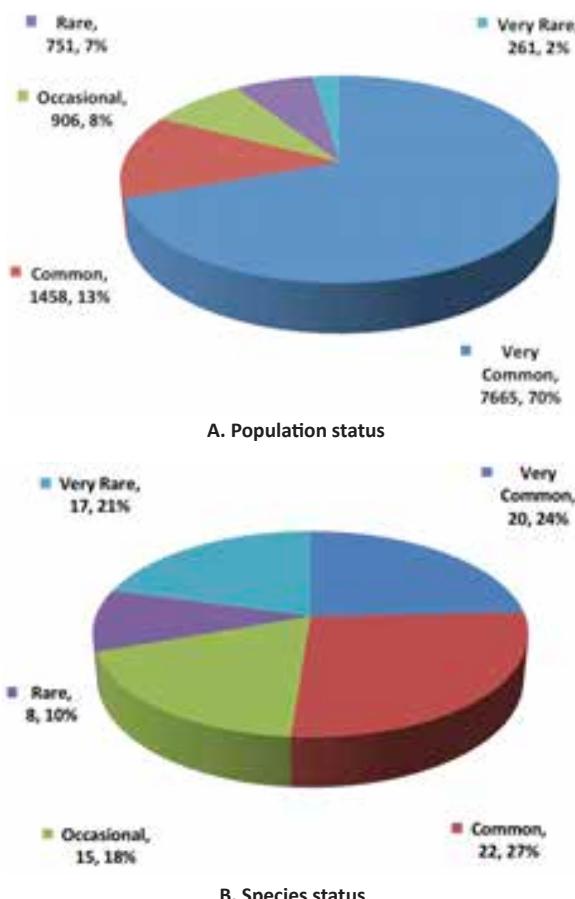


Figure 2. Population and species status (%) of avifauna at SUC.

With this index, 0 represents infinite diversity and 1 no diversity. That is, the bigger the value of D , the lower the diversity. Here, Simpson's Index D is 0.0587 which is low far to zero so it concludes that the diversity of this study site has significantly higher diversity. Simpson's Index of Diversity $1 - D$: This index also ranges between 0 and 1, the greater the value, the greater the sample diversity. Here the Simpson's Index of Diversity ($1 - D$) is 0.9413. So, it concludes that the diversity of this study site was higher. Simpson's Reciprocal Index $1 / D$: This index starts with 1 as the lowest possible figure. This figure would represent a community containing only one species. Higher the value, greater the diversity, here the Simpson's Index of Diversity ($1/D$) is 17.04. So, it concludes that this study site has higher diversity of bird species. Shannon Weiner Index (H'): If the species are evenly distributed then the H' value would be high. So, the H' value allows us to know not only the number of species but how the abundance of the species is distributed among all the species in the avian community. Typical values of Shannon Weiner Index (H') are generally between 1.5 and 3.5 in most ecological

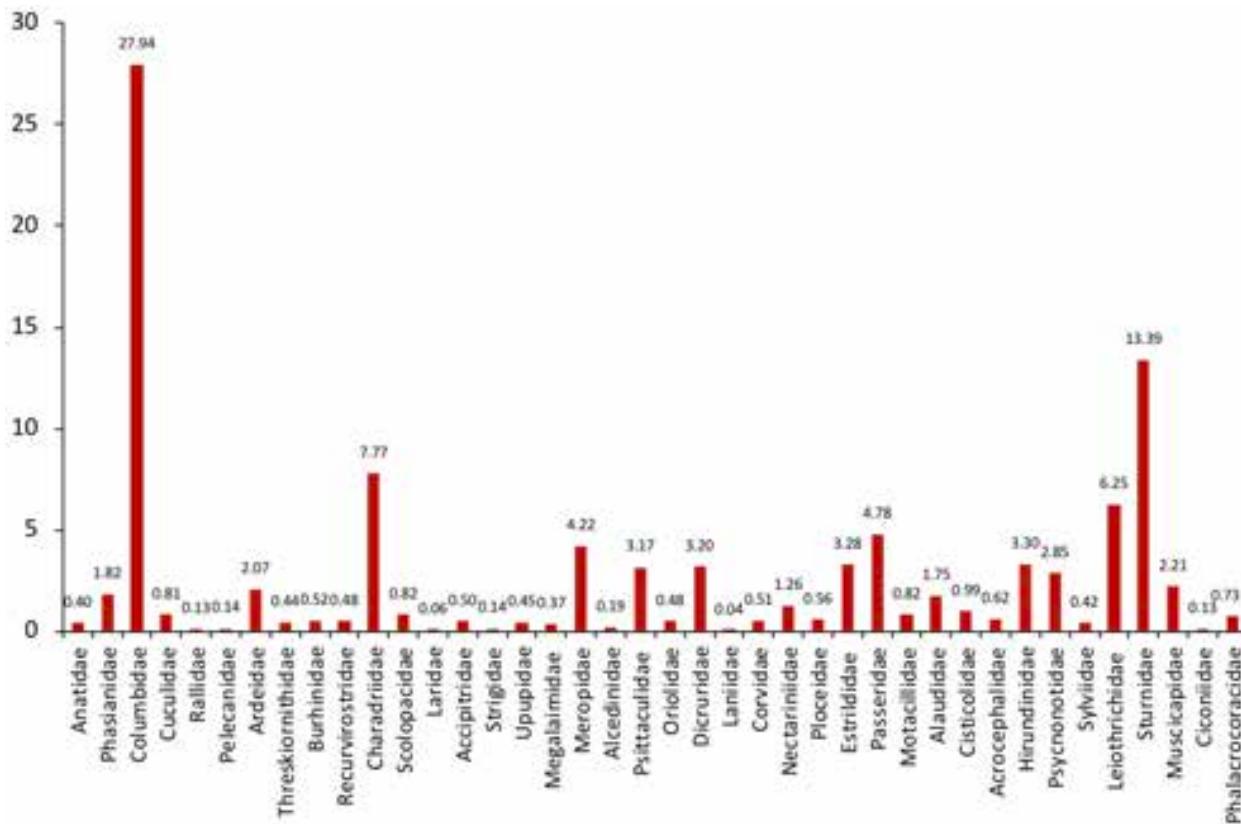


Figure 3. Familial percentages of individual birds recorded during study period at SUC.

Table 3. Month wise ecological indices of birds of Saurashtra University Campus.

Month	Total Survey (N)	Total no. of individuals (n)	Total No. of taxa(S)	Species Density (S/N)	Population Density (n/N)	Dominance (D)	Simpson's Index (1/D)	Simpson's Index (1-D)	Shannon Weiner (H')	Evenness index (e)	Margalef d=(S-1)/ logN	Fisher Diversity (α)
Jul	3	429	31	1.72	23.83	0.0725	13.79	0.9275	2.889	0.5799	4.949	7.67
Aug	3	942	43	2.39	52.33	0.0585	17.00	0.9415	3.179	0.5587	6.133	9.29
Sept	3	1691	58	3.22	93.94	0.0741	12.66	0.9259	3.134	0.396	7.668	11.63
Oct	3	2031	58	3.22	112.83	0.0666	14.93	0.9334	3.220	0.4317	7.484	11.13
Nov	3	2419	59	3.28	134.39	0.0588	17.00	0.9412	3.275	0.448	7.444	10.91
Dec	3	3529	61	3.39	196.06	0.0612	16.39	0.9388	3.273	0.4327	7.345	10.48
Total	18	11041	82	4.56	613.39	0.0587	17.04	0.9413	3.377	0.3573	8.701	12.02

studies, and the index is rarely greater than 4. The Shannon index increases as both the richness and the evenness of the community increase. Shannon Weiner Index $H' = 3.377$; So, it concludes that abundance of avian species at this study site was high (Table 3).

Data analysis on temporal scale shows that population ($n/N=196$) and species density ($S/N = 3.39$) of birds were higher in December; whereas diversity indices reveal birds species richness and Simpson diversity ($1/D = 17.0$ and $1-D = 0.941$) was significantly higher in August and

November; as Shannon diversity high in November ($H' = 3.275$); dominance ($D = 0.0741$), evenness- $e^H/S = 0.396$), Margalef's species richness ($d = 7.668$) and Fisher alpha diversity ($\alpha = 11.63$) significant high and evenly distributed in September during study period. Overall Fisher alpha diversity was high ($\alpha = 12.02$) at study areas during entire study period. This may reflect comparatively less stress in their environment and the climatic factor (i.e., Annual rainfall – 1311.2mm, average temperature 21.5–34.5 °C, average humidity ranges



Figure 4. Accumulation curve of number of species and individuals of avifauna by month.

57.9–88.4 % by morning, 2017), their physiography may provide suitable habitat and food availability during the study period at Saurashtra University Campus.

Comparing previous records from other sites reveals 68 species of birds from village areas of Gondal Taluka, Rajkot District (Borad 2009); 79 species from reservoirs of Rajkot City (Joshi 2009); 30 species of water birds of Nyari Dam1 (Vadhel 2010) Rajkot; 29 species from Sodvadar Reservoir and 24 species from Phophal Reservoir Jam-kandorna Tehsil, Rajkot District (Jambukiya 2014). From Randarda Lake, 62 species of water birds recorded by Yadav (2015) and 65 species of water birds by Kasundra (2017); 80 species of birds from Saurashtra University Campus Rajkot (Gohil 2017); 51 species of water birds recorded from Aji-1 Water reservoir, Rajkot (Vala & Trivedi 2018). This indicates that multi-habitat characteristics of Saurashtra University Campus areas support a wide range of specialist and generalist species of birds.

REFERENCES

Ali, S. (2012). *The Book of Indian Birds*. Bombay Natural History Society, Oxford University, Press, 13th Edition, 326pp.

Ali, S. & S.D. Ripley (1983). *Handbook of the Birds of India and Pakistan*. Compact edition, Oxford University Press, Oxford, 737pp.

Ansari, N.A. & A. Nawab (2015). Avian fauna of Surajpur Wetland, Greater Noida, Uttar Pradesh, India. *Journal of Threatened Taxa* 7(11): 7776–7785. <https://doi.org/10.11609/JOTT.03519.7776-85>

Bazzaz, F.A. (1975). Plant species diversity in old-field successional ecosystems in southern Illinois. *Ecology* 56: 485–488.

Borad, P.L. (2009). Birds of Meta Khambaliya, Kamadhiya and Keshvala, Gondal Taluka, Rajkot District. M.Sc. Thesis, Saurashtra University, Rajkot, 36pp.

CITES (2020). <http://checklist.cites.org/>; <https://speciesplus.net/> citeslisting. Accessed on 14 April 2020.

Clergeau, P., J.P.L. Savard, G. Mennechez & G. Falardeau (1998). Bird abundance and diversity along an urban to rural gradient: a comparative study between two cities on different continents. *Condor* 100: 413–425.

Emlen, T.J. (1974). Population densities of birds derived from transect counts. *The Auk* 88: 323–342.

Ganpule, P. (2016). The Birds of Gujarat- Status and Distribution; *Flamingo*, Newsletter of BCSG. 3(viii): xii, 1–40.

Gohil, J. (2017). Status, Diversity, Distribution and Population of Avian fauna of Saurashtra University Campus, Rajkot, M.Sc. Thesis Saurashtra University, Rajkot, 30pp.

Grimmett, R., C. Inskip & T. Inskip (2013). *Birds of the Indian Subcontinent*. Oxford University Press, India, 528pp.

IUCN (2020). The IUCN Red List of Threatened Species. Ver. 2020-1. <www.iucnredlist.org/>.

Jambukiya, H. (2014). Water Birds of Sodavadar and Phophal Reservoirs of Jamkandorna Taluka, Rajkot District. M.Sc. Thesis Saurashtra University, Rajkot, 31pp.

Joshi, K. (2009). Avifauna of Specific Attention to Wetland Areas at Rajkot. M.Sc. Thesis Saurashtra University, Rajkot, 32pp.

Kasundra, V.A. (2017). Seasonal Distribution and Diversity of Water Birds of Randarda Lake, Rajkot, District Rajkot, Gujarat. M.Sc. Thesis Saurashtra University, Rajkot, 24pp.

MacArthur, R.H. & J.W. Mac Arthur (1961). Population effects of natural selection. *The American Naturalist* 95: 195–219.

Manohar, K.A., A. Ramachandran, M.S. Syamili, E.R. Sreekumar, N. Mohan, J. Anjali, A. Reddy & P.O. Nameer (2017). Birds of the Kerala Agricultural University campus, Thrissur District, Kerala, India—an update. *Journal of Threatened Taxa* 9(8): 10585–10612. <http://doi.org/10.11609/JOTT.2455.9.8.10585-10612>

Maxwell, R.G. & H.W. Kale (1977). Breeding biology of five species of herons in costal Florida. *The Auk* 94: 689–700.

McCrimmon, D.A. (1978). Nest site characteristics among five species of herons on the North Carolina coast. *The Auk* 95: 267–280.

Nason, I. (1992). *Discovering Birds*. Pisces Publication, 67–69pp.

Odum, E.P. (1971). *Fundamentals of Ecology*. Third Edition, W.B. Saunders Co., Philadelphia, 574pp.

Parasharya, B.M., C.K. Borad & D.N. Rank (2004). A Checklist of the Birds of Gujarat. *Bird Conservation Society, Gujarat (BCSG)*, 1–26.

Pielou, E.C. (1966). The measurement of diversity in different types of biological collection. *Journal of Theoretical Biology* 13: 131–144.

Praveen, J., R. Jayapal & A. Pittie (2018). *Checklist of the birds of South Asia* (version: 3.1). <http://www.indianbirds.in/south-asia> Date of

publication: 31 July 2018.

Sangha, H. & R. Naoroji (2005). Birds recorded during seven Expeditions to Ladakh from 1997 to 2003. *Journal of Bombay natural History Society* 102(3) : 290–304.

Satose, V., V. Ramachandran, P. Roy & K. Kunte (Chief Editors) (2020). *Birds of India*, v. 2.14. Indian Foundation for Butterflies. <https://www.birdsofindia.org>

Savard, J-P. L. & B.J. Falls (1982). Influence of habitat structure on the nesting height of birds in urban areas. *Canadian Journal of Zoology* 59: 924–932.

Savard, J-P.L., P. Clergeaub & G. Mennechezb (2000). Biodiversity concepts and urban ecosystems *Landscape and Urban Planning* 48: 131–142.

Skead, C.J. (1966). A study of the Cattle Egret *Ardeola ibis* Linnaeus. *Proceedings II Second Pan-African Ornithological Congress, Ostrich Supplement 6*: 109–139.

Sugathan, R. & A.P. Varghese (1996). A review of the birds of Thattakad Birds Sanctuary, Kerala. *Journal of the Bombay natural History Society* 93(3): 487–506.

Tews, J., U. Brose, V. Grimm, K. Teilborger, M.C. Wichmann, M. Schwager & F. Jeltsch (2004). Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. *Journal of Biogeography* 31: 79–92.

Vadhel, G.S. (2010). Water Birds of Nyari - 1 Reservoir and Some Occupancy sites of Crane at Rajkot and their vicinities. M.Sc. Thesis, Saurashtra University, Rajkot, 26pp.

Vala, D.S. & V. Trivedi (2018). Status of aquatic birds at Aji-1 Water reservoir, Rajkot, Gujarat, India. *Journal of Global Biosciences* 7(2): 5375–5384 www.mutagens.co.in

WPA (1972). http://www.wiienvis.nic.in/Database/ScheduleSpeciesDatabase_7969.aspx (update dt. 28/4/ 2014).

Yadav, R. (2015). Seasonal distribution and diversity of water birds of Randarda Lake, Rajkot, District Rajkot, Gujarat. MSc Thesis, Saurashtra University, Rajkot, 26pp.





Five new species of trap-door spiders (Araneae: Mygalomorphae: Idiopidae) from India

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Abstract: The family Idiopidae is dominated by the subfamily Idiopinae with 106 species recorded from the world; 20 species (five species of *Heligmomerus*, 12 species of *Idiops*, and three species of *Scalidognathus*) are reported from India. In this paper, we describe a new species of *Heligmomerus wili* from Dehradun, Uttarakhand and four new species of *Idiops*: *Idiops bonny*, *Idiops reshma*, & *Idiops sally* from Dangs, Gujarat and *Idiops vankhede* from Maharashtra.

Keywords: Description, Gujarat, Idiopidae, Maharashtra, taxonomy, Uttarakhand.

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Author contribution: All the authors have contributed equally in the preparation of the manuscript; MS, RH & AY were responsible for the collection of specimens and taxonomic description of the species. DK and MS brought fundings for the project.

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भारतीय वन्यजीव संस्थान
Wildlife Institute of India



INTRODUCTION

The trap-door spider family Idiopidae Simon, 1889 is represented by 407 species under 22 genera in the world (WSC 2020). The subfamily Idiopinae Simon, 1889 (*Heligmomerus* Simon, 1892 and *Idiops* Perty, 1833) is the largest with 106 species and is predominantly found in the Old World (Africa, Asia, Middle-East), except for the genus *Idiops* which has widespread geographic distribution (South America, Southern Africa, northern Africa, Middle-East, India, southeastern Asia) (WSC 2020). Therefore, Idiopinae forms an important model for biogeographic study especially to test the Gondwana hypothesis.

Members of the subfamily Idiopinae can be easily distinguished from the rest of the subfamilies by the anterior lateral eyes being situated close to the clypeal edge, well advanced from the rest of the eye group. Further, *Heligmomerus* can be distinguished by the presence of a dorsal depression on tibia III, whereas in *Idiops*, it is normal (Raven 1985; Siliwal et al. 2010).

In India, Idiopidae is represented by three genera and 24 species, of which 17 species belong to Idiopinae: 12 species of *Idiops* and five species of *Heligmomerus* (WSC 2020). The diversity of Idiopinae is expected to be high in India and it is poorly reported due to the specialized burrowing habit. The burrows are short but thickly lined with silk and have thick lid or door at the entrance of the burrow, which remains closed when the spider is inside. The outer surface of the burrow is covered with dust, soil, and moss or dry vegetation, which makes the burrow highly challenging to notice even when a few centimeters away. A trained pair of eyes are required to spot these highly camouflaged burrows.

Females of the Indian Idiopinae morphologically look alike with distinct size variations (Sanap & Mirza 2015; also see below). Till date, only two types of spermathecae structure are reported from India. In Type I, the receptacle ends in a lobe which resembles a halogen bulb whereas, in Type II, the receptacle ends in a lobe that has a constriction anteriorly and appears like a teat. In this paper we report additional spermathecae structure and term it as Type III. In Type III, receptacles are doll-like with or without lateral lobes, however, males show distinct morphological variations in the first leg especially, the shape of the metatarsi and the tibial apophysis. Therefore, identification of the species is largely based on the males and it is more reliable.

Since 2009, interest in trapdoor spiders has gained momentum amongst aspiring arachnologists and a number of species have been described or redescribed

(Sanap & Mirza 2011, 2015; Mirza & Sanap 2012; Mirza et al. 2012; Sen et al. 2012; Gupta et al. 2013). Due to lack of detailed descriptive literature and comparative materials, however, many species have been either misidentified or have undergone taxonomic changes (Siliwal 2009; Siliwal et al. 2010; Siliwal & Raven 2010).

In this paper, we describe five new species, *Heligmomerus wii* sp. nov. from Dehradun, Uttarakhand, *Idiops bonny* sp. nov., *I. reshma* sp. nov. and *I. sally* sp. nov. from Dangs, Gujarat, and *I. vankhede* sp. nov. from Solapur, Maharashtra. *I. vankhede* sp. nov. is described based on both males and females; *H. wii* sp. nov. is described based on the male, whereas, the other species are described based solely on females.

METHODS

All specimens are deposited at the Wildlife Information Liaison Development Society (WILD) Museum at Dehra Dun, Uttarakhand, India. Measurements of body parts except for the eyes were taken with a Mitutoyo™ Vernier Caliper. Eye measurements were done with calibrated ocular micrometer. All measurements are in millimeters. Spermathecae were dissected and cleared in concentrated lactic acid. Total length excludes chelicerae. All illustrations were prepared with the help of a camera lucida attached to a MOTIC™ stereomicroscopes by MS. The taxonomic description style follows Siliwal et al. (2014).

Abbreviations: ALE = anterior lateral eye, AME = anterior median eye, HT = Holotype, MOA = median ocular area, PLE = posterior lateral eye, PME = posterior median eye, PLS = posterior later spinnerets, PMS = posterior median spinnerets, PT = Paratype, WILD = Wildlife Information Liaison Development Society. Abbreviations used for hair and spines count are d = dorsal, fe = femur, mt = metatarsus, p = prolateral pa = patella, pc = preening comb, r = retrolateral, ta = tarsus, ti = tibia, v = ventral.

RESULTS

Taxonomy

Class Arachnida Cuvier, 1812

Order Araneae Clerck, 1757

Family Idiopidae Simon, 1899

Genus *Heligmomerus* Simon, 1892

Heligmomerus wii sp. nov.

(Image 1, Figs. 1–11, Table 1)

urn:lsid:zoobank.org:act:2825E2C9-9EED-4BFB-8040-97BF3ED0A43E

Material examined

Holotype: WILD-16-ARA-1302, 23.vii.2016, male, Wildlife Institute of India main campus (30.284°N & 77.974°E, 591m), Dehradun, Uttarakhand, India, coll. M. Siliwal & G. Mathur.

Paratypes: WILD-16-ARA-1304, 31.vii.2016, one male, same data as holotype; WILD-15-ARA-1294, 22.viii.2015, one male, same locality as holotype, coll. M.V. Nair.

Description

Holotype (male): Total length 11.82, carapace 6.05

long, 5.38 wide; chelicerae 3.34 long; abdomen 5.77 long, 4.18 wide. Spinnerets: PMS, 0.55 long, 0.19 wide, 0.30 apart; PLS, 0.54 basal, 0.31 middle, 0.24 distal; midwidths 0.74, 0.48, 0.32 respectively; 1.09 total length. Morphometry of legs and palp are given in Table 1.

Colour in alcohol: Carapace, chelicerae reddish-brown; sternum pale yellow; maxillae, labium yellowish-brown; legs greenish-brown except for tarsi of all legs and palp, mt I distal ½ mt II–IV complete and tibia of palp greenish-yellow. Abdomen dorsally grayish-brown with pale spots radiating in curved lines; ventrally and ventro-laterally yellowish-gray. Spinnerets pale creamish.

Carapace (Fig. 1): Oval, wart-like tubercles except for striae and very few tubercles on caput. Broad black patch covering anterior half of caput, narrowing down to two parallel lines in posterior half reaching fovea. Unusual gentle recurved depression on caput just before fovea (resembles like depression made by pressing caput by fovea but it is present on all specimens), it coincides with foveal depression margin to form round rim around fovea. Fovea procurved, deep. Bristles absent.

Eyes (Figs 1–2): Eight in three rows, ALE situated far from AME on clypeal edge; posterior row procurved.



Image 1. *Heligmomerus wii* sp. nov.

Ocular group 1.27 long, 1.39 wide; MOA square, 0.87 wide and 0.71 long. Diameter AME 0.31, PME 0.21, ALE 0.27, PLE 0.33; distance between ALE-AME 0.20, PME-PME 0.25, ALE-PLE 0.37, AME-AME 0.04, PLE-PME, 0.04, ALE-ALE adjacent.

Maxillae (Fig. 3): 1.71 long anteriorly, 2.12 long posteriorly, 1.18 wide; no cuspules; anterior lobe distinct, posterior edge obscured, anterior edge straight.

Labium (Fig. 3): 0.81 long, 0.99 wide, labiosternal groove shallow, slightly procurved, cuspules absent.

Chelicerae (Fig. 3): Eight teeth on promargin and 5 teeth on retromargin; rastellum strong, raised on high triangular mound, with 24 thick, short spines, surrounded with many normal spines; two glabrous bands for length of dorsal surface of chelicerae.

Sternum (Fig. 3): 3.33 long, 2.98 wide, broader between coxae II-III; yellowish-brown, elevated in centre, sloping laterally, covered with short and long black bristles; posterior angle acute.

Sigilla (Fig. 3): Posterior sigilla absent; median pair marginal, 0.16 diameter, 2.06 apart, marginal and anterior pair 0.06 diameter, 1.47 apart, marginal.

Legs (Figs 4-7): All legs cylindrical, not flattened; leg I slightly thicker than rest; femora III clearly wider than rest; metatarsi of all legs longer than tarsi. Tibia I inflated with two prolateral tibial apophysis; distal apophysis possess stout spur with broad base, narrowing abruptly into pointed tip, facing up. Lower apophysis with blunt, smooth surface facing distal spur (Figs 6-7); mt I gently excavated in basal one-third but prolateral process absent (Fig. 5). Ti III slightly excavated dorsally (Fig. 5). Ta I-II slightly swollen. Legs covered with few scattered hairs, bristles and normal pointed spines. Two conspicuous glabrous bands through the length of femora, patellae and tibiae. Leg formula 4123 (Table 1).

Scopulae: Ta I distinct, in distal two-third, ta II distinct, distal three-fourth, ta III, distinct, in distal one-third, ta IV, very few scopuliform hairs in distal one-fourth. On all ta, scopuliform hairs sparse, restricted to only ventral side.

Spines: More on promarginal and retromarginal sides of legs and palp; normal long spines on all leg parts except for pa III-IV and ti palp, ti III, mt III with thorn-like thick spines. I: ti, p=1+2 tubercles, one with megaspine, r=9; mt, p=3, r=11, ta p=3, r=4. II: ti, r=1; mt, p=3, r=7, v=1; ta, p=2, r=4. III: pa, p=7, d=2; ti, p=7, v=3, r=9, d=50; mt, p=7, d=37, r=3, v=8; ta, p=4, r=3, v=2. IV: pa, p=72, d=23; mt, v=7; ta, p=v=6, r=1. Palp: ti, r=43; ta, d=2.

Trichobothria: Clavate absent; ta I, 15 long filiform; ta II 14 long and short filiform; ta III, 12 long filiform; ta IV, 12 long filiform and six long filiform on palp in centre, ta I-IV trichobothria in triangular area in distal three fourth.

Mt I-III, 7-8 long filiform in distal one thirds; mt IV, seven long filiform in distal one-fourth.

Leg coxae: Greenish-yellow, covered with sparse short and long black bristles.

Claws: All legs with paired and unpaired claws. Both (paired as well as unpaired) claws on IV prominent and distinctly larger than rest. Paired claws on leg I-III with unequal bifid tooth, on leg IV single tooth.

Abdomen (Fig. 1): Covered with short black hairs with few long bristle-like hairs posteriorly, cuticle appears leathery and slightly rough. Ventral region uniformly covered with short and few long black hairs.

Spinnerets: PMS digitiform covered with brown hairs; PLS covered with brown hairs, apical segment domed.

Palp (Figs 8-11): Tibia incrassate, ventral 1/3rd excavated into cavity; with band of spines in crescent shape on retrolateral side of cavity, anterior and posterior spines longer than rest. Cymbium truncated dorsally with two lateral processes, two long spines dorsally. Median haematodocha fused with bulb, embolus, long, gently curves retrolaterally, gradually tapering till mid-way and then continues of almost same width and slightly flatten towards tip; embolus distally with two teeth like dentition on retrolateral keel.

Variation male (WILD-16-ARA-1304)

Total length 10.59, carapace: 5.29 long, 4.51 wide, labium: 0.73 long, 1.08 wide, maxillae: 1.24 long in front, 1.78 long in back, 0.94 wide, sternum: 2.97 long, 2.70 wide, abdomen: 5.30 long, 3.47 wide, spinnerets: PLS, 0.57 basal, 0.24 middle, 0.16 apical; midwidths, 0.64, 0.57, 0.36 respectively; 0.97 total length; PMS, 0.47 long, 0.17 wide; distance between PMS-PMS, 0.32. Morphometry of legs and palp are given in Table 1.

Diagnosis

Male of *Heligmomerus wii* sp. nov. closely resembles *H. barkudensis* Gravely, 1921 in the absence of metatarsal process and spines; and it resembles *H. biharicus* (Gravely, 1921) by the presence of a shallow excavation on tibia III. The new species differs from *H. barkudensis* and *H. biharicus* by distal tibial apophysis with spur, broader at base narrowing distally to pointed tip, (see Figs. 6-7) (in *H. barkudensis* spur broader but abruptly narrows in distal half with pointed blunt tip; in *H. biharicus* spur is short, triangular); lower tibial apophysis with blunt, rounded tip, (see figs. 6-7) (same in *H. barkudensis*; in *H. biharicus* it is short and pointed; palp embolus distally with two teeth like dentition on retrolateral keel, (see Fig. 11) (such dentition either absent or unknown on embolus of *H. biharicus* and *H. barkudensis*).

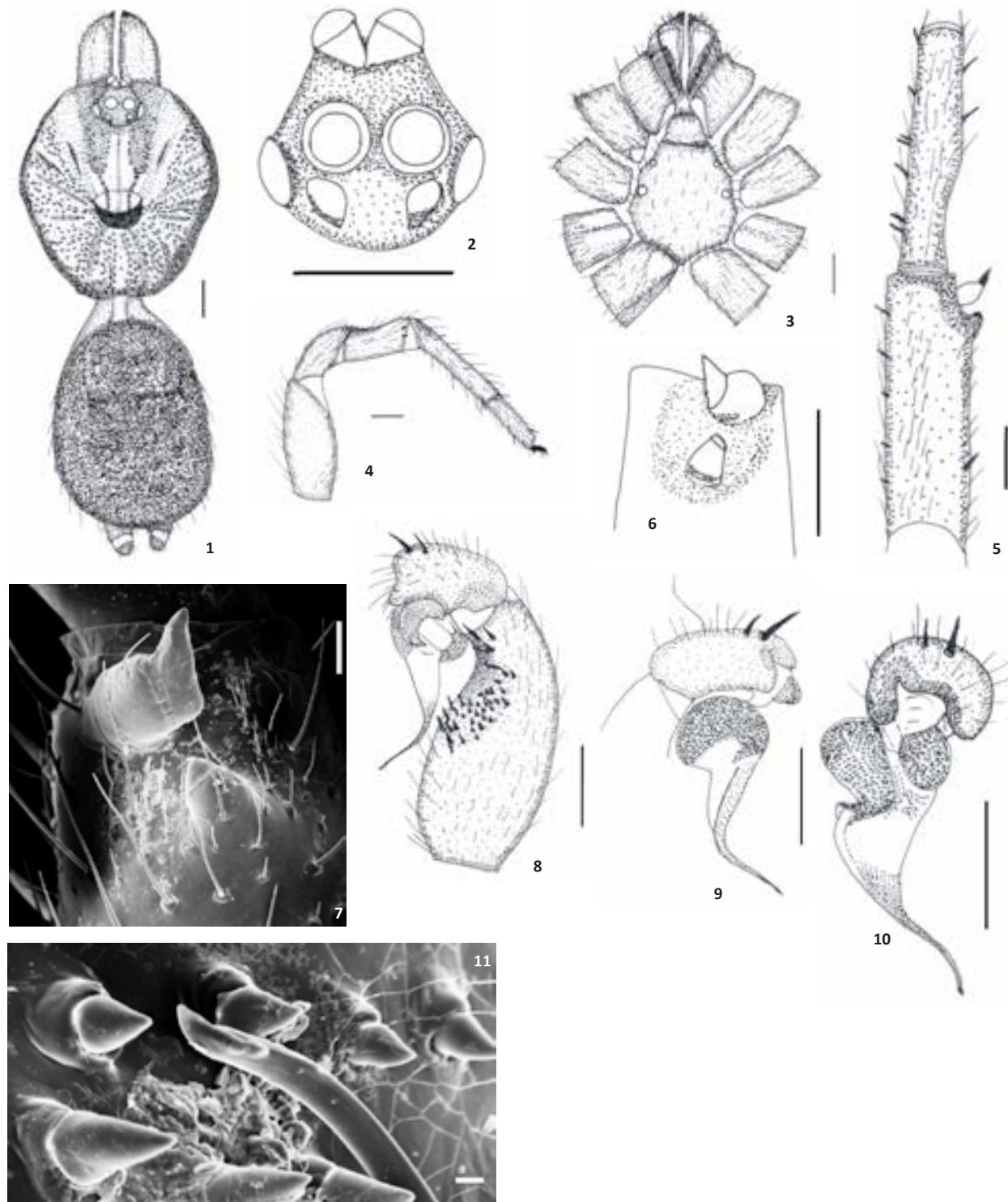


Figure 1–11. *Heligmomerus wii* sp. nov., male (WILD-15-ARA-1302).

1—carapace and abdomen dorsal view, scale 1.0mm | 2—eye, scale 1.0mm | 3—sternum, maxillae, labium, chelicerae, scale 1.0mm | 4—leg III (Fe to ta), lateral view, scale 1.0mm | 5—tibia and metatarsi of leg I, scale 1.0mm | 6—tibial apophysis, scale 1.0mm | 7—tibial apophysis, scale 0.2mm | 8—palp retrolateral view, scale 1.0mm | 9—palp ventral view, scale 1.0mm | 10—palp prolateral view, scale 1.0mm | 11—palp embolus tip, scale 2.0 mm.

Table 1. Morphometry of legs and palp of *Heligmomerus wii* sp. nov. from Dehradun, Uttarakhand, holotype (HT; WILD-16-ARA-1302) and paratype (PT; WILD-16-ARA-1304).

	LEG I		LEG II		LEG III		LEG IV		PALP	
	HT	PT	HT	PT	HT	PT	HT	PT	HT	PT
Femur	5.74	5.15	4.54	4.08	3.56	3.14	5.32	4.56	3.6	3.05
Patella	2.98	2.54	2.34	2.08	2.29	2.08	2.72	2.33	1.69	1.65
Tibia	3.89	3.32	3.18	2.62	1.77	1.81	4.22	3.69	3.19	2.96
Metatarsus	4.11	3.67	3.5	3.02	3.57	3.18	4.74	4.05		
Tarsus	1.54	1.49	1.6	1.52	1.8	1.93	2.77	2.21	1.46	1.21
Total	18.26	16.17	15.16	13.32	12.99	12.14	19.77	16.84	9.94	8.87
Midwidth										
Femur	1.06	0.95	1.04	0.84	1.48	1.14	1.1	0.97	0.67	0.54
Tibia	1.27	1.19	0.86	0.79	0.97	0.88	0.97	0.85	1.29	1.22

Etymology

The species epithet is an acronym for the Wildlife Institute of India, the type locality of the species.

Remarks

We could not provide more robust characters for diagnosis for the new species in the absence of comparative type material of the male sex of both *H. biharicus* and *H. barkudensis*. Apart from all the diagnostic characters mentioned above, the new species is from the Doon Valley, which is geographically about 1,200–2,000 km apart from the type localities of both *H. biharicus* (Sahebganj, Bihar) and *H. barkudaensis* (Barkuda Island, Chilika lake, Odisha). Also, the habitat in Dehradun is Sal dominant and subtemperate with 600–700 m elevation, whereas, Sahebganj is in the Terai region with predominant grassland habitat & Sal forests with elevation ranging from 15–100m and Barkuda Island with a mix shurby vegetation with an elevation lower than 20m and lies in subtropical region. Taking into account the geographical separation and barriers between these three type localities, the species therefore, can be considered a distinct and separate species. More diagnostic characters will be added after examining or procuring fresh male specimens of *H. biharicus* and *H. barkudensis*.

Morphometry for the paratype male (WILD-15-ARA-1294) is not provided as some deformities in eyes and sternum were observed. We, however, have used SEM pictures of this specimen to show tibial apophysis on leg I and palp embolus tip as they were identical and intact as in the holotype.

Natural history

All the spiders were found wandering on the road

during the night or early morning. The Wildlife Institute of India campus consists of Sal *Shorea robusta* forest patches in different areas. Though we have not been successful in locating an active burrow of this spider, we assume these spiders make burrows in Sal patches. Sal patches have heavy undergrowth during monsoon and post monsoon, whereas, during dry phases of winter and summer a thick layer of leaf litter is present. Therefore, it is difficult to locate these highly camouflaged burrows in the Sal patches. Males were found during the monsoon (July–August).

Genus *Idiops* Perty, 1833

Idiops bonny sp. nov.

(Image 2, Figs. 12–17, Table 2)

urn:lsid:zoobank.org:act:670B72D3-F567-4589-A67C-104614DBD8F6

Material examined

Holotype: WILD-15-ARA-1285, 12.iii.2015, female, Vansda National Park, (20.752°N & 73.483°E, elev. 131m), Dangs, Gujarat, India, coll. R. Solanki, A. Yadav and M. Siliwal.

Paratype: WILD-15-ARA-1286, 12.iii.2015, one female, same data as holotype.

Description

Holotype (female): Total length 29.81, carapace 13.30 long, 11.59 wide; 6.94 long chelicerae; abdomen 16.51 long, 10.69 wide. Spinnerets: PMS, 1.13 long, 0.63 wide, 0.46 apart; PLS, 2.08 basal, 0.90 middle, 0.73 distal; midwidths 1.94, 1.53, 1.03 respectively; 3.71 total length. Morphometry of legs and palp given in Table 2.

Colour in life: Complete spider black.

Colour in alcohol: Carapace, chelicerae, legs reddish-



Image 2. *Idiops bonny* sp. nov.

Table 2. Morphometry of legs and palp of *Idiops bonny* sp. nov. from Vansda NP, Gujarat, holotype (HT; WILD-15-ARA-1285) and paratype (PT; WILD-15-ARA-1286).

	LEG I		LEG II		LEG III		LEG IV		PALP	
	HT	PT	HT	PT	HT	PT	HT	PT	HT	PT
Femur	8.04	8.19	7.09	7.65	6.17	5.78	8.58	8.55	6.81	6.84
Patella	4.99	5.09	4.78	4.66	4.99	5.1	5.72	5.87	4.46	4.37
Tibia	4.73	4.85	4.19	4.28	3.26	3.44	6.11	6.13	4.41	4.43
Metatarsus	3.95	3.76	3.64	3.41	4.39	4.65	5.81	5.79		
Tarsus	2.26	2.27	2.12	2.29	3.21	3.48	3.25	3.49	4.86	4.83
Total	23.97	24.16	21.82	22.29	22.02	22.45	29.47	29.83	20.54	20.47
Midwidth										
Femur	2.04	2.03	1.93	2.05	2.67	2.71	2.28	2.21	1.53	1.68
Tibia	2.34	2.33	2.16	2.11	2.32	2.39	2.12	2.21	2.08	2.15

brown; carapace with reticulate marking on thoracic region, along striae and towards margin, darker patch on caput, thoracic area lighter than cephalic area; legs

lighter below. Legs and palp yellowish-brown, lighter below. Abdomen dorsally grayish-brown mottled with radiating yellow spots, ventrally yellowish-grey.

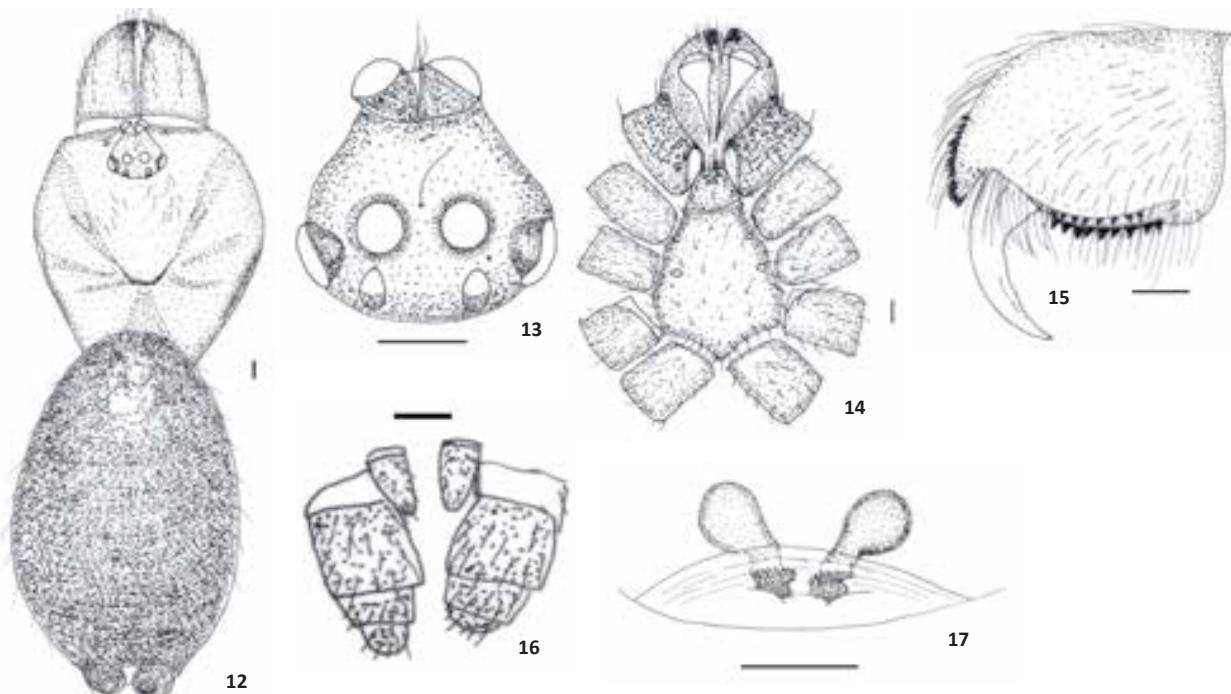


Figure 12–17. *Idiops bonny* sp. nov., male (WILD-15-ARA-1285).

12—cephalothorax and abdomen, scale 1.0mm | 13—eyes, scale 1.0 mm | 14—sternum, maxillae, chelicerae and labium, scale 1.0mm | 15—chelicerae, scale 1.0mm | 16—spinnerets, scale 1.0mm | 17—spermathecae, scale 1.0mm.

Spinnerets yellowish-brown.

Carapace (Fig. 12): Glabrous, broader anteriorly (widest between legs III) and gradually narrowing posteriorly, striae prominent. Fovea, procurved, deep; caput raised. Anterior ocular area at level of caput and not raised. Bristles: 4 long and 32 short on caput; one long between AME-AME; two long between PME-PME; one long, two short between ALE-ALE, three long and five short on clypeal edge. Clypeus absent. Few short hairs on posterior and anterior margins.

Eyes (Figs 12–13): Eight in three rows, ALE situated far from AME on clypeal edge; posterior row procurved. Ocular group 2.97 long, 2.95 wide; MOA rectangle, 1.59 wide, 1.27 long. Diameter AME 0.48, PME 0.30, ALE 0.63, PLE 0.74; distance between ALE-AME 0.54, AME-AME 0.36, PLE-PME 0.24, PME-PME 0.68, ALE-PLE 1.11, ALE-ALE adjacent.

Maxillae (Fig. 14): 4.05 long anteriorly, 4.68 long posteriorly, 3.14 wide; 167 cuspules of unequal size; anterior lobe distinct, anterior margin straight, posterior margin obscure.

Labium (Fig. 14): 2.19 long, 2.39 wide, labiosternal groove shallow, slightly procurved with seven cuspules anteriorly in two curved rows.

Chelicerae (Figs 15): 10 large, two small teeth on promargin and eight large, two small teeth on

retromargin; depression on retrolateral face where fang touches chelicerae; rastellum strong, raised on high triangular mound, with 42 thick, short spines, surrounded by many normal long spines; two glabrous bands for length of dorsal surface of chelicerae.

Sternum (Fig. 14): 7.89 long, 6.67 wide, broader between coxae III; yellowish-brown, elevated in centre, sloping laterally, covered with long black bristles; row of long bristles on margins, posterior angle blunt.

Sigilla (Fig. 14): Posterior sigilla absent; median pair 0.50 diameter, 3.79 apart, 0.42 from margin and anterior pair round, marginal.

Legs: Posterior legs slightly thicker than anterior ones. Femora III and tibiae I and III wider than others. Patellae I-III and palp longer than tarsi. Tibiae to tarsi of legs I-II and palp slightly dorsoventrally flattened, other legs normal. Legs covered with few scattered hairs, bristles and few curved thick thorn-like spines restricted to anterior legs and palp. Two conspicuous glabrous bands for length of femora, patellae and tibiae. Scopulae absent on tarsi of all legs and palp. Leg formula 4132 (Table 2).

Spines: More on promarginal and retromarginal sides of legs and palp. I: ti, p=20, r=26; mt, p=33, r=27; ta, p=11, r=10, v=1. II: ti, p=10, v=1; mt, p=21, r=8; ta, p=12, r=5, v=4. III: pa, p=35, d=3, r=1; ti, p=15, r=6; mt,

p=23, r=14, v=4; ta, p=5, r=6, v=3. IV: pa, p=28; ti, v=1; mt, p=6, v=1; ta, p=19, v=3, r=4. Palp: fe, p=3; pa, p=1; ti, p=24, r=31; ta, p=29, r=28, v=4.

Trichobothria. Clavate absent; ta I, 20 long filiform; ta II, 16 long filiform; ta III, 16 long filiform; ta IV, 16 long filiform in two irregular rows almost for length and 24 long filiform in two rows in distal two-third on palp ta. Ta I-III filiform in two inverted V-shape rows basal three-fourth. Mt I, seven long filiform in distal fourth; mt II-IV, 10 long filiform in distal one-fourth.

Leg coxae: Covered with short and long black bristles, spinules absent. Coxa III with glabrous patch in basal three-fourth, rest area sparsely covered with long bristles; coxa IV clearly broader than others, anterior edge curved, ventrally.

Claws: All legs with paired and unpaired claws. Paired claws on legs I-II with unequal bifid tooth, on legs III-IV with equal length bifid tooth; bifid tooth on palp claw. False claw tufts on each side of paired claws.

Abdomen (Fig. 12): Oval, uniformly covered with short and long black hairs. Dorsum with few yellow spots in radiating pattern, cuticle appears leathery and slightly rough; ventrally grayish-brown with few pale spots covered with short black hairs. Epigastric plate sclerotized and glabrous in anterior area.

Spinnerets (Fig. 16): PMS digitiform covered with brown hair; PLS covered with brown hair, apical segment domed.

Spermathecae (Fig. 17): Type I spermathecae. Two receptacles, each facing away from each other; each receptacle posteriorly opens into wide sclerotized slit-like opening, receptacles and slit-opening covered with transparent triangular (inverted) membrane, attached posteriorly with epigastral sclerotized region; each receptacle with slightly wider base, immediately sclerotized leading to large-sized sclerotized cup-shape lobes. Each receptacle covered with spermathecal pores except for the basal 1/4th part.

Variation female (WILD-15-ARA-1286)

Total length 30.88; carapace: 11.46 long, 10.22 wide; labium: 2.00 long, 2.50 wide; cuspules 7. Maxillae: 3.57 long in front, 4.47 long in back, 2.80 wide; cuspules 110. Sternum: 6.85 long, 6.17 wide. Abdomen: 19.42 long, 14.53 wide. Spinnerets: PLS, 1.54 basal, 0.86 middle, 0.70 apical; midwidths, 1.36, 1.19, 0.87 respectively; 3.10 total length; PMS, 1.17 long, 0.60 wide; distance between PMS-PMS, 0.61. Morphometry of legs and palp in Table 2.

Diagnosis

Females of *Idiops bonny* sp. nov. are 40–60% larger in size than other described congeners from India except for *I. fortis* (total length is 32 and carapace length 14). This species differs from females of *I. vankhede* sp. nov., *I. joida*, *I. constructor*, *I. fortis* and *I. oriya* by the absence of spinules on coxae IV; additionally it differs from *I. constructor*, *I. fortis* and *I. oriya* by the leg formula 4132 (whereas it is 4123 in *I. constructor*, *I. fortis* and *I. oriya*) and differs from *I. vankhede* sp. nov. and *I. joida* by ocular area as wide as long (see Fig. 13; distinctly longer than wide in *I. vankhede* sp. nov. and *I. joida*).

Etymology

The species epithet is treated as a noun in apposition, named in honour of Prof. Bonny Pilo, retired dean and head of Zoology Department, The M.S. University of Baroda for being a pioneer in initiating wildlife studies in the department and providing motivation and support to arachnological studies in the department.

Remarks

Basic structure of spermathecal respectale resembles 'Type-I' except for the lobes which are not inflated like a bulb as typically seen in Type-I, this perhaps could be due to the lack of sperms in the spermathecae. It is likely that the female had just nested or didn't mate in the previous season. Cup-shaped depression is relatively less in the paratype specimen.

Natural history

Idiops fortis is the largest *Idiops* recorded so far from India and *Idiops bonny* sp. nov. is the second largest species. It is almost double the size of previously recorded species from India. Interestingly, *I. sally* sp. nov. and *I. bonny* sp. nov. were found in the same area within a radius of 100m, both sharing same habitat and elevation.

The spiders were found inside their trap-door burrows made on mud-bunds inside the forest of Vansda National Park. Burrow entrances had D-shaped lid/door attached on the upper side of burrow, canopy cover ranged from 5–8%, with almost bare ground (maximum 1% ground cover), 70% leaf litter, all burrows were facing east. Burrow diameters ranged from 27–29 mm and depth of the burrows ranged from 106–127 mm and lid thickness was 2mm.

***Idiops reshma* sp. nov.**
(Image 3, Figs. 18–21, Table 3)

urn:lsid:zoobank.org:act:63DC5021-6F11-4F46-86DF-594EB545C4DB

Material examined

Holotype: WILD-15-ARA-1288, 12.iii.2015, female, Saputara Botanical Garden (20.576°N & 73.740°E, 898m), Saputara, Gujarat, India, coll. R. Solanki, M. Siliwal & A. Yadav.

Paratype: WILD-15-ARA-1289, one female, same data as holotype.

Description

Holotype (female): Total length 14.48; carapace 5.31 long, 4.33 wide; long chelicerae; abdomen 9.17 long, 5.88 wide. Spinnerets: PMS, 0.38 long, 0.19 wide, 1.10 apart; PLS, 0.58 basal, 0.34 middle, 0.19 distal; midwidths 0.74, 0.64, 0.42 respectively; 1.11 total length. Morphometry of legs and palp given in Table 3.

Colour in alcohol: Carapace, chelicerae, labium,

maxillae, sternum reddish-brown, caput and striae darker. Legs and palp greenish-brown, striae darker, anterior legs darker than posterior ones and lighter ventrally. Abdomen dorsally grayish-brown mottled with faint yellow spots in a curved pattern. Spinnerets yellowish-brown.

Carapace (Fig. 18): Glabrous, broader anteriorly (widest between legs II) and gradually narrowing posteriorly, striae prominent. Fovea, procurved, deep; caput raised. Bristles: Two long and several short hairs on caput; one long between AME-AME; three long, two short between PME-PME; two long, five short between ALE-ALE and carapace edge. Few short hairs on along striae, posterior and anterior margins. Three black patches, one starting between ALE-ALE and going down towards fovea, two on either side of ocular area ending mid-way on caput.

Eyes (Figs 18–19): Eight in three rows, ALE situated far from AME on clypeal edge; posterior row straight. Ocular group 1.30 long, 1.34 wide; MOA square, 0.48



© M. Siliwal

Image 3. *Idiops reshma* sp. nov.

Table 3. Morphometry of legs and palp of *Idiops reshma* sp. nov. from Dangs Gujarat, holotype (HT; WILD-15-ARA-1288) and paratype (PT; WILD-15-ARA-1289).

	LEG I		LEG II		LEG III		LEG IV		PALP	
	HT	PT	HT	PT	HT	PT	HT	PT	HT	PT
Femur	3	2.15	2.6	2.3	2.42	2.15	3.27	2.36	2.88	2.3
Patella	2.08	1.44	1.61	1.06	1.77	1.26	2.43	2.03	1.91	1.63
Tibia	2.19	1.76	1.58	1.45	1.25	1.07	2.48	2.26	2.05	1.7
Metatarsus	1.51	1.06	1.3	1.18	1.63	1.47	2.65	1.96	-	-
Tarsus	1.25	0.82	1.07	0.76	1.24	0.94	1.67	1.07	2.24	1.78
Total	10.03	7.23	8.16	6.75	8.31	6.89	12.5	9.68	9.08	7.41
Midwidth										
Femur	0.77	0.87	0.74	0.75	1.22	1.25	0.98	1.35	0.64	0.80
Tibia	0.94	0.9	0.79	0.72	0.98	0.96	0.84	0.88	0.87	0.98

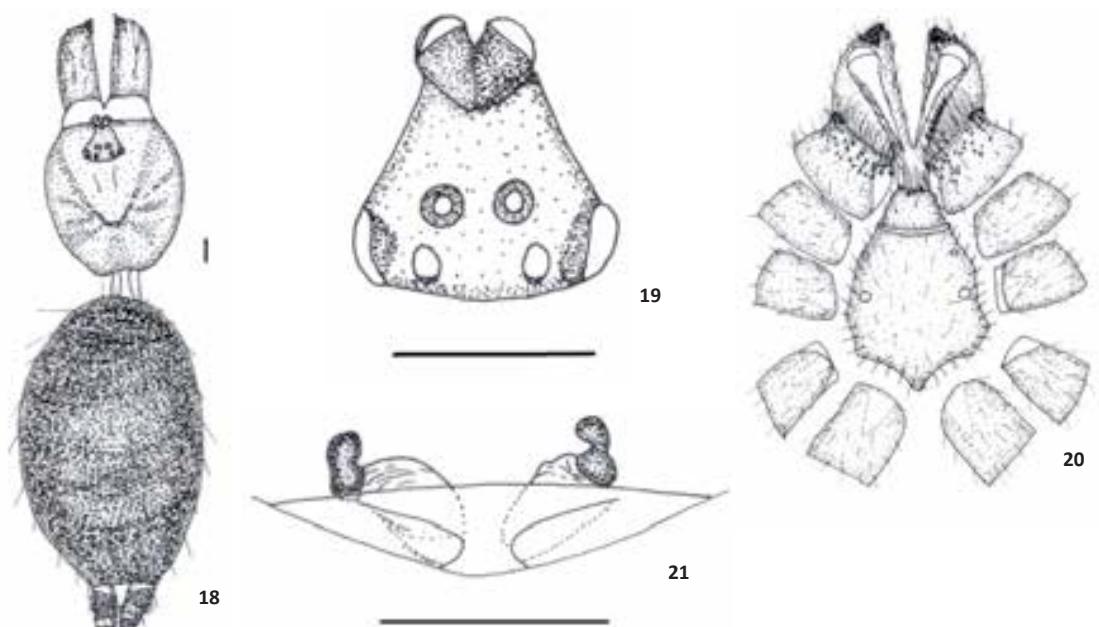


Figure 18–21. *Idiops reshma* sp. nov., female (WILD-15-ARA-1288).

18—cephalothorax and abdomen, scale 1.0mm | 19—eyes, scale 1.0mm | 20—sternum, maxillae, chelicerae and labium, scale 1.0mm | 21—spermathecae, scale 1.0mm.

wide anteriorly, 0.69 posteriorly wide, 0.45 long. Diameter AME 0.22, PME 0.18, ALE 0.24, PLE 0.27; distance between ALE-AME 0.30, AME-AME 0.16, PLE-PME 0.12, PME-PME 0.36, ALE-PLE 0.54, ALE-ALE adjacent.

Maxillae (Fig. 20): 1.44 long anteriorly, 1.86 long posteriorly, 1.17 wide; 32–35 cuspules; anterior lobe distinct, anterior margin straight, posterior margin obscure.

Labium (Fig. 20): 0.79 long, 1.16 wide, labiosternal groove shallow, slightly procurved with two cuspules anteriorly.

Chelicerae (Figs 20): Five large, four small teeth on promargin, and four large, two small teeth on retromargin; depression on retrolateral face where fang touches chelicerae; rastellum strong, raised on high triangular mound, with 12 thick, short spines, surrounded by many normal long spines; two glabrous bands for length of dorsal surface of chelicerae.

Sternum (Fig. 20): 2.77 long, 2.74 wide, broader between coxae II-III; yellowish-brown, elevated in centre, sloping laterally, covered with long black bristles; row of long bristles on margins, posterior angle acute.

Sigilla (Fig. 20): Posterior sigilla absent; median pair

0.12 diameter, 1.70 apart, 0.13 from margin and anterior pair round, marginal.

Legs: Femora and tibiae III wider than others; all metatarsi longer than respective tarsi. Tarsi of palp and mt and ta of leg II dorsoventrally flattened, other legs normal. Legs covered with few scattered hair, bristles and few curved thick thorn-like spines. Two conspicuous glabrous bands for length of femora, patellae and tibiae. Scopulae absent on tarsi of all legs and palp. Leg formula 4132 (Table 3).

Spines: More on promarginal and retromarginal sides of legs and palp. I: ti, p= r=9; mt, p=14, r=12; ta, p=7, r=6, v=4. II: ti, p=5, r=3; mt, p=13, r=5; ta, p=5, r=6, v=4. III: pa, p=8, r=2; ti, p=3, r=7; mt, p=r=7, v=4; ta, p=1, v=5. IV: pa, p=6; mt, v=7; ta, p=1, v=6, r=2. Palp: ti, p=r=14; ta, p=17, r=19, v=8.

Trichobothria: Clavate absent; ta I, 12–14 long filiform in each of four rows for length in triangular area; ta II–III, 16 long filiform in two rows for length; ta IV, 12 long filiform and 16–20 long filiform in two rows in distal half on palp ta. Mt I, eight long filiform in distal fourth; mt II–IV, 10 long filiform in distal fourth.

Leg coxae: Yellowish-brown, covered with short and long black bristles. Coxa III with glabrous patch in distal three fourth, rest coxae on with small glabrous patch at base; coxa IV clearly broader than others, anterior edge curved.

Claws: All legs with paired and unpaired claws. Both (paired as well as unpaired) claws on leg IV prominent and larger than on other legs. Paired claws with two unequal bifid tooth on legs I–IV; unequal bifid tooth on palp. False claw tufts on each side of paired claws.

Abdomen (Fig. 18): Oval, uniformly covered with short and long black hairs. Dorsum with few mottled with yellow spots in radiating pattern, cuticle appears leathery and slightly rough. The skin is now loosened up because it was in the process of moulting at the time of collection.

Spinnerets: PMS digitiform covered with brown hair; PLS covered with brown hair, apical segment domed.

Spermathecae (Fig. 21): Type III spermathecae. Two receptacles, each receptacle posteriorly opening into wide sclerotized slit-like opening, receptacles and slit opening covered with transparent membrane, attached posteriorly with epigastral sclerotized region; each receptacle wider at base, transparent (except lobes), gradually narrowing down midway leading to sclerotized lobes, primary lobe divided into two unequal halves with constriction in middle (upper half round resembling head and lower half oval). Overall lobe appear like a doll; densely covered with pores.

Remarks

Upon dissecting the spermathecae of the holotype, two identical sets of spermathecae were found inside the spider. On detailed observation, it was clear that the spider had just moulted a few hours before the collection. It is probable that the spermathecae did not get removed with the exuvia while moulting. The older spermathecae was slightly lighter in colour than the new pair of spermathecae and both pairs fitted well in each other like a pair of hand gloves that fit inside each other.

Variation female (WILD-15-ARA-1289)

Total length 12.07; carapace: 4.72 long, 3.52 wide; labium: 0.95 long, 0.99 wide; cuspules 25. Maxillae: 0.56 long in front, 0.90 long in back, 1.60 wide; cuspules 40. Sternum: 2.74 long, 2.17 wide. Abdomen: 7.35 long, 5.58 wide. Spinnerets: PLS, 0.44 basal, 0.38 middle, 0.24 apical; midwidths, 0.65, 0.59, 0.40 respectively; 1.06 total length; PMS, 0.27 long, 0.10 wide; distance between PMS–PMS, 0.09. Morphometry of legs and palp given in Table 3.

Diagnosis

Females of *Idiops reshma* sp. nov. resemble those of *I. sally* sp. nov. in primary lobe of receptacle with constriction and divided in two unequal halves but differ from the latter species by the absence of the lateral lobe (Fig. 21).

Etymology

The species epithet is treated as a noun in apposition, named in the honour of late (Dr.) Reshma Solanki, who had contributed in the collection of the species. She was a doctorate student of Dr. Dolly Kumar and worked on the spiders of Jambughoda Wildlife Sanctuary, Gujarat.

Natural history

This species was found in a degraded and highly disturbed botanical garden, which was under renovation. A cluster of 7–8 burrows were found at the base of an ornamental plant. Soil was hard and rocky, therefore, the burrows were shallow (less than 50mm deep). All burrows were vertical to the ground, with a 'D'-shaped lid at the entrance and with burrow entrances facing south. Burrows were in an open area with 2% canopy cover, 5% ground cover, and 50% leaf litter. Burrow diameters ranged from 9–11 mm.

***Idiops sally* sp. nov.**
(Image 4, Figs. 22–25, Table 4)

urn:lsid:zoobank.org:act:026CEB00-564C-41F2-95AB-DF234C534D07

Material examined

Holotype: WILD-15-ARA-1287, 12.iii.2015, female, Vansda National Park (20.752°N & 73.483°E, elev. 131m), Dangs, Gujarat, India, coll. R. Solanki, A. Yadav & M. Siliwal.

Description

Holotype (female): Total length 16.57; carapace 7.65 long, 6.18 wide; 3.92 long chelicerae; abdomen 8.92 long, 5.87 wide. Spinnerets: PMS, 0.66 long, 0.28 wide, 0.14 apart; PLS, 0.94 basal, 0.53 middle, 0.47 distal; midwidths 1.11, 0.89, 0.59 respectively; 1.94 total length. Morphometry of legs and palp given in Table 4.

Colour in life: Complete spider is black.

Colour in alcohol: Carapace greenish-brown; chelicerae reddish-brown. Reticulate marking on anterior carapace, two prominent light blackish patch on caput. Legs and palp greenish-brown, lighter below. Abdomen

dorsally grayish-brown, ventrally yellowish. Spinnerets yellowish-brown.

Carapace (Fig. 22): Glabrous, broader anteriorly (widest between legs II) and gradually narrowing posteriorly, striae prominent. Fovea, procurved, deep; caput raised. Bristles: one long and two short on caput; one long between AME-AME; one long, five short between PME-PME; one long between AME-ALE; one long, five short between ALE-ALE. Few short hairs on posterior and anterior margins.

Eyes (Figs 23): Eight in three rows, ALE situated far from AME on clypeal edge; posterior row straight. Ocular group 1.79 long, 1.82 wide; MOA rectangular, 0.82 wide, 0.77 long. Diameter AME 0.30, PME 0.18, ALE 0.32, PLE 0.38; distance between ALE-AME 0.45, AME-AME 0.05, PLE-PME 0.03, PME-PME 0.48, ALE-PLE 0.99, ALE-ALE adjacent.

Maxillae (Fig. 24): 2.20 long anteriorly, 2.77 long posteriorly, 1.67 wide; 36 cuspules spread over anterior 1/3rd maxillae width; anterior lobe distinct, anterior margin straight, posterior margin obscure.

Labium (Fig. 24): 1.21 long, 1.64 wide, labiosternal



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Image 4. *Idiops sally* sp. nov.

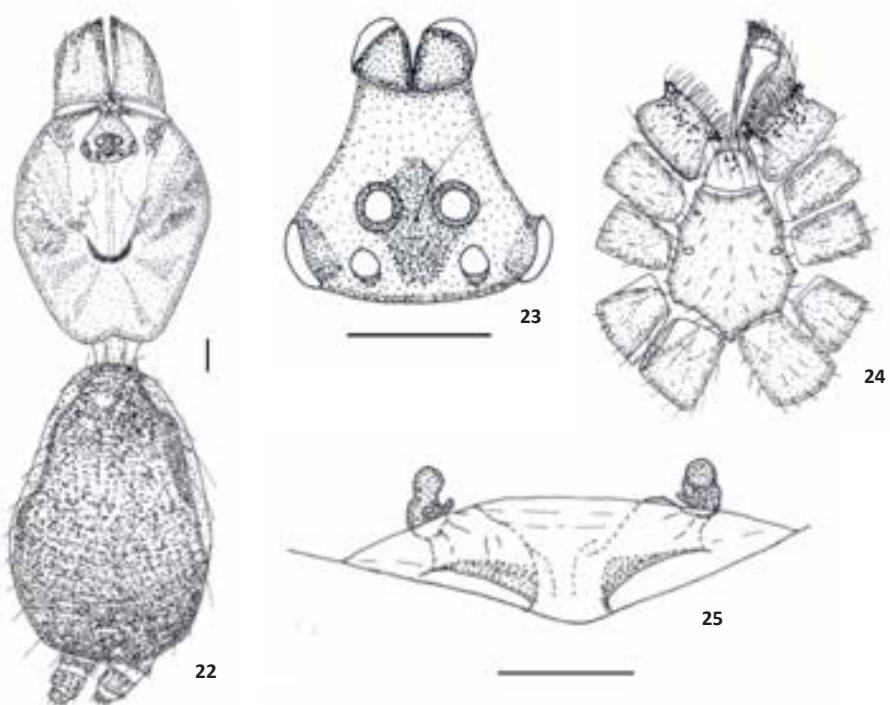


Figure 22–25. *Idiops sally* sp. nov., female (WILD-15-ARA-1287).

22—cephalothorax and abdomen, scale 1.0mm | 23—eyes, scale 1.0mm | 24—sternum, maxillae, chelicerae and labium, scale 1.0mm | 25—spermathecae, scale 1.0mm.

Table 4. Morphometry of legs and palp of *Idiops sally* sp. nov. from Dangs, Gujarat, holotype (WILD-15-ARA-1287).

	LEG I	LEG II	LEG III	LEG IV	PALP
Femur	4.78	3.66	3.25	4.39	3.84
Patella	3.17	2.59	2.74	3.36	2.88
Tibia	2.99	2.31	1.97	3.59	3.01
Metatarsus	2.1	1.9	2.22	3.71	
Tarsus	1.39	1.29	1.7	2.01	3
Total	14.43	11.75	11.88	17.06	12.73
Midwidth					
Femur	1.1	1.15	1.73	1.42	0.91
Tibia	1.49	1.12	1.49	1.37	1.44

groove shallow, slightly procurved with two large and one small cuspules anteriorly in two rows.

Chelicerae (Figs 24): Eight large, three very small teeth on promargin and five teeth on retromargin; rastellum strong, raised on high triangular mound, with 14 thick, short spines, surrounded by many normal long and short stiff bristles; two glabrous bands for length of dorsal surface of chelicerae.

Sternum (Fig. 24): 4.79 long, 3.88 wide, broader between coxae III; yellowish-brown, elevated in centre, sloping laterally, covered with long black bristles; row of

long bristles on margins, posterior angle acute.

Sigilla (Fig. 24): Posterior sigilla absent; median pair 0.17 diameter, 2.34 apart, 0.19 from margin and anterior pair round, marginal.

Legs: Posterior legs slightly thicker than anterior pairs. Femora and tibiae III wider than others; all metatarsi longer than respective tarsi. Tarsi of palp and mt-ta I slightly dorsoventrally flattened, other legs normal. Legs covered with few scattered hair, bristles; curved thick thorn-like spines only on legs I-II and palp. Two conspicuous glabrous bands for length of femora,

patellae and tibiae. Scopulae absent on tarsi of all legs and palp. Leg formula 4132 (Table 4).

Spines: More on promarginal and retromarginal sides of legs and palp. I: ti, p=12, r=14, v=2; mt, p=19, r=18, v=2; ta, p=6, r=8, v=4. II: ti, p=10, r=1, v=3; mt, p=12, v=2, r=8; ta, p=5, r=3, v=6. III: pa, p=11, r=5; ti, p=7, r=9; mt, p=14, r=12, v=5; ta, r=4, v=5. IV: pa, p=16; ti, v=3; mt, r=2, v=8; ta, p=1, v=5, r=9. Palp: fe, p=2; pa, p=1; ti, p=17, r=16; ta, p=21, r=18, v=4.

Trichobothria: Clavate absent; ta I, 15 long filiform; ta II, 14 long filiform; ta III, 16 long filiform; ta IV, 14 long filiform in two irregular rows for almost length and 16–20 long filiform in two rows in distal half on palp ta. Ta I–III filiform in inverted 'V' shape in basal three-fourth. Mt I, 12 long filiform in distal third; mt II–IV, 10 long filiform in distal fourth to half length.

Leg coxae: Yellowish-brown, covered with short and long black bristles, spinules absent. Coxa III with glabrous patch in basal one third, rest area sparsely covered with long bristles; coxa IV clearly broader than others, anterior edge curved.

Claws: All legs with paired and unpaired claws. Paired claws with equal length bifid tooth on legs I–II, single tooth on leg III, unequal bifid tooth on leg IV; single tooth on palp. False claw tufts on each side of paired claws.

Abdomen (Fig. 22): Oval, uniformly covered with short and long black hairs. Dorsum with few mottled yellow spots in radiating pattern, cuticle appears leathery, slightly wrungled and rough. Epigastric plate posteriorly sclerotized and glabrous.

Spinnerets: PMS digitiform covered with brown hairs; PLS covered with brown hairs, apical segment domed.

Spermathecae (Fig. 25). Type III spermathecae. Two receptacles, each opening into wide sclerotized slit-like opening, receptacles and slit opening covered with transparent membrane, attached posteriorly with epigastral sclerotized region; each receptacle wider at base, transparent (except lobes), gradually narrowing down midway leading to sclerotized lobes, primary lobe divided into two unequal halves with constriction in middle (upper half round resembling head and lower half oval) and short hand-like lobe emerging prolaterally at base of main lobe. Overall, lobes appear like lateral view of a praying doll; lobes densely covered with pores.

Remarks

As stated above, previously only two types of lobes of spermathecal reseptacles were reported. This species possesses the third type of lobe having a lateral lobe, which is observed for the first time in this genus.

Diagnosis

The female of *Idiops sally* sp. nov. is distinctly different from all known *Idiops* species from India in the structure of the spermathecae, the bilobed receptacles resemble a praying doll: the main lobe is divided into two unequal halves with a constriction in the middle (upper half round and lower half oval) and short hand-like lobe emerging prolaterally at the base of main lobe (Fig. 25).

Etymology

The species epithet is treated as a noun in apposition, named in honour of the founder of Zoo Outreach Organisation, late Ms. Sally Walker (1944–2019), who dedicated her whole life to the conservation of Indian biodiversity. It is a tribute to her efforts and support to the spider project.

Natural history

Idiops sally sp. nov. was found in the same as habitat as that of *I. bonny* sp. nov. Like in the latter, the burrow entrance had D-shaped lid/door attached on the upper side of the burrow. Burrow diameter was 14mm and depth of the burrow was 70–80 mm. Lid thickness was 12mm. Female was found with egg sac in month of March, which was oval, cup-shape bottom with a flat top, with the female sitting on the top of egg sac along the length to protect it. Dimensions of egg sac was 22.47mm long x 13.68mm wide x 12.12mm high, slightly longer than the female body length.

Idiops vankhede sp. nov.

(Image 5, Figs 26–44, Table 5)

urn:lsid:zoobank.org:act:8FED5FA4-83DF-4724-ACED-73A0A0739B2C

Material examined

Holotype: WILD-10-ARA-821, 24.xii.2010, male, (17.632°N & 75.878°E, 470m), Siddheshwar Van Vihar, Solapur, Maharashtra, India, coll. R. Hippargi.

Paratypes: WILD-10-ARA-871, WILD-10-ARA-859, two females, same data as holotype.

Description

Holotype (male): Total length 10.22. Carapace 5.66 long, 4.70 wide; chelicerae 2.82 long; abdomen 4.56 long, 3.49 wide. Abdomen and spinnerets shrunken because of storage in 100% ethanol. Morphometry of legs and palp given in Table 5.

Colour in alcohol: Carapace, chelicerae reddish-brown. Legs greenish-brown except for tarsi of all legs and palp, mt I distal ½ mt II distal 3/4th, mt III-IV distal ¼ and tibia of palp yellow. Abdomen dorsally grayish-



© R.V. Hippargi

Image 5. *Idiops vankhede* sp. nov.Table 5. Morphometry of legs and palp of *Idiops vankhede* sp. nov. from Solapur, Maharashtra, holotype (HT; WILD-10-ARA-821) and paratypes (PT*; WILD-10-ARA-871*, PT; WILD-10-ARA-859).

	LEG I			LEG II			LEG III			LEG IV			PALP		
	HT	PT*	PT	HT	PT*	PT	HT	PT*	PT	HT	PT*	PT	HT	PT*	PT
Femur	6.53	3.43	3.72	5.39	3	3.25	3.74	2.67	2.83	5.56	3.67	3.79	2.8	2.9	3.25
Patella	3.09	2.36	2.35	2.31	2.04	2.03	2.18	2.09	2.36	2.47	2.69	2.7	1.6	2.06	2.05
Tibia	4.41	2.2	2.18	3.68	1.66	1.84	2.18	1.44	1.32	4.5	2.82	2.79	3	2.19	2.24
Metatarsus	5.23	1.94	1.81	4.56	1.66	1.67	4.55	2.01	1.95	5.28	2.83	2.71			
Tarsus	2.79	0.73	1.1	2.12	0.73	1.1	2.04	0.94	1.36	2.54	1.2	1.79	1.37	1.98	2.45
Total	22.05	10.66	11.16	18.06	9.09	9.89	14.69	9.15	9.82	20.35	13.21	13.78	8.77	9.13	9.99
Midwidth															
Femur	0.98	0.89	0.85	0.77	0.81	0.9	1.26	1.53	1.57	1.12	1.33	1.07	0.55	0.63	0.81
Tibia	0.9	1	1.11	0.56	0.95	0.88	0.74	1.1	1.06	0.7	1.01	1.05	1.43	1.03	1.06

brown with faint pale spots radiating in curved lines; ventrally and ventro-laterally yellowish-gray. Spinnerets yellowish-brown.

Carapace (Fig. 26): Oval, wart-like tubercles except for anterior striae and anterior caput. Fovea procurved, deep. Bristles absent.

Eyes (Figs 26–27): Eight in three rows, ALE situated far

from AME on clypeal edge; posterior row straight. Ocular group 1.10 long, 1.18 wide; MOA square, 0.67 wide and 0.60 long. Diameter AME 0.29, PME 0.17, ALE 0.35, PLE 0.25; distance between ALE-AME 0.24, PME-PME 0.21, ALE-PLE 0.49, AME-AME, PLE-PME, ALE-ALE adjacent.

Maxillae (Fig. 28): 1.64 long anteriorly, 1.97 long posteriorly, 1.10 wide; no cuspules; anterior lobe distinct,

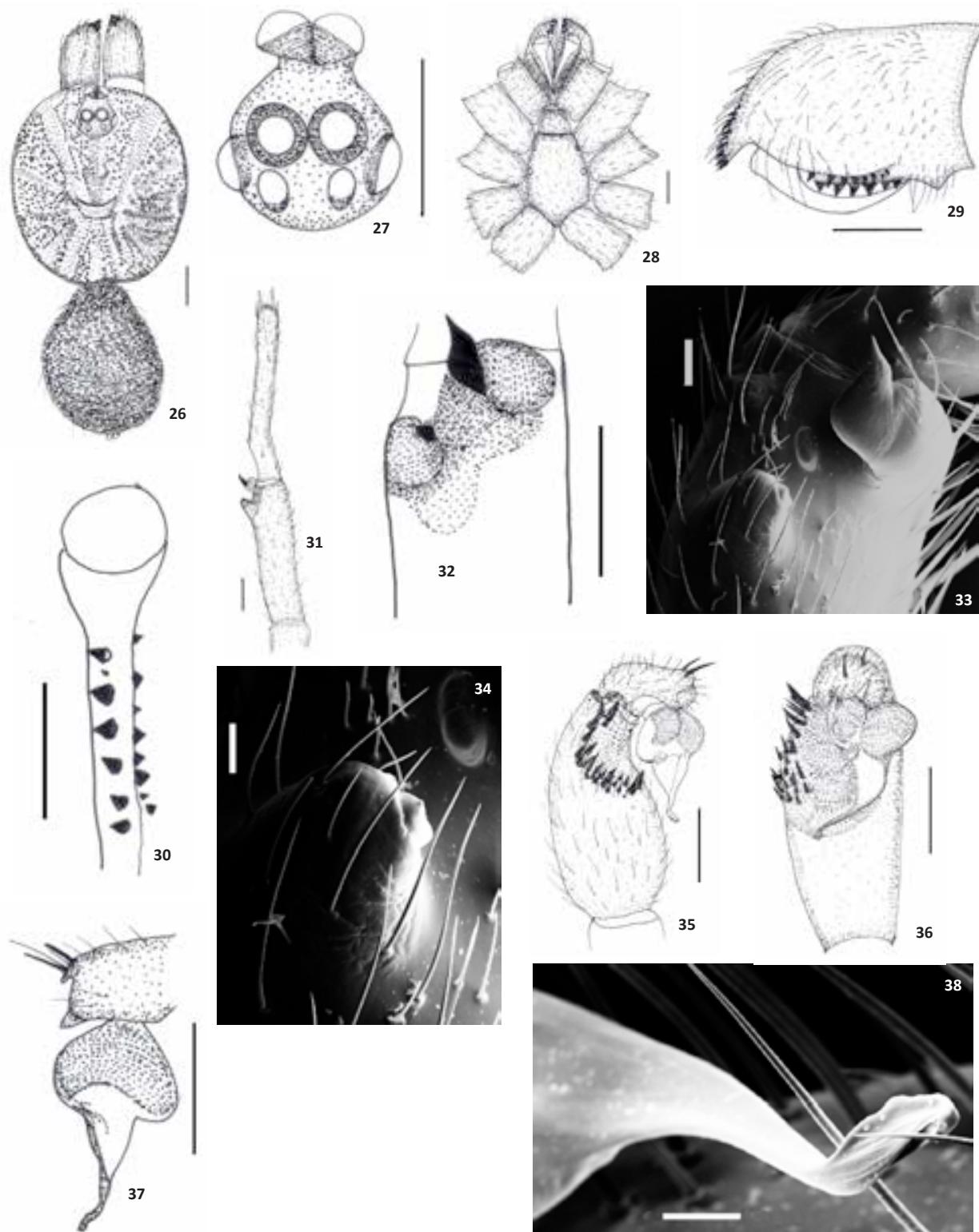


Figure 26–38. *Idiops vankhede* sp. nov., male (WILD-10-ARA-821).
 26—carapace and abdomen, scale 1.0mm | 27—eyes, scale 1.0mm | 28—sternum, maxillae, chelicerae and labium, scale 1.0mm | 29—chelicerae prolateral view, scale 1.0mm | 30—chelicerae teeth, scale 1.0mm | 31—tibia and metatarsi of leg I, scale 1.0mm | 32—tibial apophysis, scale 1.0mm | 33—tibial apophyses, scale 0.2mm | 34—tibial lower apophysis, scale 0.1mm | 35—palp prolateral view, scale 1.0mm | 36—palp ventral view, scale 1.0mm | 37—palp retrolateral view, scale 1.0mm | 38—embolus, scale 0.1mm.

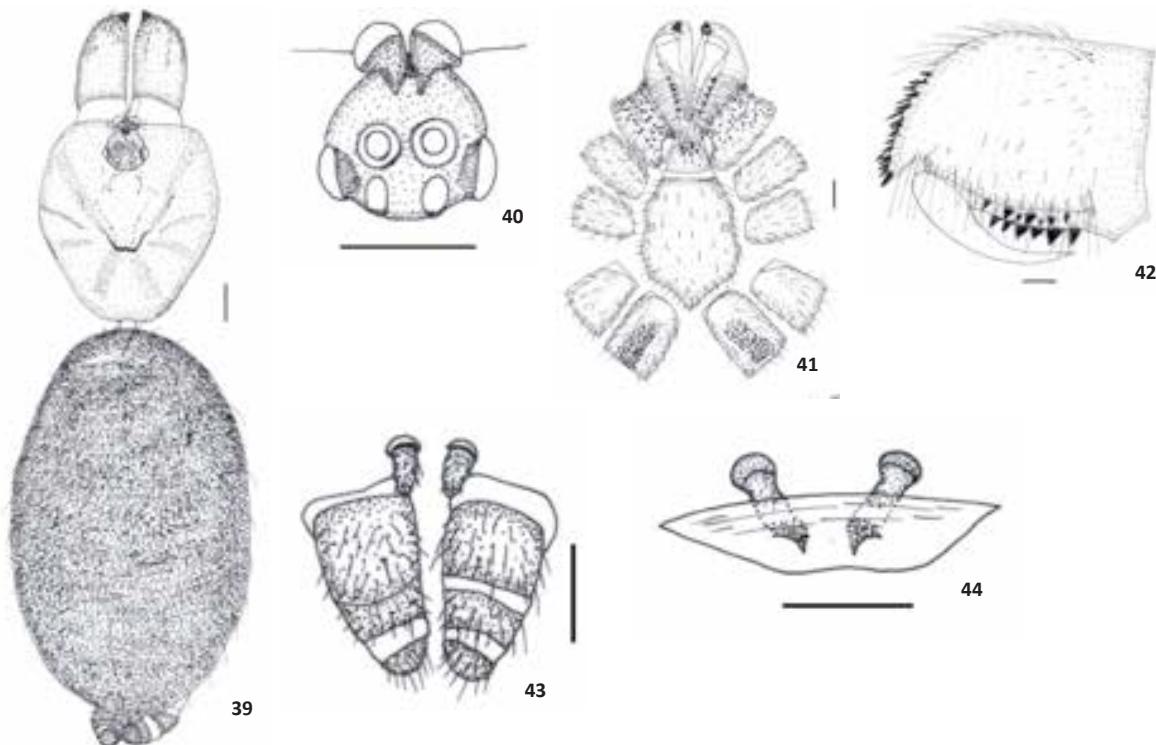


Figure 39–44. *Idiops vankhede* sp. nov., female (WILD-10-ARA-871).

39—carapace and abdomen, scale 1.0mm | 40—eyes, scale 1.0mm | 41—sternum, maxillae, chelicerae and labium, scale 1.0mm | 42—chelicerae prolateral view, scale 1.0mm | 43—spinnerets, scale 1.0mm | 44—spermathecae, scale 1.0mm.

posterior edge obscured, anterior edge straight.

Labium (Fig. 28): 0.81 long, 0.84 wide, labiosternal groove shallow, slightly procurved, cuspules absent.

Chelicerae (Figs 29–30): Eight teeth on promargin and seven teeth on retromargin; rastellum strong, raised on high triangular mound, with 25 thick, short spines, surrounded with many normal spines; two glabrous bands for length of dorsal surface of chelicerae.

Sternum (Fig. 28): 2.80 long, 1.90 wide, broader between posterior coxae; yellowish-brown, elevated in centre, sloping laterally, covered with short and long black bristles; posterior angle acute.

Sigilla (Fig. 28): Posterior sigilla absent; median pair marginal, 0.60 diameter, 1.69 apart, marginal and anterior pair indistinct.

Legs (Figs 31–34): All legs cylindrical, not flattened, similar in thickness; femora III clearly wider than rest. Tibia I inflated with two distal, prolateral tibial apophyses, distal apophysis facing upward with curved, stout triangular spine narrowing abruptly into lancet-like pointed tip; lower apophysis with wide wedge-like spine, facing opposite direction of the distal spur (Figs 31–34); mt I cylindrical, slightly bent at base, rest straight but not incrassate or excavated (Fig. 31). Legs covered with few scattered hair, bristles and normal pointed spines.

Two conspicuous glabrous bands for length of femora, patellae and tibiae. Leg formula 1423 (Table 5).

Scopula: Ta II–IV distinct, hairs sparse, restricted to only ventral side, for most length. Ta I with few scopuliform hairs.

Spines: More on promarginal and retromarginal sides of legs and palp; normal long spines on all leg parts except for ti palp and pa III–IV with thorn-like thick spines. I: ti, p=2 tubercles, one with megaspine, v=7; mt, p=1, r=3. II: pa v=2; ti, v=10; mt, p=1, r=1. III: pa, p=11, r=2; ti, p=5, r=2; mt, p=v=4, r=3. IV: pa, p=10; ti, v=10; mt, v=6; ta, p=1. Palp: ti, r=25–26; ta, d=2–3.

Trichobothria: Clavate absent; ta I, 18 long filiform; ta II 20 long and short filiform; ta III, 20 long filiform; ta IV, 13 long filiform and seven long filiform on palp in centre, ta I–IV trichobothria in two zig-zag rows in distal three fourth. Mt I–II, 10 long filiform in distal one thirds; mt III, nine long filiform in distal one thirds; mt IV, seven long filiform in distal one-fourth.

Leg coxae: Greenish-yellow, covered with short and long black bristles. Coxae IV with short spinules in triangular area in distal three fourth, rest sparsely covered with long bristles.

Claws: All legs with paired and unpaired claws. Both (paired as well as unpaired) claws on IV prominent and

distinctly larger than rest. Paired claws with 7–8 teeth on leg I, 6–7 teeth on leg II, one unequal bifid tooth on leg III–IV.

Abdomen (Fig. 26). Covered with short black hairs with few long bristle-like hairs posteriorly, cuticle appears leathery and slightly rough. Ventrally uniformly covered with short and few long black hairs.

Spinnerets: PMS digitiform covered with brown hair; PLS covered with brown hair, apical segment domed.

Palp (Figs 35–38): Tibia incrassate, ventral 1/3rd excavated into cavity; with band of spines in crescent shape on retrolateral side of cavity. Cymbium truncated dorsally with two lateral processes. Median haematodocha fused with bulb, embolus gradually tapering and bend 45° midway, slightly flattened just before tip.

Paratype female (WILD-10-ARA-871): Total length 16.20; carapace 5.78 long, 5.18 wide; 3.37 long chelicerae; abdomen 10.42 long, 6.43 wide. Spinnerets: PMS, 0.49 long, 0.18 wide, 0.22 apart; PLS, 0.73 basal, 0.39 middle, 0.24 distal; midwidths 0.98, 0.75, 0.54 respectively; 0.89 total length. Morphometry of legs and palp given in Table 5.

Colour in alcohol: Carapace, chelicerae, reddish-brown. Legs and palp yellowish-brown, lighter below. Abdomen dorsally grayish-brown, ventrally yellowish. Spinnerets yellowish-brown.

Carapace (Fig. 39): Glabrous, broader anteriorly (widest between legs II) and gradually narrowing posteriorly, striae prominent. Fovea, procurved, deep; caput raised. Bristles: two long and two short on caput; one long between AME-AME; one long, four short between PME-PME; one long between ALE-ALE. Few short hairs on posterior and anterior margins.

Eyes (Figs 39–40): Eight in three rows, ALE situated far from AME on clypeal edge; posterior row procurved. Ocular group 1.41 long, 1.26 wide; MOA square, 0.64 wide, 0.64 long. Diameter AME 0.25, PME 0.13, ALE 0.30, PLE 0.38; distance between ALE-AME 0.30, AME-AME 0.05, PLE-PME 0.04, PME-PME 0.16, ALE-PLE 0.40, ALE-ALE adjacent.

Maxillae (Fig. 41): 1.77 long anteriorly, 2.19 long posteriorly, 1.27 wide; 56 cuspules; anterior lobe distinct, anterior margin straight, posterior margin obscure.

Labium (Fig. 41): 0.87 long, 1.09 wide, labiosternal groove shallow, slightly procurved with six cuspules anteriorly in two rows.

Chelicerae (Fig. 42): Five large, two small teeth on promargin and six teeth on retromargin; depression on retrolateral face where fang touches chelicerae; rastellum strong, raised on high triangular mound, with 16 thick, short spines, surrounded by many normal long

spines; two glabrous bands for length of dorsal surface of chelicerae.

Sternum (Fig. 41): 3.92 long, 2.84 wide, broader between posterior coxae; yellowish-brown, elevated in centre, sloping laterally, covered with long black bristles; row of long bristles on margins, posterior angle acute.

Sigilla (Fig. 41): Posterior sigilla absent; median pair 0.11 diameter, 1.96 apart, 0.10 from margin and anterior pair round, marginal.

Legs: Femora and tibiae III wider than others; all metatarsi longer than respective tarsi. Tarsi of palp and mt-ta I-II dorsoventrally flattened, other legs normal. Legs covered with few scattered hair, bristles; curved thick thorn-like spines only on palp and legs I-II. Two conspicuous glabrous bands for length of femora, patellae and tibiae. Scopula absent on tarsi of all legs and palp. Leg formula 4132 (Table 5).

Spines: More on promarginal and retromarginal sides of legs and palp. I: ti, p=19, d=8, r=26; mt, p=17, r=20; ta, p=8, r=7. II: ti, p=12, r=14, d=11; mt, p=16, r=13; ta, p=7, r=5, v=1. III: pa, p=11, r=3; ti, p=r=6; mt, p=r=7, v=6; ta, p=5, r=6. IV: pa, p=17; mt, p=2, v=6; ta, p=8, v=4, r=1. Palp: fe, p=1; pa, p=1; ti, p=24, r=25; ta, p=23, r=26, v=2.

Trichobothria: Clavate absent; ta I, 16 long filiform; ta II, 16 long filiform; ta III, 20 long filiform; ta IV, 12 long filiform and 16–20 long filiform in two rows in distal half on palp ta. Ta I–III filiform in inverted 'V' shape two rows in basal three fourth. Mt I, 8 long filiform in distal fourth; mt II–IV, 10 long filiform in distal fourth.

Leg coxae: Yellowish-brown, covered with short and long black bristles. Coxa III with glabrous patch in distal three fourth, rest area sparsely covered with long bristles; coxa IV clearly broader than others, anterior edge curved, ventrally, broad patch of thorn-like spinules in distal 3/4th, others covered with long bristles.

Claws: All legs with paired and unpaired claws. Both (paired as well as unpaired) claws on leg IV prominent and larger than on other legs. Paired claws with two unequal size teeth on legs I–IV; bifid tooth on palp. False claw tufts on each side of paired claws.

Abdomen (Fig. 39): Oval, uniformly covered with short and long black hairs. Dorsum with few mottled with yellow spots in radiating pattern, cuticle appears leathery and slightly rough.

Spinnerets (Fig. 43): PMS digitiform covered with brown hair; PLS covered with brown hair, apical segment domed.

Spermathecae (Fig. 44): Type I spermathecae. Two receptacles, each receptacles posteriorly opening into wide sclerotized slit-like opening, receptacles and slit opening covered with partially sclerotized membrane,

attached posteriorly with epigastral sclerotized region; each receptacle wider at base, transparent (except lobes), gradually narrowing down, midway sclerotized and leading to lobes. Each receptacle covered with pores in distal half.

Variation female (WILD-10-ARA-859)

Total length 14.62; carapace: 5.87 long, 5.10 wide; Labium: 0.99 long, 1.07 wide; cuspules 7. Maxillae: 1.72 long in front, 2.21 long in back, 1.31 wide; cuspules 60. Sternum: 3.59 long, 2.98 wide. Abdomen: 8.75 long, 6.07 wide. Spinnerets: PLS, 0.72 basal, 0.33 middle, 0.22 apical; midwidths, 0.72, 0.33, 0.22 respectively; 1.27 total length; PMS, 0.48 long, 0.22 wide; distance between PMS–PMS, 0.19. Morphometry of legs and palp given in Table 5.

Diagnosis

The male of *Idiops vankhede* sp. nov. closely resemble those of *I. bombayensis* Siliwal et al., 2005, *I. constructor* (Pocock, 1900), and *I. mettupalayam* Ganeshkumar & Siliwal, 2013 in having a triangular spine on tibial spur of leg I but can be distinguished from those of other *Idiops* species by having prolateral metatarsi I normal without any excavation, see Fig. 31 (like *I. joida* Gupta et al., 2013 and *I. pylorus* Schwendinger, 1991) and slightly bent at base, see Fig. 31 (in *I. joida* slender; in *I. pylorus* bent in basal 1/3rd); the male differs from that of *I. joida* by leg formula 1423 (leg formula in *I. joida* is 4123). Females of *Idiops vankhede* sp. nov. resemble those of *I. joida*, *I. constructor*, *I. fortis*, and *I. oriya* in having a band of spinules on coxae IV and with *I. joida* by having tibia III distinctly longer than wide but differing from the rest of the species by the subequal legs II and III (in *I. joida* leg III longer than leg II; *I. constructor* and *I. fortis*, leg I and leg IV subequal in length and tibia III is as long as wide; *I. oriya*, tibia III slightly longer than wide and leg II is longer than leg III).

Etymology

The species epithet is treated as a noun in apposition, named in honour of the Indian arachnologist, Dr. Ganesh Vankhede for his efforts to popularize Indian arachnology.

Natural history

The Siddheshwar Van Vihar, Solapur consists of grassland mixed with thorn forest (Type 6, subgroup 6A/C1) (Champion & Seth 1968). Both sexes were collected from their trap-door burrows made verticle on ground consisting of soft, dark brown laterite soil covered with a fine layer of humus under shrubs and trees. Burrows

were like typical Indian idiopid group: burrow's entrance had D-shaped lid/door attached on the side of burrow. Burrow diameters ranged from 16 to 18 mm and depth of the burrows ranged from 105 to 110 mm. The lids of the trap-door burrows were thick (2mm), cork-like and, as spiders were found during the dry season, they had extra silk lining extensions below the lid inside the burrow.

REFERENCES

Champion, H.G., S.K. Seth (1968). *A revised survey of forest types of India*. Government of India Press, New Delhi, 404pp.

Gravely, F.H. (1921). The spiders and scorpions of Barkuda Island. *Records of the Indian Museum, Calcutta* 22: 399–421.

Gupta, N., M. Ganeshkumar, S.K. Das & M. Siliwal (2013). Three new species of *Idiops* Perty, 1833 (Araneae: Idiopidae) from India. *Zootaxa* 3635: 237–250. <https://doi.org/10.11646/zootaxa.3635.3.3>

Mirza, Z.A. & R.V. Sanap (2012). A new species of the genus *Idiops* and notes on *Idiops bombayensis* Siliwal et al. 2005 (Araneae: Idiopidae) from northern Western Ghats of Maharashtra, India. *Journal of Arachnology* 40: 85–95.

Mirza, Z.A., V.V. Vaze & R.V. Sanap (2012). A new species of the trapdoor spiders genus *Idiops* Perty, 1833 (Araneae: Idiopidae) from the western Ghats, with a key to the *Idiops* of India. *Revista Ibérica de Aracnología* 21: 9–14.

Pocock, R.I. (1900). *The fauna of British India, including Ceylon and Burma. Arachnida*. Taylor and Francis, London, 279pp. <https://doi.org/10.5962/bhl.title.48423>

Sanap, R.V. & Z.A. Mirza (2011). Two new trapdoor spider species of the genus *Scalidognathus* Karsch, 1891 (Araneae: Idiopidae) from the southern western Ghats of India. *Acta Zoologica Lituanica* 21: 96–102.

Sanap, R.V. & Z.A. Mirza (2015). A new large trapdoor spider species of the genus *Heligmomerus* Simon 1892 (Araneae, Mygalomorphae, Idiopidae) from Western Ghats, India. *Journal of Asia-Pacific Biodiversity* 8: 242–246. <https://doi.org/10.1016/j.japb.2015.07.004>

Schwendinger, P.J. (1991). Two new trap-door spiders from Thailand (Araneae, Mygalomorphae, Idiopidae). *Bulletin of the British Arachnological Society* 8: 233–240.

Sen, S., S. Saha & D. Raychaudhuri (2012). On the mygalomorphs (Araneae: Mygalomorphae) in the collection of Entomology Laboratory, University of Calcutta. *Munis Entomology and Zoology* 7: 200–214.

Siliwal, M., S. Molur & B.K. Biswas (2005). Indian Spiders (Arachnida: Araneae): Updated checklist 2005. *Zoos' Print Journal* 20(10): 1999–2049. <https://doi.org/10.11609/JOTT.ZPJ.1283.1999-2049>

Siliwal, M. (2009). Transfer of Indian *Ischnocolus* (Araneae: Theraphosidae). *Journal of Threatened Taxa* 1(10): 533–534. <https://doi.org/10.11609/jott.01981.533-4>

Siliwal, M. & R. Raven (2010). Taxonomic change of two species in the genus *Haploclastus* Simon 1892 (Araneae: Theraphosidae). *Zookeys* 46: 71–75. <https://doi.org/10.3897/zookeys.46.347>

Siliwal, M., S. Molur & R. Raven (2010). Transfer of two Indian *Idiops* spp. to the genus *Heligmomerus* Simon, 1892 (Araneae: Idiopidae) with redescription of *H. barkudensis* (Gravely, 1921). *Journal of Threatened Taxa* 2(6): 940–947. <https://doi.org/10.11609/JOTT.02344.940-7>

Siliwal, M., R.S. Kumar & R. Raven (2014). A new species of *Atypus* Latreille, 1804 (Araneae: Atypidae) from Northern India. *Arthropoda Selecta* 23(2): 221–224.

WSC (2020). World Spider Catalog. Version 21.0. Natural History Museum Bern, online at <http://wsc.nmbe.ch>, accessed on 11 June 2020. <https://doi.org/10.24436/2>



Rapid multi-taxa assessment around Dhamapur Lake (Sindhudurg, Maharashtra, India) using citizen science reveals significant odonate records

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Abstract: In the present work, we discuss the results of a four-day long rapid survey around Dhamapur Lake and surrounding freshwater habitats in the Sindhudurg District of Maharashtra through public participation. In total, 61 odonates, 51 butterflies, 17 species of amphibians and reptiles, 90 birds, and four mammals are documented. Our observations taken over a brief time reflect the importance of citizen science in documenting local biodiversity. We report involvement of citizen scientists in recovering significant odonate records for the state.

Keywords: Biodiversity, conservation, freshwater ecosystem, northern Western Ghats, Odonata, wetland.

Abbreviations: IUCN – International Union for Conservation of Nature, WPA – Wild Life (Protection) Act, 1972.

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INTRODUCTION

The indeterminate exploitation of the natural resources by humans has caused considerable alterations in the ecosystem functioning and biodiversity loss through urbanization, habitat destruction, habitat modification, and degradation of vital freshwater resources (Gleick et al. 2001; McKinney 2002; Diaz et al. 2006; Dudgeon et al. 2006). Despite the current body of knowledge of environmental degradation, several regions remain less explored in terms of data on biodiversity. The lack of knowledge on biodiversity hampers the decision making at policy level and hence considered as one of the global priorities when forming conservation frameworks (Meyer et al. 2015; Sorte & Somveille 2020). In recent years, citizen science has proved to be a beneficial tool in collecting biodiversity data through people's participation (Theobald et al. 2015; Chandler et al. 2017; McKinley et al. 2017). It is used for research, to understand distribution and possible threats to multiple taxa like insects, amphibians, birds, and mammals (Kolby 2015; Forrester et al. 2017; Zapponi et al. 2017; Sorte & Somveille 2020). In India, the practice of citizen science has proved as a useful tool for biodiversity documentation at finer spatial scale (Badrinath 2015; Seshadri & Gururaja 2015; SoIB 2020).

DragonflySouthAsia (DSA), a part of DiversityIndia (<http://diversityindia.org/>), is a citizen science network of Odonata (dragonflies and damselflies) watchers and researchers from the Indian subcontinent (<https://dragonflyindmeet.wordpress.com/>). DSA has been actively involved in conservation outreach and research, popularizing odonatology and freshwater conservation through meets and workshops every year since 2014 (Andrew et al. 2015; Dawn & Roy 2017; Koparde et al. 2018, 2020), and facilitating collaborative research (Mujumdar et al. 2018). In the current survey, we used a combination of rapid multi-taxa assessment and citizen science to document biodiversity in Dhamapur Lake area taking odonates as target taxa. Here, we demonstrate that peoples' participation in science can provide reliable biodiversity data in a very short period of time and help highlight the potential of the lake to support the urgency to protect it.

METHODS

Study area

Sindhudurg District, situated at the southernmost tip of Maharashtra, is one of the biodiversity rich areas

of the state and includes parts of northern Western Ghats, locally known as Sahyadri Hill ranges. Dhamapur Lake (16.033°N & 73.593°E; 22m) is located in the Malvan Tehsil of Sindhudurg District (Figure 1, Image 1). The climate of Malvan Tehsil remains hot and humid throughout the year having an annual average temperature 27.1°C and average annual precipitation of 2,865mm (Malvan summary 2020).

The lake is a 400 years old human-made lake with an area of 22 hectares. It provides water to Malvan City (TERI 2013). The surrounding villages Dhamapur and Walvali depend on its water for domestic use and irrigation purposes. The forest around the lake is moist deciduous and categorised as reserve forest. Streams having varying canopy cover, flow along one side of the lake (Image 3), while the other side is surrounded by marshes and paddy fields (Image 2).

Survey sites

We surveyed various freshwater habitats like lakes, ponds, wells, and streams around Dhamapur Village as our focal taxon was odonates. We also surveyed the natural vegetation, paddy-fields and forest patches around these habitats. Details of the study sites are given in Table 1 (Images 2–6).

Data collection

The 6th DragonflySouthAsia meet was conducted during 10–13 October 2019 wherein a total of 25 people participated from India and Sri Lanka. A few members of Syamantak, a local community working towards conservation of wetlands in the Sindhudurg area (<http://syamantak.cfsites.org/>), also took part.

On all the four days, we opportunistically surveyed the sites for rapid assessment of selective invertebrates and vertebrates. Rapid multi-taxa assessments are used to yield quick yet reliable results. These are cost-effective, useful to make inventories of the local biodiversity, and the information obtained in terms of species richness can be used potentially to represent the community structure (Oliver & Beattie 1993, 1996). We used citizen science model for data collection and to document the maximum number of species (Chandler et al. 2017). The process involves participation in the survey by volunteers with little or no expertise on the taxa whose observations were verified by the experts later on.

The participants were split into four different groups, each containing six to seven members, to cover different habitats surrounding the lake (Image 2 & 3). They were trained in using iNaturalist app (<https://www.inaturalist.org>



Figure 1. Location of the study area and survey sites.



Image 1. Dhamapur Lake



Image 2. Marshy habitat at Dhamapur Lake

Table 1. Study sites of Dhamapur lake area.

Survey sites	Survey locality	GPS coordinates and elevation	Habitat
S1	Dhamapur Lake (Image 1 & 2)	16.0335°N & 73.5939°E, 22m	Surrounded by moist deciduous forest and streams on one side and marshlands, paddy fields on other
S2	Stream along Dhamapur Lake (Image 3)	16.0325°N & 73.5952°E, 18m	Stream of varied canopy cover, fed by the lake flowing alongside through moist-deciduous and semi-evergreen vegetation; intermittent rocky areas forming temporary puddles; presence of algae on the rock surface
S3	Thakurwadi Lake (Image 4)	16.0112°N & 73.6474°E, 14m	Marshland with aquatic vegetation
S4	Kasartaka Stream (Image 5 & 6)	16.0448°N & 73.5746°E, 65m	A stream with varying water depth from open shallow areas to areas with 0.6–0.9 m water depth and closed canopy; intermittent grass patches and herbs along the banks
S5	Ponds and wells	16.0288°N & 73.5918°E, 17m	Temporary and permanent water sources in nearby residential areas



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Image 3. Stream along Dhamapur Lake



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Image 4. Thakurwadi Lake



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Image 5. Kasartaka Stream



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Image 6. Shady habitat at Kasartaka Stream



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Image 7. Survey at marshy habitat of Dhamapur Lake



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Image 8. Survey at Thakurwadi Lake



Image 9. Survey at Kasartaka stream.

inaturalist.org/). Taxa like odonates, butterflies, birds, and mammals were surveyed in the morning hours, i.e., from 08.00h to 12.30h. Bird activity was also recorded during afternoon hours 14.00–16.00 h. Amphibians, reptiles, nocturnal birds, and mammals were recorded during 20.30–23.00 h. Various habitats such as the moist deciduous forests, marshlands, open grasslands, paddy fields, and streams fed by Dhamapur Lake were surveyed by participants (Images 7–9).

Identification of odonates was based on field guides (Subramanian 2009) and taxonomy monographs (Fraser 1933, 1934, 1936). For identification, we referred to Bhakare & Ogale (2018) for butterflies, Grimmett et al. (2011) for birds, and Menon (2014) for mammals. Amphibians and reptiles were identified with multiple references like Daniel (2002), Whitaker & Captain (2004), Gururaja (2012), Padhye et al. (2015), and Pal et al. (2018). We documented most of the species in the field using point-and-shoot digital as well as SLR cameras. In case of ambiguity, we took photographs of the specimens on the field and later identified them to the species level with the help of field guides and taxa experts, especially in the case of amphibians and reptiles. All observations were compiled in the form of checklists adding categories according to the International Union for Conservation of Nature Red List of Threatened Species (hereafter, IUCN) at the end of the meet (IUCN 2020). Species of odonates, butterflies, and birds were arranged according to the family level and those of amphibians, reptiles and mammals according to the order level using standard references like Varshney & Smetacek (2015), Kamalakannan & Venkatraman (2017), Subramanian & Babu (2017), Aengals et al. (2018), Bhakare & Ogale (2018), Dinesh et al. (2019), Praveen et al. (2019), and Uetz et al. (2019).

RESULTS

In total, we documented 61 odonates (Table 2), 51 butterflies (Table 3), 17 species of amphibians and reptiles (Table 4 & 5), 90 birds (Table 6), and four mammals (Table 7) during the tenure. We encountered the newly described *Ceriagrion chromothorax* Joshi & Sawant, 2019 in both Dhamapur and Thakurwadi lakes (Image 17). As per the status provided by Wild Life (Protection) Act, 1972 (hereafter, WPA), *Doleschallia bisaltide* (Cramer, [1777]) and *Hypolimnas misippus* (Linnaeus, 1764) are included in schedule I, while *Cynitia lepidea* (Butler, 1868) and *Parthenos sylvia* (Cramer, 1775) are under schedule II among butterflies. In the case of birds, the majority of the species, i.e., 80 out of 90 species belong to schedule IV. Three species are categorised as Near Threatened, namely, *Anhinga melanogaster* Pennant, 1769, *Anthracoceros coronatus* (Boddaert, 1783), and *Brachypodius priocephalus* (Jerdon, 1839), while *Buceros bicornis* Linnaeus, 1758 is Vulnerable. *A. coronatus* and *B. bicornis* are included under schedule I whereas *A. melanogaster* and *B. priocephalus* are under schedule IV of WPA.

The anurans, *Euphlyctis cynophlyctis* (Schneider, 1799), *E. hexadactylus* (Lesson, 1834), *Hoplobatrachus tigerinus* (Daudin, 1802), and *Polypedates maculatus* (Gray, 1830) are Least Concern according to IUCN and first three are included under schedule IV of WPA. In order Serpentes among reptiles, *Fowlea piscator* (Schneider, 1799) and *Ptyas mucosa* (Linnaeus, 1758) belong to schedule II, *Oligodon taeniatus* (Jerdon, 1853) and *Amphiesma stolatum* (Linnaeus, 1758) belong to schedule IV of WPA and remain Not Evaluated by IUCN. No species in Order Sauria is included under WPA but categorised as Least Concern according to IUCN with exception of *Calotes versicolor* (Daudin, 1802) which is Not Evaluated. The mammalian species *Herpestes edwardsii* (É. Geoffroy Saint-Hilaire, 1818), *Macaca radiata* (É. Geoffroy, 1812), and *Funambulus palmarum* (Linnaeus, 1766) are Least Concern while *Semnopithecus hypoleucus* Blyth, 1841 is Vulnerable as per IUCN. The first two are part of schedule II of WPA while the latter are not included under any schedule.

Comments on significant records of odonates

Following odonates observed at Thakurwadi Lake on 12 October 2019 are significant records considering their current known geographical distributions. The lake is filled with emergent and submergent aquatic vegetation including members of family Nymphaeaceae (Image 4).

Table 2. Checklist of Odonata (dragonflies and damselflies) species.

	Scientific Name	Common Name	IUCN status	Locality of observation
	Suborder Zygoptera			
	Family Lestidae			
1	<i>Lestes praemorsus decipiens</i> Kirby, 1893	Sapphire-eyed Spreadwing	LC	TL
2	<i>Platylestes cf. platystylus</i>	-	-	TL
	Family Platystictidae			
3	<i>Protosticta gravelyi</i> Laidlaw, 1915	Pied Reedtail	LC	KS
	Family Calopterygidae			
4	<i>Vestalis gracilis</i> (Rambur, 1842)	Clear-winged Forest Glory	LC	S
	Family Chlorocyphidae			
5	<i>Heliocypha bisignata</i> (Hagen in Selys, 1853)	Stream Ruby	LC	S
6	<i>Libellago indica</i> (Fraser, 1928)	Southern Helidor	LC	S
	Family Euphaeidae			
7	<i>Euphaea fraseri</i> (Laidlaw, 1920)	Malabar Torrent Dart	LC	S; KS
	Family Platycnemididae			
8	<i>Copera marginipes</i> (Rambur, 1842)	Yellow Bush Dart	LC	DL
9	<i>Copera vittata</i> Selys, 1863	Blue Bush Dart	LC	DL
10	<i>Disparoneura quadrimaculata</i> (Rambur, 1842)	Black-winged Bamboo Tail	LC	KS
11	<i>Prodasineura verticalis</i> (Selys, 1860)	Black Bambootail	LC	S
	Family Coenagrionidae			
12	<i>Aciagrion occidentale</i> Laidlaw, 1919	Green-striped Slender Dartlet	LC	TL
13	<i>Agriocnemis pieris</i> Laidlaw, 1919	White Dartlet	LC	S; TL
14	<i>Agriocnemis pygmaea</i> (Rambur, 1842)	Pygmy Dartlet	LC	M; KS
15	<i>Agriocnemis splendidissima</i> Laidlaw, 1919	Splendid Dartlet	NE	M; KS
16	<i>Ceriagrion cerinorubellum</i> (Bräu, 1865)	Orange-tailed Marsh Dart	LC	DL
17	<i>Ceriagrion chromothorax</i> Joshi and Sawant, 2019	Sindhudurg Marsh Dart	NE	TL; DL
18	<i>Ceriagrion coromandelianum</i> (Fabricius, 1798)	Coromandel Marsh Dart	LC	DL
19	<i>Ceriagrion rubiae</i> Laidlaw, 1916	Orange Marsh Dart	NE	TL
20	<i>Ischnura rubilio</i> Selys, 1876	Western Golden Dartlet	LC	M
21	<i>Ischnura senegalensis</i> (Rambur, 1842)	Senegal Golden Dartlet	LC	TL; DL
22	<i>Mortonagrion varralli</i> Fraser, 1920	Brown Dartlet	DD	DL; S
23	<i>Pseudagrion decorum</i> (Rambur, 1842)	Three-striped Blue Dart	LC	DL
24	<i>Pseudagrion indicum</i> Fraser, 1924	Yellow-striped Blue Dart	DD	KS; S
25	<i>Pseudagrion malabaricum</i> Fraser, 1924	Malabar Sprite	LC	M; TL
26	<i>Pseudagrion microcephalum</i> (Rambur, 1842)	Blue Grass Dartlet	LC	M; DL
	Suborder Anisoptera			
	Family Aeshnidae			
27	<i>Anax guttatus</i> (Burmeister, 1839)	Blue-Tailed Green Darner	LC	DL
28	<i>Anax immaculifrons</i> Rambur, 1842	Blue Darner	LC	KS
29	<i>Anax indicus</i> Lieftinck, 1942	Lesser Green Emperor	LC	DL
30	<i>Gynacantha dravida</i> Lieftinck, 1960	Brown Darner	LC	KS
31	<i>Gynacantha cf. khasiaca</i>	-	-	TL
	Family Gomphidae			
32	<i>Ictinogomphus rapax</i> (Rambur, 1842)	Common Clubtail	LC	DL
33	<i>Paragomphus lineatus</i> (Selys, 1850)	Common Hooktail	LC	KS

	Scientific Name	Common Name	IUCN status	Locality of observation
	Family Macromiidae			
34	<i>Epophthalmia vittata</i> Burmeister, 1839	Common Torrent Hawk	LC	DL
	Family Libellulidae			
35	<i>Acisoma panorpoides</i> Rambur, 1842	Trumpet Tail	LC	DL
36	<i>Brachydiplex sobrina</i> (Rambur, 1842)	Little Blue Marsh Hawk	LC	DL
37	<i>Bradinopyga geminata</i> (Rambur, 1842)	Granite Ghost	LC	W
38	<i>Crocothemis servilia</i> (Drury, 1770)	Ruddy Marsh Skimmer	LC	DL
39	<i>Diplacodes nebulosa</i> (Fabricius, 1793)	Black-tipped Ground Skimmer	LC	DL
40	<i>Diplacodes trivialis</i> (Rambur, 1842)	Ground Skimmer	LC	DL
41	<i>Hydrobasileus croceus</i> (Brauer, 1867)	Amber-winged Marsh Glider	LC	P
42	<i>Indothemis limbata sita</i> Campion, 1923	Restless Demon	LC	TL
43	<i>Neurothemis fulvia</i> (Drury, 1773)	Fulvous Forest Skimmer	LC	TL
44	<i>Neurothemis tullia</i> (Drury, 1773)	Pied Paddy Skimmer	LC	M
45	<i>Orthetrum chrysium</i> (Selys, 1891)	Brown-backed Red Marsh Hawk	LC	DL
46	<i>Orthetrum glaucum</i> (Brauer, 1865)	Blue Marsh Hawk	LC	DL
47	<i>Orthetrum luzonicum</i> (Brauer, 1868)	Tricolored Marsh Hawk	LC	DL
48	<i>Orthetrum pruinosum</i> (Burmeister, 1839)	Crimson-tailed Marsh Hawk	LC	DL
49	<i>Orthetrum sabina</i> (Drury, 1770)	Green Marsh Hawk	LC	DL
50	<i>Pantala flavescens</i> (Fabricius, 1798)	Wandering Glider	LC	DL
51	<i>Potamarcha congener</i> (Rambur, 1842)	Yellow-tailed Ashy Skimmer	LC	DL
52	<i>Rhodothemis rufa</i> (Rambur, 1842)	Rufous Marsh Glider	LC	DL
53	<i>Rhyothemis variegata</i> (Linnaeus, 1763)	Common Picturewing	LC	DL
54	<i>Tetrathemis platyptera</i> Selys, 1878	Pygmy Skimmer	LC	KS
55	<i>Tholymis tillarga</i> (Fabricius, 1798)	Coral-tailed Cloud Wing	LC	DL
56	<i>Tramea basilaris</i> (Palisot de Beauvois, 1805)	Red Marsh Trotter	LC	DL
57	<i>Tramea limbata</i> (Desjardins, 1832)	Black Marsh Trotter	LC	KS
58	<i>Trithemis aurora</i> (Burmeister, 1839)	Crimson Marsh Glider	LC	DL
59	<i>Trithemis festiva</i> (Rambur, 1842)	Black Stream Glider	LC	KS
60	<i>Zygonix iris</i> Selys, 1869	Iridescent Stream Glider	LC	KS
61	<i>Zyxomma petiolatum</i> Rambur, 1842	Brown Dusk Hawk	LC	W

NE—Not Evaluated | DD—Data Deficient | LC—Least Concern | DL—Dhamapur Lake | KS—Kasartaka Stream | TL—Thakurwadi Lake | S—stream along Dhamapur Lake | M—marshes | W—well | P—pond.

1. *Lestes praemorsus decipiens* Kirby, 1894

A pair was observed in the marshy area of the lake. The male was identified as *Lestes praemorsus* on the basis of characters like thorax with greenish antehumeral stirpes, crenulate on the outer sides; segment nine with dorso-lateral blue marking; blunt and curved cerci with whitish hairs and paraprocts blackish, short with white hairs at the tip (Image 10). The female looked similar to the male with profound thoracic antehumeral stripes. Anal appendages were whitish, short, and pointed (Image 11). The species is distributed from western India to Assam (Fraser 1933), Andaman Islands and

across the northern parts of the country and consist of two subspecies *L. praemorsus sikkima* Fraser, 1929 and *L. praemorsus decipiens* Kirby, 1893 (Prasad & Varshney 1995; Dow & Sharma 2020). *L.p. sikkima* is confined to Sikkim in northeastern India and is distinguished by having a metallic posthumeral stripe (Fraser 1933). The male specimen observed at the lake lacks any metallic posthumeral markings (Image 12), thus it is concluded to be representing the widespread subspecies *L.p. decipiens*. It should, however, also be noted that the taxonomic status of the subspecies of *L. praemorsus* is insufficiently resolved (Kosterin 2019). DS found the

species in September 2017 at a natural pond with aquatic weeds in Vimleshwar Village of the district. Considering the distribution in the mentioned references and citizen science portals (Anonymous 2020a), we note that these are the first confirmed records of the subspecies from Maharashtra.

2. *Platylestes cf. platystylus*

A single female individual sighted at the lake seems to be closer to *Platylestes platystylus* (Rambur, 1842) based on the pterostigma (quadrate as opposite to elongate in *Lestes* spp.) and thoracic markings (presence of black spots on each side) (Image 13). We did not collect the specimen hence species level identification was not confirmed. We treat our record as *Platylestes cf. platystylus*. The species *P. platystylus* has distribution in West Bengal in India (Fraser 1933; Prasad & Varshney 1995; Sharma 2010). It is also reported from Tripura and Kerala on citizen science portals (Anonymous 2020b; https://www.inaturalist.org/observations?place_id=6681&taxon_id=109709). Rison & Chandran (2020) recorded the species from few localities in Kerala recently. During present study, the female was seen curling abdomen on an emergent aquatic plant, indicating probable attempt at egg-laying.

3. *Pseudagrion malabaricum* Fraser, 1924

Pseudagrion malabaricum was first reported from Maharashtra State by Tiple et al. (2013) in the Vidarbha region. Subsequently, this species has also been reported from Devgad Taluka and Chaukul Village in Sindhudurg District (Anonymous 2020c). During the present survey, several adults were observed among the reeds and grassy aquatic vegetation near the lake edge (Image 14). The species was identified based on the cerci being shorter than abdomen segment 10 and not bifid at apex (Image 15). The only other *Pseudagrion* species recorded in the habitat, *P. microcephalum*, has bifid cerci clearly longer than the segment 10 while the morphologically similar species *P. australasiae* has cerci bifid at apex as seen in profile (Fraser 1933).

4. *Gynacantha cf. khasiaca*

A single male individual was observed in the vegetation surrounding the lake. The specimen was recognised separate from the other *Gynacantha* spp. recorded during the study and showed similar characters to those of *Gynacantha khasiaca* MacLachlan, 1896 i.e. paraproct longer than half of the length of cerci (Image 18) and two lateral brownish stripes on the greenish thorax (Image 19). *G. khasiaca* is distributed in West Bengal, Assam and Khasi hills in Meghalaya in India (Fraser 1936). Few studies further add the southernmost distribution of the species to West Bengal (Mitra 2002;

Payra et al. 2017). We confirm the observed specimen as *Gynacantha cf. khasiaca* owing to confirmation of the mentioned limited characters as we did not collect the specimen. It is an interesting opportunistic record from the western India considering its affinity to *G. khasiaca* with the known distribution range in northeastern parts of the country (Mitra et al. 2010). It requires detailed study of the specimen further to confirm its identity.

5. *Indothemis limbata sita* Campion, 1923

Indothemis limbata was described as *Trithemis limbata* Selys, 1891 based on specimens from Myanmar and Malay Peninsula. A different form of the species was described as *I. limbata sita* from Sri Lanka, based on the wing venation and markings (Campion 1923). Later studies considered *I. limbata limbata* to be restricted to Myanmar and southeastern Asia and *I. limbata sita* to be restricted to the western India and Sri Lanka barring one record from Odisha (Fraser 1936; Prasad & Varshney 1995). Babu et al. (2009) reported *I. limbata limbata* as a new record for the state mentioning the distribution as Odisha, West Bengal, parts of northeastern India, and Karnataka. State checklists of odonates mention the species with the same reference (Director 2012; Tiple & Koparde 2015). The authors considered *I. limbata sita* in the checklist of India (Subramanian & Babu 2017), but there is no mention of the species in the Western Ghats atlas (Subramanian et al. 2018). Opportunistic observations indicate the presence of the species from Assam (Anonymous 2020d) and Uttara Kannada, Karnataka (<https://www.facebook.com/photo/?fbid=70741923597335&set=gm.740960425953503>). These studies show that there has been a discrepancy on the identity and distribution of both the subspecies. The new record of *I. limbata limbata* from Maharashtra needs to be confirmed by re-examining the specimens and comparing with the holotypes since all the other records of the subspecies are from Odisha and northeastern parts India and the paper didn't include any illustration or image of the specimens studied.

Present records from the lake show the presence of at least one adult (Image 20) and one sub-adult male (abdomen with yellowish markings) (Image 21). We confirm the record as *Indothemis limbata sita* based on characters of the adult male such as hyaline wing apices and 10-1/2 antenodal nervures in the forewing (apices bordered as blackish-brown and 11-1/2 - 12-1/2 antenodal nervures in *I. limbata limbata*). At species level *I. limbata* is distinguished from the congeneric species *I. carnatica* (Fabricius, 1798) by black body with black anal appendages and base of hindwing with extensive brown marking as opposite to violaceous body

Table 3. Checklist of butterflies.

	Scientific name	Common name	IUCN status	WPA schedule
	Family Papilionidae			
1	<i>Graphium agamemnon</i> (Linnaeus, 1758)	Tailed Jay	NE	-
2	<i>Graphium teredon</i> (C. & R. Felder, 1865)	Southern Bluebottle	NE	-
3	<i>Papilio demoleus</i> Linnaeus, 1758	Lime Butterfly	NE	-
4	<i>Papilio polymnestor</i> Cramer, [1775]	Blue Mormon	NE	-
5	<i>Papilio polytes</i> Linnaeus, 1758	Common Mormon	NE	-
	Family Hesperiidae			
6	<i>Aeromachus pygmaeus</i> (Fabricius, 1775)	Pygmy Scrub Hopper	NE	-
7	<i>Ampittia dioscorides</i> (Fabricius, 1793)	Bush Hopper	NE	-
8	<i>Iambrix salsala</i> (Moore, [1866])	Chestnut Bob	NE	-
9	<i>Oriens goloides</i> (Moore, [1881])	Ceylon Dartlet	NE	-
10	<i>Parnara guttata</i> (Bremer & Grey, [1852])	Straight Swift	NE	-
11	<i>Pelopidas</i> sp. Walker, 1870	-	NE	-
12	<i>Spialia galba</i> (Fabricius, 1793)	Indian Skipper	NE	-
13	<i>Tagiades litigiosa</i> Moeschler, 1878	Water Snow Flat	NE	-
14	<i>Taractrocera ceramas</i> (Hewitson, 1868)	Tamil Grass Dart	NE	-
15	<i>Udaspes folus</i> (Cramer, [1775])	Grass Demon	NE	-
	Family Pieridae			
16	<i>Catopsilia pomona</i> (Fabricius, 1775)	Common Emigrant	NE	-
17	<i>Delias eucharis</i> (Drury, 1773)	Common Jezebel	NE	-
18	<i>Eurema hecabe</i> (Linnaeus, 1758)	Common Grass Yellow	NE	-
19	<i>Leptosia nina</i> (Fabricius, 1793)	Psyche	NE	-
20	<i>Pareronia ceylanica</i> (C. & R. Felder, 1865)	Dark Wanderer	NE	-
21	<i>Pareronia valeria</i> (Cramer, [1776])	Common Wanderer	NE	-
	Family Riodinidae			
22	<i>Abisara bifasciata</i> Moore, 1877	Two-spot Plum Judy	NE	-
	Family Lycaenidae			
23	<i>Acytolepis puspa</i> (Horsfield, [1828])	Common Hedge Blue	NE	-
24	<i>Caleta decidia</i> (Hewitson, 1876)	Angled Pierrot	NE	-
25	<i>Chilades pandava</i> (Horsfield, [1829])	Plains Cupid	NE	-
26	<i>Jamides celeno</i> (Cramer, [1775])	Common Cerulean	NE	-
27	<i>Loxura atymnus</i> (Stoll, 1780)	Yamfly	NE	-
28	<i>Rathinda amor</i> (Fabricius, 1775)	Monkey Puzzle	NE	-
	Family Nymphalidae			
29	<i>Cirrochroa thais</i> (Fabricius, 1787)	Tamil Yeoman	NE	-
30	<i>Cupha erymanthis</i> (Drury, [1773])	Rustic	NE	-
31	<i>Cynthia lepidea</i> (Butler, 1868)	Grey Count	NE	II
32	<i>Danaus chrysippus</i> (Linnaeus, 1758)	Plain Tiger	LC	-
33	<i>Danaus genutia</i> (Cramer, [1779])	Common Tiger	NE	-
34	<i>Doleschallia bisaltide</i> (Cramer, [1777])	Autumn Leaf	NE	I
35	<i>Elymnias hypermnestra</i> (Linnaeus, 1763)	Common Palmfly	NE	-
36	<i>Euploea core</i> (Cramer, [1780])	Common Crow	LC	-
37	<i>Euthalia aconthea</i> (Cramer, [1777])	Common Baron	NE	-
38	<i>Hypolimnas bolina</i> (Linnaeus, 1758)	Great Eggfly	NE	-
39	<i>Hypolimnas misippus</i> (Linnaeus, 1764)	Danaid Eggfly	NE	I
40	<i>Junonia almana</i> (Linnaeus, 1758)	Peacock Pansy	LC	-
41	<i>Junonia atlites</i> (Linnaeus, 1763)	Grey Pansy	NE	-
42	<i>Junonia iphita</i> (Cramer, [1779])	Chocolate Pansy	NE	-
43	<i>Junonia lemonias</i> (Linnaeus, 1758)	Lemon Pansy	NE	-

	Scientific name	Common name	IUCN status	WPA schedule
44	<i>Melanitis leda</i> (Linnaeus, 1758)	Common Evening Brown	NE	-
45	<i>Mycalesis perseus</i> (Fabricius, 1775)	Common Bushbrown	NE	-
46	<i>Neptis hydas</i> (Linnaeus, 1758)	Common Sailer	NE	-
47	<i>Orsotriaena medus</i> (Fabricius, 1775)	Nigger	NE	-
48	<i>Parantica aglea</i> (Stoll, [1782])	Glassy Tiger	NE	-
49	<i>Parthenos sylvia</i> (Cramer, 1775)	Clipper	NE	II
50	<i>Tirumala limniace</i> (Cramer, [1775])	Blue Tiger	NE	-
51	<i>Ypthima huebneri</i> Kirby, 1871	Common Fourring	NE	-

NE—Not Evaluated | LC—Least Concern.

Table 4 Checklist of amphibians.

	Scientific name	Common name	IUCN Status	WPA Schedule
	Order Anura			
	Family Dic平glossidae			
1	<i>Euphlyctis cyanophlyctis</i> (Schneider, 1799)	Skittering Frog	LC	IV
2	<i>Euphlyctis hexadactylus</i> (Lesson, 1834)	Indian Green Frog	LC	IV
3	<i>Hoplobatrachus tigerinus</i> (Daudin, 1802)	Indian Bull Frog	LC	IV
4	<i>Sphaerotheca</i> sp. Günther, 1859	Burrowing Frog	-	-
	Family Ranidae			
5	<i>Hydrophylax bahuvistara</i> Padhye, Jadhav, Modak, Nameer & Dahanukar, 2015	Fungoid Frog	NE	-
	Family Ranixalidae			
6	<i>Indiranu</i> sp.	-	-	-
	Family Rhacophoridae			
7	<i>Polypedates maculatus</i> (Gray, 1830)	Common Indian Tree Frog	LC	-

NE—Not Evaluated | LC—Least Concern

Table 5. Checklist of reptiles.

	Scientific name	Common name	IUCN Status	WPA Schedule
	Order Sauria			
	Family Agamidae			
1	<i>Calotes versicolor</i> (Daudin, 1802)	Garden Calotes	NE	-
2	<i>Monilesaurus rouxii</i> Duméril & Bibron, 1837	Forest Calotes	LC	-
	Family Gekkonidae			
3	<i>Hemidactylus</i> sp.	-	LC	-
4	<i>Hemidactylus frenatus</i> Duméril & Bibron, 1836	Asian House Gecko	LC	-
5	<i>Hemidactylus prashadi</i> Smith, 1935	Bombay Leaf-toed Gecko	LC	-
	Family Scincidae			
6	<i>Eutropis allapallensis</i> (Schmidt, 1926)	Allapalli Grass Skink	LC	-
	Order Serpentes			
	Family Colubridae			
7	<i>Fowlea piscator</i> (Schneider, 1799)	Checkered Keelback	NE	II
8	<i>Oligodon taeniatus</i> (Jerdon, 1853)	Indian Streaked Kukri Snake	NE	IV
9	<i>Ptyas mucosa</i> (Linnaeus, 1758)	Indian Rat Snake	NE	II
	Family Natracidae			
10	<i>Amphiesma stolatum</i> (Linnaeus, 1758)	Buff-striped Keelback	NE	IV

NE—Not Evaluated | LC—Least Concern

Table 6. Checklist of birds.

	Scientific Name	Common Name	IUCN Status	WPA Schedule
	Family Accipitridae			
1	<i>Haliastur indus</i> (Boddaert, 1783)	Brahminy Kite	LC	I
2	<i>Hieraetus pennatus</i> (J.F. Gmelin, 1788)	Booted Eagle	LC	I
3	<i>Nisaetus cirrhatus</i> (J.F. Gmelin, 1788)	Changeable Hawk Eagle	LC	I
4	<i>Pernis ptilorhynchus</i> (Temminck, 1821)	Oriental Honey Buzzard	LC	I
5	<i>Spilornis cheela</i> (Latham, 1790)	Crested Serpent Eagle	LC	I
	Family Aegithinidae			
6	<i>Aegithina tiphia</i> (Linnaeus, 1758)	Common Iora	LC	IV
	Family Alcedinidae			
7	<i>Alcedo atthis</i> (Linnaeus, 1758)	Common Kingfisher	LC	IV
8	<i>Ceryle rudis</i> (Linnaeus, 1758)	Pied Kingfisher	LC	IV
9	<i>Ceyx erithaca</i> (Linnaeus, 1758)	Oriental Dwarf-kingfisher	LC	IV
10	<i>Halcyon smyrnensis</i> (Linnaeus, 1758)	White-breasted Kingfisher	LC	IV
11	<i>Pelargopsis capensis</i> (Linnaeus, 1766)	Stork-billed Kingfisher	LC	IV
	Family Anatidae			
12	<i>Dendrocygna javanica</i> (Horsfield, 1821)	Lesser Whistling-duck	LC	IV
	Family Anhingidae			
13	<i>Anhinga melanogaster</i> Pennant, 1769	Oriental Darter	NT	IV
	Family Ardeidae			
14	<i>Ardea alba</i> Linnaeus, 1758	Great Egret	LC	IV
15	<i>Ardea cinerea</i> Linnaeus, 1758	Grey Heron	LC	IV
16	<i>Ardea intermedia</i> Wagler, 1829	Intermediate Egret	LC	IV
17	<i>Ardeola grayii</i> (Sykes, 1832)	Indian Pond-heron	LC	IV
18	<i>Bubulcus ibis</i> (Linnaeus, 1758)	Cattle Egret	LC	IV
	Family Bucerotidae			
19	<i>Anthracoceros coronatus</i> (Boddaert, 1783)	Malabar Pied Hornbill	NT	I
20	<i>Buceros bicornis</i> Linnaeus, 1758	Great Hornbill	VU	I
21	<i>Ocyceros griseus</i> (Latham, 1790)	Malabar Grey Hornbill	LC	-
	Family Campephagidae			
22	<i>Pericrocotus cinnamomeus</i> (Linnaeus, 1766)	Small Minivet	LC	IV
23	<i>Pericrocotus flammeus</i> (J.R. Forster, 1781)	Scarlet Minivet	LC	IV
	Family Caprimulgidae			
24	<i>Caprimulgus atripennis</i> Jerdon, 1845	Jerdon's Nightjar	LC	IV
	Family Charadriidae			
25	<i>Vanellus indicus</i> (Boddaert, 1783)	Red-wattled Lapwing	LC	IV
	Family Chloropseidae			
26	<i>Chloropsis aurifrons</i> (Temminck, 1829)	Golden-fronted Leafbird	LC	IV
	Family Cisticolidae			
27	<i>Orthotomus sutorius</i> (Pennant, 1769)	Common Tailorbird	LC	IV
28	<i>Prinia hodgsonii</i> Blyth, 1844	Grey-breasted Prinia	LC	IV
29	<i>Prinia inornata</i> Sykes, 1832	Plain Prinia	LC	IV
30	<i>Prinia socialis</i> Sykes, 1832	Ashy Prinia	LC	IV
	Family Columbidae			
31	<i>Chalcophaps indica</i> (Linnaeus, 1758)	Asian Emerald Dove	LC	IV

32	<i>Columba livia</i> J.F. Gmelin, 1789	Rock Pigeon	LC	IV
33	<i>Spilopelia chinensis</i> (Scopoli, 1786)	Spotted Dove	LC	IV
34	<i>Treron affinis</i> (Jerdon, 1840)	Grey-fronted Green-pigeon	LC	IV
	Family Corvidae			
35	<i>Corvus macrorhynchos</i> Wagler, 1827	Large-billed Crow	LC	IV
36	<i>Corvus splendens</i> Vieillot, 1817	House Crow	LC	IV
	Family Cuculidae			
37	<i>Cacomantis passerinus</i> (Vahl, 1797)	Grey-bellied Cuckoo	LC	IV
38	<i>Centropus sinensis</i> (Stephens, 1815)	Greater Coucal	LC	IV
39	<i>Eudynamys scolopaceus</i> (Linnaeus, 1758)	Asian Koel	LC	IV
	Family Dicaeidae			
40	<i>Dicaeum erythrorhynchos</i> (Latham, 1790)	Pale-billed Flowerpecker	LC	IV
	Family Dicruridae			
41	<i>Dicrurus aeneus</i> Vieillot, 1817	Bronzed Drongo	LC	IV
42	<i>Dicrurus leucophaeus</i> Vieillot, 1817	Ashy Drongo	LC	IV
	Family Estrildidae			
43	<i>Lonchura malacca</i> (Linnaeus, 1766)	Tricolored Munia	LC	IV
44	<i>Lonchura punctulata</i> (Linnaeus, 1758)	Scaly-breasted Munia	LC	IV
45	<i>Lonchura striata</i> (Linnaeus, 1766)	White-rumped Munia	LC	IV
	Family Hirundinidae			
46	<i>Cecropis daurica</i> (Laxmann, 1769)	Red-rumped Swallow	LC	IV
47	<i>Hirundo smithii</i> Leach, 1818	Wire-tailed Swallow	LC	IV
48	<i>Ptyonoprogne concolor</i> (Sykes, 1832)	Dusky Crag Martin	LC	IV
	Family Jacanidae			
49	<i>Metopidius indicus</i> (Latham, 1790)	Bronze-winged Jacana	LC	IV
	Family Leiotrichidae			
50	<i>Alcippe poiocephala</i> (Jerdon, 1841)	Brown Cheeked Fulvetta	LC	IV
	Family Megalaemidae			
51	<i>Psilopogon haemacephalus</i> (Statius Muller, 1776)	Coppersmith Barbet	LC	IV
52	<i>Psilopogon viridis</i> (Boddaert, 1783)	White-cheeked Barbet	LC	IV
53	<i>Psilopogon zeylanicus</i> (J.F. Gmelin, 1788)	Brown-headed Barbet	LC	IV
	Family Meropidae			
54	<i>Merops leschenaulti</i> Vieillot, 1817	Chestnut-headed Bee-eater	LC	IV
55	<i>Merops orientalis</i> Latham, 1801	Green Bee-eater	LC	IV
56	<i>Merops philippinus</i> Linnaeus, 1767	Blue-tailed Bee-eater	LC	IV
	Family Monarchidae			
57	<i>Hypothymis azurea</i> (Boddaert, 1783)	Black-naped Monarch	LC	IV
	Family Motacillidae			
58	<i>Motacilla cinerea</i> Tunstall, 1771	Grey Wagtail	LC	IV
59	<i>Motacilla maderaspatensis</i> J.F. Gmelin, 1789	White-browed Wagtail	LC	IV
	Family Muscicapidae			
60	<i>Copsychus saularis</i> (Linnaeus, 1758)	Oriental Magpie-robin	LC	IV
61	<i>Cyornis tickelliae</i> Blyth, 1843	Tickell's Blue-flycatcher	LC	IV
62	<i>Eumyias thalassinus</i> (Swainson, 1838)	Verditer Flycatcher	LC	IV
63	<i>Kittacincla malabarica</i> (Scopoli, 1786)	White-rumped Shama	LC	IV
64	<i>Saxicola torquatus</i> (Linnaeus, 1766)	Common Stonechat	LC	IV

	Family Nectariniidae			
65	<i>Aethopyga vigorsii</i> (Sykes, 1832)	Vigor's Sunbird	LC	IV
66	<i>Cinnyris lotenius</i> (Linnaeus, 1766)	Loten's Sunbird	LC	IV
67	<i>Leptocoma minima</i> (Sykes, 1832)	Crimson-backed Sunbird	LC	IV
68	<i>Leptocoma zeylonica</i> (Linnaeus, 1766)	Purple-rumped Sunbird	LC	IV
	Family Oriolidae			
69	<i>Oriolus xanthornus</i> (Linnaeus, 1758)	Black-hooded Oriole	LC	IV
	Family Paridae			
70	<i>Machlolophus xanthogenys</i> (Vigors, 1831)	Black-lored Tit	LC	IV
	Family Passeridae			
71	<i>Gymnoris xanthocollis</i> (E. Burton, 1838)	Chestnut-shouldered Bush-sparrow	LC	IV
	Family Pellorneidae			
72	<i>Pellorneum ruficeps</i> Swainson, 1832	Puff-throated Babbler	LC	IV
	Family Phalacrocoracidae			
73	<i>Microcarbo niger</i> (Vieillot, 1817)	Little Cormorant	LC	IV
	Family Phasianidae			
74	<i>Pavo cristatus</i> Linnaeus, 1758	Indian Peafowl	LC	I
	Family Phylloscopidae			
75	<i>Phylloscopus trochiloides</i> (Sundevall, 1837)	Greenish Warbler	LC	-
	Family Picidae			
76	<i>Dinopium benghalense</i> (Linnaeus, 1758)	Lesser Golden-backed woodpecker	LC	IV
77	<i>Micropternus brachyurus</i> (Vieillot, 1818)	Rufous Woodpecker	LC	IV
	Family Ploceidae			
78	<i>Ploceus philippinus</i> (Linnaeus, 1766)	Baya Weaver	LC	IV
	Family Psittacidae			
79	<i>Loriculus vernalis</i> (Sparrman, 1787)	Vernal Hanging Parrot	LC	IV
80	<i>Psittacula cyanocephala</i> (Linnaeus, 1766)	Plum-headed Parakeet	LC	IV
	Family Pycnonotidae			
81	<i>Brachypodius priocephalus</i> (Jerdon, 1839)	Grey-headed Bulbul	NT	IV
82	<i>Pycnonotus cafer</i> (Linnaeus, 1766)	Red-vented Bulbul	LC	IV
83	<i>Pycnonotus jocosus</i> (Linnaeus, 1758)	Red-whiskered Bulbul	LC	IV
	Family Rallidae			
84	<i>Amaurornis phoenicurus</i> (Pennant, 1769)	White-breasted Waterhen	LC	IV
	Family Scolopacidae			
85	<i>Actitis hypoleucos</i> (Linnaeus, 1758)	Common Sandpiper	LC	IV
	Family Strigidae			
86	<i>Otus</i> sp.	Scops Owl	-	IV
87	<i>Strix leptogrammica</i> Temminck, 1832	Brown Wood-owl	LC	IV
	Family Sturnidae			
88	<i>Acridotheres fuscus</i> (Wagler, 1827)	Jungle Myna	LC	IV
	Family Timaliidae			
89	<i>Dumetia hyperythra</i> (Franklin, 1831)	Tawny-bellied Babbler	LC	IV
90	<i>Pomatorhinus horsfieldii</i> Sykes, 1832	Indian Scimitar-babbler	LC	IV

LC—Least Concern | NT—Near Threatened | VU—Vulnerable

Table 7. Checklist of mammals.

	Scientific name	Common name	IUCN Status	WPA Schedule
	Order Carnivora: Family Herpestidae			
1	<i>Herpestes edwardsii</i> (É. Geoffroy Saint-Hilaire, 1818)	Indian Grey Mongoose	LC	II
	Order Primates: Family Cercopithecidae			
2	<i>Macaca radiata</i> (E. Geoffroy, 1812)	Bonnet Macaque	LC	II
3	<i>Semnopithecus hypoleucus</i> Blyth, 1841	Black-footed Gray Langur	VU	-
	Order Rodentia: Family Sciuridae			
4	<i>Funambulus palmarum</i> (Linnaeus, 1766)	Three-striped Palm Squirrel	LC	-

Abbreviations: LC—Least Concern | VU—Vulnerable

with white anal appendages and small amber yellow colour at hindwing base in the latter. *I. carnatica* was not recorded during the present study but is reported from peninsular India (Dow 2019). DS has observed it in Sindhudurg District (Anonymous 2020e). Image 20 has been used for comparison in the novel description of *Bradinopyga konkanensis* from western coastal parts of the state (Joshi & Sawant 2020). We highlight this as the first confirmed record of the subspecies from the western Maharashtra.

DISCUSSION

Inventorying and monitoring biodiversity at a regional scale is essential as it provides vital information on the occurrence and distribution of local diversity, and their associations with local habitat. A study by Kunte et al. (1999) recommended biodiversity surveys at a local level encompassing taxa from diverse groups and not just flagship vertebrate species like birds and mammals. It further states that building a network of long-term biodiversity monitoring projects with an understanding of landscape elements (e.g., vegetation types, microhabitats requirements of particular taxa) in ecologically sensitive areas such as the Western Ghats is important.

The current study dwells on two important aspects discussed as following -

a) Role of citizen science in biodiversity documentation

The very key aspect of citizen science is public engagement in data collection through which they can connect with nature and make a positive contribution towards the environment. It acts as a bridge between researchers and the local community, including the stakeholders. The participants actively participated in

the current survey and documented different taxa of the study area with increased interest towards local biodiversity. Their effort resulted in the multi-taxa checklist of Dhamapur Lake and surroundings and also added two subspecies to the state Odonata checklist. They also uploaded their observations on the online database of iNaturalist that served the purpose of data sharing on a broader platform.

b) Conservation implications of Dhamapur Lake and surroundings

Among the odonates, presence of the species *Platylestes cf. platystylus* and *Gynacantha cf. khasiaca*, possible new records to the state (Tiple & Koparde 2015; Koparde et al. 2020), highlights the potential of the lakes for more systematic Odonata surveys in the future. Habitats around Dhamapur Lake support a rich and diverse fauna. The scheduled butterflies like *D. bisaltide*, *P. sylvia*, and *C. lepidea* and the key-stone bird species such as *A. coronatus* and *B. bicornis* are indicator species inhabiting dense moist forests. We observed a colour aberrant individual of *Psilopogon viridis* (Boddaert, 1783) during the survey (Image 46). We based the species identification, in the absence of prominent cheek and head coloration, on size and iris skin colour (black as in *P. viridis*). We speculate that the bird was either a leucistic or ino individual given features such as normal eye pigmentation, iris skin and beak colour (Grouw 2006; Koparde et al. 2014). Habitats around Dhamapur Lake are also known to harbour a large variety of animals including *Lutrogale perspicillata* (I. Geoffroy Saint-Hilaire, 1826) - Smooth Coated Otter, a Vulnerable species according to IUCN. The biodiversity action plan prepared for Sindhudurg and Malvan districts mentions the lake as a large wetland and as a unique feature of Malvan Tehsil, further mentioning that the lake has the potential to be developed as a Ramsar site, however,

biodiversity has to be studied (TERI 2013).

Biodiversity studies have been focused at certain locations in Sindhudurg District. Places like Amboli, a hill station in Sawantwadi Tehsil, attracts many nature enthusiasts and tourists every year. Explorations by the researchers have resulted in a number of scientific publications (Bhakare & Ogale 2018; Satose et al. 2018; Rao et al. 2019) and new species (Vogel & Rooijen 2011; Sayyed et al. 2018; Chaitanya et al. 2019) from this area. There are hardly any long-term monitoring studies in this area facing high tourism pressure.

Current work done over a period of just four days revealed some interesting faunal records, especially for odonates, birds, and mammals that tried to fill the knowledge gap on the biodiversity information of the district. The findings, though primary, form the base for future monitoring and conservation of the Dhamapur Lake area. We recommend systematic biodiversity surveys in this underexplored but potentially biodiversity rich area for conservation of local freshwater ecosystems such as the streams originating from the lake, and important rivers such as Karli River. Data collected on the local biodiversity can be used to target local students for awareness programmes and to promote sustainable tourism activities without disturbing the integrity of the lake and nearby forest, in order to avail the resources in the long run.

REFERENCES

Aengals, R., V.M.S. Kumar, M.J. Palot & S.R. Ganesh (2018). A Checklist of Reptiles of India. 35pp. Version 3.0. Online publication is available at www.zsi.gov.in (Last update: May 2018). [https://www.zsi.gov.in/WriteReadData/userfiles/file/Checklist/Reptile%20Checklist%20\(May%202018\).pdf](https://www.zsi.gov.in/WriteReadData/userfiles/file/Checklist/Reptile%20Checklist%20(May%202018).pdf)

Andrew, R., P. Koparde & K.A. Subramanian (2015). The 8th Indian Symposium of Odonatology and Tropical Biodiversity. *Agrion* 19(2): 32–35. https://worlddragonfly.org/wp-content/uploads/docs/agrion/Agrion_19-2_July2015_hq.pdf

Anonymous (2020a). *Lestes praemorsus* Hagen in Selys, 1862 – Scalloped Spreadwing. In Joshi, S., P. Dawn, P. Roy, & K. Kunte (eds.). *Odonata of India*, v. 1.48. Indian Foundation for Butterflies. URL: <http://www.indianodonata.org/sp/190/Lestes-praemorsus>. accessed 30 May 2020.

Anonymous (2020b). *Platylestes platystylus* Rambur, 1842. In Joshi, S., P. Dawn, P. Roy & K. Kunte (eds.). *Odonata of India*, v. 1.48. Indian Foundation for Butterflies. URL: <http://www.indianodonata.org/sp/217/Platylestes-platystylus>. accessed 29 May 2020.

Anonymous (2020c). *Pseudagrion malabaricum* Fraser, 1924 – Malabar Sprite. In Joshi, S., P. Dawn, P. Roy & K. Kunte (eds.). *Odonata of India*, v. 1.48. Indian Foundation for Butterflies. URL: <http://www.indianodonata.org/sp/394/Pseudagrion-malabaricum>. accessed 31 May 2020.

Anonymous (2020d). *Indothemis limbata* Selys, 1891 – Restless Demon. In Joshi, S., P. Dawn, P. Roy & K. Kunte (eds.). *Odonata of India*, v. 1.48. Indian Foundation for Butterflies. URL: <http://www.indianodonata.org/sp/592/Indothemis-limbata>. accessed 29 May 2020.

Anonymous (2020e). *Indothemis carnatica* Fabricius, 1798 – Light-tipped Demon. In Joshi, S., P. Dawn, P. Roy & K. Kunte (eds.). *Odonata of India*, v. 1.48. Indian Foundation for Butterflies. URL: <http://www.indianodonata.org/sp/591/Indothemis-carnatica>. accessed 29 May 2020

Babu, R., C. Sinha & M. Prasad. (2009). New records of Odonata (Anisoptera) from Maharashtra. *Records of the Zoological Survey of India* 108: 113–117. <http://faunaofindia.nic.in/PDFVolumes/records/108/04/0113-0117.pdf>

Badrinath, R. (2015). Bridging Gaps between Scientists and Citizens: Uncovering the World of Frogs and Toads in Honey Valley, Coorg, Karnataka, India. *FrogLog* 23(4): 41–43. https://www.amphibians.org/wp-content/uploads/2018/12/FrogLog116_high.pdf

Bhakare, M. & H. Ogale (2018). *A Guide to Butterflies of Western Ghats (India)*. Includes Butterflies of Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra and Gujarat State, Authors and publishers, Satara & Sindhudurg, x+496pp.

Campion, H. (1923). A new form of *Indothemis limbata* from Ceylon (Odonata). *Annals Magazine Natural History Series* 9(11): 28–31.

Chaitanya, R., I. Agarwal, A. Lajmi & A. Khandekar (2019). A novel member of the *Hemidactylus brookii* complex (Squamata: Gekkonidae) from the Western Ghats of Maharashtra, India. *Zootaxa* 4646(2): 236–250. <https://doi.org/10.11646/zootaxa.4646.2.2>

Chandler, M., L. See, K. Copas, A.M.Z. Bonde, B.C. López, F. Danielsen, J.K. Legind, S. Masinde, A.J. Miller-Rushing, G. Newman, A. Rosemartin & E. Turak (2017). Contribution of citizen science towards international biodiversity monitoring. *Biological Conservation* 213: 280–294. <https://doi.org/10.1016/j.biocon.2016.09.004>

Daniel, J.C. (2002). *The Book of Indian Reptiles and Amphibians*. Bombay Natural History Society, Bombay, 141pp.

Dawn, P. & A.B. Roy (2017). DrangonflyIndia Meet, 2016. *Agrion* 21(1): 28–32. https://worlddragonfly.org/wp-content/uploads/docs/agrion/Agrion_21-1_Jan2017_hq.pdf

Diaz, S., J. Fargione, F.S. Chapin III & D. Tilman (2006). Biodiversity loss threatens human well-being. *PLoS Biology* 4(8): e277. <https://doi.org/10.1371/journal.pbio.0040277>

Dinesh, K.P., C. Radhakrishnan, B.H.C.K. Murthy, P. Deepak & N.U. Kulkarni (2019). A checklist of amphibians of India with IUCN conservation status. 17pp. Version 2.0. Online publication is available at www.zsi.gov.in (Updated till January 2019). https://www.zsi.gov.in/WriteReadData/userfiles/file/Checklist/Amphibia_Checklist2019.pdf

Dow, R.A. (2019). *Indothemis carnatica*. The IUCN Red List of Threatened Species 2019: e.T163674A123027708. Downloaded on 03 September 2020. <https://doi.org/10.2305/IUCN.UK.2019-2.RLTS.T163674A123027708.en>

Dow, R.A. & G. Sharma (2020). *Lestes praemorsus*. The IUCN Red List of Threatened Species 2020: e.T167485A138285039. Downloaded on 05 June 2020. <https://doi.org/10.2305/IUCN.UK.2020-1.RLTS.T167485A138285039.en>

Dudgeon, D., A.H. Arthington, M.O. Gessner, Z.I. Kawabata, D.J. Knowler, C. Lévêque, R.J. Naiman, A.H. Prieur-Richard, D. Soto, M.L. Stiassny & C.A. Sullivan (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews* 81(2): 163–182. <https://doi.org/10.1017/S1464793105006950>

Director (2012). *Fauna of Maharashtra, State Fauna Series* 20(Part-2): 1–673. Zoological Survey of India, Kolkata. <http://faunaofindia.nic.in/PDFVolumes/sfs/067/index.pdf>

Forrester, T.D., M. Baker, R. Costello, R., Kays, A.W. Parsons & W.J. McShea (2017). Creating advocates for mammal conservation through citizen science. *Biological Conservation* 208: 98–105. <https://doi.org/10.1016/j.biocon.2016.06.025>

Fraser, F.C. (1933). *The fauna of British India including Ceylon and Burma. Odonata*. Vol. I. Taylor and Francis, London, 436pp.

Fraser, F.C. (1934). *The fauna of British India including Ceylon and Burma. Odonata*. Vol. II. Taylor and Francis, London, 442pp.

Fraser, F.C. (1936). *The fauna of British India including Ceylon and*

Burma. *Odonata*. Vol. III. Taylor and Francis, London. 448pp.

Gleick, P.H., A. Singh & H. Shi (2001). Emerging Threats to the World's Freshwater Resources. A Report of the Pacific Institute for Studies in Development, Environment, and Security, Oakland, California. 64pp. <http://pacinst.org/publication/threats-to-the-worlds-freshwater/>

Grimmett, R., C. Inskip & T. Inskip (2011). *Birds of the Indian Subcontinent (2nd Edition)*. Oxford University Press, New Delhi.

Grouw, V.H.J. (2006). Not every white bird is an albino: sense and nonsense about colour aberrations in birds. *Dutch Birding* 28: 79–89. https://scholar.google.co.in/scholar?hl=en&as_sdt=0%2C5&q=Not+every+white+bird+is+an+albino%3A+sense+and+nonsense+about+colour+aberrations+in+birds&btnG=

Gururaja, K.V. (2012). *Pictorial Guide to Frogs and Toads of the Western Ghats*. Gubbi Labs LLP.

IUCN (2020). The IUCN Red List of Threatened Species. Version 2020-1. <www.iucnredlist.org>. Downloaded on 19 March 2020.

Joshi, S. & D. Sawant (2020). Description of *Bradinopyga konkanensis* sp. nov. (Odonata: Anisoptera: Libellulidae) from the coastal region of Maharashtra, India. *Zootaxa* 4779(1): 65–78. <https://doi.org/10.11646/zootaxa.4779.1.4>

Kamalakannan, M. & C. Venkatraman (2017). A Checklist of Mammals of India. 70pp. Online publication is available at www.zsi.gov.in (Updated till October 2017). http://zsi.gov.in/WriteReadData/userfiles/file/Checklist/Mammals_2017.pdf

Kolby, J.E. (2015). Saving Salamanders with Citizen Science. *FrogLog* 23(4): 19. https://www.amphibians.org/wp-content/uploads/2018/12/FrogLog116_high.pdf

Koparde, P., P. Bangal & V.H.J. Grouw (2014). Brown kites and white crows: understanding color aberrations in birds. *Hornbill* (July–September): 10–13. https://www.academia.edu/8574377/Brown_Kites_and_White_Crows

Koparde, P., P. Rangnekar, K.A. Subramanian & R.J. Andrew (2018). Chasing dragonflies at the 4th DragonflyIndia Meeting and 9th Indian Symposium of Odonatology. *Agrion* 22(1): 22–27. https://worlddragonfly.org/wp-content/uploads/docs/agrion/Agrion_22-1_Jan2018_hq.pdf

Koparde, P., N. Mujumdar, P. Rangnekar & A. Sumanapala (2020). 6th DragonflySouthAsia Meeting. *Agrion* 24(1): 10–13. https://worlddragonfly.org/wp-content/uploads/docs/agrion/Agrion_24-1_Jan2020_hq.pdf

Kosterin, O. (2019). Amendments and updates to F.C. Fraser's key to Indian *Leistes* spp. (Odonata: Lestidae) to resolve confusion of *L. patricia* Fraser, 1924 and *L. nigriceps* Fraser, 1924, with notes on *L. nodalis* Selys 1891 and *L. garoensis* Lahiri, 1987. *Zootaxa* 4671(2): 297–300. <https://doi.org/10.11646/zootaxa.4671.2.12>

Kunte, K., A. Joglekar, U. Ghate & P. Padmanabhan (1999). Patterns of butterfly, bird and tree diversity in the Western Ghats. *Current Science* 77(4): 577–586.

Malvan summary (2020). Malvan climate: Average Temperature, weather by month, Malvan water temperature - Climate-Data.org. accessed 02 May 2020. <https://en.climate-data.org/asia/india/maharashtra/malvan-959552/>

McKinney, M.L. (2002). Urbanization, biodiversity, and conservation: The impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. *BioScience* 52(10): 883–890. [https://doi.org/10.1641/0006-3568\(2002\)052\[0883:UBAC\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2002)052[0883:UBAC]2.0.CO;2)

McKinley, D.C., A.J. Miller-Rushing, H.L. Ballard, R. Bonney, H. Brown, S.C. Cook-Patton, D.M. Evans, R.A. French, J.K. Parrish, T.B. Phillips, S.F. Ryan, L.A. Shanley, J.L. Shirk, K.F. Stepenuck, J.F. Weltzin, A. Wiggins, O.D. Boyle, R.D. Briggs, F.S. Chapin III, D.A. Hewitt, P.W. Preuss & M.A. Soukup (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation* 208: 15–28. <https://doi.org/10.1016/j.bioccon.2016.05.015>

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

Meyer, C., H. Kreft, R. Guralnick & W. Jetz (2015). Global priorities for an effective information basis of biodiversity distributions. *Nature Communications* 6: 8221. <https://doi.org/10.1038/ncomms9221>

Mitra, T.R. (2002). Geographical distribution of Odonata (Insecta) of Eastern India, *Memoirs of the Zoological Survey of India* 19(1): 1–208. <http://faunaofindia.nic.in/PDFVolumes/memoirs/019/01/index.pdf>

Mitra, A., R. Babu & R.A. Dow (2010). *Gynacantha khasiaca*. The IUCN Red List of Threatened Species 2010: e.T167396A6341657. Downloaded on 29 May 2020. <https://doi.org/10.2305/IUCN.UK.2010-4.RLTS.T167396A6341657.en>

Mujumdar, N., D. Thakuria, D. Halali & P. Koparde (2018). Observations on underwater oviposition in *Pseudagrion indicum* Fraser (Odonata: Coenagrionidae): an endemic species from the Western Ghats. *Halteres* 9: 39–44. https://www.antdiversityindia.com/yahoo_site-admin/assets/docs/Observation_on_reproductive_behavior_of_Pseudagrion_indicum_upload.15011747.pdf

Oliver, I. & A. Beattie (1993). A possible method for the rapid assessment of biodiversity. *Conservation Biology* 7(3): 562–568. <https://doi.org/10.1046/j.1523-1739.1993.07030562.x>

Oliver, I. & A. Beattie (1996). Designing a cost-effective invertebrate survey: a test of methods for rapid assessment of biodiversity. *Ecological Applications* 6(2): 594–607. <https://doi.org/10.2307/2269394>

Padhye, A.D., A. Jadhav, N. Modak, P.O. Nameer & N. Dahanukar (2015). *Hydrophylax bahuvistara*, a new species of fungoid frog (Amphibia: Ranidae) from peninsular India. *Journal of Threatened Taxa* 7(11): 7744–7760. <https://doi.org/10.11609/JOTT.o4252.7744-60>

Pal, S., S.P. Vijayakumar, K. Shanker, A. Jayarajan & V. Deepak (2018). A systematic revision of *Calotes* Cuvier, 1817 (Squamata: Agamidae) from the Western Ghats adds two genera and reveals two new species. *Zootaxa* 4482(3): 401–450. <https://doi.org/10.11646/zootaxa.4482.3.1>

Payra, A., G.N. Das, A. Pal, D. Patra & A. Tiple (2017). New locality records of a rare Dragonfly *Gynacantha khasiaca* MacLachlan, 1896 (Odonata Aeshnidae) from India. *Biodiversity Journal* 8(1): 27–32. [http://www.biodiversityjournal.com/pdf/8\(1\)_27-32.pdf](http://www.biodiversityjournal.com/pdf/8(1)_27-32.pdf)

Prasad, M. & R.K. Varshney (1995). A check-list of the Odonata of India including data on larval studies *Oriental Insects* 29: 385–428. <https://doi.org/10.1080/00305316.1995.10433748>

Praveen J., R. Jayapal & A. Pittie (2019). Checklist of the birds of India. (v3.1). (Date of publication: 16 December, 2019) Downloaded on 09 March 2020. <http://www.indianbirds.in/india/>

Rao, G.B., S. Babu, G. Quadros & V. Anoop (2019). Bird diversity in the coastal talukas of Sindhudurg District, Maharashtra, India. *Journal of Threatened Taxa* 11(9): 14166–14186. <https://doi.org/10.11609/JOTT.4007.11.9.14166-14186>

Rison, K.J. & V. Chandran (2020). Observations of the damselfly *Platylestes cf. platystylus* Rambur, 1842 (Insecta: Odonata: Zygoptera: Lestidae) from peninsular India. *Journal of Threatened Taxa* 12(10): 16392–16395. <https://doi.org/10.11609/JOTT.5834.12.10.16392-16395>

Satose, V., V. Choursiya, R. Deulkar & S. Menon (2018). Avian fauna of Amboli Ghat, Sindhudurg District, Maharashtra State, India. *Journal of Threatened Taxa* 10(13): 12805–12816. <https://doi.org/10.11609/JOTT.2886.10.13.12805-12816>

Sayyed, A., R.A. Pyron & R. Dileepkumar (2018). Four new species of the genus *Cnemaspis* Strauch, (Sauria: Gekkonidae) from the northern Western Ghats, India. *Amphibian & Reptile Conservation* 12(2): 1–29.

Seshadri, K.S. & K.V. Gururaja (2015). Mapping the Malabar Tree Toad—a Citizen Science Initiative in Conserving an Endangered Toad in the Western Ghats of India. *FrogLog* 23(4): 39–40 https://www.amphibians.org/wp-content/uploads/2018/12/FrogLog116_high.pdf

Sharma, G. (2010). *Platylestes platystylus*. The IUCN Red List of Threatened Species 2010: e.T167261A6319472. Downloaded on 29 May 2020. <https://doi.org/10.2305/IUCN.UK.2010-4.RLTS.T167261A6319472.en>

SoIB (2020). State of India's Birds, 2020: Range, trends and conservation status. The SoIB Partnership, 50pp. https://www.stateofindiabirds.in/wp-content/uploads/2020/02/SOIB_Web-version_Final_.pdf

Sorte, F.A.L. & M. Somveille (2020). Survey completeness of a global citizen-science database of bird occurrence. *Ecography* 43: 34–43. <https://doi.org/10.1111/ecog.04632>

Subramanian, K.A. (2009). *Dragonflies of India-A field guide*. Vigyan Prasar, Department of Science and Technology, Govt. of India, 168pp. <http://www.vigyanprasar.gov.in/digilib/>

Subramanian, K.A. & R. Babu (2017). Checklist of Odonata (Insecta) of India. Version 3.0. 54pp. Online publication is available at www.zsi.gov.in (Updated till September 2017). <https://www.zsi.gov.in/WriteReadData/userfiles/file/Checklist/Odonata%20V3.pdf>

Subramanian, K.A., K.G. Emiliyamma, R. Babu, C. Radhakrishnan & S.S. Talmale (2018). *Atlas of Odonata (Insecta) of the Western Ghats*. Published by the Director, ZSI, Kolkata, 417pp.

TERI (2013). Participatory Rural Appraisal Study in Devgad and Malvan Blocks, Sindhudurg District. The Energy and Resources Institute, New Delhi, 126pp. https://www.researchgate.net/publication/270276288_Biodiversity_Action_Plan_for_Sindhudurg_Maharashtra_India

Theobald, E.J., A.K. Ettinger, H.K. Burgess, L.B. DeBey, N.R. Schmidt, H.E. Froehlich, C. Wagner, J. Hille Ris Lambers, J. Tewksbury, M.A. Harsch & J.K. Parrish (2015). Global change and local solutions: Tapping the unrealized potential of citizen science for biodiversity research. *Biological Conservation* 181: 236–244. <https://doi.org/10.1016/j.biocon.2014.10.021>

Tiple, A.D., R.J. Andrew, K.A. Subramanian & S.S. Talmale (2013). Odonata of the Vidarbha Region, Maharashtra State, Central India. *Odonatologica* 42(3): 237–245. https://www.researchgate.net/publication/259891492_Odonata_of_Vidarbha_region_Maharashtra_state_Central_India

Tiple, A.D., & P. Koparde (2015). Odonata of Maharashtra, India with Notes on Species Distribution. *Journal of Insect Science* 15(1): 1 - 10. <https://doi.org/10.1093/jisesa/iev028>

Uetz, P., P. Freed & J. Hošek (eds.) (2019). The Reptile Database. accessed 15 March 2020. <http://reptile-database.org/>.

Varshney, R.K. & P. Smetacek (eds.) (2015). *A Synoptic Catalogue of the Butterflies of India*. Butterfly Research Centre, Bhimtal and Indinov Publishing, New Delhi, ii+261pp., 8pl.

Vogel, G. & J. van Rooijen (2011). A new species of *Dendrelaphis* (Serpentes: Colubridae) from the Western Ghats—India. *Taprobanica* 3(2): 77–85. <https://doi.org/10.4038/tapro.v3i2.3963>

Whitaker, R. & A. Captain (2004). *Snakes of India – The Field Guide*. Draco Books, Chengelpet, Tamil Nadu, India, 500pp.

Zapponi, L., A. Cini, M. Bardiani, S. Hardersen, M. Maura, E. Maurizi, L.R. De Zan, P. Audisio, M.A. Bologna, G.M. Carpaneto, P.F. Roversi, G.S. Peverieri, F. Mason & A. Campanaro (2017). Citizen science data as an efficient tool for mapping protected saproxyllic beetles. *Biological Conservation* 208: 139–145. <https://doi.org/10.1016/j.biocon.2016.04.035>

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Image 10. *Lestes praemorsus decipiens* (male)

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Image 11. *Lestes praemorsus decipiens* (female)

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Image 12. Lateral view of male *Lestes praemorsus decipiens*

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Image 13. *Platylestes cf. platystylus* (Female)

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Image 14. *Pseudagrion malabaricum* (Male)

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Image 15. Anal appendages of male *Pseudagrion malabaricum* (Lateral view)



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Image 16. *Protosticta gravelyi*

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Image 17. *Ceriagrion chromothorax*

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Image 18. *Gynacantha cf. khasiaca* (male)

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Image 19. Lateral view of male *Gynacantha cf. khasiaca*

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Image 20. Adult male of *Indothemis limbata sita*

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Image 21. Subadult male of *Indothemis limbata sita*



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Image 22. *Zyxomma petiolatum*

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Image 23. *Tetrathemis platyptera*

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Image 24. *Paragomphus lineatus*

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Image 25. *Aeromachus pygmaeus*

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Image 26. *Taractrocera ceramas*

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Image 27. *Udaspes folus*

Image 28. *Orsotriaena medus*Image 29. *Parantica aglea*Image 30. Larva of *Cynitia lepidea*Image 31. *Abisara bifasciata*Image 32. *Loxura atymnus*Image 33. *Euphlyctis cyanophlyctis*



Image 34. *Euphlyctis hexadactylus*



Image 35. *Hydrophylax bahuvistara*



Image 36. *Polypedates maculatus*



Image 37. *Calotes versicolor*



Image 38. *Monilesaurus rouxii*



Image 39. *Hemidactylus prashadi*



Image 40. *Eutropis allapallensis*



Image 41. *Amphiesma stolatum*



Image 42. *Anhinga melanogaster*



Image 43. *Anthracoceros coronatus*



Image 44. *Lonchura striata*



Image 45. *Alcippe poioicephala*



Image 46. *Psilopogon viridis*



Image 47. *Aethopyga vigorsii*



Image 48. *Herpestes edwardsii*



Image 49. *Semnopithecus hypoleucus*



Commercially and medicinally significant aquatic macrophytes: potential for improving livelihood security of indigenous communities in northern Bihar, India

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Abstract: The dispersed wetlands in the Darbhanga District of northern Bihar, India, provide a diversity of niches supporting substantial floral and faunal richness. The aquatic macrophytes of a representative range of perennial water bodies were surveyed fortnightly from June to September 2019, supported by a market survey undertaken with local stakeholders. A total of 61 species of vascular macrophytes was recorded, the majority of them Angiosperms (33 species of Dicotyledons from 21 families, and 26 Monocotyledons from 13 families) and two were Pteridophytes. This paper highlights the distribution pattern and potential commercial and medicinal values of aquatic macrophytes found in different wetland systems in northern Bihar. It further stresses their importance for subsistence, medicinal and economic purposes supporting the livelihoods of local people. Current trends and risks contributing to the degradation and loss of this diverse flora and its supporting habitats are considered. We recommend further assessment of the occurrence and values of this botanical resource, and extension of valuation to encompass the diverse additional ecosystem service benefits provided by the region's wetland systems, as a basis for wetland conservation strategies founded on sustainable management and wise use, with particular reference to the potential for enhancing livelihood security of indigenous communities.

Keywords: Aquatic macrophytes, conservation, ecosystem services, livelihoods, nutrition, wetlands.

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Author contribution: SR prepared the map of the study area, was involved in the site selection, market survey, and methodology. SR and ISS collected the field data and were involved in the identification of species. NG and ME participated in the methodology selection and evaluation of the commercial macrophytes. All authors participated in preparing the final version of the manuscript.

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INTRODUCTION

Aquatic macrophytes, also known as hydrophytes, are large plants found in the margins or littoral zones, surface or submerged bed of water bodies. They may be emergent, submerged or floating, rooted or unrooted in habit, with associated adaptations to the leaves, stems and/or roots matching the requirements of these aquatic environments (Bornette & Puijalon 2009; Peters & Lodge 2009; Rejmankova 2011). In addition, hydrophytes may serve as secondary, often seasonal habitats for numerous living organisms, with further geomorphological roles such as trapping and accreting sediment or influencing water levels and flows (Holmes & Raven 2014). Hydrophytes also produce oxygen, are significant for primary production (Nag et al. 2019), and play pivotal roles in chemical and energy cycles including important roles in decontamination of polluted water (Pandit 1984). Aquatic macrophytes thereby play key roles in many functions within aquatic ecosystems, generating a diversity of ecosystem services beneficial directly and indirectly to human society (Engelhardt & Ritchie 2001; Cherry 2011). The significance of these various roles must necessarily be included in plans for the management and restoration of wetlands (Kaplan et al. 1998; Larson et al. 2019).

Some of the direct ecosystem services provided by water plants occur through their roles as valuable bioresources with significant associated socioeconomic or subsistence values for indigenous communities. This contribution may be highly locally significant in India, where indigenous communities comprise over 8.2% of the national population (Ministry of Tribal Affairs 2013). Indigenous people traditionally use wetland plants for food, fodder and medicine and for making a range of household and artistic products in various Indian states including Bihar, Odisha, West Bengal, and throughout northeastern India (Maikhuri & Ramakrishnan 1992; Bunting et al. 2010; Jain et al. 2010a; Saha et al. 2014; Gogoi 2016). Important plant species in these regions, including *Azolla* spp., Chinese Water Chestnut *Eleocharis dulcis*, Water Chestnut *Trapa natans*, Makhana *Euryale ferox*, Wild Rice *Zizania* spp., Indian Lotus *Nelumbo nucifera*, Water Spinach *Ipomoea aquatica*, Water Cress *Rorippa nasturtium-aquaticum*, Water Mimosa *Neptunia oleracea*, and Wild Taro *Colocasia esculenta*, have been harvested from wild stock, or cultivated in flooded areas for food, aquaculture, livestock fodder, and religious significance (Hasan & Chakrabarti 2009; Meena & Rout 2016).

This pilot study surveys aquatic macrophytes, and

their associated ecological and livelihood benefits from the different wetland ecosystems of northern Bihar. It further investigates commercially important macrophytes and their utilities, and their implications for enhancing livelihood and nutritional security for dependent indigenous communities in northern Bihar. The key objective is to develop initial proposals for sustainable and wise use of this botanical resource and the wetland ecosystems that support it, including recommendations for further research to inform conservation strategies.

MATERIALS AND METHODS

The dispersed perennial wetlands of Darbhanga District, in the northern Bihar State, India, were selected for botanical surveys. These wetlands are locally known as 'Chaur' (floodplain wetlands/land depressions), 'Maun' (ox-bow lakes) and both large and small ponds are known as 'Pokhari'. Six sampling sites were selected for this pilot survey, taking account of a range of hydrologic conditions, vegetation types, floodplains, and wetland shores found in the surveyed region. Selected sampling stations included two Pokhari (Baghant & Mansar), two Chaur (Sakari & Ladha), and two Maun (Simri & Kusheswar Asthan) (Figure 1). Macrophyte sampling was conducted along transects in each surveyed wetland. Sites were sampled fortnightly from June to September 2019 during the monsoon season, when aquatic macrophytes grow most prolifically under seasonally wet conditions. Identification of macrophytes was carried out with the help of relevant literature (Biswas & Calder 1984; Cook 1996; Ramkrishna & Siddique 2002). The collected macrophytes were also checked by herbaria from the Department of Botany, CM Science College, LNM University, Darbhanga.

The four major markets in Darbhanga City (Bazar Chauki, Donar, Darbhanga tower and Lahari Sarai tower) were selected for the market surveys to assess socio-economic implications of aquatic macrophytes extracted from these wetlands (Figure 1). Market surveys consisted of identifying the economic value, quantity and preference of buyers of the products obtained from the surveyed macrophytes.

Semi-structured interviews were conducted with consumers and informants from the sampling area to retrieve the information on the economic importance of different parts of macrophytes. These included fruits (water chestnuts), pops (makhana), flowers (lotus), leaves (taro) and some medicinal plants. The questions

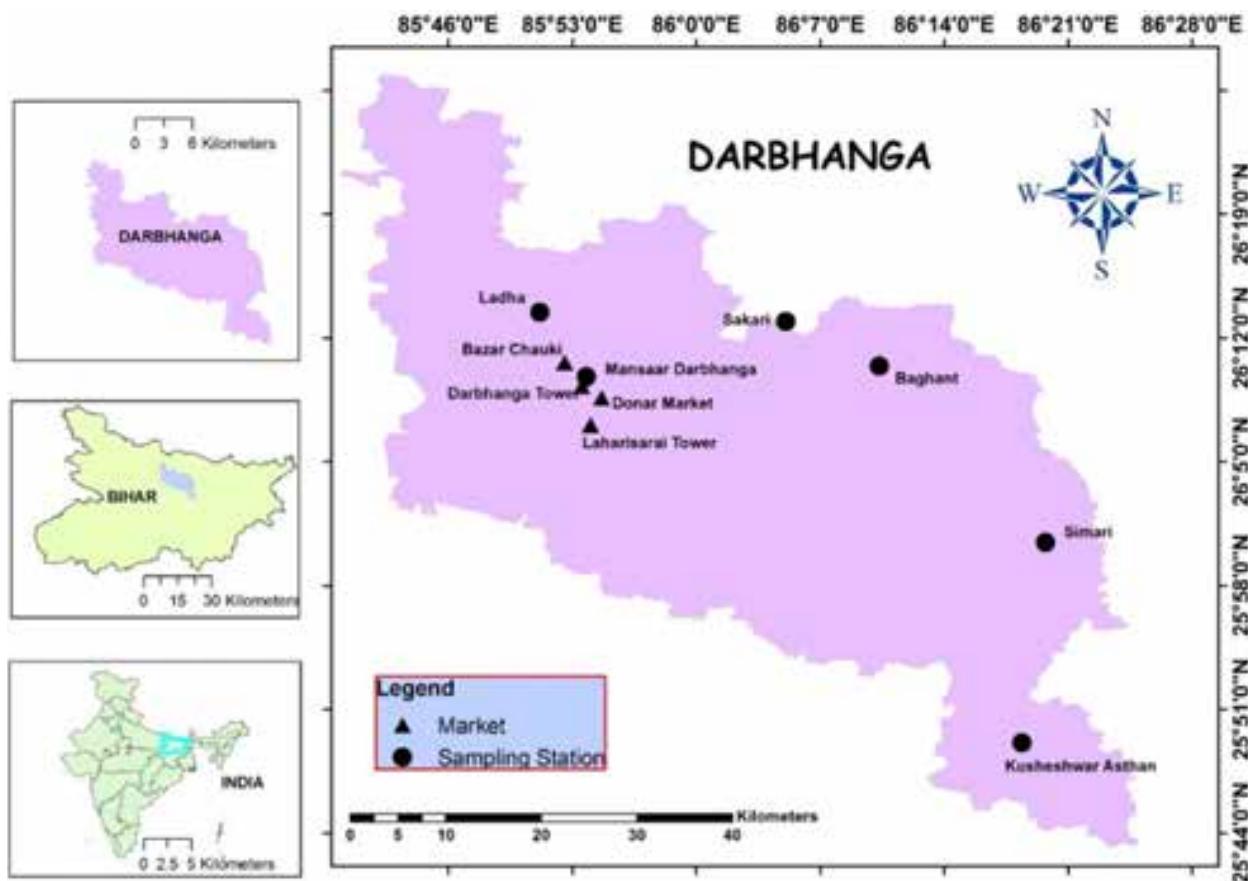


Figure 1. Darbhanga District, Bihar, India showing the sampling stations and the location of the markets

were developed based on the findings of earlier field surveys and interaction with local ethnic groups in the region by the authors (unpublished data). Ethnic group selection was based on the voluntary willingness and the availability of members in the study area during the field survey. Consent was requested and obtained from all the participants to make notes of interviews. Respondents were informed that all responses would be anonymized, so that they felt free to express their views without attribution. Discussions took place primarily in local languages and dialects. Gender sensitivity was considered, including questioning of women by a female member of the research team, though no inhibition was encountered in wider discussions with female or other informants. Conversation flowed freely with no evidence of it being dominated by any individuals. Researchers fluent in local languages translated the responses, taking written notes in English and collating them following the meeting. Additional input was derived from literature searches (as seen in the citations used in this paper).

The literature was extensively interrogated (peer-reviewed and non-peer reviewed papers, and grey

literature articles) to identify key attributes, chemical composition, ecosystem functions, and medicinal and other uses of aquatic macrophyte species most commonly used and traded in the study region. Google Scholar was used as the preferred search engine using the macrophytes as key terms. It was not possible to fully structure the literature review due to the diversity of plant species and habitats types in northern Bihar, their uses, and their range of associated market and non-market values. Given the breadth of research that had been conducted throughout the region, it was important to analyse available literature for the studied macrophytes. Data and other information obtained through previous extensive field surveys conducted by the authors have been complemented with analysis of available data and a breadth of studies conducted as the empirical basis of this paper.

RESULTS AND DISCUSSION

Aquatic macrophyte surveys of selected wetland ecosystems revealed a total of 61 relevant species of vascular plants. Most of the identified species were Angiosperms, and only two were Pteridophytes. The recorded Angiosperms included 33 species (54% of all species found) of Dicotyledons spread over 21 families and 26 (42% of the survey total) species of Monocotyledons from 13 families (Table 1). Filamentous algae (species were not recorded) and Pteridophytes (two species were recorded) were poorly represented in surveys during the monsoon season, and found to be closely associated with makhana and water chestnut. Figure 2 presents some of the most significant macrophytes extracted for human uses; Table 2 summarizes their chemical and nutritional characteristics derived from literature sources. Table 3 represents the survey prices of commercial important aquatic macrophytes. Based on the observed macrophytes from the study sites and the market surveys, 10 macrophytes were identified as having the highest ecological and commercial importance due to their environmental roles, utilities, market price, availability, and preference by buyers in the markets: Azolla, Makhana, Water chestnut, Taro/elephant ear, Indian lotus, Mandukaparni, Water spinach, Sweet flag, Brahmi, and Bhringraj (see Table 3).

Among the floating species in this survey, the alien invasive water hyacinth *Eichhornia crassipes* was found to be widely distributed and abundant in the stagnant waters of rivers, ditches and other wetland types. The submerged macrophyte *Hydrilla verticillata*, and the floating-leaved macrophyte *Nymphoides cristatum* were both found to be very common in the littoral zone of all examined wetlands. Macrophytes of high commercial value, including Makhana and Water chestnut, were mostly reported from the large ponds (Pokhari) and Chaur/Mauns (wetlands) where they were grown for production purposes, though some were also reported growing naturally in the Mauns. The floating-leaved macrophyte *Nelumbo nucifera* (lotus) was reported from temple pond and wetlands areas of 3–5m depth. Macrophyte species from the families Asteraceae, Cyperaceae, and Poaceae were mostly observed in the marginal portions of the wetlands and adjacent lowland areas. The attributes of the commercial macrophytes in terms of their scientific importance, nutritional quality and quantity, and culture practices possibly contributing to their preferred demand in the markets are summarized in Tables 3 and 4.

Diversity and distribution

The sampled wetlands support a diversity of aquatic macrophytes, which play various ecological roles as primary producers and in the recycling of nutrients (Engelhardt & Ritchie 2001; Bornette & Puijalon 2011). Nutrient recycling from the decomposition of macrophytes at the end of the growing season contributes to requirements for macrophyte growth in the following growing period (Denny 1985). From literature studies, appreciation of the conservation value of this resource appears to be lacking.

Societal benefits supported by aquatic macrophytes

Aquatic macrophytes play significant roles in supporting the needs of indigenous communities, in the forms of food, medicine and tradeable commodities, in addition to diversifying habitat supporting societally important aquatic fauna (Costanza et al. 1997; Petr 2000).

Our study finds that aquatic plants found in the wetlands of northern Bihar are important for the subsistence, medicinal and economic needs of local communities. In addition to wild harvesting, utilization of these wetlands for the culture of important aquatic macrophytes, such as Makhana and Water chestnut, has the potential to enhance the livelihoods of indigenous communities. It is important to acknowledge the extent to which indigenous communities are reliant upon these macrophytes for subsistence as well as other food, aquaculture, livestock fodder, trading and religious significance. Unstructured interviews with community members within this pilot study revealed the dependence of communities, however, with emerging opportunities such as more intensive forms of aquaculture and habitat conversion for agriculture, this low-level and inherently more sustainable dependence is now slowly giving way to habitat exploitation for “quicker benefits”.

Given the significant health benefits of these macrophytes for local people and more widely through trade, including their utility in various pharmaceutical industries, it is critical to enhance the capacity of local communities to explore the possibility of growing or harvesting these plants on a sustainable basis as cash crops, further supporting their livelihood options. These values need to be recognized, valued and embedded into the policy environment as a basis for sustainable management and wise use strategies, resisting or better informing current trends towards more intensive forms of aquaculture farms in the region.

Table 1. List of plant species recorded along with their habits.

	Scientific name	Family	Habits	IUCN status
	Pteridophyta			
1.	<i>Azolla pinnata</i> Linn.	Salviniaceae	Floating	Least Concern
2.	<i>Marsilea minuta</i> Linn.	Marsileaceae	Emergent	Least Concern
	Dicotyledons			
3.	<i>Nelumbo nucifera</i> Gaertn.	Nymphaeaceae	Floating	Data deficient
4.	<i>Nymphaea nouchali</i> Burm.	Nymphaeaceae	Floating	Least Concern
5.	<i>Asterocantha longifolia</i> Nees	Acanthaceae	Low land	Least Concern
6.	<i>Boerhaavia diffusa</i> Linn	Nyctaginaceae	Low land	Not Evaluated
7.	<i>Alternanthera sessilis</i> Linn.	Amaranthaceae	Emergent	Least Concern
8.	<i>Alternanthera philoxeroides</i> Mart. Griseb.	Amaranthaceae	Emergent	Least Concern
9.	<i>Ameranthus viridis</i> Linn.	Amaranthaceae	Low land	Not Evaluated
10.	<i>Polygonum glabrum</i> Willd	Polygonaceae	Emergent	Least Concern
11.	<i>Rumex dentatus</i> Linn.	Polygonaceae	Low land	Not Evaluated
12.	<i>Polygonum hydropiper</i> Linn.	Polygonaceae	Emergent	Least Concern
13.	<i>Scoparia dulcis</i> Linn.	Scrophulariaceae	Low land, Emergent	Not Evaluated
14.	<i>Heliotropium indicum</i> Linn.	Boraginaceae	Low land	Not Evaluated
15.	<i>Nymphoides cristatum</i> Roxb	Menyanthaceae	Floating	Least Concern
16.	<i>Trapa bispinosa</i> Roxb.	Lythraceae	Floating	Not Evaluated
17.	<i>Eclipta alba</i> (L.) Hassk	Asteraceae	Low land	Not Evaluated
18.	<i>Ageratum conyzoides</i> Linn.	Asteraceae	Low land	Not Evaluated
19.	<i>Parthenium hysterophorus</i> Linn.	Asteraceae	Low land	Not Evaluated
20.	<i>Xanthium strumarium</i> Linn.	Asteraceae	Low land, Marginal	Not Evaluated
21.	<i>Vicoa indica</i> (Willd.) DC.	Asteraceae	Marginal	Not Evaluated
22.	<i>Malvestrum tricuspidatum</i> A. Gray	Malvaceae	Low land	Not Evaluated
23.	<i>Urena spp.</i>	Malvaceae	Marginal, Submerged	--
24.	<i>Aeschynomene aspara</i> Linn.	Papilionaceae	Emergent	Least Concern
	<i>Aeschynomene indica</i> Linn.	Papilionaceae	Emergent	Least Concern
25.	<i>Desmodium triflorum</i> (Linn.) DC.	Papilionaceae	Low land	Not Evaluated
26.	<i>Ipomoea aquatica</i> Forssk.	Convolvulaceae	Floating, trailing herb	Least Concern
27.	<i>Convolvulus arvensis</i> Linn.	Convolvulaceae	Marginal, low land, trailing herb	Not Evaluated
28.	<i>Bacopa monnieri</i> (L.) Pennell	Plantaginaceae	Low land, Creeping herb	Least Concern
29.	<i>Centella Asiatica</i> Linn.	Apiaceae	Low land, Creeping herb	Least Concern
30.	<i>Utricularia stellaris</i> Linn.	Lentibulariaceae	Submerged	Not Evaluated
31.	<i>Hyptis suaveolens</i> (Linn.) Poit.	Lamiaceae	Marginal	Not Evaluated
32.	<i>Ludwigia hyssopifolia</i> (G. Don) Exell	Onagraceae	Marginal	Least Concern
33.	<i>Physalis minima</i> Linn.	Solanaceae	Marginal	Not Evaluated
34.	<i>Phyllanthus simplex</i> Retz.	Euphorbiaceae	Marginal, low land	Not Evaluated
35.	<i>Phyllanthus fraternus</i> Webster.	Euphorbiaceae	Marginal, low land	Not Evaluated
	Monocotyledons			
36.	<i>Commelinopsis benghalensis</i> Linn.	Commelinaceae	Low land	Least Concern
37.	<i>Commelinopsis nudiflora</i> Linn.	Commelinaceae	Low land	Not Evaluated
38.	<i>Lemna gibba</i> Linn.	Lemnaceae	Floating	Least Concern
39.	<i>Wolfia arrhiza</i> Wimm.	Lemnaceae	Floating	Least Concern

	Scientific name	Family	Habits	IUCN status
40.	<i>Pistia stratiotes</i> Linn.	Araceae	Floating	Least Concern
41.	<i>Colocasia esculenta</i> Linn.	Araceae	Low land	Least Concern
42.	<i>Sagittaria sagittifolia</i> Linn.	Alismataceae	Emergent	Least Concern
43.	<i>Scirpus articulatus</i> Linn.	Cyperaceae	Low land	Not Evaluated
44.	<i>Eleocharis dulcis</i> Burm.	Cyperaceae	Emergent	Not Evaluated
45.	<i>Fimbristylis tetragona</i> Br.	Cyperaceae	Low land, Emergent	Least Concern
46.	<i>Mariscus compactus</i> Nov. Comb.	Cyperaceae	Low land, Emergent	Least Concern
47.	<i>Pycreus pumilus</i> , Turril	Cyperaceae	Low land, Emergent	Least Concern
48.	<i>Potamogeton crispus</i> Linn.	Potamogetonaceae	Submerged	Least Concern
49.	<i>Hydrilla verticillata</i> (L.F.) Royle	Hydrocharitaceae	Submerged	Least Concern
50.	<i>Ottelia alismoides</i> (L.) Pers	Hydrocharitaceae	Submerged	Least Concern
51.	<i>Monochoria hastata</i> (L.) Solms.	Pontederiaceae	Emergent	Least Concern
52.	<i>Eichhornia crassipes</i> (Mart) solms.	Pontederiaceae	Floating	Not Evaluated
53	<i>Euryale ferox</i> Salisb.	Nymphaeaceae	Floating	Least Concern
54.	<i>Acorus calamus</i> Linn.	Acoraceae	Low land	Least Concern
55.	<i>Bacopa monnieri</i> Linn.	Plantaginaceae	Low land, Creeping herb	Least Concern
56.	<i>Chara zeylanica</i> Willd	Charophyceae	Submerged	Not Evaluated
57.	<i>Saccharum munja</i> Roxb.	Poaceae	Marginal	Not Evaluated
58.	<i>Saccharum spontaneum</i>	Poaceae	Marginal	Least Concern
59.	<i>Paspalidium</i> spp.	Poaceae	Marginal	---
60.	<i>Brachiaeria romosa</i> (L.) Stapf.	Poaceae	Marginal	Least Concern
61.	<i>Cynodon dactylon</i> , Linn.	Poaceae	Marginal	Not Evaluated

Table 2. Chemical composition of documented macrophytes (Reid 1977; Pullin & Almazan 1983; Becerra et al. 1995; Onwueme & Johnston 2000; Indrayan et al. 2005; Singh et al. 2010; Kumar et al. 2011; Faruk et al. 2012; Adkar et al. 2014).

Species	Carbohydrate	Protein	Crude fat	Crude fiber	Moisture	Ash
<i>Azolla</i> (dry weight basis)	10%	27%	4.6%	11.2%	Not available	15 %
Makhana (popped seeds)	76.90%	9.70%	0.2–0.5%	0.2–0.5%	10-13%	0.4%
Water chestnut (wet basis)	5.63%	1.87%	0.36%	2.13%	81%	1.33%
Taro/elephant ear (wet basis)	13–29 %	1.4–3 %	0.16–0.36	0.6–1.18	63–85 %	0.6–1.3 %
Lotus (seed)	70–72 %	10.6–15.9 %	1.93–2.8 %	2.70%	10.50%	4–4.5 %

Consequences of loss or degradation

Anthropogenic encroachment around the wetlands (such as agriculture and run-off from farming, industrial influent of various types, urbanization and associated sewage emissions) is exacerbated by lack of awareness among local people and regulatory agencies regarding the role of wetlands in the environment, with weak and poorly enforced regulation. Moreover, the presence of *Eichhornia crassipes*, an alien macrophyte in Bihar, threatens local biodiversity due to its high growth rate and tendency to form a dense mat over the water

surface (Howard & Harley 1998). These stressors have the potential to reduce the depth of wetlands and negatively impact other desirable water plants such as Water Chestnut, Lotus, and Makhana plants (Jain et al. 2010b). The recent boom of aquaculture industries in northern Bihar has also negatively impacted the diversity of the recorded macrophytes (pers. obs.). Indigenous communities which earlier relied on the cultivation of these crops have moved towards the aquaculture sector due to high profitability in a short period of time, in comparison to Makhana and Water Chestnut culture.

Table 3. Survey prices of commercial important aquatic macrophytes (INR/kg).

Macrophytes	Seed	Leaves/ flowers	Root/ tuber	Pop	Dry/ powder
Makhana	100–150	---	---	400–800	400–1000
Water chestnut	15–40	---	---	---	200–300
Taro/elephant ear	--	10–20	20–40	---	---
Lotus	300–600	10–50*	30–40	----	----
Mandukaparni	--	---	----		80–250
Water spinach	---	10–25	---	---	----
Sweet flag	---	25–35	25–40	---	100–140
Brahmi	---	----	----	---	40–150
Bhringraj	---	----	----	---	35–150

*per flower

This has led to the Chaur and Maun being converted to aquaculture ponds, denying local communities the traditional uses and values they derived from them.

Declining wetland extent and quality also results in an associated decline in the diverse ecosystem service benefits that the wetlands provide for wider societal wellbeing.

Conservation/wise use implications

The definition of “wise use” of wetlands according to Ramsar Commission is “...the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development” (Ramsar Commission 2010). In the context of the diverse wetlands of northern Bihar, the sustainable use of aquatic macrophytes, such as Makhana, Water Chestnut, Taro, and Lotus, can serve as a key focus and indicator of progress with wise and sustainable use. This may, for example, take the form of sustainable levels of harvesting and/or cultivation of local varieties of these plants in areas suitable for their production, safeguarding overall ecological character and the many additional societal benefits that flow from the wetland habitats that support them. Naturally available Taro, Azolla, Water spinach, and other medicinal plants also need critical attention as they are widely used, and relied on by many, for local consumption and medicinal proposes.

Aquatic macrophyte diversity in the study region plays an important role in the supporting aquatic ecosystems, including as a resource for local livelihoods. Therefore, incorporating the wise use of this botanical resource into aquatic management strategies, in which the diverse societal benefits that it provides is explicitly

recognized as a key element of sustainable development, can be influential in the sustainable conservation and livelihood needs of local communities associated with the wetland resource. This approach needs to be linked with planning approaches in the adjoining landscape to ensure that associated plans and policies take account of potential adverse impacts on these wetlands.

Further research and development needs

This pilot survey of aquatic macrophyte occurrence, uses and societal importance highlights the many values that flow to society from the diverse Chaur, Maun, and Pokhari wetlands naturally occurring in north Bihar. Additional surveys can augment this preliminary evidence base concerning plant distribution and socio-economic importance. Societal benefits flowing from the aquatic macrophytes form only a small part of the total ecosystem services benefits generated by these diverse wetlands. Methods such as the RAWES (Rapid Assessment of Wetland Ecosystem Services) approach (Ramsar Convention 2018), adopted in October 2018 by the Ramsar Convention as a globally standard means for assessment of wetland ecosystems on a systemic basis, enable the rapid, semi-quantitative assessment of wetland ecosystem services. Wider ecosystem service assessment can augment the knowledge base, recognizing more of the often-overlooked societal benefits provided by these wetland systems.

This broader knowledge base can in turn inform wise use strategies that reflect the many societal benefits associated with simultaneous use and conservation of wetland systems, as a bulkhead against their conversion for intensive and potentially unsustainable uses such as aquaculture, agricultural and industrial development that yield a narrow subset

Table 4. Key attributes of the ten most commercially important aquatic macrophytes found in this survey.

Azolla spp.
The genus <i>Azolla</i> comprises floating freshwater ferns within the family Salviniaceae. These plants have triangular or polygonal fronds, and float on the water surface either as individuals or in mats (Figure 2a). <i>Azolla</i> spreads very quickly in ideal growing conditions, forming dense vegetative masses on areas of still water in Maun and swampy areas. The plant plays an important role in the fixation of atmospheric CO ₂ and nitrogen due to its symbiotic relationship with cyanobacteria (<i>Anabaena azollae</i>) and rhizobium bacteria (Reddy et al. 2002). Simultaneously, it reduces evaporation rates and serves as a water purifier due to its ability to absorb unwanted organic nutrients and trace elements (Sood et al. 2012).
<i>Azolla pinnata</i> var. <i>imbricata</i> is found most commonly in Asian tropical waters, and is very common in most of the water bodies in north Bihar. The size of individual plants ranges from 1–1.5 cm. <i>Azolla</i> contains nitrogen hence, can serve as green manure or bio-fertilizer for the paddy fields and aquafarms (Hasan & Chakrabarti 2009). It also contains a substantial quantity of protein, fats and fibers (Table 2), and is also a source of vitamins (A and B12), phosphorus, potash, copper, magnesium and bioactive substances. Widespread use of <i>Azolla</i> is mainly due to its low price, and as a very abundant protein source (Reddy & deBusk 1985). Due to its high nutritive value, it is also used as feed for fish and livestock (Sherief & James 1994).
Makhana
<i>Euryale ferox</i> Salisb., locally known as Gorgon or prickly water lily, is also called Makhana. This species belongs to the family Nymphaeaceae (Zhuang 2011). It has a wide geographic range in north Bihar. It is an annual hydrophyte and its habitat comprises of stagnant perennial water bodies such as ponds, oxbow lakes, swamps and ditches (Figure 2b). The plant is used for edible and medicinal purposes in Ayurveda (Masram et al. 2015). The seed is used for its analgesic and aphrodisiac properties (Masram et al. 2015). It's also taken internally in the treatment of chronic diarrhea, vaginal discharge, kidney weakness, nocturnal emissions, and impotence (Das et al. 2006). Raw Makhana is a good source of carbohydrates, proteins, minerals. The calorific value of raw and popped seeds of Makhana is 362 and 328 K cal/100g respectively (Table 2).
Water chestnut
<i>Trapa natans</i> L. and its infraspecies <i>Trapa natans</i> var. <i>bispinosa</i> (Roxb.) Makino. is an aquatic free-floating plant with submerged and floating leaves arranged in a rosette manner (Figure 2c). It belongs to the family Trapaceae. The habitat of water chestnut requires sunny conditions and a muddy, nutrient rich, freshwater and soft substrate of ponds, marshes and lakes. Water chestnut is commonly known as Singhra/Singhada in India. The fruit of water chestnut has nutritional and medicinal values. The approximate composition of the water chestnut kernel is given by Singh et al. 2010 and Adkar et al. 2014 (see Table 2). The immature pulp of the fruit, called milky water chestnut, is eaten raw or cooked. It is also used for preparing tea in Japan, commercial production of wine, and festival food. The fruits have been used as agents of anti-inflammatory, anti-diarrhea, intestinal astringent, antileprotic and urinary discharges (Alfasane et al. 2011; Chandana et al. 2013).
Taro/elephant ear
The common name of <i>Colocasia esculenta</i> (L.) Schott. is Taro/elephant ear. It is a lowland aquatic macrophyte belonging to the family Araceae. It is a tropical and subtropical perennial plant with large, heart shape leaves (Figure 2d). The habitat of elephant ear is mostly moisture-rich areas or littoral zone of aquatic marshes, ponds and wetlands in northern Bihar. It has both roots and leaves which are edible (Opara 2001). Members of the genus are also cultivated as ornamental plants. Taro has high importance in ensuring food and livelihood security as it is also a cash crop (Revill et al. 2005; Palapala et al. 2009). Fresh taro is an excellent source of carbohydrate/starch with low amounts of fat and protein (Onwume & Johnston 2000) (see Table 2). Other nutrients such as minerals, Vitamin C, Thiamin, Riboflavin and Niacin are also present (Temesgen & Ratta 2015). Taro leaves are used as antidiabetic, antihypertensive, immunoprotective, and anticarcinogenic agents (Gupta et al. 2019), possibly due to being an excellent source of carotene, potassium, calcium, phosphorous, iron, riboflavin, thiamine, niacin, Vitamin A, Vitamin C and dietary fibre (Opara 2001). Curry preparation with leaves and stalks are given to women after childbirth to act as a treatment for anemia (Sarmah et al. 2013).
Indian lotus
The Indian lotus, <i>Nelumbo nucifera</i> Gaertn., is the national flower of India belonging to the family Nelumbonaceae. The habitat includes shallow and muddy ponds, wetlands and lakes that are exposed to direct sunlight (Figure 2e). The cultivation of lotus can be traced back more than 3,000 years ago for food, medicine, and cultural and religious activities (Shen-Miller 2002; Mandal & Bar 2013). Lotus rhizomes, stems and leaves are edible (Sridhar & Bhat 2007). Lotus rhizomes comprise 1.7% protein, 0.10% fat, 9.7% carbohydrates, and 1.1% ash (Reid 1977), and stems contain 6, 2.4 and 0.2 mg/100 g of calcium, iron and zinc respectively (Ogle et al. 2001). The seeds of lotus consist of several nutritional properties (see Table 2). Even the petals are used in soups and as a garnish. The rhizome extract has anti-diabetic and anti-inflammatory properties (Mukherjee et al. 1997). The leaves are used effectively for hematemesis, epistaxis and hemoptysis (Ou 1889). The fruits and seeds are used for dermatopathy, halitosis, menorrhagia, and leprosy (Nadkarni 1982).
Mandukaparni
Mandukaparni is a common name for <i>Centella asiatica</i> Linn., belonging within the family Apiaceae (Gohil et al. 2010). Mandukaparni grows in moist places and swampy areas of wetlands, particularly at the marginal areas of swamp and earth embankments (Figure 2f) (Khobragade & Khobragade 2016). Mandukaparni contains triterpene acids, flavonoids (Phondke 1992; Jamil et al. 2007), volatiles and fatty oil, alkaloids, glycosides (Chopra et al. 1956), and has also been reported to contain amino acids, minerals (Malhotra et al. 1961), oligosaccharides centellose, carotenoids, Vitamin-B, Vitamin-C (Phondke 1992), and tannins (Kapoor 2005). The species is widely used in Ayurvedic formulations, in Chinese medicine, and in homeopathic medicines. It is used to provide relief from insomnia, epilepsy, skin diseases, fever, high blood pressure, as a memory enhancer, and nervine tonic (Gupta & Sharma 2007). In homeopathic medicine, it is used for skin-related diseases such as itching and swelling, eczema, uterus-related ulceration and inflammation, granular cervicitis, elephantiasis and ascariasis (Singh & Rastogi 1969).
Water spinach
<i>Ipomoea aquatica</i> Forssk., commonly known as water spinach, belongs to the family Convolvulaceae. It is a semi-aquatic plant, with long hollow stems possessing a large number of air passages. Its leaves are elliptic or oval-oblong and cordate. The species is mostly associated with moist soil/mud along the margins of stagnant water bodies such as wetlands, marshes, lakes, ponds, rivers, and canals (Patnaik 1976). Water spinach is nutritionally rich and found to contain nutrients such as α -tocopherol (Candlish 1983); Vitamin-C, thiamin, riboflavin, niacin, proteins, fats, carbohydrates, fiber, organic acid, ash and minerals (Wills et al. 1984); glycolipids, phospholipids and fatty acids (Rao et al. 1990); and α and β carotenes (Ogle et al. 2001). In Indian traditional medicine, the extract of the leaves is used to alleviate disorders such as jaundice and nervous weakness (Prasad et al. 2008); nosebleed and high blood pressure (Duke & Ayensu 1985); and It also provides relief from eye diseases (Jain & Verma 1981) and constipation (Samuelsson et al. 1992). The plant also possesses anti-nematodal (Mackeen et al. 1997) and antioxidant properties (Prasad et al. 2005).
Sweet flag
Sweet flag or bach is a common name for <i>Acorus calamus</i> Linn. It belongs to the family Acoraceae. It is a semi-aquatic, perennial monocotyledonous plant naturally found in wetlands (Tiwari et al. 2012) (Figure 2g). It is mainly used for its oil due to the high occurrence of fatty acids and essential oils including acronone, isocalamendiol (Balakumbahan et al. 2010), monoterpane hydrocarbon, sequesterine ketones, asarone, and eugenol. Sweet flag has been used for the treatment of fever, asthma, bronchitis, swelling, cough, poor digestive function, epilepsy and insanity (Balakumbahan et al. 2010). Its roots and leaves also exhibit antimicrobial, antioxidant, and insecticidal properties (Asha et al. 2009; Balakumbahan et al. 2010).

Brahmi

Brahmi is the common name of *Bacopa monnieri* Linn. Brahmi is a perennial creeping herb belonging to the family Plantaginaceae. It grows in marshy wetlands (Figure 2h). The plant contains Bacoside-A and B, both nootropic major chemical entities (Chatterji et al. 1965; Devendra et al. 2018). It also contains alkaloids such as brahmine, nicotine, herpestine, triterpenoid, saponins A, B and C, betulinic acid, D-mannitol, stigmastanol, β -sitosterol, stigmasterol and pseudojujubogenin glycoside (Chopra et al. 1956; Bammidi et al. 2011).

Brahmi has been used to treat various nervous system-related disorders such as a brain tonic to enhance memory development, learning, motivation, and concentration, and to provide relief to patients with anxiety. It is also used in digestive complaints, for skin disorders, and as an antiepileptic, antipyretic, and analgesic agent (Mukherjee & Day 1966; Bammidi et al. 2011), however, its use has some clinical side effects such as mild gastrointestinal upset, nausea and intestinal motility (Aguiar & Borowski 2013).

Bhringraj

Bhringraj or *Eclipta alba* Hassk. belongs to the family Asteraceae. Its habitat is along the edges of pools, tanks, ditches, littoral zone of wetlands and rice fields. It contains active coumarins such as wedelolactone and desmethylwedelolactone (Wagner et al. 1986; Jaglan et al. 2013), and furanocoumarins, oleanane and taraxastane glycosides (Singh et al. 2010). The plant is commonly used in hair oil for healthy black and long hair (Roy et al. 2008), and is also popular for enhancing memory and learning abilities (Banji et al. 2007). It is used as a tonic and diuretic in hepatic and spleen enlargement conditions. It is also used in catarrhal jaundice, for skin and gall bladder diseases (Treadway 1998).

of short-term benefits whilst tending to undermine their wider and longer-term societal values.

As India is a signatory of the Ramsar Convention, ensuring wise use of wetlands is an obligation, also safeguarding their contributions to other areas of concern such as their roles in regulating flooding, disaster risk reduction, carbon sequestration, and fish recruitment. It is also an important contributor to protecting tribal and other local community rights for example under India's Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. This study provides preliminary evidence of the roles that aquatic macrophytes play in supporting the case for conservation and continuing sustainable use of the wetlands of northern Bihar.

REFERENCES

Adkar, P., A. Dongare, S. Ambavade & V.H. Bhaskar (2014). *Trapa bispinosa* Roxb.: A review on nutritional and pharmacological aspects. *Advances in Pharmacological and Pharmaceutical Sciences* 13: 959830. <https://doi.org/10.1155/2014/959830>

Alfasane, M.A., K. Moniruzzaman & M.M. Rahman (2011). Biochemical composition of the fruits of water chestnut (*Trapa bispinosa* Roxb.). *Dhaka University Journal of Biological Sciences* 20: 95–98. <https://doi.org/10.3329/dujbs.v20i1.8879>

Aguiar, S. & T. Borowski (2013). Neuro pharmacological review of the Nootropic Herb *Bacopa monnieri*. *Rejuvenation Research* 16: 313–318. <https://doi.org/10.1089/rej.2013.1431>

Asha, D.S. & D. Ganjewala (2009). Antimicrobial activity of *Acorus calamus* (L.) rhizome and leaf extract. *Acta Biologica Szegediensis* 53(1): 45–49.

Bammidi, S.R., S.S. Volluri, S.C. Chippada, S. Avanigadda & M.A. Vangalapati (2011). A review on pharmacological studies of *Bacopa monniera*. *Journal of Chemical Biological and Physical Sciences* 1: 250–259.

Balakumbahan, R., K. Rajamani & K. Kumanan (2010). *Acorus calamus*: an overview. *Journal of Medical Plant Research* 4(25): 2740–2745.

Banji, O., D. Banji, A.R. Annamalai & R. Manavalan (2007). Investigation on the effect of *Eclipta alba* on animal models of learning and memory. *Indian Journal Physiology and Pharmacology* 51(3): 274–278.

Becerra, M., T.R. Preston & B. Ogle (1995). Effect of replacing whole boiled soya beans with azolla in the diets of growing ducks. *Livestock research for rural development. Food and Agriculture Organization*. Volume 7, Article #26. Retrieved September 7, 2020, from <http://www.lrrd.org/lrrd7/3/7.htm>

Biswas, K. & L.C. Calder (1984). *Handbook of Common Water and Marsh Plants of India and Burma*. Bishen Singh Mahendra Pal Singh, Dehradun, xvii+216pp.

Bornette, G. & S. Puijalon (2011). Response of aquatic plants to abiotic factors: a review. *Aquatic Sciences* 73: 1–14. <https://doi.org/10.1007/s00027-010-0162-7>

Bunting, S.W., J. Pretty & P. Edwards (2010). Wastewater-fed aquaculture in the East Kolkata Wetlands, India: anachronism or archetype for resilient ecocultures? *Reviews in Aquaculture* 2: 38–153. <https://doi.org/10.1111/j.1753-5131.2010.01031.x>

Candlish, J.K. (1983). Tocopherol content of some southeast Asian food. *Journal Agriculture and Food Chemistry* 31: 166–168.

Chatterji, N., R.P. Rastogi & M.L. Dhar (1965). Chemical examination of *Bacopa monnieri* Wettst: part II -isolation of chemical constituents. *Indian Journal of Chemistry* 3: 24.

Chandana, M., R. Mazumder & G.S. Chakraborty (2013). A review on potential of plants under *Trapa* species. *International Journal of Research in Pharmacy and Chemistry* 2: 502–508.

Cherry, J.A. (2011). Ecology of Wetland Ecosystems: Water, Substrate, and Life. Nature Education Knowledge, 316pp.

Chopra, R.N., L. Nayar & I.C. Chopra (1956). *Glossary of Indian Medicinal Plants*, Vol 32, Council of Scientific and Industrial Research, New Delhi, 58pp.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton & M. van den Belt (1997). The value of the world's ecosystem services and natural capital. *Nature* 387: 253–260.

Cook, C.D.K. (1996). *Aquatic and Wetland Plants in India*. Oxford University Press, London.

Das, S., P. Der, U. Raychaudhary, N. Maulike & D.K. Das (2006). The effect of *Euryale ferox* Salisb. (Makhana), an herb of aquatic origin on myocardial ischemic repurfsion injury. *Molecular and Cellular Biochemistry* 289: 55–63. <https://doi.org/10.1007/s11010-006-9147-1>

Denny, P. (1985). *The Ecology and Management of African Wetland Vegetation: A Botanical Account of African Swamps and Shallow Waterbodies*. GEOF Vol.6, Springer, Dordrecht, 142–145pp.

Devendra, P., S.S. Patel, P. Birwal, S. Basu, G. Deshmukh & R. Datir (2018). Brahmi (*Bacopa monnieri*) as functional food ingredient in food processing industry. *Journal of Pharmacognosy and Phytochemistry* 7: 189–194.

Duke, J.A. & E.S. Ayensu (1985). *Medical plants of China*. Reference Publications in Algonac, Michigan, 260pp. <https://doi.org/10.1002/fedr.19870980707>

Engelhardt, K. & M. Ritchie (2001). Effect of macrophyte Species richness on wetland ecosystem functioning and services. *Nature* 411: 687–689. <https://doi.org/10.1038/35079573>



Image 1. Macrophytes from northern Bihar shown are A—Azolla | B—Makhana | C—Water chestnut | D—Taro | E—Lotus | F—Mandukaparni | G—Sweet flag | H—Brahmi. © Shailendra Raut.

Faruk, M.O., M.Z. Amin, N.K. Sana, R.K. Shaha & K.K. Biswas (2012). Biochemical analysis of two varieties of water chestnuts (*Trapa* sp.). *Pakistan Journal of Biological Sciences* 15: 1019–26.

Gogoi, P. (2016). Saving Deeporbeel: Assam's lone ramsar site. *Journal for Environmental Law, Research and Advocacy* 1. <http://www.nluassam.ac.in/joelraa9.htm#9>

Gohil, K.J., J.A. Patel & A.K. Gajjar (2010). Pharmacological Review on *Centella asiatica*: A potential herbal Cure-all. *Indian Journal of Pharmaceutical Science* 72: 546–556.

Gupta, A.K. & M. Sharma (2007). Reviews on Indian Medicinal plants, Vol 5. ICMR, New Delhi, 965–985pp.

Gupta, K., A. Kumar, V. Tomer, V. Kumar & M. Saini (2019). Potential of *Colocasia* leaves in human nutrition: Review on nutritional and phytochemical properties. *Journal of Food Biochemistry* 43 (7): e12878. <https://doi.org/10.1111/jfbc.12878>

Hasan, M.R. & R. Chakrabarti (2009). Use of algae and aquatic macrophytes as feed in small-scale aquaculture: a review. *FAO Fisheries and Aquaculture Technical Paper* 531: 17–27.

Holmes, N. & P.J. Raven (2014). Rivers: A natural and not-so-natural history. British Wildlife Publishing, 115–122pp.

Howard, G.W. & K.L.S. Harley (1998). How do floating aquatic weeds affect wetland conservation and development? How can these effects be minimized? *Wetlands Ecology and Management* 5: 215–225.

Indrayan, A.K., S. Sharma, D. Durgapal, N. Kumar & M. Kumar (2005). Determination of nutritive value and analysis of mineral elements for some medicinally valued plants from Uttarakhand. *Current Science* 89: 1252–1255.

Jaglan, D., A.S. Brar & R. Gill (2013). Pharmacological activity and chemical constituents of *Eclipta Alba*. *Global Journal of Medical Research Pharma, Drug Discovery, Toxicology and Medicine* 13: 35–40.

Jain, A.K., P. Tiwari & M. Basir (2010a). Nutritive aspect of *Oxalis corniculata* L. used by tribal of central India during scarcity of food. *Journal of American Science* 6: 435–437.

Jain, A., H.B. Singh & P. B. Kanjilal (2010b). Economics of foxnut (*Euryale ferox* Salisb) cultivation: A case study from Manipur in eastern India. *Indian Journal of Natural Products and Resources* 1: 63–67.

Jain, S.P. & D. M. Verma (1981) Medicinal plants in the folklore of Northeast Haryana. *National Academy Science Letters (India)* 4: 269–271

Jamil, S.S., Q. Nizami & M. Salam (2007). *Centella asiatica* (Linn.) Urban ÓA Review. *Natural product radiance* 6: 158–170.

Kaplan, D., T. Oron & M. Gutman (1998). Development of macrophytic vegetation in the Agmon wetland of Israel by spontaneous colonization and reintroduction. *Wetlands Ecology and Management* 6: 143. <https://doi.org/10.1023/A:1008420120533>

Kapoor, L.D. (2005). CRC Handbook of Ayurvedic Medicinal plant. CRC Press LLC, Florida, 208–209pp.

Khobragade, P. & M. Khobragade (2016). Cost Effective Cultivation of *Centella asiatica* Linn. (Mandukparni) – A Pilot Study. *Journal of Research in Traditional Medicine* 5: 135–137. <https://doi.org/10.21276/jrtm.2017/345>

Kumar, L., V.K. Gupta, B.K. Jha, I.S. Singh, B.P. Bhatt & A.K. Singh (2011). Status of makhana (*Euryale ferox* Salisb.) Cultivation in India. Technical Bulletin No. R- 32/PAT-21 ICAR-RCER Patna.

Larson, D.M., J. Riens, S. Myerchin, S. Papon, M.G. Knutson, S.C. Vacek, S.G. Winikoff, M.L. Phillips & J.H. Giudice (2019). Sediment excavation as a wetland restoration technique had early effects on the developing vegetation community. *Wetlands Ecology and Management*, 1–18pp. <https://doi.org/10.1007/s11273-019-09690-3>

Mackeen, M.M., M.A. Ali, M.A. Abdullah, R.M. Nasir, N.B. Mat, R.R. Abdul&K. Kawazu (1997). Antinematodal activity of some Malaysian plant extract against the pipe wood nematode, *Bursaphelenchus xylophilus*. *Pesticide Science* 51: 165–170. [https://doi.org/10.1002/\(SICI\)1096-9063\(199710\)51:2<165::AID-PS623>3.0.CO;2-2](https://doi.org/10.1002/(SICI)1096-9063(199710)51:2<165::AID-PS623>3.0.CO;2-2)

Maikhuri, R.K. & P.S. Ramakrishnan (1992). Ethnobiology of some tribal societies of Arunachal Pradesh in Northeast India. *Journal of Economic and Taxonomic Botany Additional Series* 10: 61.

Malhotra, C.L., P.K. Das, M.S. Sastry & N.S. Dhalla (1961). Chemical and pharmacological studies on *Hydrocotyle asiatica* (Linn). *Indian Journal of Pharmaceutical Sciences* 23: 106.

Mandal, R.N. & R. Bar (2013). The Sacred Lotus an Incredible Wealth of Wetlands. *RESONANCE* 18: 732–737.

Masram, P., K.S. Patel, V.K. Kori & S. Rajagopala (2015). Makhana (*Euryale ferox* Salisb)- A Review. *International Journal of Ayurveda and Pharmaceutical Chemistry* 4: 70.

Meena, T. & J. Rout (2016). Macrophytes and their ecosystem services from natural ponds in Cachar district, Assam, India. *Indian Journal of Traditional Knowledge* 15: 553–560.

Ministry of Tribal Affairs (2013). *Statistical profile of Scheduled Tribe in India*, Ministry of Tribal Affairs, Government of India, 1–5pp. <https://tribal.nic.in/ST/StatisticalProfileofSTs2013.pdf>

Mukherjee, D.G. & C.D. Dey (1966). Clinical trial on Brahmi. *International Journal of Experimental and Medical Sciences* 10: 5–11.

Mukherjee, P.K., K. Saha, J. Das, M. Pal & B.P. Saha (1997). Studies on the anti-inflammatory activity of rhizomes of *Nelumbo nucifera*. *Planta Medica* 63: 367–369. <https://doi.org/10.1055/s-2006-957705>

Nadkarni, A.K. (1982). *The Indian Materia Medica*, Vol. 2, Popular Prakashan Pvt, Bombay, India, 292–331pp.

Nag, S.K., S.K. Nandy, K. Roy, U.K. Sarkar & B.K. Das (2019). Carbon balance of a sewage-fed aquaculture wetland. *Wetlands Ecology Management* 27: 311–322.

Ogle, B.M., A.D. Ha-thi, G. Mulokozi & L. Hambraeus (2001). Micronutrient composition and nutritional importance of gathered vegetables in Vietnam. *International Journal of Food Science and Nutrition* 52: 485–499. <https://doi.org/10.1080/713671806>

Onwueme, I.C. & M. Johnston (2000). Influence of shade on stomatal density, leaf size and other leaf characteristics in the major tropical root crops: tannia, sweet potato, yam, cassava and taro. *Experimental Agriculture* 36: 509–516. <https://doi.org/10.1017/S0014479700001071>

Opala, L.U. (2001). Edible aroids: Post harvest operations INpho- Post Harvest Compendium, Food and Agriculture organization of the united Nation, 5–7pp.

Palapala, V.A., H. Talwana, J.O.M. Nandi, A.K. Sereme & B.K. Ndabikunze (2009). Morpho-agronomic characterization of Lake Victoria Basin taro genotypes. International Society for Tropical Root Crops. 15th Triennial Symposium, Lima Peru, 67–71pp.

Pandit, A.K. (1984). Role of macrophytes in aquatic ecosystems and management of fresh water resources. *Journal of Environmental Management* 18(1): 73–88.

Patnaik, S. (1976). Autecology of *Ipomoea aquatica* Forsk. *Journal of the Inland Fisheries Society of India* 8:77–82.

Peters, J.A. & D.M. Lodge (2009). *Littoral Zone*, Encyclopedia of Inland Waters, Reference Module in Earth System and Environmental Science, Academic Press, 79–87pp.

Petr, T. (2000). Interactions between fish and aquatic macrophytes in inland waters. A review. FAO Fisheries Technical Paper. No. 396. Rome FAO: 185.

Phondke, G.P. (1992). The wealth of India, A Dictionary of Indian Raw material and Industrial Product-Raw Materials Series, Publication and Information Directorate, CSIR, New Delhi, Revised Series 3 (C-Ci): 428–430.

Prasad, K.N., G.R. Shivamurthy & S.M. Aradhya (2008). *Ipomoea aquatica*, an underutilized green leafy vegetable: A Review. *International Journal of Botany* 4:123–129. <https://doi.org/10.3923/ijb.2008.123.129>

Prasad, N.K., S. Divakar, G.R. Shivamurthy & S.M. Aradhya (2005). Isolation of a free radical scavenging antioxidant from water spinach (*Ipomoea aquatica* Forsk.). *Journal of the Science of Food and Agriculture* 85: 1461–1468. <https://doi.org/10.1002/jsfa.2125>

Pullin, R.S.V. & G. Almazan (1983). Azolla as fish food. ICLARM Newsletter 1: 6–7.

Ramkrishna, Z. & S.Z. Siddique (2002). *Fauna of Kabar lake wetland*

(Bihar), Wetland ecosystem series 4. Published by Director, Zoological Survey of India, Kolkata, 39–45pp.

Ramsar Commission (2010). Ramsar Convention Secretariat, 2010. *Wise use of wetlands: Concepts and approaches for the wise use of wetlands*. Ramsar handbooks for the wise use of wetlands, 4th edition, vol. 1. Ramsar Convention Secretariat, Gland, Switzerland, 16–20pp.

Ramsar Convention (2018). Resolution XIII.17: Rapidly assessing wetland ecosystem services. 13th Meeting of the Conference of the Contracting Parties to the Ramsar Convention on Wetlands, 17–23. <https://www.ramsar.org/about/cop13-resolutions>

Rao, K.S., R. Dominic, K. Singh, C. Kaluwin, E. Donals, R. Gwyn&P. Jones (1990). Lipid, fatty acid, amino acid and mineral composition of five edible plants leaves. *Journal of Agricultural and Food Chemistry* 38: 2137–2139. <https://doi.org/10.1021/jf00102a007>

Reddy, K.R. & W.F. deBusk (1985). Growth characteristics of aquatic macrophytes cultured in nutrient-enriched water: 2. Azolla, duckweed, and *Salvinia*. *Economic Botany* 39: 200–208. <https://doi.org/10.1007/BF02907846>

Reddy, P.M., K. Euan, E.K. James & J.K. Ladha (2002). Chapter 15 - nitrogen Fixation in Rice. *Nitrogen Fixation at the Millennium*, Elsevier Science, UK 421–445. <https://doi.org/10.1016/B978-044450965-9/50015-X>

Reid, B.E. (1977). Famine Foods of the Chiu-Huang Pen-Ts'ao, Southern Materials Centre, Taipei, Taiwan.

Revill, P.A., G.V.H. Jackson, G.J. Hafne, I. Yang, M.K. Maino, M.L. Dowling, L.C. Devitt, J.L. Dale & R.M. Harding (2005). Incidence and distribution of viruses of taro (*Colocasiaesculenta*) in Pacific Island countries. *Australasian Plant Pathology* 34: 327–331. <https://doi.org/10.1071/AP05032>

Rejmankova, E. (2011). The role of macrophytes in wetland ecosystems. *Journal of Ecology and Field Biology* 34 (4): 333–345. <https://doi.org/10.5141/JEFB.2011.044>

Roy, R.K., M. Thakur & V.K. Dixit (2008). Hair growth promoting activity of *Eclipta alba* in male albino rats. *Archives Dermatological Research* 300: 357–364

Saha, M.R., D. De Sarker, P. Kar, P.S. Gupta & A. Sen (2014). Indigenous knowledge of plants in local healthcare management practices by tribal people of Malda district, India. *Journal of Intercultural Ethnopharmacology* 3: 179–185. <https://doi.org/10.5455/jice.20140630022609>.

Sarmah, B.P., D. Baruah & B. Bakalial (2013). Wetland medicinal plants in floodplains of Subansiri and Ranga river of Lakhimpur district, Assam, India. *Asian Journal of Plant Science and Research* 3: 54–60.

Samuelsson, G., M.H. Farah, P. Claeson, M. Hagose, M. Thulin, O. Hedberg, A.M. Warfa, A.O. Hassan, A.H. Elmi, A.D. Abdurahman, A.S. Elmis & Y.A. Abdi (1992). Inventory of plants used in traditional medicine in Somalia, II. Plants of the families Combretaceae to Labiateae. *Journal of Ethnopharmacology* 37: 47–70.

Singh, B. & R.P. Rastogi (1969). A reinvestigation of the triterpenes of *Centella asiatica*. *Phytochemistry* 8: 917–921. [https://doi.org/10.1016/S0031-9422\(00\)85884-7](https://doi.org/10.1016/S0031-9422(00)85884-7)

Singh, G.D., S. Singh, N. Jindal, A.S. Bawa & D.C. Saxena (2010). Physicochemical characteristics and sensory quality of singhara (*Trapanatans* L.): An Indian water chestnut under commercial and industrial storage condition. *African Journal of Food Science* 4: 693–702.

Shen-Miller, J. (2002). Sacred lotus, the long-living fruits of China Antiqua. *Seed Science Research* 12: 131–143

Sherief, P.M. & T. James (1994). Nutritive value of the water fern Azolla for fish. *Fishing Chimes* 14: 14

Sood, A., P. L. Uniyal, R. Prasanna & A.S. Ahluwalia (2012). Phytoremediation potential of aquatic macrophyte, Azolla. *Ambio* 41: 122–137. <https://doi.org/10.1007/s13280-011-0159-z>

Sridhar, K.R. & R. Bhat (2007). Lotus – A potential nutraceutical source. *Journal of Agricultural Technology* 3: 143–155.

Temesgen, M. & N. Ratta (2015). Nutritional potential, Health and Food Security Benefits of Taro *Colocasia esculenta* (L.): A Review. *Food Science and Quality Management* 36: 23–30.

Tiwari, R.K.S., K. Das, D. Pandey, R.B. Tiwari & J. Dubey (2012). Rhizome Yield of Sweet Flag (*Acoruscalamus* L.) as Influenced by Planting Season, Harvest Time, and Spacing. *International Journal of Agronomy* 731375: 1–8. <https://doi.org/10.1155/2012/731375>

Treadway, S. (1998). An ayurvedic herbal approach to a Healthy Liver. *Clinical nutrition insights* 6: 1–3.

Wagner, H., B. Geyer, Y. Kiso, H. Hikino & G.S. Rao (1986). Coumestans as the main active principles of the liver drugs *Eclipta alba* and *Wedelia calendulacea*. *Planta Medica* 5: 370–374.

Wills, R.B.H., A.W.K. Wong, F.M. Scriven & H. Greenfield (1984). Nutrient composition of Chinese Vegetable. *Journal of Agricultural and Food Chemistry* 32: 413–416. <https://doi.org/10.1021/jf00122a059>

Zhuang, X. (2011). *Euryale ferox*. The IUCN Red List of Threatened Species 2011: e.T168756A6535154. <https://doi.org/10.2305/IUCN.UK.2011-2>





Leaf nutrients of two *Cycas L.* species contrast among in situ and ex situ locations

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Abstract: An understanding of leaf nutrient relations is required for tree conservation and horticulture success. The study of cycad leaf nutrient dynamics has expanded in recent years, but direct comparisons among reports remains equivocal due to varying sampling protocols. We used *Cycas micronesica* K.D. Hill and *Cycas nongnoochiae* K.D. Hill trees to determine the influence on leaf nutrient concentrations of in situ versus ex situ locations and orientation of leaves within the tree canopy. Nitrogen, phosphorus, and potassium concentrations of leaves from ex situ plants exceeded those from in situ plants, and the differences were not explained by soil nutrient differences. Calcium concentrations of leaves varied among the site pairs, with differences primarily explained by soil calcium. Magnesium concentrations of leaves were not different among all location pairs even though soil magnesium concentrations varied among the sites more than any of the other elements. Differences in leaf macronutrient concentrations among four *C. micronesica* provenances were minimal when grown in a common garden. Lateral orientation of leaves did not influence any of the essential elements for either of the species. These findings indicate that the lateral orientation of cycad leaves does not influence leaf nutrient concentrations, leaf nutrient relations of cycad plants in managed ex situ settings do not align with leaf nutrient relations in habitat, and these differences are not explained by soil nutrition for most elements. We suggest that leaf nutrient concentrations should be determined in all niche habitats within the geographic range of a cycad species in order to fully understand the leaf physiology of each species.

Keywords: Cycad, *Cycas micronesica*, *Cycas nongnoochiae*, Guam, plant nutrients.

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Author contribution: Development of concepts for experimental methods was shared by both authors, TEM was responsible for all data collection, entry, and analysis. Both authors shared the authoring and editing role.

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INTRODUCTION

Cycads comprise a severely threatened plant group (Fragniere et al. 2015). The need for more applied research to inform cycad conservation and horticultural decisions has been recognized (Norstog & Nicholls 1997; Cascasan & Marler 2016). The literature on cycad leaf nutrient relations is insufficient, and a need to standardize sampling protocols among various studies and taxa has been discussed (Marler & Lindström 2018). Toward that end, we have recently shown that plant size (Marler & Krishnapillai 2018a), position of leaflet along the rachis (Marler & Krishnapillai 2019a), incident light, and leaf age (Marler & Krishnapillai 2019b) are plant traits that should be recorded to ensure repeatable methods in cycad leaf nutrient studies. Additionally, the nutrient status of the soils directly subtending a cycad plant differs from that of the bulk community soil (Marler & Krishnapillai 2018b; Marler & Calonje 2020), so sampling of soil directly beneath plants from which leaf samples are collected is needed to adequately interpret research results. Details on these influential plant traits and soil properties are missing from the methods of most published reports on cycad leaf nutrients (Grove et al. 1980; Watanabe et al. 2007; Álvarez-Yépez et al. 2014; Marler & Ferreras 2015, 2017; Krieg et al. 2017; Zhang et al. 2015, 2017, 2018).

Several questions concerning cycad leaf nutrient relations remain unanswered. For example, the influence on leaf nutrients of lateral orientation of leaves within the canopy has not been studied. Similarly, we are not aware of any reports which include a comparison of leaf nutrients between cultivated plants and in situ plants. Therefore, the plasticity of intra-specific leaf nutrient relations among various growing conditions is not known.

Cycas micronesica is listed as Endangered (Marler et al. 2010) and *Cycas nongnoochiae* is listed as Vulnerable (Hill 2010) by the International Union for Conservation of Nature Red List of Threatened Species. Threats to *C. nongnoochiae* are more typical of global threats, and include plant collecting, loss of habitat, and fire damage. The acute threat to *C. micronesica* is damage from invasive non-native insect species. *Cycas micronesica* leaves persist for many years and the native range includes Palau, Yap, Guam, and Rota Islands (Hill 1994). *Cycas nongnoochiae* leaves are usually replaced annually and the endemic range includes two adjacent mountains in central Thailand (Hill & Yang 1999; Marler et al. 2018). Both species are arborescent.

We used these two cycad species to answer

the following questions: (1) Do leaf macronutrient concentrations differ among ex situ versus in situ locations? (2) Does the provenance influence leaf macronutrient concentrations when grown in a common garden? (3) Does the lateral orientation of the large pinnately compound leaves of arborescent cycad plants influence leaf mineral and metal concentrations?

MATERIALS AND METHODS

Habitat relations study

An ex situ collection of Guam, Rota, and Yap *C. micronesica* genotypes was established in Angeles City, Philippines (15°09'N). The plants were grown in full sun and were maintained with no plant competition, but were not provided irrigation or fertilizer. An ex situ collection of Guam, Palau, Rota, and Yap *C. micronesica* genotypes and *C. nongnoochiae* genotypes was established at Nong Nooch Tropical Botanical Garden (NNTBG) in Chonburi, Thailand (12°46'N). The *C. micronesica* plants were grown under shade cloth with ~50% sunlight transmission and received irrigation as needed, but no fertilization. The *C. nongnoochiae* plants we sampled were managed in a landscape setting with tree canopy cover. They were irrigated as needed, but did not receive fertilization.

We collected samples from two ex situ garden locations and four in situ locations to compare leaf nutrient concentrations for five *C. micronesica* and one *C. nongnoochiae* location pairs. *Cycas micronesica* provenances included Guam, Palau and Yap. We could not include the Rota provenance because there were no healthy trees for in situ Rota habitats due to non-native insect herbivore infestations. For each in situ locality we documented canopy cover with a spherical densiometer (Forest Densiometers, Bartlesville, OK, USA). The densiometer was positioned at the horizontal plane located at the tip of the tallest leaf of each plant for each determination. We limited the replications to plants close to full sun conditions to match the Philippine ex situ replications, and close to 50% openness to match the Thailand ex situ replications. We also recorded the height of each replication from the location that was sampled first for each paired site. These data were used to locate replications with similar heights from the second location for each pair of locations. The dates of sample collection for the two locations in each pair were restricted to less than one month apart to ensure no seasonal effects would complicate the findings. There were eight replications for the Guam and Yap site pairs,

and six replications for the Palau site pair.

(1) In situ *C. nongnoochiae* leaves were sampled in Tak Fa, Thailand on 17 June 2013 (15°19'N), and the canopy openness ranged from 45% to 60%. Ex situ leaves were sampled at NNTBG on 24 June 2013, and the plants were selected to match the same canopy openness. (2) Ex situ leaves from Guam *C. micronesica* trees were sampled in Thailand on 11 August 2013 and Philippines on 30 August 2013. Matching in situ *C. micronesica* leaves were sampled in an east Guam habitat on 06 September 2013 (13°27'N). All unprotected in situ localities throughout Guam were severely threatened by several non-native insect pests, so we used a semi-managed plot in which imidacloprid was used to provide systemic tree protection. The imidacloprid applications began in 2007 and were repeated every 3–4 months. These in situ plants exhibited minimal infestations of the non-native insect herbivores. Moreover, they received no management protocols other than the pesticide applications. The densiometer was used to select appropriate trees with ≈50% sunlight for the Thailand samples and full sun for the Philippine samples. (3) In situ *C. micronesica* leaves were sampled in Ngellil Island, Palau on 20 May 2017 (7°20'N). The densiometer was used to select trees with ≈50% sunlight. Matching ex situ leaves from Palau *C. micronesica* trees were sampled in Thailand on 07 June 2017. There were no Palau genotypes in the Philippine ex situ collection. (4) Ex situ leaves from Yap *C. micronesica* trees were sampled in Thailand on 18 Jan 2018 and Philippines on 26 January 2018. Matching in situ *C. micronesica* leaves were sampled in Yap on 04 February 2018 (9°31'N).

Leaflets from the youngest leaves on plants with no visible active leaf growth were sampled. Trees with no signs of recent reproductive events were selected. Leaflets were collected from basal, midpoint, and apical locations on each leaf, and one leaf from each cardinal direction was sampled per plant. All leaflets were homogenized into one sample per replicate.

The tissue was dried at 75 °C and milled to pass through 20-mesh screen. Total nitrogen was determined by dry combustion (FLASH EA1112 CHN Analyzer, Thermo Fisher, Waltham, Mass, U.S.A.) (Dumas 1831). Samples were also digested by a microwave system with nitric acid and peroxide, then phosphorus, potassium, calcium, and magnesium were quantified by inductively coupled plasma optical emission spectroscopy (Spectro Genesis; SPECTRO Analytical Instruments, Kleve, Germany) (Hou & Jones 2000).

Common garden study

We used *C. micronesica* plants growing in homogeneous conditions at NNTBG to determine the influence of provenance on leaf macronutrient concentrations. Provenances were Guam, Palau, Rota, and Yap. Sampling was conducted on 07 June 2017. The plants were growing in homogeneous constructed mineral soil medium in raised beds underneath shade cloth with ≈50% sunlight transmission. For each replicate, leaves from the youngest flush that were oriented north, east, south, and west were selected and leaflets were harvested from base, midpoint, and apex of each rachis. Leaflets from the three rachis locations and four cardinal directions were combined into one sample for each replicate. Six homogeneous trees of each species were selected within the height range 1.0–1.6 m. Macronutrients were determined as previously described.

Leaf orientation study

The influence of leaf orientation within the canopy on essential element concentrations in leaf tissue of *C. micronesica* and *C. nongnoochiae* trees was determined at Nong Nnoch Tropical Botanical Garden. We restricted the sampling to *C. micronesica* plants from Guam. Sampling was conducted on 18 January 2018. The plants were growing in homogeneous constructed mineral soil medium in raised beds underneath shade cloth with ≈50% sunlight transmission. For each replication, leaves from the youngest flush that were oriented north, east, south, and west were selected and leaflets were harvested from base, midpoint, and apex of each rachis. The three rachis locations were combined into one sample for each cardinal direction for each replication. Six homogeneous trees of each species were selected within the height range 1.0–1.3 m. Macronutrients were determined as previously described. In addition, the nutrients boron, copper, iron, manganese, sulfur, and zinc were digested and determined by spectroscopy as described for the macronutrients.

Soil analyses

A soil sample was collected beneath each sampled tree and combined into a composite sample for each location. The soil cores were 15cm in depth and were positioned at half the length of the longest leaves. There were four cores positioned in cardinal directions for each tree. The soil was combined and homogenized for one analysis per sampling date per location. Total nitrogen content was determined by dry combustion. Extractable essential nutrients other

than phosphorus were quantified following digestion with diethylenetriaminepentaacetic acid (Berghage et al. 1987), and total metals were quantified following digestion with nitric acid (Zheljazkov et al. 2002). Analysis was by inductively coupled plasma optical emission spectrometry. Available P was determined by the Olsen method (Olsen et al. 1954) for every site except for the Yap site. A modified Truog method (Hue et al. 2000) was used for the acid Yap soils.

Statistics

Macronutrient concentrations from each of the location pairs were subjected to *t* test to compare *in situ* and *ex situ* locations. Macronutrients from plants in the common garden setting were subjected to a one-way ANOVA (PROC GLM, SAS Institute, Cary, Indiana) to compare provenances. The leaf orientation data were subjected to one-way ANOVA to determine the influence of lateral orientation on leaf traits. The two species were analyzed separately. Means separation was conducted with Tukey's HSD test for each response variable that was significant.

RESULTS

Habitat relations

Soil chemistry varied substantially among the *in situ* and *ex situ* locations (Table 1). Our two *ex situ* location differences were greatest for nitrogen and phosphorus and moderate for magnesium and zinc. Elements that exhibited the greatest range among the *in situ* locations were calcium, iron, manganese, phosphorus, and zinc. The mean of the *in situ* locations exhibited greater concentrations of every reported element than the mean of the *ex situ* locations.

Green leaf nitrogen concentration was significantly greater in the *ex situ* locations than the *in situ* locations for all six habitat pairs (Table 2). The paired comparison that exhibited the greatest difference was the Palau *C. micronesica* genotype, with nitrogen in leaves from the *in situ* site exhibiting a 44% increase above that from the *ex situ* site. Green leaf phosphorus concentration was also greater in the *ex situ* locations than the *in situ* locations for all six habitat pairs (Table 3). The location differences for *C. nongnoochiae* leaf phosphorus exceeded the location differences for all *C. micronesica* site pairs. The Palau *C. micronesica* plants exhibited the greatest difference between the two locations for the five *C. micronesica* site pairs, with the *ex situ* site exhibiting leaf phosphorus that was double that of the *in situ* site. The patterns for green leaf potassium concentration were similar to those for leaf phosphorus (Table 4). The *in situ* *C. nongnoochiae* leaf potassium concentration was one-fourth that of the *ex situ* leaf concentration. The Palau *C. micronesica* plants again exhibited the greatest difference between the two locations, with the *ex situ* plants exhibiting a 75% increase above that of the *in situ* plants.

Green leaf calcium concentration was significantly different for all six location pairs (Table 5). In contrast to nitrogen, phosphorus, and potassium, the *in situ* locations exhibited greater leaf calcium concentration than the *ex situ* locations for *C. nongnoochiae* and the Guam and Palau genotypes of *C. micronesica*. The Yap *C. micronesica* trees, however, exhibited greater leaf calcium concentration in the *in situ* locations for both site pairs. Green leaf magnesium concentration was similar for each of the six location pairs (Table 6). The leaf magnesium concentration of *C. nongnoochiae* trees was less than that of the five *C. micronesica* location pairs. The plasticity of magnesium concentration

Table 1. Chemical elements of soils subtending *Cycas micronesica* or *Cycas nongnoochiae* plants in various locations.

	Off-site	Off-site	<i>in situ</i>	<i>in situ</i>	<i>in situ</i>	<i>in situ</i>
Substrate property	Philippines	Thailand	Yap	Guam	Palau	Thailand
Nitrogen (mg·g ⁻¹)	1.3	4.3	5.2	10.2	13.4	4.9
Phosphorus (μg·g ⁻¹)	92.7	9.5	14.2	50.1	62.5	45.8
Potassium (μg·g ⁻¹)	76.7	64.4	99.5	406.6	511.2	273.8
Calcium (mg·g ⁻¹)	0.9	1.1	2.1	11.9	12.9	10.1
Magnesium (μg·g ⁻¹)	96.3	141.6	1292.2	543.4	1112.7	1021.2
Manganese (μg·g ⁻¹)	19.1	18.7	14.3	143.2	56.1	15.5
Iron (μg·g ⁻¹)	8.4	11.5	328.7	15.7	20.7	7.3
Copper (μg·g ⁻¹)	1.2	1.8	3.9	1.5	2.2	0.9
Zinc (μg·g ⁻¹)	9.9	5.5	8.8	39.6	8.7	2.8

Table 2. Green leaf nitrogen concentration ($\text{mg}\cdot\text{g}^{-1}$) of *Cycas micronesica* and *Cycas nongnoochiae* plants in various locations. Ex situ sites included Chonburi, Thailand (curated by Nong Nooch Tropical Botanical Garden) and Angeles City, Philippines (curated by University of Guam).

<i>Cycas</i> Genotype	Site	Ex situ	In situ	t	p
<i>C. nongnoochiae</i>	Thailand	25.63 \pm 1.22	29.88 \pm 1.52	2.224	0.043
Guam <i>C. micronesica</i>	Philippines	16.89 \pm 2.11	23.15 \pm 2.56	4.569	<0.001
Guam <i>C. micronesica</i>	Thailand	18.95 \pm 1.99	25.14 \pm 3.02	3.435	0.004
Palau <i>C. micronesica</i>	Thailand	20.46 \pm 2.04	29.51 \pm 2.99	8.320	<0.001
Yap <i>C. micronesica</i>	Philippines	21.12 \pm 2.14	26.89 \pm 2.01	3.849	0.002
Yap <i>C. micronesica</i>	Thailand	24.26 \pm 2.24	30.23 \pm 2.35	5.407	<0.001

Table 3. Green leaf phosphorus concentration ($\text{mg}\cdot\text{g}^{-1}$) of *Cycas micronesica* and *Cycas nongnoochiae* plants in various locations. Ex situ sites included Chonburi, Thailand (curated by Nong Nooch Tropical Botanical Garden) and Angeles City, Philippines (curated by University of Guam).

<i>Cycas</i> Genotype	Site	In situ	Ex situ	T	P
<i>C. nongnoochiae</i>	Thailand	1.31 \pm 0.06	3.44 \pm 0.41	11.997	<0.001
Guam <i>C. micronesica</i>	Philippines	1.77 \pm 0.13	2.04 \pm 0.21	2.152	0.048
Guam <i>C. micronesica</i>	Thailand	1.91 \pm 0.14	2.34 \pm 0.21	2.114	0.026
Palau <i>C. micronesica</i>	Thailand	1.45 \pm 0.16	2.94 \pm 0.18	15.395	<0.001
Yap <i>C. micronesica</i>	Philippines	1.61 \pm 0.21	2.39 \pm 0.22	3.394	0.004
Yap <i>C. micronesica</i>	Thailand	1.68 \pm 0.24	2.47 \pm 0.25	3.989	0.001

Table 4. Green leaf potassium concentration ($\text{mg}\cdot\text{g}^{-1}$) of *Cycas micronesica* and *Cycas nongnoochiae* plants in various locations. Ex situ sites included Chonburi, Thailand (curated by Nong Nooch Tropical Botanical Garden) and Angeles City, Philippines (curated by University of Guam).

<i>Cycas</i> Genotype	Site	In situ	Ex situ	t	p
<i>C. nongnoochiae</i>	Thailand	4.41 \pm 0.39	18.19 \pm 2.19	12.227	<0.001
Guam <i>C. micronesica</i>	Philippines	11.79 \pm 0.55	16.14 \pm 1.62	5.413	<0.001
Guam <i>C. micronesica</i>	Thailand	12.57 \pm 0.66	18.02 \pm 1.88	6.382	<0.001
Palau <i>C. micronesica</i>	Thailand	10.45 \pm 1.35	18.29 \pm 1.38	9.128	<0.001
Yap <i>C. micronesica</i>	Philippines	12.49 \pm 2.12	16.88 \pm 2.05	4.710	<0.001
Yap <i>C. micronesica</i>	Thailand	14.92 \pm 2.63	18.86 \pm 2.11	3.719	0.002

appeared to be highly constrained with a homeostasis among numerous settings.

The behavior of the macronutrients separated into three general groups with regard to our paired site approach. The first group was comprised of nitrogen, phosphorus, and potassium where the ex situ plants universally exhibited greater leaf concentrations than the in situ plants and the differences could not be explained by differences in soil chemistry. The second group was comprised of the single element calcium where the soil calcium concentrations appeared to control of leaf calcium concentrations within the context of our methods. The third group was comprised of the single element magnesium where constrained variability

caused no differences in leaf concentrations among all site pairs despite extreme differences in soil magnesium concentrations.

The influence of provenance

Differences in leaf macronutrient concentrations among the four *C. micronesica* provenances were not different for nitrogen ($P=0.372$), phosphorus ($P=0.656$), potassium ($P=0.551$), or calcium ($P=0.654$) when they were grown in a common garden setting (Figure 1). In contrast, leaf magnesium concentration was greater for the Guam, Rota, and Palau provenances than for the Yap provenance ($P=0.037$, Figure 1).

Table 5. Green leaf calcium concentration ($\text{mg}\cdot\text{g}^{-1}$) of *Cycas micronesica* and *Cycas nongnoochiae* plants in various locations. Ex situ sites included Chonburi, Thailand (curated by Nong Nooch Tropical Botanical Garden) and Angeles City, Philippines (curated by University of Guam).

<i>Cycas</i> Genotype	Site	In situ	Ex situ	t	P
<i>C. nongnoochiae</i>	Thailand	7.02±0.76	3.24±0.44	4.425	<0.001
Guam <i>C. micronesica</i>	Philippines	18.48±2.01	6.85±0.77	5.103	<0.001
Guam <i>C. micronesica</i>	Thailand	15.98±1.45	6.11±0.72	5.339	<0.001
Palau <i>C. micronesica</i>	Thailand	19.94±2.33	6.96±0.92	12.287	<0.001
Yap <i>C. micronesica</i>	Philippines	3.32±1.16	6.22±1.29	2.567	0.022
Yap <i>C. micronesica</i>	Thailand	3.12±1.01	5.91±1.22	2.290	0.038

Table 6. Green leaf magnesium concentration ($\text{mg}\cdot\text{g}^{-1}$) of *Cycas micronesica* and *Cycas nongnoochiae* plants in various locations. Ex situ sites included Chonburi, Thailand (curated by Nong Nooch Tropical Botanical Garden) and Angeles City, Philippines (curated by University of Guam).

<i>Cycas</i> Genotype	Site	In situ	Ex situ	t	P
<i>C. nongnoochiae</i>	Thailand	2.56±0.22	2.42±0.26	0.571	0.289
Guam <i>C. micronesica</i>	Philippines	4.46±0.53	5.22±0.87	0.858	0.202
Guam <i>C. micronesica</i>	Thailand	4.52±0.55	5.32±0.89	0.764	0.457
Palau <i>C. micronesica</i>	Thailand	6.95±1.85	5.48±1.68	1.123	0.288
Yap <i>C. micronesica</i>	Philippines	3.22±0.46	3.08±0.21	0.721	0.483
Yap <i>C. micronesica</i>	Thailand	3.66±0.78	3.41±0.69	0.555	0.587

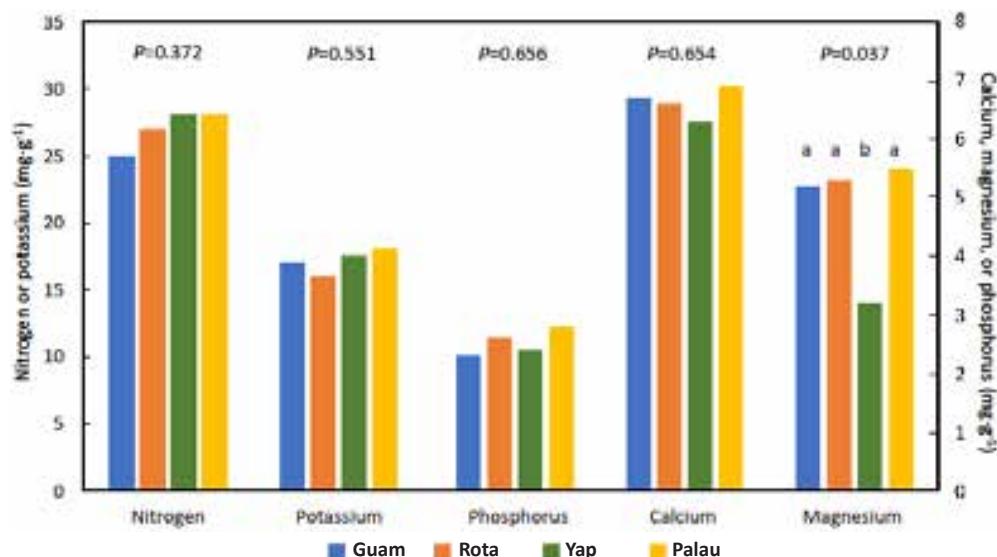


Figure 1. The influence of provenance on *Cycas micronesica* leaf tissue macronutrient concentrations when grown in homogeneous conditions at Nong Nooch Tropical Botanical Garden, Chonburi, Thailand. Columns for magnesium with same letter are not different according to Tukey's HSD test ($P<0.05$).

The influence of leaf orientation

Differences among the *C. micronesica* leaves that were oriented north, east, south, or west were not significant for any of the measured nutrient concentrations. These Guam-sourced trees produced leaves with nutrients in the following order of concentration: N ($25.29 \text{ mg}\cdot\text{g}^{-1}$) >

K ($18.09 \text{ mg}\cdot\text{g}^{-1}$) > Ca ($5.85 \text{ mg}\cdot\text{g}^{-1}$) > Mg ($4.22 \text{ mg}\cdot\text{g}^{-1}$) > P ($2.34 \text{ mg}\cdot\text{g}^{-1}$) > S ($1.12 \text{ mg}\cdot\text{g}^{-1}$) > Fe ($71.44 \mu\text{g}\cdot\text{g}^{-1}$) > B ($43.39 \mu\text{g}\cdot\text{g}^{-1}$) > Mn ($36.55 \mu\text{g}\cdot\text{g}^{-1}$) > Zn ($32.49 \mu\text{g}\cdot\text{g}^{-1}$) > Cu ($7.66 \mu\text{g}\cdot\text{g}^{-1}$). The differences among the *C. nongnoochiae* leaves that were oriented north, east, south, or west were not significant for any of the measured nutrient

concentrations. This Thailand endemic species produced leaves with nutrients in the following order of concentration: N (29.98 mg·g⁻¹) > K (18.29 mg·g⁻¹) > P (3.36 mg·g⁻¹) > Ca (3.15 mg·g⁻¹) > Mg (2.49 mg·g⁻¹) > S (1.35 mg·g⁻¹) > Fe (76.42 µg·g⁻¹) > Mn (68.58 µg·g⁻¹) > Zn (28.03 µg·g⁻¹) > B (25.64 µg·g⁻¹) > Cu (9.69 µg·g⁻¹).

DISCUSSION

We have used several approaches to examine *Cycas* leaf macronutrient plasticity, and our results indicate that plasticity of *C. micronesica* and *C. nongnoochiae* leaf concentrations of nitrogen, phosphorus, potassium, and calcium is largely determined by the growing environment. For nitrogen, phosphorus and potassium, the benign growing conditions of a managed garden versus the competitive conditions of a biodiverse forest community appeared to be a mitigating factor. For calcium, soil content variation appeared to be the mitigating factor. In contrast, leaf concentrations of magnesium were primarily under genetic control and were relatively unresponsive to variation in the growing environment.

Variability in leaf macronutrient concentrations among the various ex situ plants was generally less than that among the matched in situ plants. These observations support the interpretation that environmental variables of the growing site were more important for determining green leaf nutrient relations than genetic differences among provenances of *C. micronesica*. The same phenomenon was reported for *Quercus variabilis* Blume where differences in tissue macronutrient concentrations among various provenances disappeared when plants from each of the provenances were grown in a common garden (Lei et al. 2013).

We are aware of only three other reports in which cycad leaf nutrients were studied in more than one location. Marler & Ferreras (2015) determined leaf nutrient relations of *Cycas nitida* K.D. Hill & A. Lindstr. plants from four Philippine in situ localities with contrasting soil chemistry. The green leaf nitrogen relations were similar to our results with minimal differences among the localities, but the phosphorus concentrations varied 1.7-fold and the potassium concentrations varied 2.6-fold among the localities. Leaf nutrient relations of several cycad species were studied in two managed botanic gardens in China. In the first report from this work (Zhang et al. 2015), there were four species that were included from both gardens. In

the second report from this work (Zhang et al. 2017), no information was provided concerning leaf nutrient concentrations of individual species, so a comparison of species between the two sites was not possible. Tissue sampling of the two garden sites was separated by two to three years in these studies, so a direct comparison with our methods which minimized the time separation effects is difficult because we ensured that each pair of sites were sampled on dates that were separated by less than one month. Despite these limitations, the four species that were studied in both gardens exhibited inconsistent leaf nutrient concentrations with regard to corresponding soil nutrients (Zhang et al. 2015), a result that did not corroborate our findings for calcium. Leaf calcium concentration in three of the four species was greater in the garden site with less soil calcium concentration. A contrast in soil sampling methods may explain the differences, in that we obtained our soil samples directly beneath the sampled trees while Zhang et al. (2015) examined general soil samples from each garden. Thus our soil data were from the substrates in which the plants we examined were growing, an approach that is required to ensure accuracy (Marler & Krishnapillai 2018b; Marler & Calonje 2020). Our results and other reports indicate much is left to be learned about site-to-site differences in cycad leaf nutrient relations.

The Thailand garden exhibited greater leaf concentrations than the Philippine garden for most macronutrients. We did not collect samples for the purpose of comparing these two garden settings, however future research may be guided by two influential factors that differed between these gardens. First, the Thailand garden plants received irrigation as needed, but the Philippine garden plants were rain-fed and received no supplemental irrigation after they had become established. Leaf water relations may exert a profound effect on leaf physiology for various cycad species (Zhang et al. 2018), and the relatively greater water stress in the Philippine garden may explain the generally lower leaf nutrient concentrations. Second, the Thailand garden plants were cultured under 50% shade cloth and the Philippine garden plants were cultured in full sun. Incident light influences leaf nutrient relations for *C. micronesica* (Marler & Krishnapillai 2019b), and the generally lower leaf nutrient concentrations in the Philippine garden may have been explained by the full sun growing conditions.

Why would the managed gardens produce plants with greater leaf macronutrient concentrations than the in situ plants when the soil nutrient status

was not an explanatory factor and the plants in our two gardens received no supplemental fertilizer? We suggest the greater nitrogen, phosphorus, and potassium concentrations in the garden plants resulted from the profound inter-specific competition of the typical species rich cycad habitat versus the lack of inter-specific competition due to weed control in the garden settings. Manipulative studies have shown that greater plant species richness leads to decreased leaf macronutrient concentrations, indicating more efficient use of the leaf nutrients in the biodiverse settings (Lü et al. 2019). *Cycas* plants are responsive to containerized competition studies (Marler 2013; Marler et al. 2016). Species richness studies using sympatric species from the habitats of each model cycad species may answer these questions about greater leaf macronutrient concentrations in managed garden settings.

One of the factors that governs global leaf nitrogen and phosphorus variation is latitude. Both of these leaf nutrients are found in greater concentrations with greater latitude (Reich & Oleksyn 2004; Han et al. 2005). Our range of 7°20'N (Palau) to 14°07'N (Rota) for the *C. micronesica* provenances revealed no observable influence of latitude on leaf nitrogen or phosphorus concentration.

The collective results and observations indicate that the study of cycad leaf nutrient relations is a field of study that is in its infancy. The addition of more relevant reports is important for improving terrestrial plant conservation because cycads are one of the most threatened groups of plants worldwide (Fragniere et al. 2015). That reports are accumulating in the literature is encouraging, but appropriate sampling methods must be used to gather useful information. From the information known to date, such methods must assess plant size, position of leaflet along the rachis, incident light, and leaf age or description of the sequence of leaf flushes sampled (Marler & Krishnapillai 2018a, 2019a,b). Herein we have shown that the lateral direction of a *Cycas* leaf within the canopy did not influence the 11 minerals and metals measured, and our findings indicate the omission of this sampling information from many past reports on cycad leaf tissue analyses may be acceptable.

What are some of the areas of study that are needed? More multi-species studies are needed from robust botanic garden collections to more fully understand the genetic controls over cycad leaf nutrient status and whether these leaf physiology traits are correlated with phylogeny. To our knowledge, ours is the first provenance study for any cycad species, so more provenance studies are needed on indigenous species with wide geographic

ranges and multiple niche areas of occupancy. The influence of season on cycad leaf nutrient status has not been studied to our knowledge, and this needs to be corrected. The single study that revealed leaflet location along the rachis strongly influenced leaf nutrient status was conducted with a species with ≈ 2 m mature leaf lengths (Marler & Krishnapillai 2019a). The range in mature length of the cycad pinnately compound leaf is immense among the described species (Norstog & Nicholls 1997). Future research should exploit this range in mature leaf length to determine if the influence of position along the rachis is an allometric phenomenon such that differences along the rachis are restricted to species that produce large leaves. The mobilization and resorption of leaf elements during the senescence process is an important plant behavior. We are aware of only three reports that describe nutrient resorption traits for cycads, and all three reports used *Cycas* species (Marler & Ferreras 2015, 2017; Marler & Krishnapillai 2018a). Most botanic gardens manicure their plants such that old leaves are removed prior to becoming unsightly during senescence, so studying nutrient resorption dynamics may be difficult in most ex situ settings. Curators may want to reconsider the use of this practice for cycad plants that are not positioned in the public areas as a means of enabling more nutrient resorption research in ex situ locations.

In summary, the paucity of cycad research is a limitation for conservation of this threatened plant group. The recent reports on leaf nutrient content have been conducted without sufficient sampling conformity. We have shown that the orientation of leaves on two arborescent cycad species did not influence leaf nutrient concentrations, so the omission of this information from past reports may be acceptable. We are the first to report that a representative cycad species expresses heterogeneous leaf macronutrient relations among in situ versus ex situ locations, and the differences in soil macronutrient concentrations did not explain most of this heterogeneity. We are also the first to report leaf nutrient concentrations of cycad plants derived from multiple provenances and grown in a common garden setting. The controls over nitrogen, phosphorus, potassium, and calcium concentrations appear to be influenced primarily by environmental factors whereas the controls over magnesium concentration appear to be primarily influenced by genetic factors. We suggest that leaf nutrient concentrations should be determined in all niche habitats within the geographic range of a cycad species in order to fully understand the leaf physiology of each species.

REFERENCES

Álvarez-Yépiz, J.C., A. Cueva, M. Dovčiak, M. Teece & E.A. Yépez (2014). Ontogenetic resource-use strategies in a rare long-lived cycad along environmental gradients. *Conservation Physiology* 2: 2. <https://doi.org/10.1093/conphys/cou034>.

Berghage, R.D., D.M. Krauskopf, D.D. Warncke & I. Widders (1987). Micronutrient testing of plant growth media extractant, identification and evaluation. *Communications Soil Science and Plant Analysis* 18: 1089–1109.

Cascasan, A.N. & T.E. Marler (2016). Publishing trends for the Cycadales, the most threatened plant group. *Journal of Threatened Taxa* 8: 8575–8582. <https://doi.org/10.11609/jott.2369.8.3.8575-8582>

Dumas, J.B.A. (1831). Procedes de L'analyse Organique. *Annales de Chimie et de Physique* 47: 198–205.

Fragniere, Y., S. Bétrisey, L. Cardinaux, M. Stoffel & G. Kozlowski (2015). Fighting their last stand? A global analysis of the distribution and conservation status of gymnosperms. *Journal of Biogeography* 42: 809–820.

Grove, T.S., A.M. O'Connell & N. Malajczuk (1980). Effects of fire on the growth, nutrient content and rate of nitrogen fixation of the cycad *Macrozamia riedlei*. *Australian Journal of Botany* 28: 271–281.

Han, W., J. Fang, D. Guo & Y. Zhang (2005). Leaf nitrogen and phosphorus stoichiometry across 753 terrestrial plant species in China. *New Phytologist* 168: 377–385.

Hill, K.D. (1994). The *Cycas rumphii* complex (Cycadaceae) in New Guinea and the Western Pacific. *Australian Systematic Botany* 7: 543–567.

Hill, K.D. (2010). *Cycas nongnoochiae*. The IUCN Red List of Threatened Species 2010: e.T42060A10616197. www.iucnredlist.org. Downloaded on 14 May 2020.

Hill, K.D. & S.-L. Yang (1999). The genus *Cycas* (Cycadaceae) in Thailand. *Brittonia* 51: 48–73.

Hou, X. & B.T. Jones (2000). Inductively coupled plasma/optical emission spectrometry, p. 9468–9485. In: Meyers, R.A. (ed.). *Encyclopedia of Analytical Chemistry*. John Wiley & Sons, Chichester, United Kingdom.

Hue, N.V., H. Ikawa & X. Huang (2000). Predicting soil phosphorus requirements, p. 95–99. In: Silva, J.A. & R. Uchida (eds.). *Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture*. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, Hawaii, 158pp.

Killingbeck, K.T. (1996). Nutrients in senesced leaves: Keys to the search for potential resorption and resorption proficiency. *Ecology* 77: 1716–1727.

Krieg, C., J.E. Watkins, S. Chambers & C.E. Husby (2017). Sex-specific differences in functional traits and resource acquisition in five cycad species. *AoB PLANTS* 9: plx013. <https://doi.org/10.1093/aobpla/plx013>.

Lei, J.-P., W. Xiao, J.-F. Liu, D. Xiong, P. Wang, L. Pan, Y. Jiang & M.-H. Li (2013). Responses of nutrients and mobile carbohydrates in *Quercus variabilis* seedlings to environmental variations using *in situ* and *ex situ* experiments. *PLoS ONE* 8(4): e61192. <https://doi.org/10.1371/journal.pone.0061192>

Lü, X.-T., Y.-Y. Hu, A.A. Wolf & X.-G. Han (2019). Species richness mediates within-species nutrient resorption: Implications for the biodiversity–productivity relationship. *Journal of Ecology* 107: 2346–2352.

Marler, T.E. (2013). Kin recognition alters root and whole plant growth of split-root *Cycas edentata* seedlings. *HortScience* 48: 1266–1269.

Marler, T.E. & M. Calonje (2020). Two cycad species affect the carbon, nitrogen, and phosphorus content of soils. *Horticulturae* 6: 24. <https://doi.org/10.3390/horticulturae6020024>

Marler, T.E., N. Dongol & G.N. Cruz (2016). Plastic responses mediated by identity recognition in below-ground competition in *Cycas micronesica* K.D. Hill. *Tropical Conservation Science* 9: 648–657.

Marler, T.E. & U.F. Ferreras (2015). Disruption of leaf nutrient remobilization in coastal *Cycas* trees by tropical cyclone damage. *Journal of Geography Natural Disasters* 5: 142. <https://doi.org/10.4172/2167-0587.1000142>

Marler, T.E. & U.F. Ferreras (2017). Current status, threats and conservation needs of the endemic *Cycas wadei* Merrill. *Journal of Biodiversity Endangered Species* 5: 193. <https://doi.org/10.4172/2332-2543.1000193>

Marler, T., J. Haynes & A. Lindström (2010). *Cycas micronesica*. IUCN 2012. IUCN Red List of Threatened Species. e.T61316A12462113. www.iucnredlist.org. Downloaded on 14 May 2020.

Marler, T.E. & M.V. Krishnapillai (2018a). Does plant size influence leaf elements in an arborescent cycad? *Biology* 7: 51. <https://doi.org/10.3390/biology7040051>

Marler, T.E. & M.V. Krishnapillai (2018b). *Cycas micronesica* trees alter local soil traits. *Forests* 9: 565. <https://doi.org/10.3390/f9090565>

Marler, T.E. & M.V. Krishnapillai (2019a). Distribution of elements along the rachis of *Cycas micronesica* leaves: A cautionary note for sampling design. *Horticulturae* 5: 33. <https://doi.org/10.3390/horticulturae5020033>

Marler, T.E. & M.V. Krishnapillai (2019b). Incident light and leaf age influence leaflet element concentrations of *Cycas micronesica* trees. *Horticulturae* 5: 58. <https://doi.org/10.3390/horticulturae5030058>

Marler, T.E. & A.J. Lindström (2018). Inserting cycads into global nutrient relations data sets. *Plant Signaling & Behavior* 13: e1547578. <https://doi.org/10.1080/15592324.2018.1547578>

Marler, T.E., A.J. Lindström & W. Field (2018). Range, density, and threatened status of *Cycas nongnoochiae*. *Memoirs New York Botanical Garden* 117: 86–94.

Norstog, K.J. & T.J. Nicholls (1997). *The biology of the cycads*. Cornell University Press, Ithaca, New York, xi+363pp.

Olsen, S.R., C.V. Cole, F.S. Watanabe & L.A. Dean (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture Circular, 939.

Reich, P.B. & J. Oleksyn (2004). Global patterns of plant leaf N and P in relation to temperature and latitude. *Proceedings of the National Academy of Sciences of the United States of America* 101: 11001–11006.

Watanabe, T., M.R. Broadley, S. Jansen, P.J. White, J. Takada, K. Satake, T. Takamatsu, S.J. Tuah & M. Osaki (2007). Evolutionary control of leaf element composition in plants. *New Phytologist* 174: 516–523.

Zheljazkov, V.D. & P.R. Warman (2002). Comparison of three digestion methods for the recovery of 17 plant essential nutrients and trace elements from six composts. *Compost Science & Utilization* 10: 197–203.

Zhang, Y., K. Cao, L. Sack, N. Li, X. Wei & G. Goldstein (2015). Extending the generality of leaf economic design principles in the cycads, an ancient lineage. *New Phytologist* 206: 817–829.

Zhang, Y.-J., L. Sack, K.-F. Cao, X.-W. Wei, & N. Li (2017). Speed versus endurance tradeoff in plants: Leaves with higher photosynthetic rates show stronger seasonal declines. *Scientific Reports* 7: 42085; <https://doi.org/10.1038/srep42085>

Zhang, Y.-J., L. Sack, G. Goldstein & K.-F. Cao (2018). Hydraulic determination of leaf nutrient concentrations in cycads. *Memoirs New York Botanical Garden* 117: 179–192.





Contribution to the Macromycetes of West Bengal, India: 69–73

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Abstract: The varied topography, soil and climate of West Bengal makes conducive conditions of macrofungal habitats nurturing magnificent diversity. During exploration of macro-fungal diversity in Terai Duars region of the state during 2017–18, basidiocarps of different kinds of the genus *Lentinus* (Polyporaceae) were collected, photographed along with macro-morphological and ecological notes. The specimens were identified through macro and micro-morphological characters following standard literature. Five species of the genus *Lentinus* (*L. araucariae*, *L. fasciatus*, *L. polychrous*, *L. sajor-caju*, and *L. squarrosulus*) were identified which are presented in this paper along with amplified description, necessary figures and photographs. Literature survey revealed that out of five identified species, *L. araucariae* and *L. fasciatus* represent new distributional record for India. The outcome of the present study would enrich data related to the macro-fungal diversity from the state of West Bengal.

Keywords: Basidiomycota, *Lentinus*, Polyporaceae, polypore fungi, species, taxonomy.

সংক্ষিপ্তসার: পশ্চিমবঙ্গে, মৃততাকি এবং জলবায়ুর বভিন্নতা বৃহৎ ছত্রাক সমূহের বাসস্থানের উপরযোগী পরিবিশে তরৈ করে তার বপ্পিল বচ্ছিত্রিকক লালতি কর। এই রাজ্যের তরাই-দুয়ারস অঞ্চলে, ২০১৭–২০১৮ সালে বৃহৎ ছত্রাক অন্বন্দেগুরে সময় লন্টেনিস গণের (পল্পিরসে) বভিন্ন পরাকার বস্তোভিকরণ সংগ্রহ করা হয় এবং তাদের বৃহৎ অঙ্গসংস্থানিক চরিত্রাবলির পরিবর্তে সহ বস্তুতান্ত্রিক তথ্য ও আলাদাকচতির সংগ্রহ করা হয়। বৃহৎ অঙ্গসংস্থানিক ও আণুবীক্ষণিক বশেষ্যট্টিয় এবং প্রামাণ্য গবেষণামূলক গ্রহণযোগ্যের সাহায্যে সংগৃহীত নমুনাসমূহের সনাকতকরণ করা হয়। লন্টেনিস গণের পাঁচটি প্রজাতির (লন্টেনিস আরাকারীয়া, লন্টেনিস ফাস্যাটিস, লন্টেনিস পলকিয়াস, লন্টেনিস সাজারে-কাজু ও লন্টেনিস স্কুকায়ারসুলাস) সনাকতকরণ করা হয়েছে এবং বৃত্তমান গবেষণাপত্রে প্রযোজনীয় রোখাকচিত্রে সাহায্য এবং বিস্তারিত বরণনা পরিবিশেত হয়েছে। উপরযোগী গবেষণাপত্রের ও গ্রন্থাবলীর অধ্যয়নের মাধ্যমে, বৃত্তমান আলাদাকচতি পাঁচটি প্রজাতির মধ্যে লন্টেনিস আরাকারীয়ে এবং লন্টেনিস ফাস্যাটিস আরাকারীয়ে এবং লন্টেনিস স্কুকায়ারসুলাস সম্মুখ করব।

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Author contribution: Specimens collected by DD, PP, AR and KA. Field Photographs by Entaj Tarafder and AR. Microscopic photographs by DD. Macro and microscopic characteristics described by DD and PP. Data compiled and analysed by KA, AR and DR.

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West Bengal Forest & Biodiversity
Conservation Society

INTRODUCTION

West Bengal being a state with varied climate and topography includes Himalayan temperate-subtemperate region, foothills having moist-deciduous forests, vast gangetic plains, lateritic plateau and coastal plains which create diversified habitats for mosaic of life-forms, including macro-fungi (Pradhan et al. 2012, 2013, 2016; Dutta et al. 2013).

Among the polypore fungi, the genus *Lentinus* Fr. has subtropical distribution as lignicolous fungi and is represented globally by 40 species (Kirk et al. 2008), out of which 20 species are encountered in India (Sharma & Atri 2015).

From the evolutionary stand point *Lentinus* Fr. is an interesting taxon for its transitional nature between poroid and gilled fungi by gradual reduction of tubulate to lamellate hymenophore. Moreover, *Lentinus* Fr. represents agaricoid development with a lineage of polyporoid ancestry (Pegler 1983a; Hibbet & Vilgalys 1991). During the exploration of macro-fungal diversity of West Bengal, India, a good number of specimens were collected of which five species of *Lentinus* Fr. had been identified, two of which are new records for India (*L. fasciatus* and *L. araucariae*), and are represented in the present paper and it is in continuation of the series of publications on macro-fungal diversity of West Bengal (Bera et al. 2018; Saha et al. 2018).

Macro-fungal specimens were collected from June 2017 to October 2018 from Terai region of West Bengal, India. During fieldwork digital photographs of the samples were taken in their habitat and their macro-morphological and habitat features were noted.

During the tenure of work, by using standard identifying protocol, colour photographs and macro-morphological features of each specimen were taken in the field. Each collection was then wrapped with tissue paper and kept in separate boxes to avoid contamination/spore mixing. Finally, the collected specimens were carefully withered (separately) in a hot air drier until the moisture was minimal.

Microscopic features were observed with Carl Zeiss AX10 Imager A1 phase contrast microscope from thin handmade sections of the dried basidiocarps by staining with Congo Red and Melzer's reagent. Microscopic figures were photographed with microscope-mounted digital camera. Thirty measurements of basidiospores were taken from each sample for calculating dimensions of basidiospore. Length/breadth ratio denotes the Q value. Mean Q value (Q_m) was measured by dividing sum of Q value by total number of spores observed.

Specimens were properly identified using standard keys and published literature (Singer 1962; Pegler 1983a; Manimohan et al. 2004; Senthilarasu 2015). Kornerup & Wanscher (1978) was followed for colour terminology. The voucher specimens were preserved following Pradhan et al. (2015) and were deposited in the Calcutta University Herbarium (CUH), Kolkata, India.

1. *Lentinus araucariae* Har. & Pat.

Journal de Botanique (Morot) 17: 11 (1903)

(Image 1–2).

Basidiocarps pileate, lamellate and stipitate Pileus 34–89 mm in diam., white (1A1) to yellowish-white (1A2), deeply indented to infundibuliform, surface velutinate, with uplifted white (1A1) squamules, margin sulcate striate to rimose, white to yellowish-white (3A1 to 3A2) when young becoming pale yellow (3A3) on drying, concolorous. Context up to 3mm thick, yellowish-white (3A2). Lamellae decurrent with two–three tiers of lamellulae, lamellae width up to 3mm, margin serrate, moderately crowded, furcate with at least two dichotomies, light yellow (4A4) when young becoming (4B4) on drying, concolorous. Stipe 15–22 × 3–7 mm, slight eccentric, surface appressed white (1A1) squamulose, solid, fibrous, insitituous base, yellowish-white to pale yellow (3A2 to 3A3) when young turning light yellow (4A4) on drying.

Basidiospores (5.1)–5.7–6.7–7.4–(8.1) × (2.7)–3–3.2–3.4–(3.7) µm, Q_m =2, cylindric, hilar appendix bilaterally symmetric, thin walled. Basidia 20.4–27.8 × 5.8–6.8 µm, cylindro-clavate, basally clamped, two to four spored, sterigma 2–3.7 µm in length, thin walled. Basidioles 21–30.2 × 5.8–7.1 µm, cylindro-clavate, thin walled. Pileocystidia none. Cheilocystidia none. Hyphal system dimitic with skeleto-ligative hyphae. Generative hyphae 3–6.4 µm wide, clamped, clamp 2.7–3.7 µm wide, thin- to thick-walled, branched, interlocking projections present, content hyaline in 10% KOH. Skeleto-ligative hyphae 7.4–11.9 µm wide, with tapered branches, content not too narrow, thick walled, pale yellowish in 10% KOH. Hyphal pegs 40.8–57.8 µm wide, abundant, composed of 30 to 40 generative hyphae with rounded apical portion. Hymenophoral trama irregular, interwoven. Pileipellis trichodermal palisade, elements 8.5–13.6 µm wide.

Habit and habitat: Basidiocarps lignicolous, saprotrophic, growing gregarious, and caespitously upon fallen and decaying *Shorea robusta* Roth.

Specimen examined: CUH AM667, 04.x.2018, 26.5873N & 89.5327E, elevation 62m, Panijhora bit, Dooars, Alipurduar District, West Bengal, India, coll. K.



Image 1 (A–D). *Lentinus araucaria* | Scale= 10mm. © Entaj Tarafder.

Acharya & A. Roy.

Remarks: Presence of rigid, coriaceous basidiocarps with dichotomously furcated lamellae, pale yellowish pileus ranging from 34 to 89 mm, abundant hyphal pegs, devoid of cheilocystidia; central to excentric stipe; dimictic hyphal system with skeleton-ligative hyphae and 3–6.4 μ m wide generative hyphae, and spore size of 5.1–5.7–6.7–7.4–8.1 \times 2.7–3.2–3.7 μ m places the studied specimen under *Lentinus araucariae* (section Dicholamellatae of subgenus *Lentinus*). The studied specimen matches with the previously reported Australian specimen (Pegler 1983b) in terms of spore size [5.1–5.7–6.7–7.4–8.1 \times 2.7–3.2–3.7 μ m, vs 5–7 \times 3–3.5 μ m; Q= 2 vs 1.87], width of generative hyphae [3.4–6.4 μ m vs 2–5 μ m] and width of skeleto-ligative hyphae [7.4–11.9 μ m vs 2–12.5 μ m], making it a new record for India. Morphologically, *Lentinus badius* (Berk.) Berk. is also closely related to the present taxon. Presence of sub-distant to moderately close lamellae, pale yellowish basidiocarp, trichodermal palisade pileipellis in *L. araucariae* distinguishes it from *L. badius*. *Lentinus*

araucariae differs from *L. dicholamellatus* Manim. by its spore size [5.4–6.1–6.9–8.1–8.5 \times 2.7–3–3.4 μ m vs 6–10 \times 3–5], and absence of pseudo sclerotium.

2. *Lentinus fasciatus* Berk.

London Journal of Botany 2: 146 (1840)

(Image 3–4).

Basidiocarps pileate, lamellate and stipitate. Pileus 20–74 mm in diam., umbilicate to infundibuliform, surface white (1A1) to orange brown (5B2) to pale yellow (2A3), tomentose with numerous whitish (1A1) erect hairs, 1–3 mm long, becoming longer towards pileal margin, greyish-orange (6B4), appressed squamules present towards centre, Lamellae 2–4 mm wide, deeply decurrent with lamellulae of 1–3 tier, lamellae margin entire, smooth, distant to close, sometimes lamellae bifurcated in the region just above the stipe, yellowish grey (4B2). Stipe 10–55 mm \times 2.5–7 mm, short and stocky, central, cylindric, solid, tomentose, amount of hairs more in the base, without pseudo sclerotium, concolorous with the pileus. Context up to 2.5mm thick

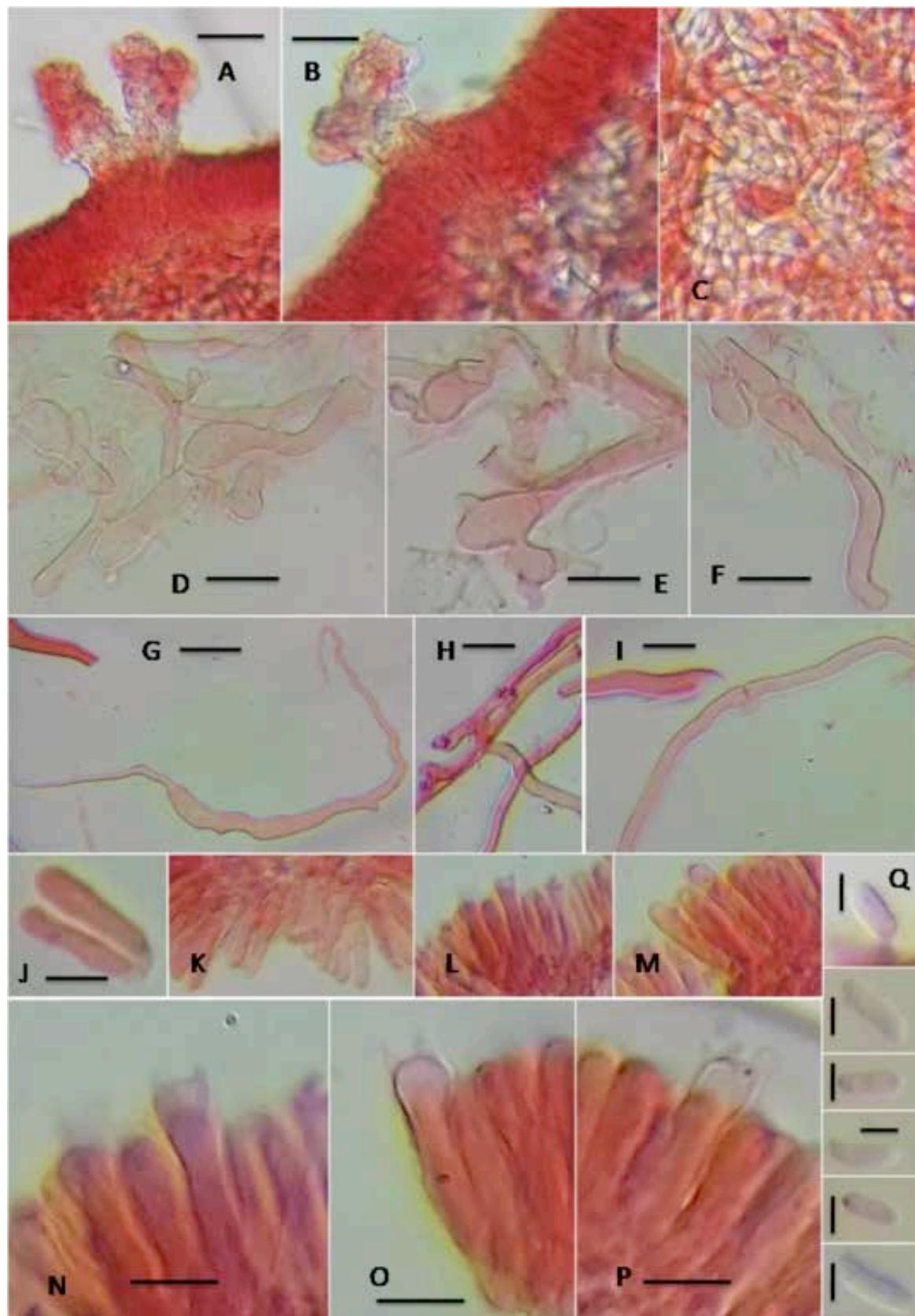


Image 2. *Lentinus araucaria*: (A–B)—hyphal peg | C—irregular lamellae trama | D–F—pileipilis elements | G—skeleto-ligative hyphae | H–I—generative hyphae of context | J—basidiole | K–M—basidia and basidioles in cluster | N–P—basidia | Q—basidiospores. Bars (A–B, D–G) = 25 μ m, (H–J) = 15 μ m, (N–Q) = 10 μ m. © Diptosh Das.

at the centre or disc, soft, yellowish-white (4A2).

Basidiospores (6)6.4–6.9–7.8–(8.2) × (2.1–)2.8–3.3–3.9(–4.2) µm [n=30; $X_M=6.9\pm0.49$ × 3.3±0.41 µm, $Q_M=2.07\pm0.24$], ellipso-cylindric, hilar appendix bilaterally symmetric, thin walled, hyaline with few contents. Basidia (21.8–28.6) × (4.2–7.1) µm, cylindrico-clavate, basally clamped, 2 to 4-spored; sterigma 2–4, 2.5–3.9 µm in length, cylindric. Basidioles (20–26) × (3.5–6) µm, clavate, basally clamped. Sclerocystidia abundant in both pleuro and cheilo position, 26–34 × 3.5–6.9 µm clavate, thick-walled, arise from hymenial base. Hyphal system dimitic with skeletal hyphae 2.1–4.2 µm wide, thick-walled with narrow lumen, unbranched; generative hyphae 2.1–3.5 µm wide, thin walled, hyaline, frequently branched, clamp-connexions present. Sterile lamellar edge consisting of numerous crowded sclerocystidia, clavate. Hymenophoral trama irregular. Pileipellis an epicutis of thin and thick-walled generative hyphae with prominent clamp connections, 3.6–5.8 µm wide, unbranched, producing loose, erect fascicles. Stipitipellis consists of thick-walled generative hyphae, up to 7 µm wide, forming erect tomentose, content hyaline in 10% KOH.

Habit and habitat: Basidiocarps lignicolous and saprotrophic, growing caespitously upon fallen and decaying trunk of *Schima wallichii* (DC.) Korth.

Specimen examined: CUH AM626, 19.ix.2017, 26.82N & 88.63E, elevation 137m, Targhera, Jalpaiguri District, West Bengal, India, coll. K. Acharya & A. Roy.

Remarks: Presence of rigid, coriaceous basidiocarps with hispid strigose pileus with short erect hairs, moderately crowded lamellae, presence of abundant sclerocystidia; central to excentric stipe; dimitic hyphal system with skeletal hyphae and 2.1–3.5 µm wide generative hyphae, and spore size of (6–)6.4–6.9–7.8–(8.2) × (2.1–)2.8–3.3–3.9(–4.2) µm places the studied specimen under *Lentinus fasciatus* (section Velutini of subgenus *Panus*). The present taxon was limited to Australia in its distribution (Pegler 1983a), is reported, hereby, from India for the first time. Current specimen shows maximum similarity with the description of *L. fasciatus* studied by Pegler (1983a) by forming a strongly hispid pileal and stipe surface, presence of abundant sclerocystidia rather than metuloids, well developed centrally placed stipe, spore size [(6–)6.4–6.9–7.8–(8.2) × (2.1–)2.8–3.3–3.9(–4.2) µm vs. 6.5–8.5 × 3–4] and Q_M value [2.07±0.24 vs. 2.20]. This taxon might be confused with widespread *L. strigosus* Fr. but presence of sclerocystidia rather than metuloids and cylindric basidiospores strongly differs the *L. strigosus* Fr. from the present taxon. It differs from *L. velutinus* Fr. by

lack of pseudosclerotium. This species differs from *L. hookerianus* Berk. by its spore size [(6–)6.4–6.9–7.8–(8.2) × (2.1–)2.8–3.3–3.9(–4.2) µm vs. 5–6.5 × 2.7–3.5 µm] and Q_M value [2.07±0.24 vs 1.87].

3. *Lentinus polychrous* Lév.

Annales des Sciences Naturelles Botanique 2: 175 (1844) (Image 5–6).

Basidiocarps pileate, lamellate, stipitate. Pileus 70–150 mm in diam., sub-infundibuliform, texture tough leathery flexible when young become rigid on drying, surface orange grey to greyish-orange (5B2–5B3) when young turn into yellowish-grey (2D2) on drying, covered with chestnut brown (6F7) coloured uplifted squamules, concolorous, margin entire. Context up to 6mm thick, white (1A1). Lamellae deeply decurrent with 1–3 tiers of lamellulae, width up to 5mm, spacing less than 1mm, crowded, tough and thick, honey yellow to golden brown (5D6 to 5D7) when young becoming brown to dark brown (7F4 to 7F5) on drying. Stipe 10–25 × 4–12 mm, slightly eccentric to central, solid, rigid, covered with minute appressed squamules, base tapered, white (1A1) at apex and slightly darker towards base.

Basidiospores (6.1–)6.4–8.1–9.5(–10.2) × 3–3.4–3.4–3.7–4 µm, $Q_M=2.3$ (n=30), cylindric, hilar appendix bilaterally symmetric or asymmetric, thin-walled, hyaline, negative in Melzer's reagent. Basidia 20–25.5 × 5.7–7.1 µm, cylindrico-clavate, basal clamp not found, hyaline in 10% KOH, 4-spored; sterigma four, 2–3.4 µm high. Basidioles 17–27.2 × 4.7–7.1 µm, cylindrico-clavate, basal clamp not found. Pleurocystidia none. Cheilocystidia none. Hyphal system dimitic with skeleto-ligative hyphae. Generative hyphae 2.7–6.8 µm wide, thin to thick-walled, branched, clamped, clamp connection 2.3–3.4 µm wide, hyaline in 10% KOH. Skeleto-ligative hyphae 3.4–8.5 µm wide, thick-walled, narrow lumen, highly branched, tapered apex, pale yellow in 10% KOH. Hyphal pegs 34–45.2 µm wide, consists of 25–35 generative hyphae. Lamellae trama interwoven irregular. Subhymenial layer too narrow to observe. Squamules of pileus formed by agglutinated thick-walled generative hyphae. Pileipellis a trichodermal palisade.

Habit and habitat: Basidiocarps lignicolous and saprotrophic, growing solitary to slightly gregarious upon fallen and decaying logs of *Shorea robusta* Roth.

Specimen examined: CUH AM668, 30.vii.2018, 26.8746N & 88.8551E, elevation 176m, near Chapramari forest, Jalpaiguri District, West Bengal, India, coll. K. Acharya & A. Roy.

Remarks: Presence of rigid, coriaceous basidiocarps



Image 3. (A–C). *Lentinus fasciatus*. Scale= 10mm. © Entaj Tarafder.

with brown coloured uplifted pileal squamules, amber coloured thick rigid hymenophore, irregular lamellae trama, central to excentric dark coloured tapered base; complicated dimitic hyphal system with skeleto-ligative hyphae and 2.7–6.8 μm wide generative hyphae, hyphal pegs and spore size of (6.1–)6.4–8.1–9.5(–10.2) \times 3–3.4–3.4–3.7–4 μm places the studied specimen under *Lentinus polychrous* (section Rigidi of subgenus *Lentinus*). The present taxon is one of the most widely distributed species in India and it has been reported several times from several localities including Bihar, West Bengal, Andhra Pradesh, Kerala (Pegler 1983a; Sharma & Atri 2015). The present specimen matches nicely with the description illustrated by Pegler (1983a) in spore size [(6.1–)6.4–8.1–9.5(–10) \times (3–)3.4–3.4–3.7(–4) μm vs. 6–9 \times 2.7–3.3 μm], width of generative hyphae [2.7–6.8 μm vs. 1.4–4.5 μm], length of basidia [20–25.5 \times 5.7–7.1 μm vs. 20–27 \times 5–6 μm] and with the description of Corner (1981) in spore size [(6.1–)6.4–8.1–9.5(–10.2) \times (3–)3.4–3.4–3.7(–4) μm vs. 6–9.5 \times 3–3.7 μm], width of

generative hyphae [2.7–6.8 μm vs. 2–5 μm] and length of basidia [20–25.5 \times 5.7–7.1 μm vs. 15–35 \times 5–6 μm]. The present taxon is distinguished from closely resembling *L. squarrosulus* Mont. by having fine tomentum, short stipe, fuliginous to umbrinous amber coloured lamellae, (6.1–)6.4–8.1–9.5(–10.2) \times (3–)3.4–3.4–3.7(–4) μm sized basidiospores instead of appressed soft squamules, deeply decurrent white lamellae, 5.5–7.5 \times 1.7–2.5 μm sized basidiospores in *L. squarrosulus*.

4. *Lentinus sajor-caju* (Fr.) Fr.

Epicrisis Systematis Mycologici: 393 (1838)

(Image 7–8).

Basidiocarps pileate, lamellate, stipitate. Pileus 25–75 mm in diam., convex to broadly convex when young, becoming infundibuliform at maturity, disc dark brown (6F7), margin golden brown (5D7) to brown (6E7), turning brown (6E5) to dark brown (6F5) on drying, margin incurved, entire to undulating. Context up to 3mm thick, off white. Lamellae ca. 1mm broad, deeply

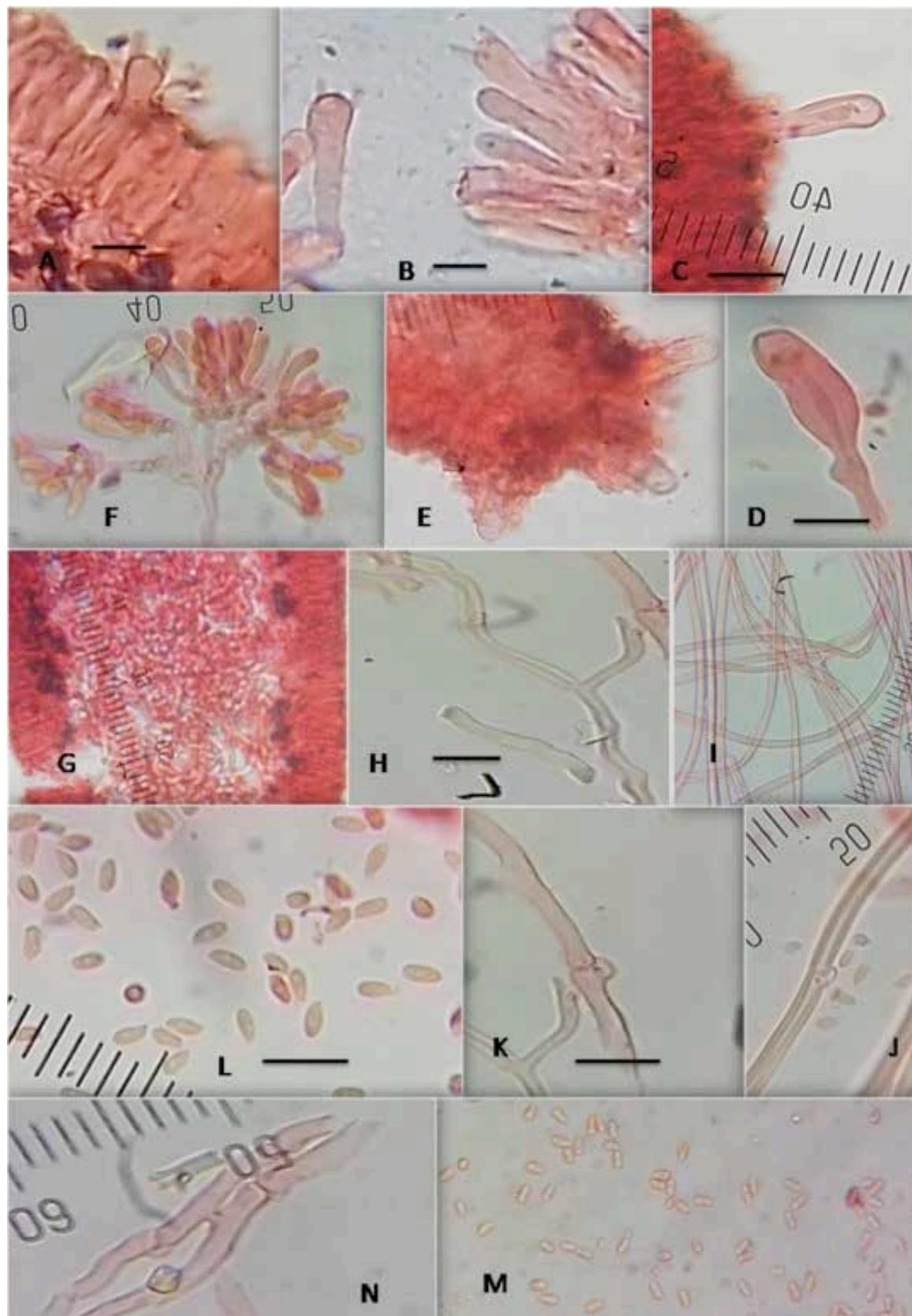


Image 4. *Lentinus fasciatus*: A–B—basidia | C–D—sclerocystidia | E—cheilocystidia | F—basidioloes | G—irregular lamellae trama | H—skeletal hyphae | I–J—thick-walled generative hyphae | K—generative hyphae of context | L—basidiospores. Bars (A–D, K) = 10 μ m | H = 15 μ m | L = 20 μ m. © Diptosh Das.



Image 5 (A–B). *Lentinus polychrous*. A—Scale = 15mm | B—scale = 10mm. © Entaj Tarafder.

decurrent, densely crowded without lamellulae, narrow, white (1A1) to pale orange (5A3) or light orange (5A4), concolorous. Stipe 15–25 × 10–15 mm, central to slightly eccentric, fleshy-fibrous, white (1A1) to pastel grey (1C1) turning yellowish-grey (3B2) on bruising. Annulus single, white (1A1), inferior, removable.

Basidiospores (4.2–)5.3–6.9–7.5(–9.6) × (2.1–)4.6–2.6–2.8(–3.5) µm, $X_m = 6.9 \pm 1.11 \times 2.6 \pm 0.33$; Q = 1.4–3.4, $Q_m = 2.6$ ($n = 30$), narrow cylindric, hyaline with KOH, inamyloid. Basidia 14–23.5 × 3.5–4.5 µm, cylindrico-clavate, 2- to 4-spored; sterigmata 2–4, 0.7–1.4 µm high, cylindrical, basally clamped. Basidioles 10.5–24 × 3.5–4.5 µm, cylindrico-clavate, basally clamped. Pleurocystidia absent. Cheilocystidia 22.8–25.5 × 3.7–6.8 µm, narrow cylindrico-clavate, basally clamped. Lamellae trama interwoven, hyphae 3–7 µm wide, cylindrical, hyaline, thin to thick-walled. Hyphal system dimitic; generative hyphae of the context 3.5–7.5 µm wide, clamp connections prominent, 0.7–2.8 µm wide, thin walled, content hyaline, sometimes branched; skeleto-ligative

hyphae 3.9–7.8 µm wide, thick walled, well branched, tapered towards the apex. Annulus hyphae 3.2–4.6 µm broad, hyaline, thin-walled, clamp-connections present. Hyphal pegs abundant, 47.6–91.8 µm wide. Pileipellis made up with repent generative hyphae.

Habit and habitat: Basidiocarps lignicolous and saprotrophic, growing solitary to gregariously in an imbricate fashion on a fallen and decaying log of *Shorea robusta* Roth. Hymenophoral surface of this species also provided shelter and food to members of the insect order Coleoptera L.

Specimen examined: CUH AM623, 16.vii.2017, 26.32N & 89.32E, elevation 115m, Damanpur, Alipurduar District, West Bengal, India, coll. K. Acharya & A. Roy.

Remarks: Presence of tough, coriaceous, central to eccentrically stipitate basidiocarps with deeply infundibuliform pileus, stipe short with distinct annulus, dimitic hyphae with skeleto-ligative hyphae and 3.5–7.5 µm wide generative hyphae, presence of hyphal pegs and spore size of (4.2–)5.3–6.9–7.5(–9.6) × (2.1–)4.6–2.6–2.8(–3.5) µm places the studied specimen under *Lentinus sajor-caju* (section Rigidi of subgenus *Lentinus*). From India this species has been reported from West Bengal, Kerala, Andaman Island (Pegler 1983a; Sharma & Atri 2015). The currently studied specimen matches with the description of specimen studied by Pegler (1983a). *L. sajor-caju* differs from its closely related species *L. umbrinus* Reichardt by having pure white pileus, a distinct annulus, densely crowded lamellae and cylindric basidiospores [(4.2–)5.3–6.9–7.5 (–9.6) × (2.1–) 4.6–2.6–2.8(–3.5) µm vs. 5–8.5 × 2.3–3.5].

5. *Lentinus squarrosulus* Mont.

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(Image 9–10).

Basidiocarps pileate, lamellate, stipitate. Pileus 40–68 mm in diam., fleshy, covered with soot brown (5F5) appressed squamules forming a circular lining on the grey (14C1) coloured pileus, margin lacerate to undulated, slightly inrolled. Context up to 3mm thick, grey (14C1) in colour. Lamellae up to 4mm in width, strongly decurrent with 1–3 tires of lamellulae, moderately crowded to crowded, light orange (5A4) in colour, gill edge denticulate. Stipe 15–25 × 6–15 mm in size, eccentrically placed, covered with grey (11C1) coloured squamules, base slightly bulbous, solid. Odor pleasant mushroomy.

Basidiospores (4.2–)5.3–6.19–6.8(–7.16) × (2.1–)2.5–2.63–2.8(–3.5) µm, $X_m = 6.19 \pm 0.71 \times 2.63 \pm 0.36$, Q-Value= 1.33–2.85, $Q_m = 2.37 \pm 0.33$, $n = 30$

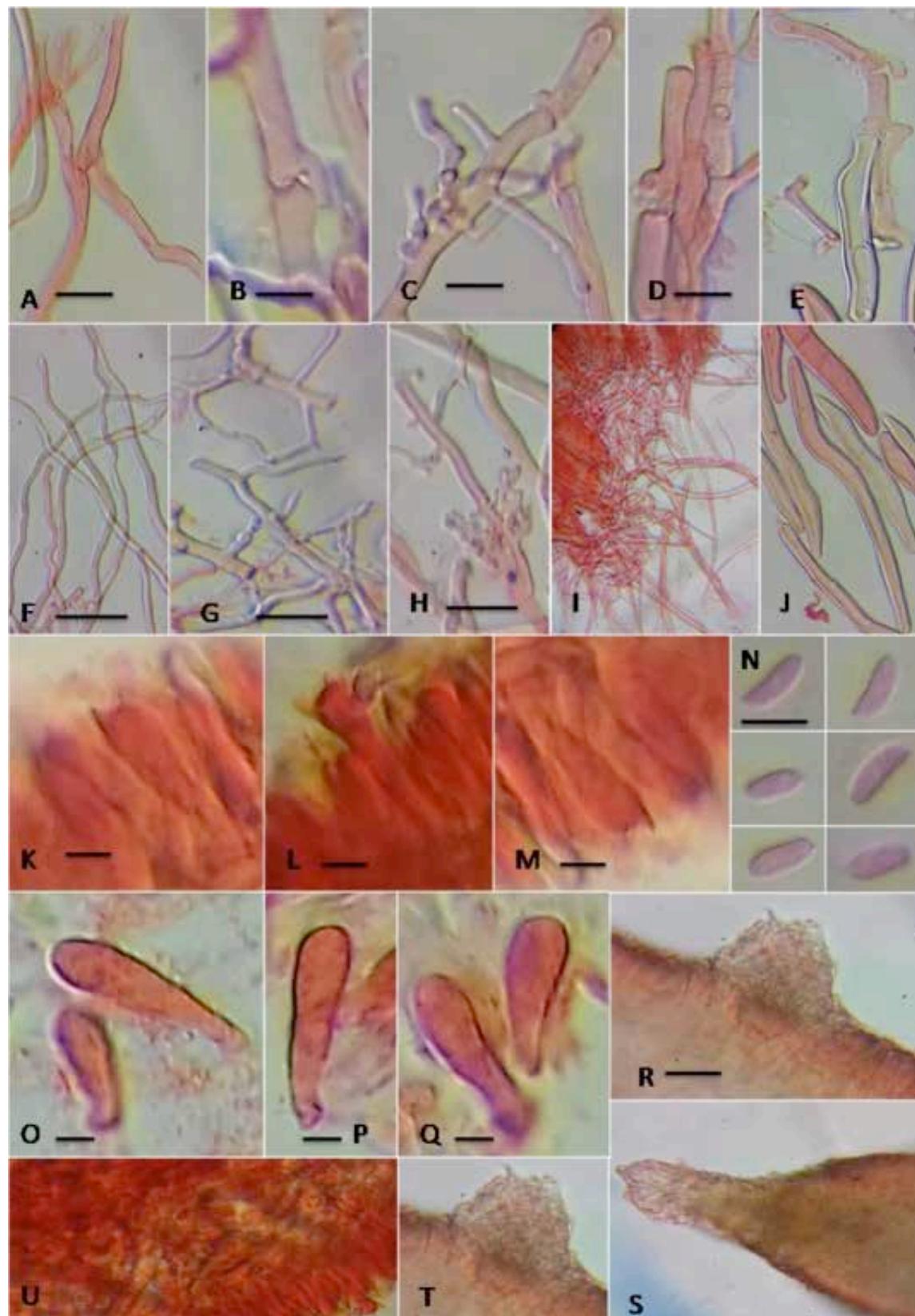


Image 6. *Lentinus polychrous*: A–B—thin-walled generative hyphae with clamp connection | C—thick-walled generative hyphae | D—agglutinated hyphae | E—generative hyphae with skeletal element | F–G—skeleto-ligative hyphae | H—coralloid skeletal element | I—squamule elements with septation | K–M—basidia | N—basidiospores | O–Q—basidioles | R–T—hyphal pegs | U—irregular interwoven lamellae trama. Bars A–E = 10µm | F–H = 30µm | O = 10µm | K–M = 10µm | R–T = 20µm. © Diptosh Das.



Image 7. A–C. *Lentinus sajor-caju*. (A–B) Scale = 5mm | C = basidiocarp with insects. © Anirban Roy.

spores, narrow cylindric, hilar appendix asymmetric, thin-walled, hyaline, negative in Iodine test. Basidia $14.32\text{--}24.34 \times 3.9\text{--}4.6 \mu\text{m}$, 2–4 sterigmate, cylindro-clavate; sterigmata $0.3\text{--}0.7 \mu\text{m}$ in length. Basidioles $17.5\text{--}21.4 \times 5.01\text{--}7.1 \mu\text{m}$, cylindro-clavate, basal clamp present. Cheilocystidia $11.8\text{--}21.4 \times 6.4\text{--}7.8 \mu\text{m}$, narrow clavate with emergent skeletal hyphae, content hyaline with no oil guttule. Pleurocystidia none. Lamellar edge sterile. Hyphal peg abundant, $32.2\text{--}64.4 \mu\text{m}$ wide, consisting of 25–30 generative hyphae, extruded from the lamellae trama. Hyphal system dimitic. Generative hyphae of context $3.5\text{--}5.3 \mu\text{m}$ in width, clamped, thin walled, branched, content hyaline. Skeleto-ligative hyphae of context $5.7\text{--}10.74 \mu\text{m}$ in width, become tapered towards apex, highly branched, thick-walled, wall $1\text{--}2 \mu\text{m}$ thick. Generative hyphae of stipe $3.5\text{--}7.1 \mu\text{m}$ in width, clamped, thin to thick-walled, content hyaline. Skeletal hyphae of stipe $6.8\text{--}11 \mu\text{m}$ in width, thick walled, wall $1.2\text{--}2 \mu\text{m}$ thick. Hymenophoral trama irregular interwoven, devoid of sub-hymenium layer. Pileipellis consists of inflated generative hyphae. Squamules of pileus emerging from the disrupt epicutis.

Habit and habitat: Basidiocarps lignicolous and

saprotrophic, grows in troops or clusters of 1–4 caespitose basidiocarps upon fallen and decaying logs of *Shorea robusta* Roth.

Specimen examined: CUH AM622, 15.vii.2017, 26.64N & 89.54E, elevation 116m, near Buxa forest, Alipurduar District, West Bengal, India, coll. K. Acharya & A. Roy.

Remarks: Presence of tough, coriaceous, excentrically stipitate basidiocarps with soot brown coloured appressed squamules which forms a ring-like pattern on pileus surface; dimitic hyphae with skeleto-ligative hyphae and $3.5\text{--}5.3 \mu\text{m}$ wide generative hyphae, presence of hyphal pegs and spore size of $(4.2\text{--})5.3\text{--}6.19\text{--}6.8(-7.16) \times (2.1\text{--})2.5\text{--}2.63\text{--}2.8(-3.5) \mu\text{m}$ places the studied specimen under *Lentinus squarrosulus* (section Rigidi of subgenus *Lentinus*).

Spore dimensions of the collected specimen is similar with the previously reported taxon from Kerala (Manimohan et al. 2004) $[(4.2\text{--})5.3\text{--}6.19\text{--}6.8(-7.16) \times (2.1\text{--})2.5\text{--}2.63\text{--}2.8(-3.5) \mu\text{m}$ vs $5\text{--}7.5 \times 1.75\text{--}3 \mu\text{m}$], but the length of the spore of the material studied by Pegler (1983a) slightly larger $[(4.2\text{--})5.3\text{--}6.19\text{--}6.8(-7.16) \times (2.1\text{--})2.5\text{--}2.63\text{--}2.8(-3.5) \mu\text{m}$ vs $5.5\text{--}9 \times 1.8\text{--}2.7 \mu\text{m}$].

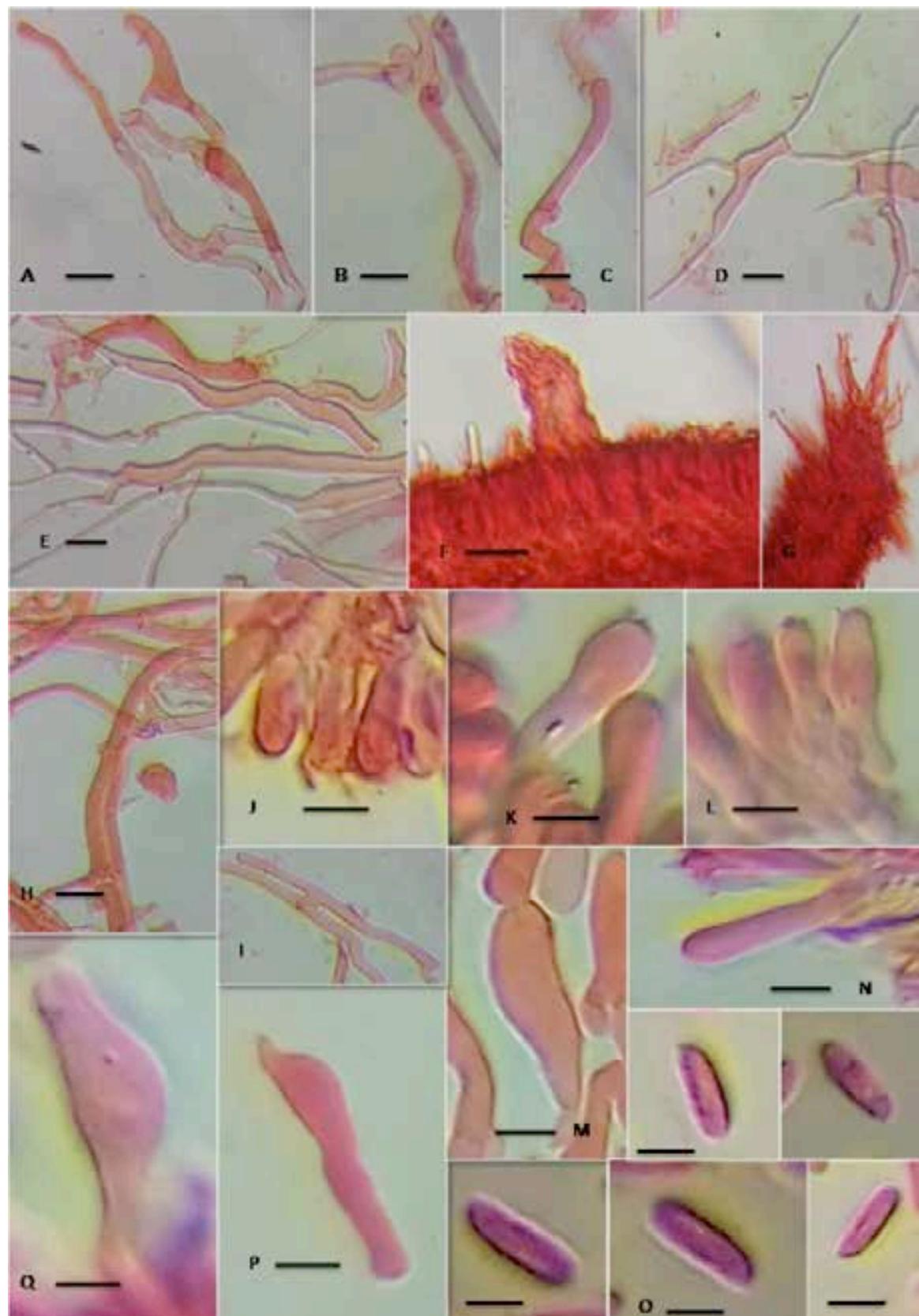


Image 8. *Lentinus sajor-caju*: A–C—generative hyphae of context | D–E—skeleto-ligative hyphae | F—hyphal peg | G—lamellae edge and trama | H—generative hyphae of annulus | I—H-connection | J–L—basidia | M–N—basidioles | O—basidiospores | P–Q—cheilocystidia. Bars A–C = 15 μ m | D,E,H = 10 μ m | F = 70 μ m | J–Q = 5 μ m. © Diptosh Das.



Image 9 A–C. *Lentinus squarrosulus*. A–B—Scale = 15mm. © Anirban Roy.

A provisional key to the species of *Lentinus* reported in the study

1. Lamellae bifurcation absent 2
- 1a. Lamellae bifurcation prominent. Cheilocystidia absent. Basidiospores $5.1\text{--}8.1 \times 2.7\text{--}3.7 \mu\text{m}$ *L. araucariae*
2. Hyphal pegs present. Cystidia occasionally found. Pileus surface appressed or uplifted squamules or glabrescent 3
- 2a. Hyphal pegs absent. Sclerocystidia abundant. Pileus covered with erect hairs. Basidiospores $6\text{--}8.2 \times 2.1\text{--}4.2 \mu\text{m}$ *L. fasciatus*
3. Basidiocarps soft flexible, infragile. Hymenophore some shade of white or paler. Hyphal system dimitic with skeleto-ligative hyphae 4
- 3a. Basidiocarps comparatively rigid. Hymenophore honey-coloured when young, becoming dark brownish during maturity. Hyphal system dimitic complex. Cheilocystidia absent. Basidiospores $6.1\text{--}10.2 \times 3\text{--}4 \mu\text{m}$ *L. polychrous*
4. Annulus absent. Soot brown squamules forming a circular lining on the pileus surface. Imbricate caespitose in habit. Basidiospores $4.2\text{--}7.2 \times 2.1\text{--}3.5 \mu\text{m}$ *L. squarrosulus*
- 4a. Annulus present on the stipe. Pileus surface glabrescent. Solitary to gregarious in habit. $4.2\text{--}9.6 \times 2.1\text{--}3.5 \mu\text{m}$ *L. sajor-caju*

The present taxon is one of the most widely distributed species in India and it was reported previously from Chennai, Kerala, Maharashtra, West Bengal (Manimohan et al. 2004; Sharma & Atri 2015). Among other members of the section *Rigidi*, the studied specimen differs from *L. cladopus* in having absence of branched stipe, *L. sajor-caju* and *L. umbrinus* in the absence of annulus or annular ridge, *L. polychrous* in the absence of complex hyphal system tending towards trimitic amber coloured

tough hymenophore.

REFERENCES

Bera, M., S. Paloi, A.K. Duta, P. Pradhan, A. Roy & K. Acharya (2018). Contribution to the Macromycetes of West Bengal, India: 23–27. *Journal of Threatened Taxa* 10(9): 12270–12276. <https://doi.org/10.11609/jott.3875.10.9.12270-12276>

Corner, E.J.H. (1981). The agaric genera *Lentinus*, *Panus* and *Pleurotus*. *Beihefte zur Nova Hedwigia* 69: 1–169.

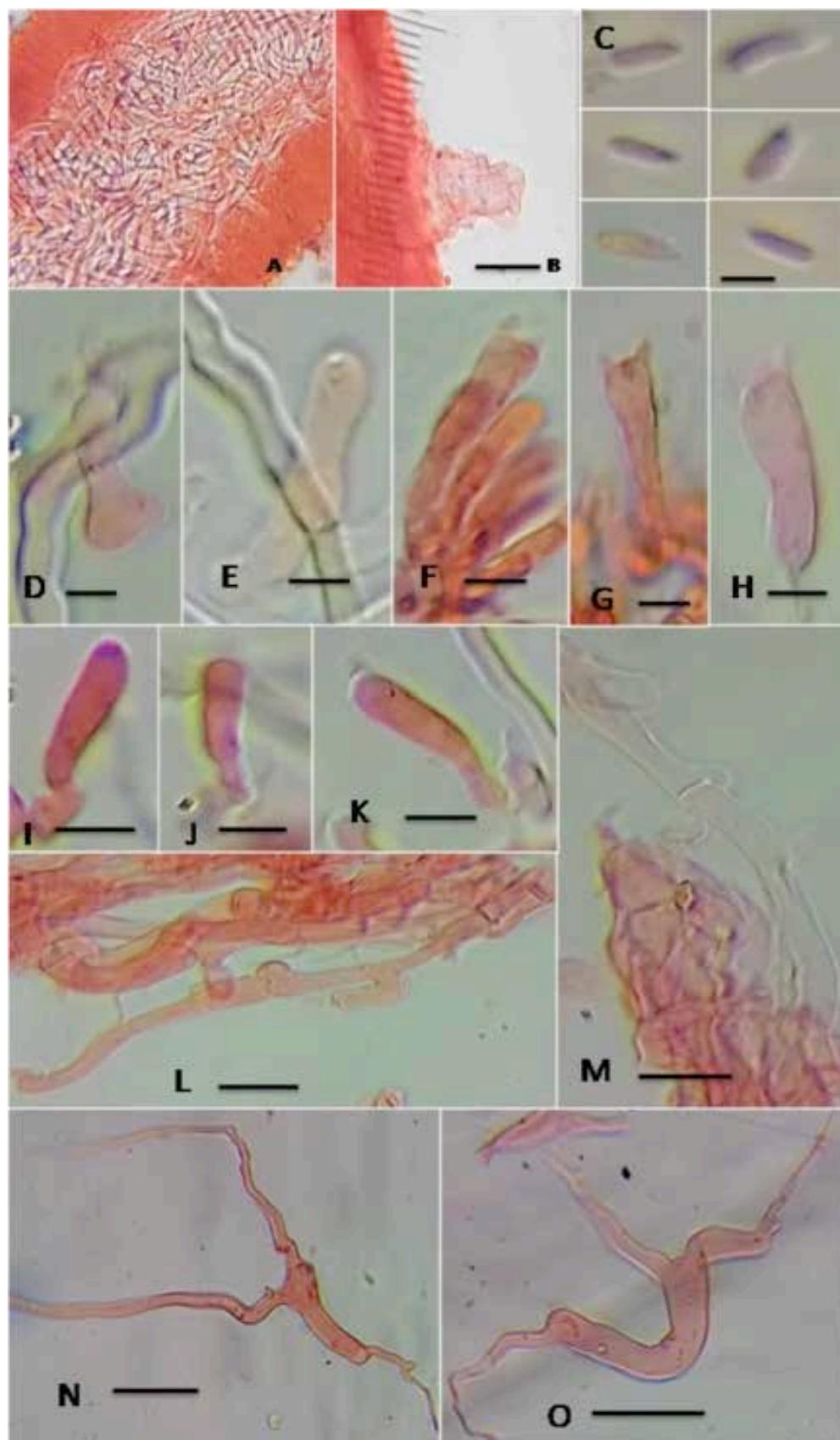


Image 10. *Lentinus squarrosulus*. A—interwoven lamellae trama | B—hyphal peg | C—basidiospores | D—E—cheilocystidia | F—H—basidia | I—K—basidioles | L—M—generative hyphae | N—O—skeleto-ligative hyphae. Bars B = 30 μ m | D—H = 5 μ m | I—M = 10 μ m | N—O = 20 μ m. © Diptosh Das.

Dutta, A.K., P. Pradhan, S.K. Basu & K. Acharya (2013). Macrofungal diversity and ecology of the mangrove ecosystem in the Indian part of Sundarbans. *Biodiversity* 14(4): 196–206. <https://doi.org/10.1080/14888386.2013.848824>

Hibbett, D.S. & R. Vilgalys (1991). Evolutionary Relationships of *Lentinus* to the Polyporaceae: Evidence from Restriction Analysis of Enzymatically Amplified Ribosomal DNA. *Mycologia* 83(4): 425–439. <https://doi.org/10.2307/3760353>

Kirk, P.M., P.F. Cannon, P.F. Minter & J.A. Stalpers (2008). *Ainsworth Bisby's Dictionary of Fungi* (10th edition). CAB International Wallingford, Oxon, UK, 771pp.

Kornerup, A. & J.H. Wanscher (1978). *Methuen Handbook of Colour*. Methuen Publishing Ltd, London, 256pp.

Manimohan, P., N. Divya, T.K.A. Kumar, K.B. Vrinda & C.K. Pradeep (2004). The Genus *Lentinus* in Kerala State, India. *Mycotaxon* 90(2): 311–318.

Pegler, D.N. (1983a). *The Genus Lentinus A World Monograph*. Kew Bulletin Additional Series. 10. HMSO, London, 281pp.

Pegler, D.N. (1983b). *Lentinus araucariae*, an Australasian member of the *Lentinus badius*-complex. *Cryptogamie Mycologie* 4: 123–128.

Pradhan, P., A.K. Dutta, A. Roy, S.K. Basu & K. Acharya (2012). Inventory and spatial ecology of macrofungi in the *Shorea robusta* Roth. forest ecosystem of lateritic region of West Bengal. *Biodiversity* 13(2): 88–99. <https://doi.org/10.1080/14888386.2012.690560>

Pradhan, P., A.K. Dutta, S.K. Basu, A. Roy & K. Acharya (2013). Macrofungal diversity and habitat specificity: A case study. *Biodiversity* 14(3): 147–161. <https://doi.org/10.1080/14888386.2013.805660>

Pradhan, P., A.K. Dutta & K. Acharya (2015). A low cost long term preservation of macromycetes for fungarium. Protocol Exchange. Accessed online on 17 March 2015. <https://doi.org/10.1038/protex.2015.026>

Pradhan, P., A.K. Dutta, S. Paloi, A. Roy & K. Acharya (2016). Diversity and distribution of macrofungi in the Eastern Himalayan ecosystem. *Eurasian Journal of Biosciences* 10: 1–12. <https://doi.org/10.5053/ejobios.2016.10.0.1>

Saha, R., A.K. Dutta, S. Paloi, A. Roy & K. Acharya (2018). Contribution to the Macromycetes of West Bengal, India: 28–33. *Journal of Threatened Taxa* 10(15): 13006–13013. <https://doi.org/10.11609/jott.4188.10.15.13006-13013>

Senthilarasu, G. (2015). The Lentinoid fungi (*Lentinus* and *Panus*) from Western Ghats, India. *IMA Fungus* 6(1): 119–128. <https://doi.org/10.5598/imapfungus.2015.06.01.06>

Sharma, S.K. & N.S. Atri (2015). The genus *Lentinus* (Basidiomycetes) from India - an annotated checklist. *Journal of Threatened Taxa* 7(11): 7843–7848. <https://doi.org/10.11609/JOTT.o3864.7843-8>

Singer, R. (1962). Diagnoses fungorum novorum Agaricalium II. *Sydowia* 15(1–6): 45–83.





A new species of *Platylestes* Selys (Odonata: Zygoptera: Lestidae) from the coastal area of Kannur District, Kerala, India

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Abstract: The genus *Platylestes* Selys, 1862 is known from India, by only one species, *P. platystylus* from eastern India, West Bengal, and recently from Kerala. Here, we describe a new species *Platylestes kirani* from the coastal tracts of the northern part of Kerala, southern India. The new species differs from all other known species of the genus by its unique coloration, distinct marking on synthorax, and the shape of anal appendages.

Keywords: *Platylestes kirani* sp. nov., *P. platystylus*, southern India, wetland.

The genus *Platylestes* Selys, 1862 is a group of medium-sized damselflies (2.2–3.3 cm) resting with wings expanded, non-metallic, and dull colored. This genus is distinguished from other genera of family Lestidae, by its subquadrate pterostigma twice as long as broad, with white at both ends. Fraser (1933) reported a single species of *Platylestes*, i.e., *P. platystyla* from Bengal and Burma (Myanmar). Based on the recent Odonata species list of the World (Schorr & Paulson 2019), three species of the genus are known, viz.: *P. heterostylus* Lieftinck, 1932, *P. platystylus* (Rambur, 1842), and *P. pertinax*

Lieftinck, 1932. The distribution record of *P. heterostylus* is from Indonesia, Malaysia, and Singapore (Dow 2009), while the distribution of *P. pertinax* is not mentioned anywhere in the literature. *P. platystylus* is relatively well known and distributed through West Bengal (India), Myanmar, Lao People's Democratic Republic, Thailand, and Vietnam (Fraser 1933; Hämläinen & Pinratana 1999; Yokoi 2001; Sharma 2010; Subramanian & Babu 2017). *P. platystylus* was recently reported from various localities of Kerala, through several photographic records by many naturalists.

MATERIALS AND METHODS

As a part of faunistic survey of the various wetland habitats of northern Kerala the third author (CC) photographed the species from the coastal wetlands of Kannapuram, Kannur District on 20 August 2017 (Figure 1). Later on, several intensive surveys to the area fetched more specimens. As many as seven specimens were observed in a single day during the period. Subsequently, in the year 2018, we noticed the activity

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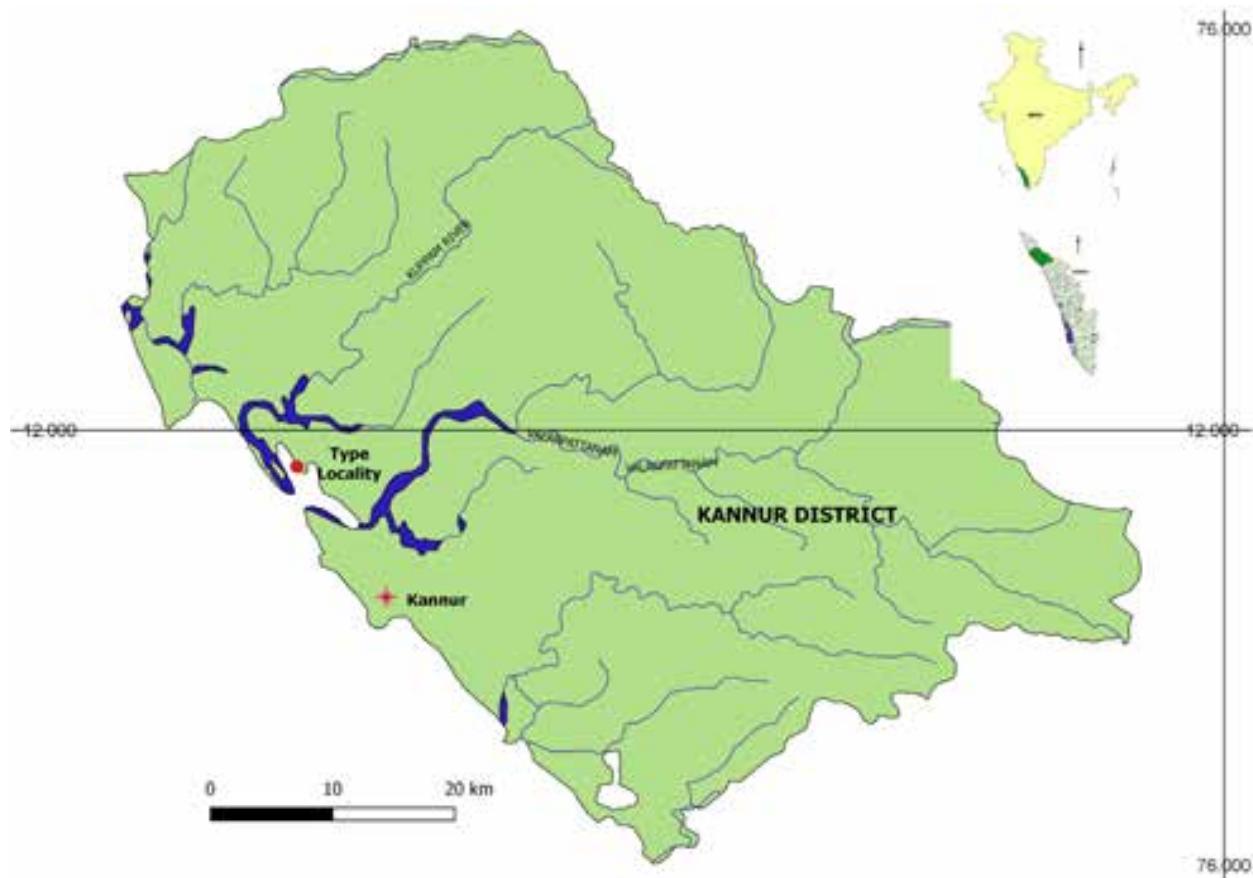


Figure 1. Type locality of *Platylestes kirani* sp. nov.

of the species by 11 August which continued until 2 October. We counted 4–5 specimens during 2018 from the locality. The collected specimens were preserved in absolute alcohol for future reference. Morphological terminology follows Chao (1953) and Watson & O'Farrell (1991). Measurements are given in millimeters (mm). The specimens were photographed using a Leica MZ 16 binocular microscope and deposited in the National Zoological Collection (NJC) of Zoological Survey of India (ZSI), Western Ghats Regional Centre (WGRC), Kozhikode.

***Platylestes kirani* sp. nov.**
(Images 1–11)

urn:lsid:zoobank.org:act:E71D153F-38AF-49C0-92DF-AEB9421F5DE0

Holotype: ZSI/WGRC/IR.INV/12167, 20.viii.2017, male, India, Kerala, Edakkepuram, Kannur District (11.5836N & 75.1816E, 2m), coll. C. Chareesh and Muhammed Jafer Palot.

Paratypes: ZSI/WGRC/IR.INV/12168, 3.ix.2017, female, same data as holotype. ZSI/WGRC/IR.INV/12169, 3.ix.2017, female, same data as holotype.

The holotype and paratypes are preserved wet in 70% ethyl alcohol. All the types are deposited in the NJC of WGRC, ZSI, Kozhikode.

Holotype male: Head: Labium creamy yellow with bluish tinge; labrum apple green, anterior tip black; mandibles and genae apple green; ante and post clypeus greenish-yellow with brownish tinge; postclypeus with a small black spot at the centre; frons dull greenish with three black spots, the middle spot is bigger than other two lateral spots; vertex black; eyes apple green, area adjacent to vertex pale blue with small black spots; antennae brownish black, basal segment brownish, remaining segments pale black. Thorax: Prothorax: pale greenish-blue, with a black stripe similar to that of synthorax traversing from anterior to posterior lobe at the middle; a pair of black spots on the middle and posterior lobe laterally; synthorax bright olive green on dorsum, laterally greenish-yellow; a broad black stripe on the dorsum, straight on the inner border, outwardly crenulated expanded at the upper, middle and at the lower end; mid dorsal carina pale creamy at the middle of this marking; mesothoracic triangle black; humeral



Image 1–11. *Platylestes kirani* sp. nov. 1—Adult male | 2—Adult female | 3—Head and thorax of male | 4—Head and thorax of female | 5—Male and appendage - lateral view | 6—Male anal appendage - dorsal view | 7—Secondary genitalia of male | 8—Female anal appendage - lateral view | 9—Female anal appendage - ventral view | 10—Female anal appendage - dorsal view | 11—Wings. © K.G. Emiliyamma & C. Charesh.



Image 12. Comparison of genitalia. Male anal appendage: a—*Platylestes kirani* sp. nov. | b—*Platylestes platystylus*. Male secondary genitalia: c—*Platylestes kirani* sp. nov. | d—*Platylestes platystylus*. © K.G. Emiliyamma.

suture thin black, two small black spots at the upper and lower ends; four black spots on mesepimeron, two at its upper third, one over the spiracle and one at the lower third; metepimeron greenish-yellow with two black spots at upper and lower ends; pleura of fore coxa with a small black stripe; antealar sinus pale blue; undersurface of thorax pale yellowish-green with two black spots between the hind legs; legs pale yellowish-white with black stripes on extensor surfaces of femora and tibiae on forelegs, mid legs and hind legs; a black spot on each hind coxa, underside of each coxa black, claws black;

wings hyaline, petiolated as far as ac, pointed at apices; forewing with 10–11 and hindwing with 9–10 postnodal nervures; pterostigma short and broad, twice as long as broad, distal end straight, proximal end oblique and in line with brace, covering two cells, black, with creamy yellow at coastal, distal and proximal ends; abdomen greenish-yellow, with brown stripes on dorsum, similar to that in *P. platystylus*; segment 1 and 2 bright yellowish-green; segment 2 with a brownish spear mark with hook like shape at the bottom, split at the middle; segments 3–6 with subdorsal brownish spots, pale yellow at both



Image 13. Comparison of adult specimens of *Platylestes kirani* sp. nov. and *P. platystylus*: a—*Platylestes platystylus* - male | b—*Platylestes platystylus* - female | c—*Platylestes kirani* sp. nov. - male | d—*Platylestes kirani* sp. nov. - female

ends; segment 7 with yellow spot fused and extended laterally; segment 8 with a greenish-blue crescent marking; segment 9 and 10 black, without marking; segment 1 and 2 with small black spots ventrally; segments 2–6 with black apical rings, pale yellowish-green with a blue tinge underside; *anal appendages* as in *P. platystylus*, creamy white, base of superior

and inferior appendages black; superior appendages as long as segment 9, broad, forcipate, apices curving gradually in to meet with, blunt at apices, outer border with 3 big and 1 small spine near apices; inner border with a small membrane like expansion beginning from near the base as an obtuse knob and ends with a sharp spine, apex of superiors ends with a few white, delicate

Table 1. Morphometric measurements of type specimens of *Platylestes kirani* sp. nov.

Type	Sex	Abdomen (mm)	Forewing (mm)	Hindwing (mm)
Holotype	Male	32	21	20
Paratype 1	Female	31	22	21
Paratype 2	Female	29	21	20

long hairs; inferior appendages less than half the length of superiors, ends at the middle of sharp spine of inner membrane like expansion of superiors, slender throughout its length, convergent and meet at extreme apices so as to enclose a small oval space, ends with a tuft of long, delicate, white hairs.

Female: Differs from the male in many aspects. The differences are follows: eyes pale greenish-yellow; labrum with a deep, median black spot; vertex pale brown with black patches; two black spots near the base of antenna; anterior lobe of prothorax brownish, middle lobe with two elongated black spots, middle and posterior lobe with pale brownish stripe as in male; synthorax dull green, laterally pale greenish-yellow; black stripe on dorsum of synthorax absent and with black spots as in *P. platystylus*; two long black spots on the outer side of mesothoracic triangle; dorsum with 4 black spots of various sizes at the posterior half; anterior and posterior humeral stripe with black long spot at the base; mesepimeron with a big triangle black spot and another three spots at anterior part and a round spot at the posterior; metepimeron with two spots; ventral surface of thorax with two small spots at anterior and posterior parts; wings with 10–11 postnodals in forewings, 10 in hindwings; abdomen similar to male in markings, but pale colored, first and second abdominal segment with two small spots laterally. In the second specimen, the dorsum of synthorax with a black straight stripe, spots on synthorax similar to the first specimen; postnodals 9–10 in forewings, 8–9 in hindwings; abdomen pale brownish, markings similar to male. The anal appendages are creamy white, conical, blunt at tip, longer than segment 10; vulvar scale robust, black, extending up to the end of abdomen.

Diagnosis: This species can be easily distinguished from all other species of *Platylestes*, by its unique coloration, distinct black marking on its synthorax and shape of anal appendages. This species is characterized from *P. platystylus* and *P. heterostylus* by its broad black band on synthorax and apple green coloration.

The new species, *Platylestes kirani* sp. nov. is differentiated from its close relative, *P. platystylus* by



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Image 14. Type locality of *Platylestes kirani* sp. nov.

the following set of characters (Images 12 & 13):

1. Dorsum of synthorax with a broad black marking, its inner side straight, while its outer side crenulated expanded structure at three points (*in P. platystylus*, dorsum of synthorax without stripe, and with many black spots)
2. Synthorax apple green (*P. platystylus*: pale khaki brown)
3. Apex of superior anal appendages blunt and rounded, meeting each other (*P. platystylus*: apex is conical, not meeting each other, pointing downwards)
4. The colour of pterostigma is much darker than *P. platystylus*.

Etymology

The species is named after the late C.G. Kiran, in recognition of his outstanding contribution to the odonatology of Kerala. He co-authored the first Odonata book in Malayalam (local language) and popularized odontology among the nature enthusiasts of the region. He passed away in 2017, at an early age of 40 years. The species name *kirani* is used as a noun in the genitive case.

HABITAT AND DISTRIBUTION

The type locality Edakkepuram wetlands (11.5836N & 75.1816E) is about 5km north of Azheekkal estuary, where both Valapattanam and Kuppan rivers discharge water to the Arabian Sea. The locality is primarily a creek extending from Madackara (close to the estuary) to Edakkepuram and the water inflow is controlled by a sluice at Edakkepuram. The area was mainly a paddy field, bordered with a small patch of mangrove trees of *Avicennia officinalis*, *Rhizophora mucronata*, and *Excoecaria agallocha* on the bunds. The other mangrove associated species observed were *Clerodendron inerme*, *Premna latifolia*, *Derris trifoliata*, and *Ipomoea carnea*.

The swamp vegetation was dominated by *Nymphaea naucifolia*, *Hydrilla verticillata*, *Ipomoea aquatica*, and a thick growth of *Cynodon arcuatus* grasses. The shoreline vegetation was mainly of *Mariscus javanicus*, *Colocassia esculenta*, *Ipomoea marginata*, *Impatiens minor*, *Eclipta alba*, *Urena lobata*, *Cayretia trifolia*, and *Passiflora foetida*.

The new damselfly species was mainly found foraging inside the shoreline vegetation and occasionally resting on the stems of *Colocassia* plants or on the leaf blades of grasses and sedge (Image 14). Interestingly, most of the specimens observed were males during the last two seasons. No breeding activity was noted from the area.

Platylestes kirani sp. nov. is currently known only from the coastal wetlands of Kannur District, northern Kerala. Several individuals were located during the months of August, September, and October. The species frequented paddy-fields and mangrove wetlands, where the water was saline during the dry season. The type locality is typically dry from March to May. The species was found to be locally abundant during the short flight period from August to September or October. It was first

sighted in the last week of August and seen throughout almost for two months. The locality is also shared by its close congener *P. platystylus* during the month of June to August. Other odonates collected or observed at the type locality include *Agriocnemis pygmaea*, *Ceriagrion cerinorubellum*, *C. coromandelianum*, *Ischnura rubilio*, *Psuedagrion microcephalum*, *Acisoma panorpoides*, *Brachythemis contaminata*, *Brachydiplax sobrina*, *Crocothemis servilia*, *Diplacodes trivialis*, *Neurothemis tullia*, *Orthetrum sabina*, *Rhodothemis rufa*, *Rhyothemis variegata*, *Tholymis tillarga*, *Trithemis aurora*, *T. pallidinervis*, and *Anax guttatus*.

REFERENCES

Chao, Hsiu-Fu (1953). The external morphology of dragonfly *Onychogomphus ardens* Needham. *Smithsonian Miscellaneous Collections*, 122(6): 1–56.

Dow, R.A. (2009). *Platylestes heterostylus*. The IUCN Red List of Threatened Species 2009: e.T163635A5627616. Accessed on 28 November 2018. <https://doi.org/10.2305/IUCN.UK.2009-2.RLTS.T163635A5627616.en>

Fraser, F.C. (1933). *The Fauna of British India including Ceylon and Burma. Odonata* Vol. I. Taylor and Francis Ltd., London, 423pp.

Hämäläinen, M. & A. Pinratana (1999). Atlas of the Dragonflies of Thailand. Distribution maps by provinces. Brothers of St. Gabriel in Thailand, Bangkok, 176pp.

Schorr, M. & D. Paulson (2019). <https://www.pugetsound.edu/academics/academic-resources/slater-museum/biodiversity-resources/dragonflies/world-odonata-list2/> (Accessed on 23 February 2019)

Sharma, G. (2010). *Platylestes platystylus*. The IUCN Red List of Threatened Species 2010: e.T167261A6319472. Downloaded on 23 February 2018. <https://doi.org/10.2305/IUCN.UK.2010.RLTS.T167261A6319472.en>

Subramanian, K.A. & R. Babu (2017). Checklist of Odonata (Insecta) of India. Version 3.0. www.zsi.gov.in. Accessed on 23 February 2019.

Watson J.A.L. & F.A. O'Farrell (1991). Odonata (dragonflies and damselflies), pp. 294–310. In: *The Insects of Australia*, CSIRO (ed.), 2nd Edition. Melbourne University Press, Melbourne.

Yokoi, N. (2001). Nine species of dragonflies record for the first time in Laos. *Tombo* 43: 25–28.





A first complete documentation of the early stages of Hampson's Hedge Blue *Acytolepis lilacea lilacea* Hampson, 1889 (Lepidoptera: Lycaenidae) from Western Ghats, Kerala, India

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Abstract: This is the first complete documentation of the early stages of *Acytolepis lilacea lilacea*, the subspecies from southern India, with the first record of the larval host plant *Cycas circinalis*, and a comparison with the early stages of *Acytolepis puspa felderii* Toxopeus, 1927, a sympatric and similar species, highlighting the notable differences. The significant differences noted in the early stages of *Acytolepis lilacea lilacea* with that of *A. puspa* are the difference in ornamentation of eggs, more fluffy, blue shaded and less hairy larvae and more elongated pupae. No previous record of the early stages of any of the subspecies of *Acytolepis lilacea* Hampson, 1889 is available. Preliminary observations regarding the flight period and seasonal variations of *Acytolepis lilacea lilacea*, from Parambikulam Tiger Reserve, Kerala, India, are also presented.

Keywords: *Acytolepis lilacea lilacea*, *Cycas circinalis*, early stages, larval host plant, Parambikulam Tiger Reserve, Western Ghats.

Acytolepis Toxopeus, is a small genus of lycaenid butterflies under the *Lycaenopsis* group, represented by five species in the world, viz: *A. puspa* (Horsfield, 1828), *A. lilacea* (Hampson, 1889), *A. najara* (Fruhstorfer, 1910), *A. rippe* (Druce, 1895), and *A. samanga* (Fruhstorfer, 1910). The first two species are known from India and

the others are from the Indomalayan and Australasian realm. *Acytolepis lilacea*, Hampson, 1889 (Hampson's Hedge Blue or Lilac Hedge Blue) is a lesser known butterfly under the subfamily *Polyommatinae* of tribe *Polyommatinii* and has a recorded distribution in southern India, Sri Lanka, Myanmar, Vietnam, Laos, and Thailand. There are three subspecies of *Acytolepis lilacea* in the world. The distribution record of *A.l. lilacea*, Hampson, 1889 is from southern India, *A.l. moorie*, Toxopeus, 1926 is known from Sri Lanka, and *A.l. indochinensis*, Eliot & Kawazoe, 1983 is widely distributed in Laos, Vietnam, Myanmar, and Thailand.

Acytolepis lilacea lilacea was described by Hampson in 1889 from the southern slopes of Nilgiris (914m), Western Ghats, India as *Cynaris puspa* var. *lilacea*. After this, sometimes it was treated as a separate species (Bingham, 1907; Swinhoe, 1910; Evans 1932) and later as a subspecies of *Acytolepis puspa* (Cantlie 1963). But Eliot & Kawazoe (1983), after detailed work, confirmed its status as a separate species and also described a

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new subspecies, *A.I. indochinensis* from Laos. The male genitalia of *A. lilacea* is of the same pattern as *A. puspa*, but one-third larger (Eliot & Kawazoe 1983). Males have a more rounded apex and termen than *A. puspa* and significantly, the series of post discal striae on the underside of the forewing is more regular. The subspecies *lilacea*, which flies in southern India, is distinguished from other subspecies by the male lacking whitish discal areas above on the forewing, the hindwing without whitish patches and edging to the marginal spots, and on underside the forewing postdiscal spot in space 9 is usually present (Eliot & Kawazoe 1983). This subspecies is uncommon and only recorded from very few places in southern India, mainly from Palni Hills, Nilgiris, and Coorg (Larsen 1987). Recently, the taxa has been reported from Neyyar Wildlife Sanctuary (WS) and Parambikkulam Tiger Reserve (TR) of Kerala (Kunte et al. 2019). Gaonkar (1996) in his report on butterflies of Western Ghats also recorded the species from Kerala, Karnataka, and Tamil Nadu. The species is protected under Schedule II of the Indian Wildlife (Protection) Act, 1972. Recent work on the larval host plants of the butterflies of the Western Ghats by Nitin et al. (2018) has not listed any larval food plant for *A. lilacea*.

This species is probably often overlooked in its habitats with the sympatric, similar looking and quite common *Acytolepis puspa* (Common Hedge Blue). It

occurs with *A. puspa* in low land forests, penetrating the subtropical zone, but is very much scarcer. Nothing has been published so far, concerning the early stages of this speceis anywhere in the world. Here we present, for the first time, the early stages of *Acytolepis lilacea lilacea*, recorded from Parambikulam TR, Western Ghats, Kerala, India. The recorded early stages, larval feeding patterns and the recorded host plant show marked differences from those of *A. puspa*, and once again confirms the status of *A. lilacea* as a distinct species from *A. puspa*. We present here the images of egg, final instar larva, and pupa of both species for comparison (Image 3 & 4).

MATERIALS AND METHODS

During the annual butterfly survey held in Parambikulam TR, Palakkad District, Kerala in November 2018, we came across a female *A. lilacea* at Anappady area (Image 1), (10.443N & 76.813E) laying eggs on the tender leaves of *Cycas circinalis* (Cycadaceae). We collected the eggs, reared five caterpillars in air-tight transparent plastic containers by providing fresh leaves of the larval host plant. We photographed all relevant stages of the life history using a Canon 5D Mark III SLR Camera with a Canon 100mm macro lens and a Kenko 1.4X Teleconverter. We compared the images of the early stages with the relevant, previously recorded early stages of *A. puspa* by VKC. We analysed the images taken



Image 1. The study area, Anappady forest of Parmabikulam Tiger Reserve.

of the adult *A. lilacea lilacea* from the reserve during the months from October to January for seasonal variations and for ascertaining an approximate period of its flight in the reserve.

OBSERVATIONS AND RESULTS

Larval host plant

The female laid eggs on the tender leaves of *Cycas circinalis*, a gymnosperm, commonly known as the Queen Sago plant (Image 2), having a distribution in Indo-Malaysia and tropical eastern Africa. The only other butterfly species breeding on *Cycas circinalis* in the Western Ghats is *Chilades pandava* (Cycad Blue or Plains Cupid), and the larvae of both these species eat up the tender leaves and damage the plant considerably. We also searched the garden variety of Cycas – *Cycas revoluta*, which is commonly grown in the garden as an ornamental plant, for the early stages of *A. lilacea*, but did not encounter any. Well-wooded areas with an abundance of *Cycas circinalis* appear to be necessary for the survival of *A. lilacea* and this may be one of the reasons for its limited population and distribution compared to that of *A. puspa*. Whereas, *A. puspa* is widely distributed all over India and its larvae are known to feed on many plant species, namely, *Shorea roxburghii* (Dipterocarpaceae), *Cratoxylum cochinchinense* (Hypericaceae), *Moullava spicata*, *Paracalyx scariosus*, *Peltophorum pterocarpum*, *Xylia xylocarpa* (Fabaceae), *Hiptage benghalensis*, *H. madablotia* (Malpighiaceae), *Bridelia retusa*, *B. stipularis* (Phyllanthaceae), *Lepisanthes tetraphylla*, *Schleichera trijuga*, and *S. oleosa* (Sapindaceae) (Nitin et al. 2018).

Early stages

The eggs were laid on the underside of tender leaf blades of the host plant *Cycas circinalis*, mostly one on each blade. The eggs are white, button-shaped, with irregular tiny projections on the surface. They are similar to the eggs of *Chilades pandava* but quite different from that of *A. puspa*. We collected five eggs. Three eggs hatched on the fourth day and two on the fifth day. The newborn tiny caterpillars were light yellow with two rows of obscure white spots on the dorsum, divided by a longitudinal greenish-yellow line. Caterpillars live on the underside of the leaf blade, eating up the soft tissues leaving the cuticle. In advanced instars the colour of the caterpillar on the upperside acquired bluish-green to rich sky blue shades, while the front, rear and lateral sides remain yellow. The caterpillar had tiny tubercles on its body, each of which bears a light yellow hair. The density of these tiny hairs is less compared to the caterpillars of



Image 2. Queen Sago Plant *Cycas circinalis*. Leaves eaten up by *Acytolepis lilacea* larvae in inset.

A. puspa. The pupa was similar in shape to that of *A. puspa*, but more elongated. It had thin, tiny hairs all over, and two rows of black spots on the upper side. Many pupae were found decorated by black markings. The pupae were held by a body band. The pupa measured 10mm and the adult butterfly emerged eight days after pupation. The entire life cycle was completed in 32 days. The adult specimen was deposited at Zoological Survey of India, Western Ghats Regional Centre, Kozhikode (Reg. No. ZSI/WGRC/IR/IV.No. 12859).

Interestingly, we have not seen any ants attending to the caterpillars found in the field. Also, in the absence of tender leaves, the larvae were found to feed on semi-matured and matured leaves. Many pupae found in the field were either infected by parasites or damaged. This may be one of the reasons behind the restricted population of this species, even in its conducive habitats. Also, it was observed that the deeply coloured larvae found were those affected by parasites. Detailed studies have to be carried out on the rates of survival of the caterpillars with a special reference to the effect of parasites and other factors.



Image 3. Comparison of early stages of *Acytolepis lilacea lilacea* with that of *A. puspa felderii*: 1—egg of *A. lilacea* | 2–3—final instar larva of *A. lilacea* | 4–5—pupa of *A. lilacea* | 6—egg of *A. puspa* 7–8—final instar larva of *A. puspa* | 9–10—pupa of *A. puspa*. © Chandrasekharan VK.



Image 4. Early stages of *Acytolepis lilacea lilacea*. © Chandrasekharan VK.



Image 5. Adult images of *A. lilacea lilacea* taken from Parambikulam Tiger Reserve. © Chandrasekharan VK

Seasonal variations and flight period

We made most of our observations in the Anappady area of Parambikulam TR. We have images of live field specimens (Image 5) of this butterfly from October to January and we also found new eggs, larvae, and pupae from November to the end of January. We saw this species even in May, but we were unable to get photographs. Analysing this, it is assumed that this species is multivoltine, having several broods in a year presumably starting from the post monsoon months up to the month of May. Markings are bold for the individuals seen in the months of October and November, whereas the markings are narrower in individuals that are seen in December and January. We presume that the former individuals represent a wet season form and the later a dry season form. Undoubtedly, we still lack the details on flight patterns, specific behaviour, and we suggest that future studies pay more attention to the details on the natural history of this lesser known species. Also, as Eliot & Kawazoe (1983) suggested, *A. lilacea* might have a wider distribution in India with its range extending up to the northeastern part of India.

REFERENCES

Bingham, C.R. (1907). *The Fauna of British India. Butterflies.* Vol. 2. Taylor and Francis Ltd, London, 325pp.

Cantlie, K. (1963). The Lycaenidae portion (except Arhopala group) of Brigadier Evans' *The identification of Indian Butterflies* 1932: 42pp.

Evans, W.H. (1932). *The identification of Indian Butterflies* 2nd Edition, Bombay Natural History Society, Mumbai, 221pp.

Evans, W.H. (1953). A note on the Indian species of the Genus *Lycaenopsis* (Felder). *Journal of the Bombay Natural History Society* 51: 755.

Eliot, J.N. & A. Kawazoe (1983). *Blue butterflies of the Lycaenopsis group.* © Trustees of the British Museum (Natural History), 309pp.

Gaonkar, H. (1996). Butterflies of the Western Ghats with notes on those of Sri Lanka. Report to Centre for Ecological Sciences, Indian Institute of Science, Bengaluru, Zoological Museum, Copenhagen and Natural History Museum, London, 89pp.

Hampson, G.F. (1888). The butterflies of the Nilgiri District, south India. *The Journal of the Asiatic Society of Bengal* 57: 346–368.

Kunte, K., K.S. Sondhi & P. Roy (chief editors) (2019). *Acytolepis lilacea* (Hampson, 1889) – Lilac Hedge Blue. Butterflies of India, v.2.61. Indian Foundation for Butterflies. http://www.ifoundbutterflies.org/sp/890/Acytolepis_lilacea. Accessed on 03 July 2019.

Larsen, T.B. (1987). The butterflies of the Nilgiri mountains of southern India (Lepidoptera: Rhopalocera) *Journal of the Bombay Natural History Society*. 84(1): 26–54; 84(2): 291–316; 84(3): 560–584.

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/jott.3104.10.4.11495-11550>.

Swinhoe, C. (1910). *Lepidoptera Indica* 7: Rhopalocera, Family Papilionidae and Family Lycaenidae, Lovell Reeve and Co. Limited, London (1905–1910), 210–211pp.

Toxopeus, L.J. (1926). Lycaenidae Australasiae 1. New investigations on the Genus *Lycaenopsis* Felder. *Treubia* 8: 365–375.





A checklist of butterfly fauna of Bankura Town, West Bengal, India

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Abstract: The present study on butterflies was conducted in different habitat types in Bankura Town along the banks of Gandheswari and Dwarakeswar rivers for 24 months from January 2017 to December 2018. The results of the study recorded the presence of 1,273 individuals of butterflies belonging to 57 species and 42 genera in six families. The study recorded 20 species of butterflies under Nymphalidae, 14 species under Lycaenidae, 10 species under Pieridae, eight species under Hesperiidae, six species under Papilionidae, and only one species under Riodinidae. The present study provides a preliminary report on the butterfly diversity of Bankura Town which in turn may generate awareness among the local people and government about the importance of these essential pollinators and their conservation.

Keywords: Diversity, Dwarakeswar, Gandheswari River, Lepidoptera, Nymphalidae, pollinator, riverside vegetation.

Bankura, the fourth largest district of West Bengal is located in the western part of the state. It covers an area of 6,882km² and is bounded by Paschim Medinipur and Hooghly districts in the east, Purulia District in the west, and Bardhaman District in the north and east. The town is well-connected with its surrounding districts by two state (SH-2, SH-9) and two national highways (NH-14 and NH-314). Two rivers, Gandheswari and Dwarakeswar flow from the north-east to the south-west in courses roughly parallel to one another.

Being very frequent visitors of a wide variety of

flowers, butterflies constitute an effective and potential pollinator group along with other insect pollinators of the world. These beautiful floral visitors contribute to the pollination of more than 75% of the leading global food crops and thereby saving US\$235–577 billion per year (Breeze et al. 2016; Grooten & Almond 2018).

In recent times several authors have reported on the diversity of butterfly population in different ecosystems under many districts of West Bengal (Chowdhury 2014; Mandal 2016; Samanta et al. 2017). No comprehensive report on butterfly diversity from any part of Bankura District, however, has been reported to date. The present study was conducted in the municipality areas of Bankura Town and several villages located near the river banks Gandheswari and Dwarakeswar of Bankura I community development block (Fig.1).

STUDY AREA

Bankura Town (23.25N & 87.07E) with an average elevation of 78m, is located in Bankura District and has a narrow alluvial strip along the lateritic and red soils (Ghosh & Guchhait 2015). Bankura District belongs to a tropical savannah climate that represents a hot summer (April–May), monsoon (June–September) and winter (November–February). The town experiences a hot and

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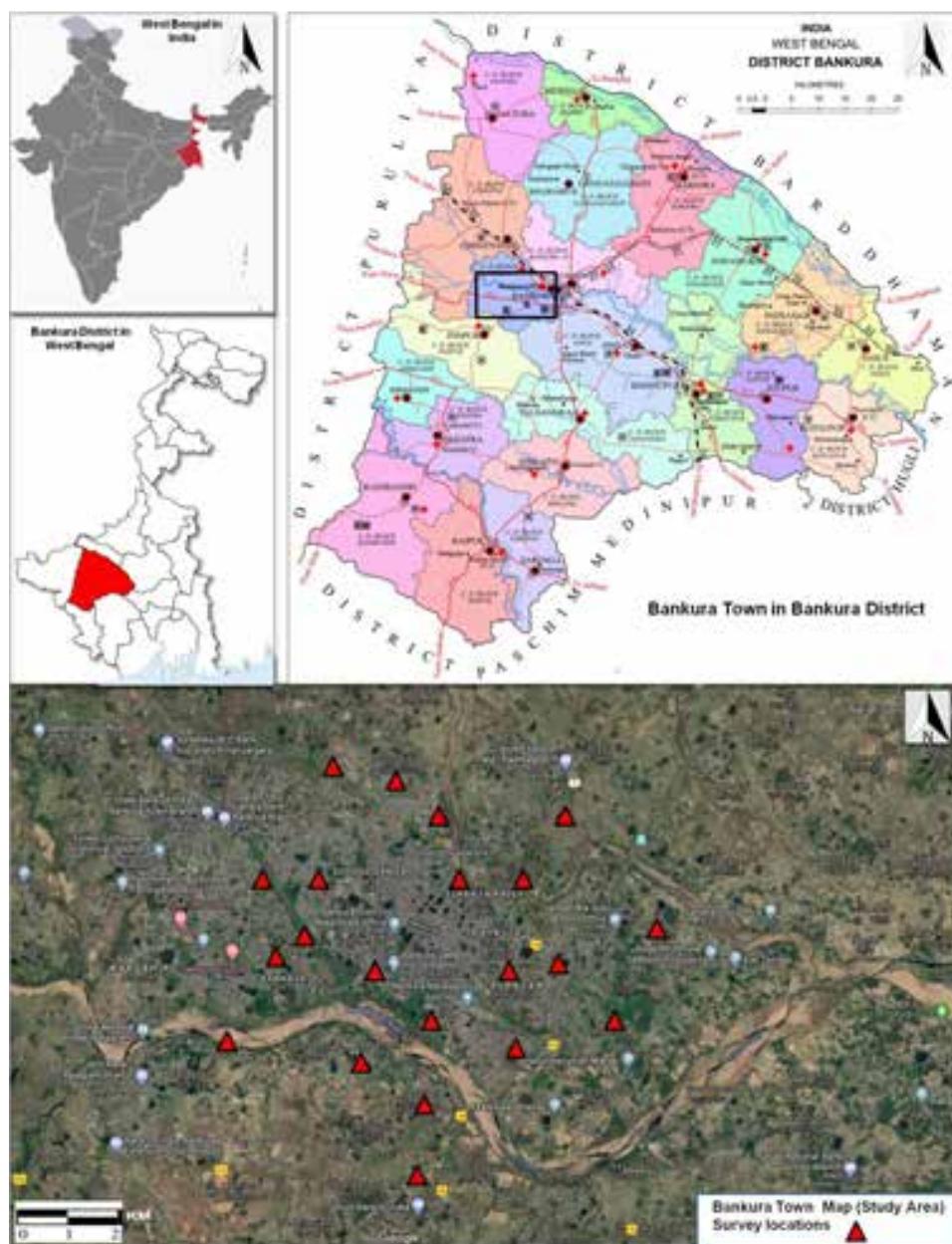


Figure 1. Geographical location of the study area: Bankura Town and adjoining areas (Map data: India and West Bengal from Wikipedia; Bankura District from Census of India 2011, Govt of India; Bankura Town @2019 Google).

humid weather except during the three months of winter. In summer the temperature rises to a maximum of 48°C and in winter the temperature barely goes below 7°C. Relative humidity is generally high throughout the year.

The study area encompasses a heterogeneous landscape characterized by diverse patches of aquatic and terrestrial ecosystems including riverside vegetations of the two rivers, roadside plantations, habitats on railway embankments, grasslands, barren lands, bushes of weeds, gardens, agricultural lands, ponds, two rivers, and different forms of human habitation which ranges from a single settlement to densely populated city areas

(Image 1 and 2).

Riverside vegetation: It includes a wide variety of natural flora of the river basin (e.g., wild sugarcane, *Acacia* sp., *Solanum xanthocarpum*, *Calotropis gigantea*), scrubland (e.g., *Calotropis gigantea*, *Datura metel*, *Justicia adhatoda*) and trees (e.g., *Alstonia scholaris*, *Azadirachta indica*, *Terminalia arjuna*, *Ficus benghalensis*) along the riverbanks, agro-ecosystems (e.g., paddy field and other crop plants) and plantations by human habitations (e.g., *Carica papaya*, *Cocos nucifera*, *Moringa oleifera*, *Psidium guajava*).

Roadside plantations: These are characterized by



Image 1. Dwarakeswar River and adjoining areas near Bankura Town, one of the study sites. © Ananya Nayak.



Image 2. Gandheswari River and adjoining areas near Bankura Town. © Ananya Nayak

distinct vegetation assemblages dominated by weedy plant species (e.g., *Argemone mexicana*, *Cuscuta reflexa*, *Lantana camara*, *Parthenium hysterophorus*) and other trees like *Albizia lebbeck*, *Azadirachta indica*, *Bombax ceiba*, *Borassus flabellifer*, *Butea monosperma*, *Cassia fistula*, *Phoenix sylvestris*, *Tamarindus indica*, *Acacia auriculiformis*, and *Eucalyptus tereticornis*.

Railway embankments: These artificial habitats around the railway tracks harbour species-rich plant communities including various flowering plants and invasive plant species (e.g., *Parthenium hysterophorus*, *Lantana camara*, *Hyptis suaveolens*) that constitute an important part of biodiversity in the urban landscape.

Home garden: These habitats are represented by several ornamental plants (e.g., *Catharanthus roseus*, *Chrysanthemum indicum*, *Clitoria ternatea*, *Combretum indicum*, *Hibiscus rosa-sinensis*, *Ixora coccinea*, *Rosa* sp., *Tagetes erecta*, *T. patula*) and a number of common ethnomedicinal and fruit plants (e.g., *Aloe barbadensis*, *Ocimum sanctum*, *Mentha spicata*, *Annona squamosa*, *Mangifera indica*, *Punica granatum*, *Psidium guajava*)

Open grassland: These are naturally occurring areas where the vegetation is dominated by different types of grasses along with sedges and other herbaceous plants. Most of the abandoned agricultural lands near Bankura Town are examples of this type of habitat.

Some of the places that were visited for data collection are Palastola, Bhairabsthan, Krishivaban, Machantala, Satighat, Kenduadihi, Junbedia, Arabindanagar, Nutanchati, Lalbazar, Lokepur, Gobindanagar, Katjuridanga, Keranibandh, Kesiakole, Pratapbagan, Kamrarmath, Doltala, Dhaldanga, Heavy More, Sanbandha, Railway station and five kilometres along the railroad that traverse the town. Besides these several villages in the suburban areas of the town and the river banks were also visited.

METHODS

Bankura Town was surveyed for 24 months between January 2017 and December 2018. In order to estimate the number of individuals of each butterfly species and to record all the species each study site was visited twice a month and more than four hours were spent at each site from dawn to dusk.

Butterfly counts were done from 10.00h to 15.00h, using binoculars (Olympus 10×50) and species were identified and counted. Most of them were photographed using DSLR Camera with zoom lens to support further identification. Butterflies were identified based on physical features with the help of field guides and reference books viz. (Kehimkar 2016; Shihan 2016;

Kasambe 2018) and previously published works (viz., Sondhi et al. 2013; Chowdhury 2014; Mandal 2016; Samanta et al. 2017) and website on Indian butterflies (ifoundbutterflies.org). Surveys were conducted in all possible types of butterfly habitats mentioned in the study area. The study has classified the encounter rates of each species in four groups- Very Common (number observed >30), Common (15–30), Uncommon (8–14), and Rare (1–7). We analysed our data with Microsoft Office Excel, 2010. None of the species was captured or killed during the entire period of the study.

RESULTS

The present study has observed a total of 1,273 butterflies belonging to 57 species and 42 genera in different habitats of Bankura Town and adjoining areas (Images 3–8). The results showed that Nymphalidae was the most abundant family followed by Lycaenidae, Pieridae, Papilionidae, Hesperiidae and the least abundant family, Riodinidae (Fig. 2). The study has observed 12 genera and 20 species under the family Nymphalidae, 14 genera and 14 species under the family Lycaenidae, six genera and 10 species under the family Pieridae, six genera and six species under the family Hesperiidae, three genera and six species under the family Papilionidae and only one species under the family Riodinidae (Table 1). Depending on the occurrence of these species during the study period they can be grouped into four broad classes namely very common, common, uncommon, and rare. The study found 12 very common, 31 common, eight uncommon and six rare species of butterflies in the study area (Table 2). The most abundant species encountered in the study was Common Castor *Ariadne merione* (Cramer, 1777) followed by Common Evening Brown *Melanitis leda* (Linnaeus, 1758), Plain Tiger *Danaus chrysippus* (Linnaeus, 1758), Common Emigrant *Catopsilia pomona* (Fabricius, 1775), Psyche *Leptosia nina* (Fabricius, 1793), and Grey Pansy *Junonia atlites* (Linnaeus, 1763). The study, however, has also been able to detect the presence of some of the rare butterfly species of southern Bengal like Purple Leaf Blue *Amblypodia anita* (Hewitson, 1862), Plum Judy *Abisara echerius* (Stoll, 1790), Apefly *Spalgis epius* (Westwood, 1851), Common Tit *Hypolycaena erylus* (Godart, 1824), Common Baron *Euthalia aconthea* (Cramer, 1777), and Slate Flash *Rapala manea* (Hewitson, 1863). The study has also tried to assess the habitat-wise occurrence of these species in the total study area. The highest number of species was observed in the riverside vegetations followed by roadside plantations, railway embankments, home gardens and open grasslands (Fig.

Table 1. Subfamily-wise diversity of the butterflies of Bankura town and adjoining areas.

Family	Subfamily	Number of Genera	Number of Species
Hesperiidae	Hesperiinae	6	6
Papilionidae	Papilioninae	3	6
Pieridae	Coliadinae	2	6
	Pierinae	4	4
Lycenidae	Theclinae	4	4
	Polyommatainae	9	9
	Miletinae	1	1
	Danainae	2	3
	Satyrinae	3	5
Nymphalidae	Heliconiinae	2	2
	Limenitinae	2	2
	Biblidinae	1	2
	Nymphalinae	2	6
Riodinidae	Nemeobiinae	1	1
Total: 6	14	42	57

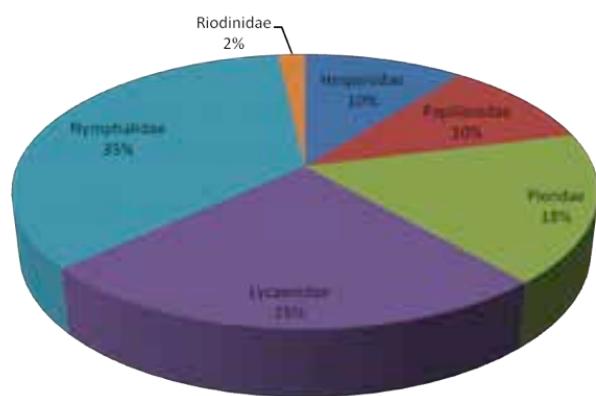


Figure 2. Family-wise abundance of butterflies found in and around Bankura Town.

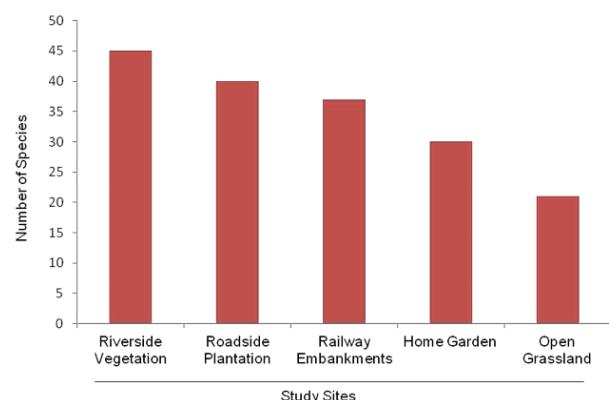


Figure 3. Habitat-wise abundance of butterfly species found in and around Bankura Town.

3). A total of 45 species were recorded from different types of habitats near the river banks of Gandheswari and Dwarakeswar rivers (data not shown). These rivers are rain-fed followed by the drying up to a perennial stream throughout the cold and hot seasons. The maximum habitat diversity of the riverine landscape encompassing the town, may be a key factor behind the existence of a large number of butterfly species in these regions. The study has observed a large number of species in different habitats along roadsides. A number of main roads including national and state highways have passed through the town with a wide range of habitats harbouring these species. A large number of species besides the railway track were recorded. Railway embankments, built of crushed stone or different sized gravel, are linear habitats that are warmer at the top of the embankment and colder and wetter at the bottom (Moroń et al. 2014). The study also noticed that the density of some of the species was much more in these man-made altered ecosystems having a higher number of natural vegetations that serve as host plants for these species. This observational evidence is also consistent with some of the studies reported earlier (Moroń et al. 2014; Kalarus & Bąkowski 2015). This can be explained by the fact that the railway track encompasses an area containing numerous nectar plants that thrive there in an undisturbed landscape without human intervention for a long time.

DISCUSSION

Bankura District like some other southern Bengal districts has an almost entirely tropical climate. Most of the flowering plants essential for human nutrition and survival are pollinated by insects and other animals. Studies have shown that the proportion of animal-pollinated wild plant species rises from an average of 78% in temperate-zone communities to 94% in tropical communities (Ollerton et al. 2011; Grooten & Almond 2018). The role of butterflies as a pollinator is more important in a drought prone district like Bankura where chances of pollination may make the difference between a good and poor production of some of the principal crops of the area.

In the process of rapid urbanization several species have lost their habitats. For example, this study has revealed that a number of butterflies prefer their host plants as bushy weeds which are annihilated during the course of building construction or other processes of urbanization. The study has noticed similar destruction of the host plants during the process of trenching and widening of shallow Gandheswari River near Satighat

Table 2. Detailed checklist of the butterflies of Bankura Town and adjoining areas.

	Scientific name	English name	Relative Abundance	Number of individuals Observed	Schedule Species -WPA, 1972
Family: Hesperiidae					
Subfamily: Hesperiinae					
1	<i>Parnara</i> sp.		Common	18	
2	<i>Telicota bambusae</i> (Moore, 1878)	Dark Palm Dart	Very Common	39	
3	<i>Udaspes folus</i> (Cramer, 1775)	Grass Demon	Common	19	
4	<i>Suastus gremius</i> (Fabricius, 1798)	Indian Palm Bob	Common	24	
5	<i>Borbo cinnara</i> (Wallace, 1866)	Rice Swift	Common	21	
6	<i>Pelopidas mathias</i> (Fabricius, 1798)	Small Branded Swift	Common	28	
Family: Papilionidae					
Subfamily: Papilioninae					
7	<i>Graphium doson</i> (Felder & Felder, 1864)	Common Jay	Uncommon	14	
8	<i>Papilio demoleus</i> (Linnaeus, 1758)	Common Lime	Common	28	
9	<i>Papilio clytia</i> (Linnaeus, 1758)	Common Mime	Common	13	
10	<i>Papilio polytes</i> (Linnaeus, 1758)	Common Mormon	Common	23	
11	<i>Graphium agamemnon</i> (Linnaeus, 1758)	Tailed Jay	Common	17	
12	<i>Pachliopta aristolochiae</i> (Fabricius, 1775)	Common Rose	Common	19	
Family: Pieridae					
Subfamily: Coliadinae					
13	<i>Catopsilia pomona</i> (Fabricius, 1775)	Common Emigrant	Very Common	44	
14	<i>Eurema hecabe</i> (Linnaeus, 1758)	Common Grass Yellow	Very Common	32	
15	<i>Catopsilia pyranthe</i> (Linnaeus, 1758)	Mottled Emigrant	Common	29	
16	<i>Eurema andersonii</i> (Moore, 1886)	One-spot Grass Yellow	Uncommon	14	
17	<i>Eurema brigitta</i> (Stoll, 1780)	Small Grass Yellow	Common	16	
18	<i>Eurema blanda</i> (Boisduval, 1836)	Three-Spot Grass Yellow	Uncommon	12	
Subfamily: Pierinae					
19	<i>Cepora nerissa</i> (Fabricius, 1775)	Common Gull	Very Common	31	
20	<i>Pareronia hippia</i> (Fabricius, 1787)	Common Wanderer	Common	27	
21	<i>Leptosia nina</i> (Fabricius, 1793)	Psyche	Very Common	41	
22	<i>Appias libythea</i> (Fabricius, 1775)	Striped Albatross	Common	23	Sch IV
Family: Lycaenidae					
Subfamily: Theclinae					
23	<i>Spindasis vulcanus</i> (Fabricius, 1775)	Common Silverline	Uncommon	8	
24	<i>Hypolycena erylus</i> (Godart, 1824)	Common Tit	Rare	6	
25	<i>Amblypodia anita</i> (Hewitson, 1862)	Purple Leaf Blue	Rare	5	
26	<i>Rapala manea</i> (Hewitson, 1863)	Slate Flash	Rare	7	
Subfamily: Polyommatinae					
27	<i>Jamides celeno</i> (Cramer, 1775)	Common Cerulean	Uncommon	11	
28	<i>Castalius rosimon</i> (Fabricius, 1775)	Common Pierrot	Very Common	31	
29	<i>Zizeeria karsandra</i> (Moore, 1865)	Dark Grass Blue	Common	27	
30	<i>Catochrysops strabo</i> (Fabricius, 1793)	Forget-Me-Not	Common	24	
31	<i>Zizina otis</i> (Fabricius, 1787)	Lesser Grass Blue	Common	27	
32	<i>Chilades lajus</i> (Stoll, 1780)	Lime Blue	Common	26	
33	<i>Tarucus balkanicus</i> (Freyer, 1844)	Little Tiger Pierrot	Uncommon	12	

	Scientific name	English name	Relative Abundance	Number of individuals Observed	Schedule Species -WPA, 1972
34	<i>Pseudozizeeria maha</i> (Kollar, 1844)	Pale Grass Blue	Uncommon	14	
35	<i>Tarucus nara</i> (Kollar, 1848)	Striped Pierrot	Uncommon	12	
Subfamily: Miletinae					
36	<i>Spalgis epius</i> (Westwood, 1851)	Apefly	Rare	6	
Family: Nymphalidae					
Subfamily: Danainae					
37	<i>Euploea core</i> (Cramer, 1780)	Common Crow	Common	25	
38	<i>Danaus chrysippus</i> (Linnaeus, 1758)	Plain Tiger	Very Common	44	
39	<i>Danaus genutia</i> (Cramer 1779)	Striped Tiger	Common	21	
Subfamily: Satyrinae					
40	<i>Mycalesis perseus</i> (Fabricius, 1775)	Common Bushbrown	Very Common	33	
41	<i>Melanitis leda</i> (Linnaeus, 1758)	Common Evening Brown	Very Common	48	
42	<i>Elymnias hypermnestra</i> (Linnaeus, 1763)	Common Palmfly	Common	15	
43	<i>Melanitis phedima</i> (Cramer, 1780)	Dark Evening Brown	Common	19	
44	<i>Mycalesis mineus</i> (Linnaeus, 1758)	Dark-branded Bushbrown	Common	17	
Subfamily: Heliconiinae					
45	<i>Phalanta phalantha</i> (Drury, 1773)	Common Leopard	Common	19	
46	<i>Acraea terpsicore</i> (Linnaeus, 1758)	Tawny Coster	Common	18	
Subfamily: Limenitidinae					
47	<i>Euthalia aconthea</i> (Cramer, 1777)	Common Baron	Rare	6	
48	<i>Neptis hylas</i> (Linnaeus, 1758)	Common Sailer	Common	20	
Subfamily: Biblidinae					
49	<i>Ariadne ariadne</i> (Linnaeus, 1763)	Angled Castor	Very Common	33	
50	<i>Ariadne merione</i> (Cramer, 1777)	Common Castor	Very Common	55	
Subfamily: Nymphalinae					
51	<i>Junonia orithya</i> (Linnaeus, 1758)	Blue Pansy	Common	15	
52	<i>Junonia iphita</i> (Cramer, 1779)	Chocolate Pansy	Common	17	
53	<i>Hypolimnas bolina</i> (Linnaeus, 1758)	Great Eggfly	Common	20	
54	<i>Junonia atlites</i> (Linnaeus, 1763)	Grey Pansy	Very Common	40	
55	<i>Junonia lemonias</i> (Linnaeus, 1758)	Lemon Pansy	Common	28	
56	<i>Junonia almana</i> (Linnaeus, 1758)	Peacock Pansy	Common	27	
Family: Riodinidae					
Subfamily: Nemeobiinae					
57	<i>Abisara echerius</i> (Stoll, 1790)	Plum Judy	Rare	5	

WPA, 1972—Wildlife Protection Act (1972).

of Bankura Town. In recent times several unauthorized constructions on Gandheswari river banks have also resulted in a rapid decline of a number of native flora, essential for the survival of some butterfly species. Rapid urbanization of both the river bank areas is a leading cause for the production of massive amounts of household and industrial wastes which in turn causes pollution of the riverbank soil and vegetations.

Another matter of concern regarding loss of

butterfly diversity was observed in Dwarakeswar River. Unauthorized excessive instream sand mining has resulted in the partial or complete destruction of the river bed which in turn causes the erosion of the river banks leading to increased flooding and causing a severe threat to butterfly host plants and affect riverine ecology.

Although known for its dry and drought areas, in the past few years several places of Bankura have experienced a tremendous flood situation and the flood



Image 3. Butterflies representing the family Hesperiidae in and around Bankura Town: a—*Parnara* sp. | b&c—*Telicota bambusae* | d—*Udaspes folus* | e—*Suastus gremius* | f—*Borbo cinnara* | g&h—*Pelopidas mathias*. © Ananya Nayak.

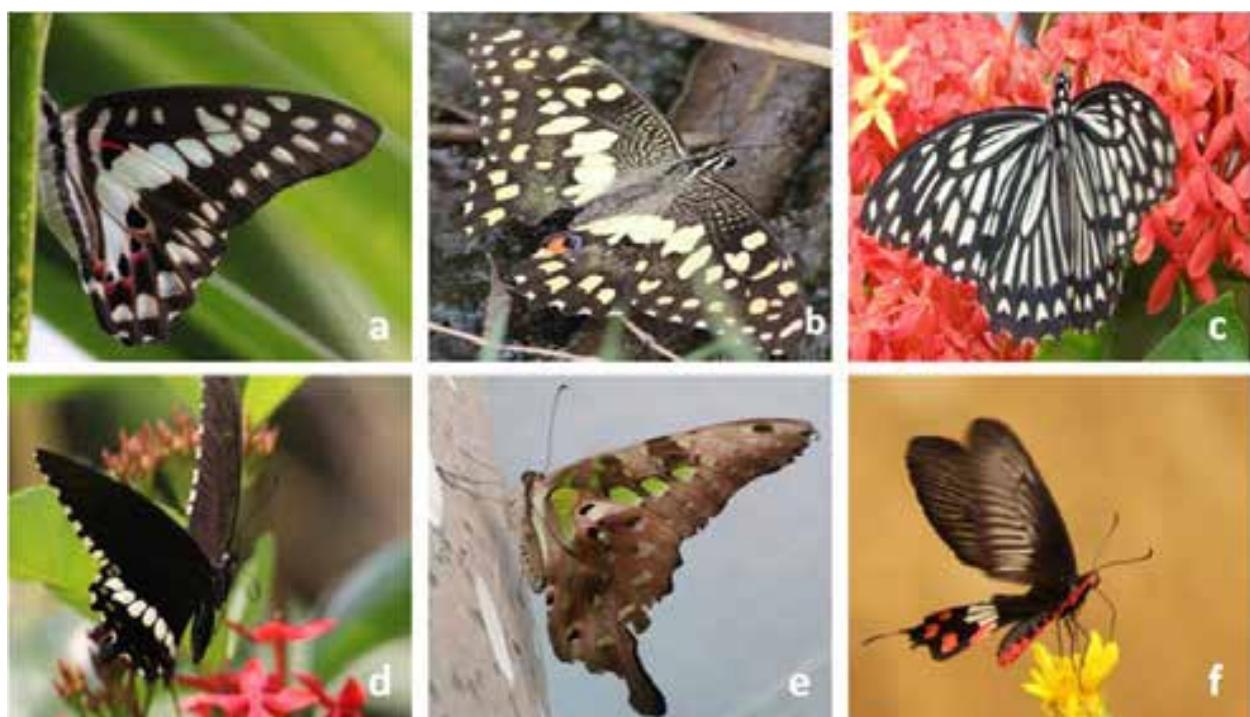


Image 4. Butterflies representing the family Papilionidae in and around Bankura Town: a—*Graphium doson* | b—*Papilio demoleus* | c—*Papilio clytia* | d—*Papilio polytes* | e—*Graphium agamemnon* | f—*Pachliopta aristolochiae*. © Ananya Nayak.

season occurs during the months of June, July, August and September. Generally, it happens during the months of July and August. Sudden cloudbursts and shallow riverbeds of Dwarakeswar and Gandheswari are the two major causes of this flood situation. In most of the places including Bankura town it does not last long. But when the flood comes, it destroys a large part of the biodiversity

particularly in the ecosystems of the river banks leading to an annihilation of a large number of flora and fauna.

CONCLUSION

The investigations presented in this study address several significant and previously unreported aspects of butterfly population and their diversity in the study



Image 5. Butterflies representing the family Pieridae in and around Bankura Town: a—*Catopsilia pomona* | b—*Eurema hecabe* | c—*Catopsilia pyranthe* | d—*Eurema andersonii* | e—*Eurema brigitta* | f—*Eurema blanda* | g—*Cepora nerissa* | h—*Pareronia hippia* | i—*Leptosia nina* | j—*Appias libythea*. © Ananya Nayak.

area. The present study also identified a number of anthropogenic factors which directly or indirectly cause destruction or alteration of the natural habitat. The study was conducted in a very small area in comparison to the whole district. More surveys and research are needed to unveil the actual status of butterfly diversity in other parts of the district with a vast range of landscapes. This in turn will deepen our understanding of their conservation status and will help us to stop and reverse the decline of many insect species and create a healthier environment.

REFERENCES

Breeze, T.D., N. Gallai, L.A. Garibaldi & X.S. Li (2016). Economic measures of pollination services: shortcomings and future directions. *Trends in Ecology & Evolution* 31: 927–939. <https://doi.org/10.1016/j.tree.2016.09.002>

Chowdhury, S. (2014). Butterflies of Sundarban Biosphere Reserve, West Bengal, eastern India: a preliminary survey of their taxonomic diversity, ecology and their conservation. *Journal of Threatened Taxa* 6(8): 6082–6092. <https://doi.org/10.11609/JoTT.o3787.6082-92>

Ghosh, S & S.K. Guchhait (2015). Characterization and evolution of primary and secondary laterites in northwestern Bengal Basin, West Bengal. *Journal of Palaeogeography* 4(2): 203–230. <https://doi.org/10.3724/SP.J.1261.2015.00074>

Grooten, M. & R.E.A. Almond (eds.) (2018). *Living Planet Report–2018: Aiming Higher*. World Wide Fund For Nature, Gland, Switzerland, 148pp.

Kalarus, K. & M. Bąkowski (2015). Railway tracks can have great value for butterflies as a new alternative habitat. *Italian Journal of Zoology* 82: 565–572. <https://doi.org/10.1080/11250003.2015.1078417>

Kasambe, R. (2018). *Butterflies of Western Ghats*. 2nd edition. Published by author, 372pp.

Kehimkar, I. (2016). *BNHS Field Guides, Butterflies of India*. Bombay Natural history Society. Oxford University Press, Mumbai, 506pp.

Mandal, S. (2016). Butterflies of the Rice Research Station and adjoining locality in Chinsurah, West Bengal, India. *Journal of Threatened Taxa* 8(5): 8804–8813. <https://doi.org/10.11609/jott.2815.8.5.8804-8813>

Moroń, D., P. Skórka, M. Lenda, E. Rożej-Pabijan, M. Wantuch, J. Kajzer-Bonk, W. Celary, Ł.E. Mielczarek, P. Tryjanowski (2014). Railway Embankments as New Habitat for Pollinators in an Agricultural Landscape. *Plos One* 9(7): e101297. <https://doi.org/10.1371/journal.pone.0101297>

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

Samanta, S., D. Das & S. Mandal (2017). Butterfly fauna of Baghmundi, Purulia, West Bengal, India: a preliminary checklist. *Journal of Threatened Taxa* 9(5): 10198–10207. <http://doi.org/10.11609/jott.2841.9.5.10198-10207>

Shihan, T.R. (2016). *A Photographic Guide to the Butterflies of Bangladesh*. Butterfly Reintroduction Farm, Chaudanga, Bangladesh, 165pp.

Sondhi, S., K. Kunte, G. Agavekar, R. Lovalekar & K. Tokekar (2013). *Butterflies of the Garo Hills*. Samrakshan Trust (New Delhi), Titli Trust (Dehradun) and Indian Foundation for Butterflies (Bengaluru), 200pp.



Image 6. Butterflies representing the family Lycaenidae in and around Bankura Town: a—*Spindasis vulcanus* | b—*Hypolycaena erylus* | c—*Amblypodia anita* | d—*Rapala manea* | e&f—*Jamides celeno* | g—*Castalius rosimon* | h—*Zizeeria karsandra* | i—*Catochrysops strabo* | j—*Zizina otis* | k—*Chilades lajus* | l—*Tarucus balkanicus* | m—*Pseudozeeria maha* | n—*Tarucus nara* | o—*Spalgis epius*. © Ananya Nayak.



Image 7. Butterfly representing the family Riodinidae in and around Bankura Town: *Abisara echerius*. © Ananya Nayak.



Image 8. Butterflies representing the family Nymphalidae in and around Bankura Town: a—*Euploea core* | b—*Danaus chrysippus* | c—*Danaus genutia* | d—*Mycalesis perseus* | e—*Melanitis leda* | f—*Elymnias hypermnestra* | g—*Melanitis phedima* | h—*Mycalesis mineus* | i—*Phalanta phalantha* | j—*Acraea terpsicore* | k—*Euthalia aconthea* | l—*Neptis hylas* | m—*Ariadne ariadne* | n—*Ariadne merione* | o—*Junonia orithya* | p—*Junonia iphita* | q—*Hypolimnas bolina* | r—*Junonia atlites* | s—*Junonia lemonias* | t—*Junonia almana*. © Ananya Nayak.



A diversity of spiders (Arachnida: Araneae) from a cashew ecosystem in Kerala, India

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Abstract: An exhaustive study was conducted to document spider fauna in cashew orchards of the Cashew Research Station, Madakkathara, Kerala, India from January 2015 to July 2017. A total of 63 species of spiders under 52 genera belonging to 14 families were recorded. The most species-rich families were Salticidae and Araneidae representing 33 and 27 per cent, respectively, of the total spider fauna. A guild structure analysis revealed six feeding guilds, viz.: stalkers, orb-web builders, foliage runners, scattered line weavers, ground runners, and ambushers. The occurrence of spiders was at a maximum during the monsoon with 59 species, followed by 26 during winter, 16 species during summer, and eight species being present all-round the year.

Keywords: Araneidae, Cashew orchards, guild structure, Madakkathara, Salticidae, seasonal variation.

Cashew is a perennial agricultural ecosystem with a rich arthropod diversity including pests and natural enemies. Cashew growers mainly depend on synthetic insecticides for the management of insect pests without any consideration to the system that may have deleterious effects on natural pest controlling biota. Hence, there is a need to redefine pest management with an emphasis on non-chemical methods. Ants and spiders are the most abundant general predators in a cashew ecosystem (Beevi & Mahapatro 2008).

The World Spider Catalog (2020) documents a total of 48,642 described species belonging to 4,173 genera and 128 families worldwide. Presently, 1,843 species under 471 genera in 61 families are known from India (Caleb & Sankaran 2020). Spiders have an important role in ecosystem functioning (Kralj-Fiser & Gregoric 2019) and were reported as predators of the Tea Mosquito Bug *Helopeltis antonii* Signoret, a major insect pest of cashew, causing economic yield loss (Devasahayam & Nair 1986).

The diversity as well as the role of spiders in agricultural fields have been documented in several studies (Breene et al. 1993; Marc et al. 1999; Rajeshwaran et al. 2005; Baba et al. 2018; Yang et al. 2018). They serve as general predators in agricultural ecosystems (Riechert & Bishop 1990) especially in orchard crops associated with diverse pest fauna. So far, a few attempts have been made to document spider fauna associated with the cashew ecosystem in Kerala. Choudhuri (1962) reported spiders under seven families occurring in cashew plantations of Kerala. Raghavendra (2001) collected 156 spider specimens belonging to Araneidae, Salticidae, Thomisidae, and Oxyopidae. Several spiders

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Figure 1. Location map of Cashew Research Station Farm, Madakkathara, Thrissur, Kerala

were reported predating on early instar nymphs of *H. antonii* (Sundararaju 1984; Devasahayam & Nair 1986). Among a list of arthropod predatory fauna recorded from cashew panicles, Sundararaju (2003) reported six species of spiders. A notable initiative was made by Beevi & Mahapatro (2008); they recorded 35 species of spiders under nine families and differentiated them under four guild structures, namely: stalkers, orb weavers, and foliage & ground runners. According to Bhat et al. (2013), among 117 species under 18 families recorded in a cashew ecosystem, *Telamonia dimidiata*, *Oxyopes shweta*, and *O. sunandae* have a preference for the Tea Mosquito Bug in spite of spiders being generalist predators.

Systematic documentation is necessary to conserve these natural pest-regulating factors for maintaining ecosystem sustainability and conservation of biodiversity. The studies that have been done so far in Kerala documented some species but almost a decade has passed and there has been no attempt to update the status of spider diversity associated with cashew ecosystems. In view of the importance of spiders in an ecosystem, the present study will help improve the understanding on diversity and seasonal occurrence and thereby help in developing a future integrated pest management strategy (IPM) in cashew.

MATERIALS AND METHODS

The study was carried out in cashew plantations of 120 acre farm area under Cashew Research Station, Madakkathara, Kerala Agricultural University, Thrissur, India in two crop seasons in fields planted under normal spacing of 7m × 7m. The farm is situated between 10.555–10.548 N & 76.259–76.268 E and at an altitude of 30m. Soil type is laterite with pH 5.5, annual rainfall of 280cm, maximum temperature 29.1–36.5 °C and minimum temperature 21.2–25.1 °C (Beevi & Mahapatro 2008). The study area consists of only cashew plantations with different weeds including grasses in the ground level vegetation.

Field observations were made from January 2015 to July 2017. Spiders were handpicked from the foliage and twigs, covering all age-classes of cashew trees. The specimens were collected from reachable tree-heights and were preserved in 70% ethyl alcohol in glass vials labeled with the date of collection. The spiders were categorized based on their abundance in the cashew orchard and noted with respect to their seasonal occurrence. Specimens were observed under a Leica M205 C stereozoom microscope and identified following the literature available from World Spider Catalog (2020). Voucher specimens were deposited at Centre for Animal Taxonomy and Ecology (CATE), Department of Zoology,

Table 1. List of spider species collected from cashew ecosystem with seasonal occurrence.

	Species	Seasonal occurrence		
		M	S	W
I. Araneidae				
1	<i>Anepion maritatum</i> (O. Pickard-Cambridge, 1877)	+	-	-
2	<i>Araneus bilunifer</i> Pocock, 1900	+	+	-
3	<i>Araneus mitificus</i> (Simon, 1886)	+	-	-
4	<i>Argiope anasuja</i> Thorell, 1887	+	-	-
5	<i>Argiope pulchella</i> Thorell, 1881	+	+	+
6	<i>Cyclosa bifida</i> (Doleschall, 1859)	+	-	-
7	<i>Cyclosa confragata</i> (Thorell, 1892)	+	-	-
8	<i>Cyrtarachne raniceps</i> Pocock, 1900	+	+	-
9	<i>Cyrtophora citricola</i> (Forsskal, 1775)	+	-	+
10	<i>Eriovixia excelsa</i> (Simon, 1889)	+	-	-
11	<i>Eriovixia laglaizei</i> (Simon, 1877)	+	-	-
12	<i>Eriovixia poonaensis</i> (Tikader & Bal, 1981)	+	-	-
13	<i>Gasteracantha geminata</i> (Fabricius, 1798)	+	-	+
14	<i>Neoscona mukerjei</i> Tikader, 1980	-	+	+
15	<i>Neoscona molemensis</i> Tikader & Bal, 1981	+	-	-
16	<i>Parawixia dehaani</i> (Doleschall, 1859)	+	-	-
17	<i>Porcatoraneus bengalensis</i> (Tikader, 1975)	+		
II. Cheiracanthiidae				
18	<i>Cheiracanthium danieli</i> Tikader, 1975	+	-	+
19	<i>Cheiracanthium melanostomum</i> (Thorell, 1895)	+	-	+
III. Clubionidae				
20	<i>Clubiona drassodes</i> O. Pickard-Cambridge, 1877	+	-	+
21	<i>Matidia incurvata</i> Reimoser, 1934	+	-	+
IV. Corinnidae				
22	<i>Aetius decollatus</i> O. Pickard-Cambridge, 1897	+	-	-
23	<i>Castaneira zetes</i> Simon, 1897	+	-	-
V. Gnaphosidae				
24	<i>Drassodes delicatus</i> (Blackwall, 1867)	+	-	-
25	<i>Gnaphosa rohtakensis</i> Gajbe, 1992	+	-	-
VI. Hersiliidae				
26	<i>Hersilia savignyi</i> Lucas, 1836	+	-	-
VII. Lycosidae				
27	<i>Hippasa agelenoides</i> (Simon, 1884)	+	-	+
28	<i>Pardosa sumatrana</i> (Thorell, 1890)	+	-	-
VIII. Oxyopidae				
29	<i>Oxyopes birmanicus</i> Thorell, 1887	-	+	+
30	<i>Oxyopes javanus</i> Thorell, 1887	-	+	+
31	<i>Oxyopes wroughtoni</i> Pocock, 1901	+	+	+

	IX. Philodromidae			
32	<i>Philodromus bigibbus</i> (O. Pickard-Cambridge, 1876)	+	-	-
	X. Salticidae			
33	<i>Asemonea tenuipes</i> (O. Pickard-Cambridge, 1869)	+	+	-
34	<i>Brettus cingulatus</i> Thorell, 1895	+	-	-
35	<i>Carrhotus viduus</i> (C.L. Koch, 1846)	+	-	-
36	<i>Epeus indicus</i> Proszynski, 1992	+	+	+
37	<i>Epeus triangulopalpis</i> Malamel, Nafin, Sudhikumar & Sebastian, 2019	+	-	-
38	<i>Harmochirus brachiatus</i> (Thorell, 1877)	+	-	-
39	<i>Hasarius adansoni</i> (Audouin, 1826)	-	+	-
40	<i>Hyllus semicupreus</i> (Simon, 1885)	+	+	+
41	<i>Indopadilla insularis</i> (Malamel, Sankaran & Sebastian, 2015)	+	-	+
42	<i>Menemerus bivittatus</i> (Dufour, 1831)	+	-	-
43	<i>Myrmaplata plataleoides</i> (O. Pickard-Cambridge, 1869)	+	+	-
44	<i>Myrmarachne ramunni</i> Narayan, 1915	+	-	-
45	<i>Phintelloides jesudasi</i> (Caleb & Mathai, 2014)	+	-	-
46	<i>Piranthus planolancis</i> Malamel, Nafin, Sudhikumar & Sebastian, 2019	+	-	-
47	<i>Plexippus petersi</i> (Karsch, 1878)	+	+	+
48	<i>Phintella vittata</i> (C.L. Koch, 1846)	+	+	+
49	<i>Portia fimbriata</i> (Doleschall, 1859)	+	-	-
50	<i>Rhene danieli</i> Tikader, 1973	+	-	-
51	<i>Siler semiglaucus</i> (Simon, 1901)	+	-	-
52	<i>Telamonia dimidiata</i> (Simon, 1899)	+	+	+
53	<i>Thiania bhamoensis</i> Thorell, 1887	+	-	-
XI. Sparassidae				
54	<i>Heteropoda venatoria</i> (Linnaeus, 1767)	+	+	+
55	<i>Olios milleti</i> (Pocock, 1901)	+	-	-
XII. Tetragnathidae				
56	<i>Leucauge decorata</i> (Blackwall, 1864)	+	-	+
57	<i>Tetragnatha viridorufa</i> Gravely, 1921	+	-	-
58	<i>Typhlosa striata</i> (Thorell, 1877)	+	-	+
XIII. Theridiidae				
59	<i>Nesticodes rufipes</i> (Lucas, 1846)	+	-	+
60	<i>Propostira quadrangulata</i> Simon, 1894	+	-	+
XIV. Thomisidae				
61	<i>Strigoplus netravati</i> Tikader, 1963	+	-	+
62	<i>Thomisus projectus</i> Tikader, 1960	+	-	+
63	<i>Thomisus pugilis</i> Stoliczka, 1869	+	-	+

M—Monsoon (June–November) | W—Winter (December–January) | S—Summer (March–May).

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RESULTS AND DISCUSSION

A total of 63 species of spiders belonging to 52 genera under 14 families were identified during this study (Table 1). The family with the highest number of species is Salticidae with 21 species (33%), followed by Araneidae with 17 species (27%). The families Philodromidae and Hersiliidae were recorded with only a single species (Table 2, Figure 2). A study of seasonal variation showed that more species (i.e., 59 species) were recorded during the monsoon followed by 26 species in winter and 16 species in summer (Figure 3). The sampled spiders belong to six functional groups (guilds) based on their foraging behavior (Uetz et al. 1999). The dominant guild was the stalkers with 24 species followed by orb-web builders (20 species), foliage runners (six species), ground runners (six species) and ambushers (five species). Scattered line weavers (two species) were the least represented among the feeding guilds from the study area (Figure 4).

The study recorded 63 species of spiders belonging to 14 families representing 22.95% of the total 61 families reported from India. The maximum number of species was collected during monsoon, clearly indicating the occurrence in response to the availability of prey populations (Bhat et al. 2013), mainly leaf feeding caterpillars and leaf miners infesting cashew in the flushing phase coinciding August–September. This is followed by winter with crop in full bloom during which the inflorescence pests are available in plenty. The availability of inflorescence pests from December to April has supported the spiders during winter and even in the summer season as evidenced from the diversity with 16 species during summer.

CONCLUSION

The present investigation documents the diversity of spiders associated with cashew representing a perennial agro-ecosystem. This data provides scope for further

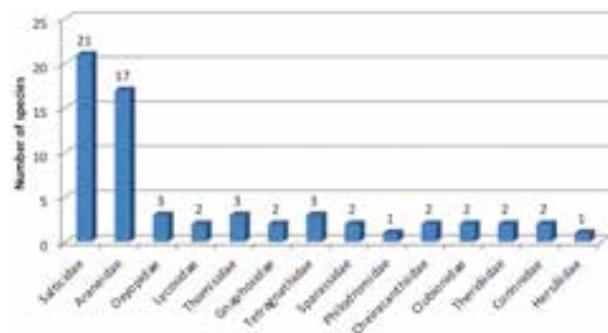


Figure 2. Family diversity of spiders in a cashew ecosystem.

Table 2. Families, genera, species, and functional guilds of spiders collected from cashew orchards of Cashew Research Station, Madakkathara, Kerala.

	Family	Number of genera	Number of species	Guild structure
1	Araneidae	11	17	Orb-web builders
2	Cheiracanthiidae	1	2	Foliage runners
3	Clubionidae	2	2	Foliage runners
4	Corinnidae	2	2	Ground runners
5	Gnaphosidae	2	2	Ground runners
6	Hersiliidae	1	1	Ambushers
7	Lycosidae	2	2	Ground runners
8	Oxyopidae	1	3	Stalkers
9	Philodromidae	1	1	Ambushers
10	Salticidae	20	21	Stalkers
11	Sparassidae	2	2	Foliage runners
12	Tetragnathidae	3	3	Orb-web builders
13	Theridiidae	2	2	Scattered line weavers
14	Thomisidae	2	3	Ambushers
	Total	52	63	

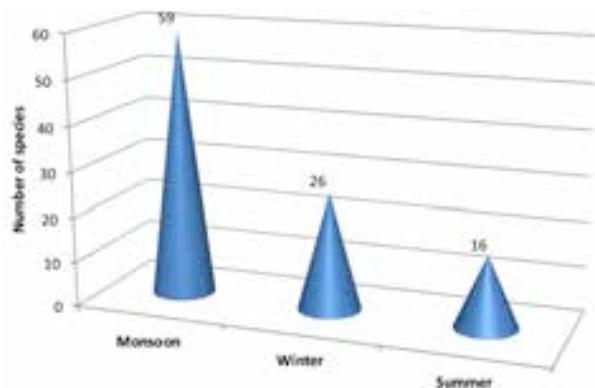


Figure 3. Species diversity of spiders in a cashew ecosystem during different seasons.

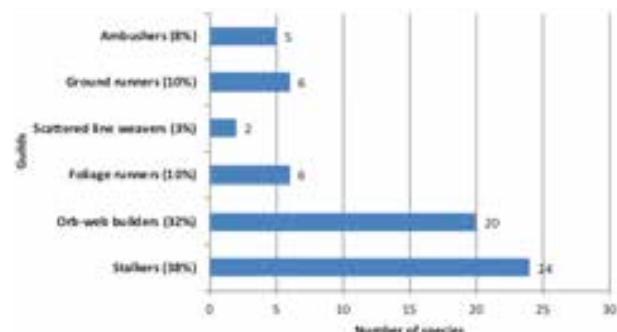


Figure 4. Guild-wise distribution of species of spiders in a cashew ecosystem.



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Image 1. *Cyrtarachne raniceps* (Araneidae)

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Image 2. *Neoscona mukerjei* (Araneidae)

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Image 3. *Cheiracanthium melanostomum* (Chericanthiidae)

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Image 4. *Castaneira zetes* (Corinnidae)

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Image 5. *Oxyopes javanus* (Oxyopidae)

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Image 6. *Asemonea tenuipes* (Salticidae)

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Image 7. *Brettus cingulatus* (Salticidae)

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Image 8. *Epeus indicus* (Salticidae)

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Image 9. *Hyllus semicupreus* (Salticidae)

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Image 10. *Menemerus bivittatus* (Salticidae)

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Image 11. *Myrmaplata plataleoides* (Salticidae)

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Image 12. *Phintella vittata* (Salticidae)

Image 13. *Piranthus planolancis* (Salticidae)Image 14. *Telamonia dimidiata* (Salticidae)Image 15. *Olios milleti* (Sparassidae)Image 16. *Leucauge decorata* (Tetragnathidae)Image 17. *Thomisus projectus* (Thomisidae)Image 18. *Thomisus pugilis* (Thomisidae)

research on the relationship of spider fauna with other biotic factors in the background of bio-intensive pest management in cashew. Further studies could focus on the variation in the spider population with respect to sprayed and unsprayed orchards. In an era of organic crop production, a better understanding of natural pest-regulating factors would assure an ecosystem-oriented pest management and a safe harvest.

REFERENCES

Baba, Y.G., Y. Kusumoto & K. Tanaka (2018). Effects of agricultural practice and fine-scale landscape factors on spiders and a pest insect in Japanese rice paddy ecosystems. *Bio Control* 63: 265–275.

Beevi, P.S. & G.K. Mahapatro (2008). Species-spectrum and inter-relationship between ant and spider fauna in cashew agro-ecosystem. *Journal of Plantation Crops* 36(3): 375–381.

Bhat, P.S., K.K. Srikumar & T.N. Raviprasad (2013). Spider (Arachnida: Araneae), diversity, seasonality and status in cashew agro-ecosystem. *Indian Journal of Arachnology* 2 (2): 7–16.

Breene, R.G., R.L. Meagher & D.A. Dean (1993). Spiders (Araneae) and Ants (Hymenoptera: Formicidae) in Texas Sugarcane Fields. *The Florida Entomologist* 76: 645–650.

Caleb, J.T.D. & P.M. Sankaran (2020). Araneae of India. Version 2020, online at <http://www.indianspiders.in>. Accessed on 28 July 2020.

Choudhury, J.C.B. (1962). Preliminary investigation on the insect pests of cashew plants in Kerala. *Indian Forester* 88: 516–522.

Devasahayam, S. & C.P.R. Nair (1986). The tea mosquito bug, *Helopeltis antonii* Signoret on cashew in India. *Journal of Plantation Crops* 14: 1–10.

Kralj-Fiser, S. & M. Gregoric (2019). Spider welfare, pp.105–118. In: Carere, C. & J. Mather (eds.). *The Welfare of Invertebrate Animals*. Vol. 18. Springer, Cham, 248pp.

Marc, P., A. Canard & F. Ysnel (1999). Spiders (Araneae) useful for pest limitation and bioindication. *Agriculture, Ecosystems and Environment* 74: 229–273.

Raghavendra, N. (2001). Diversity of arboreal spiders in cashew orchards. M.Sc. Dissertation, Department of Applied Zoology, Mangalore University, 130pp.

Rajeshwaran, J.P., P. Duraimurugan & P.S. Shanmugam (2005). Role of spiders in agriculture and horticulture ecosystem. *Journal of Food, Agriculture and Environment* 3: 147–152.

Riechert, S.E. & L. Bishop (1990). Prey Control by an Assemblage of Generalist Predators: Spiders in a Garden Test System. *Ecology* 71: 1441–1450. <https://doi.org/10.2307/1938281>

Sundararaju, D. (1984). Studies on cashew pests and their natural enemies in Goa. *Journal of Plantation Crops* 12: 38–46.

Sundararaju, D. (2003). Record and cumulative effect of recommended insecticidal spray schedule on arthropod predatory fauna occurring on cashew. *The Cashew* 17(1): 30–33.

Uetz, G.W., J. Halaj & A.B. Cady (1999). Guild structure of spiders in major crops. *The Journal of Arachnology* 27: 270–280.

World Spider Catalog (2020). World Spider Catalog, Version 21.5. Natural History Museum Bern, online at <http://wsc.nmbe.ch>. Accessed on 11 July 2020.

Yang, H., Y. Peng, J. Tian, J. Wang, B. Wei, C. Xie & Z. Wang. (2018). Rice field spiders in China: A review of the literature. *Journal of Economic Entomology* 111(1): 53–64.





Clinical and pathological findings in a Dwarf Red Brocket *Mazama rufina* (Mammalia: Cetartiodactyla: Cervidae) attacked by dogs

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Abstract: Capture myopathy is a common fatal syndrome in wild ungulates resulting from anthropogenic stressful events such as the capture or transport of specimens. There are, however, few published data on this issue due to predator attacks. The present report describes for the first time the capture myopathy syndrome in a Dwarf Red Brocket *Mazama rufina* following dog *Canis familiaris* attack. Clinical signs included pale mucous with increase capillary refill time, tachycardia, tachypnea, hypertension, hypothermia, hypoglycemia, and red brown urine. Muscle tremors, ataxia, prostration, paralysis, and opisthotonus were progressively observed. Laboratory tests showed increased levels of cortisol, creatinine, creatine kinase, lactate dehydrogenase, and potassium; decreased blood urea nitrogen-creatinine ratio; and myoglobinuria. The animal died 72 hours after hospital admission. At necropsy, findings included injuries on both hindlimbs with edema, emphysema, and soft-friable texture in affected muscles, dark kidneys and brown urine in bladder. Histopathological exams were indicative of skeletal-cardiac muscle degenerative lesions and myoglobinuric nephrosis. Immuno-histochemistry revealed myoglobin depletion in degenerate muscles and myoglobin accumulation in renal tissues. We strongly recommend that treatment for capture myopathy be initiated when a wild ungulate is admitted with history of predator attack, since the syndrome may have already established. This report adds to the instances of negative impacts caused by domestic dogs on threatened wildlife species.

Keywords: Capture myopathy, exertional rhabdomyolysis, myoglobin depletion, myoglobinuric nephrosis, predator attacks, wild ungulates

The Dwarf Red Brocket *Mazama rufina* is a member of the order Cetartiodactyla, family Cervidae, native from montane forest and paramos at altitudes between 1,500–3,500 m of Colombia, Ecuador and Peru. Currently, however, the species is restricted to remnant forest patches and paramos, and population trend is decreasing. The IUCN Red List of Threatened species classifies it as Vulnerable due to habitat destruction, hunting and predation, including domestic dog *Canis familiaris* attacks (Lizcano & Alvarez 2016).

Domestic dogs are considered a potential threat to 15 threatened species of the order Cetartiodactyla, including the Dwarf Red Brocket *Mazama rufina* (Doherty et al. 2017). Specifically, in Ecuador, Zapata-Ríos & Branch (2016) have documented decreased abundance and altered activity patterns of this species where dogs were present. The real impacts of dogs on native species, however, are not currently recognized in Ecuador, and studies that identify threats to wildlife are needed (Zapata-Ríos & Branch 2018).

Capture myopathy, or exertional rhabdomyolysis,

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is a potentially fatal syndrome commonly documented in wild ungulates (Paterson 2014). The existing reports mainly describe cases attributed to stressful events such as captures or transport of specimens (Montané et al. 2002b; Hamidieh et al. 2011; Nuvoli et al. 2014; Zahid et al. 2018). Although interactions with domestic dogs contribute substantially to admissions of wild mammals at rescue centers around the world (Wimberger & Downs 2010; Loyd et al. 2017; Romero et al. 2019; Taylor-Brown et al. 2019), as far as we know, there are no published data on capture myopathy triggered by dog attacks.

This report describes the diagnosis of capture myopathy in a Dwarf Red Brocket attacked by dogs in an Ecuadorian mountain forest, based on the history, clinical signs, laboratory tests, gross necropsy, histopathology, and immuno-histochemistry findings.

CASE HISTORY

On 20 January 2019, an adult male Dwarf Red Brocket was found in a state of shock after dog attacks in a mountain forest of Pichincha, Ecuador. The specimen was transported to the wildlife hospital of the Universidad San Francisco de Quito (USFQ) for evaluation. No chemical restraint was required for the clinical examination as the patient was depressed. Blood and urine samples were collected for laboratory analysis.

Initial treatment included oxygen via facemask and fluid therapy with warmed lactated Ringer's solution (3.5ml/kg/hour) through a catheter placed in the cephalic vein. Additionally, a bolus of dextrose 50% was administered (1ml/kg intravenous once). Antibiotic treatment was also initiated with ceftriaxone (25mg/

kg intravenous twice a day) and metronidazole (15 mg/kg intravenous once a day). For analgesia, meloxicam (0.2 mg/kg intravenous once a day) was used. We also injected a prokinetic, metoclopramide (0.1 mg/kg intravenous once a day) and supplementation with selenium, phosphorus, and vitamins A, D & E (0.02ml/kg subcutaneous once) were administrated. The patient was then transferred to an isolation room to monitor the recovery. The patient died 72 hours after admission.

A complete necropsy was performed two hours later. Samples from the affected as well as apparently healthy muscles, heart, and kidneys were collected, fixed in 10% neutral buffered formalin. After seven days, we embedded the specimen in paraffin wax, and sections of 4µm were cut to be stained with hematoxylin and eosin for routine histopathology evaluation. In addition, immunohistochemical examination was performed on skeletal and cardiac muscles, and renal tissue sections using the protocol described by Herráez et al. (2013).

CLINICAL RESULTS

Upon admission, the Dwarf Red Brocket presented multiple penetrating fresh wounds in its hindlimbs muscles: gluteus, quadriceps, semimembranosus, and semitendinosus. Clinical examination revealed pale mucous membranes, increased capillary refill time, tachycardia, tachypnea, hypertension, hypothermia and hypoglycemia. Laboratory tests revealed increased levels of cortisol, creatinine, creatine kinase, lactate dehydrogenase, potassium, decreased blood-urea/nitrogen-creatinine ratio, and myoglobinuria (Table 1).

Muscle tremors, ataxia, prostration, paralysis and opisthotonus were progressively documented in the

Table 1. Biochemical values of a *Mazama rufina* (post dog attack blood samples). Normal range values for *Mazama temama* were obtained from the Zoological Information Management System database (Species 360 2018), with the exception of cortisol, which pertains to *Mazama gouazoubira* (Munerato et al. 2010).

Biochemical parameter	First sample (12h post-admission)	Second sample (72h post-admission)	Reference values ^a
AST (U/L)	3.9	7.8	47–174
BUN (mmol/L)	5.41	5.32	4.5–13.5
BUN/C (ratio)	6.3	1.2	16.6 (M)
CRE (µmol/L)	214.2	1109.7	53–184
CK (U/L)	1870	1085	72–725
K (mmol/L)	4.64	12.87	3.3–7.1
LDH (U/L)	ND	29818	366 (M)
COR (ng/ml)	73.2	25.69	10.04

AST—aspartate-aminotransferase | BUN—blood-urea-nitrogen | BUN/C—blood-urea nitrogen/creatinine | COR—cortisol | CRE—creatinine | CK—creatinine-kinase | K—potassium | LDH—lactate-dehydrogenase | M—mean | ND—not determined. ^a There are no published reference values for *Mazama rufina*, reference from *Mazama temama* and *Mazama gouazoubira* were used for this reason

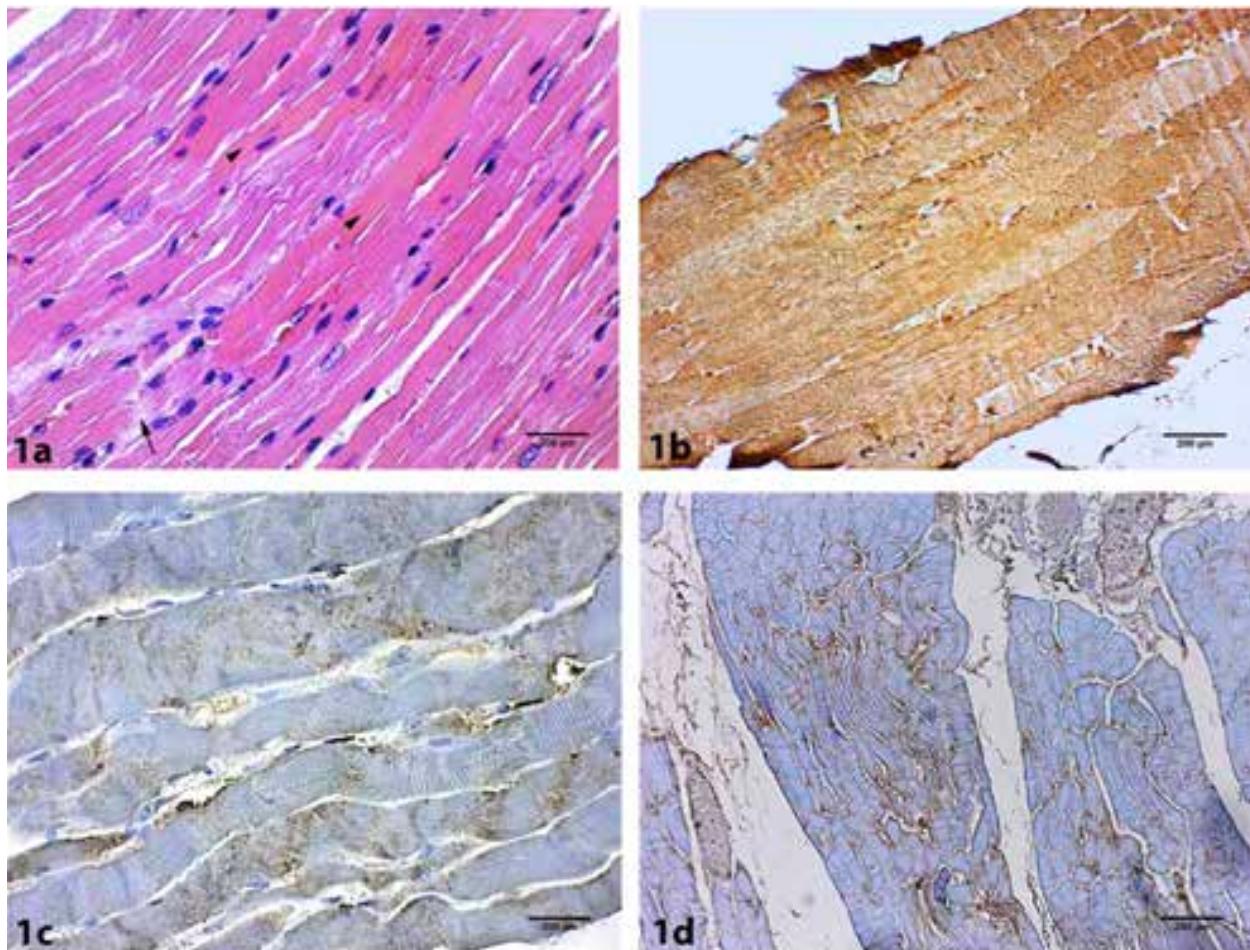


Image 1. Skeletal muscle: a—acute degenerative changes with loss of striation (arrowhead) and cytoplasmic fragmentation (arrow) (hematoxylin and eosin method) | b—positive control for myoglobin. Note the strong immuno-reaction and normal distribution in the tissue (avidin-biotin-peroxidase method) | c—depletion of myoglobin in the skeletal fibers and degeneration. Depletion denoted by the weak immuno-reaction (avidin-biotin-peroxidase method) | d—almost complete depletion of myoglobin in the affected tissue of *Mazama rufina* compared with the positive control (b). Accumulation of myoglobin is present in the extracellular space (avidin-biotin-peroxidase method).

patient. During the gross post-mortem examination, multiple lacerations and puncture injuries were observed macroscopically over the gluteus, quadriceps, semimembranosus, and semitendinosus muscles. The affected muscles were edematous and emphysematous with soft friable texture, but no gross lesions were evident in other muscles. Kidneys appeared swollen and dark, and the bladder contained brown urine. Microscopically, both affected and apparently normal muscles showed signs of degeneration (Image 1). Aseptic myositis and severe necrosis were seen in the skeletal muscles. Myocardial degeneration adjacent to the pericardium was also observed (Image 2). Kidneys showed signs of tubular and glomerular degeneration and necrosis, with intra-tubular and glomerular accumulation of eosinophilic proteinaceous material (Image 3). The immuno-histochemistry exams corroborated depletion

of myoglobin in degenerated muscles (Image 1) and presence of intra-tubular and glomerular myoglobin where eosinophilic proteinaceous material was present (Image 3).

DISCUSSION

The clinical signs detected in the present case are in agreement with those described as characteristic of capture myopathy in wild ungulates by Paterson (2014); however, although hyperthermia and hyperglycemia have been described after capture in White-tailed Deer *Odocoileus virginianus* (Boesch et al. 2011), our patient showed hypothermia and hypoglycemia upon examination. Decrease in body temperature and blood glucose has been documented during transport (Montané et al. 2002a) and one hour after capture (Montané et al. 2007) in Roe Deer *Capreolus*

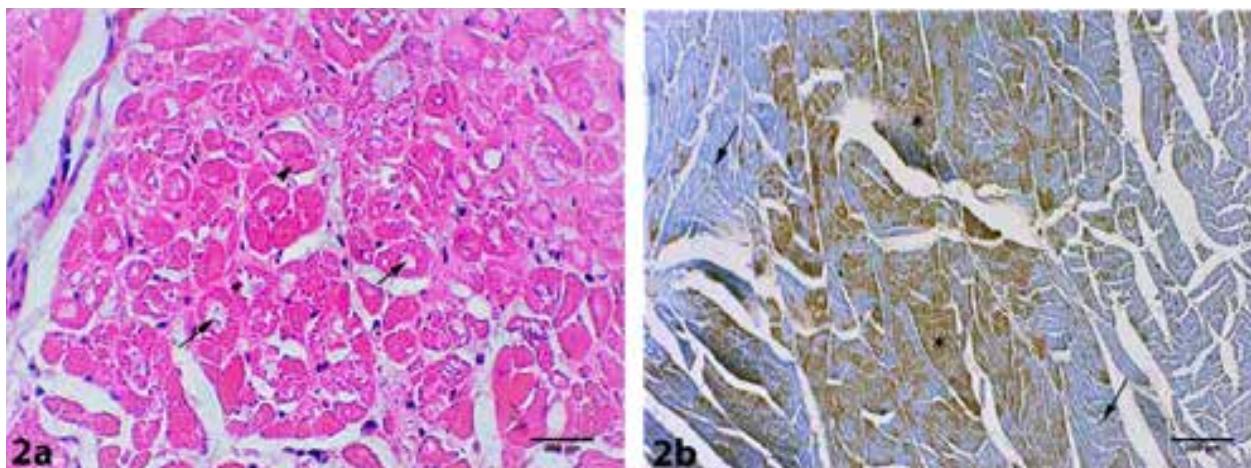


Image 2. Heart: a—myocardial degeneration adjacent to the pericardium, with perinuclear vacuolation (arrows). Note some fibers are hypereosinophilic and others are pale, necrosis is also seen (arrowhead) (hematoxylin and eosin method) | b—less injured fibers (asterisks) have a homogenous reaction for myoglobin, while injured fibers do not react to myoglobin (arrows) (avidin-biotin-peroxidase method).

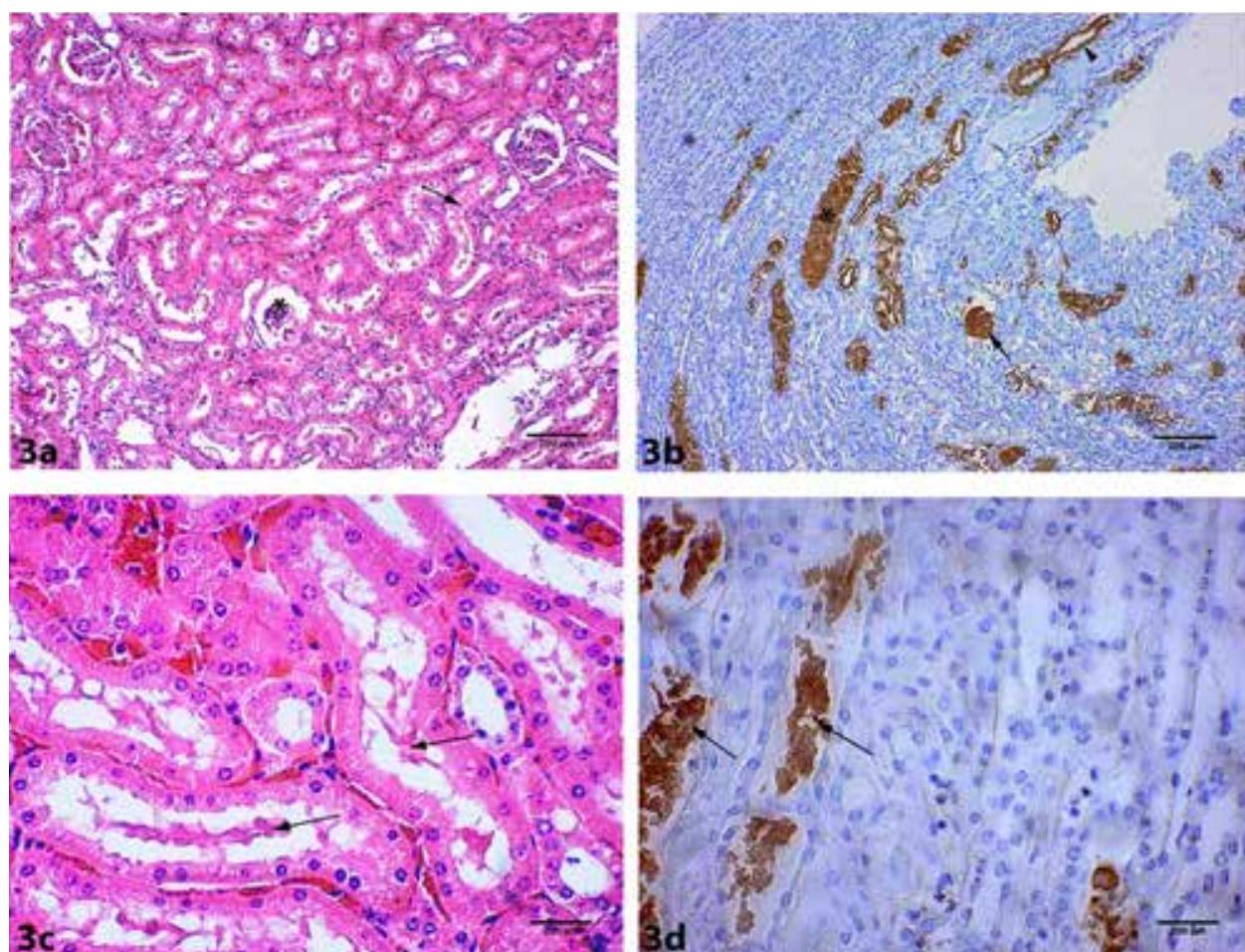


Image 3. Kidney: a—swelling, congestion and degenerative changes with necrosis of the glomerulus (asterisk) and accumulation of eosinophilic proteinaceous material (arrow) (hematoxylin and eosin method) | b—strong immuno-reaction for myoglobin in veins (asterisk), glomerulus (arrow) and tubules (arrowhead) (avidin-biotin-peroxidase method) | c—accumulation of eosinophilic proteinaceous material in the tubules (arrows) (hematoxylin and eosin method) | d—immuno-reaction for myoglobin in the tubules (arrows), where the eosinophilic proteinaceous material was present in (c) (avidin-biotin-peroxidase method).

capreolus. The Dwarf Red Brocket was found just after the dog attacks but the transport to the hospital took approximately three hours, therefore, the low values could be due to the delayed measurement. In fact, 24 hours later the patient reached normal levels of body temperature and blood glucose.

Capture myopathy is characterized by muscle injury resulting in release of myofiber content into the bloodstream. The diagnosis is based primarily on the findings of elevated serum creatine kinase levels and myoglobinuria (Nance & Mammen 2015). The early increase in serum potassium (Bagley et al. 2007) and creatinine (Zimmerman & Shen 2013) levels are also a consequence of muscle injury. These alterations have been described in wild ungulates and are consistent with our findings (Montané et al. 2002b, Nuvoli et al. 2014).

Muscle damage in wild ungulates is also responsible for increase in enzymes lactate dehydrogenase and aspartate aminotransferase (Montané et al. 2007; Casas-Díaz et al. 2010). The patient's laboratory tests corroborated the increase in lactate dehydrogenase, but not that of aspartate aminotransferase. In this context, metronidazole can cause a false decrease in readings of aspartate aminotransferase when ultraviolet absorbance measurement is used (Plumb 2008). The Dwarf Red Brocket received metronidazole as antibiotic, and aspartate aminotransferase concentration was measured by ultraviolet absorbance (Chemray 120 Vet, Rayto Life and Analytical Sciences, Shenzhen 518107, China), which could explain the low aspartate aminotransferase values.

On the other hand, increase in serum cortisol concentration has also been observed in wild ungulates subject to stressful management events (Arzamendia et al. 2010; Carmanchahi et al. 2011; Nuvoli et al. 2014). There are no cortisol values reported in a Dwarf Red Brocket, but the values detected in the present report are higher than previously reported for another species in this genus (Munerato et al. 2010), corroborating that serum cortisol can be used as a stress indicator in the species.

Finally, macroscopic, histopathological and immunohistochemical findings of muscles and kidney necrosis have been previously described by Nuvoli et al. (2014) in Red Deer *Cervus elaphus*, and suggest an acute renal failure associated with myoglobinuric nephrosis as a consequence of capture myopathy.

We have described for the first time a fatal myopathy syndrome in a Dwarf Red Brocket attacked by dogs based on history, physical examination, clinical signs, laboratory tests, gross necropsy, histopathology

and immuno-histochemical findings. We recommend that capture myopathy should be considered as a complicating factor in the diagnosis and treatment of wild ungulates after predatory attacks. This report also adds to the list of negative impacts on wildlife caused by domestic dogs.

REFERENCES

Arzamendia, Y., C. Bonacic & B. Vilá (2010). Behavioural and physiological consequences of capture for shearing of vicuñas in Argentina. *Applied Animal Behaviour Science* 125(3-4): 163–170. <https://doi.org/10.1016/j.applanim.2010.04.013>

Bagley, W.H., H. Yang & K.H. Shah (2007). Rhabdomyolysis. *Internal and Emergency Medicine* 2(3): 210–218. <https://doi.org/10.1007/s11739-007-0060-8>

Boesch, J.M., J.R. Boulanger, P.D. Curtis, H.N. Erb, J.W. Ludders, M.S. Kraus & R.D. Gleed (2011). Biochemical variables in free-ranging white-tailed deer (*Odocoileus virginianus*) after chemical immobilization in clover traps or via ground-darting. *Journal of Zoo and Wildlife Medicine* 42(1): 18–28. <https://doi.org/10.1638/2009-0146.1>

Carmanchahi, P.D., R. Ovejero, C. Marull, G.C. López, N. Schroeder, G.A. Jahn, A.J. Novaro & G.M. Somoza (2011). Physiological response of wild guanacos to capture for live shearing. *Wildlife Research* 38(1): 61–68. <https://doi.org/10.1071/WR10170>

Casas-Díaz, E., I. Marco, J.R. López-Olvera, G. Mentaberre & S. Lavín (2010). Use of acepromazine for stress control in Spanish ibex (*Capra pyrenaica*) captured by drive-net. *The Veterinary Journal* 183(3): 332–336. <https://doi.org/10.1016/j.tvjl.2008.11.003>

Doherty, T.S., C.R. Dickman, A.S. Glen, T.M. Newsome, D.G. Nimmo, E.G. Ritchie, A.T. Vanak & A.J. Wirsing (2017). The global impacts of domestic dogs on threatened vertebrates. *Biological Conservation* 210: 56–59. <https://doi.org/10.1016/j.biocon.2017.04.007>

Hamidieh, H., A. Alhami & J. Mirian (2011). Capture myopathy in red deer and wild goat. *Archives of Razi Institute* 66(2): 147–149.

Herráez, P., A.E. de Los Monteros, A. Fernández, J.F. Edwards, S. Sacchini & E. Sierra (2013). Capture myopathy in live-stranded cetaceans. *The Veterinary Journal* 196(2): 181–188. <https://doi.org/10.1016/j.tvjl.2012.09.021>

Lizcano, D. & S.J. Alvarez (2016). *Mazama rufina*. In: IUCN Red List of Threatened Species 2016: e.T12914A22165586. Downloaded 12 on November 2019. <https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T12914A22165586.en>

Loyd, K.A.T., S.M. Hernandez & D.L. McRuer (2017). The role of domestic cats in the admission of injured wildlife at rehabilitation and rescue centers. *Wildlife Society Bulletin* 41(1): 55–61. <https://doi.org/10.1002/wsb.737>

Montané, J., I. Marco, J. López-Olvera, X. Manteca & S. Lavín (2002a). Transport stress in roe deer (*Capreolus capreolus*): effect of a short-acting antipsychotic. *Animal Welfare* 11(4): 405–418.

Montané, J., I. Marco, J.R. Lopez-Olvera, L. Rossi, X. Manteca & S. Lavín (2007). Effect of acepromazine on the signs of capture stress in captive and free-ranging Roe Deer (*Capreolus capreolus*). *Veterinary Record* 160(21): 730–738. <https://doi.org/10.1136/vr.160.21.730>

Montané, J., I. Marco, X. Manteca, J. López & S. Lavín (2002b). Delayed acute capture myopathy in three roe deer. *Journal of Veterinary Medicine Series A* 49(2): 93–98. <https://doi.org/10.1046/j.1439-0442.2002.jv409.x>

Munerato, M.S., Duarte, J.M.B., G.T. Pereira & J.A. Marques (2010). Effects of physical and chemical immobilization on hematologic and biochemical variables in captive brown brocket deer (*Mazama gouazoubira*). *Veterinary Clinical Pathology* 39(4): 454–463. <https://doi.org/10.1111/j.1939-165X.2010.00264.x>

Nance, J.R. & A.L. Mammen (2015). Diagnostic evaluation of

rhabdomyolysis. *Muscle & Nerve* 51(6): 793–810. <https://doi.org/10.1002/mus.24606>

Nuvoli, S., G.P. Burrai, F. Secci, N. Columbano, G.M. Careddu, L. Mandas, M.A. Sanna, S. Pirino & E. Antufermo (2014). Capture myopathy in a Corsican red deer *Cervus elaphus corsicanus* (Ungulata: Cervidae). *Italian Journal of Zoology* 81(3): 457–462. <https://doi.org/10.1080/11250003.2014.942712>

Paterson, J. (2014). Capture myopathy, pp. 171–179. In: West, G., D. Heard & N. Caulkett (eds). *Zoo Animal and Wildlife Immobilization and Anesthesia. 1st Edition*. John Wiley and Sons, Ames, Iowa.

Plumb, D.C. (2008). *Veterinary Drug Handbook. 6th Edition*. Blackwell Publishing, South State Avenue, Iowa, 611pp.

Romero, F., A. Espinoza, N. Sallaberry-Pincheira & C. Napolitano (2019). A five-year retrospective study on patterns of casuistry and insights on the current status of wildlife rescue and rehabilitation centers in Chile. *Revista Chilena de Historia Natural* 92(1): 6. <https://doi.org/10.1186/s40693-019-0086-0>

Species 360 (2018). Zoological Information Management System. Downloaded on 12 November 2019.

Taylor-Brown, A., R. Booth, A. Gillett, E. Mealy, S.M. Ogbourne, A. Polkinghorne & G.C. Conroy (2019). The impact of human activities on Australian wildlife. *PLoS One* 14(1): e0206958. <https://doi.org/10.1371/journal.pone.0206958>

Wimberger, K. & C.T. Downs (2010). Annual intake trends of a large urban animal rehabilitation centre in South Africa: a case study. *Animal Welfare* 19(4): 501.

Zahid, U. N., L.M. Dar, U. Amin, S.A. Shah, R.Y. Naqash, D.M. Makhdoomi, S.A. Kamil & I. Suhail (2018). Delayed peracute capture myopathy in a Himalayan Ibex *Capra sibirica* (Mammalia: Cetartiodactyla: Bovidae). *Journal of Threatened Taxa* 10(10): 12363–12367. <https://doi.org/10.11609/jott.3899.10.10.12363-12367>

Zapata-Ríos, G. & L.C. Branch (2016). Altered activity patterns and reduced abundance of native mammals in sites with feral dogs in the high Andes. *Biology Conservation* 193: 9–16. <https://doi.org/10.1016/j.biocon.2015.10.016>

Zapata-Ríos, G. & L.C. Branch (2018). Mammalian carnivore occupancy is inversely related to presence of domestic dogs in the high Andes of Ecuador. *PLoS one* 13(2): e0192346. <https://doi.org/10.1371/journal.pone.0192346>

Zimmerman, J.L. & M.C. Shen (2013). Rhabdomyolysis. *Chest* 144(3): 1058–1065. <https://doi.org/10.1378/chest.12-2016>





Indigenous uses and traditional practices of endemic and threatened Chilgoza Pine *Pinus gerardiana* Wall. ex D.Don by tribal communities in Kinnaur District, Himachal Pradesh, northwestern Himalaya

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Abstract: *Pinus gerardiana* is an endemic and threatened pine of northwestern Himalaya. It is the only conifer in India which is traded for its nuts. In addition to subsidiary source of income to Kinnaura tribes, it is an important part of ecology, traditions, and culture of Kinnaur District of Himachal Pradesh. Kinnaura are one of the largest ethnic groups of Himachal Pradesh famous for their own unique traditions, culture, and lifestyle. In view of this, the present study was conducted to document the indigenous uses and traditional practices of *Pinus gerardiana* (Chilgoza Pine) by Kinnaura tribes of Himachal Pradesh. At present, destructive harvesting practices of collection of Chilgoza nuts, fuelwood, torchwood, timber, and needles of Chilgoza Pine is not only causing serious damage to trees but also affecting its natural regeneration and future crop production. Thus, this continuous loss of Chilgoza Pine will affect the livelihood of the tribal communities and ecosystem of the area in near future. Hence, population assessment, ecological niche modeling, awareness programmes, and sustainable harvesting of cones are suggested for its conservation.

Keywords: Endemic, indigenous uses, threatened, tribal communities.

The Himalayan region is one of the recognized mega biodiversity hotspots (Johnsingh et al. 1998; Mittermeier et al. 2004) as it is known for rich, representative, natural, unique and socio-economically

important species (Samant et al. 1998, 2007). Among the conifers of Himalayan region, *Pinus gerardiana* is very popular. This species is native and endemic to the northwestern Himalaya (Kumar et al. 2013) and falls under the threatened category. It belongs to the family Pinaceae and is a well-established multipurpose species in the area of occurrence. This species was discovered by British Army Officer Captain Patrick Gerard in 1932 (Farjon 1984) and commonly known as Chilgoza or Neoza and also known as 'Ree' in Kinnaur. Chilgoza Pine is a very slow growing tree and its average life span is 150–200 years. It is a small to medium size tree up to 25m tall. Chilgoza Pine is the only conifer in India, which is traded for its edible nuts which are rich source of carbohydrate (21.6%), proteins (15.9%), fats (49.9%), moisture content (7.5%), fiber (2.2%), and mineral matter (2.90%) (Anonymous 1969). The species has restricted distribution in India and is confined to hilly tracts in dry temperate region of northwestern Himalaya at 1,600–3,300 m and also extends in the mountains of

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eastern Afghanistan and Pakistan. In Himachal Pradesh, it mainly occurs in Kinnaur District and Pangi divisions and Threta range of Chamba Forest Division. In Kinnaur District Chilgoza is found only in Morang, Kalpa, Kilba, and Pooh forest ranges of Kinnaur forest division. It also extends westwards to Kishtwar District of Jammu & Kashmir union territory. Chilgoza Pine is found associated with *Cedrus deodara*, *Pinus wallichiana*, *Juniperus polycarpos*, *Fraxinus xanthoxyloides* at higher elevations and with *Quercus ilex*, *Olea cuspidata*, and *Alnus nitida* at lower elevations. The undergrowth in Chilgoza forest are represented by *Daphne oleoides*, *Lonicera quinquelocularis*, *Lonicera hypoleuca*, *Ephedra gerardiana*, *Rosa webbiana*, and *Artemisia maritima*. In Kinnaur District, the species replaces *Pinus roxburghii* (Cheel) near Wangtu and continues along the Sutlej Valley up to Dubling, Ropa, and up to Lambar in Tidong Valley.

Seeds of Chilgoza are the only commercial edible pine nuts available in India and accordingly major source of its indigenous supply is Kinnaur District of Himachal Pradesh. Small quantities of the nut, however, are also collected from Pangi Valley (Chamba District) of Himachal Pradesh besides some parts of Jammu & Kashmir union territory. Out of total 2,060ha in Himachal Pradesh, about 2,040ha falls in Kinnaur Division and a small portion (20ha) in Chamba District (Troup 1921), which is the main source of Chilgoza nuts in the country. Being in short supply there is a heavy demand of Neozza nuts (sold as dry fruit) and 80–100 tons per year Chilgoza reaching the Indian market comes from Kinnaur District. The approximate export value of its annual produce is around INR 180 million (Negi 2002). On an average, one tree yields about 7.4kg of nuts per year. Income from the sale of Chilgoza seeds contributes to the annual income of many poor tribal families of Kinnaur, usually in the form of supplementary income. For some families, however, this species is the main source of income. Overall, in the zone, the share of the financial income due to Chilgoza in the total financial income of the households varies 5–25%; this share can exceed 25% for some household (Peltier & Dauffy 2009). Chilgoza Pine are mostly located in natural forests, and are not cultivated by local people because of its slow growth and takes long time to produce commercial nuts. But, due to the dependency of local people, it has been classified as social forestry species in spite of being a conifer (Sehgal & Khosla 1986). In Afghanistan, the government promotes community-based conservation programmes to protect and conserve the Chilgoza Pine and also to enhance the livelihood of local communities (MAIL 2012). The

area under Chilgoza forest has already shrunk to about 2,000ha in Himachal Pradesh because each and every cone is lopped except those which are out of reach and left on the trees by the tribal communities (Tandon 1963; Singh et al. 1973; Sehgal & Sharma 1989), which not only affect natural regeneration, but also future crop production.

Previously, Chilgoza of Kinnaur was not so intensively exploited for nuts, because Chilgoza forest of Afghanistan and Baluchistan used to meet most of the country's requirement before partition (Tondon 1963). In addition to this, in the past, due to the concern for wild animals and natural regeneration, the tribal communities kept some cones on trees to allow a small portion of seeds to reach the ground and regenerate. In spite of difficult ecological conditions, the forests of the species are able to regenerate. During the last five decades, the network of roads has allowed horticulture development in Kinnaur due to which tribal communities have started considering Chilgoza as subsidiary source of income. The village communities sell the nuts harvest contracts to private contractors who employ contractual workers for harvesting Chilgoza cones. They cut many branches and collect all cones without the concern of future cone production and natural regeneration. Since, there is no restriction on the quantity of Chilgoza nuts collection and the tribal communities harvest almost every mature cone resulting in poor regeneration. Due to lack of regeneration, young size classes of trees are scarce or entirely lacking, while mature and over mature trees predominating in its natural habitat. Today, due to over exploitation and habitat destruction, reduction in Chilgoza Pine forests is growing concern throughout the range of distribution. Because of its dwindling population, this species is also listed in the Near Threatened category as per IUCN threat category (Farjon 2013). The studies carried out so far are related to ecology, regeneration and insect pest problems of Chilgoza Pine, however, none of the studies have investigated and documented the traditional uses of Chilgoza Pine. Therefore, the present study was carried out to document the indigenous knowledge and traditional practices of Chilgoza Pine in Kinnaur District of Himachal Pradesh.

MATERIAL AND METHODS

Study Area

Kinnaur is one of the tribal districts of Himachal Pradesh ($31^{\circ}55'50''$ – $32^{\circ}05'15''$ N & $77^{\circ}45'00''$ – $79^{\circ}00'35''$ E) with total geographical area $6,400 \text{ km}^2$ (Figure 1). There are five tehsils in district Kinnaur, namely Kalpa,

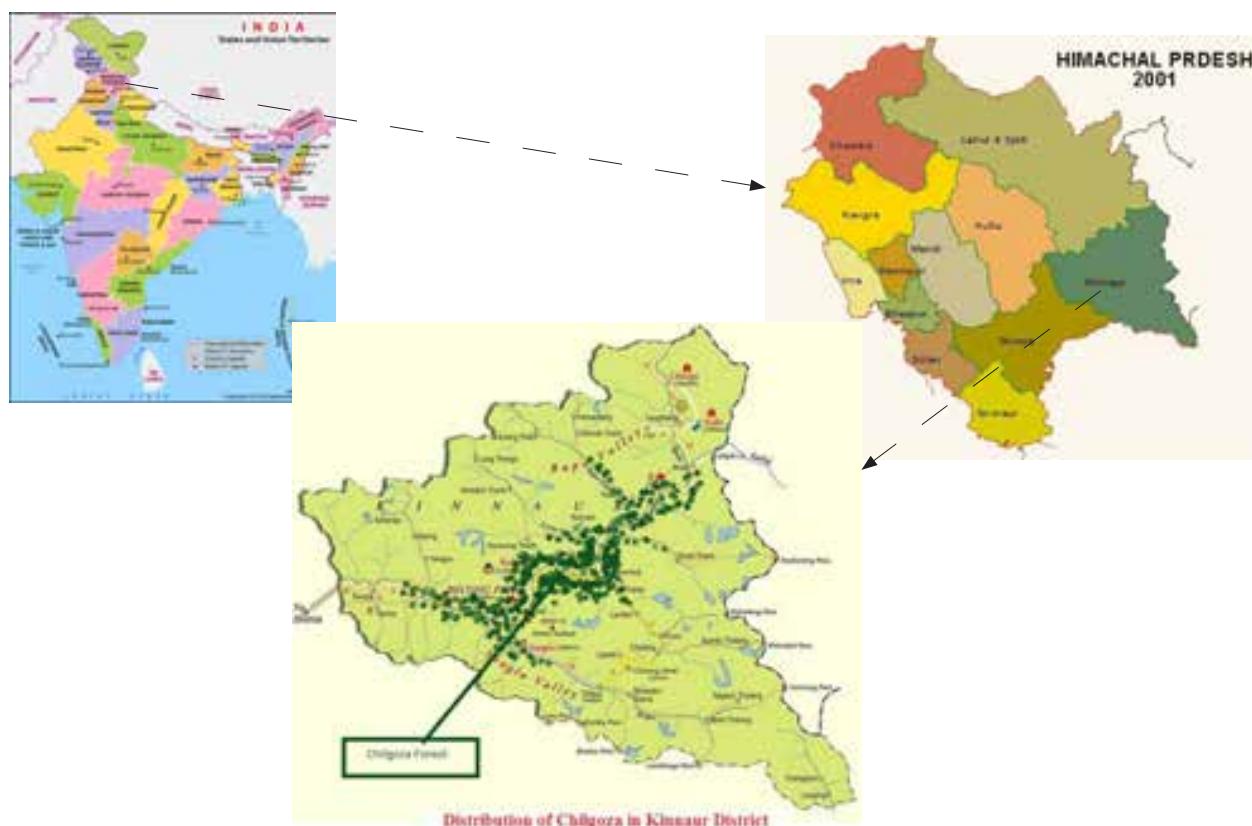


Figure 1. Kinnaur District in Himachal Pradesh and India.

Sangla, Morang, Pooh, and Nichar. The major soil types of the region are sandy loam and clayey loam. The climate of the region is dry temperate sub-alpine and alpine types, and the region is dominated by conifers and broadleaved species i.e., *Cedrus deodara*, *Pinus wallichiana*, *P. gerardiana*, *Alnus nitida*, *Acer caesium*, *Picea smithiana*, *Fraxinus xanthoxyloides*, *Betula utilis*, *Taxus wallichiana*, *Abies pindrow*, *A. spectabilis*, *Quercus semecarpifolia*, and *Q. ilex*, *Juniperus polycarpos* in dry temperate and sub-alpine zones and medicinal and aromatic plants and other herbaceous species in alpine region.

Methods

Present study is based on extensive and intensive surveys conducted from 2017 to 2019 in the representative 16 tribal villages namely Rarang, Ribba, Rispa, Jangi, Moorang, Thangi, Lippa (Morang range), Nesang, Sunnam, Labrang (Pooh range), Pangi, Tangling, Barang, Telangi (Kalpa range), and Kilba, Urni (Kilba range) of Kinnaur forest division of district Kinnaur. From each village, 3–8 knowledgeable persons were interviewed and the names and other details of persons interviewed are given in Table 1. The informants included

men, women, youth and elders between the age of 29 and 78 years. These knowledgeable local persons were interviewed through semi-structured questionnaire. The questions were mainly for the information generation on indigenous uses and traditional practice of Chilgoza by Kinnaura tribal communities. For information generation, questions related to the Chilgoza were asked in local dialect and Hindi as well. Details of the indigenous uses and traditional practices of Chilgoza have been given under results. Plant specimens were also collected, dried by using routine botanical collection and herbarium techniques, identified and preserved (Jain & Rao 1997). Plant species voucher specimens (0012-18, 0013-18, 0014-18, 0015-18, 0016-18) have been kept in the herbarium of Himalayan Forest Research Institute, Shimla, Himachal Pradesh, India. The information was compiled, analyzed and documented.

RESULTS AND DISCUSSION

Pinus gerardiana is an important conifer tree mainly occurs in dry higher and trans-Himalayan tract of district Kinnaur, Himachal Pradesh. Kinnaura tribes of district Kinnaur collect its nuts due to their economic and socio-cultural importance. Sale of the nuts contributes to the

annual income of most of the families of Kinnaur District and contributes significantly in fulfilling daily livelihood needs. The total production of Chilgoza in Kinnaur is 100–300 ton/year and approximate export value of its annual produce is around INR 150–450 million depending upon crop production (Peltier & Duffy 2009). In addition to nuts, other parts of this valuable tree are also used by the tribal communities in various household needs and to perform various religious and socio-cultural functions. The details of indigenous uses are given below.

1. Timber: The wood of Chilgoza pine is hard, tough, durable and used as timber. It is used for the construction of houses especially for roof thatching, flooring and central poles of kitchen and stairs, and preparation of wooden boxes which is used for storing fruits, grains, and other items.

2. Fuel wood: The wood is used as fuel wood throughout the year. After the seed extraction, dried cones are also used as fuel wood during winter season.

3. Torch wood: The wooden flakes of Chilgoza Pine are used as traditional torch wood known as 'Sang' (Image 1D). It is used for burning fire, night movements and irrigating fields during night. A special torchwood dance known as 'Sangpuling chasham' is also performed by the villagers of Ribba village on the occasion of festival of flowers known as 'Fulaich' where the festival is celebrated at district level. Villagers collect long resinous wooden flakes and arrange them into bundles by tying with twigs of *Indigofera heterantha* and in the midnight, they burn the top of the bundles and dance (Image 1G).

4. Agriculture implements: Logs are hard, resinous, water proof and immune to fungal attack and used for the preparation of agricultural implements, i.e., plough and yoke locally known as 'tal' and 'kol'. In older time, these were used for ploughing the agricultural fields, now few local farmers use it. Wood is also used as drains for irrigation purposes in agricultural fields and construction of small bridges over streams and nullahs. The small poles and branches are used for the fencing of agricultural and horticultural fields and overhead shed formation for cultivation of grapes and storage houses of dried grasses.

5. Household items: The wood is used for the preparation of traditional mortar and pestle known as 'kaning' and 'musling' and used for mashing grains, seeds, etc. In Kinnaur District, it is traditionally used for the extraction of oil from Apricot nuts, Walnut, and Chilgoza nuts. The small pieces of Chilgoza wood is used in preparation of 'takli' locally known as 'pankt' or 'koru pankt' which is used for spinning of wool by the tribal

communities during winter (Image 1E, F).

6. Medicine: Resin of Chilgoza Pine mixed with mustard oil is used to cure arthritis and swellings. Resin is used to cure cracked feet. The nuts are eaten raw as well as in roasted form to cure physical weakness, cough and cold. Seed oil is used to cure, body pain, eye problem, wounds, and ulcers.

7. Traditional food and beverage: The Chilgoza nuts are used as one of the ingredients for preparation of salted tea locally known as 'Namkeen cha or Chha cha'. After removal of seed coat, nuts are mixed with Walnut *Juglans regia* and kernels of Apricot *Prunus armeniaca*. The mixture is ground to make paste, and is used in preparation of nutritious salted tea (Image 1C). Nuts are also used as dry fruit in halwa and kheer preparation in festival occasions especially in Sazo festival (Image 1B).

8. Detergent: Previously, ashes of Chilgoza cones were used for washing cloths and kitchen utensils by the tribal communities.

9. Farmyard manure: The dried needles are collected by tribal communities from forest in large quantities during the month of September–October and used in the agricultural fields and orchards for mulching to retain moisture, protect top soil from erosion and improve soil fertility (Image 1A). The needles also used as bedding material in cowsheds of the cattle and decomposed needles are removed from the cowsheds and subsequently used as farmyard manure in agricultural fields and orchards. Tribal communities also collect cones and spread them in their agricultural fields. The decomposed cones help to soften the hard soil.

10. Economic use: Chilgoza nuts play a significant role in improving livelihood of the tribal communities. In the whole distribution area of Chilgoza in Kinnaur District every household of the tribal communities collect the Chilgoza in the months of September–October from adjoining forest areas. They earn money INR 1,500–1,800/ kg by selling the Chilgoza nuts locally and use it for fulfilling their daily household needs.

11. Cultural uses: Chilgoza is an important part of a marriage ceremony in Kinnaur District for generations. Seeds are used in preparation of garlands known as 'ree maling' which is used in performing various marriage rituals, and also offered to local deities, brides, grooms, family members, relatives and guests during wedding ceremonies as a token of respect and love. It is also used in various death ceremonies and offered to dead bodies before funeral as a symbol of homage to the departed soul. The branches of the Chilgoza Pine are also used for the preparation of welcome gate during the visit of dignitaries to the villages and marriage ceremonies. The

Table 1. List of Kinnaur tribes interviewed in Kinnaur District of Himachal Pradesh.

	Name	Age	Gender	Village	Forest range	Altitude (m); latitude & longitude
1	Chering Pur	78	M	Rarang	Morang	2,500; 31°36'06.58"N & 78°21'08.32"E
2	Upkari Devi	65	F	Rarang		
3	Jai Nand	42	M	Rarang		
4	Kabeer Singh	55	M	Rarang		
5	PushapLata	45	F	Rarang		
6	Maya Devi	49	F	Rarang		
7	Rajeev Rathore	34	M	Rispa	Morang	2,300; 31°34'47.6"N & 78°23'16.2"E
8	Shiv Ram	53	M	Rispa		
9	Lajvanti	47	F	Rispa		
10	Sharda Devi	47	F	Rispa		
11	Raj Bhagat	55	M	Rispa		
12	Harnam Singh	67	M	Ribba		
13	Abhishek Negi	31	M	Ribba	Morang	2,400; 31°35'2.0"N & 78°21'50.0"E
14	Bhag Narayan	66	M	Ribba		
15	Dan Bhajan	55	M	Ribba		
16	Suminder Singh	59	M	Ribba		
17	Hans Raj	38	M	Ribba		
18	Yogita	51	F	Ribba		
19	Narayan Singh	34	M	Ribba	Morang	2700; 31°36'12.2"N & 78°25'40.6"E
20	Rattan Singh	36	M	Jangi		
21	Rajinder Singh	44	M	Jangi		
22	Tenzin Zangmo	49	F	Jangi		
23	ChetanDorjee	55	M	Jangi		
24	Priyakumari	45	F	Jangi		
25	Sita Devi	52	F	Jangi	Morang	2,700; 31°39'19.8"N & 78°23'11.1"E
26	Chetan Dorjee	55	M	Morang		
27	Dinesh Kumar	44	M	Morang		
28	Ghyan Kiran Devi	67	F	Morang		
29	Promila Kumari	35	F	Morang		
30	Chherring Palden	58	M	Morang		
31	Prem Singh	67	M	Morang	Morang	2,800; 31°33'58.4"N & 78°28'11.6"E
32	Mal Jeet	58	M	Morang		
33	Kalyan Singh	66	M	Morang		
34	Padam Chand	46	M	Thangi		
35	Daleep Singh Negi	65	M	Thangi		
36	Partiba	62	F	Thangi		
37	Indu	48	F	Thangi	Morang	2,700; 31°39'27.15"N & 78°22'57.84"E
38	Ashok	62	M	Thangi		
39	Chering Tashi	43	M	Lippa		
40	Geeta Ram	46	M	Lippa		
41	Indravati	39	F	Lippa		
42	ShyamLal	56	M	Lippa		
43	Sher Singh	60	M	Lippa	Pooh	2,700; 31°39'04.4"N & 78°30'13.4"E
44	GyalchenZangmo	62	F	Lippa		
45	Bogan Singh	44	M	Nesang		
46	Jaglender Singh	46	M	Nesang		
47	Susheel Kumar	40	M	Nesang		
48	Kamal Singh	50	M	Nesang		
49	Raghunath Singh	57	M	Nesang		

	Name	Age	Gender	Village	Forest range	Altitude (m); latitude & longitude
50	Padam Bhutil	55	F	Sunnam	Pooh	2,800; 31°45'36.26"N & 78°27'58.82"E
51	Prem Lal	45	M	Sunnam		
52	Jeeta Singh	42	M	Sunnam		
53	Terseem	43	M	Sunnam		
54	Tulsi Negi	55	M	Sunnam		
55	Rajeev Negi	39	M	Labrang	Pooh	2,900; 31°45'09.28"N & 78°37'55.8"E
56	Badri Sen	48	M			
57	Jagat Negi	49	M			
58	Sant Ram	29	M	Pangi	Kalpa	2,300; 31°35'19.4"N & 78°16'27.8"E
59	Dev Bhagat	29	M	Pangi		
60	Rajeshwari	50	F	Pangi		
61	Sant Ram	45	M	Pangi		
62	Durga Singh	49	M	Pangi		
63	Radha	34	F	Pangi		
64	Rajender Singh	36	M	Pangi		
65	Premi Devi	55	F	Tangling	Kalpa	2,100; 31°31'35.4"N & 78°16'55.2"E
66	Balbir Singh	61	M	Tangling		
67	Laxman Singh	40	M	Tangling		
68	Gyatzin	38	M	Barang	Kalpa	2,200; 31°30'42.48"N & 78°15'59.46"E
69	Pyarmani	37	F	Barang		
70	Parmila	60	F	Barang		
71	RadhaPyari	50	F	Barang		
72	Basanti Devi	54	F	Telangi	Kalpa	2,000; 31°31'33.77"N & 78°16'53.65"E
73	Vikram	37	M	Telangi		
74	Samat Bahadur	59	M	Telangi		
75	Jiu Chand	55	M	Kilba	Kilba	1,900; 31°30'44.5"N & 78°09'38.1"E
76	Nandesh Kumar	34	M	Kilba		
77	G.S.Negi	46	M	Kilba		
78	Jamna Geer	54	M	Kilba		
79	Chander Pal	53	M	Kilba		
80	Kapil	31	M	Urni	Kalpa	2,400; 31°31'41.56"N & 78°07'43.06"E
81	Veer badr	46	M	Urni		
82	Manohar	53	M	Urni		

fumes of needles are used for the purification of houses during child birth, marriages, festivals, etc. The garland made from Chilgoza seeds are used in various fairs and festivals, i.e., Ormig, Duyal, Suskar, Losar, Beesh, and Fulaich celebrated in various parts of Kinnaur District. In addition to this, it is important part of various rituals in festivals and other customary rituals performed all across the Kinnaur District of Himachal Pradesh (Image 2A,B).

The above mentioned cultural importance of Chilgoza Pine, clearly reflects that this tree is not only ecologically and economically important to the area but also forms important part of traditions and culture of the tribal communities. Although, Kinnaur is major producer and supplier of Chilgoza in the country, still

its forests need proper management. Since the sixties, Himachal Pradesh Forest Department has been facing the problem of Chilgoza Pine regeneration, and tried to overcome from this problem by carrying out plantation programmes. But, results were not satisfactory because of typical environmental conditions including soil of the region not allowing to survive. The present traditional practices for the collection of fuelwood, torchwood, agricultural tools, timber, cones for seeds, and manuring agricultural fields are mostly destructive and require awareness among the tribal communities for the sustainable utilization of this highly valuable multipurpose endemic species. Most of the people are not aware about the impact of excessive lopping which is causing heavy damage to the trees and also affecting

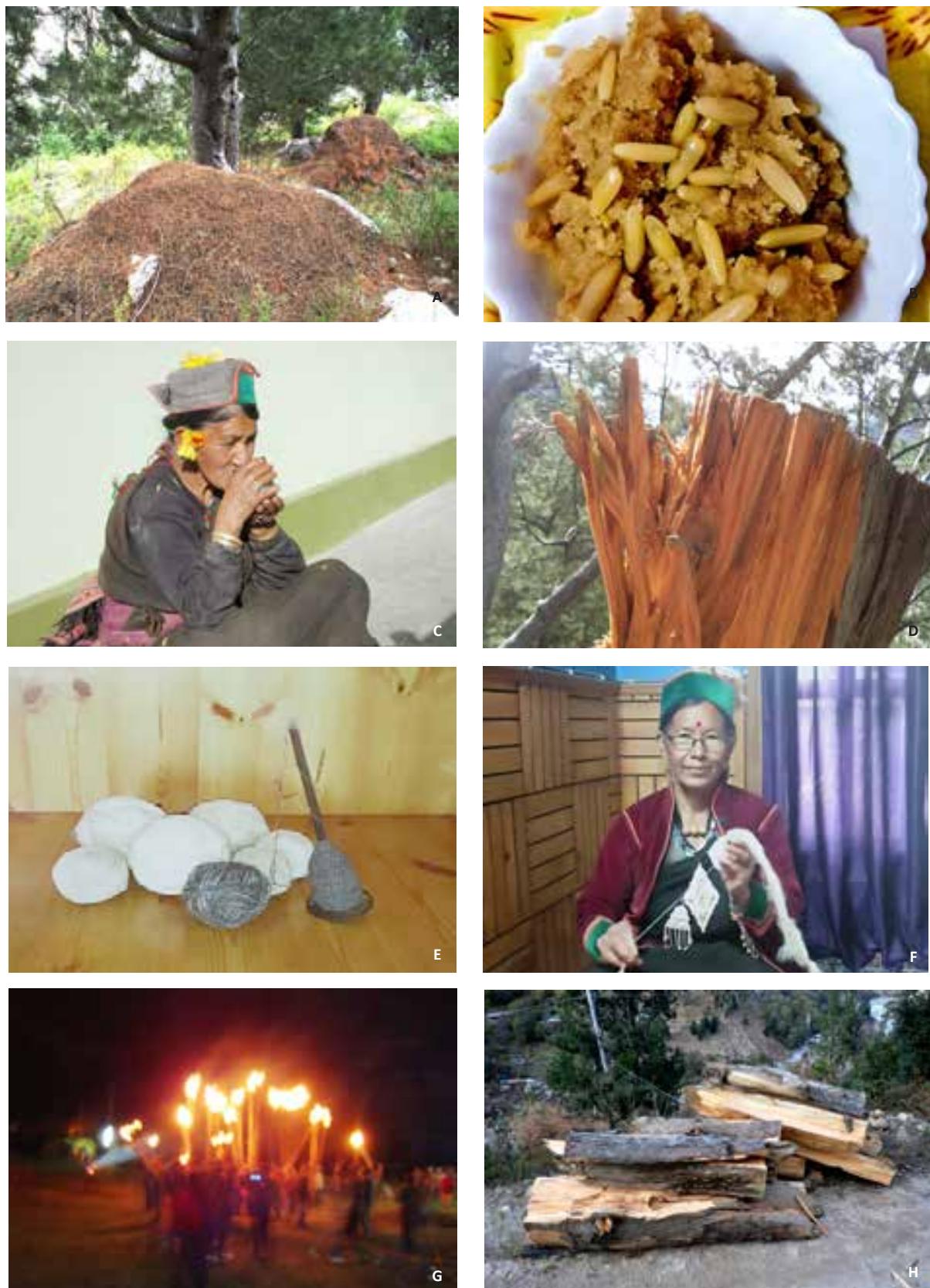


Image 1. (A–H) Utilization of Chilgoza pine by Kinnaura tribes of Kinnaur District: A—Chilgoza pine needle collection | B—Halwa preparation in Sazo festival | C—Local woman enjoying salted tea | D—Chilgoza torch-wood collection | E—Spinning of wool using “Koru- Pankt” | F—Spinning of wool using “Pankt” | G—Chilgoza torch-wood dance | H—Chilgoza fuel wood. © Swaran Lata.



Image 2. (A–B) Utilization of Chilgoza nuts in marriage ceremonies in Kinnaur district, Himachal Pradesh: A—Marriage ceremony in Kinnaur | B—Kinnauri brides and grooms wearing Chilgoza garlands. © Shiv Raj.

natural regeneration and cone production in successive years. In addition, intensive grazing, damage by insects and pathogens, birds, rodents and reptiles, conversion of Chilgoza forest into orchards and other developmental activities like construction of roads, buildings, and hydro-power projects are also affecting Chilgoza habitats and stand population. Such severe biotic interferences and lack of natural regeneration may result in rapid decline in the species population and continued such practices may lead the extinction of species in future. Keeping in view of its limited distribution, there is still considerable scope for increasing its yield and regeneration through sustainable harvesting and management of Chilgoza Pine forests. Therefore, it is of utmost important to

create awareness among the local communities about the conservation and sustainable utilization of the species. If the present trend of utilization continues, it will not only lead to the loss of all the services provided by this species but also, lead to soil erosion and overall change in the environmental condition. The loss of Chilgoza Pine and existing biodiversity will lead to drastic change in the ecosystem of the area, which may lead to various disasters in the fragile area. Therefore, population assessment and periodic monitoring using quadrat method for understanding the dynamics, sustainable harvesting of cones, and other parts of the species, ecological niche modeling for predicting the suitable area for in situ conservation, standardization

of propagation techniques for mass multiplication, establishment of nurseries, and plantation of seedlings in degraded forests, marginal lands and other suitable habitats with the help of tribal communities and forest department are suggested.

CONCLUSION

Pinus gerardiana is one of the pioneer, native, endemic, multipurpose, and threatened species of district Kinnaur. It is not only important for maintaining the ecology of the region but, also for providing various ecosystem services to the tribal communities. This species is highly suitable for the typical topographical gradients and environment. Therefore, the conservation and sustainable utilization of this species would help in conserving the ecosystem, ecosystem services, livelihood options, traditional culture and customs and overall environment of the region.

REFERENCES

Anonymous (1969). Wealth of India, Raw Materials 8: 65–66.

Farjon, A. (1984). Pines: Drawing and Description of Genus *Pinus*. Antiquarian Booksellers, Association of America Pub, New York, USA, 220pp.

Farjon, A. (2013). *Pinus gerardiana*. The IUCN Red List of Threatened Species 013:e.T34189A2850009. Downloaded on 17 June 2020. <https://doi.org/10.2305/IUCN.UK.2013-1.RLTS.T34189A2850009.en>

Johnsingh, A.J.T., G.S. Rawat, P.V. Satyakumar & J. Kuar (1998). Prioritization of area for biodiversity conservation of alpine zone-1Trans and Greater Himalaya in India. Biodiversity Conservation Prioritization Project in India, WWF, New Delhi, 212–224pp.

Kumar, R., G.S. Shamet, O.P. Chaturvedi, R.K. Avasthe & C. Singh (2013). Ecology of Chilgoza pine (*Pinus gerardiana* Wall.) in dry temperate forest of North West Himalaya. *Ecology, Environment & Conservation* 19(4): 1063–1066.

MAIL (2012). Chilgoza Pine Forest Conservation and Restoration Plan-Draft Report.

Mittermeier, R.A., P.L. Gil, M. Hoffman, J. Pilgrim, T. Books, C.G. Mittermeier, J. Lamoreux & G.A.B.D. Fonseca (2004). Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions, Conservation International, Washington.

Negi, S.S. (2002). Chilgoza or Neoza pine—an important NTFP of the tribal areas of Kinnaur District in H.P. *Journal of Non-Timber Forest Products* 9 (1/2): 70–72.

Peltier, R. & V. Dauffy (2009). The Chilgoza of Kinnaur. Influence of the *Pinus gerardiana* edible seed market chain organization on forest regeneration in the Indian Himalayas. *Fruits (Paris)* 64(2): 99–110.

Samant, S.S., U. Dhar & L.M.S. Palani (1998). Medicinal plants of Indian Himalaya: Diversity, Distribution, Potential Value. Nanital Gyanodaya Parkashan.

Samant, S.S., S. Pant, M. Singh, M. Lal, A. Singh, A. Sharma & S. Bandari (2007). Medicinal plants in Himachal Pradesh, North Western Himalaya, India. *International Journal of Biodiversity Science & Management* 3: 234–251.

Sehgal, R.N. & P.K. Khosla (1986). Chilgoza Pine: The Threatened Social Forestry Tree of Dry Temperate Himalaya. National Symposium on Research in Social Development, 1–2 January.

Sehgal, R.N. & P.K. Sharma (1989). Chilgoza: The Endangered Social Forestry Pine of Kinnaur. Technology Bulletin, FBTI, 6.

Singh, R.V., D.C. Khanduri & K. Lal (1973). Chilgoza Pine (*Pinus gerardiana*) regeneration in Himachal Pradesh. *Indian Forester* 99(3): 126–133.

Tondon, J.C. (1963). Revised working plan for the Kinnaur and Kochi Forest (Upper Satluj Valley), Himachal Pradesh. Vol-2. Office of the Chief Conservator of Forests. Working Plan Circle, Himachal Pradesh, India, 284pp.

Troup, R.S. (1921). The Silviculture of Indian Trees. Vol-3, Oxford University Press, 1195pp.





Range extension and first confirmed record of the Flightless Anomalure *Zenkerella insignis* (Matschie, 1898) (Mammalia: Rodentia: Anomaluridae) in Nigeria

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The Cameroon Scaly-tail *Zenkerella insignis* (Matschie, 1898) is one of the least studied of African mammals. It has so rarely been encountered that virtually nothing has been published about its behaviour, feeding habits, and time budgets (Heritage et al. 2016). The species was previously classified in the genus *Zenkerella* under the family Anomaluridae along with *Idiurus* and *Anomalurus* (Kingdon, 2013), though Marivaux et al. (2017) adds a fourth genus *Anomalurops*. The new study by Fabre et al. (2018), however, puts the genus *Zenkerella* under a new completely different well-circumscribed family called Zenkerellidae based on new phylogenetic results. This puts Anomaluridae and Zenkerellidae as two separate families under the Suborder Anomaluromorpha, which are endemic to the thick rainforest habitats of western and central Africa (Kingdon 2013) and peculiar among mammals for the two rows of pointed scales on the ventral side of their tufted tail, which helps them to climb in the forest canopy (Marivaux et al. 2017; Fabre et al. 2018).

Cameroon Scaly-tail *Zenkerella insignis* stands out from the rest of the suborder. It is presently the only

known species in the family Zenkerellidae and it lacks patagia, the membranes possessed by the genera in Anomaluridae which enable them to glide, similar to gliding squirrels (Kingdon 2013; Heritage et al. 2016; Marivaux et al. 2017). Kingdon (2013) suggests the absence of patagia could be an adaptive feature for the species, enabling it to adapt to very thick vegetation. *Zenkerella* has been viewed as an important example of macroevolutionary reversion in the development of locomotory adaptations because it is assumed that the species lost its patagia and hence its ability to glide (Fabre et al. 2018). Molecular analysis, however, proves that the species is from a lineage called Zenkerellidae, a distinct non-gliding, and long-lived lineage. This would mean that the lineage never developed patagia or any adaptation that enables gliding flight, rather than having lost its capabilities of performing gliding flight (Fabre et al. 2018; Heritage et al. 2016).

Remarkably, the first pictures of a live specimen of *Zenkerella insignis* were taken in 2015 on the Island of Bioko by Curtis Hart (Dinets 2017). Dinets (2017) also recorded his encounter with a *Zenkerella* in the lowland

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Image 1. Lateral view of *Zenkerella insignis*.

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Image 2. Posterior view of *Zenkerella Insignis*.

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Image 3. Image showing the curious specimen with the digits and claws.

forest of the Dzanga-Sangha Special Protected Area in the central African republic (Dinets 2017). From his observations, the specimen had a preference for dense thickets and was nocturnal, observed at 22.00h, a possible reason why it was so rarely seen and observed in the wild (Dinets 2017).

We encountered the elusive and mysterious flightless Cameroon Scaly-tailed on 17 May 2019. We were in the Queen's Forest (core zone) of Omo Forest Reserve sitting under a short tree at 6.756N & 4.353E from 18.00h. The vegetation at that particular location was

relatively dense and shrubby with little undergrowth. At about 20.08h, we heard something rustling just above where we were seated. We put on our headlights and saw the scaly-tail on the branch directly above us. We were instantly interested in the specimen because of its tail tuft which stood out unlike in any other previously observed species in the forest reserve. The tail tuft is the shape of a spherical fan. The branch was at a height of about 5m above the ground. When we put on our headlights, the animal ceased moving for a few seconds and just glared at the light source similar to what was



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Image 4. Ventral image of the specimen showing the prominent maxillary incisors and the smaller mandibular incisors.



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Image 5. Image showing the scales on the anterior section of the tail.



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Image 6. Image showing the facial features of the specimen.



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Image 7. Image showing the tail tuft of the specimen.

previously observed by Dinets (2017). Then, it started traversing the tree branch going up and down. This could be a display of territoriality, seen in some male and female rodents, or investigative behavior. It could also be a protective display to ensure it is not followed back to its young ones if it had any. This behaviour would have been easier to understand if we could tell the sex of the specimen. Its territorial behaviour was further confirmed when the specimen urinated directly on the branch and upon us. Observations continued for about 19 minutes while pictures were taken.

Unlike other rodents, the specimen showed no signs of fear, probably because it had never seen or interacted with humans before. It seemed simply curious, looking down from different positions on the branch to get a better view of us.

The specimen had a dark grey body pelage (Image 1). The tail tuft and ankle tuft (both visible in Image 3, 7) were clearly black in colouration. It is also noticeable that the ear of the observed specimen lacked fur and was almost bare even on the outer surface of the ear (Image 2).

Similar to the observation by Dinets (2017), the tail of the specimen was kept straight out from the specimen's body and was used as a rudder. Unlike descriptions from previously curated specimens, the observed *Zenkerella* had tail hair that stood straight on end in a spiky manner rather than the bushy hair depicted from curated specimens (Image 3, 7). Dinets (2017) suggested that the very conspicuous tail tuft is used for either intraspecific signaling or to distract predators from vital parts of the body.

Another observation made was that the specimen had two prominent maxillary incisors that were larger

than the mandibular incisors visible in Image 4 and 6 (Heritage et al. 2016). The specimen also had four and five digits on its fore and hind feet respectively and all digits ended in decurved claws (Image 3, 5, 6) (Heritage et al. 2016).

This is the first confirmed record of the Cameroon

Scaly-tail *Zenkerella insignis* in Nigeria and the first set of clear pictures showing accurate morphological descriptions of the species. This find is quite remarkable because it extends the species' range significantly westwards across important biogeographic boundaries such as the Cameroonian volcanic range and across the large Cross and Niger rivers. Given the distance of over 800km from the previously described sightings, the observation could very well be a subspecies or a new species in the *Zenkerella* genus.

References

Dinets, V. (2017). First observations on the behaviour of the flightless anomalure (*Zenkerella insignis*). *Zoology* 123: 121–123. <https://doi.org/10.1016/j.zool.2017.06.003>

Fabre, P. H., M.K. Tilak, C. Denys, P. Gaubert, V. Nicolas, E.J.P. Douzery & L. Marivaux (2018). Flightless scaly-tailed squirrels never learned how to fly: A reappraisal of Anomaluridae phylogeny. *Zoologica Scripta* 47(4): 404–417. <https://doi.org/10.1111/zsc.12286>

Heritage, S., D. Fernández, H.M. Sallam, D.T. Cronin, J. Manuel, E. Echube & E.R. Seiffert (2016). Ancient phylogenetic divergence of the enigmatic African rodent *Zenkerella* and the origin of anomalurid gliding. *PeerJ* 4: e2320. <https://doi.org/10.7717/peerj.2320>

Kingdon, J. (2013). Family Anomaluridae: anomalures, pp. 602–617. In: Happold, D.C.D. (ed.). *Mammals of Africa - Volume III: Rodents, Hares and Rabbits*. Bloomsbury Publishing, London.

Marivaux, L., S. Adnet, M. Benammi, R. Tabuce & M. Benammi (2017). Anomaluroid rodents from the earliest Oligocene of Dakhla, Morocco, reveal the long-lived and morphologically conservative pattern of the Anomaluridae and Nonanomaluridae during the Tertiary in Africa. *Journal of Systematic Palaeontology* 15(7): 539–569. <https://doi.org/10.1080/14772019.2016.1206977>

Matschie, P. (1898). Eine neue mit *Idiurus* Mtsch. verwandte Gattung der Nagethiere. *Sitzungs.-Berichte. der. Gesellsch. naturforsch. Freunde Berlin* 4: 23–30.





Power lines as a threat to a canopy predator: electrocuted Harpy Eagle in southwestern Brazilian Amazon

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Harpy Eagle *Harpia harpyja* Linnaeus, 1758 is the largest bird of prey in the Americas (Sick 1997). Globally listed as a Near Threatened (NT) species (Birdlife International 2017), it is threatened with extinction in several countries within its Central to South American geographic range. In Brazil, the species was classified in 2014 as Vulnerable (VU) (Brasil/MMA 2014a). Deforestation, habitat loss and hunting are

the main impacts affecting Harpy Eagle populations (Álvarez-Cordero 1996; Trinca et al. 2008; DeLuca 2012; Gusmão et al. 2016; Birdlife International 2017). Electrocution from power transmission lines is another threat affecting large birds (e.g., eagle owls, Sergio et al. 2004; cranes, Shaw et al. 2010; raptors, Lasch et al. 2010; storks, Kaluga et al. 2011; condors, Rideout et al. 2012; vultures, Angelov et al. 2013). Such impacts

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Carlos Alberto Reyes Maldonado



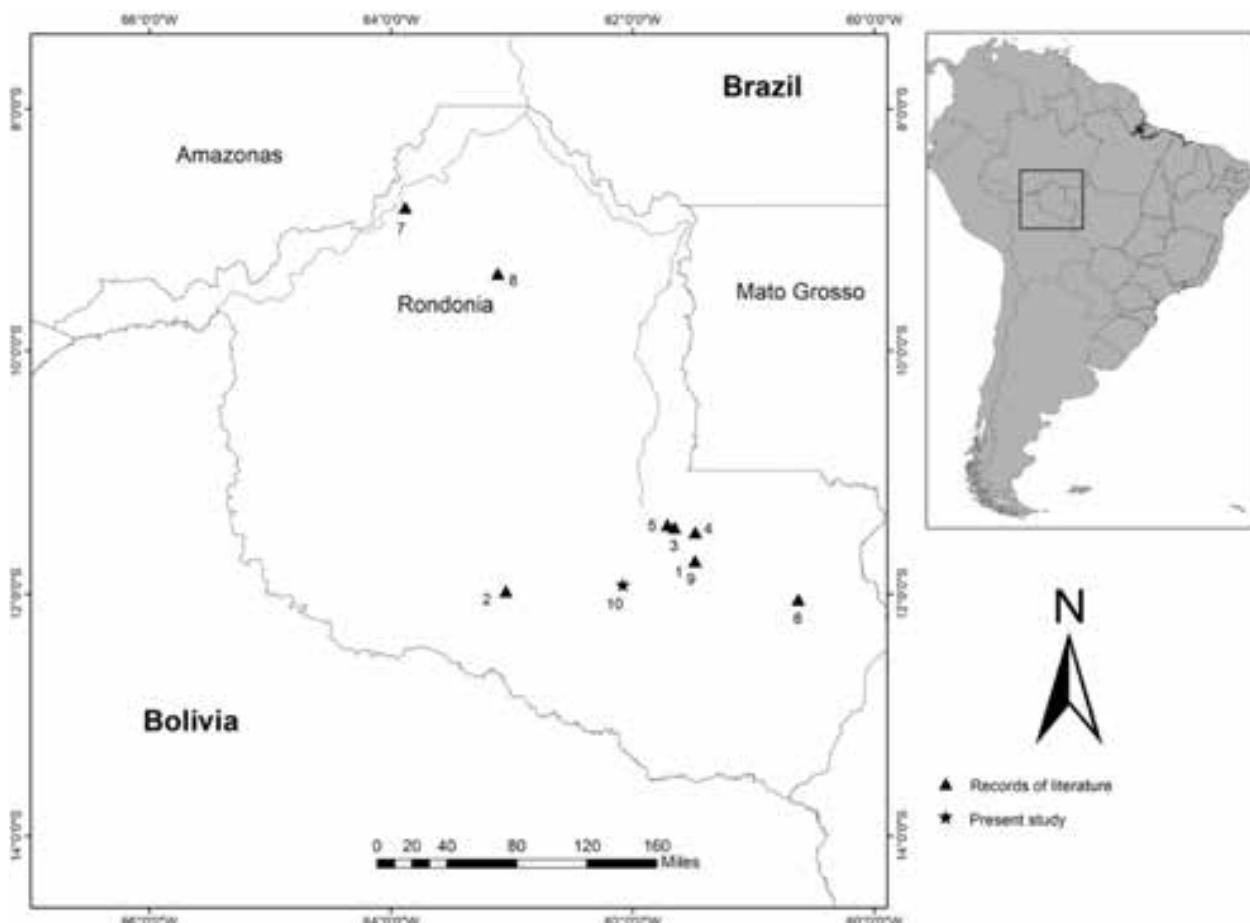


Figure 1. Rondônia State, Brazil: map with the records known from the literature, and the location of the Harpy Eagle electrocution event in the Alta Floresta D'Oeste, Seringueiras and Porto Velho municipalities.

may sometimes be sufficiently severe to alter local species distributions (Sergio et al. 2004). The effects on Harpy Eagle population dynamics of electrocution from collisions with power lines is unknown. Modelling of a Bonelli's Eagle *Aquila fasciata* population predicted that even low levels of electrocution may threaten the overall population viability of long-lived raptors (Hernández-Matías et al. 2015).

Concern over negative interaction between birds and transmission lines began to emerge early in the 20th century (Michener 1928). Most reported case studies were of migratory birds and resident birds in North America, Europe, Africa, Asia, and Oceania (Avery 1978; Salvador & Ibanez 2006; Lehman et al. 2007; Kagan 2016; Mojica et al. 2018). More recently this problem started attracting attention in South American countries such as Argentina (Orellana & Cornejo 2010; Ibarra & DeLucca 2015; Galmes et al. 2017), however, there has been little attention in Brazil, a country that has an extensive network of high-tension transmission

lines (see Raposo 2013). Transmission lines drive several threats to Brazilian Amazon conservation (Hyde et al. 2018), among which are bird collision risk and mortality. Studies of bird collision on high voltage lines are still limited to licensing studies and mitigation measures (such as bird flight diverters), with uncertainty as to their effectiveness (Biasotto et al. 2017; Biasotto & Kindel 2018).

Harpy Eagle nesting trees have been mapped in Rondônia State (Costa et al. 2015; Gusmão et al. 2016; Costa & Nunes 2017), a region of Brazilian Amazonia with extensive anthropic impacts on biodiversity over the last 50 years (Fearnside et al. 2012; Ochoa-Quintero et al. 2015). Here we present a case study of a juvenile Harpy Eagle electrocution in the southern region of the Amazon forest known as the “arc of deforestation”.

The study site was located in Alta Floresta D'Oeste municipality, in the southwest center of Rondônia State, Brazil (Figure 1). In this area, the native forest is highly fragmented as a result of land-use changes,



Image 1. Harpy Eagle adult male electrocuted and taxidermized specimen deposited in the UFMT collections (UFMT4910).

resulting in a matrix of pasture and commercial crops, with small blocks of poorly-connected forest (Fearnside 1989; Piontekowski et al. 2019). The average annual precipitation is 2,000mm and the average annual temperature is 24°C (Alvares et al. 2014).

On 29 August 2018, a juvenile Harpy Eagle female was found dead (Image 1) below a Rural Aerial Power Distribution Network (RDR) with standardized voltage Level of 13.8kV (low voltage). The bird was found beside the Linha 47.5 Highway in a terra firme forest, 10km from the nearest urban area and 6.5km from a known Harpy Eagle nest (Gusmão et al. 2016). Inspection of external and internal morphology found no evidence of trauma, body lesions, or firearm-associated damage. The claws had a crumbled and flaking surface texture and appeared blackened, giving an overall appearance typical of burned tissue (Kagan 2016). Thus, while the incident was not witnessed, inspection of the body during dissection with the evidence of the burnt claws, and the positioning of the body near the pole and below the power transmission network were consistent with the animal having tried to perch on the high-tension wire, with subsequent death by electrocution. Post mortem examination at the Laboratório de Mastozoologia in

Centro de Pesquisa em Limnologia, Biodiversidade e Biotecnologia (CELBE - Limnology, Biodiversity and Biotechnology Research Center), Mato Grosso State confirmed electrocution. The specimen was later taxidermized and deposited in the UFMT reference collection (accession number UFMT 4910).

This is the second record of a fatal Harpy Eagle electrocution in Rondonia. The first reported case was of an adult electrocuted in 2008, around 105km west Seringueira municipality on a similar type of power line, and 6km away from a Harpy Eagle breeding site (Gusmão et al. 2016). According to Urios et al. (2017), juvenile Harpy Eagles are known to disperse more than 35km from the natal nest.

There are two other records of Harpy Eagle interaction with power lines in Brazil. One was an adult female that was rescued and rehabilitated in the wild after a collision with a low voltage electricity distribution line in a rural area of Senador José Porfírio municipality, Para state (Aguiar-Silva et al. 2014). The other was a juvenile born in captivity and released as a part of a reintroduction program, that died in Panama after contact with power lines (Watson et al. 2016).

These data compiled from different reports indicate

that power transmission networks are potentially a threat to adult and dispersing juvenile Harpy Eagles (Urios et al. 2017; Mojica et al. 2018). Juvenile eagles in general were electrocuted at approximately twice the rate of subadults or adults (Mojica et al. 2018). Harpy Eagles are at particular risk in human-modified landscapes, as habitat discontinuity may force juveniles to cross deforested areas to pair up, and establish feeding territories and reproductive sites. Due to the loss of tall trees in forest fragments (Nascimento & Laurence 2006), Harpy Eagles might use the pylons of power line systems as perches (Rettig 1978).

The impact of habitat loss on electrocution of raptors has been noted in other sites, affecting species that include the Black-chested Buzzard Eagle *Geranoaetus melanoleucus* (Ibarra & DeLucca 2015), Griffon Vulture *Gyps fulvus*, Golden Eagle *Aquila chrysaetos*, Bonelli's Eagle *Aquila fasciata*, Eurasian Eagle Owl *Bubo bubo* (Hernández-Matías et al. 2015, Pérez-Garcia et al. 2017) and Crowned Solitary Eagle *Buteogallus coronatus* (Galmes et al. 2017).

A number of mitigation measures such as retrofitting (Fox & Wynn 2010; Chevallier et al. 2015; Dwyer et al. 2019) have been implemented successfully in Europe and elsewhere (Bevanger 1994; Janss & Ferrer 2001; Tintó et al. 2010). These practices could be followed in Brazil and included in action plans (Plano de Ação Nacional para Conservação das Aves da Amazônia, Brasil 2014b). In addition, future research should focus on impacts on juvenile raptors, since they seem to be disproportionately involved in collisions with power lines (Harness & Wilson 2001; Sergio et al. 2004; Tabolka 2014).

References

Aguiar-Silva, F.H., T.M. Sanaiotti, O. Jaudoin, F.D. Martins, D. Vasconcelos & V.S. Peres (2014). Remoção e reintegração de gavião-real em área de conflito no Pará: conservação na Volta Grande do Rio Xingu. In: I International Symposium and V Meeting of the Post-Graduate Program in Tropical Biodiversity, Macapá. https://ppgbioconservation.weebly.com/uploads/2/7/5/7/27576775/abstract_book_ppgbio2014.pdf

Angelov, I., I. Hashim & S. Oppel (2013). Persistent electrocution mortality of Egyptian Vultures *Neophron percnopterus* over 28 years in East Africa. *Bird Conservation International* 23(1): 1–6. <https://doi.org/10.1017/S0959270912000123>

Alvares, C.A., J.L. Stape, P.C. Sentelhas, J.L. Gonçalves, M. & G. Sparovek (2014). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift* 22(6): 711–728

Álvarez-Cordero, E. (1996). *Biology and conservation of Harpy Eagle in Venezuela and Panamá*. PhD. Dissertation, University of Florida, Gainesville, FL U.S.A. 214pp.

Avery, M.L. (1978). *Impacts of transmission lines on birds in flight: proceedings of a workshop*. U.S. Fish and Wildlife Service, FWS/OBS 78/48, 151pp.

Bevanger, K. (1994). Bird interactions with utility structures: collision and electrocution, causes and mitigating measures. *Ibis* 136(4): 412–414. <https://doi.org/10.1111/j.1474-919X.1994.tb01116.x>

Biasotto, L.D., A. Barcelos-Silveira, C.E.Q. Agne & A. Kindel (2017). Comportamento de voo de aves em resposta ao uso de sinalizadores em linhas de transmissão de energia elétrica. *Iheringia, Série Zoologia* 107: e2017047. <https://doi.org/10.1590/1678-4766e2017047>

Biasotto, L.D. & A. Kindel (2018). Power lines and impacts on biodiversity: A systematic review. *Environmental Impact Assessment Review* 71:110–119. <https://doi.org/10.1016/j.eiar.2018.04.010>

BirdLife International (2017). *Harpia harpyja* (amended version of 2017 assessment). The IUCN Red List of Threatened Species 2017: e.T22695998A117357127.. Downloaded on 19 June 2019.

Brasil (2014a). Lista Nacional das Espécies da Fauna Brasileira Ameaçadas de Extinção. Portaria Nº 444, 17 de dezembro de 2014. Brasília: MMA/ICMBio.

Brasil (2014b). Plano de Ação Nacional para Conservação das Aves da Amazônia ameaçadas de extinção, PAN - Aves da Amazônia. Portaria Nº 35, 27 de Março de 2014. Brasília: MMA/ICMBio.

Chevallier, C., A. Hernández-Matías, Real, J., N. Vincent-Martin, A. Ravayrol & A. Besnard (2015). Retrofitting of power lines effectively reduces mortality by electrocution in large birds: an example with the endangered Bonelli's Eagle. *Journal of Applied Ecology* 52(6): 1465–1473. <https://doi.org/10.1111/1365-2664.12476>

Costa, T.M., Souza, L. S., A.C. Gusmão, J. Costa, E.O. Silva (2015). Nidificação de harpia (*Harpia harpyja* Linnaeus, 1758) (Accipitriformes: Accipitridae) na RESEX do Rio Cautário, sudoeste do estado de Rondônia, Brasil. *Atualidades Ornitológicas* 185(3): 20–21.

Costa, A.R. & R.O. Nunes (2017). Ecologia e conservação de um casal de gavião-real, *Harpia harpyja* (Linnaeus) (Aves, Accipitridae), em uma área rural a 10 km do centro urbano no município de Porto Velho (Rondônia, Brasil). *Farol* 4(4): 56–71.

DeLuca, J.J. (2012). Birds of conservation concern in eastern Acre, Brazil: distributional records, occupancy estimates, human-caused mortality, and opportunities for ecotourism. *Tropical Conservation Science* 5(3): 301–319. <https://doi.org/10.1177/194008291200500306>

Dwyer, J.F., T.I. Hayes, R. Thorstrom & R.E. Harness (2019). Retrofitting power poles to prevent electrocution of translocated Ridgway's Hawks (*Buteoridgwayi*). *Journal of Caribbean Ornithology* 32: 4–10.

Fearnside, P.M. (1989). Ocupação humana de Rondônia: impactos, limites e planejamento. Relatórios de Pesquisa No. 5, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brasília, DF. 76pp.

Fearnside, P.M., W.F. Laurance, M.A. Cochrane, S. Bergen, P.D. Sampaio, C.D. Barber, S. Angelo & T. Fernandes (2012). O futuro da Amazônia: modelos para prever as consequências da infraestrutura futura nos planos plurianuais. *Novos Cadernos NAEA* 15(1): 25–52. <https://doi.org/10.5801/ncn.v15i1.865>

Fox, N. & C. Wynn (2010). The impact of electrocution on the New Zealand falcon (*Falco novaeseelandiae*). *Notornis* 57(2): 71–74.

Galmes, M.A., J.H. Sarasola, J.M. Grande & F.H. Vargas (2017). Electrocution risk for the endangered Crowned Solitary Eagle and other birds in semiarid landscapes of central Argentina. *Bird Conservation International* 28(3): 403–415. <https://doi.org/10.1017/S0959270917000272>

Gusmão, A.C., A. Banhos, F.H. Aguiar-Silva, L.S. Souza, T.M. Sanaiotti, A.M. Silva, T.M. Costa, L. Oliveira, W.G. Morais & S.F. Ferrari (2016). Records of the occurrence, nesting, and hunting of the Harpy Eagle (*Harpia harpyja*) (Aves: Accipitridae) in Rondônia, Southwestern Brazilian Amazonia. *Atualidades Ornitológicas* 190(2): 18–23.

Harness, R.E. & K.R. Wilson (2001). Electric-utility structures associated with raptor electrocutions in rural areas. *Wildlife Society Bulletin* 29(2): 612–623.

Hernández-Matías, A., J. Real, F. Parés & R. Pradel (2015). Electrocution threatens the viability of populations of the endangered Bonelli's Eagle (*Aquila fasciata*) in southern Europe. *Biological Conservation* 191(11): 110–116. <https://doi.org/10.1016/j.biocon.2015.06.028>

Hyde, J.L., S.A. Bohlman & D. Valle (2018). Transmission lines are an under-acknowledged conservation threat to the Brazilian Amazon. *Biological Conservation* 228: 343–356. <https://doi.org/10.1016/j.biocon.2018.10.027>

Ibarra, J. & E. De Lucca (2015) Águilas Moras (*Geranoaetus melanoleucus*), víctimas de electrocución en Luján de Cuyo, Mendoza, Argentina. *Nótulas Faunísticas* 176(2015): 1–7.

Janss, G.F. & M. Ferrer (2001). Avian electrocution mortality in relation to pole design and adjacent habitat in Spain. *Bird Conservation International* 11(1): 3–12. <http://doi.org/10.1017/S0959270901001022>

Kagan, R.A. (2016). Electrocution of raptors on power lines: a review of necropsy methods and findings. *Veterinary Pathology* 53(5): 1030–1036. <https://doi.org/10.1177/0300985816646431>

Kaługa, I., T.H. Sparks & P. Tryjanowski (2011). Reducing death by electrocution of the white stork *Ciconia ciconia*. *Conservation Letters* 4(6): 483–487. <http://doi.org/10.1111/j.1755-263X.2011.00203.x>

Lasch, U., S. Zerbe & M. Lenk (2010). Electrocution of raptors at power lines in Central Kazakhstan. *Waldökologie, Landschaftsforschung und Naturschutz* 9(1): 95–100

Lehman, R.N., P.L. Kennedy & J.A. Savidge (2007). The state of the art in raptor electrocution research: a global review. *Biological Conservation* 136(2007): 159–174. <https://doi.org/10.1016/j.biocon.2006.09.015>

Michener, H. (1928). Where engineer and ornithologist meet: Transmission line troubles caused by birds. *Condor* 30(3): 169–175.

Mojica, E.K., J.F. Dwyer, R.E. Harness, G.E. Williams & B. Woodbridge (2018). Review and synthesis of research investigating Golden Eagle electrocutions. *Journal of Wildlife Management* 82(3): 495–506. <https://doi.org/10.1002/jwmg.21412>

Nascimento, H.E.M. & W.F. Laurence (2006). Area and edge effects on forest structure in Amazonian forest fragments after 13–17 years of isolation. *Acta Amazonica* 36(2): 183–192. <https://doi.org/10.1590/S0044-59672006000200008>

Ochoa-Quintero, J.M., T.A. Gardner, I. Rosa, S.F.D.B. Ferraz & W.J. Sutherland (2015). Thresholds of species loss in Amazonian deforestation frontier landscapes. *Conservation Biology* 29(2): 440–451. <https://doi.org/10.1111/cobi.12446>

Orellana, S.A. & M.R. Cornejo (2010). Electrocución en Águilas Moras (*Geranoaetus melanoleucus*) por tendido eléctrico en Calera de Tango, Chile. *Spizaetus* 9(1): 13–15.

Pérez-García, J.M., T.L. De Vault, F. Botella & J.A. Sánchez-Zapata (2017). Using risk prediction models and species sensitivity maps for large-scale identification of infrastructure-related wildlife protection areas: The case of bird electrocution. *Biological Conservation* 210(2017): 334–342. <https://doi.org/10.1016/j.biocon.2017.04.033>

Piontekowski, V.J., F.P. Ribeiro, E.A.T. Matricardi, I.M. Lustosa Junior, A.P. Bussinguer & A. Gatto (2019). Modeling deforestation in the State of Rondonia. *Floresta e Ambiente* 26(3): e20180441. <https://doi.org/10.1590/2179-8087.044118>

Rettig, N.L. (1978). Remote wordofthe Harpy Eagle (*Harpia harpyja*). *The Auk* 95(4): 629–643.

Raposo, M.A.F., C.P. Assis & D. Figueira (2013). *Aves & Linhas de Transmissão - um Estudo de Caso*. Rio de Janeiro: Arte Ensaio, 124pp.

Rideout, B.A., I. Stalis, R. Papendick, A. Pessier, B. Puschner, M. Finkeslein, D.R. Smith, M. Johnson, M. Mace, R. Stroud, J. Brand, J. Burnett, C. Parish, J. Petterson, C. Witte, C. Stringfield, K. Orr, J. Zuba, M. Wallace & J. Grantham (2012). Patterns of mortality in free-ranging California Condors (*Gymnogyps californianus*). *Journal of Wildlife Diseases* 48(1): 95–112. <https://doi.org/10.7589/0090-3558-48.1.95>

Salvador, D.J.I. & J.C. Ibanez (2006). Ecology and conservation of Philippine Eagles. *Ornithological Science* 5(2): 171–176. [https://doi.org/10.2326/1347-0558\(2006\)5\[171:EACOPE\]2.0.CO;2](https://doi.org/10.2326/1347-0558(2006)5[171:EACOPE]2.0.CO;2)

Sergio, F., L. Marchesi, P. Pedrini, M. Ferrer & V. Penteriani (2004). Electrocution alters the distribution and density of a top predator, the eagle owl *Bubo bubo*. *Journal of Applied Ecology* 41(5): 836–845. <https://doi.org/10.1111/j.0021-8901.2004.00946.x>

Shaw, J.M., A.R. Jenkins, J.J. Smallie & P.G. Ryan (2010). Modelling power-line collision risk for the Blue Crane *Anthropoides paradiseus* in South Africa. *Ibis* 152(3): 590–599. <https://doi.org/10.1111/j.1474-919X.2010.01039.x>

Sick, H. (1997). *Ornitología Brasileira*. Rio de Janeiro: Nova Fronteira. 862pp.

Tintó, A., J. Real & S. Mañosa (2010). Predicting and correcting electrocution of birds in Mediterranean areas. *Journal of Wildlife Management* 74(8): 1852–1862. <https://doi.org/10.2193/2009-521>

Tobolka, M. (2014). Importance of juvenile mortality in birds' population: early post-fledging mortality and causes of death in White Stork *Ciconia ciconia*. *Polish Journal of Ecology* 62(4): 807–813. <https://doi.org/10.3161/104.062.0403h>

Trinca, C.T., S.F. Ferrari & C.L. Alexander (2008). Curiosity killed the bird: arbitrary hunting of Harpy Eagles. *Cotinga* 30(2008): 12–15.

Urios, V., R. Muñiz-López & J. Vidal-Mateo (2017). Juvenile dispersal of Harpy Eagles (*Harpia harpyja*) in Ecuador. *Journal of Raptor Research* 51: 439–445. <https://doi.org/10.3356/JRR-16-54.1>

Watson, R.T., C.J.W. McClure, F.H. Vargas & J.P. Jenny (2016). Trial restoration of the Harpy Eagle, a large, long-lived, tropical forest raptor, in Panama and Belize. *Journal of Raptor Research* 50(1): 3–22. <https://doi.org/10.3356/rapt-50-1-3-22.1>





First record of the Assam Leaf Turtle *Cyclemys gemeli* (Fritz et al. 2008) (Reptilia: Testudines: Geoemydidae) from the Darjeeling-Sikkim Himalaya, India

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In India, 30 species of tortoises and turtles have been recorded so far, out of which the northeastern region has 22 species (Das & Gupta 2015), including *Cyclemys gemeli*. This species, however, has never been reported to occur in the Darjeeling-Sikkim Himalaya, which comprise the state of Sikkim, and the hilly regions of Darjeeling and Kalimpong districts of West Bengal, India, which is an integral part of the eastern Himalaya. Historically, four species, namely, *Melanochelys tricarinata*, *M. trijuga*, *Indotestudo elongata*, and *Lissemys punctata* have been reported to occur here (Smith 1931), of which *Indotestudo elongata* and *Lissemys punctata andersoni* have been recorded in the present-day Darjeeling-Sikkim Himalaya (Jha 2009; Pradhan & Yonle 2019). *Cyclemys gemeli*, commonly known as the Assam Leaf Turtle is protected under Schedule I of the Wildlife Protection Act 1972 in India, but has not been assessed by IUCN. It is currently listed in CITES under Appendix II. It was first described from Assam, and is the only species to be reported in India under *Cyclemys* (Ahmed & Das 2010). This species has been known to occur in Uttar

Pradesh (near the Nepal border), northeastern India (Fritz et al. 2008), including Nepal (Rai 2004), Bangladesh (Kabir et al. 2009), and southeastern Bhutan (Wangyal et al. 2012). This species prefers large rivers and its oxbows, fast flowing creeks, and leaf litter of evergreen forest (Praschag et al. 2009).

The current sighting of *Cyclemys gemeli* is the first record from the Darjeeling-Sikkim Himalaya. The turtle was first sighted by the second author on 20 August 2020, crossing a motorable road approximately 230m from Riyang Khola (a perennial tributary of River Teesta), in the Government Cinchona Plantation, Sittong, Darjeeling, and was subsequently identified as *Cyclemys gemeli*. It was based on the descriptions in Ahmed & Das (2010) and Fritz et al. (2008). The photographs and video of the sighted individual were also sent to experts for the confirmation of its identity. The closest published locality record for this species is in Sershong, Sarpang District, Bhutan (Wangyal et al. 2012), about 210km from the current sighting area. The sighting took place at around 11.30h (26.948°N & 88.380°E) in an

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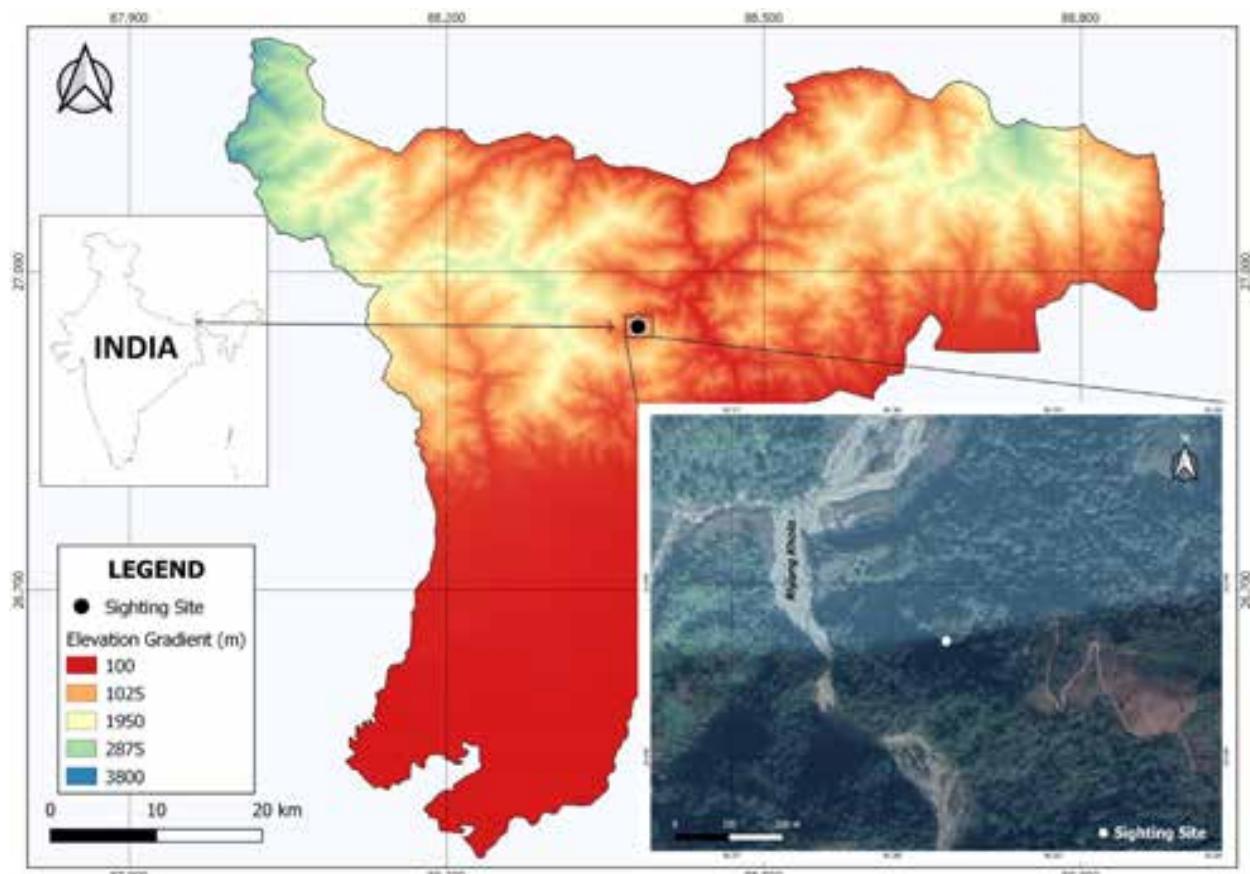


Image 1. The location and a satellite image of the sighting site in Darjeeling, India.

area, currently under rubber cultivation at an elevation of 580m, and approximately 20m from the nearest non-perennial stream (Image 1). The vegetation of the area is characterized by trees like *Terminalia* sp., *Schima walichii*, *Ailanthus grandis*, *Cinchona officinalis*, *Ficus elastica*, and ferns.

The sighted individual (Image 2) was a juvenile female, dark in color with prominent brown blotches on its carapace, while the plastral pattern was characterized by dark brown to black radiating lines. The carapace was raised and slightly elongated, with a distinct vertebral keel and two lateral keels. The digits were webbed, with fingernails. Eleven pairs of marginal scutes were present. The anal notch was wide and obtuse angled. The crown of the head and the throat was uniform dark brown in color. The individual weighed 450g. Morphometric measurements of the individual were as follows: carapace length = 15.2cm; carapace width = 11.9cm; plastron length = 14.1cm.

The individual was later handed over to the West Bengal Forest Department, and is currently at Latpanchor Range Office.

References

Ahmed, M.F. & A. Das (2010). Tortoises and turtles of northeast India: saving them from extinction! Survey, assessment of present status and conservation of tortoises and freshwater turtles in northeast India. Technical Report. Aaranyak, Guwahati, India, xiv+168pp.

Das, K.C. & A. Gupta (2015). New distribution records of tortoises (Chelonia: Testudinidae) from Barak Valley, Assam, northeastern India with notes on ecology and vernacular traditional taxonomy. *Journal of Threatened Taxa* 7(3): 7017–7023. <https://doi.org/10.11609/JoTT.o3623.7017-23>

Fritz, U., D. Guickling, M. Auer, R.S. Sommer, M. Wink & A.K. Hundsdörfer (2008). Diversity of southeast Asian leaf turtle genus *Cyclemys*: how many leaves on its tree of life? *Zoologica Scripta* 37: 367–390.

Jha, A. (2009). Order Testudines: first recorded instance in Sikkim. *Tigerpaper* 36(1): 31–32.

Kabir, S.M.H., M. Ahmad, A.T.A. Ahmed, A.K.A. Rahman, Z.U. Ahmed, Z.N.T. Begum, M.A. Hassan & M. Khandker (Eds.) (2009). *Encyclopedia of Flora and Fauna of Bangladesh*. Vol. 25. Asiatic Society of Bangladesh, Dhaka, xviii+204pp.

Pradhan, A. & R. Yonle (2019). Occurrence and evidence of *Lissemys punctata andersoni*, a sub-species of Indian flapshell turtle, at record elevation of 1440m in Darjeeling Hills, West Bengal. *Uttar Pradesh Journal of Zoology* 39(4): 166–170.

Praschag, P., A.K. Hundsdörfer & U. Fritz (2009). Further specimens and phylogenetic position of the recently described leaf turtle species *Cyclemys gemeli* (Testudinidae: Geoemydidae). *Zootaxa* 2008: 29–37.



Image 2. Carapace and plastron of the Assam Leaf Turtle *Cyclemys gemeli* sighted in the Darjeeling-Sikkim Himalaya, India. © Niran Chettri.

Rai, K.R. (2004). Ecological Distribution Of *Cyclemys oldhamii* (Gray 1863) from Nepal. *Our Nature* 2: 7–12.

Smith, M.A. (1931). The fauna of British India, including Ceylon and Burma. Reptilia and Amphibia. Vol. I. Loricata, Testudines. Taylor & Francis, London, 185pp.

Wangyal, J.T., D. Wangchuk & I. Das (2012). First report of turtles from the Himalayan Kingdom of Bhutan. *Chelonian Conservation and Biology* 11(2): 268–272.





Breeding biology of Malabar Tree Toad *Pedostibes tuberculosus* (Anura: Bufonidae) from Castle Rock, Karnataka, India

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The Western Ghats biodiversity hotspot harbors a wide variety of herpetofauna, especially anurans, with many endemic and endangered species (Roelants et al. 2004; Naniwadekar & Vasudevan 2006; Chandramouli & Ganesh 2010; Van Bocxlaer et al. 2012; Dahanukar et al. 2016). Anurans in the Western Ghats face numerous threats such as habitat loss, pollution and changing climate, and are endangered due to their small populations, specialized adaptations, and narrow distributions (Naniwadekar & Vasudevan 2006; Van Bocxlaer et al. 2012; Dahanukar et al. 2013; Gaitonde et al. 2016; Thorpe et al. 2018). Despite the endangered status of many Western Ghats endemic anurans, their natural history is largely unknown, hampering conservation efforts. We, therefore, report the breeding behavior of the Western Ghats endemic toad, *Pedostibes tuberculosus* from the northern Western Ghats and highlight the variation in their reproductive traits from populations distributed along the length of the Western Ghats. This will not only help in conservation prioritization, but also aid in the systematics of this group (Das et al. 2006).

The genus *Pedostibes* Günther, 1876 (Anura: Bufonidae) along with other endemic genera such as *Xanthophryne* and *Ghatophryne*, is a part of the Bufonidae lineage that dispersed into the Western

Ghats and diversified during the Miocene (Van Bocxlaer et al. 2009; Chan et al. 2016). Many species of these endemic genera are patchily distributed, and are highly specialized to their habitats with strict micro-habitat requirements, making them vulnerable to climate change (Biju et al. 2009; Gaitonde et al. 2016; Thorpe et al. 2018). For example, the northern Western Ghats endemic *Xanthophryne* species, exclusively use lateritic rocky outcrops as breeding habitats and lay eggs only in shallow ephemeral rocky pools/ semi-aquatic rocky habitats which are vulnerable to desiccation, and their embryos undergo large-scale mortality due to stochastic fluctuations in humidity and temperature (Biju et al. 2009; Gaitonde et al. 2016; Thorpe et al. 2018). *Pedostibes* also exhibits several specialized adaptations such as, an arboreal habit, a short breeding period, and rapidly developing exposed embryos in aquatic/ semi-aquatic conditions and may be vulnerable to environmental fluctuations during their breeding period (Dinesh & Rahakrishnan 2013; Chan et al. 2016; Sayyed & Nale 2017). There is limited information on the reproductive biology of *P. tuberculosus* and its mating sequence and spawning behavior has not been documented in details.

Here, we describe the breeding behavior of *P. tuberculosus* with a pictorial sequence of their mating and spawning behavior, opportunistically encountered

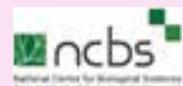
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during field-work at Castle Rock, Karnataka, India.

Castle Rock (Latitude 15.41 & Longitude 74.33) is situated at an altitude of 620m, on the Goa-Karnataka border and has tropical semi-evergreen forests with numerous mountain streams. *Pedostibes tuberculosus* is locally abundant at Castle Rock and is found near perennial streams and agricultural canals. Observations for the current study were taken in an agricultural water-channel situated in a patch of evergreen forest. The channel was mostly dry and had a single 0.3m wide and 10m long pool of water fed by a small water cascade at one end. The water column was ~2–3 inches deep and channel was filled with leaf litter and surrounded by thick undergrowth.

During a light pre-monsoon rainfall, we opportunistically encountered an aggregation of *P. tuberculosus* males at around 23.00h near an agricultural canal fed by a perennial stream. Males were observed calling repeatedly while perched on vegetation at a height of about ~1m from the ground (Image 1, A). Approximately, 15 males were observed in a 10m² area. The males were calling repeatedly, and constantly shifted their positions on nearby vegetation. At times, they wrestled with each other in short duels lasting 10–30 seconds. At 01.00h, the first pair in an axillary amplexus was observed on the ground, initially motionless, but soon started moving around presumably searching for a suitable oviposition site (Image 1B). At 03.00h the pair entered shallow water but were chased away by a *Duttaphrynus* sp. males in full breeding-color, who had also aggregated to breed in the same pool, slightly further away. Eventually, at 03.45h the *P. tuberculosus* pair found shallow water where they were not disturbed and started oviposition (Image 1C). The female was submerged in water up to her throat whereas; only a small part of the male's hindquarters was submerged (Image 1D). The male's hind limbs were positioned between the hind limbs of the female and the male's feet were spread beneath the female's abdomen (Image 1C). During oviposition, the female arched her back downwards and extended her hind limbs and deposited 10–20 eggs at a time. The male simultaneously performed 2–3 pelvic thrusts presumably to release sperms over the freshly released eggs. After depositing the eggs, the pair moved 10–20 cm away from the previous oviposition site and sat motionless until the female was ready to lay the next set of eggs. The female laid eggs in several bouts and the initial clutches contained 20–60 eggs (first two bouts) while subsequent clutches had fewer eggs (next four to five bouts). The female laid approximately 150 eggs by the time the mating concluded. The fresh eggs

were brownish in color and a clump of eggs laid was later extended as a loose string with few detached single eggs. Subsequently, a few more pairs started oviposition at the same site. After about an hour, the focal pair had finished laying all the eggs and the male released the female from a tight axillary amplexus and crawled into the bushes. We observed the female arch her back after being released from amplexus, and soon left the oviposition site, completing the mating sequence. The other pairs formed later continued oviposition in the same manner described above until early morning (05.00h). Sympatric anurans at the breeding site of *P. tuberculosus* included *Raorchestes* sp., and *Duttaphrynus* sp. We also observed two species of snakes, *Macropisthodon plumbicolor* Green Keelback and *Xenochrophis piscator* Checkered Keelback, near the breeding site and may be potential predators of *P. tuberculosus*. The stagnant water pool where eggs were deposited and tadpoles developed, contained *Chironomus* larvae and plenty of leaf litter.

Anurans have evolved a high diversity of reproductive behaviors in response to the varied habitats they occupy, and exhibit distinct reproductive strategies to overcome numerous biotic and abiotic challenges (Haddad & Prado 2005; Wells 2007; Crump 2015). The Western Ghats endemic toad lineages have locally adapted to specific microhabitats (Van Bocxlaer et al. 2010; Thorpe et al. 2018), and understanding the reproductive biology of anurans of the Western Ghats will not only help conservation prioritization by identifying breeding sites and specific micro-habitat requirements, but also help understand the role of ecological factors in shaping reproductive behaviors and mating systems. *Pedostibes tuberculosus* shares several traits with other Bufonid lineages, such as, a semi-terrestrial adult niche, parotid glands, ability to use a wide variety of oviposition sites, and, rapidly developing exotrophic tadpoles, that aided the dispersal of the Bufonid lineage helping it attain a global distribution (Pramuk et al. 2007; Van Bocxlaer et al. 2010). On the other hand, reproductive traits such as, a small clutch size and loose single eggs often exposed to semi-aquatic conditions, seem to have evolved in response to local conditions in Western Ghats endemic toads *Pedostibes* and *Xanthophryne*, and highlight the adaptive nature of reproductive traits in the Bufonid lineage (Gaitonde et al. 2016). A novel case of pelvic thrusts during amplexus was first reported in *Xanthophryne* toads (Gaitonde et al. 2016), but we observed similar behavior in *P. tuberculosus* from the northern Western Ghats, and the pelvic thrusts seems to be widespread among bufonid species, where they possibly function to increase fertilization success,



Image 1. Mating sequence of *Pedostibes tuberculosus* from Castle Rock, Karnataka, India: A—males usually perch on vegetation at about ~1m above ground and have a single gular vocal sac | B—a mating pair in a tight axillary amplexus | C—the female carries the male in amplexus in search of suitable oviposition sites, and the female extends her hind limbs and arches her back to release a clump of eggs. As soon as the female spawns, the male simultaneously thrusts his pelvis probably to deposit sperms on the eggs while holding the egg clump with its hind limbs | D—the oviposition site is a shallow stagnant pool of water filled with leaf litter | E—as the pair moves forward before depositing more eggs, the deposited egg clump is later extended in loosely attached eggs which float on the shallow water column. © Deepak Deshpande.

especially in species breeding in semi-aquatic habitats. Precise estimates of fertilization and hatching success, however, need to be measured in *P. tuberculosus*. We observed tadpoles of *P. tuberculosus* to develop rapidly and metamorphose in approximately a month, which is consistent with earlier study (Dinesh & Rahakrishnan 2013).

Pedostibes tuberculosus populations in the Western Ghats exhibit substantial variation in crucial life history traits such as clutch size and choice of the oviposition site. For example, *P. tuberculosus* populations in southern India are reported to oviposit approximately 1,100 eggs after a single mating (Chan et al. 2016), whereas, at Castle Rock we observed females to lay only 150 eggs. A clutch size of 250 eggs is also reported for *P. tuberculosus* from an unknown location as a personal observation (Van Bocxlaer et al. 2009). Such magnitude differences in crucial life history traits such as clutch size are unlikely to be observed within a species; and life history traits of *P. tuberculosus* need to be estimated in other populations along with evaluating species diversity. Apart from clutch size, *P. tuberculosus* seems to exhibit substantial variation in oviposition sites, and populations from southern Western Ghats are reported to lay eggs in hollow cavities on tree barks, or, in clumps of *Ochlandrae* (Dinesh & Rahakrishnan 2013; Chan et al. 2016); whereas, populations in the northern Western Ghats lay eggs in shallow ephemeral pools of water or on wet ground at the edge of streams without considerable standing water (Van Bocxlaer et al. 2009; Sayyed & Nale 2017). The variation in oviposition sites indicates the utilization of suitable sites in local habitats and suggests reproductive behavior of *P. tuberculosus* to be influenced by local availability of resources.

References

Biju, S., I. Van Bocxlaer, V.B. Giri, S.P. Loader & F. Bossuyt (2009). Two new endemic genera and a new species of toad (Anura: Bufonidae) from the Western Ghats of India. *BMC Research Notes* 2(1): 241. <https://doi.org/10.1186/1756-0500-2-241>

Chan, K.O., L.L. Grismer, A. Zachariah, R.M. Brown & R.K. Abraham (2016). Polyphyly of Asian Tree Toads, Genus *Pedostibes* Günther, 1876 (Anura: Bufonidae), and the description of a new genus from southeast Asia. *PLOS ONE* 11(1): e0145903. <https://doi.org/10.1371/journal.pone.0145903>

Chandramouli, S.R. & S.R. Ganesh (2010). Herpetofauna of southern Western Ghats, India – Reinvestigated after decades. *Taprobanica* 02(02): 72–85.

Crump, M.L. (2015). Anuran reproductive modes: evolving perspectives. *Journal of Herpetology* 49(1): 1–16. <https://doi.org/10.1670/14-097>

Dahanukar, N., K. Krutha, M.S. Paingankar, A.D. Padhye, N. Modak & S. Molur (2013). Endemic Asian chytrid strain infection in threatened and endemic anurans of the northern Western Ghats, India. *PLoS ONE* 8(10): e77528. <https://doi.org/10.1371/journal.pone.0077528>

Dahanukar, N., N. Modak, K. Krutha, P.O. Nameer, A.D. Padhye & S. Molur (2016). Leaping frogs (Anura: Ranixalidae) of the Western Ghats of India: an integrated taxonomic review. *Journal of Threatened Taxa* 8(10): 9221–9288. <https://doi.org/10.11609/jott.2532.8.10.9221-9288>

Das, A., J. Krishnaswamy, K.S. Bawa, M.C. Kiran, V. Srinivas, N.S. Kumar & K.U. Karanth (2006). Prioritisation of conservation areas in the Western Ghats, India. *Biological Conservation* 133(1): 16–31. <https://doi.org/10.1016/j.biocon.2006.05.023>

Dinesh, K.P. & C. Rahakrishna (2013). Description of tadpole stages of the Malabar Tree Toad *Pedostibes tuberculosus* Günther, 1875 (Anura: Bufonidae). *Journal of Threatened Taxa* 5(14): 4910–4912.; <https://doi.org/10.11609/jott.o3398.4910-2>

Gaitonde, N., V. Giri & K. Kunte (2016). 'On the rocks': reproductive biology of the endemic toad *Xanthophryne* (Anura: Bufonidae) from the Western Ghats, India. *Journal of Natural History* 2933(July): 1–16. <https://doi.org/10.1080/00222933.2016.1200686>

Haddad, C.F.B. & C.P.A. Prado (2005). Reproductive modes in frogs and their unexpected diversity in the Atlantic Forest of Brazil. *BioScience* 55(3): 207. [https://doi.org/10.1641/0006-3568\(2005](https://doi.org/10.1641/0006-3568(2005)

Naniwadekar, R. & K. Vasudevan (2006). Patterns in diversity of anurans along an elevational gradient in the Western Ghats, South India. *Journal of Biogeography* 34(5): 842–853. <https://doi.org/10.1111/j.1365-2699.2006.01648.x>

Pramuk, J.B., T. Robertson, J.W. Sites & B.P. Noonan (2007). Around the world in 10 million years: biogeography of the nearly cosmopolitan true toads (Anura: Bufonidae). *Global Ecology and Biogeography* 17(1): 72–83. <https://doi.org/10.1111/j.1466-8238.2007.00348.x>

Roelants, K., J. Jiang & F. Bossuyt (2004). Endemic ranid (Amphibia: Anura) genera in southern mountain ranges of the Indian subcontinent represent ancient frog lineages: evidence from molecular data. *Molecular Phylogenetics and Evolution* 31(2): 730–740. <https://doi.org/10.1016/j.ympev.2003.09.011>

Sayyed, A. & A. Nale (2017). New Distribution Record and Intergeneric Amplexus in the Malabar Tree Toad, *Pedostibes tuberculosus* Günther 1875 (Amphibia: Anura: Bufonidae). *Reptiles and Amphibians: Conservation and Natural History* 24(3): 193–196.

Thorpe, C.J., T.R. Lewis, S. Kulkarni, A. Watve, N. Gaitonde, D. Pryce & M.E. Knight (2018). Micro-habitat distribution drives patch quality for sub-tropical rocky plateau amphibians in the northern Western Ghats, India. *PLOS ONE* 13(3): e0194810. <https://doi.org/10.1371/journal.pone.0194810>

Van Bocxlaer, I., S.D. Biju, S.P. Loader & F. Bossuyt (2009). Toad radiation reveals into-India dispersal as a source of endemism in the Western Ghats-Sri Lanka biodiversity hotspot. *BMC Evolutionary Biology* 9(1): 131. <https://doi.org/10.1186/1471-2148-9-131>

Van Bocxlaer, I., S.D. Biju, B. Willaert, V.B. Giri, Y.S. Shouche & F. Bossuyt (2012). Mountain-associated clade endemism in an ancient frog family (Nyctibatrachidae) on the Indian subcontinent. *Molecular Phylogenetics and Evolution* 62(3): 839–847. <https://doi.org/10.1016/j.ympev.2011.11.027>

Van Bocxlaer, I., S.P. Loader, K. Roelants, S.D. Biju, M. Menegon & F. Bossuyt (2010). Gradual adaptation toward a range-expansion phenotype initiated the global radiation of toads. *Science* 327(5966): 679–682. <https://doi.org/10.1126/science.1181707>

Wells, K.D. (2007). *The Ecology and Behavior of Amphibians*. University of Chicago Press.





First record of *Ourapteryx dierli* Inoue, 1994 (Lepidoptera: Geometridae: Ennominae) from India

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The genus *Ourapteryx* Leach, 1814 (Geometridae: Ennominae: Ourapterygini) is distributed in Europe and Asia, with over 75 described species (Lepidoptera Barcode of Life: Geometridae; Parsons et al. 1999). Ratnasingham & Hebert (2007) identified 89 *Ourapteryx* species in addition to 23 unidentified species. Hampson (1895) listed nine species of *Ourapteryx* (as *Urapteryx*, a junior synonym) from the Indian subcontinent. An unpublished compilation "A Checklist of Indian Geometridae" by Gunathilagaraj Kandasamy listed 13 *Ourapteryx* species, while Kirti et al. (2019) listed 24 species. In Nepal, Stüning (1994) and Inoue (1995) listed 17 *Ourapteryx* species. Stüning (2000) added three more species, bringing the Nepal list to 20 species. In Uttarakhand, adjacent to Nepal, only five species have so far been identified: *Ourapteryx clara* (Butler, 1880), *O. convergens* Warren, 1897, *O. ebuleata* (Guenée, 1858), *O. inouei* Stüning, 2000, and *O. sciticaudaria* (Walker, 1862) (Smetacek 2008; Sondhi & Sondhi 2016; Sanyal et al. 2017; Kirti et al. 2019).

The first author conducted opportunistic moth surveys between 2017 and 2019 in Sarmoli Village, Muniari, Pithoragarh District, Uttarakhand. During

these surveys, *Ourapteryx dierli* Inoue, 1994, a moth species hitherto known only from Nepal, was recorded.

Sarmoli Village is located a kilometer from the town of Muniari in Pithoragarh District, Uttarakhand. The village, which is located in the Kumaon region of Uttarakhand, is on an east-facing hill slope of the Greater Himalaya. The village is located in the Gori Ganga River basin, which flows through the landscape.

In 2017, moth screens using a 160W mercury vapour bulb were set up on 31.v.2017 at Emmanuel Theophilus's home (30.078N & 80.231E, 2,291m) and on 2.vi.2017, at Anusuya Devi's village homestay (30.07916N & 80.23535E, 2,200m). In 2018, a moth screen was set up on 22.v.2018 at Sarmoli Village using an 8W actinic tubelight at Hirma Devi's homestay in Sarmoli village, no more than 50m from Anusuya Devi's homestay. In 2019, a moth screen using a 160W mercury vapour bulb was set up on 22.v.2019 at Emmanuel Theophilus's home (30.078N & 80.231E, 2,291m). No individuals of *Ourapteryx dierli* came to the screens mentioned above. On 23.v.2019 at Saraswati Devi's homestay (30.079N & 80.235E, 2,200m), in Sarmoli village, a single individual of *Ourapteryx dierli* came to the moth screen at 2055

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Image 1. *Ourapteryx dierli*, male NCBS-BK945, collected on 23.v.2019 at Sarmoli, Muniari, Pithoragarh District, Uttarakhand, UP/UN.



Image 2. Genitalia of *Ourapteryx dierli*, male NCBS-BK945.



Image 3. *Ourapteryx dierli*, live individual, NCBS-BK945, photographed at Sarmoli, Muniari on 23 May 2019.

hours. The live individual was photographed and collected (Image 1, 3).

The area adjacent to the moth screen was a typical village vegetable garden growing legumes, citrus plants, and members of the Brassicaceae family. The area surrounding the village includes two Van Panchayats (Village Council Forests), the Sarmoli Janti Van Panchayat covering 34ha, and the Sankhdura Van Panchayat covering 88ha. The primary vegetation surrounding the Sarmoli Village consists of West Himalayan Temperate forest with trees such as Deodar *Cedrus deodara*, Cypress (Cupressaceae), Horse Chestnut *Aesculus* sp., *Rhododendron* sp., Himalayan Oaks *Quercus* sp., Alder *Alnus nepalensis*, Maple *Acer* sp. and Ringal Bamboo.

Material examined: The specimen (NCBS-BK945) of the male *O. dierli* was collected by Sanjay Sondhi on 23.v.2019 from Sarmoli Village, Muniari, Pithoragarh District, Uttarakhand, India (30.07916N & 80.23535E, 2,200m) and is deposited in the Research Collections (<http://collections.ncbs.res.in/>) of the National Centre

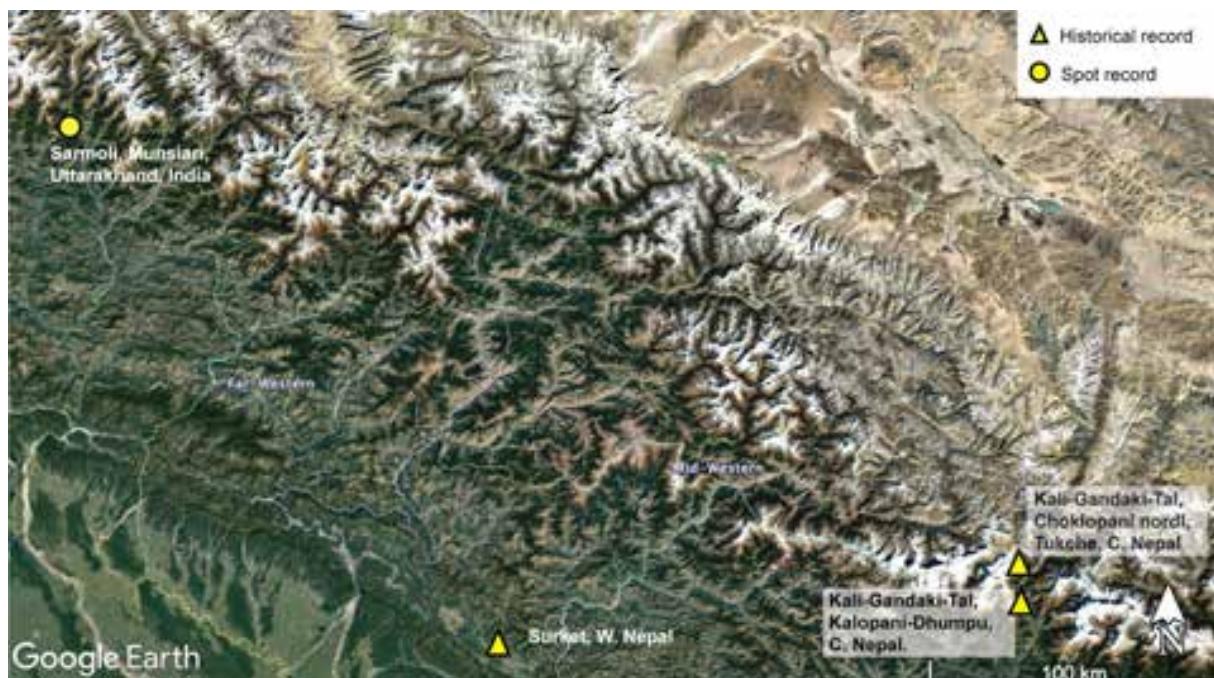


Image 4. Global distribution of *Ourapteryx dierli*.

for Biological Sciences, Bengaluru, India.

Adult moth description: Male. Voucher code NCBS-BK945 (Image 1). Forewing length 24mm. Upperside: forewing ground colour, greyish-brown. Forewing base is white. A broad, oblique white ante-medial band from costa to inner margin. Another broad, oblique post-medial band of similar width from costa to inner margin, the bands forming an incomplete V. Some diffused whitish costal striations between the two white bands. A narrow, white sub-marginal band and orange cilia. Hindwing tailed, with ground colour, greyish-brown. A white medial band widening from tornus to costa. At the costa, the white band merges with a broad white costal area. A large rufous-brown oval tornal patch, with three black spots at its outer edge, the uppermost of these black spots being red-centered. Inner margin of hindwing is narrowly white. A narrow, white sub-marginal band and orange cilia. Underside: forewing ground colour dirty white with bands above, showing through below. Mottled brown striations in the cell and the area surrounding it, as well as the area between the post-discal and sub-marginal white bands. A prominent brown band on the inner edge of the white post-medial band. A white sub-costal streak from near base to 2/3rd along costa. Hindwing ground colour dirty white with bands above, showing through below. A broad brown medial band from inner margin to costa. Mottled brown striations in the post-medial area. The

upper and underside markings of the male specimen are a good match to the original description of *O. dierli* (Inoue 1994). The only variability displayed when compared with the holotype is slightly broader white bands on both wings in the Uttarakhand individual, and the white costal striations, which are largely absent in the holotype.

Genitalia description: Genitalia dissection of the specimen by DNB revealed damaged uncus and distal tips of valves (corona and cucullus) in the Uttarakhand specimen (Image 2). Other parts of genitalia including aedeagus, asymmetric juxta, tegumen and proximal extent of valves, however, matched well with the original description (Inoue 1994). A redescription of the male genitalia, examining the Uttarakhand specimen NCBS-BK945 and the holotype is mentioned below:

Uncus falcate bent downwards at the distal end adhered to broad proximally rounded tegumen at the lateral profile. Vinculum slender and forms a sigmoid proximal margin in conjunction with tegumen. Saccus short, gnathos conjoined at the tip and form a lip shaped spinous lobe. Juxta elongates into characteristic furca acutely recurved inward from ventral angle and downward beneath the uncus from lateral angle. Distal tip of furca forms an ellipsoid spinous lobe from lateral angle. Valves are elongated with highly chitinized costal process rounded at the distal tip, and inner margin of corona laden with trichia. Aedeagus short with long

sub-zonal and with spinous cornuti.

Distribution: *Ourapteryx dierli* Inoue, 1994 was first described from central Nepal (Inoue 1994). The holotype and paratypes of this species were collected on various dates in vi.1973 at altitudes between 2,500–2,600 m from central Nepal (Inoue 1994, 1995). Subsequently, *O. dierli* was recorded from western Nepal at an altitude of 1,000m on 25.vii.1996 (Stüning 2000). These remain the only published records of this species. Hence the species' known range is now re-stated as eastern Kumaon in Uttarakhand, India, to western and central Nepal (Image 4).

Natural history: *Ourapteryx dierli* Inoue, 1994 has been recorded flying in the months of May, June and July only in India and Nepal. In India, the moth was attracted to a 160W mercury vapour bulb. There is no information about its early stages (Robinson et al. 2010). The species has been recorded on the wing at an altitudinal range of 2,400–2,600 m in eastern Kumaon and central Nepal, though a specimen was collected from western Nepal at 1,000m.

Existing publications on geometrid moths from India do not list *O. dierli* (Hampson 1895; Rose 2001; Smetacek 2008, 2009, 2011; Shubhalaxmi et al. 2011; Kirti et al. 2012, 2019; Sanyal et al. 2013a,b, 2017; Sondhi & Sondhi 2016; Kumar et al. 2018). SS has also surveyed moths widely across Uttarakhand and Himachal Pradesh in the last decade, and has never recorded this species. There are no published records of this species on the Moths of India website (Sondhi et al. 2020). Hence, our record of *O. dierli* extends its known range westwards into Uttarakhand in India.

References

Hampson, G.F. (1895). *The Fauna of British India including Ceylon and Burma. Moths*, Vol. 3 Taylor & Francis, London. Noctuidae (cont.) to Geometridae, 546pp, 226 figs.

Inoue, H. (1994). Description of a new species of *Ourapteryx* Leach Geometridae: Ennominae) from Central Nepal. *Tinea* 14 (1): 10–12.

Inoue, H. (1995). The genera *Abraxas* and *Ourapteryx* from Nepal (Geometridae, Ennominae), pp. 119–139. In: Haruta, T. (ed.). (1995). *Moths of Nepal*. Part 4. TINEA. Vol. 14 (Supplement 2). The Japan Heterocerists' Society, Tokyo, 206pp+32pls.

Kirti, J.S., T. Goyal & M. Kaur (2012). An inventory of family Geometridae (Lepidoptera) from Western Ghats of India. *Journal of Entomological Research* 36(1): 83–94.

Kirti, J.S., K. Chandra, A. Saxena & N. Singh. (2019). *Geometrid Moths of India*, Nature Books of India, New Delhi, 296pp.

Kumar, M., P. Kumar & A. Kumar (2018). Taxonomic Study on Geometrid Moths (Lepidoptera: Geometridae) Diversity in Chir pine Forest of Himachal Pradesh. *Asian Journal Advanced Basic Sciences* 6(1): 49–53.

Parsons, M., M. Scoble, M. Honey, L. Pitkin & B. Pitkin (1999). *Geometrid Moths of the World: A Catalogue (Lepidoptera, Geometridae)*. CSIRO, Clayton North, Victoria, Australia, 1016pp+Index 129pp.

Ratnasingham, S. & P.D.N. Hebert (2007). BOLD: the barcode of life data system (www.barcodinglife.org). *Molecular Ecology Notes* 7: 355–364.

Robinson, G.S., P.R. Ackery, I.J. Kitching, G.W. Beccaloni & L.M. Hernández (2010). HOSTS – A Database of the World's Lepidopteran Hostplants. Natural History Museum, London. <https://www.nhm.ac.uk/our-science/data/hostplants>. Accessed on 29 January 2020.

Rose, H.S. (2001). Inventory of the Geometrid Moths (Lepidoptera) of Patiala, *Bionotes* 3(1): 183.

Sanyal, A.K., V.P. Uniyal, K. Chandra & M. Bhardwaj (2013a). Diversity, distribution pattern and seasonal variation in moth assemblages along altitudinal gradient in Gangotri landscape area, Western Himalaya, Uttarakhand, India. *Journal of threatened Taxa* 5(2): 3646–3653. <https://doi.org/10.11609/jott.02597.3646-53>

Sanyal, A.K., V.P. Uniyal, K. Chandra & M. Bhardwaj (2013b). Diversity and indicator species of moth (Lepidoptera: Heterocera) assemblages in different vegetation zones in Gangotri Landscape, Western Himalaya, India, pp. 114–129. In: Uniyal, V.P. & A. Srivastava (Eds.) ENVIS Bulletin: Wildlife and Protected Areas, Vol. 14, Wildlife Institute of India, Dehradun, 232pp.

Sanyal, A.K., P. Dey, V.P. Uniyal, K. Chandra & A. Raha (2017). Geometridae Stephens, 1829 from different altitudes in Western Himalayan Protected Areas of Uttarakhand, India. (Lepidoptera: Geometridae). *SHILAP Revista de Lepidopterología* 45(177): 143–163.

Shubhalaxmi, V., R.C. Kendrick, A. Vaidya, N. Kalagi & A. Bhagwat (2011). Inventory of moth fauna (Lepidoptera: Heterocera) of the northern Western Ghats, Maharashtra, India. *Journal of the Bombay Natural History Society* 108(3): 183–205.

Smetacek, P. (2008). Moths recorded from different elevation in Nainital district, Kumaon Himalaya, India. *Bionotes* 10(1): 5–15.

Smetacek, P. (2009). Additions and corrections to the list of moths recorded from different elevations in Nainital district, Kumaon Himalaya, India. *Bionotes* 11(4): 117–118.

Smetacek, P. (2011). Further Additions to the Moths (Lepidoptera: Heterocera) of Nainital District, Kumaon Himalaya, India. *Bionotes* 3: 4.

Sondhi, Y. & S. Sondhi (2016). A partial checklist of moths (Lepidoptera) of Dehradun, Mussoorie and Devalsari in Garhwal, Uttarakhand, India. *Journal of Threatened Taxa* 8(5): 8756–8776. <https://doi.org/10.11609/jott.2814.8.5.8756-8776>

Sondhi, S., Y. Sondhi, P. Roy & K. Kunte (eds.) (2020). *Moths of India*, v. 2.00. Indian Foundation for Butterflies. <https://www.mothsofindia.org>. Accessed on 30 January 2020.

Stüning, D. (1994). On the identity of *Ourapteryx ebuleata* Guenée, 1857, *O. multistrigaria* Walker, 1866, and *O. caschmirensis* Bastelberger, 1911, with description of two new species (Lepidoptera: Geometridae, Ennominae). *Nachrichten des Entomologischen Vereins Apollo (NF)* 15: 109–134.

Stüning, D. (2000). Additional notes on the Ennominae of Nepal with descriptions of eight new species (Geometridae), pp. 94–152. In: Haruta, T. (ed.) *Moths of Nepal*. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists' Society, Tokyo, 163pp+14pls. Lepidoptera barcode of life: Geometridae (<http://lepbarcoding.org/geometridae>) accessed on 28 January 2020)



Threatened Taxa



Notes on a communal roosting of two oakblues (Lepidoptera: Lycaenidae: *Arhopala*) and the Common Emigrant (Pieridae: *Catopsilia pomona*) butterflies in Uttarakhand, India

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Communal roosting, a type of aggregation has been observed in different types of animals, including birds, bats, and primates (Ward 1965; Soini 1987; Lewis 1995; Merkel & Mosbech 2008), and is particularly common in insects, especially in bees, wasps, beetles, dragonflies, butterflies, and moths (Pearson & Anderson 1985; DeVries et al. 1987; Salcedo 2010). Communal roosting of butterflies has been described as a behaviour in which individuals aggregate inertly in close vicinity to each other at a site for more than a few hours (DeVries et al. 1987). Roosting behaviour has been reported for a few of the migratory and non-migratory species of butterflies in India (Antram 1924; Smetacek 2002; Tigers et al. 2014; Patil 2016; Sondhi et al. 2017).

Here, we report the roosting behaviour of three butterfly species, two species of *Arhopala* genus, *A. atrax* and *A. amantes*, and one species of *Catopsilia* genus, *Catopsilia pomona*, on an Elephant Apple tree *Dillenia indica* (an evergreen medium to large-sized tree, native to southern Asia) in the Forest Research Institute Campus, Dehradun, Uttarakhand, India.

The New Forest Campus (Figure 1) (30.34°N &

71.00°E, 660m) lies in the 'tropical moist deciduous' Sal *Shorea robusta* forest sub-type (Champion & Seth 1968) and provides a unique assemblage of natural forest and human habitations. The campus, comprising an area of 4.45km² lies in the Doon Valley of Uttarakhand State, India. The area receives an annual rainfall of over 2,000mm, and the temperature fluctuates between 0°C and 42°C from winter to summer, with a mean of 20°C. The natural forest is dominated by *Shorea robusta* with 267 species of trees, 214 species of shrubs, 446 species of herbs, 83 species of grasses, 41 species of woody climbers, 32 varieties of bamboos, and 186 species of fungi in the New Forest Campus (FRI 2019). The campus harbours a botanical garden (400 species), an arboretum (85 species), a bambusetum (32 species), big undulating fields, nurseries, tree, bush avenues, and canals. The plant species are either distributed in mixed or pure patches. Providing a mosaic of both natural and human-made habitats, the campus nurtures a wide range of larval host plants to support almost all butterflies species reported from the campus (Singh 1999).

On 15 October 2018 at 17.00h we first observed 17

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Figure 1. Map showing the location (red dot) of the *Dillenia indica* tree in Forest Research Institute campus.

individuals of the Indian Oakblue *Arhopala atrax*, Large Oakblue *Arhopala amantes*, and Common Emigrant *Catopsilia pomona* on a *Dillenia indica* tree (Image 1) in the New Forest Campus, FRI (Figure 1). The height of the tree was approximately 20m, and other species like *Coffea arabica*, *Reinwardtia indica*, *Echinochloa colonum*, *Kyllinga brevifolia*, *Crape jasmine* and *Suregada multiflora* were present nearby. There were five other individuals of *Dillenia indica* in different locations of the campus. After the aforementioned initial record, regular observations were made twice a day to ensure the butterflies are found throughout the day and not at any specific time of the day (once in the morning at 09.00h and once in the evening at 16.30h, 04 November –07 December 2018) to find out the regularity of the observed roosting behaviour. Butterflies were identified using standard identification keys suggested by Wynter-Blyth (1957), Kunte (2000), and Kehimkar (2008). Field guides by Singh (2011) and Smetacek (2017) were used to identify photographic records. Moreover, Kunte et al. (2019) was also consulted for proper identification. To check the site fidelity of the three above mentioned species: (a) we regularly searched other trees near the *Dillenia indica*, (b) we checked other *Dillenia indica* in the surrounding area for other roosting incidents, and

(c) we disturbed the leaves on which the butterflies roosted to check if they left the site to roost elsewhere on a different individual of the same tree species that existed nearby. We also documented butterflies that were observed near the tree.

Throughout the observation period, *Arhopala amantes* were the highest in number (Maximum=19, minimum=14) followed by *Arhopala atrax* (Maximum=14, minimum=10), and *Catopsilia pomona* (Maximum=5, minimum=4). *A. atrax* and *A. amantes* were observed roosting together on the same leaves (Image 2), whereas individuals of *C. pomona* (Image 3) were observed roosting on different leaves of the same tree. There were species of butterflies other than the study species (viz., *Junonia lemonias*, *Pareronia valeria*, *Phalanta phalantha*, *Neptis hylas*, *Ypthima baldus*, *Pieris* sp.) near the tree during the period of study. Roosting, however, was not observed in any of those species.

Apart from documenting diversity and richness, there is no mention of observing any behavioural characteristics of the butterflies from the study area (Singh 1999). The amount of aggregation increased in terms of individuals as the days of observation increased. Even after providing mechanical disturbance, the butterflies were seen to roost on the leaves of the



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Image 1. The *Dillenia indica* tree where the roosting behaviour was observed.

same *Dillenia indica* tree. No change in the species number was observed throughout the study period, and no roosting instances were found on the nearby trees in the same area. Apart from the regularly monitored tree, no other individual of the species in close proximity is recorded with any events of aggregation of butterflies, however, we have not observed any individual of the three species on fruits throughout the study period. Also, the species is not a host plant of any of the three studied species. The studied tree has been preferred as a suitable roosting site as it is located in a shady area, which may provide a favourable resting spot to the

butterflies, safe from predators, unlike other individuals. The claim can be justified as the butterflies are mostly found roosting on the underside of the leaves or towards the base of the leaves. The study period coincides with the fruiting period of the tree species, which may be the reason to attract butterflies for feeding, but this may not be the specific reason for roosting in the particular tree. If this may have been the only reason, roosting incidences may have been observed from the nearby trees as well.

References

Antram, C.B. (1924). *Butterflies of India*. Thacker, Spink & Co., Calcutta and Simla, India, 226pp.

Champion, H.G. & S.K. Seth (1968). *A Revised Survey of Forest Types of India*. Govt. of India Press, New Delhi, 404pp.

DeVries, P.J., J. Schull & N. Greig (1987). Synchronous nocturnal activity and gregarious roosting in the neotropical skipper butterfly *Celaenorrhinus fritzgaertneri* (Lepidoptera: Hesperiidae). *Zoological Journal of the Linnean Society* 89(1): 89–103.

F.R.I. (2019). *Nature's Kaleidoscope-Biodiversity of the New Forest Dehradun*. Forest Research Institute, Dehradun, 186pp.

Kehimkar, I.D. (2008). *Book of Indian Butterflies*. Oxford University Press, Mumbai, 497pp.

Kunte, K. (2000). *India, a Lifescape: Butterflies of Peninsular India*. Universities Press, Hyderabad, 254pp.

Kunte, K., S. Sondhi & P. Roy (Chief Editors) (2019). Butterflies of India, v. 2.65. Indian Foundation for Butterflies. <https://www.ifoundbutterflies.org> Electronic version accessed 15 December 2018.

Lewis, S.E. (1995). Roost fidelity of bats: a review. *Journal of Mammalogy* 76(2): 481–496.



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Image 2. Roosting of *Arhopala* sp. on the leaves of *Dillenia indica*.



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Image 3. *Catopsilia pomona* on the leaves of *Dillenia indica*.



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Image 4. Other observed species near the tree (Common Five-ring, *Ypthima baldus*) on the fruit of *Dillenia indica*.

Merkel, F.R. & A. Mosbech (2008). Diurnal and nocturnal feeding strategies in Common Eiders. *Waterbirds* 31(4): 580–587.

Patil, M.D. (2016). Natural history observations on mass congregation and diapause behaviour of pre-migratory roosting Danainae

(Lepidoptera: Nymphalidae) from Sahyadri Mountains, India. *South Asian Journal of Life Sciences* 4(1): 25–31.

Pearson, D.L. & J.J. Anderson (1985). Perching heights and nocturnal communal roosts of some tiger beetles (Coleoptera: Cicindelidae) in southeastern Peru. *Biotropica* 17(2): 126–129.

Salcedo, C. (2010). Environmental elements involved in communal roosting in *Heliconius* butterflies (Lepidoptera: Nymphalidae). *Environmental Entomology* 39(3): 907–911.

Singh, A.P. (1999). New Forest, Dehradun, India: a unique man-made habitat for butterflies in the lower western Himalayas. *Indian Forester* 125(9): 913–922

Singh, A.P. (2011). *Butterflies of India*. Om Books International, Delhi, 184pp.

Smetacek, P. (2002). The study of butterflies. *Resonance* 7(7): 6–14.

Smetacek, P. (2017). *A Naturalist's Guide to the Butterflies of India, Pakistan, Nepal, Bhutan, Bangladesh and Sri Lanka*. John Beaufoy Publishing Limited, London, 176pp.

Soini, P. (1987). Ecology of the saddle-back tamarin *Saguinus fuscicollis illigeri* on the Rio Pacaya, northeastern Peru. *Folia Primatologica* 49(1): 11–32.

Sondhi, S., B. Valappil, Y. Sondhi & A. Sondhi (2017). A report on some butterflies (Lepidoptera) from Ladakh in Jammu & Kashmir and Lahaul in Himachal Pradesh, India. *Journal of Threatened Taxa* 9(3): 9971–9987. <https://doi.org/10.11609/jott.3024.9.3.9971-9987>

Tigers, S., C. Crows & B. Tigers (2014). Danainae congregation in the Konkan region of Maharashtra, India. *Current Science* 106(4): 514.

Ward, P. (1965). Feeding ecology of the Black-faced Dioch *Quelea quelea* in Nigeria. *Ibis* 107(2): 173–214.

Wynter-Blyth, M.A. (1957). *Butterflies of the Indian region*. Bombay Natural History Society, Mumbai, 523pp.





First report of mango leaf gall midge *Procontarinia robusta* Li, Bu & Zhang (Diptera: Cecidomyiidae) from India

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Currently, 22 species of gall midges (Diptera: Cecidomyiidae) are known to be associated with mango *Mangifera indica* L. (Anacardiaceae) (Gagné & Jaschhof 2017; Jiao et al. 2018) which includes 16 species belonging to the genus *Procontarinia*. *Procontarinia robusta* Li, Bu & Zhang known for its gall on the leaves of mango tree, was described from China in the year 2003 based on adult male and female (Li et al. 2003). Later, immature stages of this species were described by Cai et al. (2013). Even though a similar type of gall on mango is known from India (Jharkhand and Andhra Pradesh) (Kieffer 1909; Mani 1959), the identity of the causative agent is not known. Cai et al. (2013) have considered the causative agent of this gall as *P. robusta* based on the illustrations given by Kieffer (1909) and Mani (1959). The checklist of Indian gall midges revealed 394 species which includes 11 species of *Procontarinia* but the *P. robusta* has not been included in the list as it is known only from gall morphology not from insect life stages (Sharma 2009). Here, we report the occurrence of *P. robusta* in India based on the larva and pupa for the first time.

Mango leaves with cylindrical galls mentioned by Kieffer 1909 & Mani 1959 were collected from different

localities (in the vicinity of Tamhini, Pune District, Maharashtra; Guntur, Andhra Pradesh; and Singanallur Lake area, Coimbatore District, Tamil Nadu) (Figure 1) and transferred to the laboratory. Some galls were cut open to obtain immature stages (larvae and pupae) and the remaining galls were kept in a plastic bag to rear into adults. As adults had not emerged from the galls, efforts were made to identify the larva and pupa. The larvae and pupae were cleared by using 10% KOH and processed to prepare slides as per the method described by Kolesik et al. (2009). The slides mounted in Canada balsam were deposited in the National Zoological Collections of ZSI, Western Regional Centre, Pune.

Material examined: Larva and pupa (2 numbers each dissected and mounted on slides) collected as leaf galls (Ent 10/210) from Guntur, Andhra Pradesh (16.303°N & 80.482°E) on 29.v.2018, coll. Senthilkumar; two larvae in alcohol collected as gal (Ent 10/211) on 22.ix.2018 from Singanallur Lake area, Coimbatore, Tamil Nadu (10.994°N & 77.024°E), coll. Vasanthakumar D.; larvae and pupae (three numbers each in alcohol) collected as gall (Ent 10/212) on 09.viii.2019 from vicinity of Mulshi, Pune District, Maharashtra (18.501°N & 73.513°E), coll. D. Vasanthakumar.

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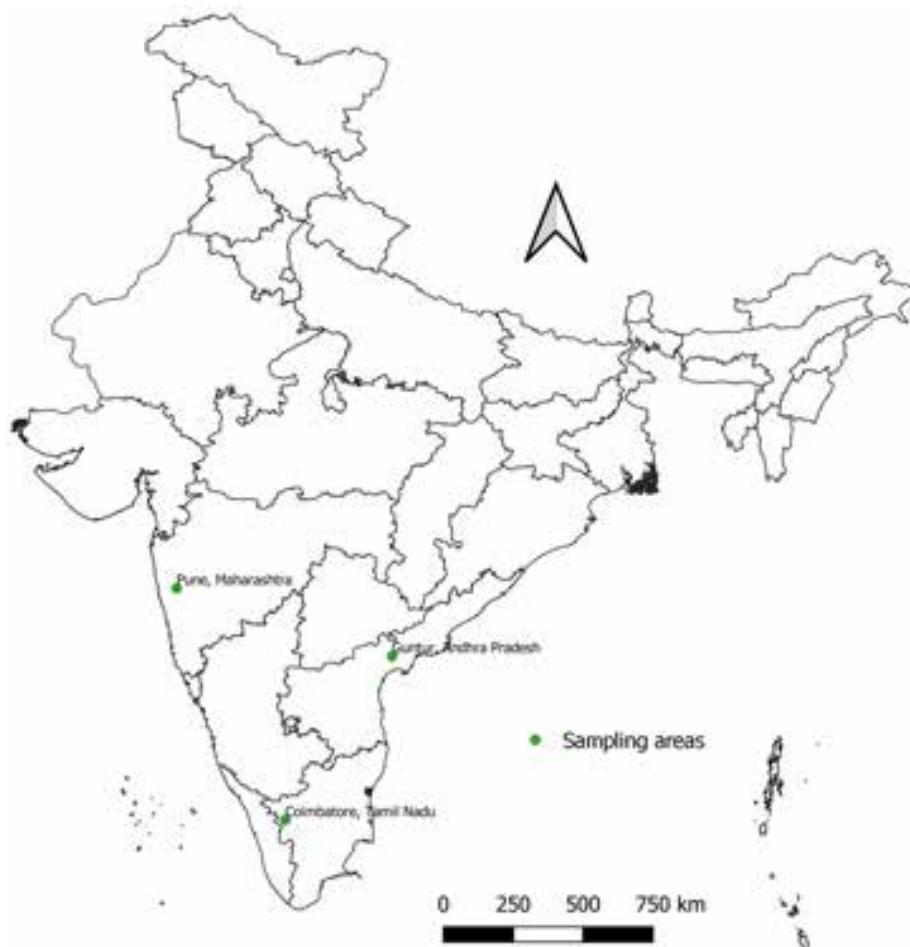


Figure 1. Details of sampling areas.

Diagnosis: Colour of larvae yellowish-white (Image 1A), antennae short, as long as wide. Sternal spatula long, narrow (270 µm) and trilobed, with large central lobe and minute lateral lobes (Image 1 B). No visible papillae on terminal segment as well as near sternal spatula as described by Cai et al. (2013). Antennal horns of pupa prominent, outer edge serrated (Image 1C). Prothoracic spiracle short, as long as wide. No visible facial papillae.

Gall: Leaf gall (Image 1D). Epiphyllous, cylindrical often obtusely conical, sessile, glabrous, brown to reddish-brown, shiny, hard, unilocular (Image 1E), indehiscent galls, 1mm in diameter at the base and 1–2.5 mm in height. The leaf epidermis bursts when the gall develops, leaving a structure resembling a calyx around the base. On the underside of the gall is a slightly discoloured blister with a necrotic area in the centre (Image 1F). At gall maturity, a round necrotic area appears at the gall's apex. Pupation takes place inside the gall. The pupal skin can be seen attached to the emergence hole (Image 1G) (Mani 2000).

Distribution: China, Indonesia, East Timor (Cai et al. 2013). India (new record)

Notes: *P. robusta* can be easily identified from its larva. A large central anterior lobe accompanied by a small lobe on either side of sternal spatula of larva is the key character to identify this species as described by Cai et al. (2013).

References

Cai, H.J., P. Kolesik, H.Y. Wang, F.R. Liao, V. Quintao, K.M. Harris & G.A. Bellis (2013). Description of the immature stages and gall morphology, and molecular characterisation of *Procontarinia robusta*, a gall midge (Diptera: Cecidomyiidae) damaging leaves of mango *Mangifera indica* L. (Anacardiaceae) in southern Asia. *Australian Journal of Entomology* 52: 206–211.

Gagné, R.J. & M. Jaschhof (2017). A Catalog of the Cecidomyiidae (Diptera) of the World, 4th Edition. Digital, USDA, Washington, 762pp.

Jiao, K.L., H. Wang, D.W. Wei, J.Y. Mo, Y.H. Wang, W.J. Bu & P. Kolesik (2018). A new species of *Procontarinia* (Diptera: Cecidomyiidae) damaging fruit of mango, *Mangifera indica* (Anacardiaceae), in China. *Zootaxa* 4413(2): 368–376.

Kieffer, J.J. (1909). Description de galles et d'insectes galloïques d'Asie. *Marcellia* 7: 149–167.

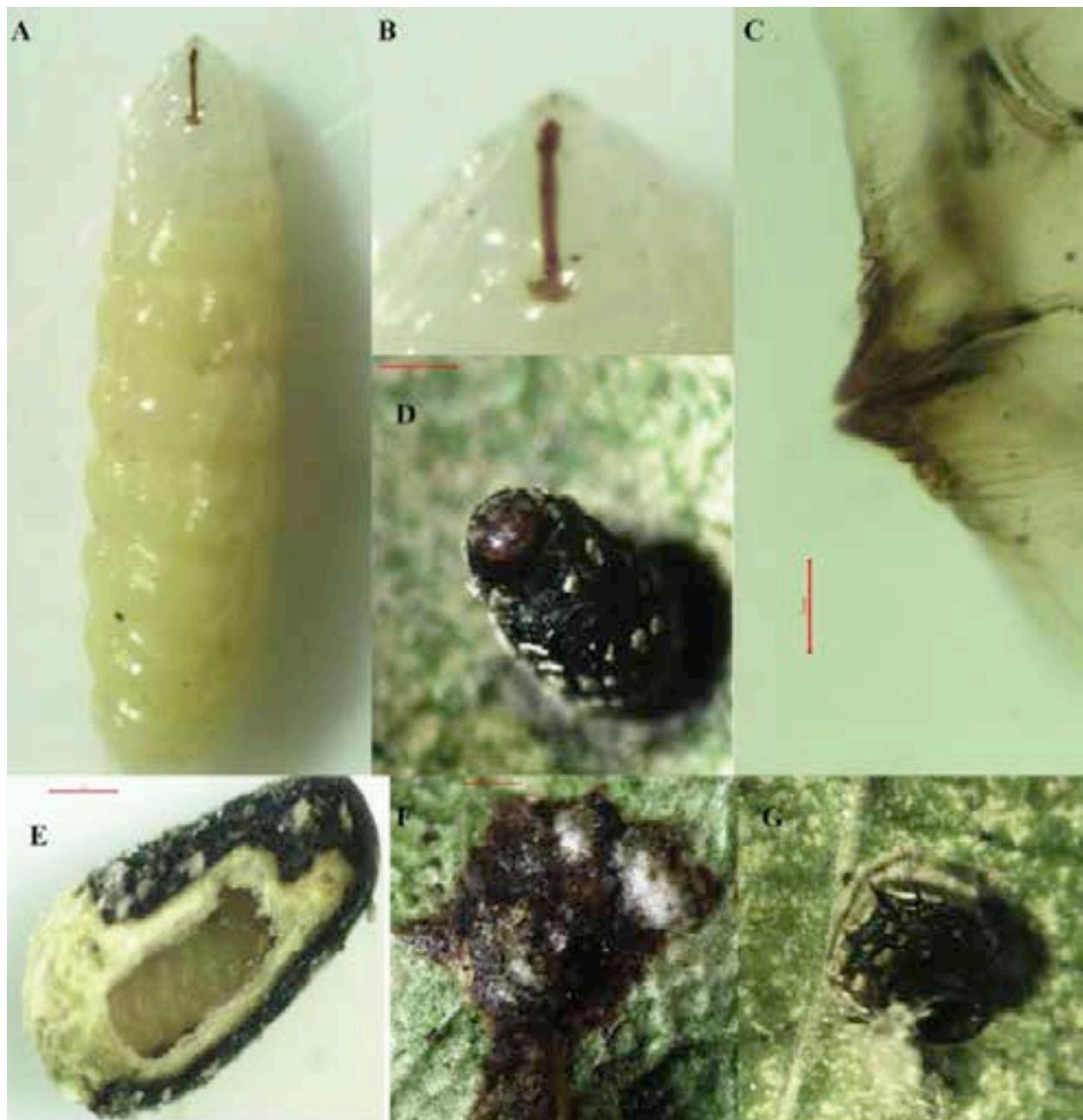


Image 1. A—larva | B—sternal spatula | C—antennal horns of pupa | D—leaf gall | E—dissected gall containing larva | F—underside of the gall | G—pupal exuviae. © D. Vasanthakumar.

Kolesik, P., A.D. Rice, G.A. Bellis & M.G. Wirthensohn (2009). *Procontarinia pustulata*, a new species of gall midge (Diptera: Cecidomyiidae) feeding on mango *Mangifera indica* (Anacardiaceae), in northern Australia and Papua New Guinea. *Australian Journal of Entomology* 48: 310–316.

Li, J., W.J. Bu & Q.Y. Zhang (2003). A new species of gall midge (Diptera: Cecidomyiidae) attacking mango leaves from China. *Acta Zootaxonomica Sinica* 28: 148–151.

Mani, M.S. (1959). Cecidotheca Indica. *Agra University Journal of Research (Science)* 8: 91–279.

Sharma, R.M. (2009). Checklist of Indian Gall midges (Diptera: Cecidomyiidae). <http://www.zsi.gov.in/zoologicalesurveyofindia/zsidaata/checklist>. Digital, Zoological Survey of India, Kolkata, 23pp.



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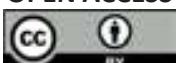
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First record of *Ourapteryx dierli* Inoue, 1994 (Lepidoptera: Geometridae: Ennominae) from India

– Sanjay Sondhi, Dipendra Nath Basu & Krushnamegh Kunte, Pp. 16916–16919

Notes on a communal roosting of two oakblues (Lepidoptera: Lycaenidae: *Arhopala*) and the Common Emigrant (Pieridae: *Catopsilia pomona*) butterflies in Uttarakhand, India

– Sohom Seal, Debanjan Sarkar, Agnish Kumar Das & Ankush Chowdhury, Pp. 16920–16923

First report of mango leaf gall midge *Procontarinia robusta* Li, Bu & Zhang (Diptera: Cecidomyiidae) from India

– Duraikannu Vasanthakumar, Senthilkumar Palanisamy & Radheshyam Murlidhar Sharma, Pp. 16924–16926

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